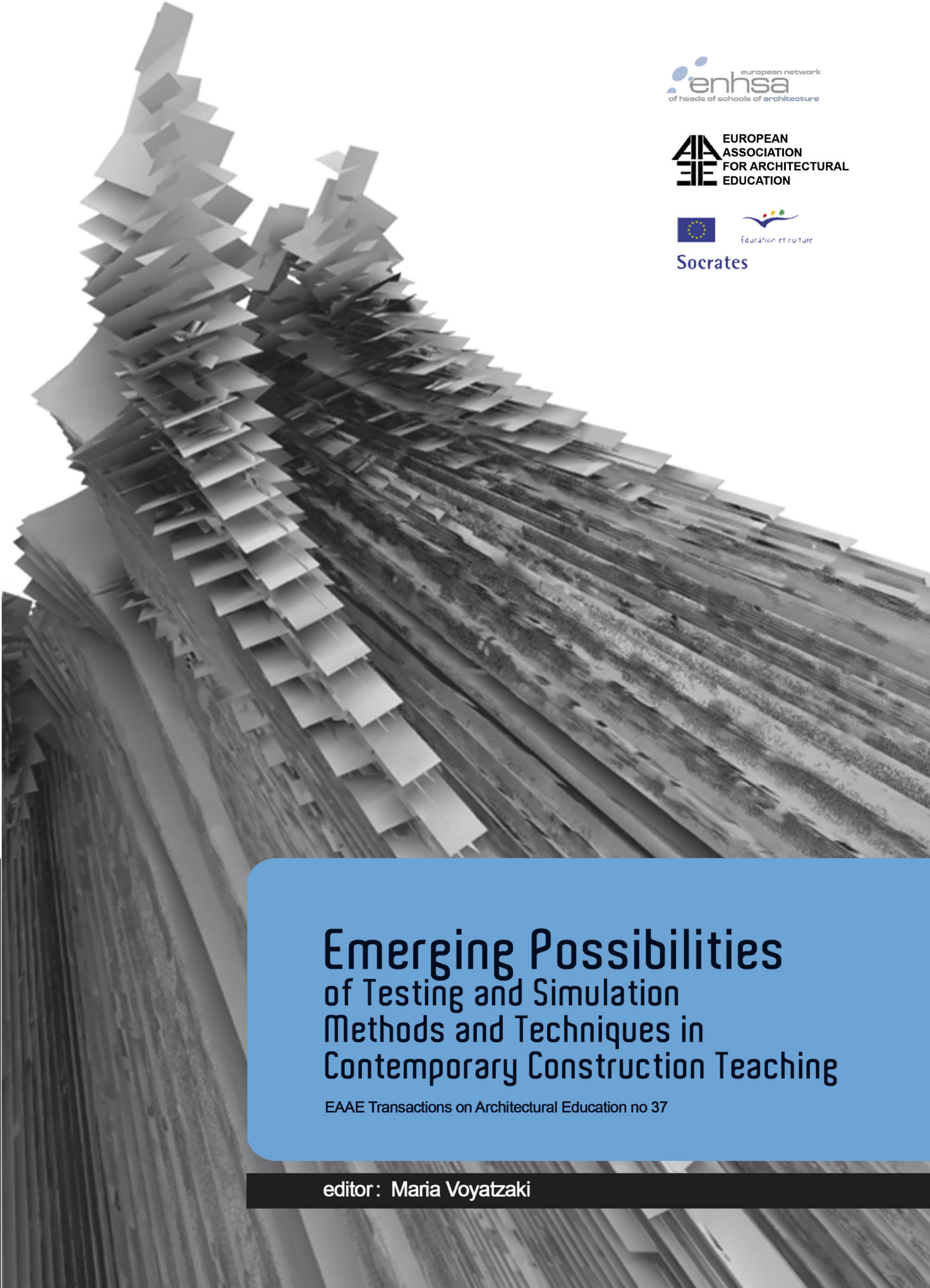

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Éducation et culture

Emerging Possibilities of Testing and Simulation Methods and Techniques in Contemporary Construction Teaching

EAAE Transactions on Architectural Education no 37

editor: Maria Voyatzaki

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EUROPEAN ASSOCIATION FOR ARCHITECTURAL EDUCATION

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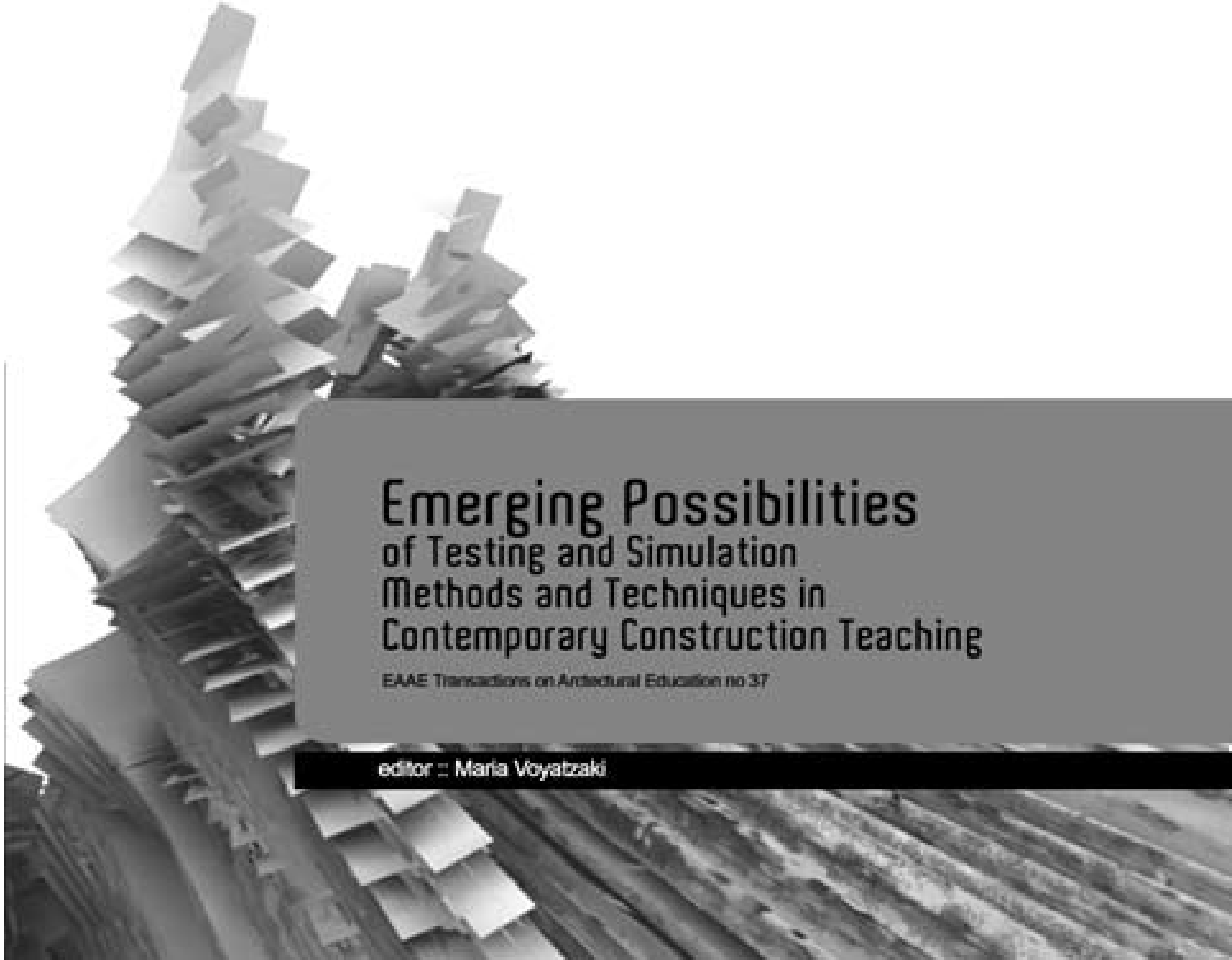

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EAAE-ENHSA Construction Teachers' Network Coordinator, Project Organiser
Dr. Maria Voyatzaki
As. Professor, School of Architecture, Aristotle University of Thessaloniki, Greece

Transcription and speech adaptation: Maria Grammatikopoulou

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Keynote Addresses

Session 1 - Testing and Simulation

Session 2 - Environmental Control - Testing and Simulation

Session 3 - Form and Structure - Testing and Simulation

The Rationale

Emerging Possibilities of Testing and Simulation Methods and Techniques in Contemporary Construction Teaching

Maria VOYATZAKI
As. Professor Aristotle University of Thessaloniki, Greece
Coordinator of the European Network of Construction Teachers

Contemporary architectural education in Europe, to a greater or lesser extent, has not encapsulated in its teaching practices advanced testing and simulation methods. Even when it does, these methods take place in isolation and not as part of an integrated design teaching approach. Despite the technical possibilities and potential of the existing advanced technological infrastructures, schools of architecture use technology mostly at the level of representation or of morphogenesis.

However, there is a great deal of innovation on contemporary construction in the building industry regarding the simulation of reality and the control over the behavior of forms, structures and materials, their aesthetics, loading conditions, environmental particularities and properties before their materialization[1].

These changes impose on the design process new logics that support parametrically the design-construction choices within a flexible and continuously changing context of decisions and constraints. These logics enable a direct control on the constraints that affect the materiality of a building and to the possibility to get direct feedback for potentially costly[2] in full scale errors, problems, as well as the potential advantages in the ways certain parameters can be manipulated.

These new approaches to the production of the built environment render design as a process of continuous testing and put the term 'testing' on the pedestal of the contemporary design process as a crucial keyword. Moreover, the development of simulation techniques has allowed for the significant convergence of the design process with construction.

For a long time physical modeling has served as the closest-to-reality representation when ideas are tested. Notwithstanding its valuable contribution and development of tactility and visualization skills of architects physical modeling has its limitation and pitfalls especially in complex situations. These limitations and pitfalls can be possibly remedied by contemporary methods, while not necessarily replacing physical modelling but often complementing it.

From the static, timely, costly, passive, tedious and inaccurate simulation of reality that physical modeling has served until recently, we are nowadays in a position to simulate reality dynamically, in no time, at the cost of the digital infrastructure (that schools of architecture and architectural practices possess) but above all interactively and accurately. Interaction and accuracy could be considered the most important characteristics of contemporary simulation and modeling as they directly involve the design team with the dynamic forms/structures that emerge and allow for their freezing, modification and through *computation* to the actual *prototype building* and eventual manufacturing. Architects more than ever before have more control over the building process. Simulation through computation and model building offers greater control of the construction of their ideas that derives from the digitally produced design information that can automatically become construction information 'through the processes of data extraction and exchange'. Models are capable of consistent, continual and dynamic transformation and replace the norms of conventional processes.

Analytical computation techniques have shifted the value system of the design process from modularity to variability, from singularity to multiplicity and finally from mass-production to mass-customisation. Designers no longer 'create form' but 'find form' from an infinite spectrum.

Moreover, analytical computation techniques accurately perform structural, energy and fluid dynamics, airflows within and around a building and dynamic behaviours of other fluids such as smoke, water etc. The use of 3-D and 4-D models software releases all necessary qualitative and quantitative dimensional information for the design, analysis, fabrication and construction, assembly and sequencing. Models are used for conceptual, formal and tectonic exploration. The debate of the irreplaceable tactility of physical modeling comes to support rapid prototyping which is an affordable opportunity to investigate design iteratively with physical modeling up to one-to-one scale.

The outcome of the design process is no longer a simulation that differs dramatically from the characteristics of the real building and functions primarily as representation. On the contrary, the design outcome encapsulates with great accuracy the characteristics of the building that is being designed and can be directly manufactured. These fundamental changes in the domains of design and construction, as expected, demand a different work environment, knowledgebase, priorities and certainly values which will legitimize and reflect all the above.

The designers' role to negotiate their ideas on the way to manufacturing, that has been traditionally the case, has been limited. Their new role is to achieve the continuum from their idea to its manufacturing, and with fidelity and coincidence between concept and built form.

Are the ways methods and practices we employ to teach construction friendly and welcoming to these new changes? Do we give our students the possibility to enter a labor market which is rapidly adopting, and is orienting itself in the extensive use of these new techniques and logics?

Are the traditional teaching methods and techniques capable of receiving this new context or do they need an overall reassessment? What infrastructures do we need to have, and how close to the building industry do we need to get? What is the cost of such adaptation and what is our benefit? What examples have developed that could inform us about their effectiveness, the problems and the possibilities that they have created firstly to our students' competences and skills and secondly to the dynamics of our teaching? How do students respond to such innovations, what are the learning modes and patterns, what are they capable of doing with what they learn?

The overall theme of *testing and simulation could develop around five thematic areas, each one of which elaborates on the teaching examples of testing and simulation in construction teaching with special emphasis on topics of form and structure, the environmental control, the materials and the building components.*

While elaborating on the theme it proved to be impossible to isolate and discuss one issue from the other. The points made by eminent architects and engineers who have profound experience in testing and simulation due to their involvement in complex projects and given the diversity of their profiles and insightful thoughts encouraged this integration. Their points were further supported by construction teachers participating in the 6th workshop of Construction Teachers in Schools of Architecture in Europe.

For the past four years the European Network of Construction Teachers has been discussing the new reality of the dominance of digital tools in every day life as a whole and in the domain of architecture in particular. Either by calling them digital tools, digital design partners, or digital instruments they undoubtedly play a central role both in architectural practice as well as in architectural education. It is certain that words are not innocent, as they relate to the way things are perceived. One calls a computer or a software an instrument when one is an acoustician and tests noise control. One calls it a tool when one uses it for representation and finally one calls it a partner when one attributes to it the ability to generate, hence propose architectural forms.

On this new reality and its role on testing and simulation there was an opportunity offered by six entirely different personalities of this domain. The first one coming from Mathias Kohler and Fabio Gramazio from ETH Zurich both practising architects and teachers of architecture. In their approach they illustrated their method with several examples both from their practice and teaching. One characteristic example was the extraordinary use of an already existing and traditional building material, such as a brick[3]. In this example a robot was programmed to challenge and transcend its established positioning in a building and its established construction technique attributing to it this way meanings and offering to architecture new possibilities. With this example Kohler and Gramazio offered their experience on how digital technologies can be used creatively towards innovative architectural propositions.

Hanif Kara[4], one of the cutting-edge engineers of our times from London working with eminent architects, talked from another angle about the necessity of learning to work with others as the complexity of contemporary construction demands people with entirely different backgrounds and expertise. Testing and simulation is proving to be a new specialization necessary for the design and construction of buildings. The provocative title of his contribution 'Tools and Weapons…Engineers take' is telling of a situation where the means, including testing and simulation ones, to achieve a goal can be on one's side if used properly or turn against one if misused. Kara elaborated on the need to learn to work closely with specialists on simulation rather than pretending to be one and pointed out the need for architectural education to cultivate this multidisciplinary profile of the contemporary design team.

Philippe Samyn[5] an eminent engineer from Belgium made a contribution the first reading of which was about structural lightness and structural efficiency. However, it was mostly focused on the sustainable use of tools, including testing and simulation, in order for us to be in turn sustainable as a profession, as architects, as people conscious of the environment, on the use of materials, on the way we teach. Again, it was suggested that the sustainability of the professions of the architect and the engineer is a concern, which contemporary education has to address.

Vincent Servais despite his reputation of being one of the engineers of the longest bridges in the world that connects Sweden and Denmark, talked about the use of digital technology for building restoration. Construction teachers who are also involved in the teaching of building restoration can make the connection and use digital tools to test and simulate when rehabilitating a listed building. It was interesting to note that a specialization that has kept itself intact from digital technologies for some time, uses digital testing and simulation to test the performance of interventions when rehabilitating historic buildings.

Last but not least, Emmanuel Tzekakis's contribution was a surprise. Even though it seemingly appeared to focus on the case of acoustics, it offered a literature review on the evolution of testing and simulation tools and illustrated how progress has allowed for more precision and simulation of real life conditions. It was also useful to realize that acoustics such as other aspects of a building's ambience that need design and control can influence design itself and the form of a building, which is what architecture is about.

The overall impressions focused on the fact that even when testing and simulation is deployed in schools of architecture, this happens indeed outside design courses. The testing and simulation in design modules is limited at representation level in 3d animation images for understanding spatial, formal and lighting qualities of a building. Testing and simulation through advanced computer modeling yields precise and detailed results that are of no use in the hands of people who are neither familiar with what the process and the logic of the software is about, nor can they improve their designs by taking into account what the results are suggesting.

Despite the usefulness of modeling, its fragmentation from studio work renders its teaching sometimes irrelevant and disconnected from the broader context of design in the consciousness of students. As it has been rightly pointed out this is yet another sign of the era we live which is characterised by a crisis of integration. It was also suggested that testing and simulation can be an operational teaching tool with great learning outcomes. One of the tasks of teachers familiar with testing and simulation techniques and methods is, therefore, to simplify and adjust them to become valuable teaching tools. According to many views the iterative process of design, testing and simulation methods can be deployed to improve the design. It is for this reason that all architects should have insights into simulation software and should be able to understand what can be simulated and tested and consequently to be able to 'read' and interpret the results yielded. Moreover, architects have to be able to select, from the almost infinite information resulting from testing and simulation techniques, those few pieces necessary for their work. Moreover, it was also stressed out that simulation methods are advanced research tools.

There was a view expressed and charged with skepticism from some construction-design teachers also keen to protect the uniqueness of the tactile and bodily experience of space that cannot be 'modeled' or substituted by any modeling technique even of the highest caliber.

It was also pointed out that another dimension of testing and simulation in the contemporary design process, which is that of achieving a continuum between idea and its manufacturing thanks to contemporary testing and rapid prototyping processes. Precision and speed assured by these methods can advance ideas in no time with limited compromise from the original idea to the final product.

It was interesting to note that from the encounter of construction teachers, the theme appeared incredibly appealing to construction teachers that specialize in environmental and structural issues. The lack of extended examples on testing and simulation on design itself could be partly attributed to the fact that the discussion was addressed to construction teachers most of whom either do not regard themselves as design teachers at the same time or their school does not regard them as such.

Despite the extensive use of testing and simulation in environmental issues environmental-construction teachers explained that one has to be careful with results due to the lack of specifications for geography and site in a given context. Moreover, it was suggested that there is need for integration of environmental simulation with design.

Finally, there was also a view that simulation is a tool, architecture is a means. This view was supported by a number of environment-construction teachers who suggested that the aim is architecture, whether you achieve it by exploiting your 'window of opportunity' to be digitally literate or physical moderately literate is a different issue. But they are not two comparable things. It is a reality, we have to come to terms with.

All in all, it seems that there is a shift towards cultivating new skills and competences in contemporary construction and design education deriving from contemporary priorities and values. Whilst the structure, the letters, the alphabet, the language, the syntax and the grammar are there, one uses different tools and chooses different paths and methods to arrive at the same goal, which is architecture.

Testing and simulation can either aid on how something can be built or on how it can perform. This way complexity of what can be built can increase with digital models and design can be tested while it evolves through tangible examples achieved with rapid prototyping[6]. To deal with complexity and to be able to test design while it evolves has always been the objective of all times in the history of architecture irrespective of the way complexity or design is perceived. Architectural education, in turn, should have as objective to follow the evolution of the design process of every period and try to teach it in the form of simulation of reality, its context, value system and attestations[7].

Nowadays that digital fabrication strives to enable procedural techniques to bring together form generation and its construction, it is high time to eliminate compromise from one to another and to arm architects to pursue all they desire. In the history of architectural education it is the moment where design teaching and construction teaching could not get any closer. It is the moment where design pedagogy and construction pedagogy converge and are in a continuum. The artificial barriers that for years have been separating the world of design and the world of construction, the world of ideas and the world of their materiality have been deconstructed and a new paradigm has shone through with many promises and high potential architectural education should not overlook. The broad and thorough use of testing and simulation techniques will enrich the formal language of architecture as the more the means available to create ideas the wider the range, just to paraphrase William Mitchell[8].

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Opening Session

Immanence / transcendance
Réalité / réalités

Prof PhD Eng arch **Hugues WILQUIN**
Full Professor, Head of Architectural and Urbanistic Department,
Faculté Polytechnique de Mons, Belgium

- No, no,…NO, Doctor, I cannot see the reality…just these strange shadows…undoubtly colourful but.... this is not the reality ! NO, NO,...No!

    Just nearby, from the waiting room, I can clearly hear the conversation between a certain Mr Cube and his ophtalmologist, the famous doctor Openedeyes.

- Doctor Openedeyes, I cannot see the precise limits of the volumes...

- Try these glasses, Mr Cube...

- But, Doctor, I cannot distinguish the colours now,.... it's black and white!

- Ok, try these other glasses...

- But,...DOCTOR!, it's allright for the colours, this red, this yellow and this black,... but I have lost the definition of the lines...

- Ok, try these third glasses

- DOCTOR, Doctor...NO! The lines are now a little bit flou, the colours are too light, the contrast is other..and...and I want to perceive... the infrared radiations,...and, and I want to feel ...the temperature of the buildings and... of the bodies..and I WANT TO KNOW what are thinking the persons I meet ..and, and, ...Doctor, Doctor, DOCTOR... I want to know if they appreciate me,....and, and...

- STOP,STOP... What do you want? What do you want?...that's the most important question you have to ask to yourself!

- But, DOCTOR...

- What do you want...and to do what?
  ... That's the complete question, Mr Cube...not JUST to get toools to do everything or... anything ...But to choose and profile your toools in purpose to...in purpose to act in a certain way.
  What to do and how to do FOR WHICH PURPOSE....that's the question!

Good afternoon, ladies and gentlemen,

Mesdames, mesdemoiselles, Messieurs, bon après-midi!

Il me revient , en l'absence de M. le Recteur Conti , retenu à la dernière minute par des obligations impérieuses du monde universitaire en pleine mutation, …il me revient donc de vous accueillir dans les locaux de la Faculté Polytechnique de Mons.

Cette sixième rencontre-atelier thématique issue du Réseau Européen ENHSA, intitulée Emerging Possibilities of Testing and Simulation Methods and Techniques in Contemporary Construction Teaching va nous réunir dans le bâtiment le plus récent de cette vénérable institution que constitue la Faculté Polytechnique de Mons, fondée en 1837 au cœur de la ville historique de Mons.

Mons dont le souci de la préservation, de la restauration et de la réhabilitation a été constant depuis maintenant presque quarante ans.

I hope you will enjoy your lectures and communications, I hope you will enjoy our university, I hope you will enjoy your meeetings, I hope you will enjoy our meals, our wines, ...our beeers!

I hope when you will return back home that you will remind these days as the upper part of the head of the monkey at the grand-place...

Le singe, ce porte-bonheur au crâne luisant où tant de regards se sont portés, où tant de mains gauches, la main du cœur se sont déposées...

The monkey, symbol of thoughts, feelings, exchanges...and smiles will guide us during these three days!

Maria VOYATZAKI, Thessaloniki, Greece

Even though around this room there is a seventy percent of people that keep coming back for the sixth year, equally nervous as I was in the first year trying to explain what is actually after as a Thematic Network. The reason why I am nervous is because seventy percent of people that are here, hear the same story every year. Somehow in my effort to connect it to what we are doing this year; I will try to make it as abstract as possible, so that I do not bore those that hear this for the sixth time, while I will try to be detailed enough, analytical enough for those that are here for the first time and are not really familiar with the context of this event. If we look at it very roundly, what it is that we are really after, as construction teachers is the amelioration or the improvement of our teaching methods as construction teachers. When we set up the network, we never knew what its future was going to be. But the fact that we are still here on an annual basis to organize the sixth year is somehow proof that we are really keen on improving the subject area we teach. Within the Network that Professor Constantin Spiridonidis is going to talk to you about, we develop this Thematic Network in this effort. But each time we concentrate it on several issues, starting from very general points to very specific ones, like the one we are dealing with this particular year. And this is pretty expected and understandable in the sense that when you get together with your peers, because as it happens, due to the fact that we teach the same subject area, we happen to be peers. There are still unkown issues that have to do with several things that concern our teaching from the profile of ourselves, the profile of our students, the timing in which we teach construction, the content of our construction teaching. The extent to which we teach. Therefore, the first meeting that we had was a very tentative one, where we discussed these issues, regarding the what, the when, the how, the to what extent and primarily the method of teaching construction. The pedagogy of the teaching subject. It was a very informative, while at the same time, a very tentative meeting. People came very green to this meeting without knowing each other and we got together to discuss these issues, mapping somehow the state of the art of construction teaching around Europe. We started off with 45 people. What the conclusion was to start with apart from the conclusions that had to do with the themes that touched upon themselves was that firstly we have to do it again and secondly we have to focus on the method and the pedagogy of construction teaching. Therefore the second meeting concentrated on the exercises that were described as a vehicle to explain the teaching methods by several approaches that we adopt in order to teach construction and that was the second meeting. Then we realized that we still wanted to keep talking about construction teaching, but with a prospect to the future. We started in 2002, I described already the second meeting in 2003. In 2004 upwards or towards nowadays dealt with the future of construction education. Firstly, as a whole and in a general terms and then in 2005 it concentrated mostly on how the digital reality is or might affect our methods of teaching. Last year, we discussed in Venice, the issue of interdisciplinarity as a new reality of the teaching environment, the architectural environment and the built environment, which affects effectively or might affect effectively the teaching of construction. This year we are dealing with a very special issue, which is about simulation and testing. And I would like to give you a little bit of feedback on this and explain to you, why we felt that this is a very interesting issue to discuss. Traditionally, what we do as teachers is very tentative and it is an eterotopia, in the same way that it is an eterotopia in the student of the School of Architecture based on simulation. We have never been taught to teach architecture. Our background is either architecture or engineering or both, but none of us has studied to become a teacher of architecture. It happens very often to simulate the reality of the creation of the built environment, of an architectural practice when we teach architecture. It is a method. Similarly a student of architecture, very often simulates or is urged to simulate what happens in the real world of the production of the built environment in a class. In other words simulation is a reality in education as a whole. But if we come to construction especially and we put things in contemporary context, we have tools nowadays employed to either give birth to form. In other words to do what we call morphogenesis or we use tools to represent what is created in a studio or through a design. In the history of architecture, simulation has always been a very crucial issue. Simulation of the form. Simulation of the volume. Simulation of the vision. Simulation of the senses. Construction is the closest, or perhaps the most crucial field, domain, in which simulation is necessary. Firstly to understand how we put things together and secondly to understand, whether the things we put together will undergo loads, will be tested again forces from the earth, different phenomena. Structures that are innovative. Innovation and simulation go hand in hand. I can never perceive innovation with no simulation and simulation that does not eventually lead to innovation. Therefore, the pursuit of architecture happens to be to innovate, we always strive for something new, whether that is new in form, new in structure, new in the use of materials new in perceptions of using a traditional material in an innovative way. Somehow testing and simulation is always what we are about as architects, as structural engineers, as environmental designers, as teachers, as students of architecture. Therefore, I feel that simulation and testing is something we are concerned about and we are here to discuss it from many different perspectives. I know it is a very difficult subject to touch upon. I had many people that wrote to me, that they want to follow this, but in order to justify my existence in this meeting at my school, I need to have a presentation, but I do not really know what to write about, which is totally understandable. We are not here to present necessarily what we do about simulation, but our views are what we feel as a historical value, perhaps a criticism to the old, a criticism to the new. Please feel at home, as far as this issue is concerned. This is not addressed to specialists on computers or whatever. This is addressed to all the audience, because what we are mostly about around this meeting, is to learn from each other and hear different views. Maybe the young people or the people that deal with computers and do simulation have something to hear from the other views and vice versa. We are here to gain. We have done our best with the set of keynote speakers that we have invited. It is in fact the first year, that we have six keynote speakers, which was quite an expensive exercise I must say, given the number of people around this room. But I feel it is really worth it and since the subject itself is quite genuine, it is important to hear people that specialize in the subject and use simulation as a modus operandi, as a way of existing as designers and as teachers of architecture. What is also quite interesting with the people that have been invited and you will hear their CVs as we go along just before their presentations. They are well established practitioners who build around the world. But they are also hugely and seriously involved in education. They find the time, in other words, they have the passion to approach students and convey their knowledge and understanding, but obviously they are there, because they feel they gain something back from their relationship with the students. This is more or less the framework. As we go along I will give you more details, that I am sure I have forgotten as I am speaking, but I would like to pass the floor to Professor Constantin Spiridonidis, to give you an overview of the activities of the Network and how he sees the development of subject area, Thematic Networks.

Constantin SPIRIDONIDIS, Thessaloniki, Greece

Good afternoon ladies and gentlemen, dear friends. Maria insisted that I have to say a few words about the Thematic Network. I consider that it is something boring, since after six years the same Introduction and the same presentation of the Network could appear a repetition with no reason. I found that there is a possible legitimization of this short intervention of my part, when I thought this is the last Workshop organized under the umbrella of the European Network of Heads of Schools of Architecture. And I say the last one, because this project, this program will finish next September and if there will be another meeting of construction subnetwork, then this will be under a different umbrella. This is an interesting issue, I think, because we are in front of a dilemma. Shall we continue that? Shall we go for another application for three more years of this Thematic Network or we will leave this self-sustainable and to develop without any constraints coming from the background of the framework of this Thematic Network. I cannot say that our feelings are very clear for the time being, but the fact that this Thematic Network as a total was one of the most successful Thematic Networks in the domain of Socrates or now Lifelong Learning Projects makes us hope that we have chances if we ask for a third extension, for three more years. If that will happen, then the question is what will be the orientation of a subnetwork like this one and this is a question that we have to address to you. We do not want to give our own answer, but in order to make things a little bit easier, it would be useful to remind you that in the previous versions of this Thematic Network Project, the subnetworks like this one, like architectural design, like theory, like restoration and renovation had as main objective in the project that we had developed in the framework of this Thematic Network. We have two objectives to achieve. The one was that Professor Maria Voyatzaki already mentioned, that is to say, to map, what is existing in the domain of architectural education related to the teaching of this subject areas and the second one was to try to eliminate the limits between the different subject area, like construction, like design, like theory, like restoration, because we strongly believe that these limits are more or less artificial and what is significant in our times to bring the bridges and to bring closer the different, separated until now teaching and understanding of those subject areas and I think that this Construction Thematic Network was very successful on that, since the discussion was not, from the very beginning, not only concentrated on the teaching of construction but in a broader view of the role of the construction in the understanding of architecture. If the mapping more or less has been done and we have rather good knowledge about what is happening in this domain, then the main question that will be very significant for us in the perspective of a new application would be, what will a project of a Thematic Network on construction teachers for the future. Probably towards the direction of action as Professor Hugues Wilquin already mentioned and I would like to ask you to keep in mind this question and probably through the discussions and the debates of this session at the end there will be some kind of suggestions, which will be useful in case that we will proceed next March for a new application. I would like to wish you a fruitful stay at this Institution and fruitful debates and exchanges and I would like to thank, first of all, the hosts Alain and Hugues for their help and support and of course I would like to thank Professor Maria Voyatzaki, because I know how anxious she was, during the preparation of this event.

Keynote Addresses

Keynote Address

Fabio Gramazio
Mathias Kohler

Towards a Digital Materiality*

Technical University of Zurich
School of Architecture
Zurich
Switzerland

* This article/paper was first published
in Branko Kolarevic and Kevin Klinger (editors),
*"Manufacturing Material Effects:
Rethinking Design and Making in Architecture",*
London: Routledge, 2008.

The digital revolution had an unquestionable impact on contemporary architecture; it has changed the ways in which architecture is conceived, built, mediated, and used. This evolution has only just begun, and it is still too early to predict the long-term consequences for the architectural discipline. Already, a whole spectrum of polemical views on digital technology – ranging from unbridled enthusiasm, at one extreme, to reactionary fear, at the other – have dominated the debate and divided the professional community. Due to its intangible nature, the digital realm is generally misconstrued as being antagonistic to the analogue or physical realm. Our intention is to unite these seemingly opposing realms.

Since its foundation in 2000, *Gramazio & Kohler* has been exploring digital realities within architecture, working with the firm conviction that the digital paradigm will inevitably redefine the discipline. Human intelligence allows architects to take design decisions on complex issues using associative capacities and experience, yet unlike computers, humans are unable to process large amounts of discrete data. By understanding the fundamental concepts of digital logics and mastering its processing techniques, we expand our capacity to integrate information into the design process without losing control over it. The architect is engaged in the selection of relevant architectural parameters and the definition of subsequent rules and processes. The construct is created by a system that is entirely defined by the architect.

One of the most radical consequences of the digital revolution is the computer-controlled fabrication machine. As decades of artificial intelligence research have shown, a physical body is a precondition for every kind of intelligence. Architecture cannot be reduced to a conceptual, geometric, or mathematical phenomenon. Artificial "intelligence" in architecture can only manifest itself through a tectonic logic and a physical, material "body." The application of a fabrication machine in architecture allows a direct coupling between information and construction. In digital fabrication, the production of building parts is directly controlled by the design information. This seamless link between data and material, design and building, dissolves the apparent incongruities between digital and physical realities and allows a new constructive understanding of the discipline. Thus, these issues are the primary focus of our research in the Department of Architecture at the *Swiss Institute of Technology* (ETH) in Zurich.

Robotic Additive Fabrication

In order to investigate the consequences of informing designs with the logic of physical materials and vice versa, we opened a research laboratory at ETH for the digital fabrication of full-scale prototypes and non-standard building parts (DFAB). For our first experiments, we chose a standard industrial robot. Its extreme flexibility, both in terms of the software that controls it and its physical capacities, allows us to program its movements and design the actual construction tools it selects for operations. For us, it is a veritable "personal computer" for construction. With this robot, we investigated the logic of *additive* fabrication, using the most elementary architectural building block – the brick. The resultant projects, described below, confirm that digital logic, both in design and fabrication, will lead to profound changes in architecture, blurring and ultimately dissolving the boundaries between analogue and digital realities. We stand at the very threshold of an exciting development and believe that we should, as architects and authors of design information, actively lead this process towards a new, contemporary, and integral understanding of architecture that is relevant to our age.

Mtable

The *mTable* table series project, completed in 2002, enabled us to examine the consequences of customer interaction when designing non-standard products. In the process, interesting questions emerged: How much responsibility is the customer able to assume? How much does he or she want to assume? Who ultimately is the author? To what extent does the co-designer identify with the product? What consequences does this development have on architecture?

With *mTable*, we created a table (figure 1) that customers can co-design. Modern communications and digital production technologies were used for its customized design and fabrication: we declared the mobile cell phone to be a personal design tool, and examined how it can be utilized to assist the individual to co-design his or her physical environment.

The design principle is simple. Customers choose the size, dimensions, material, and color of the table from their cell phone display (figure 2). Next, they place deformation points on the underside of the table and "press" them (figure 3); these points then "break through" the surface, creating holes with extremely thin edges, turning the table's top and underside into two distinct "landscapes" (i.e. topographies). The program on the cell phone then verifies that the table with holes is structurally feasible.

Using a mobile phone is an enjoyable and inventive way to control the future physical shape of the table. The phone display's low resolution and a deliberately simplified interface make customers focus on the most essential design features. As soon as the customer is satisfied with the design, he or she transmits the parameters that define the table as a simple series of numbers to the web-based platform at *mshape.com,* where the designed table can be seen in high resolution, and compared with the designs by other customers (figure 4). Following the placement of the order, the table is cut by a computer-controlled milling machine

Fig. 1

The *mTable* designed using a mobile phone and digitally fabricated.

Fig. 2

mTable: dimensioning the table using a mobile phone.

Fig. 3

mTable: creating the deformation points and holes in the table's surface.

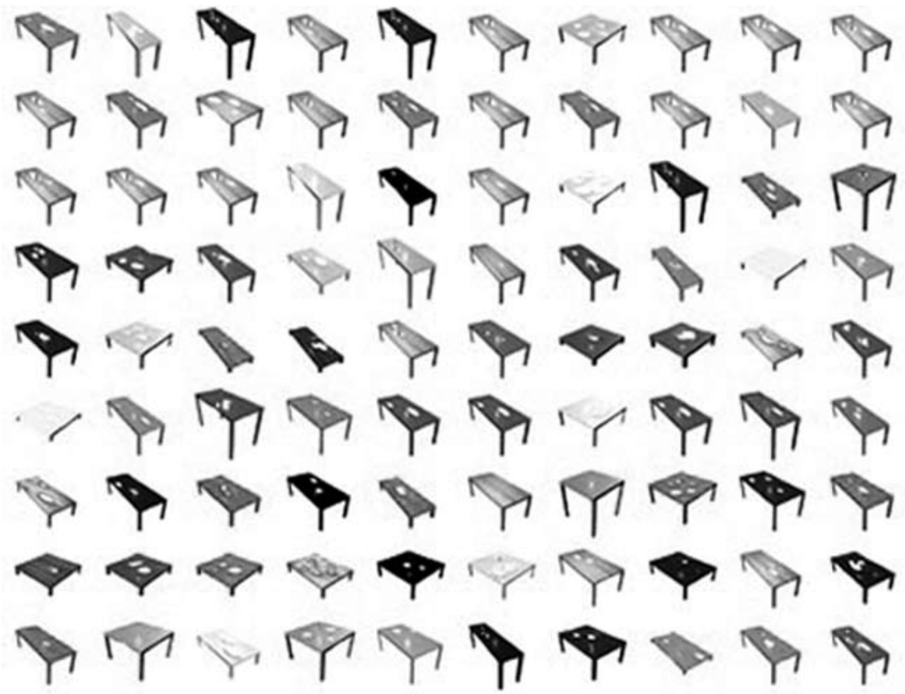


Fig. 4

mTable: many different designs can be produced effortlessly.

Fig. 5

mTable: the CNC milling machine produces the table "landscape" based on the data transmitted from a mobile phone.

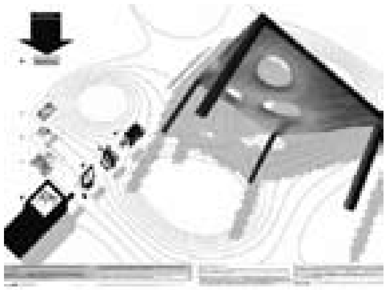


Fig. 6

mTable: each table features opening in the top, curved edges, and a spectacular underside.

(figure 5) directly driven by the data (parameters) transmitted from the mobile phone. The virtual three-dimensional model is transferred to the physical material.

The openings in the table top, the curved edges, and spectacular underside (figure 6) lend every table a unique quality. Admittedly, different tables are only unique on the surface, as they all share a common formal and conceptual origin. Still, each table is a result of the customer's decisions and variations on a design pattern. Together, the tables form an entity – the *mTable* design family (figure 4).

The *mTable* project changes the task of designing form to defining the *rules of a design system*. The design concept and the formal consequences are carefully embedded in the software that provides a framework within which the customers can develop their own creative strategies, thus giving them control over the ultimate outcome of the design – the form. By deciding for themselves if and where the holes are placed, they assume partial responsibility for the aesthetic appearance, and functional efficiency of the tables. The designer, however, still retains control over which decisions are delegated to the customers and how freely they can intervene. This blurs the distinctions between designer and the customer, as the customer becomes a co-designer.

"The World's Largest Timepiece"

The project for the *Christmas lighting* on Bahnhofstrasse in Zurich, Switzerland (2005)[1], is based on a winning entry in a competition that called for a contemporary interpretation of the lighting installation designed over thirty years ago by Willi Walter und Charlotte Schmid. Their project was described as "distinctive, generous, unique," and these were qualities the new design was naturally expected to incorporate.

We designed a continuous band of lights with a dynamically changing pattern (figure 7). The main premise behind the time-based light installation is that light is not static, but fundamentally dynamic in nature. Light can now be used as a highly flexible and interesting information medium, due to contemporary digital technology that can provide control over its intensity. By changing its appearance during the Advent season, "The World's Largest Timepiece," as the installation is called, accentuates the passing of time and creates a constantly changing "lightscape" on Bahnhofstrasse, and provides every visitor with a truly unique experience.

Fig. 7

Christmas lighting on Bahnhofstrasse in Zurich, Switzerland (2005).

Fig. 8

Christmas lighting: a visual backbone of the city.

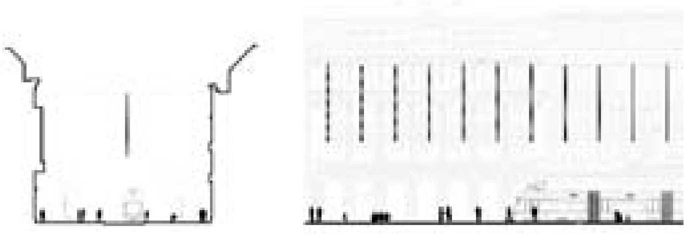


Fig. 9a,b

Christmas lighting: a section and an elevation drawing.

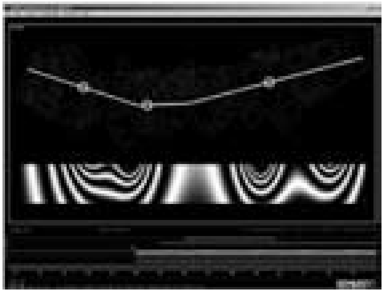


Fig. 10

Christmas lighting: interface of the XMAS Generator software.

Fig. 11

Christmas lighting: manufacturing of tubes using woven glass fibers.

The installation is conceived as a single illuminated line running from the railway station to the lake, emphasizing the urban "boulevard" atmosphere of the Bahnhofstrasse and accentuating its two slight, yet distinct turns in direction as it negotiates the heart of downtown Zurich (figure 8). Its simple, linear course turns the band of light into a visual backbone of the city. The vertical shaft of light in the middle of the street contrasts with the surrounding building façades and points upward to the night sky. Depending on where the viewer is standing, the *Christmas lighting* can either look like a slick series of individually lit tubes or a glowing, constantly changing curtain of light.

The installation consists of 275 tubes of light, each 7m high, and placed at 4m intervals (figure 9a,b). Each light tube has 32 small LED bulbs and contains the electronic equipment necessary to regulate 256 brightness levels within each bulb. There are 8,800 LED bulbs in the 1km-long band of light. The intensity of each bulb can be controlled in real time, using custom-made software written in C++ called *XMAS Generator* (figure 10). Approximately 26,000 lines of code were necessary for the creation of this software. Different light patterns were generated and transmitted to the light tubes via an optical databus at the rate of 17 times per second.

The changing patterns of light are generated by an algorithm controlled by the dates associated with the holiday season and the street activities that were recorded using sensors. An increase or decrease in the number of visitors affects the character of the lighting patterns and the frequency of change. Hence, the light patterns not only reflect the passing of time, but also the daily activities on the street itself. In this way, each passer-by can alter the street's ambience by influencing the lighting patterns. In a form of collective interaction the *Christmas lighting* becomes the city's inner timepiece, and creates an unpredictable, dynamic, and immaterial architecture, similar to clouds in the sky.

Each of the 7m-long tubes had to illuminate in all directions, withstand wind and water, and be lightweight. We had to find a sufficiently rigid material for the shell of the tubes that allowed the transmission of light; a supporting aluminum core would have created unattractive shadows on the outer shell and thus compromised the effect. After several trial and error experiments, we stumbled upon the manufacturing technique for woven glass fibers used in high-tension insulation, in which glass fibers are soaked in resin and spun around a mandrel (figure 11). We were fascinated by the additive logic of this process. The winder controls the stacking of the fibers via two computer-coordinated movements. A sliding carriage drives the wound glass fibers back and forth along the spinning mandrel. This creates an extremely stable multi-layered shell. The stacking winder and the number of tiers and overlaps determine the flexural rigidity and torsional stiffness, as well as the transmission of light.

The bands of glass fibers are woven into a rhombus structure: the thick areas are responsible for the stability of the structure, and the slender necks create optical brilliance. In order to optimally join both light diffusion and rigidity, we developed software that simulates the fabrication process, enabling us to test weaving variations with different bandwidths, angles, and tiers. Using more than thirty physical prototypes, we tested effective optical qualities such as brilliance, light transfer, and surface structure for both night and day conditions. We also tested wind resistance. The final tube was 7m long and 15cm in diameter; its shell was only 2 mm thick. It weighed less than 23 kg, including lighting and control technology. An intense involvement with the computer-operated production process allowed us to integrate two normally incongruent requirements into one single material, and thus implement for the first time wound glass fibers for lighting on this scale.

Gantenbein Vinery Facade

The new service building for the *Gantenbein Vinery* in Fläsch, Switzerland (2006), was already under construction when *Bearth & Deplazes Architects* invited us to design the façade (figure 12).[2] The building had three stories: a cellar for storing the wine barrels, a large fermentation room for processing grapes, and a terrace-like lounge for wine-tasting and receptions. The fermentation hall had to be windowless, because constant temperatures and subdued lighting are required to ferment the grapes properly. To provide natural lighting despite these preconditions, we designed a façade in which the bricks were laid with gaps between them to allow daylight to enter the fermentation hall (figure 13). The façade itself has two layers: outside, the masonry layer functions as sun protection, light filter, and temperature buffer; inside, polycarbonate panels protect against wind.

We decided to imbue the façade with a pattern that looked from afar like a basket filled with grapes (figure 12). To create this effect, we designed an information generation process that produces an impression of a precisely controlled result by applying purely systematic chance. We interpreted the *Bearth &*

Fig. 12

The new service building for the *Gantenbein Vinery* in Fläsch, Switzerland (2006).

Fig. 13

Gantenbein Vinery: interior of the fermentation hall.

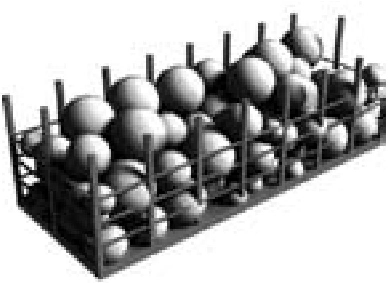


Fig. 14

Gantenbein Vinery: a "basket" filled with "grapes."

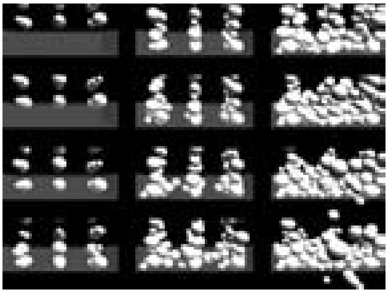


Fig. 15

Gantenbein Vinery: the falling "grapes."

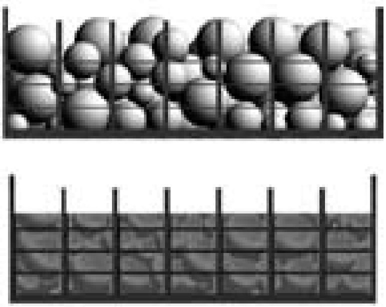


Fig. 16a,b

Gantenbein Vinery: elevation images of the digital "basket" were used to create the "grape-like" brick wall patterns.

Deplazes' concrete frame structure as a massive basket, and filled it with abstract balls (the "grapes") that varied in diameter (figure 14). The balls fell into a virtual container via digitally simulated gravity, until a specific density was reached (figure 15). The elevation images of the digital "basket" were then used to create the "grape-like" brick wall patterns (with gaps), using an automated layout process (figures 16a,b).

The brick wall patterns are three-dimensional. Bricks are rotated slightly, and thus reflect light differently, resulting in slightly different tonal values on the surfaces (figure 17). In this way, bricks function like pixels that form the "grapes" image pattern on the façade, and thus brand the identity of the vineyard. Unlike a two-dimensional image, however, there is a subtle interplay between plasticity, depth, and color in a three-dimensional brick pattern, producing not one but many material effects that constantly shift during the course of the day (figure 9.18). The result is a dynamic surface that possesses a sensual, textile softness.

On closer view, the walls reveal a materiality that resembles stonework, and one is surprised that the soft, round form is actually composed of individual, orthogonal, hard bricks (figure 18). The façades appear as solidified dynamic forms, whose shallow three-dimensional depth invites the viewer's eye to wander. Once inside, the transparency of the brick wall surface becomes evident. The daylight creates a mild, yet luminous atmosphere in the fermentation hall (figure 9.13); the design intent becomes manifest through the subtle light modulation by the gaps between the bricks. The superimposed image of the landscape glimmers through in various ways.

A three-dimensional brick façade, therefore, is far more *affective* than a two-dimensional image. To create subtle visual and tactile effects, bricks were rotated in two counter-directions, with a maximum deflection of 17° (figure 19). Each façade was balanced, so bricks would progressively rotate as much in one direction, as in the other.[3] Where there is no visible "grape" (meaning where a gap is created in the virtual "basket"), bricks are in a neutral position and thus form a simple running bond.

The construction technology we developed at the ETH enabled us to lay each brick precisely using an industrial robot[4] (figures 20a,b). Not only did the robot lay the bricks, it applied a special bonding agent onto each brick (figure 21) rather than traditional mortar. With this new digitally driven, additive production method, we were able to construct each wall differently, so that each would possess the desired light and air permeability,[5] and thus create the overall pattern that covered the entire façade. We designed 72 different brick wall panels using a computer program created expressly for that purpose. The program generated the production data directly from the design data and calculated the exact rotation for each of the 20,000 bricks that comprise the 400 m2 façade. The bricks were then laid out automatically by the robot according to programmed parameters, at prescribed angles and at exact intervals.

Because each brick is rotated differently, every single brick has a different and unique overlap with the brick underneath. We had to find a method of applying the bonding agent so that it fits precisely every overlap (all of which were dimensionally unique) and, at the same time, distributes the adhesive evenly. Working closely with an engineer from the brick manufacturer, we devised a strategy whereby four parallel bonding agent paths could be applied at pre-defined intervals to the center axis of the wall panel. This strategy allowed us to attain consistent dimensions. Load tests performed on the first manufactured prototypes revealed that the bonding agent was so structurally effective that the reinforcements normally required for conventional prefabricated walls could be completely eliminated.

Manufacturing 72 façade panels was a big challenge, both technically and in terms

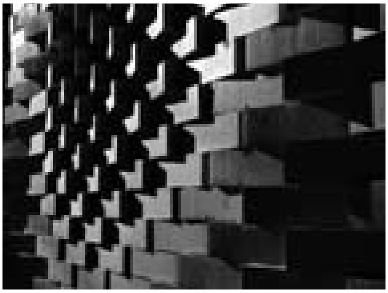


Fig. 17

Gantenbein Vinery: the brick wall patterns are three-dimensional.

Fig. 18

Gantenbein Vinery: rotated bricks function like "pixels" that form the "grapes" image pattern on the façade.

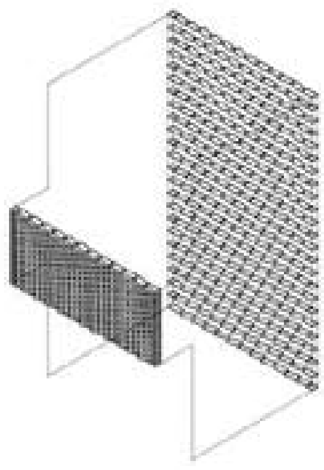


Fig. 19

Gantenbein Vinery: the bricks can be progressively rotated in two counter-directions.

Fig. 20a,b

Gantenbein Vinery: the bricks were laid in a layer-by-layer fashion by an industrial robot.

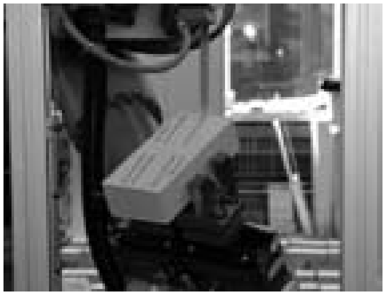


Fig. 21

Gantenbein Vinery: the robot also applied the bonding agent to the bricks.

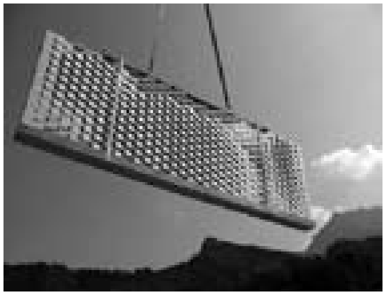


Fig. 22

Gantenbein Vinery: the wall panels were installed on-site by a crane.

of deadlines. Due to the advanced stage of construction, we only had three months to complete the design and production before installation on-site. Because the robot could be directly driven by the design data, we were able to work up to the last minute on the façade design, while developing simultaneously the production method.[6] In the end, the façade panels were produced over just two weeks (with the robot working double shifts!). They were then transported by truck to the construction site and installed by a crane (figure 22). The procedure was developed in collaboration with a brick manufacturer who, as an industry partner, was subsequently able to take on the system guarantee on our manufactured panels.

Perforations

What is the spatial effect and architectural significance of a perforation in a wall, in the form of a diagonal, round hole? Openings regulate the amount of light and air that enters a building. Moreover, by allowing one to look into or out of the building, they also create visual relationships between the interior and exterior. Qualities such as dimension, position, depth of a reveal, and geometry determine their architectural expression. The complexity is heightened if an opening (i.e. a perforation) passes through a wall at a non-orthogonal angle; the reveal's visual presence is emphasized and the wall acquires more depth. Besides formal qualities, the number and arrangement of the holes also affect the architectural effect of a perforation.

Today, complex, perforated architectural components can be created using digital design methods. In contrast to industrially manufactured elements, such as a punched perforated metal sheet, the digitally designed perforations do not need to be based on a repetitive, regular grid. The individual openings can be different in shape or diameter, and the material can be perforated not only orthogonally, but also at different angles through the surface. Moreover, given that each element can have a unique pattern of perforations, larger constructs made of different perforated components, such as façades, can be designed without repetition.

What is the best way to design using a large number of openings? What would it mean if each individual opening was at a different angle to the surface? In several elective courses[7] at the ETH in Zurich, the students were asked to examine the spatial potential of highly perforated wall elements. These wall elements had to be developed using innovative digital tools, which we encouraged to be seen as more than simple technical aids to manage geometric complexities. In each course, students produced full-scale prototypes of perforated wall panels, concentrating on the materialization and development of a self-devised production technique. Designing with large amounts of information – and "informing" the material in the process – required the development of computational tools as an integral element of the design process. The students altered and expanded the digital tools in an agile, creative manner, based on the feedback attained through the iterative processes of design and production.

In the "oblique hole" course *(Das schiefe Loch),* students had to allocate 2,000 holes over an irregular polygonal volume (figure 23). The objective was to examine the architectural potential of spatial perforations pro-

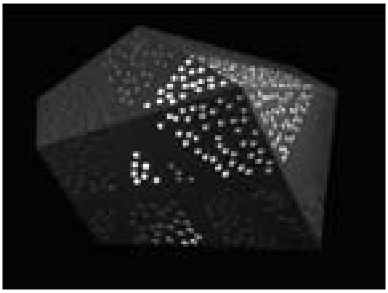


Fig. 23

The "oblique hole" project: 2,000 holes were created in an irregular polygonal volume.

Fig. 24

Simple robotic drilling inscribes the digital architectural information into the material.

Fig. 25

The "perforated wall" panels.

Fig. 26

Cutting of the formwork boards for the perforated wall.

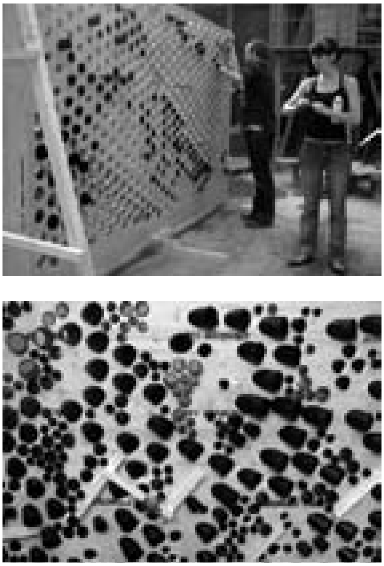


Fig. 27a,b

Completing the formwork by inserting standard pipes into the holes.

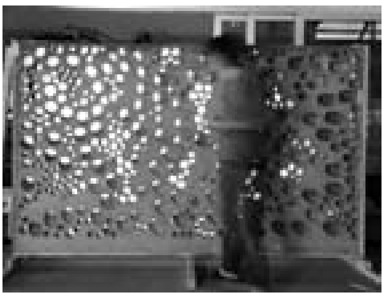


Fig. 28

Perforated panels were tested for their load-bearing capacity.

duced by distributing a large amount of circular openings in an irregularly shaped form. The production tool was a milling spindle mounted on a robot hand; the robot's ability to drill holes at any angle to the surface expanded the design possibilities from merely distributing the holes to also defining their direction. Various algorithmic tools for distributing the holes had to be developed, as it was impractical to process such a large number of perforations with conventional computer-aided design (CAD) technology. The digitally generated design data was translated into production data for the robot by a custom-developed post-processor. The production data for each individual hole consisted of its position in space and a vector that described the tool's drilling path through the material (figure 24).

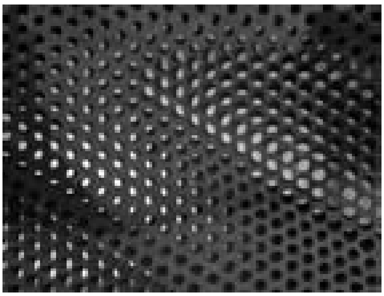
Surprising architectural artifacts were created despite the fact that design options were intentionally limited to a single hole (i.e. drill) size of 10mm in diameter. It was the thickness of the material, which transformed a supposedly two-dimensional job into a complex three-dimensional design task, that revealed the project's full architectural potential. Orienting fields of holes towards a certain point in space caused the physical depth of the material to collapse into an abstract, almost immaterial surface when seen from a particular vantage point. The openings created new spatial and visual paths between the interior and exterior that were independent of the volume's physical geometry. For the viewer moving about the room, the three-dimensional nature of the perforations changed the effects of the architectural volume.

The exploration of perforations continued in the "perforated wall" *(Die perforierte Wand)* course. The students examined the potential of "informing" large Styrofoam panels (1 x 2 m in size) with a large number of round holes; the panels were considered full-scale components of a larger wall or façade design (figure 25). As in the previous project, the holes could be defined using five different parameters: the

X and Y position on the wall, the "alpha" *directional* ("deflection") *angle vector* into the wall mass, the "beta" *cut-out angle* around the central axis of the hole, and the *radius* of the hole. The holes were distributed using dynamic force fields of attraction and repulsion, in which parameters defining the location and intensity of the forces could be interactively changed. The holes could produce different perforation patterns on two sides with the use of "target" points to define the "deflection" of the holes. We also used the custom-developed "color mapping" tool that translated the red, green, and blue (RGB) values associated with pixels in a chosen image into the "alpha" *directional vector,* the "beta" *cut-out angle,* and the *radius* of the hole, respectively. Working with images provided the students with an intuitive and direct way to "inform" the material.

With another group of students, we worked on developing a method to cast a large (3 x 2 m in size) perforated wall in cement. We used a robot to cut the geometric extensions of the holes into the formwork boards (figure 26), in order to transfer the perforation information onto the concrete formwork. After assembling the formwork, standard plastic pipes were inserted into the holes as block-outs (figure 27a,b). The design information was thus indirectly transferred to the material via the formwork design.

Manufacturing the formwork presented a particular challenge, because, due to the irregularly distributed holes and the narrow breadth of the web, neither a conventional reinforcement, nor a mechanical re-densification of the concrete was possible.[8] Also, we were unable to use the self-compacting steel-fiber concrete that had recently been developed by the *Institute for Building Materials (Institut für Baustoffe)* at the ETH Zurich. After a successful casting, we used various load tests (figure 9.28) to check the structural effectiveness of the wall element. We tested wall elements with different densities of perforations and demonstrated that even highly perforated walls could be used as bearing walls in a building structure. We also demonstrated that the load-bearing capacity can be locally controlled with a density of perforations and the deflection of the holes. Our prototypes revealed the multiple architectural potentials of a perforated wall. By moving from Styrofoam to concrete, we created not only complexly "informed" concrete panels with some very interesting potential for light and sight modulation (figures 29a,b), but also produced actual load-bearing, structural components.



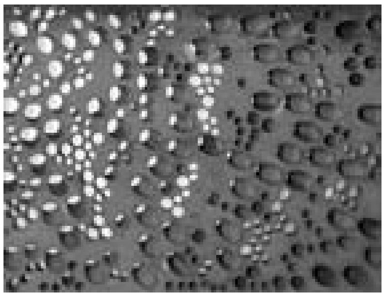


Fig. 29 a, b

Perforated panels cast in concrete.

The Programmed Wall

Fig. 30 a-c

The robot producing one of the "programmed walls" brick by brick.

A key assumption underpinning our work is that new digital technologies of design and production will influence the architectural definition of building components. Our research interests are not limited to the technology only. Examining the robotic additive fabrication of brick wall panels, we asked our students to explore social and cultural implications of that technological possibility.[9] What does it mean to digitally fabricate a brick wall using a robot rather than a person? A robot is not only quicker, more precise, and more productive, but it also enables complex designs that are impossible for a human to build with that level of accuracy. The robot does not need an optical reference or an identifiable pattern in order to lay bricks precisely. It also allows complex walls to be built without relying on repetition.

We chose to work with bricks, because a brick is perhaps the most highly developed module in building history. For over 9,000 years, human hands have optimized the brick's dimensions, proportions, weight, and material. The sequencing, the joint detail and the type of bonding agent used determined the specific structural qualities and appearance of the brick wall. Despite the long history and well-established traditions in the building industry, the brick walls today aren't nearly as ubiquitous as they were not long ago; the brick is now mainly used as a single-layered facing on a building. Due to the high cost of labor, walls today are mostly made of large, industrially manufactured blocks or reinforced concrete.

If the brick walls are too expensive because of the high cost of labor, to continue working with this material, the assembly of brick walls could be programmed and automated. A wall made of brick is subject to the rules of mathematics, meaning the relationships (i.e. connections) between the bricks, and can be described by an algorithm and therefore, "programmed." In turn, digital production allows direct translation of computer programs into physical artefacts. A robot can build a wall: it can lay each brick in the exact prescribed position, at the exact angle, and at the exact interval, as described by the author of the program, i.e. the designer. The robot can also position each brick differently with no additional time and effort, which is not possible for humans (figures 30a–c).

New spatial and architectural possibilities open up with "programmed" brick walls. Continuous, procedurally controlled variations of the position and rotation of each brick could create flowing transitions between open and closed areas. Some walls can be formed three-dimensionally by bricks receding or projecting out of the surface plane of the wall; even if the bricks are laid on one plane, the wall can still appear three-dimensional. Structural patterns, plasticity, and transparency can change dramatically depending on where the viewer is standing or the angle of light (figure 31).

The appearance of the wall is not only affected by a purely surface effect, but by its *depth*. The qualities of this third dimension cannot be designed two-dimensionally or described pictorially. The geometry of the walls has to be programmed, i.e. algorithmically, procedurally defined; it can only be experienced in physical space in time, through movement of the body through space.

We asked students to design a "different" brick wall and to produce it using the industrial robot in our research lab. The wall had to be 3m in length and 2m in height (containing about 400 bricks). Students developed algorithmic design tools to define the spatial disposition of the bricks according to procedural logic. These tools drew upon the knowledge that the layout of a brick wall is based on a system of rules that describe the sequence of operations needed to build a wall. A brick is laid next to another brick, shifted, and perhaps rotated until the end of a row is reached. The next row is then shifted by half of the brick width, and the previous procedure repeated, and so on, until the desired height is

Fig. 31

Different "programmed walls."

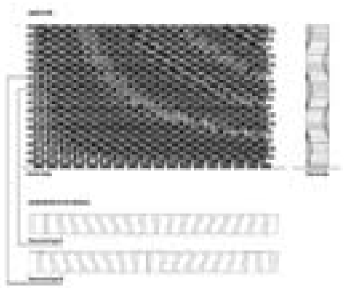
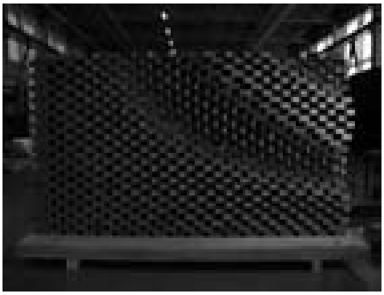


Fig. 32

This "programmed wall" is defined by two nested loops, one for the horizontal direction and one for the vertical direction.

Fig. 33

The concepts were first tested manually.



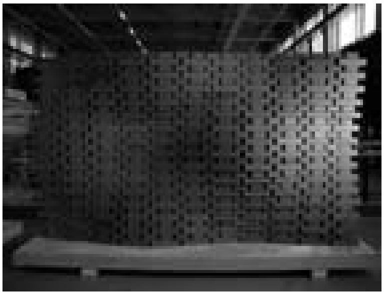


Fig. 34 a, b
A different kind of a brick wall.

reached. When programming, this process can be described with two nested loops, one for the horizontal direction and one for the vertical direction (figure 32).

Students examined different brick bonding schemes along with various criteria for brick laying, stability, and overall bonding effect. First, they manually tested the feasibility of the concepts (figure 33). Afterwards, they transferred their findings to a simple computer script, which they could expand and redefine through an iterative, step-by-step process. The students did not design a geometric system, but rather constructive logics that created an architectural form by organizing material in space and this directly provided the production data for the robot.

In the end, the walls – products of a digital, highly rationalized, design process and built by a robot – contain both the archaic presence of the material as well as the differentiated qualities of their procedural design. Adding information created a new, different kind of a brick wall, of previously unknown forms coming from a familiar and trusted element of the construction industry (figures 34a,b).

Screens

Fig. 35
The robot cutting holes to produce a screen.

The German writer Kurt Tucholsky once said, "A hole is where there is nothing."[10] Around the hole is a material from which it has been carved. If the holes (i.e. perforations) increase in size, a grid structure develops in the material between the holes and the attention shifts from the holes to the resulting mesh-like structure or screen.

Screens are a common and rich architectural device that can separate spaces, while maintaining a certain visual (and often audible) transparency. In contrast to glass, screens have a strong spatial presence and offer great potential for variation in material, color, texture, etc. The architectural definition of the screen mesh, i.e. its width, alignment, and form, can guide the eyes' glance, obstruct it selectively, or allow full views.

Grid-like structures make the structural depth of a building layer tangible. According to where they are positioned, hybrid structures like screens can assume other functions, such as *passive shading* (sun protection) on façades. Screens have been used throughout the history of architecture by very different cultures; they have developed in many different ways due to a wide variety of available technological means. As an example, consider the screens in Islamic religious architecture: highly perforated grid structures separate women from the main room of prayer. Besides a purely ornamental value, these highly sophisticated devices allow observation of the events in the main prayer hall without the viewers being seen.

Our work with screens is in many ways a continuation of the previous experiments with the perforated walls – with a shift in focus from the openings to the material remaining between them (figure 9.35). We asked students to produce full-scale prototypes (2 x 1 m in size) in styrofoam.[11] We also varied the forms of the openings, i.e. we didn't limit the explorations to the round holes only. With the help of algorithmic tools, we were able to manipulate the contours, dimensions, angles, and the sequence of openings, which could take any regular or irregular form (figures 36a–e). Moreover, in addition to being at an angle to the surface, the openings could also be distorted three-dimensionally, meaning that the front and the back of the screen-wall element could be different in appearance.

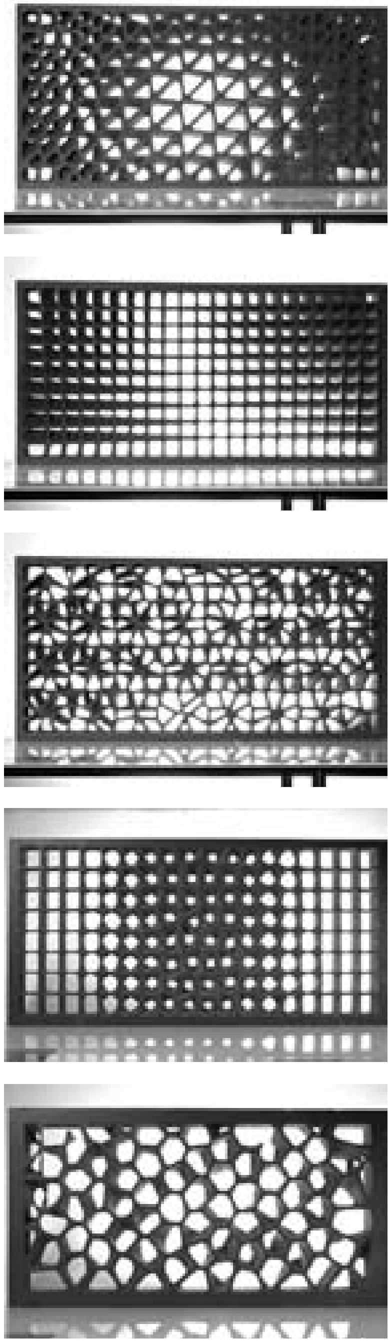


Fig. 36 a-e

The different screens designed with algorithmic tools and produced with robotic cutting.

Conclusion

The projects presented express our empirical approach to the physical and constructive reality of architecture as well as our understanding of the digital as a tangible and sensual reality. We believe that a truly substantial discussion on "digital architecture" can only arise from built projects that physically manifest the underlying logic of this technology. We want to know how it looks, feels, smells, sounds and how much it costs. To do this, we adopt a strategy of operating in small steps and experiments, finding ways (or creating them if necessary) of integrating this technology into projects we are actually building, testing their architectural potentials as well as their limits in terms of technological and economic feasibility. We work, whenever possible, at full scale, using the real materials and construction methods. This provides us with substantial feedback for our design process, both at a conceptual and technological level and allows us to understand the real consequences of digital technologies on architecture.

The beauty and power of digital technology lies in its universality and its generic quality. Binary data is an abstract entity that can contain anything we want. We consider it a new raw material in our hands that we can creatively manipulate in an infinite variety of ways with a degree of complexity we would not dare attempt by hand. It is like a brick, its generic nature does not impose one given architectural form but rather offers the potential for an infinite variety on a given theme. Programming thus becomes an open and self-evident exploratory technique like sketching and model building.

While the technology necessary to change from mass-produced serial parts to mass-produced custom parts certainly does exist, and is thriving in other industries, it is not yet available to architects. This is largely because architecture-specific interfaces for digital fabrication do not yet exist. If we want to take full and creative advantage of the amazing technological possibilities at our hands and finally fuse the seemingly separate worlds of analog construction and digital design data we have to get involved in the conception of these interfaces and directly link the design data, we produce and the machines that are actually able to fabricate architecture in both directions, technically and conceptually. We should be able to "get our hands dirty," so to speak, and proactively develop a technological *savoir faire* that directly relates to the way architecture is conceived, processed, built and used today. Technology needs to be demystified and (re)integrated into the architectural discipline, not just as a source of inspiration but as an integral part of the professional vision.

The fundamental architectural potential of the "digital materiality" we have been describing here remains of course to be explored through more built projects and at larger scales. One can still question whether or not the deterministic and rational nature of digital logics really is compatible with the creative and subjective practice of architectural design. Our work attempts to dispel this doubt and we hope that our projects will convince others who will in turn make their own contributions to this effort. Indeed, we feel that our own experience proves that digital technologies do not contradict the architectural process. If we understand its nature and use it as a complementary tool to our intuition and intelligence, digital technology will unleash its systematic, aesthetic, and poetic potential.

Notes

1 The project's clients were Zurich's Bahnhofstrasse Association and the Electric Utility Company of the City of Zurich.

2 The project's clients were Martha und Daniel Gantenbein. The façade was designed in cooperation with *Bearth & Deplazes Architects*.

3 Despite the relatively slight deviation from linearity, the human eye could detect even the finest rotations with the subtlest light reflection, making them architecturally readable.

4 The wall panels for the Gantenbein vineyard were manufactured within the framework of a pilot project at our research facilities at the ETH in Zurich.

5 While we were testing the interior of the space using prototypes, we realized that it would be difficult to read the design if the openings between the bricks were too large. For this reason, we laid the bricks as close as possible, so that the gap between two bricks at full deflection was nearly closed. The eye reads this as maximal contrast value.

6 The robotic brick-laying production method was initially developed for an elective course entitled "The Programmed Wall." We had to optimize it for the 400m2 façade, so that the production time and the quality of the elements could be guaranteed. Besides further developing the picker arm and the feeding chute, this mainly involved developing an automated process to apply the two-component bonding agent. We installed a pneumatic, hand-held, hot glue gun as a fixed external tool onto the robot, linked its activation mechanism with an interface to the robot's control unit, and integrated the application of the bonding agent into the automated process.

7 The courses were: *Das schiefe Loch* (The oblique hole) elective course offered in the winter semester in 2005/2006 academic year, *Die perforierte Wand* (The perforated wall) elective course offered in the summer semester in 2006, and *Die perforierte Wand* (The perforated wall) graduate elective course, also offered in the summer semester in 2006.

8 There were other difficulties too: the forces resulting from the pouring of concrete had to be dealt with by geometrically complex braces in the formwork.

9 These themes were explored in the "programmed wall" *(Die programmierte Wand)* graduate-level elective course, offered in the winter semester in 2005/2006 academic year and also during the seminar week in 2007 at the *Domoterra Swissbau Lounge*.

10 Kurt Tucholsky, *Gesammelte Werke*, edited by Mary Gerold-Tucholsky and Fritz J. Raddatz, vol. 3, Reinbeck bei Hamburg: Rowohlt, 1961, p. 804 (original 1931).

11 The screens were first explored in the "disintegrated wall" *(Die aufgelöste Wand)* elective course offered in the winter semester of the 2006/2007 academic year; the explorations were then continued in an elective course during the summer semester in 2007, when we asked the students to design a safety fence that surrounded the construction site for the new Science City Campus at the ETH Zurich.

Keynote Address

Philippe Samyn

Les Indicateurs de Volume et de Deplacement Comme Outil Conceptuel pour l'Ingenieur

Architecte, Ingénieur et Docteur en Sciences Appliquées
Belgium

Resume

Les indicateurs de volume et de déplacement, que j'étudie en détail depuis août 1997, permettent à l'ingénieur concepteur d'objectiver sa démarche, dès ses premières esquisses, lorsqu'il est à la recherche d'économie de matière.

Deux biennales de Recherches Industrielles de base de la Région de Bruxelles-Capitale nous ont permis de développer largement la théorie entre 2000 et 2004. Ce travail se poursuit maintenant, entre autres, par mes collègues à la Vrije Universiteit Brussel.
Mon ouvrage « Etude de la morphologie des structures à l'aide des indicateurs de volume et de déplacement », publié en 2004 à la Classe des Sciences de l'Académie royale de Belgique, consigne les résultats jusqu'à la fin de la première biennale.
Les doctorats à la V.U.B. de Pierre Latteur, de Jan Van Steirteghem et de Ben Verbeeck (en cours de finalisation) complètent déjà substanciellement ce travail.

Introduction et Objectifs

L'indicateur de volume W représente le volume de matière d'une structure plane, sur appuis donnés, de longueur unitaire (L = 1m) et de hauteur valant H/L dont toutes les parties sont sollicitées à la même contrainte unitaire (σ = 1Pa) lorsqu'elle est soumise dans son plan à une résultante de force unitaire (F = 1N).

Toute forme structurelle, quels qu'en soient les matériaux constitutifs, pour des conditions d'appui données et pour une résultante de forces donnée, quelle qu'en soit l'intensité, est caractérisée par une seule valeur de W (en quelque sorte son gène), qui n'est fonction que de sa proportion H/L, pour autant qu'aucun de ses constituants ne soit en état d'instabilité élastique et que la matière des assemblages soit négligée.

Le volume de matière V (m^3) de la même structure de longueur L (m)(et de hauteur H (m)) dont toutes les parties sont sollicitées à la même contrainte σ (Pa) lorsqu'elle est soumise dans son plan à une résultante de force F (N) vaut V = (FL/σ) . W (fonction de H/L).

La connaissance des valeurs de W, pour différentes morphologies structurelles avec leurs conditions d'appui et cas de charge, est précieuse non seulement pour guider le concepteur d'une structure dès ses premières esquisses mais aussi pour lui permettre d'évaluer l'efficience de sa proposition par rapport à d'autres.
Elle permet également d'évaluer avec grande précision la quantité de matière et le coût d'une structure au stade précoce de son étude.

L'indicateur de déplacement Δ est le déplacement (maximum) de la même structure unitaire dont le module d'élasticité est unitaire (E = 1Pa); il n'est également fonction que de H/L.

Le déplacement de la même structure de longueur L(m) dont toutes les parties sont sollicitées à la même contrainte σ(Pa), en un matériau de module E (Pa) lorsqu'elle est soumise dans son plan à une résultante de forces F(N) vaut δ = (σ.L/E). Δ(fonction de H/L).

La connaissance de la valeur de Δ permet d'évaluer tant la raideur que la sensibilité aux vibrations de la structure.

Progres et Resultats

La liste ci-dessous reprend les morphologies archétypales étudiées à ce jour chez nous; elle doit être étendue par celles étudiées depuis 2005 en particulier à la Vrije Universiteit Brussel.

- l'élément comprimé soumis à instabilité élastique,
- l'élément tendu avec ses moyens d'ancrage et le ballon léger,
- la portée horizontale sous charge verticale (uniformément répartie ou ponctuelle mobile):
  - la poutre droite continue,
  - les treillis,
  - les arcs et câbles,
  - les structures haubanées,
  - les poutres sur appui continu,
  - les poutres sous-tendues,
- les mâts,
- les portiques,
- les coupoles de révolution en membrane sous charge verticale (uniformément répartie ou ponctuelle mobile).

A titre d'exemple, les figures 1 et 2 illustrent les valeurs de W et de Δ (toutes deux fonction de H/L) pour quelques morphologies de la portée horizontale isostatique sous charge verticale et uniforme.

La figure 3 donne les valeurs linéarisées de W pour la portée horizontale sous charge verticale et uniforme. Cette approximation est très pratique pour calculer la valeur de W pour des structures complexes composées d'éléments de différentes morphologies.

La figure 4 illustre la recherche de l'élancement optimum d'une poutre en treillis tenant compte du coût de la façade vitrée qui l'habille: à la droite du coût de la structure (Es : W découlant de la figure 3 et transformé en k€) s'ajoute la courbe hyperbolique du coût de la façade (Ev). Lorsque la façade est prise en compte, l'élancement optimum de l'ensemble est plus grand que celui du treillis seul.

C'est ainsi que fut déterminée la proportion des poutres-treillis du pont de l'aire de Nivelles-Orival illustrée ci-après.

Les indicateurs de nombreuses structures hybrides ont en outre été calculés à l'occasion de projets sur commande en vue d'optimiser ces derniers. C'est le cas, entre autres:

- du pont treillis de l'aire autoroutière de Nivelles-Orival (1998-2000; figure 5)
- des mâts haubanés d'éoliennes étudiés par Fabricom (1999-2001; figure 6),
- de la couverture de la gare de Leuven (1999-2007; figure 7),
- du projet de couverture de l'aire autoroutière de Thieu (2001; figure 8),

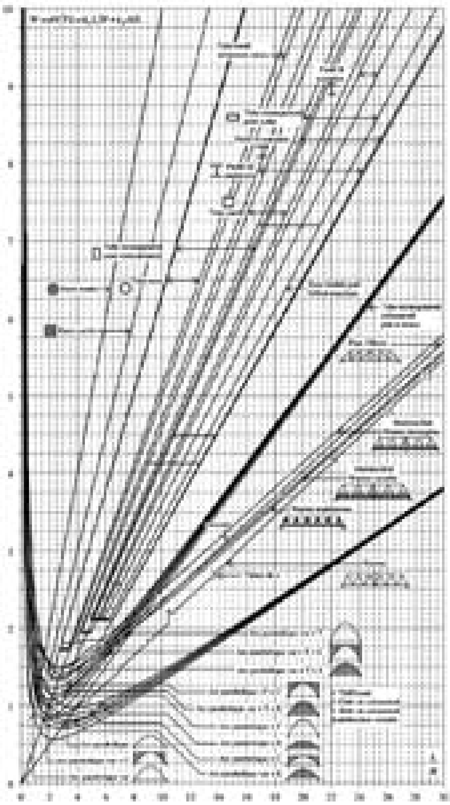


Figure 1

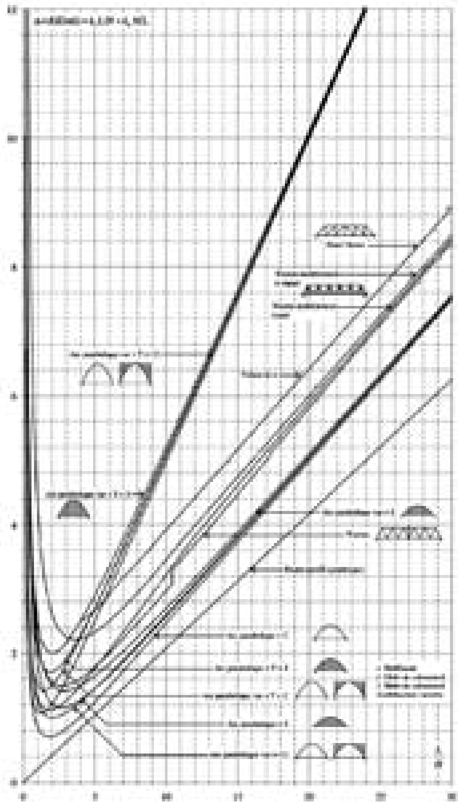


Figure 2

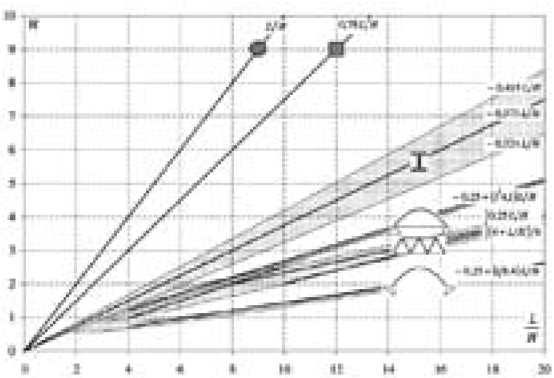


Figure 3

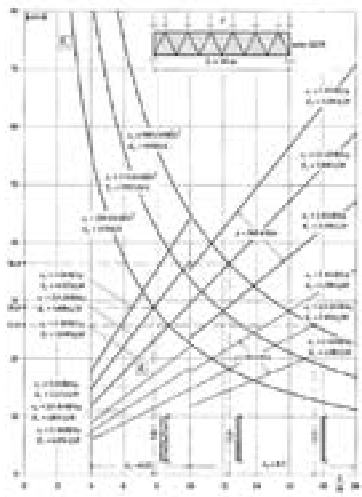


Figure 4

Figure 7

Figure 8

Figure 9

Figure 6

Figure 5

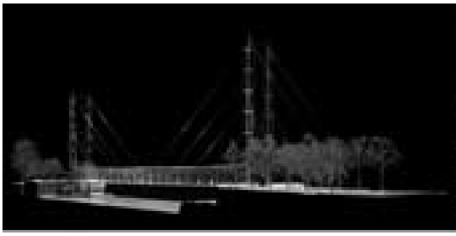


Figure 11

Figure 12

Figure 13

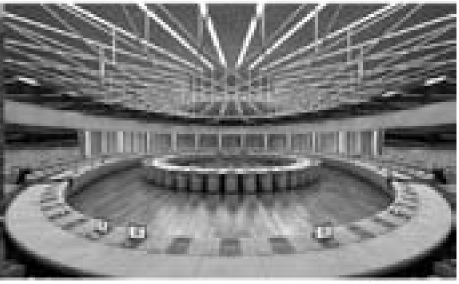


Figure 14

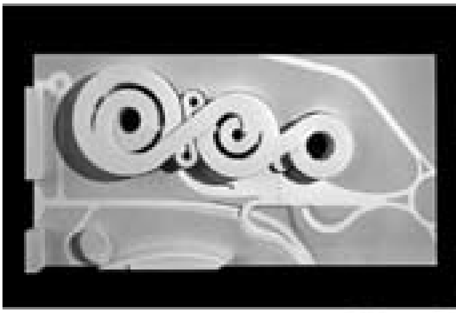


Figure 15

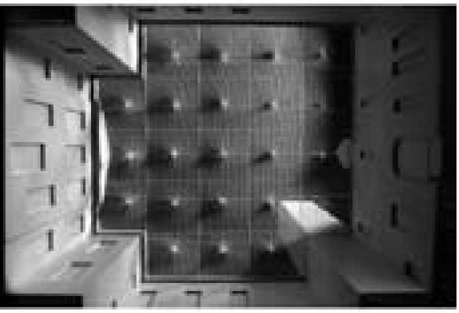


Figure 10

- du projet d'une passerelle piétonne sur le Pô à Turin (2001; figure 9),
- du projet de couverture ultra légère de la cour du château d'Alden Biesen (2001; figure 10),
- du premier projet de passerelle piétonne à la gare de Leuven (2002; figure 11) et, suite à la modification des données urbanistiques, du second projet (2005; figure 12),
- de la façade de l'atrium et des planchers sous-tendus des grandes salles de réunion du projet de Conseil de l'Union Européenne à Bruxelles (transformation et extension du Residence Palace avec Studio Valle Progettazioni et Buro Happold, pour la Régie de Bâtiment) (2005 – 2013; figures 13 et 14),
- d'un parking de 2.800 places pour GlaxoSmithKline Biologicals à Wavre, dont la structure est en treillis métallique et plancher bois (2007- ; figure 15).

Conclusion

Les indicateurs de volume et de déplacement sont des outils très féconds pour l'ingénieur concepteur qui est soucieux de concevoir les structures les plus légères possibles.

Ces dernières années, l'argument du coût plus élevé des structures légères, à cause de la main d'œuvre supplémentaire qu'elles requièrent, m'a souvent été opposé. Cet argument se voit aujourd'hui mis en brèche par l'augmentation impressionnante du coût des matières premières qui se manifeste depuis 18 mois.

La recherche de la légèreté, associée à celle de la démontabilité et des possibilités de réemploi, va bien évidement aussi dans le sens du respect de l'environnement.

Keynote Address

Hanif Kara

Tools and Weapons... Engineers Take

Adams Kara Taylor
A White Young Green Company
London
UK

While my presentation is coming up, just a quick introduction. When I was a very small child, I owned about 4 or 5 different sets of clothes. There were thousands of different possibilities of how to combine them. So, today is very difficult for me, what I mean by that, is that with very simple mathematics, five items of clothing will give thousands of ways to look. I am therefore going to be talking with many different hats, all across our work as this is a very unusual audience for me because I'm often talking to the commercial world of Developers and Architects or students, not teachers. So this seems to me something that is in between. I struggled to edit the whole thing, but what I'll promise you is that I'll keep on changing hats all the time. From talking as a teacher or talking as a practitioner. Sometimes talking as an Engineer, but never ever talking as an Architect. And often, I think trying to give a human perspective.

How do you start something like this? If you are stuck, you perhaps search the internet to see how you might introduce yourself, and the subject. What I did can be seen from a few introduction slides that will set the scene of what I think is important in the concept of this audience. I'm then going to break the lecture itself down into five specific themes, which I'll go into. This is a slide that I really enjoy, but we will discuss it later.

If you are keeping up with the Press, you'll know that two events happened last year. One was this building, which won the Stirling Prize in British Architecture for David Chipperfield Architects. In some ways this was seen as a moment of change, at least in the trade press comparing with recent other wins. We can talk about this later on through the themes I am going to weave in.

At the same time, this village in Yemen, which is hundreds of years old, was awarded an Aga Khan Award for Architecture. The structure is a series of towers made out of mud. Although it is very old, it came to light during the course of last year as some recent restoration is underway.

Two weeks ago, this was a headline in the New York Times. Frank: Ghery was accused of causing delays. Although this has not been proven yet, the primary cause and reason given is that he allegedly did not produce the information that is needed to construct the buildings, which is what an Architect is supposed to do, the outcome will be intriguing.

I saw this interesting set of slides published by Sheffield University, in which we redraw the map of the world in different ways. Funnily enough, this was done by Social Scientists of some sorts. To me, they should have been done by an Architect. Continuing with the press one also sees issues of scale. On one level, we are worrying about saving the world with macro agendas. On another level, about three months ago, Scientists managed to find the smallest possible!(the slide on the bottom left) which is less than an atom. It is actually a piece of graphite, which you can make the tiniest ! with. So, at one end we are developing forensic expertise, and at the other end of the picture we are becoming irresponsible, at a global level according to the press.

I really enjoy this one, because it is a very successful tower that has recently been finished in the UK. For very good reasons Broadgate, a very commercial area in the UK, has just put this after the Gherkin as a new tower. I include this to raise a question for me as to which side of the fence this is on, in terms of Architecture, and the whole of construction. This is because at one level you see the whole of the building with this external cross bracing system. However, when you look closely, the cross bracing stops just before you arrive at the ground floor. Therefore, the impression to the public is that this is a braced external frame that the building is being held up by, and yet the bracing not reaching the ground raises a question about it performing a structural role- does it matter?

So, the themes that I am now going to break down the main lecture into, and I will say quite clearly, this is the work of many from Adams Kara Taylor, from teaching to construction. So, you can actually swap the projects around the themes. But I thought it would be worthwhile to gather the themes to illustrate simply what is interesting us. I should say that teaching is a new area for us, and like I said at the beginning, what I have always found is that if you arm yourself with different things and have an expertise in one in particular, which is the structural engineering, it allows you to be adaptive and be able to deal with many situations. So, in terms of the teaching, currently I am teaching at GSD, Harvard, on a particular course, which is called In Search of the Engineer, where Harvard and MIT students are being brought together in one room to try and encourage this discussion across disciplines. With Lina Martison, I am also a Professor of Architectural Technology at KTH Stockholm, which is also an experimental thing. In fact, it is a completely new way of trying to teach technology to architects.

Now, from here on I want to bring in projects. So, the first theme discussion is about the tools that you can use, and how they can be played with to customise what used to be fairly homogenous systems. We can discuss later on whether these systems are good or bad, but firstly I want to show a series of examples taken from our office that demonstrate the ways in which we try to engage with these new emerging ideas with varying degrees of success.

So, we have a "nursery" in the office that isn't purely based on structural engineering. It is made of a number of people in the office who are from other disciplines, not entirely clear in their purpose. But, they are not meant to practice their particular discipline. Instead, one role they are meant to play is to improve our main discipline, which is structural engineering. This does not work totally, but it is an experiment that is beginning to work, slightly. So, I have brought a series of examples here that show some of the works of this nursery of variety of disciplines. Within a bigger environment of structural engineering you can create something, which hopefully you can play back (in projects or in teaching) with the aim of trying to find new questions and answers, as well as discovering how we should be teaching Architects or Engineers for that sake.

This first slide touches the issue of 'parametric' design and 'visions'; two words I hate to use. In fact I think use of both of these words should be stopped in our fields. For example, we can use tools like this in the context of thinking about how we would masterplan a city, like the city of London, today. So, this is a very 'Sim City' like approach by an engineering office that tries to demonstrate how we could build new powerful tools. In effect, it points to the master planning people in the world of architecture, that if they do not engage with the tools that one can use, which a lot of them don't, they are in danger of not actually fully understanding the complexity of natural and artificial forces.

A second point we were trying to emphasise here was that we must all face up to the reality that everything we do has to consider both 'love and money' (the title of a recent British Council Exhibition). You can't separate the two things, so I think it is important to teach students this. I think a common failing in architecture is that too many students are taught about 'love' for design but not enough of them know about 'money'. So this tool was really to illustrate the power of this kind of expertise in predicting or organising future cities.

Another event that goes on every year in London is Architecture Week, during which we all try and show or exhibit something. We chose Farringdon station, which is quite a complicated infrastructure hub- to demonstrate similarly the power of such tools. We chose this case study to map and speculate potential interventions over time. The tools thus show again how over time one is able to predict the impact of certain design decisions.

For example we took the land between a very busy railway line and showed a way of adapting two parts of a city that are cut by this railway line. Some slides just to show how you could adapt as the city changes, in a customised way. Another tool, one here is the manipulation of a field, to rethink the way foot bridges are designed. What you are looking at is a real place that we were asked to look at in Reading. What you are seeing is the tool automating the process, so the fixed parameters are set; in this sense, by the constraints of site. They are not, as I feel is often the case with many contemporary architects, just a part of a geometric desire.

Here, what we tried to show was that by having a distance to span, having trees and buildings, a tool could be developed that automates the priorities and finds a way of spanning the bridge or finding a route through these conditions in the city, rather than purely an optimal engineering solution. This next one is a real project, where Future Systems had the challenge of bridging across two buildings in the city and for good reason this became an object that has to go from a vertical through a transition into a horizontal. What we have shown, what we have done there, is that the group has gone a lot further in techniques from rapid prototyping through to how you connect these tools to analysis tools to find a homogenous customisation of themes, let's say. In all of these things, the reality for us is often difficult, because basically most of the tools that you see being used by architects ultimately connect with the tools we analyse structure with. Once we have connected those there remains another issue that our tools do not always connect with the industry that fabricates these things raising some doubts about digital fabrication. As an office we want to find ways of encouraging this way of working as we see a good future in it. So, we take this on as "research" projects. For example one where we are looking at a customized tile that will be the ideal geometry, not necessarily optimum structurally. What we started with was to initiate a study with a triangle and hexagon or a combination of the two that will perform as the structure, the surface and everything else. So, there is a lot of scripting to be done formally, just to find geometries at speed. The task includes how we connect what we start with to something that we can actually make. So what we have is engineering design tools, whereby you are measuring something that is 'quantifiable' meaning weight or production time or cost of something else. This can only really happen when the Engineers and the 'other experts' are in the same room. By this we are able to attempt a connection between design and fabrication using such tools. So the optimisation is going on at all levels, at all of the time.

Ok, I will skip through that first theme and then come back to it if there are any discussions on it, because the whole lecture could easily be about this subject on its own! To us, though, this is the first time that really as an office we have been able to do it. I think there are other people in this industry working in this area, but not many have reached that level yet. The bridge project is not built yet, and that is the kind-of dream of how we put this work, which is theoretical research, into practice in the future. Otherwise, it means very little to us.

Now, another group of projects is where we there are tools available and finding a good use for them. For example as an office, to engage with another stream of what is going on, we bought digital projects (Catia based), which is probably the most advanced tool that can actually go from though to production. The problem with that tool is that you need a PhD to drive it for daily use in a typical office. You do not just need to be a good Engineer or Architect; you need to go beyond that. Most people, who attain that standard don't seem to stay in practice. They become so focused and expert at that particular tool that they are unable to then have this discussion or for that matter interested or afforded in mainstream practice.

So, we tried this out in the office, because we wanted to understand the limits of this software. The project I will show you, fairly quickly, is by Thomas Heatherwick who is an artist in Architecture. The project was conceived by him as a metaphor of a rock on a sand beach that becomes a café. So this is the image we first get and we start tooling with it again on several levels, trying to test whether we will ever be able to first of all make it real, and then beyond that, how we will convince the industry or whoever is going to make it, how will we choose what material it will be. That goes on in parallel in the office so at one level we are analyzing and at another level we are unfolding the strips, so that we can see how we can draw, fabricate and assemble the form. By this time, we are beginning to think of it as a steel element, because the location that it is in, in a place called Little Hampton, which is the home of a local fabricator called Little Hampton Welding who were willing to sponsor this project. So, the strategy was developing. If we are ever going to succeed with this, you have to either find somebody who can make it locally and economically, even though it's a complex project, let's say. We try to operate at many levels, to find something out of it. So, what we do with an object like that (the normal way of reading it which is cross sections and long sections through it) is to find a way of analysing it. The objective being, can we find a position where a six millimetre steel plate will do all of the work. That is what the basis of the beginning is in a way, because that is what the local fabricator can make. So, we are almost perversely applying a 'simple' title to something that is complicated as a whole, in order to find out whether these tools help achieve this.

So, we get to a point where a process is very different from the 'linear way' that we are trained to design buildings. One task is to make such processes commercially viable. How can you gauge the amount of time that is taken, so you can actually charge for these things rather than just do them for the love of it? Then we also get very close to the fabricator. This shows the unfolded strips, this particular slide shows a cross section which is a series of 'stepped frames' that are cut in one direction and then the strips basically join to create the geometry span between this. This is the finished object. I wanted to put that in, mostly not to talk about the Architecture, but really to talk about use of existing tools and how they are allowing new potentials in process. To date, our own experience on generative components and 'digital projects' is one of not necessarily finding an easy application as it is day to day practice. In my conclusion, I will try and bring that back into the discussion.

The second theme was taken out of Maria's 'kind-of description' of what this wants to discuss. What are the new processes and how do you teach them and use them, because there are many of them, and collapse them into finished product? So, from here on I will show you a few projects that could be real prototypes. The first one, which we are very well known for it is a Zaha Hadid building in the Phaeno Centre, which in its finished stage has had quite a lot of criticism and critical acclaim for many reasons, but from the point of view of this discussion, we as an office took it on as the biggest prototype that you can imagine, because this particular building deals with all of the themes that I wanted to raise in this forum.

The project demonstrates how to materialise ideas that Zaha and others alike have had for three decades both on paper and on site. One theme is where its surface turns into wall and floor, turns to whatever, column free spaces and similar agendas. So, by chance in a way teaching at the AA in close proximity with Patrick Schumacher, and Zaha's office which is part of the search for new thinking, we came to a point where we felt that this was a good way of testing some real possibilities, and winning the design competition allowed a great opportunity to test some of these ideas.

The building itself is set on a trapezoidal plan, with what is seen being the white coloured area on this slide being the 'comes' that support it. The idea was to create a building that is up in the air and a building that really has no columns, the floors span between 'cones' that support but are also spaces within themselves. Blurring which part is the city and which part is the building, simultaneously blurring where the Engineers stopped and the Architects started. These are all agendas played out in this building. The process of design from our side was really inspired by this initial representation (by the architect) of the concept, where we were first shown the idea of 'collapsing the void', meaning to raise an object in the air and collapse the voids. Now, to Engineers, we read this very differently. When we saw the model, what we were looking at, was something that was very liquid and we were imagining how we would make it or how we would analyse something that is so complex and difficult to break into pieces.

So, the inspiration, if we had not seen this as the beginning, we would not really have been inspired to rethink the way we are taught as structural Engineers. So, there is a role for 'pure representation' in this case to act as a beginning of a new way of thinking of space, because this kind of architecture can inspire and actually force, not only other disciplines to produce, but in this case, the client. Because when this was produced and shown to the competition jury let's say, you can imagine the reaction. Six or seven years ago, people just could not believe that you can produce this even digitally, never mind as a real building on a site. These are typical sections, there is no such thing as typical sections in the building. And our challenge was really how do we take these new geometries, where the platonic forms of cones, spheres and cubes and so on, are really collapsed into more complex geometry, let's say. Or geometry that is closer to the complex form of nature.

How do we develop such concepts and make them real? Unfortunately the tools are not always there, so even to break this down into an understandable set of drawings, we had to collapse the information into conventions of sections and plans. I just want to flick through the Engineers section very quickly. A typical reinforcement drawing so, despite all of the clever stuff that you see; the dumbest elements of this project is still a single reinforcement bar, which is a linear element and what we have to do is engage with that right from that first image of the project, which you show of the concept. How would we actually reinforce something like this? What became the cones in the end? Almost every drawing package you can think of was used to develop the fabrication information for the contractors. So it was again an attempt to make it as 'seamless' as possible that the idea of 'concept and construction' and I have to congratulate the German contractors on that. I don't want to go into details of the construction, but it was complicated. The roof itself is a steel element and here we again had to first of all convince the Architects. So, to tell Zaha's office that the roof could not be reinforced concrete was the first step. You have to show it. So the idea we came up with was this, which comes from a 'biological model' where you take a single cell of structure. You take a very simple cross section and connect two of them and then you extrude it. So, now you are looking at a six meter by six meter module, so to get an idea of scale you then pan these out across the whole roof. What then happens is a three meter deep unit, six meters wide, spanning up to 35- 45 meters in places. This allows us to span across, without any columns, because what we wanted to achieve was those cones you saw to stop earlier on. And only four of them go through, to support the roof. What we did is actually 'fan' out the plan geometry so each connection suddenly changes and takes up a different geometry. So here the theme of 'mass customisation' became important. In the old days a vierendel would have been a ninety degree junction.

Today, it is not difficult to make every joint different with automated fabrication. All you have to do is develop a relationship with a reasonable fabricator and persuade him of, or at least demonstrate, an easier way to do it. One way is to customise the junction rather than universalise it, the reverse is also true sometimes. The most complicated part of the project is how you analyse such a large 'pointless' building in one piece. Because the minute you put a joint in this building, anywhere, everything collapses. Not only the structural system, but the whole idea of a seamless Architecture, the structural system would become unstable, so the building really only becomes alive when everything is finished. It is like a table with all those pods underneath it. And it took us close to eighteen months to get this through the design process, so the risk we had to take after winning the competition was not to necessarily admit to the client nor the Architect that the tools were not fully developed. We had to work in a parallel world basically.

We were developing information to cost this project, using simple tools and simple methods, knowing that there was bound to be some redundancy in the system, but in parallel we worked with 'Sophistic', who are a software producer in Germany who were developing the best finite element analysis package. These packages could not deal with a model on this scale with the load combinations that we had. So, the game was really, we had to carry on producing but hopefully arrive at the point where the two (the simple methods and complex F.E analysis) would meet, and it did. And when we reached that point of sharing with the Architects we also managed to take out a lot of redundancy in the concrete with greater confidence. The problem then is that the Architects understood what we were doing and started to excavate into that structure further. So, what you really saw in the end was different from the original concept. The cones have very little concrete left in them by the time we finish, I will show you just the way we optimise the roof, because the discussion was about the economy` of mass customising the joints versus the steel tonnage. We also had to show how expensive the miles of welding, that is perceived to be expensive, could be reduced to less miles of welding and rather than just accept that bolted joints were more economical.

We had to quantify all these things and develop four of five solutions for the roof to compare and sent one out to the contractor with the knowledge that the industry may come back and say that what we had selected was unworkable or unaffordable and here are the four ways of doing it. As it happens, we were lucky because that is what happened. None of the 'German Steel fabricators' accepted our proposal at the initial stage. They did not agree with it. The objective they had was to prove it was more expensive because it was outside the comfort zone in terms of past precedence. The options done by us could thus be used as comparisons to negotiate a mutually acceptable solution. So the strategic thinking became a tool rather than a weapon. I leave you with this one, because having achieved that successfully, we are now on the next level of this kind of project.

This is in Cagliari Italy, a museum that we have just won with Zaha Hadid Architects again, where we are going to take that idea further, which I have to confess I am not looking forward to! On another level, bearing in mind we often have to deal with image and idea at the same time. I think there is a Greek word, 'idios', which means image and idea being the same thing. Often we are given an image, and this is an image of a museum in Baku, Azerbaijan, which was very simply portrayed as having the potential to be Central Asia's equivalent of the Sydney Opera House. This was a competition entry, that we really didn't know anything about how we will make it and so on. But by this point, the collaborative process with an office like Zaha Hadids has been in place for over ten years, and there is certain shorthand that we will find a way of making it work. So we are going through a process here, where we do not want to simply repeat the Phaeno Centre or Cagilari. The structural system in central Asia demands something else, so the structural solution is more likely to be steel work.

What the difficult part of this project is, how do we take the image that the client has fallen in love with, and nobody has ever asked why the curves are the shape they are or what it is for, or why we should be doing this. But how do we produce something interesting? So we come back to the tools that I showed you at the first series of slides. This is how a project on site and what we are going through is a very basic module to find a certain tile size and looking at a tile that will panellize the whole building that you saw by finding the closest fit. So, what you are now about to see is this work in progress. For example a 6m x 3m tile. How do we take that against the whole surface that you saw earlier, and how do we find ways of applying that tile, because we know that if we find a best fit, then we will be able not only to suggest the material, but we will also be able to deal with the variations and deviations that we will find on site and as it deflects. But most of all, we will be convincing the local manufacturers that this is a simple process of making sheets that are not so variable.

So, we are going through the process right now of rationalising, automating and optimising the form. Often this sort of exercise is undertaken without fee. But we have to invest if we are going to believe in this and if we have to convince people of producing buildings like this. Here is another tile type, so automating these things; we can quickly look at the rationale behind shapes like this. We can create all sorts of distribution again, to show that really the 'complex' areas are is a small part of this surface, most of it is flat and so on. I am not going to get into too much detail, but I think you get the picture. Such digital prowess has become an obsession in some groups of architects. What is happening often is that it is taking over everybody's minds, particularly young Architecture students, and everything is possible for whatever reason or sometimes for no reason at all, in the computer. I found this very disturbing as an Engineer, so we have in parallel, also tried often now to take material research and I will show you three very quick examples.

Here we were playing with glass as a material, where we are tiling this 'B spline' curve very simply. This is an eight year old project by the way, so before the days of parametrics and all the tools, this was a curve (in a railway station) of a leaning glass wall, this 'B spline'. And the idea was to try and develop a glass tile that would work and fit a thin shape. There are good reasons for the curve, which I can explain later. The point is that we wanted to explore customizing of glass, so a number of things were done. The steelwork, what you see here, is very simply the structure itself with radial and vertical elemets. The complexity is really in the triangle, because every 'node' where six triangles meet is different potentially, if you map it out. So, our job in this case was to experiment with glass at two levels, as a surface and as a structure that supported it. When we want to engage computer science, the Engineer does not become a computer scientist, we instead find a computer scientist and work with him to achieve what he does well. So, this is a very important message that I need to give, because listening earlier to the presentations I could hear what I hear all the time, that Architects become very good Engineers and Engineers become very good Architects. It is never going to happen. So, what we tried to do is really engage with the best expert in a particular field to make our own expertise even better.

What we developed is a piece of software that can unfold and drop every triangle onto a sheet of paper. This would then be sent as a disc that you can cut the glass from, and you have all heard the story. But the real invention was in how you translate geometries across curves and surfaces. What you see on the right hand side is again a forensic analysis of the glass supports, so if we are going to propose something as-complex as this then, glass thickness is to vary, in order to justify and legitimize the complexity. If you just say this triangle is different every time and is 20 millimetres thick all the time, you will never sell it. You have to then be able to optimise the glass to compensate for other complexities. So, in parallel we are forensically looking at the connection and the glass, and what you see here is the surface. This is a typical drawing, which went to the contractors and what we found was that the glass manufacturers did not want to take this risk, because they were afraid that the glass might be cut differently, deflections, tolerances would not work. So, we actually took the responsibility for work. The 'eureka moment' such a concept still exists, was the discovery of this particular device, which was very simple, where you take a single arm and you slide an 'L' shape in it and you rotate it at the same time. What that allows you is that red envelope that you see with two circles, that is the geometric envelope of the surface that you can pick up, by having this kind-of device, i.e the variety of point supports fall into this zone.

Now, when you apply that across six arms, you can see the potential of a device like this is really incredible. So, you can slide the end of this and rotate it to pick up the point of a glass while six triangles are coming in. We could not explain this to the Architects in the early days, this is a recent movie, but in the early days we had to make physical models to show, not only the contractor but everybody else, how this was not a frightening thing to do. It is a very simple animation. But you get a feeling of how each spider is different. So, any triangle that is offered up to this spider can be picked up by this device. So, we really enjoyed that project and it was one of those rare projects where the site work was also successful. One reason for that is that it was so complicated is that often when you are working on projects like this, you do a lot of pre-design and you produce a lot of information so the risk of site error is reduced. Unlike conventional buildings where most signs stop too soon in the process increasing the potential of site errors. The success of the Jubilee Lane Project continued later in another guise.

This one was with FOA where we were taking a hexagonal tile, which we then wanted to adapt to be unfolded or folded (into internal rooms) as a partitioning device for a particular phone company, the 3G phone company. Rather than finding a universal joint, as in the previous project, what we ended up doing really was moving the node away from the joint. So instead of having a single junction that will work with all of this, we created a simple 'door hinge' that would fix the panels to each other. So, three hinges pick up any node. Sometimes this kind-of research today isn't funded. So what do we do? We have to find clients who are willing or at least believing in such experimental work and we had such a client in this case,. The next project is with a client called Cadogan Estates whom we have done a lot of work with. And because they knew that we took a lot of risks they were quite keen for us to make an all glass atrium, totally glass in a very conventional building in Chelsea, London. So, the slide on the right shows the actual atrium.

Now when you are doing that sort of thing, because nobody funds this, as I said you either need to be able to invest in it as an organisation, or find a client who will permit some physical testing, because you cannot rely on software. You often have to actually model this type of research with physical tests under laboratory which costs a lot of money today. But what it does do is develop valuable technical knowledge, within the practice which allows us to work with glass for instance outside the normal codified practice. So, as a result of trying to do thirteen meters span glass and get into a fortunate situation where we tested it in all sorts of directions, we now have knowledge which we protect very much, that gives us confidence to do really difficult things in glass opening a new market in the area. But also, more importantly, an innovation agenda. So we are able to take more risks with glass than, most engineers.

So, another material that I find underused is often concrete. We had this fortunate opportunity last year, to curate an international masterclass at the Bauhaus, which was a year long process but involved organisations and students from seven countries. There was a competition for students to produce something out of concrete, and I had to set the agenda. What I suggested was to reduce the notion of plasticity and opacity as an idea, because these are qualities that concrete has that one cannot alter but can use to invent new ideas. For instance, buildings are becoming more and more opaque, for the green agenda. So let's find a way of using concrete more. This offered a fantastic opportunity to develop another way of working with Schools through intense Workshops to explore or examine something highly specific in detail for the sake of practice and learning.

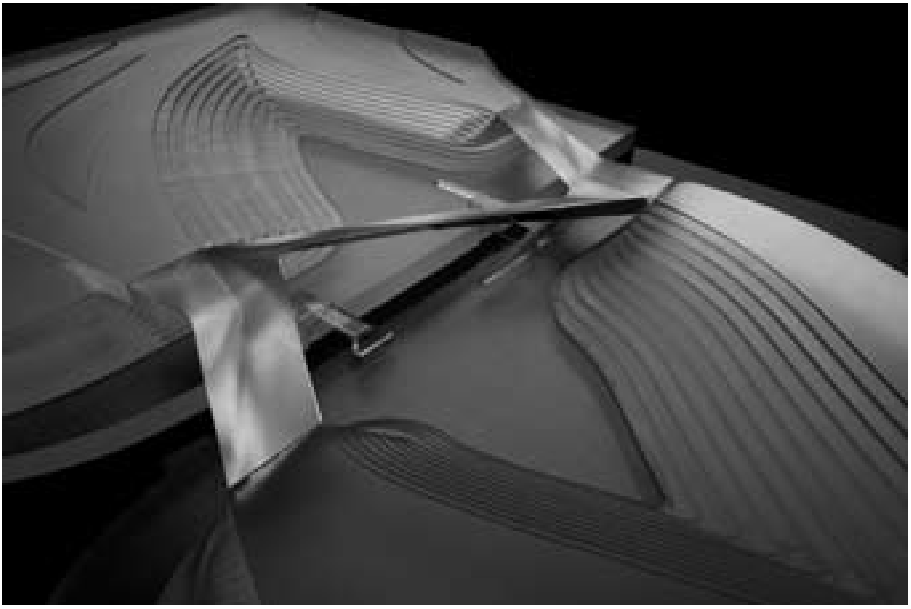
So, the agenda was very simple. We went from the scale of dress and furniture right up to reinterpreting the structure of the Sendai Mediatech tech by Toyo Ito. The students spent a whole week with about sixteen visiting tutors from all disciplines at a workshop at the Bauhaus learning to work in teams and with concrete. All funded by a concrete industry, I have to say. And the result was pretty amazing. There is a book published on it and a DVD and so on. What is interesting is that it has opened up a number of new projects for us in concrete, because we are now assisting many in the concrete industry to try and experiment. So, sometimes you have to put the 'cart rather than the horse' in these situations, otherwise this sort of research does not happen.

More recently in Istanbul, with the University in Istanbul and the AA and Ecologic studio, we have been experimenting with something a lot more precarious, which is the idea of branching with structures and how we can use fibers in structures. It's early days on this one. The project is not as satisfactory as the Bauhaus, because at the moment we do not have a technical solution for it. Continuing along the material line, more research in glass with Foreign Office Architects that relates to their work on opacity. This is a department store in Leicester, FOA proposed the idea of doing this because department stores do not want to be transparent right now, and they do not like being totally opaque. So, we suggested something else. Farshid Moussavi, who has done a lot of work on ornament recently, was the partner of FOA. When we were invited to the competition, the work we had done previously helped get a unique solution. And what you see is a laced glass pattern, Again, a lot of prototypes were made to persuade the client of its value, ranging from how it will change at different times of the year, to what are the values of colour and so on, to create what is effectively a semi-opaque building which has just finished on site. I am sure, that we will be reading about this project in every Architectural magazine next year.

A current project which is just going through the office is to take a very recent material called Fibre C, which is manufactured in sheets about 3 X 1.2m. This was done with the design research lab at the AA. They are celebrating their anniversary, their tenth anniversary, and we have been engaged with that research group for a long time. So, what a competition was devised by the directors for the students, past students for the last ten years, to come up with a pavilion that we could make out of a 'very dumb' material, but to also try and find a way of exploiting new tools of design and fabrication. This is only three weeks old, by two students called Alain Dempsey and Alvin Huang, who both work, coincidentally, with Future Systems who won the competition. There were forty entries and we were part of the selection process and charged with collaborating as structural engineers. Reider, who are an Austrian manufacturer, and the AA who are funding the pavilion. We are currently going through the problems of how this 'unstable mechanism' of discontinuous elements can be jointed and constructed.

The last sort of group of slides draw on, the real possibilities of these tools or the possible realities, are a big discussion in the office. This is because to re-shape our own thinking as Engineers is also very difficult, as we are taught in a certain way, in a very contained way, the theory of structures, the theory of science and so on. But not many of us have been taught aesthetics or beauty. You only engage with that, in your real life, I guess. So, it is difficult in the office to separate the two, because the pure structural Engineer wants to be totally efficient, totally scientific about it, but really that is not going to get the discipline any further. So, our own discipline is changing, like Architecture is going through a crisis, I believe. We therefore find projects which are sometimes deceiving. They look real, but they might not be, For Example Tower typologies that have mushroomed lately. Today, I was reading in the newspaper that Paris has suddenly decided that they want new Towers now, as a big agenda by the mayor. So, what we did was, with an Architecture office called BIG from Copenhagen is to start work on an idea they had which is both a bridge and a tower, at the same time,

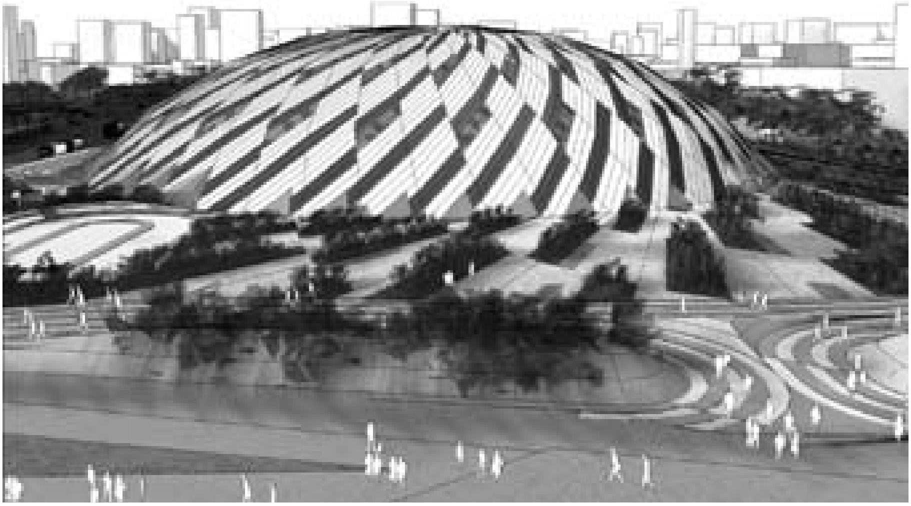
Highcross Quarter
Foreign Office Architects



Carpenters Lock Footbridge
Heneghan Peng Architects

DRL 10 Pavilion
Alan Dempsey & Alvin Huang

Littlehampton Cafe
Heatherwick Studio



Olympic Velopark
Foreign Office Architects

Heydar Aliyev Merkezi
Zaha Hadid

Southwark Station
MacCormac Jamieson Prichard

Phaeno Centre
Zaha Hadid

Fibrous Workshop

plastic
OPACITY

because the ultimate dream for a structural Engineer is to design a bridge and a tower, because one is very vertical and the other one spans; that we all dream about.

So, what we have tried to do here is collapse the two typologies into one, and furthermore circle packing idea is examined as a structural system. The symbol for steel in China is a circle we are told. It might not be necessarily the most beautiful structure or the most optimum structure, so we basically started with that as an idea and, using the tools we have, take a very simple tower and show in various stages what happens to it when you split it in one direction, and then push it apart to 'split its legs', literally, in terms of vertical structure. Now this is done at two scales, which is why I wanted to show it to you. At one scale, we are looking at the global typology, the tower, its height and so on. But at the local scale, a parallel exercise is going on with the tools that we have got, where we are looking at the circle, at the same time. We are looking at how we optimize, if it is going to be a structural system that is made of circular rings of steel. How will it affect the global at the same time? So, you are looking at forensic and global scales with the tools at the same time a 'holistic' optimisation. Then intuition and human intervention are implemented, which is critical to all of this.

It is pretty obvious that when you displace the circles rather than stack them, they are more gravity friendly. And all of that is happening through the same process continuing with the theme of representation. In a theme of the representation I also wanted to show you another project which is a velodrome for the Olympics, with Foreign Office Architects, which we did not win. But I wanted to show it to you anyway, because here we thought that the ideal metaphor was a bicycle wheel and together we tried to create a new dome structure. So, sometimes taking things from the Fifties and Sixties, and improving them, is innovation.

There are different ways of doing what would effectively look like a shell, with bicycle spokes underneath, so when you look up, it would look like a very large bicycle wheel. That was the idea we were trying to play with. But what I find interesting about this project, is not the usual kind-of stories that you hear about how you build it and do it quickly, but when we were playing with this structure, we came across this graphical idea when we were trying to plot the construction sequence, we suddenly found that you could time the speed in which you can construct this, and correlate that with the reality on site. So, one of our selling points on the project was that this is probably going to be the fastest way to construct, compared to our competitors. What we are illustrating is that our idea is flexible and can be constructed radically so you don't use as many cranes. You do things much faster and so on. I do not think that would have been possible, had there not been a computer really, because you do not see it with this kind-of speed in any other way when you are inventing something.

Now, the last two projects and I will finish at that point. Purely about representation, they are very new. Here (watching the slide), Thomas Heatherwick's British Pavillion. We won the competition about two months ago. The idea is to show 'Britishness' in Shanghai. The brief is that everything we do in this project has to made in the UK, shipped to Shanghai and made on site. I am just showing it to you, because all of the structure and everything else inside is pretty simple. Heatherwick's idea is about creating green grass, which is what UK is very well known for, and when wind blows on grass effectively, something like this happens (showing the slide). We were able to represent and project in our competition entry the moving object that we were trying to portray. You could not just say that it is going to be grass. We had to kind of show how this building would actually react and respond to many conditions; wind, acoustics, projection and so on. And we have gone on to actually win the competition. Frankly, we do not know how we are going to make it yet.

The last project is a similar story with Heneghan and Peng. So, Olympics are a great ground for taking risks. So, when you get an opportunity to compete on these, you really have to pull off something difficult when you can. We won the competition, which was quite tough with Heneghan and Peng, for the main FO6 bridge. This bridge is going to lead from the park to the stadium. And we had a very simple line that the whole idea was not about the bridge. We were not going to do an arch and a cable stay, and all those things that turn on Engineers. The metaphor came from Cedric Price, a very simple thing. The bridge is really about getting to the other side, not about what it is made of and so on. With that we came up with a very sculptural idea, and the concept is that you have to deal with seventeen days of Olympics and then you have to deal with a legacy mode of this bridge. So, for the Olympics mode, what you see here is a plan. We create two large landscapes as petals that connect and organise a space, so that the space underneath is real public space and what you are looking at up above is the sky and the artificial sky, which is a stainless steel bridge, effectively. The stainless steel bridge can span short, but we then created a gallery to create a Z shape, so you can actually stand and linger in the middle. Now, we were very pleased to win it, but what was a telling point was, I will just play this and then I will tell you (plays on the slide).

We are still just talking about representation, but let me just carry this on and finish it. Can you hear the music? I have shown you that, because the last piece on that slide of the movie was what I think clinched the win. It was nothing to do with Architecture, politics or all the things that we have been talking about for the time I have been here. The sad fact is that most people who are judging what we do, literally have seconds to make a choice so you need all the help you can get. So, the red coloured objects that you see are 're-used Nike shoes' that will be put on the landscape, which is a connection to sport. But what was critical, I can go through the whole thing, was that we felt very strong as a team and Heneghan and Peng predominantly, that we could not just do an animation. It almost had to be like a 'Pearl & Dean Hollywood presentation'. And Heneghan Peng literally went to an organisation that makes adverts to sell beer, to get them to actually make that movie. So, sometimes you have to use tools in a representational form that are really nothing to do with all the intellectual things we talk about. I think that this is something that is very difficult, but very important to teach today to all the students.

My conclusions are very personal and specific. I say that deliberately. I think there is very little doubt, in my mind at least, that the digital realm is the future. There is a new competing horizon for both the disciplines of Architecture and Engineering, and those who do not engage in that realm will suffer. However there is a danger and this is where I think that the tools can also become a weapon. The production and speed in which we do these things, when you saw the things that I showed you, they were done in the process of two weeks in a competition . It is so productive, that there is often no time to think about whether it is good for the human being or not. There is no time to ask why we are doing it. Should we really be doing something like this? And at that point, in the wrong hands, the tool becomes a weapon and this is where my question was to the previous groups really. How do we, as teachers and practitioners, try to avoid that? I think we have that responsibility. I firmly believe that Architecture, not tools, should have the latent capacity to harmonise the different levels of reality. I think I have shown you that. And it is that latent capacity really, that I feel I can reconcile and make better places rather than technology or tools. I will leave that for you to read.

What I am convinced about, and I think I have tried to show, is what we can do with these tools. You can with your Engineers, if you are an Architect, unify, objectify and universalise. These things become almost religious for many Engineers, even today, although I think the day of the individual is dead; those who are almost treated as religious objects, and there are many more in your world of architecture. That is to me a very dangerous thing. The last thing I would say, is that I feel architecture can be constructed and produced, but richness has to be created. By that, I mean that if you look at the ugly diagram on the other side of the corbusier diagram, this is the most efficient way to make a human being, if you want him to live a hundred years. Our tools, and brilliant structural engineers, can do that for you, every day. The question you have to ask or teach your students of architecture is, how do they quantify these things or how do they bring a qualitative discussion, which to me is beauty. My own interpretation is that if I make the human being, like the man on the right (showing the slide), I am sure I would not want him to have babies again. That is the end of my lecture. Thank you.

Keynote Address

Emmanuel Tzekakis

Testing and Simulation
The Acoustics Design Case

Aristotle University of Thessaloniki
School of Architecture
Greece

1. Introduction, context and targets

Testing and simulation have always been used by engineers as tools useful for studying and predicting the behavior of buildings or structures, as models have been used by designers and architects for displaying and studying their form. The depth of the analysis and the accuracy of the prediction depended always on the available technologies. The current digital technologies support the advancement of modeling, testing and simulation techniques to a new level of complexity and usefulness. This reality is described and commented upon in this presentation, using acoustics design as a suitable example.

1.1. Presentation context

This presentation has been prepared and adapted with the context of the meeting in mind, which is a "Construction Teachers' Network" meeting.

The discussion topics during these meetings are usually about

- The relations between architecture and building construction
- The relations between building construction and technology
- The new evolving design/technology relations
- The new evolving design/construction relations
- The digital technologies and especially
  - their impact on the work of architects
  - teaching about digital technologies
  - teaching through digital technologies

1.2. Presentation targets

The targets of the presentation, formed with the context of the meeting in mind, are about the following subjects

- understanding what testing and simulation is about
- showing some testing and simulation applications
- presenting the acoustics case and its development around testing and simulation
- describing how testing and simulation is interacting with the architect's work
- discussing how testing and simulation may be related to building construction teaching

2. On the subject of testing and simulation

2.1. Terms

The terms testing and simulation have a specific meaning used within the context described above.

Testing is a more specific term than simulation. It tries to answer questions of the following type:

- Does the proposed solution meet a specific parameter request? This type of question concerns a specific design parameter of known target value and uses testing in order to check if the proposed design complies with the set requirements.

- What is the actual interaction between different parameters? This type of question concerns the interaction between design parameters and addresses the known problem of adjusting the design in order to meet one parameter request, and as a consequence introducing a major change on other parameters.

Simulation on the other side is a more general term then testing. It describes usually:

- A testing tool of a more advanced and complex nature
- A tool able to test the response and behavior of a system or design, not only the parameter values or the parameters interaction

2.2. Models

Models are physical or mathematical representations of real objects or situations, used to describe certain reaction phenomena. Many types of models have been developed and used until throughout time:

- Simple clay models have been found in excavations that are simple representations of existing or proposed buildings.
- Working models have always been used by architects and engineers as tools for observation during the design period.
- Detailed models are used for presentation purposes, mainly to help the client understand the design characteristics of the proposed building.
- Detailed walk through models have been used during the second halve of the 20th century, using optical viewing and recording equipment.
- Detailed architectural models in scale of up to 1:10 have also been used during the same period, for simple light and more complex acoustics tests using sound.
- Finally, digital models are used today for all the above purposes and many more.

2.3. Testing/simulation/modeling (the need)

The basic question asked about testing, simulation and modelling is very simple. Why do we need these tools?

The simple and obvious answer would be:

- to be able to overview a complex entity and understand the way it works or looks
- to examine a close approximation of the real thing before it is build in full scale
- to perform simple or complex tests under specific conditions in order to understand its possible behavior

The more complicated answer to the question why do we really need these tools may be:

- to reduce the pressure of responsibility for the results of the design
- to fight the natural fear before an unknown result, or a possible failure
- to be able to see the future, in a way, to foresee the results of the design

2.4. Testing/simulation/modeling (the example)

In order to discuss these subjects I have chosen acoustics as an example. The reasons behind this are that:

- acoustic design and acoustic modelling is a good and representative example, in order to examine the topics of the meeting
- acoustic modelling represents an old and relatively mature physical as well as digital application
- acoustic modelling is a field I did some work myself

3. Technologies & architecture (the digital environment)

3.1. The environment (digital technologies)

Architectural design (not architecture) has been relatively immune to influences from the advancement of the technical and technological environment. Today's technological environment however is obviously influencing at least the design procedure, through a series of new technologies. They include:

- New design tools, enabling the architect to create much more complex design forms and still produce accurate drawings
- New visualization tools, helping the architect and the client to better understand the design object
- New modeling means, to create 3D models of the building or object
- New communication methods, enabling the architect to collaborate much easier with the engineering team
- New testing tools, providing useful data about the building or object from the early stages of the design

The question whether this environment is creating a new architecture, is a very interesting current discussion topic.

3.2. The environment (design work)

Assuming that the technical and technological environment is changing or has already changed, and in order to follow the thought through, the next question would be what are the effects of this change on the work of architects. The main changes have to do with:

- Presentation methods. Photorealistic three dimensional representations of the building, from any angle, in any conditions, inside and outside
- Design research and depth. Easy production of a variety of solutions and forms, allowing an in depth research of all aspects of the design
- Form generation. Parametric or otherwise controlled form generation, opening new dimensions to the designers
- Rapid prototyping. Various technologies enabling the creation of a three dimensional representation of the design object from the early stages of the design
- Testing possibilities. Digital models of the design object allow the testing of various parameters of the design, supporting the optimization process
- Dynamic behaviour simulation. Advanced modelling technologies producing answers about the behaviour of the design object under dynamic conditions

3.3. The environment (team work)

Today's technological environment offers new and advanced communications media. These change the way the design team works, by offering:

- A common set of architectural drawings for the team of engineers to work with
- Easy, low cost introduction of changes during almost all stages of the design process
- Immediate exchange of drawings between the members of the engineering team
- Cooperation with remote team members with the same communication means used within the office
- More accurate and consistent drawings
- Easy generation of 3d models for visualization and testing

4. Testing & simulation, the acoustics design

Testing has always been of prime importance in the development of acoustics. Advancements in building acoustics and room acoustics during the 20th century were based mainly on measurements and testing. Simulation through models started also very early and evolved continuously until today, giving us a good example to follow the advancement of testing and simulation.

4.1 A short history of acoustics modeling

The following describes in summary the development of acoustics modeling:

1920 - The scientific foundations of room and building acoustics are set by the pioneers of the new branch of science

1930 - New measuring instrumentation is developed, allowing the quantification of level, frequency and other parameters of sound

1940 - Simple modeling techniques are developed in an effort to produce visual representations of the sound waves

1960 - Analog 3D modeling techniques are developed with the aid of tape recorders in an effort to produce audio simulations of the sound field in rooms

1970 - The first simple digital modeling techniques are made public starting a revolution in testing that is still going on

1980 - Rough 3D digital models of rooms are used to test acoustic parameters (used in Greece for the first time in the Athens Music Hall) and produce sound recordings

1990 - The digital models, as we know them today, are developed, producing faster and more accurate results

Of special importance are also modeling techniques developed since the 90s that widen the application field of acoustics modeling. These techniques will be discussed later.

4.2. Physical (analog) modelling

Before the arrival of digital technologies, testing and simulation has been carried out for decades with considerable success using physical (analog) models. The basic types of analog models used during this period are the following.

- Water tank models, using water waves to imitate the movement of sound waves in two dimensional water tanks
- Light ray models, using light beams to study the reflexion patterns of complex wall or ceiling designs
- Spark models, using an electrical discharge to imitate the movement of sound waves in two dimensional models, with increased accuracy compared to the water tank models
- Laser ray models, using laser beams to study the reflexion patterns of complex wall or ceiling designs, with increased accuracy compared to the light ray models
- Simple 3D models, using an electrical discharge to imitate the movement of sound waves in three dimensional models and study the succession of reflections
- Advanced 3D models, using transposed sound to imitate the sound field in three dimensional models, study the succession of reflections and create simple recordings

4.3. Digital modeling (partial modeling)

Digital technologies have not always been as advanced as today. In the beginning the available hardware and software limited the possible applications. Partial modeling that required limited capabilities came first. As partial modeling we understand techniques focused on testing one aspect of the design only. In the following, two typical examples of partial modeling are presented. Both have been developed by the author and are still in use.

- Ray tracing in a section of the room

  This type of model uses a two dimensional section of the room and traces the paths of the sound 'rays' in order to optimize the shape of the reflecting surfaces and indicate late reflexions that must be absorbed.

- Calculating reverberation time with the use of absorbing materials

  This type of model uses a numerical description of the room and using the size and absorption characteristics of the surface materials of the rooms calculates the predicted reverberation time.

4.4. Digital modelling (3D modelling)

Advanced hardware and software allowed the development of what we may describe as the current mainstream digital model technology for acoustics. Good examples of the capabilities of the available high end applications are among others Odeon and Catt. These applications use detailed 3D room models and provide predictions for all aspects of the acoustical design. All known acoustical parameters are tested and the predicted values are presented in numerical and graphics forms.

In addition simpler, low cost 3D modelling applications exist, offering accurate but limited parameter predictions.

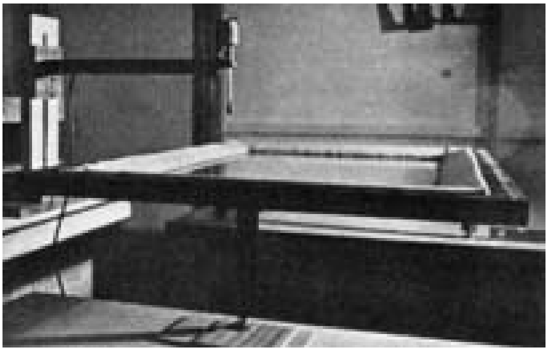


Fig. 1
Water tank

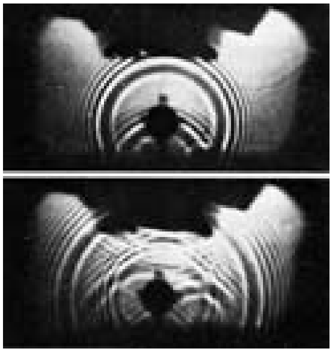


Fig. 2
Water tank model, wavefronts

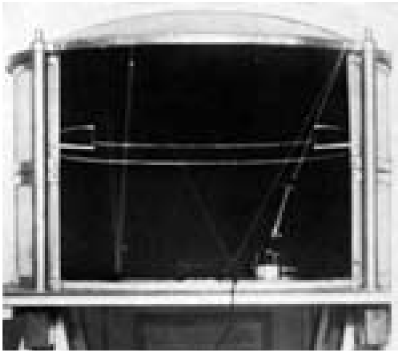


Fig. 3
Light beam model

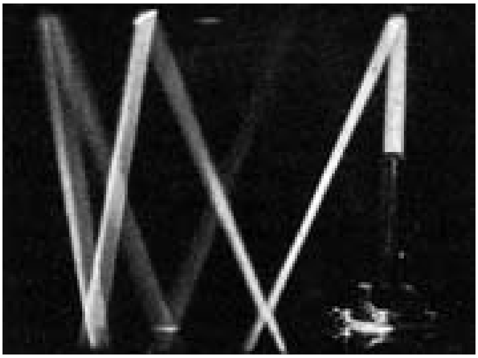


Fig. 4
Light beam reflexions pattern

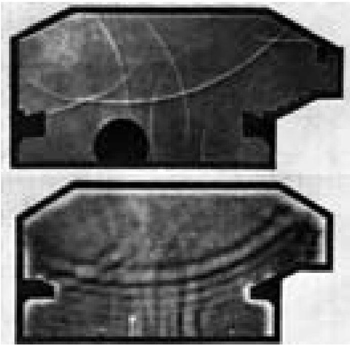


Fig. 5
Water tank model and spark model comparison

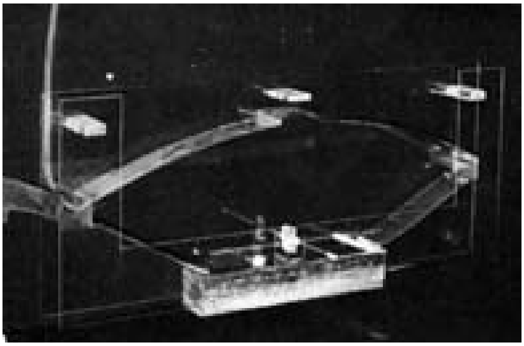


Fig. 6
Laser model – Sports hall in Thessaloniki

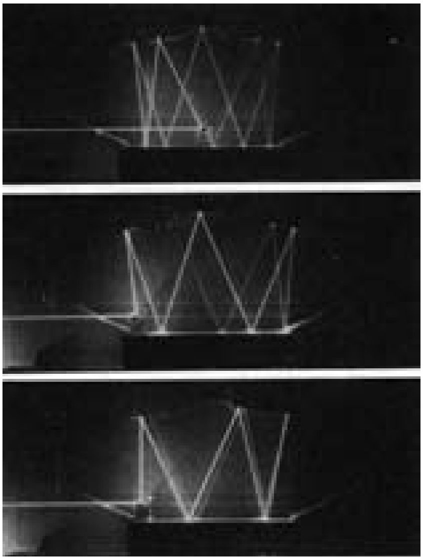


Fig. 7
Laser model results, reflexions pattern

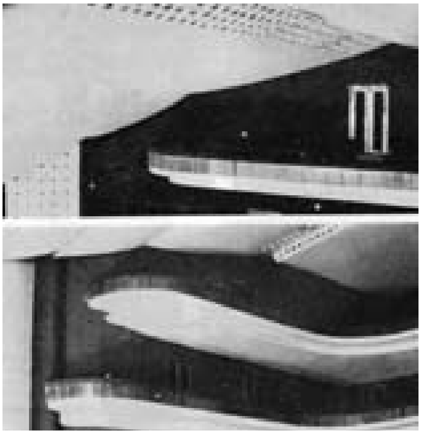


Fig. 9
Thessaloniki theatre 3D model in 1:20 scale

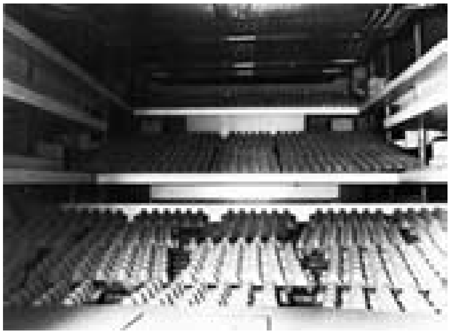


Fig. 8
Typical 1:10 scale model

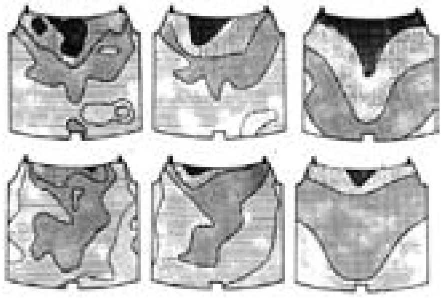


Fig. 10
Energy distribution comparison between model and the real hall

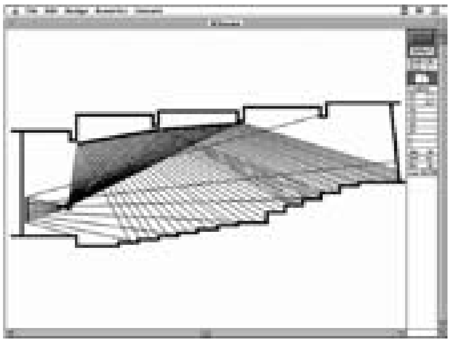
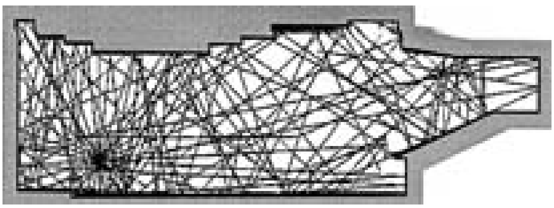


Fig. 12
2D ray tracing software – Secan (developed by the author)

Fig. 11
Sound ray tracing in a 2D model of a room



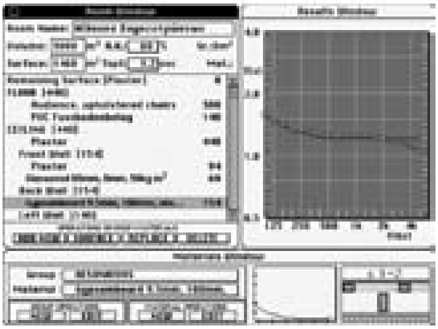


Fig. 13

Reverberation time prediction software – Tosan (developed by the author)

Fig. 14

Photorealistic interior of a sports hall design

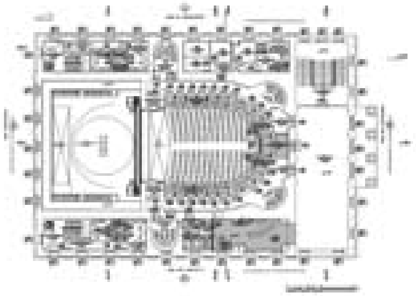


Fig. 15

Municipal theatre of Pireas, plan

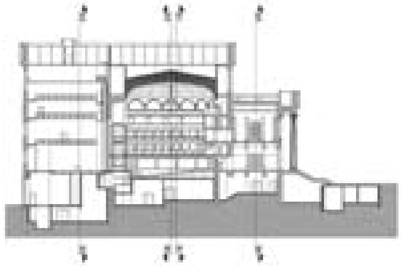


Fig. 16

Municipal theatre of Pireas, section

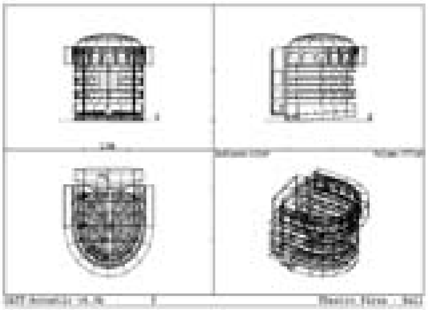


Fig. 17

Municipal theatre of Pireas, 3D model

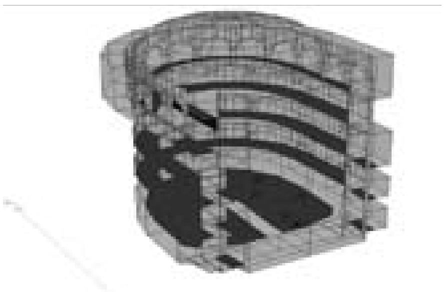


Fig. 19

Municipal theatre of Pireas, 3D model results

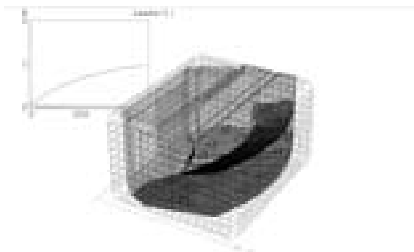


Fig. 18

Municipal theatre of Pireas, leaks test results

Fig. 20
Walk through church model

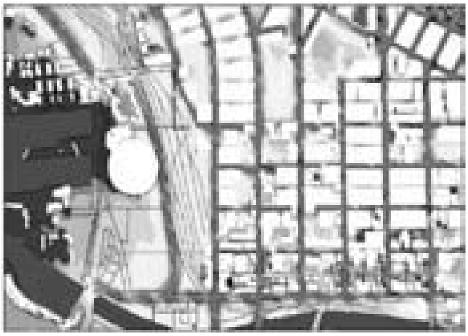


Fig. 21
Urban noise prediction software, plan

Fig. 22
Urban noise prediction software,
3D presentation of results

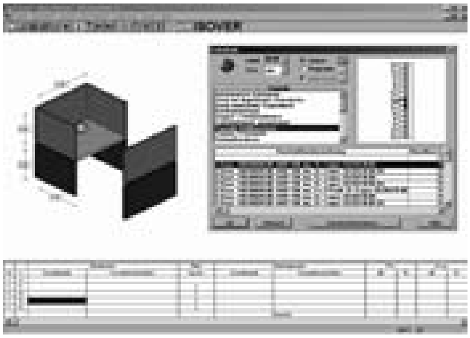


Fig. 23
Sound insulation prediction software

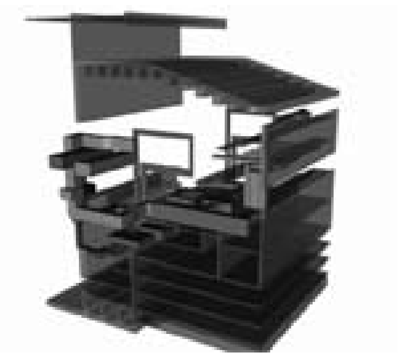


Fig. 24
3D model of the air conditioning system,
Athens music hall

ACOUSTIC CRITERIA FOR THEATRES WITH VOLUMES OF UP TO 5000 CUBIC METRES					
NR	**Symbol**	**Name**	**Unit**	**Value**	**Notes**
1	RT	Reverberation Time	sec	0,9 - 1,0	The Eyring formula will be considered
					12 positions on one side of the room to be tested
					Low frequency increase 25 - 30% is allowed
					Spherical source will be used
2	EDT	Early Decay Time	sec	> 0,8 RT < RT	Spherical source will be used
3	D50	Definition	%	> 50 (min)	Directional source will be used
				> 65 (mean)	Tests at 0 and 90 degrees will be made
4	G10	Strength	dB	> 0 (min)	Directional source will be used
				> 5 (mean)	Tests at 0 and 90 degrees will be made
5	C80	Clarity	dB	> 0 (min)	Spherical source will be used
				3 - 7 (mean)	This criterion is mainly for rooms for music
6	TS	Central Time	msec	< 130 (max)	Spherical source will be used
				< 80 (mean)	
7	LEF	Lateral Efficiency	%	> 20 (min)	Spherical source will be used
				> 30 (mean)	
8	L	Noise Level	dB(A)	< 25	

Fig. 25

Typical room acoustics criteria for a drama theater

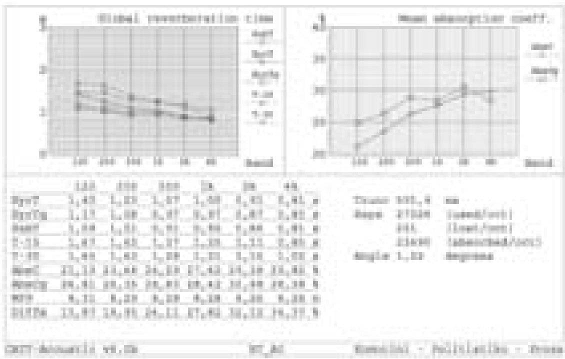


Fig 26

Room acoustics criteria 3D model prediction

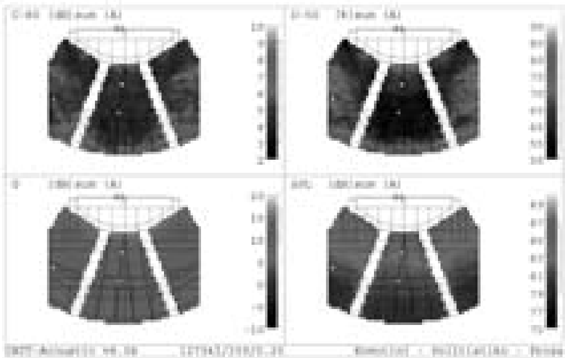


Fig. 27

3D model test results in map form

Special applications are also available for addressing certain special problems. Some well known such applications address the problem of loudspeaker positioning, taking into account the technical and acoustical characteristics of the used loudspeakers. Other applications offer reliable predictions for the distribution of noise in an urban environment, very helpful in order to test the effects of urban noise reduction measures.

4.5. Digital modelling (movement and time)

The development of very fast processors made practical the addition of a 4th dimension in simulation technologies, namely time. Since the eighties 3D acoustic models were used to simulate the sound field of rooms and using "dry" sound (recorded in a reflexion free environment) to create recordings with acoustical characteristics similar to the characteristics of the room to be built, in stereo. These applications were complicated and time consuming. Today similar applications produce such recordings in no time, although not yet in real time, as subjective test tools.

These developments led to more advanced 4D simulation results such as the reproduction of the sound insulation efficiency of a proposed construction (simulating direct and flanking transmission from one room to another) or the reproduction of a walk through experience (walking through the simulated sound field of a new designed space).

4.6. Model simulation results

The results of room acoustics simulations through digital models are usually the values of the criteria used to evaluate the acoustic qualities of a room. Acoustic criteria are objective parameters that can be calculated from the geometrical and acoustical data of a room. These parameters have known relations to the subjective impression formed by the audience about the acoustics of a room. Such criteria calculations are very complex and thus time consuming and are practically impossible to produce without the use of digital technology. An example of the criteria used to evaluate the acoustic quality of a drama theater is presented in a following table.

The speed of the calculations possible with present time hardware technology allows for the easy presentation of the results in map form. These maps are prepared by predicting the criteria values in many points inside the designed room, usually using a grid pattern. This form of results is very useful because it helps understanding the relations between room shapes and acoustic qualities, which in itself is a very complex subject.

Finally auralization techniques help produce real like recordings in models, offering us very useful subjective evaluation tools.

4.7. Technology limitations

However impressive the results of digital modeling may be, the scientist must have always in mind the fact that this is only a simulation. The reliability of the simulation results, whether in optical, acoustical or numerical form, depend on the accuracy of the algorithm used and ultimately on our current understanding of the actual physical phenomena that are simulated.

There are many examples of software applications using fast but not very accurate algorithms. That means that the algorithm does not take into account all aspects of the simulated phenomenon. This fact, if unnoticed by the user, may result in unreliable results, presented in usually very impressive forms.

A good example in acoustic modeling is diffraction, that is the amount of sound energy that goes around an obstacle. Ray tracing techniques used in acoustic prediction software do not offer accurate calculation solutions for this phenomenon and in many cases this energy fraction is not taken into account at all. This is a known deficiency and although of limited consequence, it may result in significant inaccuracies in certain room shapes.

There are also hidden shortcuts in aspects of the physical phenomena that are not yet completely defined, in a way that may be used reliably in simulations.

A good example is diffusion, that is a reflexion of sound by a surface that does not follow the simple geometry of light reflexion. Because diffusion has not yet been standardized (as for example is absorption) its introduction in modeling may produce very large variations of the results.

Should we forget the fact that simulation depends upon our current understanding of the real world, it is very likely that we may find ourselves dealing with a simulated reality that does not exist. Simulation is a representation of reality, not reality itself. Results and especially scientific results produced by simulation may be impressive but misleading. One must not confuse real science with what we may call "digital" science.

4.8. Conclusions

To conclude this discussion concerning the use of models in the design of acoustics, we may note the following:

- They are certainly very useful design tools, used by acoustics experts throughout the world
- They produce very impressive results, in numerical and map form, helping us understand better a complex situation
- They use fast working algorithms, enabling us to have results in no time and producing realistic recordings as subjective testing tools
- They are nevertheless limited in various ways
- Therefore they are dangerous, especially in the hands of inexperienced users
- They represent an evolving technology, that is getting better with each new generation of software

5. Consequences for architecture and construction

5.1. Technologies and their application

The development of new technologies is not always followed by their application in everyday life and work.

- What is available as technology is different from what is needed by the user.
- What is needed by the user is again different from what is accepted by the market.
- And finally, what is accepted by the market is different from what is actually used.

There are many examples that support this view. When the first Macintosh was released in the eighties, it was evident to those using computers as tools to work with, that this would be the machine of the future. Nevertheless the reality is that many years after this, other systems, Windows on PCs became the dominant systems throughout the world.

In the early nineties, a group of researchers in California developed i-cads, an intelligent cad system offering parallel working software tools to help and guide the designer (such tools as are those presented in the paragraph about partial modeling). Although such tools are used today in many forms, the designers do not use them during the design process (in parallel), but only after the design is complete (in series) and usually through consultants to check and comment upon the design, with obvious consequences in time and expense. Although at that time this type of applications seemed to be the obvious way to develop advanced cad systems, it did not materialize and is still not available.

5.2. The effects on the architects work

All developments discussed in the previous paragraphs do introduce changes in the work of architects. Some of these changes spread rapidly, others slowly, almost unnoticed. A few of these changes are:

- The change in the allocation of effort

  The architect today may produce typical drawings for a new building in a fraction of the time he needed a few years back. This however leads to some disadvantages such as the fact that he has more items to consider and study in order to produce more detailed drawings. He also has more solutions to consider, because it is easy to produce and discuss them with the client.

- The expansion of the field of architectural work

  Digital drawings offer the possibility to consider many more aspects of the design, simply because the available tools give the architect a much better presentation of the design object (for instance night views). The use of the architectural drawings by other engineers and consultants results in an obligation to know more about building and construction sciences and at the same time produces more drawings changes and revisions.

- The possible (and dangerous) responsibility shift

  The increasing difficulty in dealing with complex subjects such energy efficiency (to do with the building envelope) or acoustics (to do with the interior design), may result in a responsibility shift away from the architect. Such negative developments must be avoided at all costs. In that respect the available digital tools offer a way out, by allowing the architect to retain control over these aspects of the design.

Although the first impression is that the work of architects may be easier now with the advent of digital drawings, a deeper examination of the situation may reveal that it is actually not.

On the other hand, developments in other fields may be of help, such as the introduction of building products in most aspects of the building and its design and the standardization of the characteristics of these products.

Whether easier or not, all this is changing the work of architects considerably.

6. Conclusions for construction teaching

6.1. Conclusions for construction teaching (simple ones)

A simple and obvious conclusion for construction teaching would be to start using testing and simulation tools in the schools, and in particular:

- use testing and simulation tools to get students to know them
- use testing and simulation tools to get students to be able to use them in their work

Some good questions concerning this conclusion would be:

- are these tools going to be there tomorrow
- will the students really use them, when they become architects

The answer to such questions should also be obvious. We must use the tools but we must focus on the problems to be addressed, not the tools used.

6.2. Conclusions for construction teaching (complex ones)

A more complex and difficult conclusion for construction teaching would be to introduce real world simulation methods in the work of the students. This may be done in more than one ways:

A good approach would be this

- The school simulates the missing design parameters (civil engineer, mechanical engineer, consultants) and introduces the student in the real world of his future profession

A better approach however would be a more complex one

- The above simulation is organized between schools (civil engineering schools, mechanical engineering schools, etc) with the involvement of the students of the other faculties in their respective roles

Of course everybody understands the immense difficulties. But also everybody understands that these would represent really advanced environments for the students of tomorrow.

6.3. Conclusions for construction teaching

To conclude the presentation we may say that:

- The new tools give us new opportunities
- They change many aspects of the profession and of teaching about it
- However new tools introduce also new problems
- The balance will be positive, I think

Session 1

Testing and Simulation

Chair: **Jelle Laverge** *Ghent University, Belgium*

Nathan Van den Bossche

Department of Architecture and Urban Planning
Ghent University
Belgium

Caution: Students in the Lab!

The Architectural education is confronted with an ambiguous problem: for five years we are drawing, sketching, calculating and simulating. But actually it is all fiction. Then the graduates are set free in the real world and erect building after building. When you look at the labour market, I do not see a lot of other highly skilled academic professionals who are that involved in the design, erection and quality control of their products as the architect. Due to the quick succession of completely different projects it is not cost-effective to subdivide the assignment into a lot of different tasks. That way the same architect is usually involved in all stages of the design and building process.

The transition from theory to practice is a small step for human kind, but an enormous leap for the architect. Does the contrast have to be that big? The department of architecture and planning of the University of Ghent has worked out a collection of hands-on assignments throughout the curriculum. That way the students have a more gradual shift from theory to practice.

In my opinion we are only at the beginning of that evolution, because didactical research points out that the biggest progression in education for the students can be reached if they comprehend the relationship between theory, application and their own frame of reference.

A degree of engineer-architect does not necessarily mean the person in question will in fact become an architect. A lot of graduates become building contractor, researcher, engineer, salesman or teacher. The school has to take that into account and provide for a solid education that leaves all doors open.

Experimental research

One way to get acquainted to practice is the use of experiments throughout education. We basically distinguish two types of experimental scientific research for the students:

- *The students already know what they ought to find* (typical are the tests we all did for physics and chemistry, like calculating the acceleration due to gravity and producing salt out of acid and base). These kind of experiments teach the students to work with test results, error rate and error analysis. No extensive prior knowledge is necessary, the test is relatively easy and the students can easily verify the accuracy of the results. These kinds of experiments are situated in the bachelor years.
- *The students do not know what the results will be*, and have to search for scientific laws that predict the behaviour of certain phenomena. This requires a lot of prior knowledge and the boundary conditions are usually a lot more rigorous. It also takes more time to study the basic laws and interpret the results. This kind of research is predominantly executed within the framework of a master thesis.

However, as the architect is often the odd person out, some experiments in architectural education cannot be classified that easy. If one designs a building, landscape or an eave the outcome can not be predicted, but this is no scientific research too. Students should learn to deal with that situation: within the restraints of technical feasibility they have to design configurations that are more than just a 'solution'...

The department of architecture and urban planning of the University of Ghent wants to emphasize the interaction between design and construction, and here construction comprises material science, building physics, structural engineering, feasibility on the construction site etc. The level of the exercises is adjusted to the grade of the students: in the bachelor years the exercises are primarely multidisciplinary so students have to combine different expertises within one exercise. One consequence is that the student can not go very deep into the different aspects of the problem, because he only works on a need-to-know basis. These exercises can not replace subjects as building fysics or material science, they are only an application of the knowledge they have obtained in those courses. Last year the students of the third year made an exercise on 'scale models'.

In the master years the students get the opportunity to choose between a number of special assignments on different topics. One of these topics focusses more on the fusion of design and structural engineering. This course is organised every two years, the other years there is a special assignment that combines design and material science. That way students can follow the course they want within the master program of two years.

Because the impact of structural engineering on certain constructions is that high, a designer should be able to acquire total control on the project to get direct feedback on every line he draws. In order to do so, students have to use computer software to calculate the impact of design options on the construction. The special assignment 'bridge' generated some interesting designs...

Scale models

This project is organised as an exercise within the course 'façade construction techniques' in the third bachelor year. The students are divided into teams of three persons, and every group is assigned a specific task with respect to their personal interests and ambitions. There are three different tasks and every group will perform one task: architect, engineer or material consultant.

The architects will work on a specific intricate construction detail (the junction of a wall with the foundation in a sloped terrain, the window-wall interface when the window is projected 20 cm outwards…). In order to generate correct construction drawings they can use building codes and construction manuals, and they have to collaborate with the engineers and the material consultants. At the end of the exercise they have to construct a mock-up to visualize the interface and chosen solution.

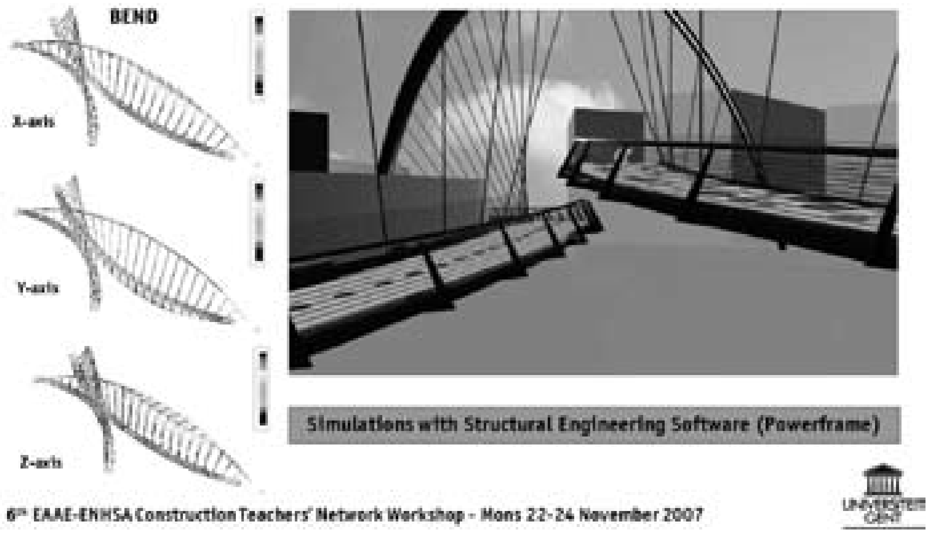
Other students will act as engineer and use finite element analysis software to assess the risk of condensation on thermal bridges, and try to decrease the heat loss through those thermal bridges by suggesting alternative solutions. That way they are involved in the design process of different groups, and will pick up a lot from the other teams.

A third group of students will advise on material properties and construction techniques. Every group analyses one material e.g. brickwork support systems, and will advise the architects to select the right materials. They also have to produce the materials for the scale models according to the plans of the architects. When possible, they try to imitate the production process of real products, for example the mock-up concrete consists of wax, expanded polystyrene and expanded clay grains.

In this exercise we try to achieve different goals: stimulating a problem-solving attitude, collaboration and communication with people in own team and other teams (which deal with other aspects of the same problem), multidisciplinary thinking and combining material knowledge, construction techniques and building physics. Next to that they get the opportunity to visualize the problem in a three-dimensional way in the mock-up, and learn to translate this into 3D-computer simulations and 2D drawings.

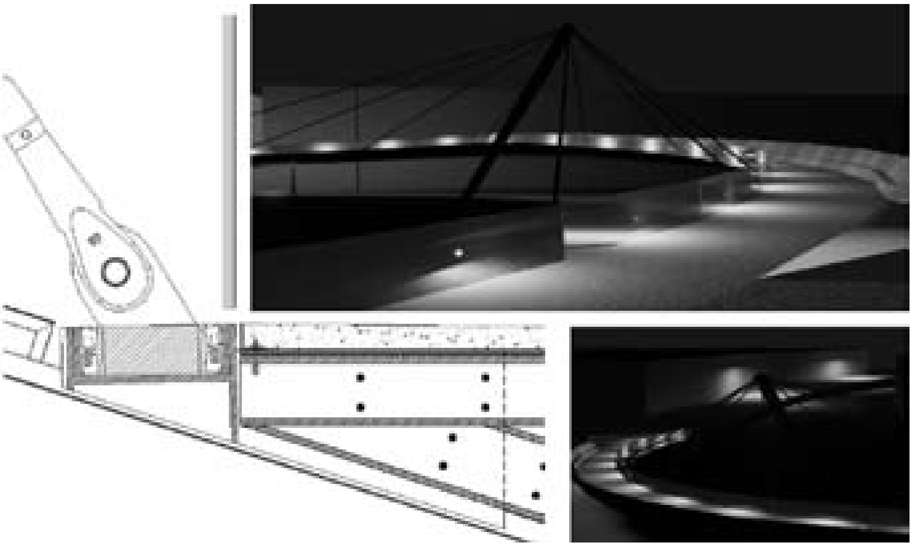
Within the framework of the Belgian building codes the students search for feasible solutions that are airtight, watertight, sustainable and have a low risk of internal condensation. The building codes are often not suitable for these kinds of issues, so students have to balance the pros and cons whether to comply with superseded codes or to desicively design solutions themselves, based on a thorough and well-founded analysis. If there would be a perfect solution, there would be no discussion about the result. However, these kinds of problems generate different solutions with different accents and focal points, and that makes it more difficult to judge the outcome. On the other hand the path may be more important than the destination: next to the inherent knowledge to deal with the exercise the students also acquire other competences that are very important concerning the profession of architect or engineer.

Bridge



Much too often the design of bridges is made without an architect or designer involved (I do not consider drawing a bridge and designing a bridge as the same thing). In this optional course students of the first and second master year had to design a bridge for pedestrians over a river in the city center of Ghent. 8 teams of 3 or 4 students worked on the projec during 6 weeks, and every week there was one counseling session. In that short period of time the students came up with some very interesting and different designs.

Most teams had worked out a fairly good analysis of the structural behaviour of the construction, and it points out that it is really worth the effort to organise these kinds of exercises. Of course the structural design is too complex to fully design and calculate it, but nevertheless the students generate very useful information that enhances the overall quality. A student that understands the interaction between design and construction will have a more shades of meaning on the design proces.



Ambition

Education in general has two major focal points: first of all young people have to go through the process of allocation: jobs have to be filled with people with the right competences to ensure the continuation of our society as we know it (selection, specialisation and integration). Next to that, education is also very important for the (emancipation) of the students: every person needs certain skills, competences and knowledge to function as an involved, critical citizen. Educating architects clearly involves both aspects.

The task of an architect is very complex and deals with design, materials, structural engineering, building fysics, HVAC, sustainability, legal affairs etc. However, there is too much to teach and too little time. We can not expect a student to master all competences involved in the building proces (does anyone?), so we have to make choices. In fact, we can not choose, what can we leave out? The only solution is to teach the fundamentals of all aspects in order to give students the potential to go whatever direction they want. Next to that, they need the potential to process all the information that is coming out of the different disciplines into one design. The exercises presented in this paper are in the line of this philosophy: a multidisciplinary approach with a good understanding of the interaction between all aspects will generate better architects and architecture that is more complete.

Miltiadis Tzitzas
Eleni Alexandrou

School of Architecture
National Technical University of Athens
Greece

The Necessity of the Physical Model

Education

In recent years the *technological advances* have become a reality and have taken over in many fields. One of these fields is *architectural technology*. The material and construction industry is expanding rapidly, with innovations that challenge the design process. New materials are emerging and the properties of the basic ones are exploited for more and diverse applications, creating a new field of study in the construction area.

This technological advance makes nowadays the *interrelation of design and construction courses* more apparent than ever. The choice of materials and construction methods is a *decisive parameter* and a *powerful tool* that should be considered in the conceptual process of design. In the near future designers will choose from a wide range of structural systems instead of designing the components and details. Therefore they must be well trained and qualified, in order to be able to select the proper systems. Consequently, it is obvious that this new situation makes the *education and training in architectural technology* a very essential issue.

Teaching

Students of architecture must comprehend from the early years of study that during the design process, the *choice of materials and construction methods*, as well as *environmental and bioclimatic constraints* are critical for the outcome.

All these parameters should be considered accordingly from the *first steps of the conceptual process of design* in order to produce a solid and sensible solution. In other words *what* they design and *how* it will be realized are issues that need to be addressed from the beginning of the design process.

For years in our school students developed their design idea with sketches, either in two or three dimensions. As the concept elaborates, more expression tools were used to support their project, such as axonometrics, working models and photographs. Finally the presentation of the project was a pile of skilful and well-executed drawings and models.

The comprehension of all parameters and constraints, such as materials and structure, which impose the design process and define a building, was obtained and challenged at all evolution stages of the project, with the equivalent construction drawings and physical working models.

Through this procedure they created forms and structures with their own hands in an attempt to appreciate their conceptual idea and its restrictions.

New Technologies

The invasion of the digital drawing process gave to students a powerful tool to express the design idea in a magnificent and impressionable way from the very beginning. Slowly but inexorably sketches by hand were constricted in preliminary ones of a very deteriorating, poor quality and working physical models were replaced by three dimensional drawings elaborated in two dimensional monitors.

Gradually students' attention was deflected to the potential offered by digital tools. Materials were easily chosen from the computer memory banks and working physical models on the other hand, because of the easiness of digital three dimensional models started to become obsolete.

However it is essential to have in mind that students – especially at early years of study- have no experience of the construction field and reality, through which they would comprehend and learn to manage with real challenges of a structure and its parameters. Therefore omitting sketches and physical models and work directly with digital tools, leads them eventually to distance themselves from the authentic, design forms that could not be assembled and propose impossible construction details. In the end they have no control of the project they design.

We have seen students with no previous experience or even information about materials, construction details, becoming fascinated with digital three dimensional models and producing ones that can be seen from impossible angles, lightened in most cases with sources of inexistent natural light, all that in a two dimensional monitor or paper.

The traditional way

Sketching is expressing directly ideas, picturing architectural thoughts in a piece of paper by hand using a pencil or marker. Sketches could be good, excellent, mediocre or even poor in expressing an architectural concept, but finally they are a unique personal expression of an individual idea.

We in our school are gradually reintroducing and implementing the idea of making working physical models during the development of the design process. Thus students are expressing their concept by materializing it in scale, taking photos understanding structure, volumes and consequentially gaining control over their architectural design.

After that they feel confident to use all digital wonders in order to express their design concept with outstanding results.

The future

Nevertheless, in our time *digital modeling and simulation* are taking over rapidly and are becoming the standard method of visualizing and sometimes conceive a structure. Different computer programs can accurately and interactively define and express the form and the performance of buildings, in means of structure, materials and environmental controls. Simultaneously, they produce all the necessary data, that in extend helps in statistics and comparisons between different kinds of structures or similar structures which differ in some parameters. Special forms that are hard to perceive and visualize with two dimension sketches of drawings, can be developed with digital models and parts of the building even be constructed consequently, using digital technology (CNC). These tools seem unique and are very important for a developing architect to acquire.

However, proceeding with *physical modeling* is still the unrivalled experience for students that help them sense the structure and its components, because they construct it themselves. This experience is *essential* in order to pass and excel in the use of digital modeling and simulation.

Avraham Mosseri

The David Azrieli School of Architecture
The Faculty of the Arts
Tel-Aviv University
Israel

A Vision for the Future - Testing and Simulation Methods and Techniques (TSMT) in Construction Teaching

Introduction

Many efforts are devoted today in order to develop advanced testing and simulation methods and techniques (TSMT) in different fields, including the field of construction. Indeed, in the contemporary situation it is possible to identify, relatively, a large gamut of different advanced TSMT tools in construction, which can be adequate also for teaching. These tools can be in the practical world but also in the academic life. In different schools of architecture it is possible to find today different TSMT tools, in specific courses or in the design studio – where the integration of knowledge, including the construction knowledge, has to occur. This activity is not always well organized and understood and in many cases it is an outcome of sporadic actions which are taken by different entities.

In this situation there is a need to classify and to map the different TSMT tools in construction, to analyze their strategic problems and to clarify the possible future environments.

Testing and simulation methods and techniques in construction

The diversity of TSMT tools in the field of construction and their different roles, require first to have a typology, which can act as an orientation map. There are many ways to classify the different TSMT tools. In this article it is proposed to make the classification according to the functionality and the assignment of the different tools, when each tool is described and characterized. This basic typology can lay the foundation for a more detailed typology – or a second cycle typology - with a matrix, which can describe the different types deeply. In this case each tool is described systematically according to a list of parameters, when each parameter can have different variants. The whole parameters with their variants create a matrix that characterizes all the different types of the tools according to their detailed skills. This morphological analysis is based, in general, on the morphological analysis of Zwicky (Zwicky, 1969, see Ritchey, 1998) but it will not be developed in the framework of this article, and only the basic typology will be developed.

Typology of the main TSMT tools

The suggested typology is based on an identification of selected TST tools, which are relevant to construction, from the practical area and from the academic field. It is important to stress that not all the tools are in the same position. Several of them are relatively well developed - after many years of research and production, while others are still in a process of development and have to be more elaborated. The typology even contains tools which are not totally identified with construction but are included because of their potential to be more relevant to the construction field in the future. In addition, the borders between the different TSMT tools are objectively not always sharp and there may be, in some cases, common features. In the following paragraphs the main advanced TSMT tools in construction teaching are classified according to their assignments and in relation to their main features (partially based on Kalay, 2004, Mussel, 2004):

- *Visual presentation and communication tools* – this category includes all the means which can help to present and to communicate visually - Drawing tools, visual simulations, video films, animations and others. In many cases these tools are used mainly as descriptive tools and part of them are still detailed and not yet conceptual enough.
- *Scientific-mathematical tools* – these tools are mainly being used for engineering simulations and analysis, especially in scientific fields like: structural analysis, lighting, climatic design, acoustics. In this category it is also possible to include techniques like linear programming and other mathematical methods. In many cases these tools are being used mainly for analysis of functional performance of the built environment. They can be dynamic or static and in the current situation many of them are more detailed and less conceptual.
- *Form generation tools* – the main purpose of these tools is to help the designer to create and generate forms, shapes and geometries as an outcome of a complex process. For this reason, in many cases, this process is usually a computer-supported process. This category includes: morphogenesis techniques, parametric design, genetic algorithms, topology architecture, free form architecture and others. In many cases these tools are still not enough integrated with other tools.
- *Heuristic tools* – in this group there are tools which can assist the designer to have a better reasoning and to rationalize the design process. It can be based for example on known rules like "if- then" rules. This category includes tools like expert systems, which are considered to be a part of artificial intelligent. Because of the complexity of these tools they are still in a process of development and part of them are yet not friendly and practical enough.
- *Case studies and precedents tools* – these tools can help the designer to use knowledge from projects, events or circumstances, which took place in the past. This way enables to use the past experience when dealing with the simulation of the future. This experience-based knowledge can include conceptual solutions, technical details or any other information presented in drawings, illustrations, photographs, video, etc. of different precedents. For this reason these tools usually include a data-base which is mainly digital. Example for using the digital resources with special data-base for case studies and precedents in the construction field can be found in Mosseri (2005).
- *Analogies and metaphors tools* – this category includes tools that allow using analogies and metaphors as accelerators for the creativity in the design process. In this case an image, object or any entity can be a source for getting ideas and inspirations for the new design (for example a skeleton of an animal which gives an inspiration for a new artificial skeleton). This can be based on data-base including different entities from the natural or the artificial world. When this data-base is digital it can allow a wide span of exposure to analogies. This data-base can be used and organized as mentioned in Mosseri (2005).
- *Procedural qualitative tools* – these tools can help to find enumeration and arrangements possibilities under different constraints. This can be helpful to find different combinations by using the computer ability to scan a large amount of cases. For example: scanning different possibilities to build a structure with a minimum amount of bars.

- *Collaboration tools* – these tools enable collaboration of different agents, using computers. They include collaborative software, e-systems for collaboration like e-learning, participation means and others.
- *3D physical-simulation models* – these tools includes 3D physical models, which enable to supply relatively precise and accurate information about the behavior of the systems in the real life. For example: 3d physical models of buildings based on a shaking table to simulate their seismic behavior under dynamic loads. In some cases it is possible to obtain even realistic models in a full scale.
- *Virtual – Physical transformation tools* – This group includes tools which make the transformation from virtual forms or objects to 3D physical models and vice-versa. The CAM – Computer Aided Manufacturing systems are considered to be important elements in this category as well as 3D scanners.
- *Integrated tools* – this group includes an integration of different tools which are mentioned above. It can be different combinations like form generation tools integrated with scientific-mathematical tools, case studies and precedents tools integrated with visual presentation - communication tools and other possibilities.

The current environments

The overview of the different TSMT tools, which were introduced in the above typology, shows that, indeed, there is relatively a great diversity of TSMT tools, a high level and advanced development and a significant potential. But there are still different problems from the point of view of construction teaching:

In the current situation there is relatively a low level of utilization of TSMT in construction teaching, especially in the design studio. Most of the work of the design process is still made according to the traditional way. This situation is mainly an outcome of two factors: the technology factor and the human factor.

From the technology factor point of view, many of the tools are not yet friendly enough, especially in the design studio. Many of them are not conceptual enough and they are more detailed-oriented (time consumers). As an outcome in many cases most of the evaluation work in the design process, including the construction evaluation, is usually made on detailed and final models rather then on conceptual and initial models. That leads to a process which can be called "one cycle evaluation" at the final-detailed stage. In addition to that, there is not enough "lateral" connection and technological integration between the different kinds of tools in construction teaching and thus there are less integrated tools which would allow a dialogue between different methods and techniques.

From the human factor point of view, in many cases, especially in the design studio, there is not enough awareness of the different existing possibilities. Usually, each expert or student uses his specific favorite tool and in general there is a lack of an integrative and interdisciplinary approach. The tools are not being used as optional-flexible tools in the design process and as an outcome of specific circumstances and context. In addition, in many cases the TSMT tools are not used enough as generative tools, in the synthesis phase of the design, and they are more used for analysis.

A vision for the future – the future environments

According to the above description about the current situation there is a need to have a vision for future – general directions which can give a possible picture about the future. It is important to note that this vision is only a flexible picture and it could be changed as an outcome of various circumstances. This act of vision creation is an essential element in strategic planning. It can enrich our understanding of actions, which have to be taken in the present in the light of the future possibilities.

Looking ahead to the future, based on approaches like extrapolations, can indicate that the development of computers power will continue to be accelerated. According to Intel information (Kalay, 2004, Intel.2008) the computers power along the last nearly 40 years was all the time in a process of acceleration ("In 1965, Intel co-founder Gordon Moore saw the future. His prediction, now popularly known as Moore's Law, states that the number of transistors on a chip doubles about every two years" (Intel,2008)). Extrapolation or projection of these facts today, from the past to the future, can show that in different scenarios, including moderate scenarios, it is still possible to assume that in the future there will be a continuation of the intensification of computers power. We shall be able to see more advanced computers with more power and computational abilities. As an outcome it is assumed that there will be a continuation in the development of advanced TSMT in the different fields, including the construction field.

The continuation of the development of advanced TSMT tools will have many benefits and advantages, but there will still be a need for more integration between the different advanced tools. A better communication and coordination between these TSMT tools, as opposed to the current situation (where the development is mainly introverted and deep in each specific tool), will have many benefits. It will allow an essential "lateral dialogue" between the different tools through all the design process - from the early stages until the most detailed ones. For example, form generation tools will be connected directly to scientific-mathematical tools and it will be possible to analyze the implications of specific suggested forms in the light of different aspects like: movement, structure, climate, lighting, acoustics etc.

In this situation the design process, which has to relate to different aspects, including the construction aspect, will be a Multi- TSMT Design. With the integration of the different tools it will be possible to use, in a flexible way, different advanced TSMT tools in parallel, during the design process, as an outcome of specific needs and circumstances.

But in addition to that, the use of advanced TSMT tools will have to show not only a diversity of different tools, connected and well coordinated between them, but also a diversity along the design process. The TSMT tools will have to appear in a flexible way in each phase of the design process – analysis, synthesis, evaluation and final design - with possibilities to have feedbacks and loops in a cyclic way – connected to manufacturing at the end.

In these circumstances, the TSMT tools will have to be also friendlier in relation to the current situation - easy to operate and less time consuming. This is especially important for the initial phase of the design. In this stage the TSMT tools will have to be based mainly on conceptual principles rather then on detailed ones. This fact can allow fast reasoning about the initial design, to consume less time and to scan different possibilities in a relatively short time. The TSMT tools for later-detailed stages will have to be more accurate and precise. This way it will be possible to have two main cycles in the design process, using different TSMT tools according to the specific stage in the design process: for the first stage - conceptual TSMT tools and for the later stage including the final stage - more detailed TSMT tools. After having the final design, the CAM – computer aided manufacturing - tools will be an integral part of the TSMT tools.

These TSMT tools will be an integral part of construction teaching. They will mainly take place and be integrated in the design studio, where the main fusion of the construction aspects has to occur, but in parallel they will also take place in other teaching activities - in different and specific construction courses. The construction teaching in the design studio will have to be an integral part of the overall supervision process, using the advanced TSMT tools amongst other tools. Naturally, many of the TSMT tools in this process will be computer-supported tools, using digital resources.

It is important to note that in spite of the advantages of these computerized tools, the traditional supervision will still have many benefits and thus, the whole supervision process in the design studio will include the traditional and the computer-supported supervision.

The computer-supported supervision will include the internet resources but also independent computer resources – private digital resources of individual or groups, not necessarily connected to the web. In this kind of teaching part of the digital resources can be used in a real time - in an interactive dialogue between the supervisor and the student (a computer-supported supervision in addition to the traditional way of supervision). An example for this kind of supervision using the internet and other digital resources during supervision can be found in Mosseri, 2005.

The whole design process, including the construction aspects can be called a multi TSMT design – using advanced TSMT tools in the design process in a flexible way in each one of the design stages in addition to the traditional supervision.

Summary and future directions

The use of advanced TSMT tools, mainly computerized tools, in the future has a great potential to enrich the design process and the construction teaching. It seems that the technology factor will probably continue to ensure the development of advanced computers and as an outcome advanced TSMT tools. In general these tools will have to be more integrated and well coordinated but also more conceptual to allow two main cycles in the design process - strategic versus detailed.

But in spite of the possible positive-successful vision about the technological factor there is still a question about the human factor which will have to be an integral part of the vision – shall we be able to overcome the human factor? Shall we have polymath and interdisciplinary personalities who will be able to use all the advantages of the advanced TSMT technology?

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Marios C. Phocas
Aimilios Michael

Program of Architecture
Faculty of Engineering
University of Cyprus
Cyprus

Construction Design through the (Micro-) Studio

Architectural Design

Based on the modern interpretation of architectural education at University level, architectural design is developed within the multidisciplinary nature of the area, at various levels of analysis, at all scales of the project. In this frame the present paper underlines the necessity of integrating technology courses with design, and in clarifying this, the respective pedagogical approach, followed at the Program of Architecture at the University of Cyprus, is presented.

It is self-evident that architectural education is related to a wide disciplinary field. It extends between the arts and sciences, while it interrelates with other specialized disciplines, governed by aesthetic, technological, social, cultural, economic and political issues. Architectural designs are often a reflection of the respective development methodology applied, in most cases following a specific morphological direction in the creation process. The main question in respect to the present subject of interest is whether architecture is driven in its development by the process of construction design or whether construction serves the initial architectural concept. The interdisciplinary character of the design process requires mature and balanced knowledge from the areas of design per se, theory and construction, as well as relevant horizontal relations, the collection of information and the coordination of qualified expert contributions. The basis for such an understanding applies to the profession.

As regards the building technology component within the architectural education – Structures, Construction, Environmental Design –, the application of the respective technical knowledge, obtained through lectures and exercises, in a design project is of major importance. In this context of development, of central significance is the concordance of construction, function and form in architecture. The design project may be organized within a micro-studio or within the main studio of a respective semester. In the first case the studio work becomes the major assignment of one or more joint technology courses, while in the second case a holistic approach of design is practiced. Necessary component for a successful integrated design is the iterative realization of an architectural aim, the design vision that binds every element of the design of different scales together. In this way and at the same time, construction design substitutes the merely more empirical act of "architectural design" throughout the integration process.

The establishment of a new Academic Program

The establishment of the Program of Architecture at the University of Cyprus, initiated in September 2005, takes place within the European wide ongoing restructure into distinct cycles of studies according to the Bologna process. Especially, as regards the Bachelor degree decisive criteria are those related to the interdisciplinary character of the studies and the profession, the cultivation and advancement of the design abilities of the students, as well as the social responsibility on different planning levels. In particular for the case of Cyprus, the professional practice and perspectives are reviewed on the basis of social changes on national and European level, ranging from the globalization of the economy, modifications in the social structure, to the increasing environmental responsibility. These requirements favour a solid and wide knowledge of the fundamentals during the initial years of a core program of studies and a related integrative and internally interdisciplinary character of the educational contents. The program of studies embodies four basic areas of study as regards both theory and design courses: Architectural theory and history, architectural communication media, architectural technology and urban design. The first three years of study comprise the core of the architectural education, whereas all courses are compulsory. Beyond this stage the students may select specific courses of interest and the instructors for their design projects.

The methodology in teaching technology is directly related to the courses per se that comprise the subject area, their sequence within the curriculum and their interrelation and role in terms of architectural design. Two introductory courses of the initial year of studies on Structures are followed in the subsequent three semesters by courses on Construction I-III – Timber, reinforced concrete and lightweight-steel buildings. The second course on Construction is offered in parallel to a respective course on reinforced concrete (r/c) Structures. Both courses are taught independently in the first third of the semester, ending up with an integrated design assignment in a micro-studio. Construction III and a course on Technical Services in the fifth semester prepare the students with lectures, exercises and design assignments in the micro-studios for the integrated design, which constitutes the main studio work of the sixth semester. At this stage of the studies, a parallel course to the integrated design studio, on Building Technology, emphasizes the methodology of interdisciplinary design, especially on aspects arising from the entire area of technology.

Within the respective courses, the integrated design approach followed, results from the integrative architectural development of the building's form and functions, construction elements and energy efficiency. In this context the structural building design plays a most fundamental role and influences the subsequent interactive development in detail of all elements that result from the three main areas of the structure, the construction and the technical systems. The schedule of development of the applied design methodology is based on a strict organizational plan, consisting of the preliminary design as regards the functional areas, the structure and the building skin, the development of a selected alternative up to large scale, in its architectural, structural, construction and energy efficiency sections, and general design reviews, based on large scale models and computer simulations.

Timber Construction

The course "Construction I", the first in the series of three courses on Construction, aims at introducing the students to the area of building tectonics. The syllabus concentrates in the clarification of the characteristics of different structural systems in timber and the analysis of building envelopes, as regards form, structure, construction design of the load bearing and non load bearing elements and the development of working drawings.

In addition to lectures that provide a wide spectrum of respective fundamental technical knowledge, the course includes a micro-studio assignment of architectural and construction design. The design requirement remains consciously simple for enabling an understanding of the basic principles of the structural systems and the particularities of the design of timber, skeleton structures, mainly as regards the requirements for the systems stiffness and appropriate construction connections. The entire design process is based on the integration of structure and construction, with the aim to boost the approach of integrated architectural design.

In the fall semester 2006/07 a timber structure was required to have a volume of about 100 m^2 with a closed space of about 10 m^2 (Fig. 1-4). The students in groups of five proposed an action scenario for the set up of the brief by defining geographic position, plot, building size, function and sequence of erection of the structure. Other issues as for example topography, fauna, climate and years period of functionality were also taken into consideration throughout the design development.

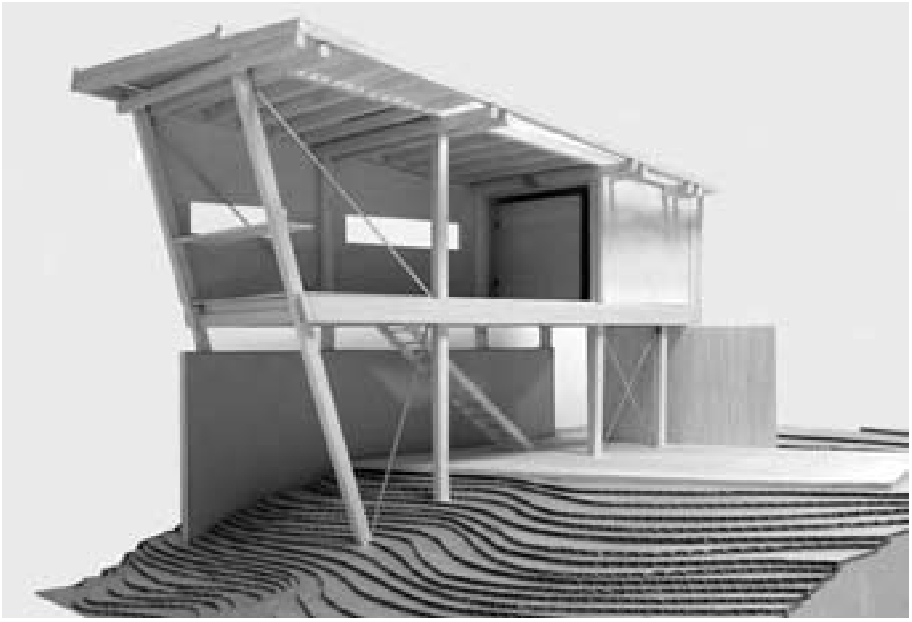

Fig. 1
Large scale construction model of a painters atelier – design project for Construction I

Massive Structures and Construction

The course "Construction II" refers to the construction design of reinforced concrete buildings. The syllabus consists of lectures in the respective area, accompanied at the initial phase of the course with a theoretical exercise for an existing building analysis that is to be conducted by the students. In addition, a micro-studio of architectural and construction design is realized, so that the students can apply the technical knowledge acquired through the lectures and study in-depth the structure and construction of the building design.

The design of a building with specific functional program aims at the study of the syntax of construction design in reinforced concrete through the analysis of the structural systems, the development of the load bearing elements and the building envelope, and the design of appropriate construction details. In collaboration with the course on Reinforced Concrete Structures the analysis and dimensioning of the

Fig. 2
Building structure

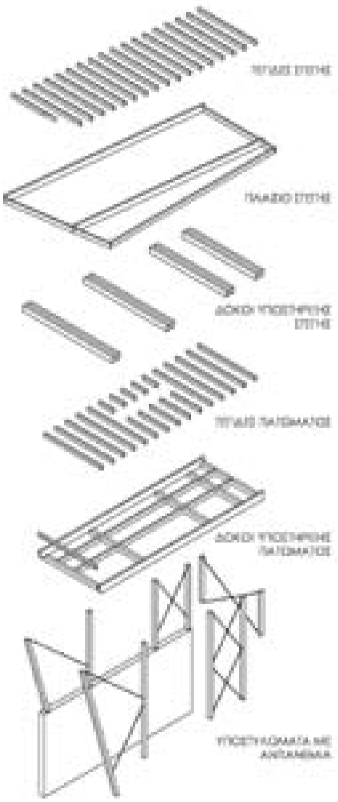

Fig. 3
Structural elements

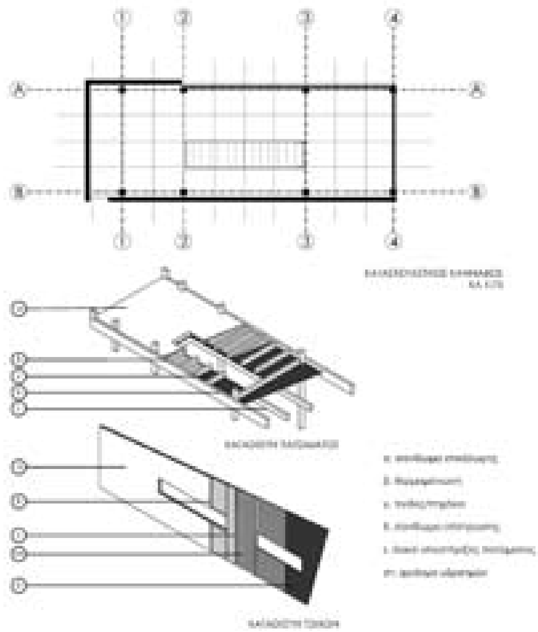

Fig. 4
Construction elements

proposed load bearing structure is effected. The process of integrated architectural design brings the students closer to the real terms of development and realization of the architectural concepts.

In the spring semester 2006/07 the design assignment required a residential and office building for a young architect, with an area of about 110-140 m^2 (Figures 5-8). The given plot had a specific geomorphology and orientation. The functional areas of the building consisted of a living space with kitchen, bathroom, sleeping space, library, and a design studio with conference space.

Although in its current form the syllabus of the individual courses in the course of study states that the architectural design in the fourth semester is combined with the two technology courses assignment of the same semester – Construction II and r/c Structures – this was not practiced in the first time of its realization in 2007. The main reason for this lied in the linear development approach that was to be followed in the main design studio. By having combined all three design assignments in one, the structural and construction design might have taken place within a compact phase prior to the final studio juries. The experience gained up to now by the authors suggest that unless the main architectural design allows for interdisciplinary development from the initial phase, the individual technology courses are difficult to be effectively linked with their final assignments to the main studio work. Otherwise, the students experience inherently that technology is there, just to support any initial architectural concept developed on another ground.

Lightweight – Steel Construction

The course "Construction III" refers to the construction design of lightweight-steel buildings. The educational aims serve at first place the provision of technical knowledge through a series of lectures on the typology of steel buildings, the structures and the building envelopes. Horizontal component comprises the design of a building under functional requirements in a micro-studio, with primary aim the consistent gradation of the design scale, from the capture of the architectural concept up to the construction detail in 1:1.

Representative projects for the micro-studio design assignment may comprise buildings based on the industrialization and standardization of the construction elements, or with large structural spans and minimized mass. In the fall semester 2007/08, the design of a temporary building unit serving as exhibition premises of the University of Cyprus was required, with a total area of 260 m^2, including 200 m^2 of the main exhibition area (Fig. 9-12). The design proposal referred to an integrated functional unit that would be composed of element parts of the steel structure and envelope. The construction design of the elements and connections needed to favor the possibility of erection and reuse of the building at another site. The development of an adaptable steel structure aimed at the achievement of minimized self weight and adequate static behavior in connection to the remaining design parameters and the morphology of the building. The building façade in combination with a preliminary energy concept were expected to secure visual transparency based on the proposed functionality of the spaces and comfort of the users in the interior of the building.

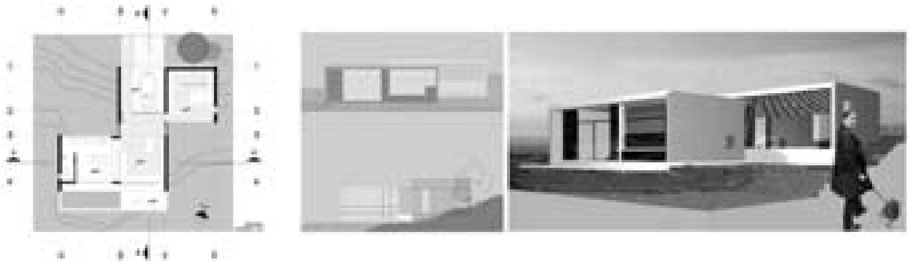

Fig. 5

Preliminary architectural design, design project for Construction II

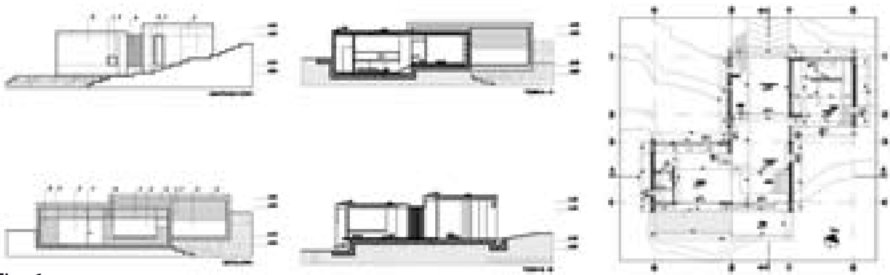

Fig. 6

Development of architectural design

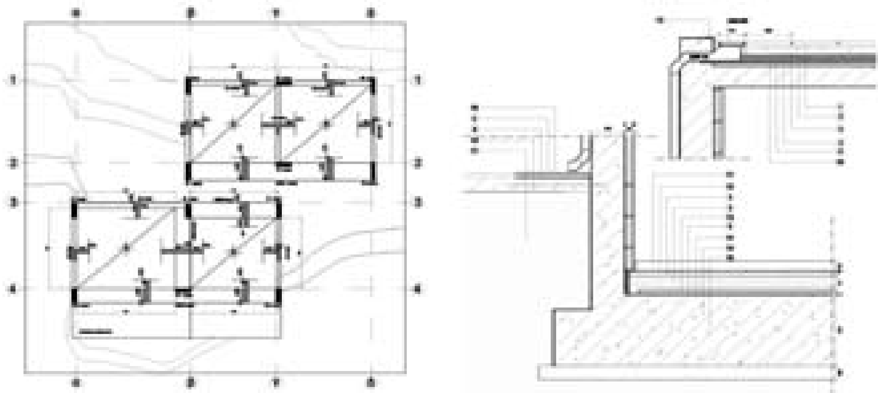

Fig. 7

Structural and construction design

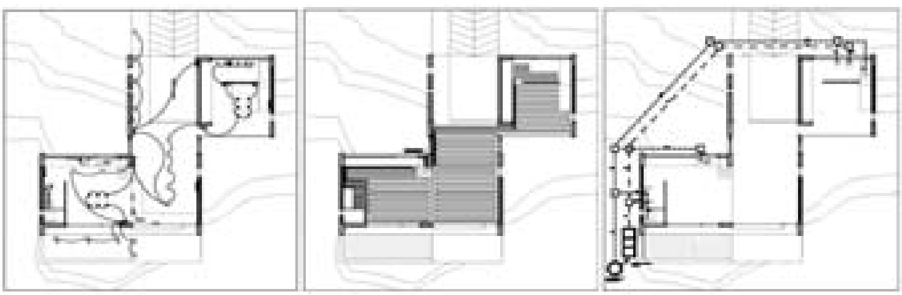

Fig. 8

Technical systems design

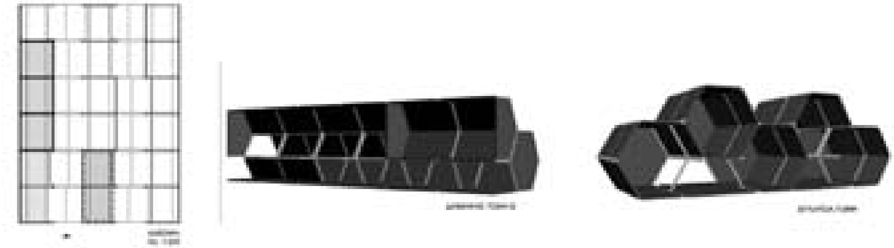

Fig. 9

Preliminary architectural design, design project for Construction III

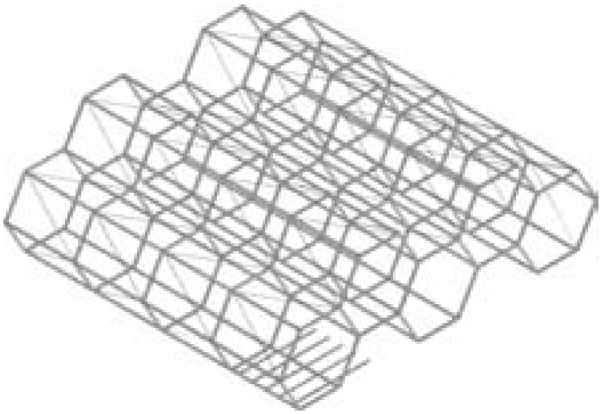

Fig. 10

Building structure

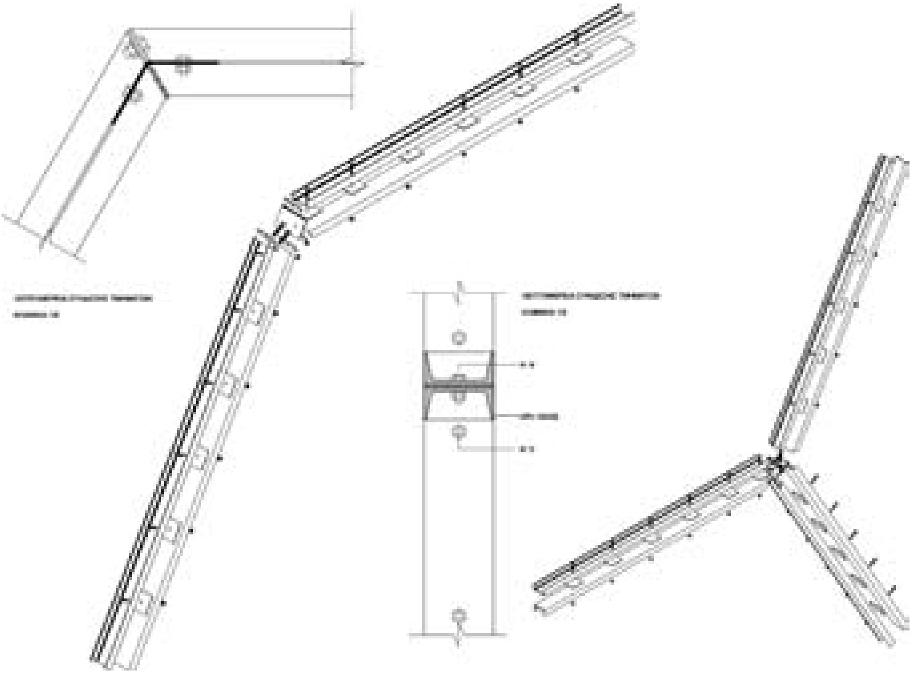

Fig. 11

Building structure design

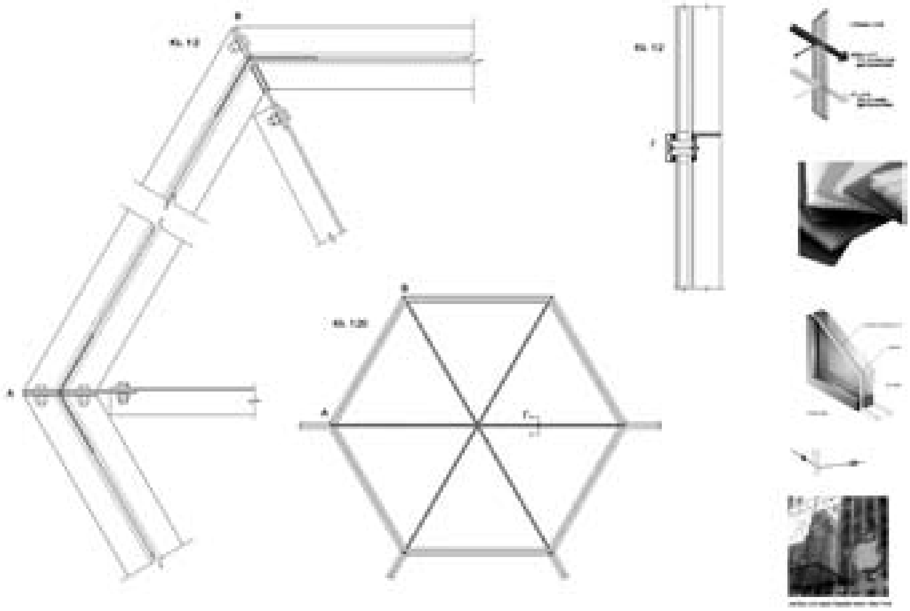

Fig. 12
Building envelope design

Conclusions

The present paper examines the building technology component as part of the architectural education at University level, especially its interrelation with the architectural design. Based on the pedagogical requirements set, such as the best possible integration of technology courses within the architectural curriculum and the practice of basic principles of architectural design through a holistic, interdisciplinary approach, the authors propose the interconnection of individual courses of technology through development of joint micro-studio design assignments, and the development of a main technology driven studio design in the core program of studies. Three case studies of micro-studio coursework on Construction at the University of Cyprus are presented herein for clarifying the aim of teaching and applying the syntax of construction design in the frame of architectural design.

Jerzy Gorski

Faculty of Architecture
Warsaw University of Technology
Poland

Emerging Possibilities of Testing and Simulation Methods and Techniques in Contemporary Construction Teaching

The statement from the workshop's introduction, that *designers no longer "create form" but "find form from an infinite spectrum",* shows actual tendencies though both approaches – creating and finding – are still present in the professional and educational area and both have risks. The case of 'creating' is internalized and separating. One uses only one's actual knowledge and instinct and the result is adequate to author's quality (works are sometimes simplified or naive though usually consistent).

'Finding' is externalized. Students, with their extensive ability of using digital sources of information, examine a wide spectrum of technical and formal possibilities. In many cases students use this information accidentally without a deep understanding of basic principles. Such an approach often has a negative impact on design. Students are more concerned with using the computers effectively rather than designing an effective building. In such use of digital techniques attention to "materials and testing" is seldom part of the process of 'finding'. To improve this situation students simultaneously should be taught the basic knowledge of constructional, structural and physical principles and the ability to use digital possibilities not only for final representation but for entire design process taking into consideration all it's interactive elements – formal and technical. The ability to use the two elements, theoretical and virtual, should prepare them to act professionally within a flexible and changing reality. Private and school digital infrastructures allow students to exercise fully modern possibilities though the effects of their activity will depend on understanding of principles as mentioned above.

My observations of didactic problems in our school show that the incorporation of rational knowledge obtained in various lectures and exercises of technical subjects are not fully or only intuitively used in developing architectural design. Partly this is caused by a traditional didactic structure when several subjects are taught as separate units and without the close cooperation between specialties (as happens in normal professional practice). Collaboration occurs very seldom in school. Of course we may expect that these fractured pieces of knowledge and experience should be united in students' minds but without help and guidance it is quite difficult for them.

Our curriculum is divided into the following areas:

- Architectural and Urban Design,
- Structures, Construction, Services, Economics,
- History and Art,
- Elective lectures and seminars.

In the Architectural Design area, the objectives of the preliminary design are more abstract with the aim of developing students' imagination. The objectives of the design of the upper years are based on set functional programs for specified types of buildings. Students must fulfil this program and, depending on view and experience of the teacher, the design is more or less realistic. In some cases the objectives of the design are so specific that rationalistic analysis would raise the quality of the design. In many cases such opportunity does not occur.

I will try to illustrate this problem by showing an example of a "passive house " design prepared by a group of students in one of the architectural design studios. The subject is "trendy" so students were very excited. They studied examples of such buildings, learned very basic principles like using "very thick thermal insulation" and "large glazing from the south", but they treated this information as sort of intuitive trick. Also, technical aims such the energy requirement of 0,7 to 15 kW/m^2/a was an abstract symbol never checked by calculation. Construction solutions were often not satisfactory. On the other hand fulfilling of basic principles of a "passive house" also caused problems with proper functional arrangement of single family house. Nevertheless introducing the students to contemporary and future problems of architecture is very positive even though their concept designs resulted in only intuitive attempts. Students became aware of current aims and possibilities and hopefully will develop their practical ability later. But in this case the opportunity of conducting a multidisciplinary exercise was lost due to the lack of coordination between school units each teaching a particular subjects.

In the Building Physics course, for example, students used specialized software to determine the energy efficiency of building elements. Such tests are used also for "passive house" concept but remained as only theoretical exercises within this course. The knowledge and ability of technical calculations were not transferred to the students' design projects. Also, in the Structure course the students prepared calculations of building elements using digital programs but often the conclusions drawn from these experiences were not transferred to architectural concept, e.g. proportions of structural members – height depending on span.

Most of teachers are aware of need of multidisciplinary cooperation and we tried to organise architectural design studios with regular attendance by consultants from other fields but the results have not been fully satisfactory. Partly this is due to the way the architectural concept is developed during the studio - functional layout and abstract building form are the focus. It is very difficult to introduce the consultants' suggestions at the preliminary stage of concept development. By the end of term it is too late to correct architectural ideas and forms after (theoretically compulsory) structural and construction intervention. Another reason which makes cooperation difficult is the administrative organisation connected with evaluation methods and teachers' workload.

Nevertheless the general outlook shows that a digital simulation in various ways and fields of architectural education is developing fast and hopefully it will be used in the way more closely resembling the real, professional way of designing – this means working in professional multidisciplinary teams.

Parallel to the digital area, experience with the physical and material elements should be also emphasized. No digital presentation replaces fully the physical contact with real materials and the testing of their properties. It helps to examine the nature of things – to understand the basic and invariable principles and on the other hand the causes and effects of technological progress. The scale of such studies differs depending on economic resources of the school. Exercises executed in the "Grand Atelier" of l'Isle d'Abeau are beyond our possibilities nevertheless we do our best. Practical exercises in combination with views of various scientific fields should cause students' awareness of historical evolution of technologies and understanding of their internal substance. This substance derives from long-time experience of logical use of materials connected with their natural properties, local climate and functional needs. From that originated the architectural forms typical for certain geographic areas. Such awareness should foster a proper understanding of the properties of new materials and technologies and discourage the automatic imitation of forms and construc-

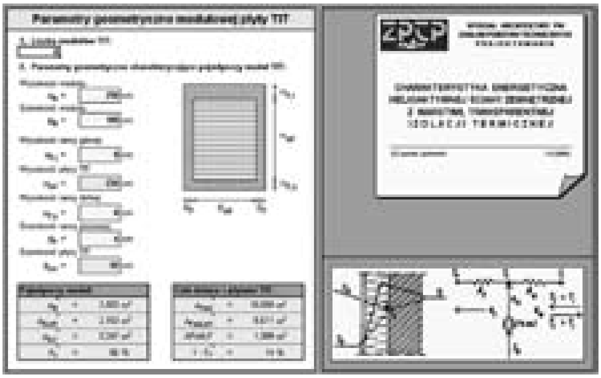

Fig. 1

Example of calculation sheets used by students at the Building Physics course to determine the energy characteristic of helioactive external wall with layers of transparent insulation

Fig. 2

Example of calculation sheets used by students at the Building Physics course to determine heat loss

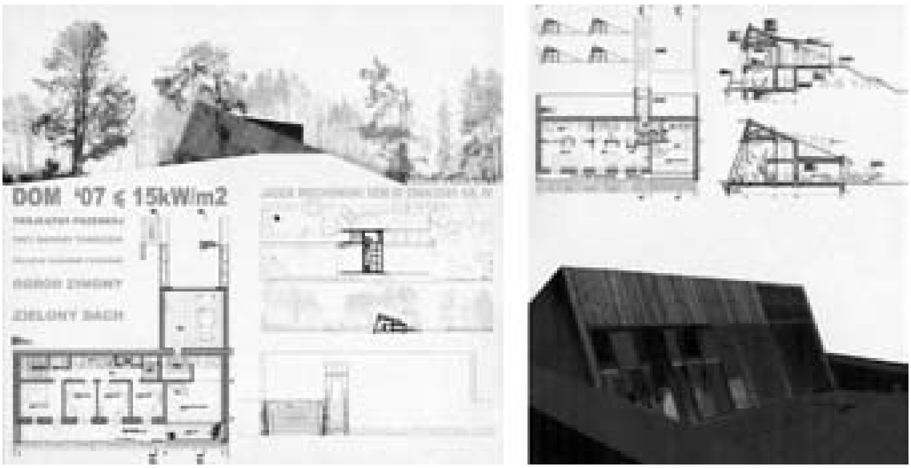

Fig. 3

Example of "Passive House" design prepared in architectural studio

Fig. 4

Physical contact with real materials – testing of the strength of laminated glass

Fig. 5

Documentation of the depth of soil layers

Fig. 6

Pressing of earthen blocks

Fig. 7

Wall of earthen pressed blocks after three years – covered

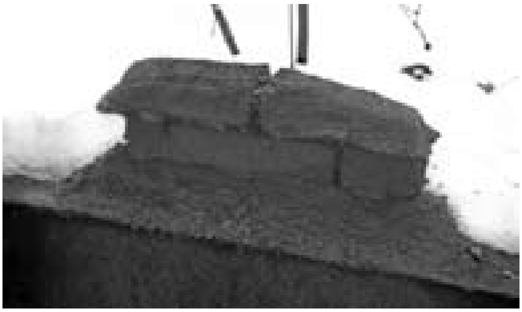

Fig. 8

Wall of earthen pressed blocks after three years – uncovered

Fig. 9

Student applies earthen plaster to reed board during a field trip

Fig. 10

Sample of rammed earth wall with surface modifications for visual effect

Fig. 11

Visualisation of experimental building to be erected with rammed earth and other earthen technologies

Fig. 12

Experimental building during construction

tion despite their inappropriateness to local climatic conditions. The example of the simulation exercises shown later is connected with checking necessary conditions for buildings constructed in earthen technologies (rammed earth, adobe bricks etc.) in northern climates. Earthen technology, typical for warm climate areas, has been also used in other places like the Alpine Highlands and various areas in our country but with specific attention to conditions.

An aspect of our didactic curriculum requires students to visit chosen building sites and produce the appropriate report. At these visits students have opportunity to observe construction processes but for safety reasons very seldom to do something physically. Real physical contact gives additional special experiences. We try to do it by presenting real samples of construction materials in the basic course. A better result is achieved in elective courses where a smaller number of students may gather necessary materials for conducting practical exercises. Prof. Teresa Kelm, from Contemporary Architecture Dept. and in co-operation with Construction Dept., has taught an elective seminar examining issues in *ecological architecture* for some years. She maintains contacts with scientific centres in various countries such USA, Germany and especially with CraTERRE in Grenoble (additional information at her website – www.geocities.com/ziemna). As a part of this seminar workshops in *earthen technologies* were organized. From Belgium we received a hand operated press for making earthen structural blocks. Students were exposed to all stages of block production from digging earth to making walls. One of the reasons for using earthen technologies is the reduction of fuel consumed in production and transportation, since building materials are taken usually from excavations at the site. This is one of the steps towards developing solutions aiming at sustainability. Earth suitable for construction elements must have proper composition of various parts such as clay, sand, loam. Earth from various sites has to be analysed and then properly adjusted. Samples are taken from different places and from different depths under humus soil layer and then analysed using several methods (sedimentation, organoleptic etc.). Earth should be sieved to exclude too big and hard pieces, then adjusted to contain components in proper proportions. An adequate amount of water is added to achieve rather dry mixture whose consistency can be checked scientifically but also by traditional, practical methods – such as throwing a hand-pressed earthen ball against a hard surface and observing it's breakup. Blocks are compressed in the press and put aside for drying for some weeks under special care – drying should be steady and slow. The mechanical and physical properties of blocks produced by students at the workshops were checked in laboratories and by constructing small walls at the school yard for observation. As expected, natural earth materials have to be protected from rain water and ground moisture. Outside walls proved the theoretical assumptions: the covered wall can sustain severe conditions (one of them has already lasted six years); the uncovered one disintegrated after three years. The surface of covered wall was also in good condition which means that damp air can be absorbed for some time but it dries out quickly when weather permits. This property has positive impact for internal climate of rooms when earthen elements and earthen plaster is used.

Seminars were supplemented by field trips to places where clay and straw blocks are manufactured (produced for the firm Claytec). Although not structural, these elements are used to infill frame structures and have thermal insulation properties similar to aerated concrete but are produced from natural materials without energy consuming industrial methods. Students had the opportunity to observe the manufacturing process and also to try to do it by themselves. Other technologies of this type like straw bales mineralised with clay and earthen plaster on panels of reeds, were also demonstrated.

As the result of these proecological activities our school, with financial help of the Ministry of Education, the co-operation of Paslek, a town in the north of Poland and a local earthen blocks manufacturer had the opportunity to build a small but real building with walls constructed of rammed earth and other natural elements. The students who participated in this exercise learned about applying traditional tectonics to contemporary needs. When completed the building will serve as an information center in the ecological park at Paslek. The design passed all normal procedures necessary to obtain building permission and in 2007 construction started. All requirements for such construction were met - a base constructed with stone raised to min. 50 cm above the ground to avoid splashing, a roof with wide eaves to protect the walls from rain. From the south a glazed veranda will be erected with a rammed earth wall and a stone floor inside as passive solar elements. The building has an experimental character and some innovations were introduced in view of further testing. A structural layer of 40 cm wide rammed earth wall is situated outside with insulation layers of cellulose fiber and lime and straw blocks put inside (opposite to construction used usually in our climate where thermal insulation is outside structural layer). We wanted to expose the surface of the earthen wall to external conditions and observe its ageing. Another reason was to present a characteristic surface structure as a sort of advertisement of this natural technology. Exposed surface earthen technology is also shown in contemporary works like the Chapel of Reconciliation at Bernauer Strasse in Berlin, designed by architects Reitermann & Sassenroth, and Brother Claus Field Chapel in Switzerland, designed by Peter Zumthor.

Herman Neuckermans
Stefan Boeykens
Frank De Troyer
Benjamin Geebelen

Department of Architecture
K.U. Leuven
Belgium

Integrated Testing and BIM

Problem Statement

The most important design decisions are taken in the early stage of design and thus merits most of our attention and research efforts. However a computerized system which provides the right information to an architect at the right time while designing, which is part of his designerly way of thinking[1], still is missing today. Is it utopian or just not feasible to build such a system? Closest to this ambition was the idea to create an integrated design environment[2]. One of these was initiated at the *Design & Building Methodology research* group at the K.U.Leuven (Belgium) in the beginning of the 90-ies[3]. Design methodology has learned that there is not a single design method for architects, but rather a collection of approaches. After studying the design activity of many architects, a conceptual model was elaborated, which has the ambition to cope with a considerable subset of design approaches and at the same time remaining open enough not to trap in the pitfall of software for closed building systems.

This article describes the reasoning behind this conceptual design model and how it proposes to enhance Building Information Modeling, through the integration of evaluation tests into a design environment.

Conceptual Model for Architectural Design

This conceptual system is conceived as an open system allowing the architect to enter the design upon choice on one of three scale levels, being the master plan, block and space (Illustration 1). That implies that an architect can start a design from bottom-up, extending a design from individual building elements or—as it is mostly the case—from the top-down, gradually refining a design from a global idea of its volume or shape. The conceptual model structures most of the entities an architect is working with. These are organized in a hierarchical structure, according to the scale levels. Entities are positioned on grids and are supported by appropriate evaluation tests. The mutation of a sketch design (SD) into a preliminary design (PD) and later on into working drawings (WD) is part of the system.

Digital Building Model

A prerequisite to derive qualitative and quantitative information about a design is the availability of the design into a digital building model. Starting from the conceptual model, this system has been translated in a *core object model*[4], where a custom digital building structure was described. Recently, the crucial steps in that model have been implemented in prototype software, which allows the modeling of a structured digital building, providing not only common building elements but also conceptual design entities, such as spaces (Illustration 2). Currently, the system is limited to a fairly simple geometry[5]. Within this research, the twofold evolution of a design in a normal design process was elaborated. Architectural designs evolve from sketch design to a preliminary design and finally to working drawings. Additionally, architectural designs cover large scale projects which require a masterplan as well as small scale projects like a single room design; in many cases the latter fits in the former.

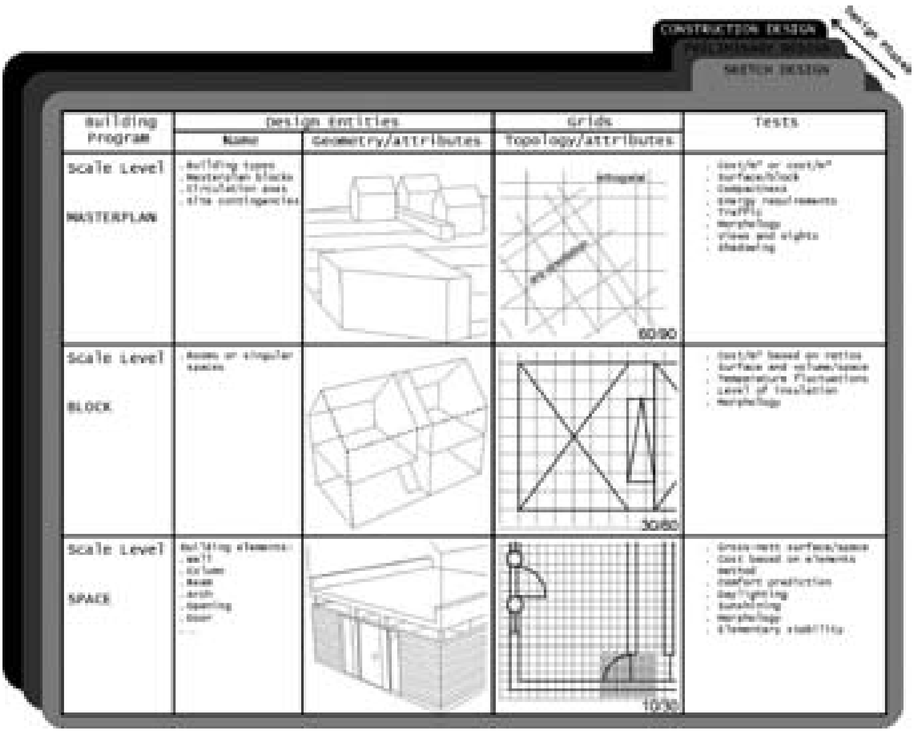

Illustration 1
Conceptual Model for Architectural Design

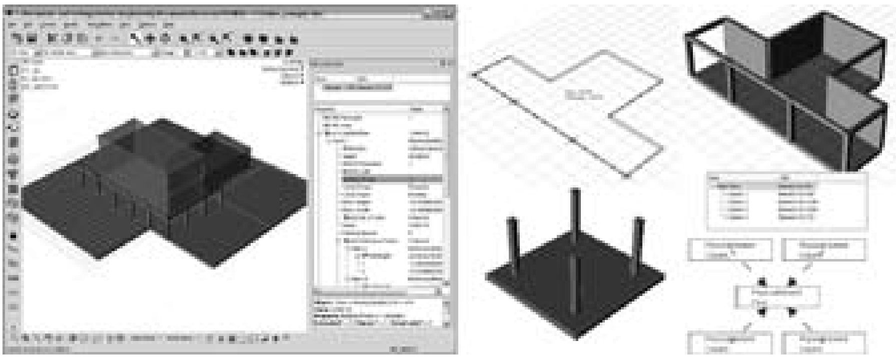

Illustration 2
IDEA+ Prototype

Building Information Modeling

Building Information Modeling (BIM) is a methodology to translate a building into a digital model, offering a consistent representation of the building to all partners in the design team (Illustration 3). Instead of creating plans, sections or elevations, drawings are derived from a single building database. Additionally, quantitative information can be extracted from the building database for evaluation and simulation tests.

Codification of building elements and materials plays an important role in BIM. While modeling a part of the building, classification codes, such as CI/SfB (or the Dutch-French version BB/SfB)[6], can be generated or added in order to facilitate the generation of specifications and bills of quantities.

Currently, different companies have implemented this methodology into their BIM software, with varying completeness and widely differing functionality. However, most of their solutions are clearly focused on the construction and documentation phase, after major design decisions have been taken. The potential for BIM to enhance the design elaboration phase is currently underdeveloped.

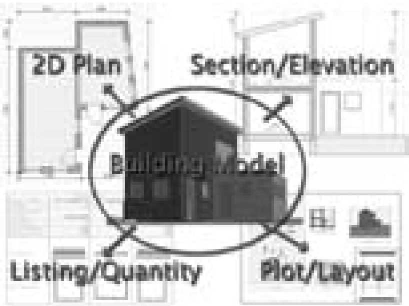

Illustration 3
Building Information Modeling

Physical versus Virtual Engineering

Evaluation and simulation tests have evolved from their initial physical form into mostly digital-only formats, leading to *Virtual Engineering*. A few examples are explained in this section.

Visual simulation (Illustration 4) initially required elaborate physical models and was supported by sophisticated and expensive equipment, such as the TU/Delft *endoscope*. Similarly, a heliodon system provided an approach to simulate insulation and shadowing.

However, advancements in computer graphics have enabled digital walkthroughs and visualization with very convincing results (Illustration 5). The determination of *insolation, shade and shadow patterns*, insolation duration and coupled energy gains/benefits for whatever place on earth at whatever date and hour, is much more than what could be obtained with physical systems.

As far as *daylighting* is concerned, software is bringing the daylight room in the office. It provides daylighting levels as well as *isoluxlines*, and a rendering of light. The in-

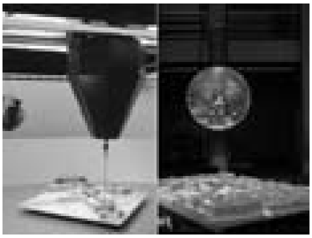

Illustration 4
endoscope & heliodon

Illustration 5
digital reconstruction using visualization software

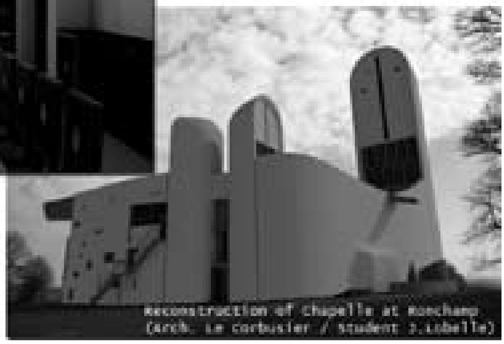

Illustration 6
daylight room

Illustration 7
isoluxlines

tegrated computation of daylight and energy balance surpasses the physical daylight room (Illustration 6). An example of isoluxlines is displayed in Illustration 7[7].

The simulation of *room acoustical qualities* can be performed in software[8]. Till recently the prediction of room acoustical qualities required large scale physical models in order to be able to measure the impulse-response. Today reverberation time, distribution of loudness and speech intelligibility are tested and predicted with software allowing for iterative testing and refinement of the design solution by adapting the software model. The results of these simulations are no longer bare seconds and decibels, they are shown in graphics and they even can be heard acoustically via auralization (Illustration 8).

Energy computation used to be done in the post-design phase, limited to and resulting in the dimensioning of the heating and cooling system. Today thermal performances, such as the global level of insulation and the maximum U-value of elements belonging to the building envelope, are imposed by law. Software is available to compute surface temperatures, the risk for surface or internal condensation under stationary and non-stationary condition as soon as the composition of the building envelope is known[9] (Illustration 9).

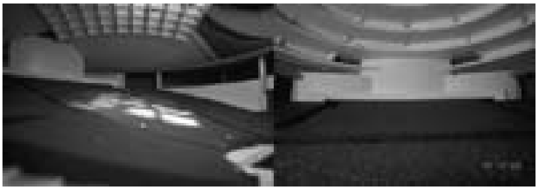

Illustration 8
aula maxima, K.U.Leuven

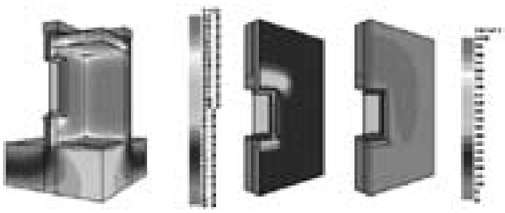

Illustration 9
3D temperatures & energy flowin W/m^2

Towards Integrated testing and BIM

Virtual Simulation and testing can be bolted on the digital building model as described in the BIM methodology. The integration of these testing methods within the design context, however, is rarely obtained. The current approach usually consists of making minor design alterations, such as material choices and dimension adjustments, based on "post-design evaluation methods". Even though these methods definitely provide benefits, they still fail to fundamentally inform the design in an early stage.

Testing, appraisal and evaluation require the development of computational methods capable of coping with an incomplete model description, as is typical in the early stages of design.

If we take *daylighting* as an example, we can distinguish between two major groups of computation methods: simple, manual methods - tables, diagrams, protractors - and advanced simulation software. In its current form the latter are not suited for early design stages, as the input entails the painstaking gathering of data, most of which is not yet available, and operating the software requires a large amount of expert knowledge. The former, however, offer very low accuracy and their use, though very simple, is still rather laborious. In line with these two groups, one can come up with two new kinds of tools, tailored to the early design phases: software versions of the manual methods and user-friendly front-ends to the advanced simulation tools. A third approach that has not yet been explored is to develop completely new tools that are based upon the same algorithms as the simulation packages but use fine-tuned versions of those algorithms to fit the needs and wishes of early design phases. This approach would combine current computation power with any desired level of user friendliness and accuracy[10,11].

A second example is *the calculation of the cost of a building*. On the level of a masterplan, this can be based upon statistic m^2 or m^3 ratings, while the detailed bill of quantities is applied during the construction phase. However, it would also make sense to apply the *element method* throughout the different scale levels[12]. As illustrated in the following table, the element method derives costing from ratios expressing quantities according to floor areas. These ratios can be derived from previous similar projects as default value in the early design stages, but can be corrected from the first masterplan sketches on. At the end of the design process, they can even be based on a detailed quantification. In the same line one can start with default budgets for unit rates for elements and gradually adapt budgets when more accurate information becomes available.

Total floor area = TFA

BB/SfB	Element	Unit Price	Unit	Ratio (units/TFA)	Price/TFA	Total Price
(13)	Floor on ground	p1	m2	r1	p1 x r1	p1 x r1 x S
(16)	Strip Foundation	p2	m1	r2	p2 x r2	p2 x r2 x S
(21)++	Ext. Wall (+ openings)	p3	m2	r3	p3 x r3	p3 x r3 x S
…						
TOTAL COST					**SUM / TFA**	**SUM**

The problematic gap between virtual testing and design elaboration can also be found at the construction stage. *Construction Information Modeling*, as opposed to Building Information Modeling, is currently being proposed by firms such as *Vico Software*[13]. In "Virtual Construction", building entities are not merely modeled as singular parametric entities, but as complete construction recipes, embedding all manipulations and materials, to obtain an accurate estimation of the total building cost and the construction timeline. However, as clarified in the illustration material from Vico explaining this approach, the initial BIM model as created by the architect can not be directly used for the construction model. There seems to be a fundamental problem to translate the design model into a usable construction model.

Data Sharing

As a consequence of applying digital building models and performing evaluation tests, there is a growing necessity to translate the design information between different systems. Ideally, an integrated design environment could remove this requirement, but as explained above, no such complete environment is currently available.

To stress the importance of data sharing, it is necessary to understand the conceptual difference between CAD formats and product model formats. Typical CAD formats, such as DXF or IGES, only consider geometric objects, such as drafting entities and 3D surfaces or solids. In product model formats, such as STEP and IFC, the underlying information about the entities is kept. IFC is currently accepted as the single most important standard for the exchange of building information between BIM applications, although it will only assist in getting a static snapshot of the design to be transferred from one system to another. There is limited support for the underlying design intent or the specificities of the particular design application that was applied.

Conclusion

Both architectural design and building construction would benefit from a more thorough integration of teaching and simulation methods.

Architectural design could be informed by the results of integrated tests, from an early design stage, to improve and adapt the design to different criteria. This article discussed an approach to realize a design environment adhering to the concepts of Building Information Modeling, with the integration of simulation tests.

A better understanding of how design information can be transferred and shared is required to both improve and adapt the testing methods and to ease the translation of the digital building model throughout different stages in the building lifecycle, from inception to realisation and maintenance.

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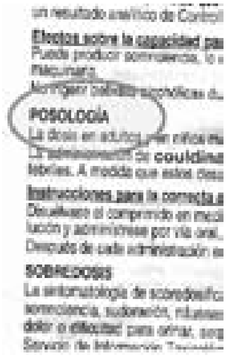
Ramon Sastre

ETS Arquitectura del Vallès
Universitat Politècnica de Catalunya
Spain

Technology Illiteracy versus High-Tech Teaching

Functional illiteracy

Some years ago, the term "functional illiterate" was coined to express the inability of many people to understand some texts. Of course they could read all the words in that text, but the terms were unknown or, what is worse, despite knowing the meaning of the words they could not grasp what the text was explaining.



One of the most clear examples of this problem could be seen when laypeople tried to read medicine texts. Posology was the word used to explain the dose they must take. But posology is not a usual term and practically nobody knew what it meant.

This is only a word. And probably not an essential word to understand the rest of the text. So, in this case, there was no real problem with this type of ignorance.

Technology illiteracy

We all know how laypeople react in from of the reference book of any device they buy, no matter if there is a camera, a video player or a simple mobile phone. They don't read it because most of them do not understand what the book is talking about.

Probably, these books don't use Greek-rooted words, but although most words are known the whole text is not understandable. What is happening then? Simply it is to complicate for what they really need. Most of the features of these devices will never be used.

So clear this problem is that some manufacturers try to sell "simple" devices or gadgets, with only a few features. This is the way that most users will feel confident in front of the gadget and they will experiment that they can govern it and not vice-versa.

It is widely accepted that young people, and students even more, are much more skilful with new technologies. They rapidly know how to manipulate computers, cameras, mobile phones, etc. So, if they are more skilful they can not be considered technologically illiterate. But is this really true? As it will be commented later on, I'm not so sure.

Sometimes it's easy to confuse skilfulness with knowledge or understanding, and we know that is not always true. And we even can confuse skilfulness with speed. Young people, children or youngsters, have not problem to try, to press keys, to open and close, to click the mouse buttons, etc. just to see what happens. Adults use to think before acting and, if they don't know what to do, they don't do anything.

Building technology illiteracy

To some extent, when our students arrive at our University Schools of Architecture they are technologically illiterate in front of all the capacities that present buildings entail: materials, techniques, behaviour, etc. They are just laypeople about this. And one of our missions is to change this fact. We will try that they learn not only vocabulary but contents.

Construction is not mathematics, or physics or any other science where all must be learned. Construction is in some way instinctive. People has constructed always, with or without architects. So when our students begin to study architecture they have (or they should have) some common knowledge about construction, just think about the Do It Yourself materials and information you can get almost anywhere.

I suppose we all agree that our teaching is something *more* than a DIY course. And this more needs time and teaching techniques to achieve the goal of the knowledge transmission. And among present teaching techniques we can not forget simulation software.

Simulation software

Unfortunately, we are not as medicine students, that can be taught with real bodies and real patients. Sometimes our students have the opportunity to visit a building site, nevertheless most of their learning is based on theoretical subjects and design. But nowadays we have a wonderful help which is simulation software. With these programs we can imagine what will happen if we design and construct a real building according to this design: resistance, earthquake behaviour, acoustics, light, thermal fluxes, etc., not to mention all 3D visualisation programs.

However, software is kind of similar to what we have written about before. Software is a gadget in the computer, and we have seen how complicated these gadgets shows can be, and how easy is just using a few features of this gadget.

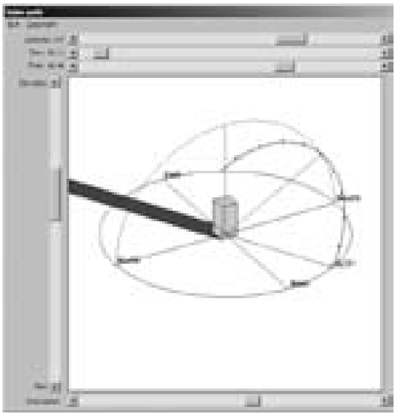
And what about our students and technological software? Do they understand all the choices this software shows? Or do they react just like laypeople: the use just what is straight and ignore what is not understood?

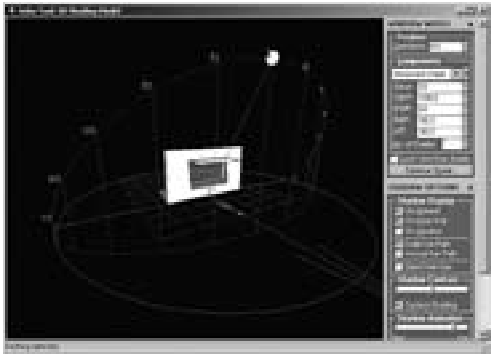
On these premises, our teaching construction must take into account that students mus be able to use and deeply understand new technologies, and this means new simulation software, new hardware and the ability to read help and instruction of both, hardware and software, and comprehend what they are reading. And to achieve this goal, we, the teachers, must be able to do that as well!

Some examples

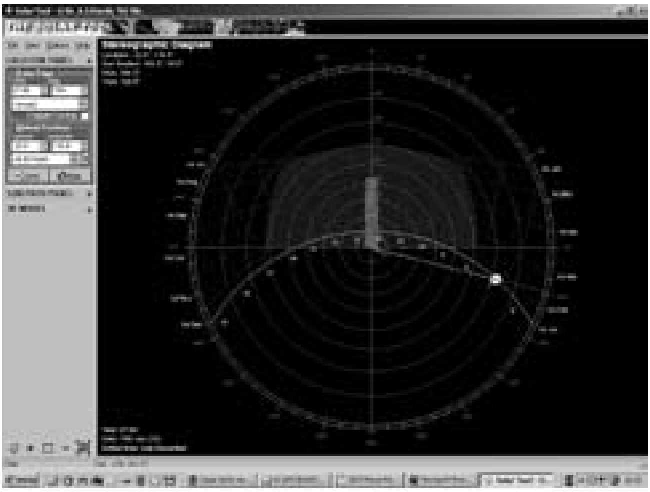
Two years ago, at this same EAAE Workshop, held in Barcelona-Vallès, I showed a very simple piece of software I had done to explain something I used to do up to then by means of several images. It was about the path the sun follows along the sky in a precise day, time and latitude: *Solar.exe*

Well, this time I want to compare this simple software with the excellent software of Square One called *SolarTool.exe*. This software has a lot of possibilities, not only showing the path of the sun in the sky, but showing the shadows a wall and a window project at any moment.

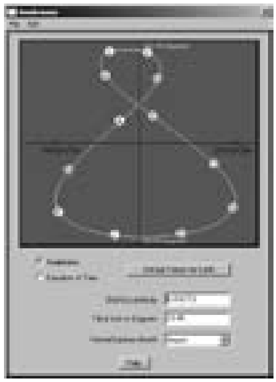




At the main screen of the program we can see a stereographic diagram of the sun path along the whole year. These paths are shown as a set of circles representing the days and a set of strange 8-shaped forms, that represent the same time along the year. In some simple programs, these forms are just straight lines. Why are they here so different?



Students and teachers, when using more complex and powerful simulation programs are confronted to much more information than when using simple tools. Knowing the meaning of Analemma is not a common situation, but it is the only way to explain the reason of these strange 8-shaped forms. Otherwise we are in the dangerous position of using a tool (simulation software) without understanding what it serves to.



Unfortunately this is, in my opinion, a common situation. Students like to use the most powerful tool they can get (through Internet or in the school laboratories). There is a feeling that if you use a better tool you will obtain a better result. And this might be true in many situations, but it's obvious that this is not true in case you don't know how to use this tool. What is better to go from Paris to Moscow, drive a car or pilot a plane? If you can fly and know how to manage a plane, it's much better, fast and probably safer to fly. But in my case I would prefer to drive. It would take much longer, it would be more tiring and boring, however I can use a car but I cannot use a plane.

Stimulation to teach and learn more

Nevertheless I don't want to transmit a negative or alarming feeling about this. I consider that using simulation software is not only positive and interesting, it's just going to be necessary! So this situation about high-tech illiteracy when using powerful software must not be negative. It must stimulate us, the teachers, to give more information and knowledge to our students so that they are able to access and use properly these new tools.

Another typical example of simple and complex software can be found in structure-design computer programs. You can find a huge variety of these programs, but you can also observe how some students are prone to get the most expensive available programs, even using not completely legal ways. They follow the common rule: the most expensive is the best.

In my own experience I've seen these strange situations:

a) students use a very simple program (WinEva) where they are asked for an elasticity modulus, E value, for every material in the structure. This is quite clear and there is no problem about entering this value. In some cases, even the program suggest these values, so they have only to accept it or not. And of course the most usual is to press the *ok* button and accept it without wondering about the convenience of the suggested value.

b) students use a very complex program (SAP2000). At the materials section they are not only asked for an elasticity modulus but they are asked about material isotropy, anisotropy, orthotropy, etc. An each of this possibilities shows a different set of values to enter. This becomes a surprise for them and they seem to be like disorientated. When asked for an explanation, the easiest answer for a teacher is to say: *"Oh, just use isotropic materials, because in our case this is enough and the data are much more simple."* And may be this is true, but if we say so I think we have lost and excellent opportunity to improve their knowledge about real materials.

A powerful and complex structural software is indeed a simulation software. Calculating structures lies nowadays in simulating how they behave, by means of a computer. So, if the real structure is something real, material and complex, the more powerful the software is the more exact the output will be. But to reach this stage, we must use all the features this software provides. And to do it we must have a high level of knowledge.

With that, we have found something that sometimes is difficult to get: *the need!* When we try to transmit knowledge, we must create a situation that facilitates this process. Teachers explain, students receive information, but in this situation there is no sureness that they have assimilated the information. There are many factors that intervene in this process. And one of them requires that the students feel they need to learn this, that this is important for them to do something, otherwise they well pass over it.

Conclusions

A reflection exercise and two main points out of this experience are:

1. We have to use only the tools we can manipulate. It's childish to use more expensive, more complex, more modern tools if we don't know how to use them. We will use just a small part of their capacities or, what is worst, we will misuse the tool. Many times, a simple simulation software will give use the flexibility, the straightness we need to explain something much better than a complex tool.

2. If we want to reach a high level of precision and simulate a real process as exactly as it is in the real world, we must use a powerful tool. Using this tools will require a high level of knowledge, sometimes beyond the one the students have. These cases are excellent opportunities for us to teach them. We'll find the students in an optimum position to get and assimilate what we tell them. We must take advantage of this situation!

Susanna Fülöp

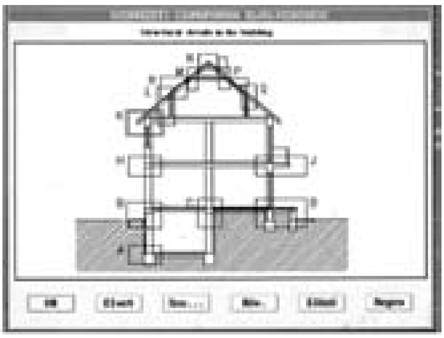
Department of Building Constructions
Faculty of Architecture Engineering
Budapest University of Technology and Economics
Hungary

Performance Based Architectural Design Methods

The huge number of Information Technology Building Industry products (CAD etc.) gives architects the feeling that almost any geometrical shape may be physically realized. Consequentially, professionals envision increasingly unusual building types. Are price consequences appropriately considered? Houses are more often than not too complicated, too expensive and too uncomfortable. This is true in the case of exclusive buildings as well as simple family houses. The question is whether architecture is to create special houses at the border of structural possibilities, or are there other factors to consider as well?

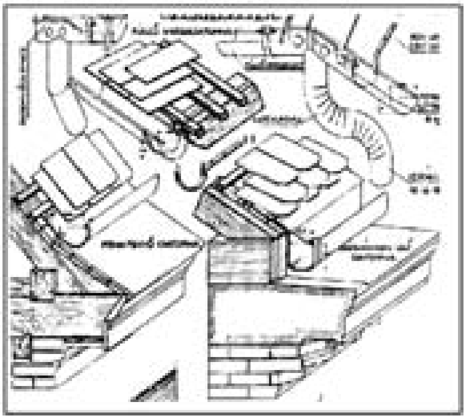
Most people neither want a particularly "high-tech" house, a particularly "low-tech" house, "an energy machine" nor "a designer's status symbol". Most people want a healthy, ecological and attractive dwelling, fit for both soul and body. To obtain this, we need to make choices based on practicality. How can the architect choose structural elements that fit these requirements?

In the last centuries it was a lot more simple and easy. Each country had their own, traditional, building materials and structures which were developed over a long time and served very common functions. Recently, we have thousands of new materials and structures sold all over the world while the functions of our buildings have been changed and expanded.



Changing and Increasing the Number of Building Materials and Contruction Methods is a Great Challenge for the Architect!

Traditional, common eaves roof detail, in case of a non-accessible roof space - in the beginning of the 20th century, in Hungary,



Materials:

Roof load bearing construction:
Traditional timber

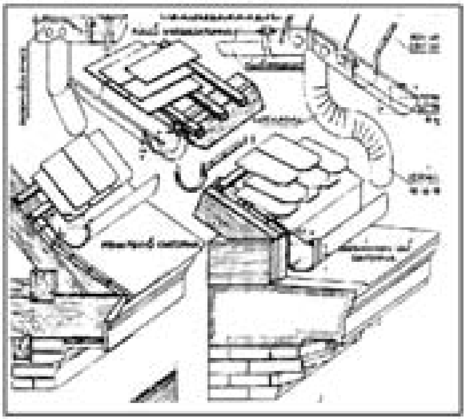
Wall:
Stone and solid ceramic brick

Wall cladding:
Cement mortar

Roof covering:
Ceramic tiles, slates, metal or
Ceramic roof tiles

Roof accessories:
Galvanised iron, zinc

Contemporary eaves detail in Hungary in case of an accessible roof



Materials:

Roof:
load bearing construction: Traditional timber, up to date timber, r.c., steel

Wall:
Hollow ceramic, lightweight concrete, r.c., lightweight framed (metal, timber)

Wall cladding:
Cement mortar, brick, stone, ceramic, metal, plastic, rendered thermal insulations

Vapour barrier:
Plastic foil (PVC, PP)

Thermal insulation:
Plastic foams (PS, PU) mineral wools (glass, rock)

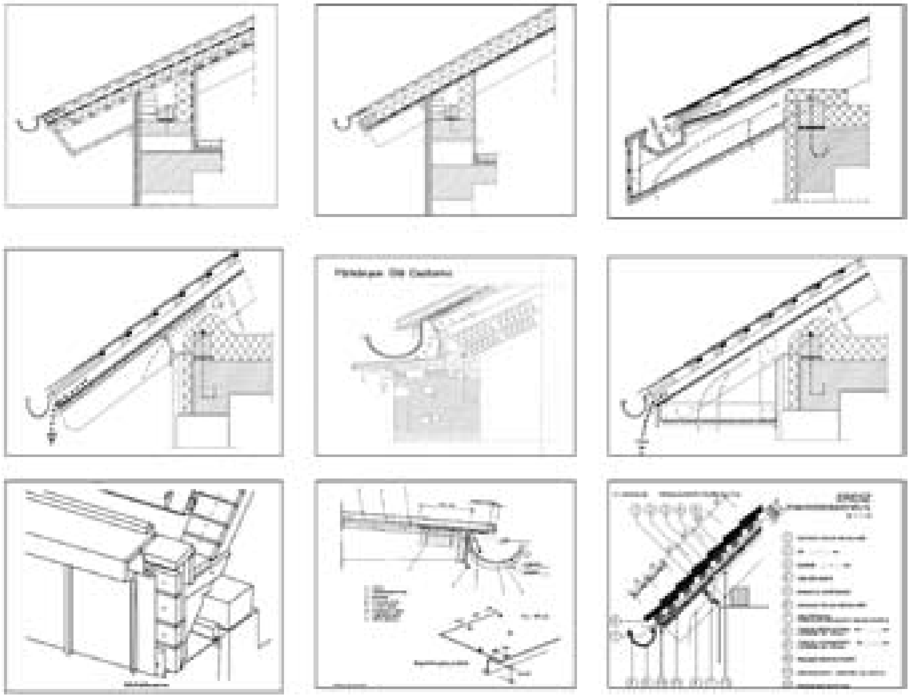
Under layer foil:
Non breathing (PVC) Micro perforated breathing foils

Roof covering:
Ceramic tiles, concrete tiles, slates, bitumen shingle, metal…

Roof accessories:
Zinc. titanium-zinc galvanised iron, copper, painted-galvanised iron

Analytical computation techniques have changed the evaluation system of the design process. Designers very often don't create form anymore, but "select" a form from an infinite spectrum.

Up to date eaves details (Examples from catalogues):



Which is the best structural solution? How can the architect choose materials and products according to the building's requirements? How can she or he provide a healthy, long-lasting building construction without making un-professional mistakes?

Although we have a wide array of simulation and testing methods for building constructions and building physics processes at our disposal, it is a fact that we, even today - almost 30 years after the "revolution" of building materials - have great difficulties with our housing constructions.

For example, the indoor climate and durability of smaller, more crowded houses is often unsatisfactory. A closed system will keep the bad air and chemical vapours given off by modern building materials in. Water vapour will become high in concentration and may cause diseases. It will seem rather paradoxical that we put people into the closed "plastic bag" where air is mechanically ventilated, when we could breathe through traditional and natural ventilation systems. Instead, we make constructions that are basically hermetically steam tight, that can regulate indoor climate positively only to a certain extent.

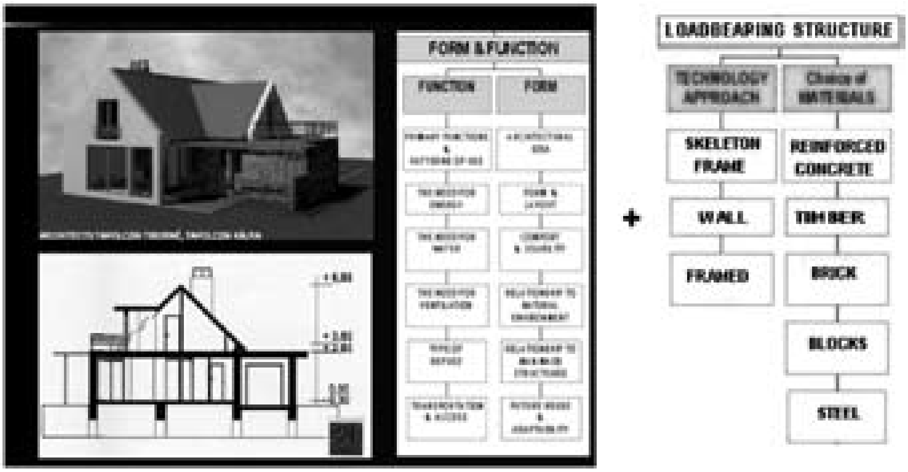
Healthy breathing is a question, on which unfortunately there is not enough clear information.

Furthermore, we have a lot of other structural problems in new buildings, in spite of the fact, that modern materials and products are used:



How can we eliminate mistakes? How can we use the results of controlling the behaviours of forms, structures and materials more effectively? What can be the common denominator of architects and other building science experts?

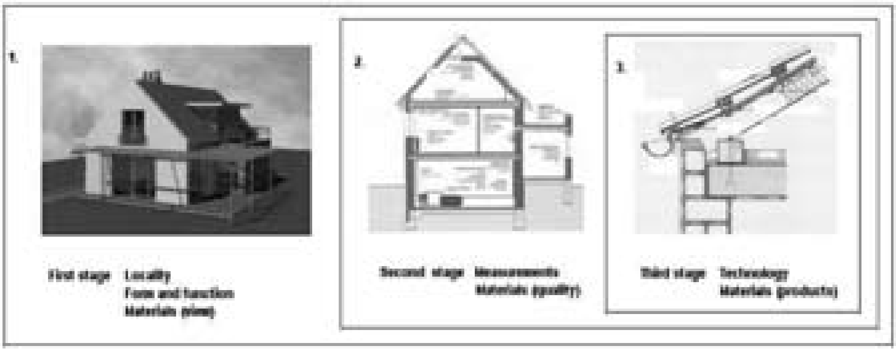
Computer aided design systems (CAD solutions) make the construction and drawing of building plans rapid and accurate. Projected physical dimensions and surfaces may be changed very easily. Architects – in theory - could have more control over the building design process, based on this freedom of shaping, modification through computer modelling, contemporary simulation, and calculation methods of reality. This technique does seem to be very simple and accurate, but new houses are still all-too-often too complicated, too expensive, deviated from the original plans, and last but not least not too healthy.



When the architect envisions the concept of a building, she or he proposes not only form and function, but also the basic building materials. Each material has its special properties, from which given requirements of installation must be derived.

If the architect does not take into consideration the requirements of various building materials, the final solution will not be appropriate, however much expert calculation, simulation and computer testing is performed.

Structural Decisions during the Design Process



First stage

Basic decisions on architectural form (dimensions and shape), appearance (colours, surfaces) need to be made in this stage. The virtual computer model of the building is yet nothing but a sculpture, without consideration for structural behaviours. The accurate calculation and simulation methods can not be used in this stage, since at a scale of 1:200 we do not yet know the exact dimensions and elements of the building construction. The evaluation of structural possibilities can be based only on very basic performances of the materials and the structural requirements derived from external and internal influences on the building. However, without this awareness the later computation and testing could result with the need to fully change the primary architectural decisions, alternatively the building could become too expensive or uncomfortable.

Second stage

The shape and dimension of the building is already set at the beginning of this stage. The experts will accurately calculate, control and test through analytical computation techniques of structural performance, energy-, air- and fluid dynamics, within and around a building as well as dynamic behaviours of other fluids such as smoke, water etc. based on the exact data of the structural properties and requirements derived from the requirements of human activities and natural influences. The use of 3D and 4D software models will produce all necessary qualitative and quantitative dimensional information for the design, analysis, fabrication and construction, assembly and sequencing.

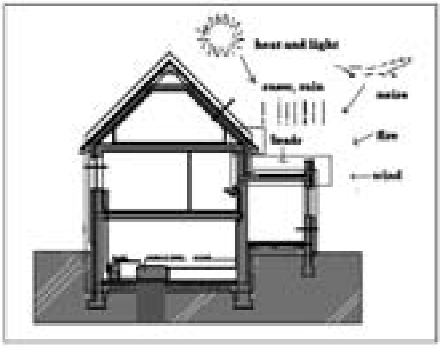
If the architectural decisions made in the first design stage were consistent with real data, the building could correspond with the first stage view and fulfil all structural and human demands.

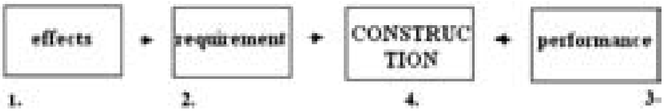
Third stage

The aim of this stage is to choose building industry products based on the previous design stage results. This can only be successful, if we have all the necessary information on and properties of structures and materials that may be purchased at the time. Sometimes this data is not enough or comparable. To clarify the properties of each product is very important, as a lot of structural mistakes are retraced to problems with faulty material selections.

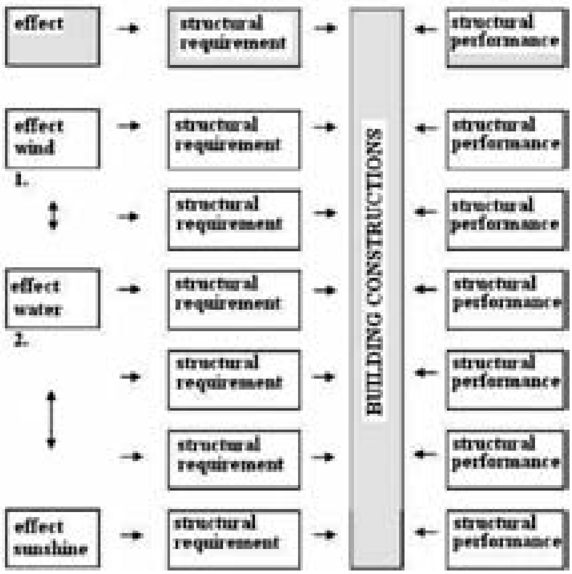
The Architect must Evaluate Connections between Building Environment (Effects) and Structural Performances from the very first Step of the Design Process

The architect has to pay close attention to possible structural and construction problems from the very beginning of the design process. She or he must base decisions on the analysis of projected structural performances and effects, with focus on the basic properties of materials and construction solutions.

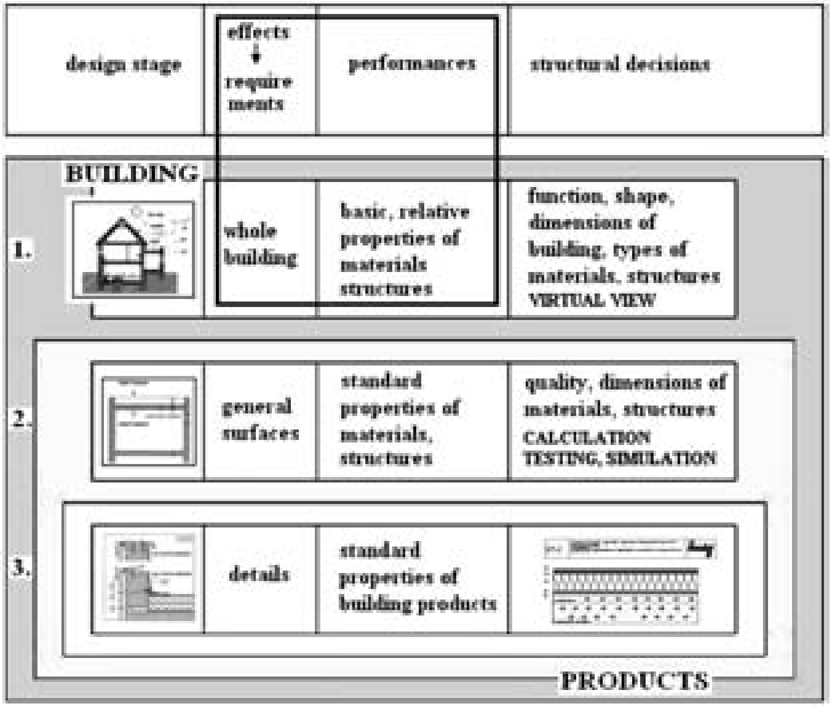




The steps of the evaluation process should not be changed and need to be worked out for each environmental condition (effect) due to the interaction of the conditions.



Performance based Matrix for Architectural Design.



The framed area may be the common ground between architects (students) and other specialists. This will allow for an understanding of the greater perspective and correlations of various building constructions. After learning and using the basic method, we can further educate ourselves to use available special techniques of various sciences, such as contemporary computer testing, calculation, and simulation systems.

Sandy De Bruycker
Marcel Heistercamp
Laurens Luyten

Department of Architecture
Sint-Lucas
Brussels-Gent
Belgium

In Search of Testing and Simulation Integrated Design Aimed Thinking

In search …

Within the department, 'IVOTO' (institute for design aimed technological research) is a research team around construction techniques: structure, construction, climate and comfort, technical installations, material …

The teams want in the first place to conduct investigation and create knowledge from design aimed thinking by means of technical (construction) actors and appliances.

This research field varies from basic to applied problem solving.

An important component of this research will formulate a design aimed instrument.

However this research needs further technical study to be able to act as a supplier for passing positive and innovating design attitudes in the future.

The research topic treads within the framework of the search for solutions for the challenges of tomorrow.

They are formulated to design attitudes which can be used inventively in education and design practice.

In the field of this research we distinguish four study fields: capacity evaluation of relevant buildings, structural concept, comfort in an energetic draft form and study of materials.

Free your mind !!!

Photograph: www.anvari.org.

Bringing the construction techniques into the design-process

One of the problems in the Belgian design practice is the gap between the architectural design process and the technical knowledge: the architect-designer passes on the technical side of the building to the expert-engineer and is no longer master of the entire design process. This technical input, however, needs to be taken into account as early as possible in the design process in order to enhance the quality of the architectural project. An important reason for this problem lies in the analytical and mainly quantitative way this technical knowledge is brought to the architect: for the non-expert it is hard to see the essence and keep the overall view.

In order to integrate the technical knowledge more into the design process, a more synthetic and qualitative approach is needed: the accurate scientific knowledge of construction needs to be translated into relevant design oriented knowledge formulated in the language of the architect. This involves defining what 'relevant knowledge' is for the designer and determining how to formulate it so that it will enrich his design process.

In this process two fields need to be considered:

1. Construction-rules for the architect-designer

The knowledge of the existing construction typologies can be transformed into construction-rules described by design parameters instead of pure engineering parameters. These rules have an appropriate accuracy to make the main parameters become more apparent for the designer. With the help of a computer the influence of the different parameters on the design-result can easily be visualized. It is possible to use these rules without understanding the deeper laying constructional science. In a way they have their own logics focused on the creating world of the architect-designer. The purpose of these rules is to help the architect-designer in an early stage of his design-process to understand the impact of the construction on the overall design.

2. Developing constructional insight

If the architect-designer wants to create new construction solutions, not described by the known construction-rules, he/she needs to understand the essence of the sciences dealing with the construction. For the architect-designer a synthetic and mainly qualitative understanding is needed, keeping the overall view. The classical analytical teaching of construction by breaking up a problem into different steps and parameters makes this understanding more chattered. The current software-technology certainly makes it possible to explain the nature of construction in a more synthetic way without having to show every step of the scientific solving-process. Because the construction-insight of the architect-designer can be more a qualitative than a quantitative one, an appropriate accuracy can be chosen in order to make the essence more apparent.

Capacity evaluation of relevant buildings

At the capacity evaluation of relevant buildings, the synergy between the different technical aspects and concepts (energy, structure, material) is examined. This evaluation bases itself among other things e.g. on literature research, studying and analyzing relevant buildings, designs or constructions and technical measuring …

This research leads as a feeding floor for timeless solutions to a holistic and syncretic quality.

The research of structural concepts aims at a first stage at intuitive, rationally and creatively exploration and developing innovative structures within a scientifically experimental framework.

In this research structural systems are devised and evaluated by physical and virtual experiments. It concerns here e.g. light structures (membrane, pneumatics, tensegrity, etc.) but also scale constructions, rule areas, plane-active systems and hybrid structures.

Case: Structural evaluation of relevant buildings

In their fifth year the architecture students examine the technical component of different architecturally relevant buildings. This study enriches their overall constructional insight.

In the shown example students have used a structural engineering program (Powerframe by Buildsoft N.V.) in order to evaluate an existing structure. The examined building is the Stratford Station (Wilkinson Eyre Architects) in London (UK) which has a very readable structure.

Fig. 1

Stratford Station, Wilkinson Eyre Architects, photo: Laurens Luyten

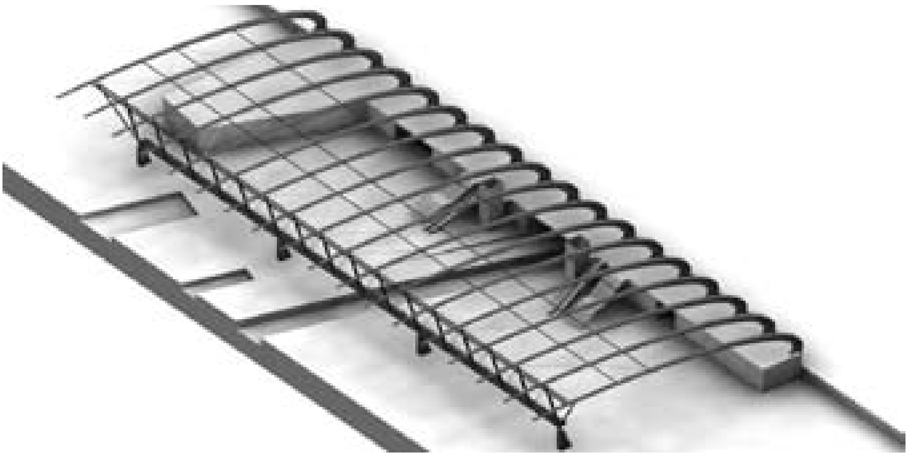


Fig. 2

Structure Stratford Station

The profile-dimensions of the structural arches are higher at the base than at the top. In order to be transportable, the steel arch consists of two parts that are connected close to the base. The differences of the profile-dimension suggest that it has a fixed floor-support at the base. Three possibilities were investigated: only a fixed support at the base (A), a rotational free support at the base and a support from a rotating bar at the top (B), and a fixed support at the base and a support from a rotating bar at the top (C)

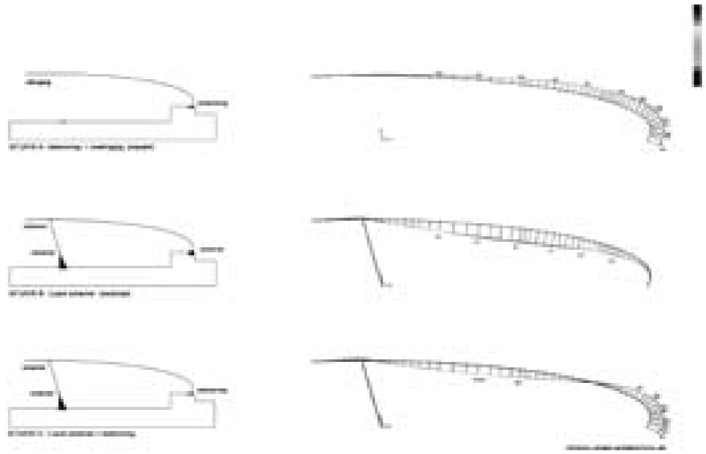


Fig. 3

Arch Stratford Station, 3 different support-schemes and their bending moment diagram

Although the profile-dimension suggest a bending moment diagram according to situation A, it is situation C that delivers the smallest bending moments and therefore the better structural solution. After further examination it became apparent that the place where the two profiles of the arch are connected together, is the same place where the bending moment is very small in situation C. So the different profile-dimension made some sense: high at the fixed floor-support and small at the top, and at the connection high so the low bending moments could easily be transmitted with the bolded plates. But still the ideal dimensions would need fewer steel than the one used now.

This exercise intends to enlarge the structural insight of the students by letting them test this virtual model so they can understand how the structure works and evaluate the structural value of the building. Because this software is written to be used by structural engineers, the main drawback is that the students need intense support in order to use it correctly.

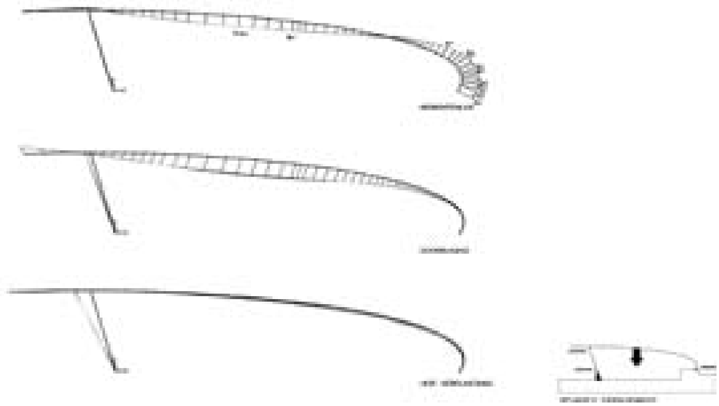


Fig. 4

Arch situation C + dead load, bending moment diagram, global displacement, horizontal displacement

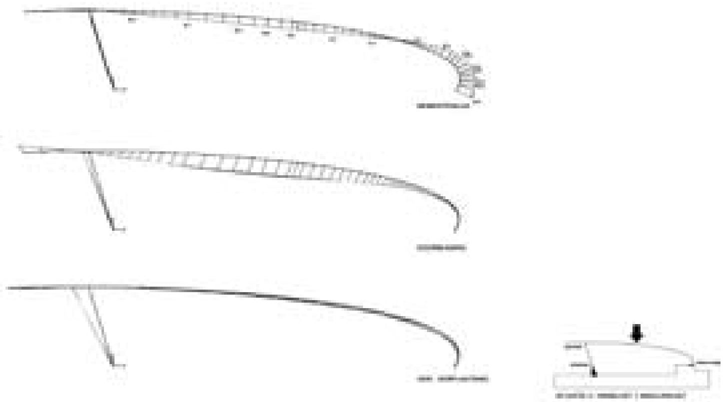


Fig. 5

Arch situation C + variable downward forces, bending moment diagram, global displacement, horizontal displacement

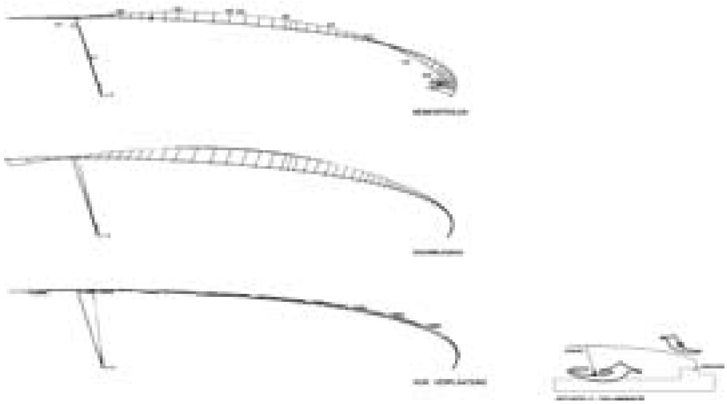


Fig. 6

Arch situation C + variable upward forces, bending moment diagram, global displacement, horizontal displacement

Comfort in an energetic draft form

For comfort in an energetic draft form, we only have partial criteria for some sub-aspects of comfort (acoustically-, visually-, thermal-, air quality …) that not always speaks for itself with the overall concept.

An important not fulfilled wish of the designer is to have verifiable comfort criteria which take account with all these (very several) influences.

As people can influence more their surroundings, it is necessary to examine closely the comfort requirements in a context of sustainability.

Case: Thermal Bridge Idea.

Understanding and designing thermal bridge free (or –poor) details.

The preparation of an approach for the assessment of thermal bridges in de EPR-context (Energy Performance Regularisation) has been worked out in the framework of the Flemish TETRA-IDEE project, coordinated by the department of Architecture Sint-Lucas Ghent, (WenK) with the support of BBRI, UGent, KULeuven and Physibel.

Calculations of thermal bridge influence are in most cases not required if good building details are used. A database of good building details is developed with an open structure allowing other details to be added in the future. For each type of detail (e.g. connection exterial wall with flat roof) a maximum ψ-value (which indicates the extra heat transmission trough the thermal bridge) is defined. The following list of maximum ψ-values is proposed:

Fig. 7

Maximum ψ-values, Koudebrug-IDEE (coordinated by the department of Architecture, Sint-Lucas Ghent Belgium)

In order to make the approach applicable in practice, it is necessary that a set of good Building details are available. Such building details have been developed and the approach is such that other partners (companies, educational organisations,...) can develop their sets of building details.

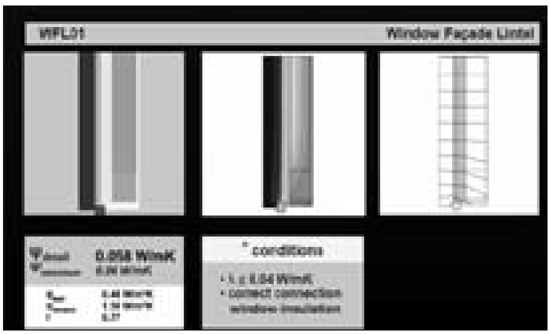


Fig. 8

Example of a detail with ψ-value and conditions, Koudebrug-IDEE (coördinated by the department of Architecture, Sint-Lucas Ghent Belgium)

The building details with their heat transmission (ψ-criteria) will be made easily accessible by an on-line internet application. The concept of the database is such that the content of the database is easily extendable.

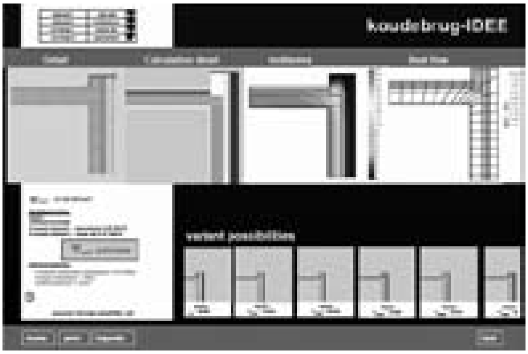


Fig. 9

Concept of witbsite page, Koudebrug-IDEE (coordinated by the department of Architecture, Sint-Lucas Ghent Belgium)

Designing the details

1. Using any CAD-software allows every designer to develop a detail folowing some procedures as:
   - A rigid layer-system based on material-based colors.
   - Using polylines (closed contour).
2. Conversion of the color-based drawing into a pixel-based surface (bmp).
3. Recognition of the material-based pixel-surface and the dimensioning of the bmp in existing building-physics-software (e.g. BISCO, Physibel).

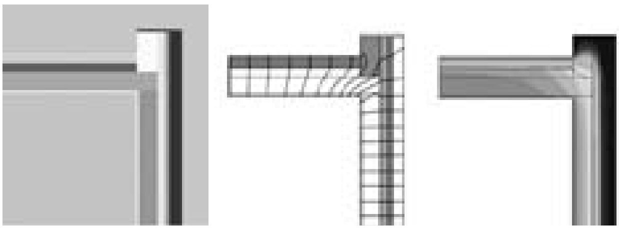


Fig. 10
Output bmp, heat flow, temperature distribution, Koudebrug-IDEE (coordinated by department of Architecture, Sint-Lucas Ghent Belgium)

The research-team (Physibel) developped a software tool to activate the details by making them adaptable: thermal conductivity, dimensions and boundaries are editable in order to maximalize as many as possible detail-compositions. The software will automaticaly recalculate the ψ-value to evaluate. This software tool will be freely availbale for use in Belgium. The windows-based software tool KOBRA will be accompanied by an atlas of some 3000 building details.

So without complex physical foreknowledge it will be possible for the designer in a direct way to design and to evaluate his detail with certainty and guarantee in dialogue with his client or with the watching government.

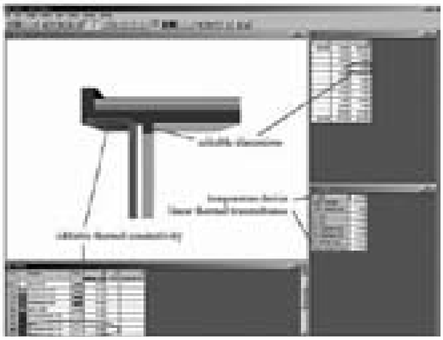


Fig. 11

Example of a software tool page, overview, partner Koudebrug-IDEE www.physibel.be (coordinated by department of Architecture, Sint-Lucas Ghent Belgium)

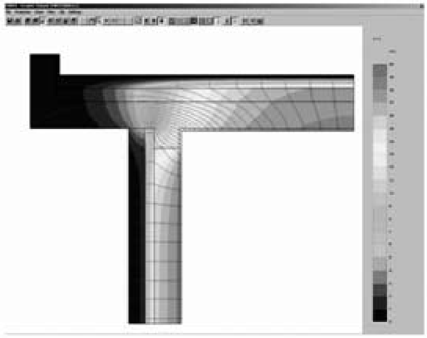


Fig. 12

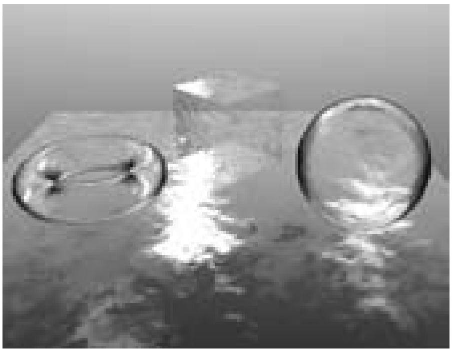
Example of a software tool page, temperature distribution, partner Koudebrug-IDEE www.physibel.be (coordinated by department of Architecture, Sint-Lucas Ghent Belgium)

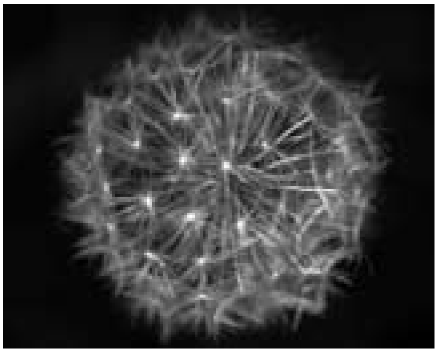
Material

The Material research has the following objectives:

First: create a technical documentation centre (TDC) to make a critical map of the material offer.

Second: develop strategies for material choice, material floated, energy efficiency and striving toward multi-purpose nature, sent from further going dematerialization and an active striving towards a durable design in all his facets.





In a sense, 'interdisciplinary of testing and simulation' involves attacking a subject from various angles and methods.

Copyright

Fig. 1 Stratford Station, Wilkinson Eyre Architects, photo: Laurens LUYTEN

Fig. 2 Structure Stratford Station, software Autocad,
author: students Sebastien DELAGRANGE, Frederik DEPROUW, David MINOODT

Fig. 3 Structure Stratford Station, software Powerframe,
author: students Sebastien DELAGRANGE, Frederik DEPROUW, David MINOODT

Fig. 4 Arch + dead load, software Powerframe,
author: students Sebastien DELAGRANGE, Frederik DEPROUW, David MINOODT

Fig. 5 Arch + variable downward forces, software Powerframe,
author: students Sebastien DELAGRANGE, Frederik DEPROUW, David MINOODT

Fig. 6 Arch + variable upward forces, software Powerframe,
author: students Sebastien DELAGRANGE, Frederik DEPROUW, David MINOODT

Kyriaki Oudatzi
Niki Andreadis-Manou

School of Architecture
Faculty of Technology
Aristotle University of Thessaloniki
Greece

Testing and Simulation Methods in Contemporary Construction Teaching

Introduction

In the last twenty years, even before the closing of a generation cycle, computers, gradually but dynamically, entered the architect's everyday professional life.

In the beginning of this new era of computers, the architects – belonging to a generation of the tracing paper and rapidograph -drew the first digital lines reluctantly and in some fear, resisting to the tremendous invasion of an unknown, awesome tool which seemed more likely to prohibit their freedom of thought and productive process rather than to facilitate their work. From the time of those first lines drawn until today, the scenery has radically changed! Twenty years later, the development seems to have gone far beyond the sphere of fiction! The computer has been transformed, incredibly fast, from a simple design tool into a processing machine which processes basic compound data and thought and generates the architect's final work. The initial incapability of the computers: a) to generate multi-faceted synthesis containing more than just compatible parameters and b) to support the architects's complex concepts has now been replaced by the tremendous capabilities of computers not only to materialize the complex architect's thought –considering that a single human mind can only process a limited number of data- but also to provide (by contemporary software) specific selected and desirable data. Architecs have gained speed, accuracy and implementation of their unlimited imagination in designing. Furthermore, computers can very well process desirable solutions that meet the user's demands, as well as additional demands with reference to construction economy needs, environmental conditions, use of new hi-tech and aesthetics, "smart" and interactive materials, designing elements that seemed unapproachable twenty years ago.

Unavoidably, the whole community of architects, both academics and private professionals, struggle to become fully conscious of this reality and to catch up with it.

Consequently, and in order to adjust to the new labor market conditions, the method of education in Schools of Architecture inevitably changes along. In some Schools this change is superficial and implemented only by introducing design subjects, limited to drafting, synthetic and construction issues, with the use of computers, without this being connected with other educational actions. In other Schools, where the arousal and harmonization with new technologies and data is set among the main educational objectives, computers are not introduced just for the sake of carrying out some drafts and drawings. On the contrary, these schools take full advantage of the indefinite potential offered by the complex digital design programs and the production of high technology architecture. By exploiting the computer and using these sophisticated softwares, integrated in the curriculum and practiced in digital design studios, they aim at a more mature and complete form of education.

Traditional teaching methods within a new context

The question that seems to concern teachers of architecture who are active today, is whether the traditional teaching methods are sufficient for the incorporation of the new data or whether a completely new revision, re-assessment and re-determination of the curriculum is imperative. Whether the curriculum in the school of architectures has to change radically and provide students with all those qualifications and skills that will make them efficient not only in getting involved and surviving but also in following a successful course in today's and tomorrow's increasingly evolving labor market is a matter of debate. It is also apparent that current education, however hard and complete, is not sufficient on its own. What is absolutely necessary is that the architect of tomorrow develops his capacity and potential to constantly validate his knowledge and process the information throughout his whole professional career. So, one first consideration is that teaching computer-aided design and at the same time following the existing advanced design programs and modern software, do not necessarily void the traditional teaching method, at least in the initial stages. On the contrary, it seems that teaching is based on this conventional method, as this provides the essential background for the creation of a documented and integrated architectural thought. In this initial period, the students go through the first steps in learning the digital language. In the second stage, it follows the combination and interaction of this acquired digital knowledge with the construction and contemporary material production industry, which will generate scientists who have the final integral profile of absolute creators, composers and constructors at the same time.

The architect's training will be completed when the new demands that have emerged in modern architecture are met.

i) The reaction of the building envelope to changing environmental conditions and natural phaenomena, as well as to the more general wear and strain, are issues that often concern the architect at a second phase, particularly following the completion of the construction.

ii) The industry of building materials and constructions, especially in modern massive production, applies complex methods of simulation, endurance and quality assurance for materials and for the overall construction outcome. Unfortunately, the whole preparation of the building material, before this enters the competitive market, remains absolutely unknown at a teaching level.

iii) The inadequacy in teaching energy and environmental architecture management, make students to try to respond only to the process of synthesis by simply aiming at an aesthetically acceptable result, ignoring the involvement and fulfillment of contemporary parameters, such as endurance, efficacy, environmental consciousness.

iv) Although the upgraded control and model simulation techniques constitute a prerequisite for production in the industry of materials, this has not effectively been integrated and harmonised with the educational process. In fact, the simulation process is not only attractive but also particularly educational, given that the identification and diagnosis of building problems become much better and clearer, before the building is even constructed. Thus, the architect has full control of the construction details and their sufficiency, as these derive from the digitally generated design information which also can automatically be interpreted into construction information, by extracting data and converting the software into tangible matter. All this takes place with special operations through a screen that simultaneously monitors and controls all stages for the completion of the construction.

Computer model simulation concerns building structure, envelope energy management, endurance of materials and structure, resistance to natural - weather phaenomena, as well as exploitation of the positive microclimate elements of the region.

All the above issues are considered inextricable parts of a modern curriculum. Teaching is suggested to take place at three levels of difficulty and elaboration, which could be connected with the basic and postgraduate degree of studies, in such a way that the knowledge concerning architectural thought and building production meet the demands of the corresponding degrees and certificates.

The use of design programs offer the potential of 3-D (three-dimensional) models, containing all essential qualitative and quantitative information and parameters nesecary for the designing, analysing into partial construction sections, producing and constructing. In this way, the student can visualize the outcome of his synthesis and the behavior of the building structure in external conditions, under real circumstances. In addition, he is given the opportunity to actually complete the stage from the moment of composition to the point of construction, a process which had not been covered so far by the teaching process. In this way, the result of the design evolution will have the features of the real building and will no longer be just a simulation. On the contrary, the final design will include all the construction elements and reactions that the building will have under normal conditions.

Proposal

First of all, it is proposed that all basic subjects are based on the use of computers, as an essential design tool for expressing ideas. In other words, composing directly upon the 3-D screen, instead of the film paper is becoming the corner stone of training. At first level, the synthetic approach is implemented considering investigating building structure issues, form and volume, functional consistency, coloring aspects, materiality of the architectural, structural physical geometry, orientation. Composing takes place with the computer use, already from the "run-in" study stage. The target of this stage is to acquire general knowledge and teach the basic principles for composing within a digital environment.

At a second level, special subjects will be taught which will focus on the synthesis and construction with the use of advanced technology. The objective is the computer use at a second stage of synthesis. In other words, it is not simply that an idea is transferred from the paper to the computer. On the contrary, it moves more thoroughly; from the level of some draft study, it becomes integrated into an implemented study where special demands are set, such as analysis of the form and building structure. This takes place with the application of simulation techniques, synthetic elaboration, environmental parameters, energy, lighting and acoustic control and management systems, as well as construction details, endurance and quality analysis of materials, special features of materials. The objective of this stage is the completion of the pre-graduate education (stage A + B), providing fundamental essential knowledge that will be transformed into priceless weapons for today's architect.

The third and final stage is suggested to be at a post-graduate level, either integrated in a post-graduate digital synthesis study or in the form of short seminars which could refer to a wider thematic postgraduate program. This stage concerns elaborating on the digital construction design, which is connected with the digital interactive design production. This process directly links simulation software with the industrial production and robotic construction systems. It includes analysis and synthesis of the building form, physics of the building structure, full technological integration, materials and, at the same time, implementation practice. All this new data is provided through real, geometrical models and realistic images and environmental, lighting and ventilation control systems created by using advanced mathematical models and algorithms applied in modern software for the elaboration of the architectural information within an architectural model process. The theoretical background is supported not only by digital technology, but also with educational workshops accommodated either in the facilities of the School of Architecture or in co-operation with production workshops, which by contract will host postgraduate students groups and give them the opportunity to test the outcome of what they have been taught in realistic models. The objective is not only to elaborate on the 3-D model digital design synthesis, but also to connect the digital model with the physical one, with the support of software programs simulating the dynamic behavior of building and structural elements.

Examples

Massimiliano Fuksas
Congress Center
EUR District
Rome, Italy

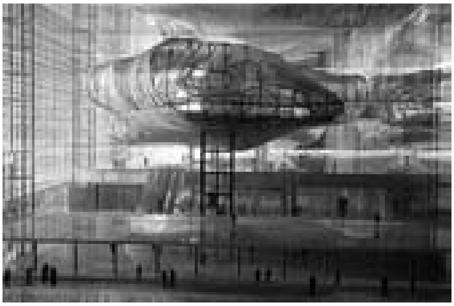
Image courtesy, Massimiliano Fuksas, architect

Sketch courtesy, Massimiliano Fuksas, architect

"The idea came to me in a very special moment. I was at the seaside, a group of clouds where being blown quickly across the sky by a strong wind. As I looked at the clouds I remembered a dream I had had, which involved constructing a building that had no crystallized form at all.", Massimiliano Fuksas

The building is basically large, 30 meters high, translucent container that extends lengthways. On each side a square opens on to the immediate area and the city. The first converses directly continuously with the local area and can be crossed from viale Europa to viale Shakespeare.

The second, a space that can be composed freely using moveable structures, is for welcoming conference participants and accompanying them to the various rooms in the center.



Images courtesy, Massimiliano Fuksas, architect

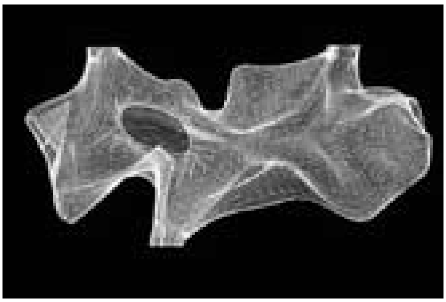
The simple, squared lines pay tribute to the 1930s rationalist architecture that characterizes so strongly the Eur and the nearby Conference center designed by Adalberto Libera.

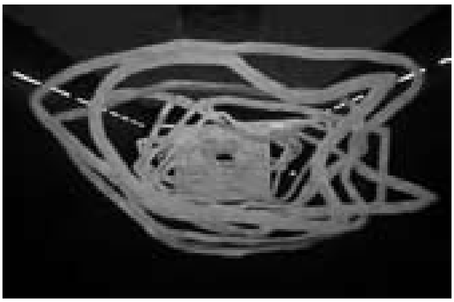
Inside this shell, a 3,500 square meter steel and teflon cloud, suspended above a surface area of 10.000 square meter, is designed to hold a 2.000 square meter auditorium and various meeting rooms.

When the cloud, supported by a thick network of steel cables and suspended between the floor and the ceiling of the main conference hall, is lit up, the building seems to vibrate. The construction also changes completely depending on the viewpoint of the observer.

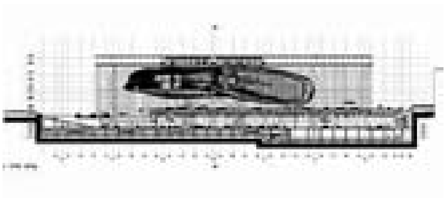
In addition the center will also contain three halls and spacious foyer, cafè and restaurant areas, covering a total multi-functional space of 15.000 square meters. A grand stair will link the building to the outside plaza.

The Congress Center was the winning project in an International competition.





Images courtesy, Massimiliano Fuksas, architect



Drawing courtesy Massimiliano Fuksas, architect

Construction start: 2004

Expected completion: 2007

Total area: 26,981 square meters

Conclusion

Image courtesy Ateliers, Jean Nouvel

The inadequate traditional teaching method may become the starting point for the creation of a new program which will create the framework for the integration of new technology into contemporary teaching. Only in this way will there emerge scientists who will be able to successfully distinguish within the highly demanding labor market.

The basic principle and prerequisite condition for these changes to take place is to accept that neither the orientation nor the culture of the Schools of Architecture changes. In fact, these are simply being verified and "re-set" in accordance with the newly emerging conditions and demands of our times and of the contemporary architectural process.

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Session 2

Environmental Control
- Testing and Simulation

Chair: **Miltiadis Tzitzas** *NTUA, Greece*

Kleo Axarli

School of Civil Engineering
Aristotle University of Thessaloniki
Greece

The Role of Simulation Techniques in Energy Conscious Design and Construction: Simulation Software in Education

Introduction- Environmental Design of Buildings

We all know that the study of the environmental performance of a building is not a trivial issue. According to the latest research developments in the area, a bioclimatic shell should interact with Its environment in several ways. For example, according to building use and energy demands, it should:

- minimize heat losses in winter and capture sunlight
- minimize heat gains in summer and avoid sunlight
- use natural light efficiently
- have the right amount of thermal mass
- allow for sufficient natural ventilation without maximising the thermal losses
- keep the moisture out

Various climatic factors affect the heating and cooling of the buildings: ambient temperature, precipitation, humidity, wind speed and direction, and amount of sunlight available. All these factors must be taken into consideration when designing buildings, otherwise they can add greatly to the heating and cooling problems.

The energy related needs of buildings vary from day to night and from winter to summer. For example, in cold weather, the design goal is to maximise solar and other free heat gains, reduce heat losses and allow for suitable ventilation. On the contrary, in warm weather, the goal is to minimise heat gains, exclude solar radiation, avoid overheating and optimise the several forms of natural cooling.

The environmental performance of a building is a complex, dynamic situation, directly related to time and the continuously changing environmental conditions. The thorough investigation of the subject involves deep understanding of building physics and all the simultaneous interactions taking place, like heat gains and losses, occupancy patterns and behaviour, climatic changes etc.

Although many hand calculation techniques have been written in the past in order to describe the physical phenomena involved, due to the complexity of the whole situation it is almost impossible for one to actually work with them and really understand all the processes involved in order to come up with a design that meets all the requirements.

This is where simulation software comes to bridge the gap.

Simulation Software

There are several techniques and tools that enable the designer to understand, before the building is designed, how the building is likely to interact with the climate and to use energy, so that the appropriate architectural design strategies are applied. Hand calculations, physical or digital models and software simulations are used for the prediction and evaluation of the energy performance of the building (fig. 1).

The development of simulation software concerning building physics has started early, following the advance in computer technology. Nowadays, it would be argued that the large variety of simulation software can face the above mentioned complex physical phenomena at a satisfactory level. In particular, current simulation software allows us:

Fig. 1

Tools used in the design process by the architects

- to evaluate the interaction between the different components which make up the environmental performance of a building shell (e.g. a good design for daylighting may be bad for avoiding overheating)
- to easily manipulate the model by speeding up time (e.g. when studying solar shading), by making quick changes at the design of the shell or by concentrating on a specific aspect alone (e.g. air flow) if desired.

It should also be noted that very often two or more simulation softwares are combined in order to reach the desired conclusions. For example, one package may be very good at shading design but really weak on CFD calculations. In such a case, the first software could be combined (via an export engine) with a stronger package on CFD analysis.

Simulation Software in Architectural Education

"Architecture has received many interesting situations with the arrival of environmental sciences into university curricula. Architecture as part of the city generator, and the society that lives on it, should be changing and dynamic. That is the reason why teaching future professional architects cannot be based anymore on conventional ways of delivery"

Radovic D., 1998

It is true that more and more Schools of Architecture are trying to integrate Environmental Design into their curricula and are clear that promoting awareness of Sustainability, efficient and effective teaching is essential.

According to recent research carried out in UK (De Jesus et al, 2000), lecturing is the most widely used method of teaching environmental design at postgraduate level in the UK. (fig.2)

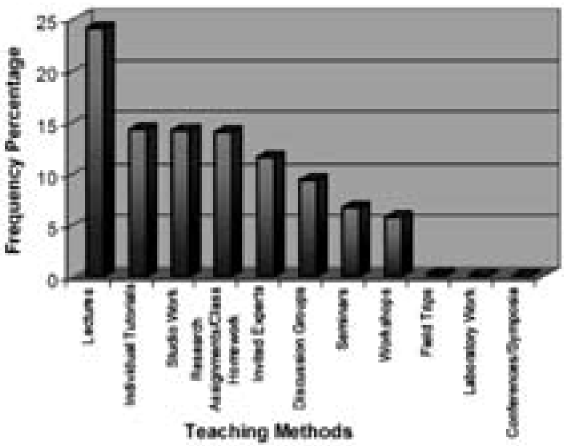


Fig. 2

Proportion of time spent on various teaching methods in Environmental Postgraduate Courses in Architecture

Lectures are intended to provide information. Nevertheless, according to Neel (1969), architecture students frequently pay little attention to the courses that support Design (considering them secondary). Therefore, a great part of the necessary information is not reaching students. This causes demoralisation of staff members and devaluation of the lectures.

On the other hand, the form of architectural education around the world seems to have begun a *gradual shift into the electronic era*. This change is somewhat related to the level computers have invaded human life in all sectors and also to the increased interest of students. This means that as time goes by, architectural students will have previous knowledge of computers and greater ease to deal with the digital world.

Simulation techniques as a teaching method: is tit necessary? Is it pedagogic?

As far as simulation techniques are concerned, they are increasingly appreciated as a successful teaching medium. *The pedagogic advantages offered are of great importance and promise an advanced level of teaching and learning in environmental design.*

Simulation allows students *to investigate and visualise the behaviour of a model* using images of three dimensional objects enabling them to experience the relationship between different results and to manipulate inputs to achieve desired outcomes, for example, to vary the orientation of a building to ensure that a space is in sun or shade at a particular season or time of the day. This is particularly useful for design students who tend to have well developed visual and spatial analysis skills." Millard (1997) (Fig 3.)

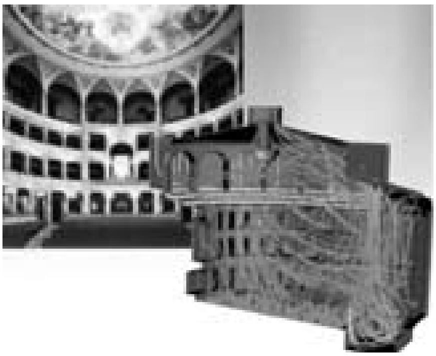
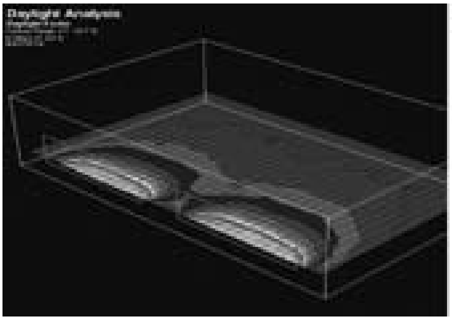


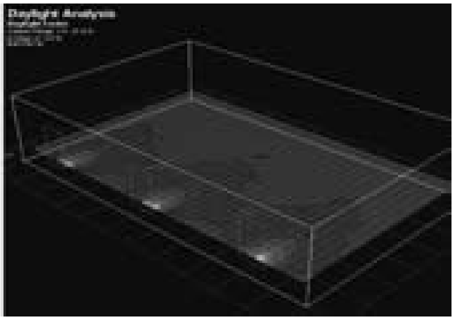
Fig. 3
Visualization of the thermal behaviour (eg. air movement) of the building shell or the open air space, with the help of CFD prograammes

Also, according to Strand (2001), as far as building thermal physics are concerned, the courses tend to teach 'rules of thumb' and general guidelines that usually have restricted applicability and liability. Questions like "Is this glazing area too big for the summer (overheating), too small/big for the winter (low direct solar gain / great heat losses through the glass) or just OK?" can be difficult to answer for a specific situation without a good understanding of the thermal response of the building in relation to the specific climate. (fig.4)

However, a good simulation software for thermal analysis of buildings can investigate various design options quickly and help the user understand some basic guide-



a. Daylighting performance with two horizontal openings



b. Daylighting performance with three vertical openings

Fig. 4

Studying the impact of openings to daylighting. (study with Ecotect software)
Aspects to teach: size, shape , orientation and placement of openings, in respect to daylighting performance (daylight distribution in a space- quantity and quality of daylighting)

lines he/she has to follow. *In this way the computer provides a platform for more in-depth analysis and understanding of buildings.*

Apart from the above mentioned advantages of simulation software, its contribution to the development of *thermal intuition* is also significant. Just as producing physical models is important to checking spatial intuition, creating thermal models is crucial to checking that the complex interactions of the building's thermal physics have been correctly understood. In this way students can start, little by little, to understand what, for example, the increase in glass area means for thermal losses and what for daylighting, without having to use dull hand calculation techniques (fig.5).

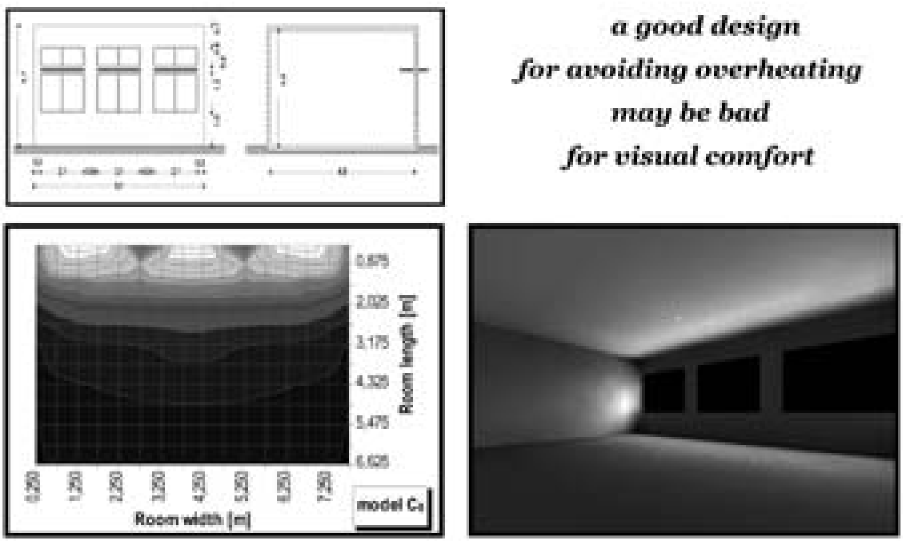
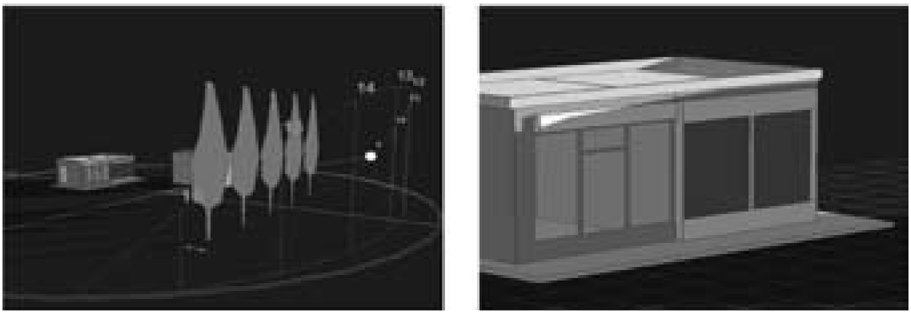


Fig. 5

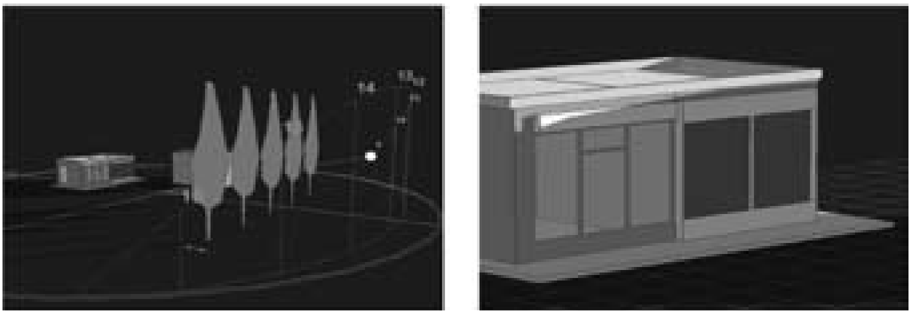
The estimation of daylight distribution and glare formation:
Simulation software allows students to understand the several aspects of environmental design

While no simulation program is "perfect", Strand argues, that *programs do provide an opportunity to improve on thermal load predictions. Discussing the differences between the methods used in hand calculation and thermal simulation, it is obvious that thermal simulation can lead to a better understanding of the underlying physics that governs the thermal processes as well as an appreciation of the capacity of the thermal simulation programmes, to analyze situations quickly and accurately* (Strand, 2001).

On the other hand, simulation techniques offer *advantages to tutors* as well. By using these techniques, a teacher's lecturing seems a lot more interesting to students, who are more attentive and make more questions. The visualization of the results that a computer model may offer, makes the teaching more attractive. Also, for a tutor it is easier to teach e.g. the overshadowing of building volumes by means of simulation paradigms than with traditional methods (fig. 6)



Daily shading effect – December 19th 8.45



Daily shading effect – December 19th 15.15

Fig. 6

The shading due to the trees during a winter day

In this way both teacher and students are highly motivated, making the best of their interaction.

The choice of the suitable software for teaching purposes is not an easy job:

- The simulation tool that will be chosen as a means for teaching and learning must be particularly user-friendly, so that the students will not be disappointed by struggling to learn it.
- The amount of time required for students to gain sufficient proficiency in the software in order to actually make use of the analysis results is critical. Since the most

time-consuming stage is the generation of the model, the class should not duel on this, but start with really simple examples that quickly give simple results. In this way big mistakes in modelling are avoided and confidence is built.

As a conclusion, it could be said that simulation techniques contribute in the following ways in the teaching and learning of energy conscious design and construction.

For students:

- They facilitate the deep understanding of the interaction between the several aspects of environmental design
- They help the development of thermal intuition

For teachers:

- They help the teacher explain the theory in an easier and more interesting way

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6 Ecotect software, www.squ1.com

Giuliana Lauro
Manuela Musto

Architecture Faculty
Second University of Naples
Italy

Simulation Models for Environmental Control

Cellular Automata Application to Urban Planning

During the last two decades, spatial analysis tools, Geographic Information System (GIS) and Remote Sensing (RS) technologies have been widely deployed to monitor, analyze and visualize the urban growth phenomena. Maps and satellite images, however are limited to static displays of past and current data sets. They portray the current state of the system, with neither the reason, nor possible futures. Although GIS based tools provide useful analysis and have been widely used to assist urban planners, the static mapping concepts on which they are built are clearly insufficient to study the dynamics of urban growth.

The causal mechanisms associated with land use changes remain relatively poorly understood, in part due to the complexity of urban systems. Consequently, policy makers and planners are often faced with a difficult task of making land use decisions without a sufficient analysis or vision. To build a comprehensive urban simulation model involves collaboration of scientist from multiple disciplines. Very recently, computer simulation models based on Cellular Automata are being employed to forecast and evaluate land use change in urban systems (Batty and Xie 1994). These models represent a spatial and dynamic approach that enables planners to view and analyze the future outcomes of current decisions and policies before they are put in action, hence, it is important to encourage the students in getting acquainted with these new tools.

Cellular automata applications have found their way into 2-Dimension applications in urban growth modeling. The basic idea is very simple: in a gridded space (lattice, raster) a series of transition rules are enforced to govern the state of a randomly placed cell depending on the configuration of its neighborhood. A fundamental characteristic of the lattice is that cells have some adjacency or proximity to one another. Usually the lattice is a uniform gridded space, but, potentially, cells can be of any shape. Each cell in the lattice can adopt only one state of a set of possible states defined by the system being modeled (residential, industry, commercial, green areas). The configuration of the neighborhood of a cell defines the current state of the cell. In classical CA's, the neighborhood is usually the four or eight nearest neighbors. There is a set of transition rules that govern the types of changes in cell states in relation to the neighborhood configuration. Note that the cellular structure of CA has natural affinity with raster data format of Remote Sensing images and GIS grid map. Hypothetical urban forms emerge from CA models with surprisingly simple local transition rules. This aspect is very appealing in the context of construction teaching as the students are stimulated to think about the possible choices of the local transition rules in line with differently oriented territorial plans, comparing the different values of sustainability of the final settlements.

For the application, two territories have been selected in the town of Aversa and in the town of Piedimonte Matese. The first is a north portion of Aversa's town. The selected zone has been chosen among those in which future sceneries are defined by a master plan. This area is interested by three tools of urbanistic planning: P.R.G, the Contract of District and the Urban Recovery Program. It has been developed a grid having dimensions 50 ms. x 50 ms., distance among the principal road aces. The grid has been colored and each color has a precise meaning: the grey individualizes the built part of territory, the green the agricultural areas, the yellow the free areas, the brown the railroad.

Subsequently, to check the reliability of the software (Haug2), the students have created the laws of transition, by beginning from the actual configuration, that should have transformed the territory according to the zoning of the planning[1]. The result has been amazing, the cells of the CA, after different runnings, have reached the configuration corresponding to the zoning of the master plan. In a successive research, by using the preceding experience, such a software has been experimented for a territory in Piedimonte Matese, deprived of urbanistic instrumentation.

The main lines have been: the refurbishment of historical center, the recovery of the vacanty buildings and forecast of new standards for the historical center that, with green and parking areas, help to create new pedestrian areas inside the center.
However, the urban system evolves in a much complex way in reality. In applying cellular models to urban development, transition rules must reflect significant factors

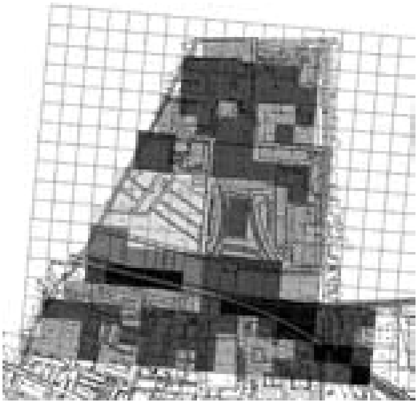

Fig. 1

The grid overlapping the actual settlement of the northen zone in Aversa AC third running.

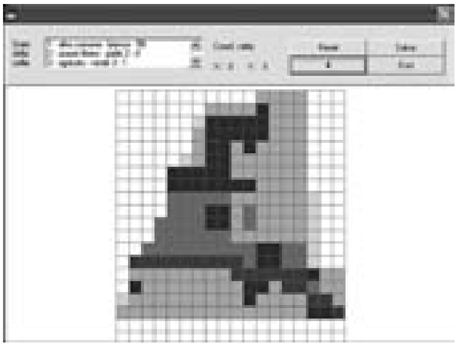

Fig. 2

AC third running.

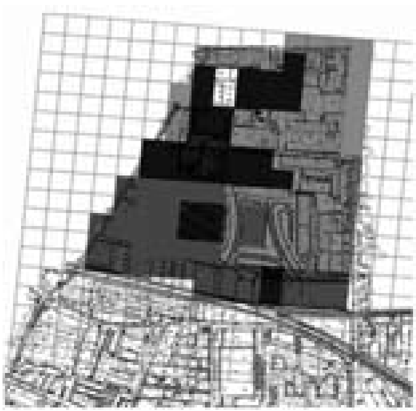

Fig. 3

Overlapping of the AC final running and Aversa Master Plan.

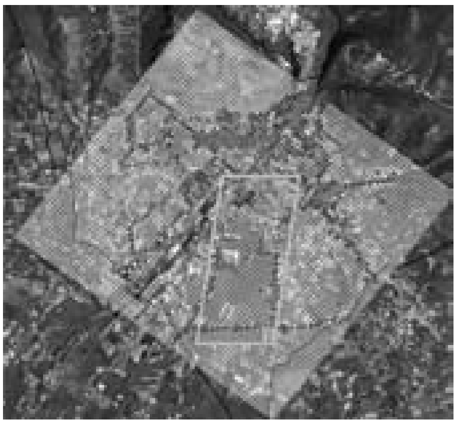

Fig. 4

The grid overlapping the actual plan of Piedimonte Matese.

that influence urban development and consequently can comprise a range of socio-economic and biophysical factors. Consequently, most CA models are still developed as research projects, and applications are conducted more like experiments to test models. Currently, few CA based models are operational as productive tool to support regional planning practice. In the most advanced CA, cells are intelligent agents which not only can get the local information, but also can sense the regional or global information, like social environment and economic trend. That's why it is important to prepare students in this field.

Static Simulation Model for environmental control
Territorial Graph

In the modern discipline of Landscape Ecology, the landscape is defined as a heterogenous land composed of interacting ecosystems that exchange energy and matter (bioenergy), and where natural and anthropic events coexist.

In the considered model an environmental system is subdivided in a given number, m, ofl different ecological patches separated from each other by natural or anthropic barriers. These barriers, as we will see further on, can have different degrees of permeability to the migration of bioenergy. The bioenergy magnitude of each patch may be represented by a circle (node) whose diameter is proportional to the magnitude itself. The energy exchange among them will be more or less strong depending on the degree of permeability of the barriers which can obstruct the energy passage. Therefore, each patch is connected to the others by links (arches) whose width is proportional to the energy flux shared among them. The collection of nodes and arches is frequently called graph of the environmental system.

The graph so obtained, represents in a static way the exchange of energy that occurs in the territory.
The bioenergy of the patch j, j = 1,….,m, is given by

$$M_j = (1 + K_j)B_j$$

where K_j, environmental indicator, is a dimensionless parameter characterizing the morphological features of the patch and B_j is the biopotentiality of the patch itself.

The last quantity assumes values between 0 and approximately 5 Mcal (Megacalories) per year and can be computed, on the basis of a standard classication, once is determined the kind of land uses present in the patch. Such a classification runs from the lowest, concerning edificated (biologically non-active) areas, to the fifth, characterized by natural wooden areas.

$$B_{tc} = B_E \text{ x area of ecotope}$$

B_E is the indicator of biopotentiality

The K_j parameter is computed as the average between three parameters K_{Fj}, K_{Pj}, K_{Dj}, each with values in [0, 1]. The first is a parameter related to the shape of the patch borders, since their morphology influences strongly the energy exchanges between the patches themselves, the second parameter K_{Pj}, again with the purpose of evaluating energy exchanges, takes into account the permeability of the barriers, following some standard values of the permeability parameter.

Class	Typology of ecotope	B^{E}
A (Low)	Prevalence of system that needs energy (industries, infrastructures, buildings, brownfields area, rocky areas).	< 0,5
B (Md – Low)	Prevalence of agricultural technological systems or degraded ecotopes (sowed areas, shed buit areas, incolted grassy areas, rivers corridords).	0,5 – 1,5
C (medium)	Prevalence of agricultural seminatural Systems (sowed areas, orchards, vineyards, hedges to medium resistance)	1,5 – 2,5
D (Med – High)	Prevalence of natural ecotopes (bushes area, pioneer vegetation, rows, poplars areas, reforestations areas, urban green).	2,5 – 3,5
E (High)	Prevalence of natural ecotopes that don't need energy (woods, mountains areas, damp zones).	> 3,5

Fig. 5

Indicator of biopotentiality B_E.

Typology of barriers	p
Highways, principal net of communication	0,05
urban or secondary roads	0,4
artificial water net	0,4
railroad	0,6
White road	0,7
natural water net	0,85
principal river	1,0

Fig. 6

Indicator of permeability p.

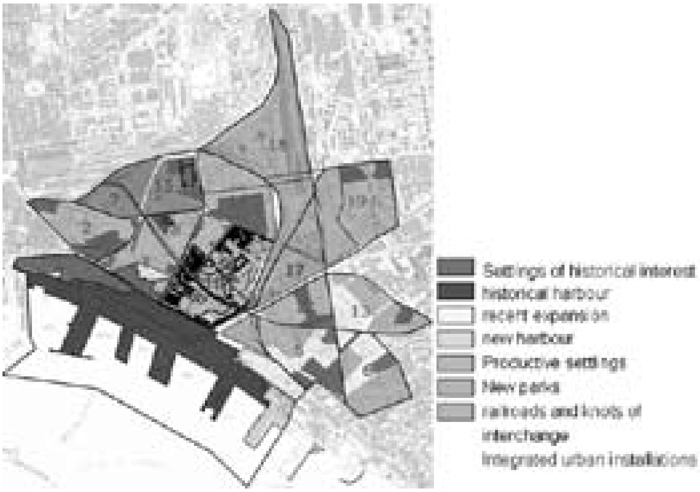

Fig. 7

Use's destinations of the hypothesis of project of the area

Finally, the third parameter K_{Dj} is related to biodiversity, determined by a Shannon entropy value, that takes into account the presence of different ecotopes (smallest ecologically distinct units) inside each patch. High values of biodiversity contribute to more stable ecosystems.

The bioenergy fluxes through the border between two patches i and j are given by

$$F_{ij} = (M_i + M_j) / 2) L_{ij} p_{ij} / (P_i + P_j)$$

where L_{ij} is the length of the border, P_i and P_j the perimeters of the two patches and p_{ij} the permeability parameter of the barrier whose value, as already said, is known in literature and depends on the type of the barrier itself.

This model has been applied to study[2] a brownfield area of eastern part of Naples subject to a Master Plan in the direction of improving the environment.

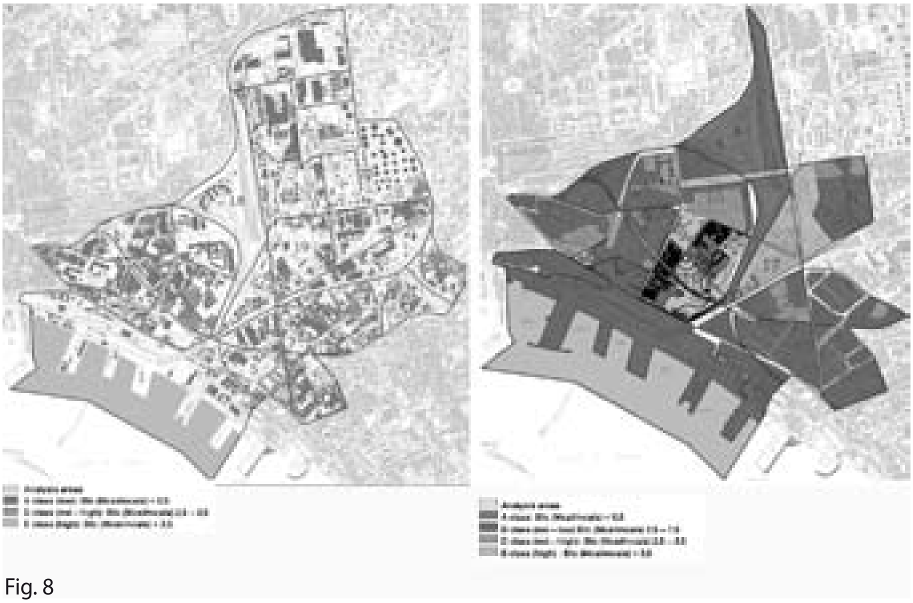

Fig. 8

Actual state of area and project of area: Analysis of the biopotenziality.

Fig. 9

The graphs: the actual state of area, the project and the overlap of of the actual state's graph and the graph's project.

The application consists in the elaboration of two different sceneries: the first scenery represents the actual situation, the second scenery represents the project solution in line with the intents of the Master Plan.

Between the two situations there will be different typologies of intended use of the ground and barriers that will make changes in the analysis and in the calculation of the environmental indicators.

The comparison among the graphs of the two sceneries, has allowed, in decisional phase, to define an intervention for the area aware of the interactions with the surrounding territory.

For the construction of the graph the students have used the software ArcView 3x. The shape files furnish the informations about the use destination of the ground, the presence and the connection of road infrastructures (railroads, highways, government and provincial roads), the system of water courses (natural and artificial) and the administrative subdivision of the various urban territories within the studied area. If the urban administration don't allow the use of GIS systems, the students can use the classical methods of analysis of the territory used in the courses of final laboratory design of the architecture. They are sustained by software as AUTOCAD to acquire all the useful information

These two softwares are used for dividing the area in patches and to get elements, for every patches, useful for the calculation of the environmental indicators as:

- Perimeter of the patches
- Area of the patches
- Barriers among the patches and the quality of barriers like antrophic barriers (Railroads, roads, etc.) or natural (hedges, masting etc.).

For the elaboration of the calculations, they have used spreadsheets with Excel.

Dynamic Simulation Model for Environmental Control Logistic – Type Differential Equation

The territorial graph represents in a static way the exchange of energy that occurs in the territory. Hence, it is interesting to investigate the time evolution of bioenergy and of other quantities describing the territory.

In fact, changes in bioenergy and environmental conditions may produce territorial modifications toward which individual landscapes will tend to move smoothly (attractors) or may produce, instead, critical thresholds that result in radical changes in the state of the ecological system. In this sense, ecological systems are metastable.

The investigation on mestability can be performed by means of the study of the equilibrium solutions of suitable differential equations that model dynamics of the territory's evolution. The primary objective of these models is to perform qualitative predictions on the sustainability of the territorial plan, finding, eventually, critical values of the quantities characterizing the territory itself.

In order to study the dynamical behavior of the ecological value of the environmental system, starting from its present territorial settlement, it has been used the following nonlinear differential equation:

$$M'(t) = c\, M(t)[1 - M(t)] - h\, S_o$$

M(t) is the average of values of the bioenergy over the entire system, the prime indicates the time derivative, t the variable time, c a connectivity parameter related to the number of links in the graph, h is the ratio between the sum of the impermeable barrier lengths, inside the environmental system, and its external perimeter, S_o, is the ratio between the sum of the territory surfaces, that present low values of biopotentiality, and the total surface of the system.

The model basic assumption is that the time evolution of bioenergy will depend on two terms with opposite signs. The first, positive, describes the bioenergy growth following a logistic law, the second term with a minus signe is opposite to bioenergy growth, due to the presence of barriers that are impermeable to flux of energy and to the presence of edified areas.

As previously remarked, ecological systems are metastable. Stability means that an ecological system remains relatively unchanged and returns to the same attractor if subjected to some disturbances. Metastability means that it can maintain itself over a limited range of changes in environmental conditions but may eventually undergo significant alterations if environmental constraints continue to change. As remarked, the more or less metastability (i.e., more or less resistance to disturbances) is related to the more or less presence of biodiversity and connectivity. Hence, it is interesting to study the equilibrium solutions of the differential equation because it can give, together with the parameters involved, indications on the level of metastability of the model. The students have used a software that furnishes the graph of the solution.

One can see three sceneries: the first one shows that the actual state of the area tends, very quickly, to collapse; in the second one the value of the bioenergy grows, visibly, due to the project solution and tends to a stable value; the third one gives a critical value of the parameter, h, above which the system collapses even if it starts from the project solution, showing the important role played by the impermeable barriers.

After this analysis the students have realized their own projects in line with the indications of sustainability given by the model.

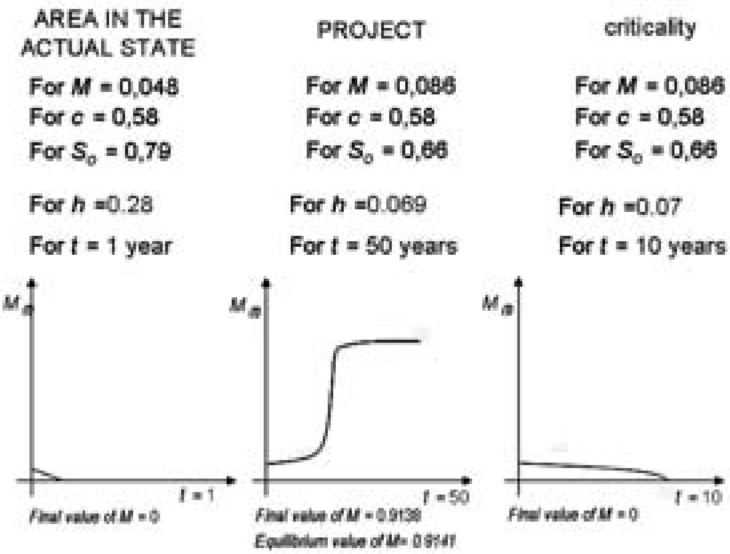

Fig. 10

Behaviour of the solution of the logistic - type equation.

Notes

1 The software (AUGH) used for the simulation on the cities of Aversa and Piedimonte Matese can be found at the following address: http://bibo.lampnet.org/link/gotolink/addhit/1/?Url=stratema.lampnet.org from the homepage of Prof. Arnaldo Bibo Cecchini – Faculty of Architecture of Alghero – Sassari – Italy.
The research has been developed by Anna Mandia, in her Ph.D. thesis-Faculty of Architecture-Second University of Naples - (Coordinator prof. arch. C. Gambardella) and by Silvia Romano, Degree in Computer Science, in her research work sponsored by B.E.N.E.C.O.N.- Faculty of Architecture - Second University of Naples (Advisor prof. Giuliana Lauro).

2 Argument of Architecture Degree's thesis of the fifth year students: Tommaso Fumante, Vincenza La Vedova, Ulderico Tornincasa.

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Maria Isabella Amirante
Caterina Frettoloso

School of Architecture
Seconda Universita di Napoli
Italy

Mathematical Models' Contribution into Environmental Design Teaching

Toward a more integrated approach into Environmental Design Teaching

Maria Isabella Amirante

The environment as a collective heritage poses, as well as a reflection of a global relation between human-nature, also delicate issues on the rational use of natural resources, stressing the need to guide any activity project (chance processing) toward sustainable management strategies. The result is the identification of protection policies of the natural and built environment according to innovative goals and procedures.

Today the problem of protection can't be posed as a static bond: the safeguarding has to think in a dynamic way, and it is necessary to evaluate and define, in every case, the relationship between humans and nature. This requirement entails necessarily the control of chance processing, or rather technology.[1]

Environmental Design, in collaboration with experts coming from different disciplinary fields, has built in the years an own method of analysis directed to territory safeguard according to its specific designing finalities. Such approach is translated, on the didactic point of view, with a continuous and constructive cooperation with teachers coming from different disciplinary fields finalized to the formation of a professional figure able both to have a dialogue with the other actors of the project, and to use diversified tools for supporting the own design choices. In this case, the collaboration with professor Giuliana Lauro, a mathematician, has helped to strengthen the belief of the importance of a confrontation among different research fields, methodologically similar.

To this end "the education, finalized to transformation, should be an integrating part in university technology programs that should be able to ensure, inside an approach oriented to improvement of environmental and social conditions, the formal quality of actions technologically appropriate in a project that creates a systemic breakdown of different objectives. To educate the future architect is a priority in order to ensure a widespread technical capacity that is able to maintain, in time, the quality and the original form of intervention".[2]

In the didactic experience of the "Final Laboratory in Technological Disciplines for the Architecture and the Building Production", the students are dealing with the delicate theme of the environmental recovery in sustainable key and particularly they experiment the applicability of a mathematical simulation model, based on graph construction (static evaluation) and differential equation (dynamical behaviour), as a choice decision support tool.

The aim is to understand if the introduction of such decision-making model can contribute to pursue the objectives of quality of the project through simulation of the environmental system working. To this end the experimentation has been developed in two years: the first dedicated to territory knowledge, the second more finalized to the elaboration of design hypothesis.

The used tool is a model of representation of complex systems and it is directed not to a graphic simplification of the territory but to underline intangible aspects such as the "bio-energy".

In such sense this tool has the assignment to improve and to support the choice ability's students and it requires:

- advanced didactic program

- responsibility in the design process
- good ability of project management.[3]

The "mathematical model" is a complex tool so we require from the students a good ability of design process management, in the specific case, to urban scale. This responsibility is expounded through an aware use of the tools proper of the discipline of the Environmental Design, as those used inside the Integrated Course in Environmental System Design (IV year): the Environmental Initial Analysis of the site for a Environmental Management System, the impact and state indicators, study of environmental network.

"The territory is, in fact, a set of interacting ecosystems (…) it can be exhaustively defined as a system composed by different ecologically space-units interlinked with each other, (…) that is how a meta-system".[4] The dynamic nature of processes that act on an area needing analysis tools appropriate in terms of flexibility and capability to represent variables involved in processes such as the exchange of matter, energy and information. From models graphically advanced to those based on different scientific theories the choice is wide and the selection criteria have chosen and evaluated in each case in relation to the specific design goals: the designer must identify the most suitable one to "simulate" the particular phenomenon.

The most complex method to formalize the complex territorial system is both to outline some basic elements which constitute this complexity, and to investigate their structure, without neglecting the interdependence and hierarchical links between the parties. One of the possible reading of the territory is made taking in account the human signs, the manufactured and the natural ecosystem transformations in relation to the, more or less devastating, human presence.[5]

This didactic experimentation, therefore, shares the same goals and, from them, tries to understand the potential and applicability in the environmental design of specific mathematical models. The identification of "strategic" ecological areas, in which the territory is divided in relation to bio-potentiality classes and barriers (images 1 and 2), as well as the choice of the parameters and unknowns that then generates the graph of the territorial bio-potentiality, represent the theoretical - practical core of adopted methodology well illustrated by professor Giuliana Lauro and applied by students to the design.

The permeability, connectivity and bio-diversity in the degree thesis
Caterina Frettoloso

To reorganize, reconfigure and enhance a degraded landscape, as the east area of Naples, is a stimulant and a complex design challenge that requires tools and technologies finalized to the specific objectives identified that have in common the need to increase and, in some cases, re-establish the environmental quality of site and its context. According to the methodological approach of Environmental Design Discipline, in which design choices are the result of the conducted survey on the territory in the different scales, there is a need to innovate these processes through both a critical re-reading of the basic principles behind them, and to increase its innovative component.

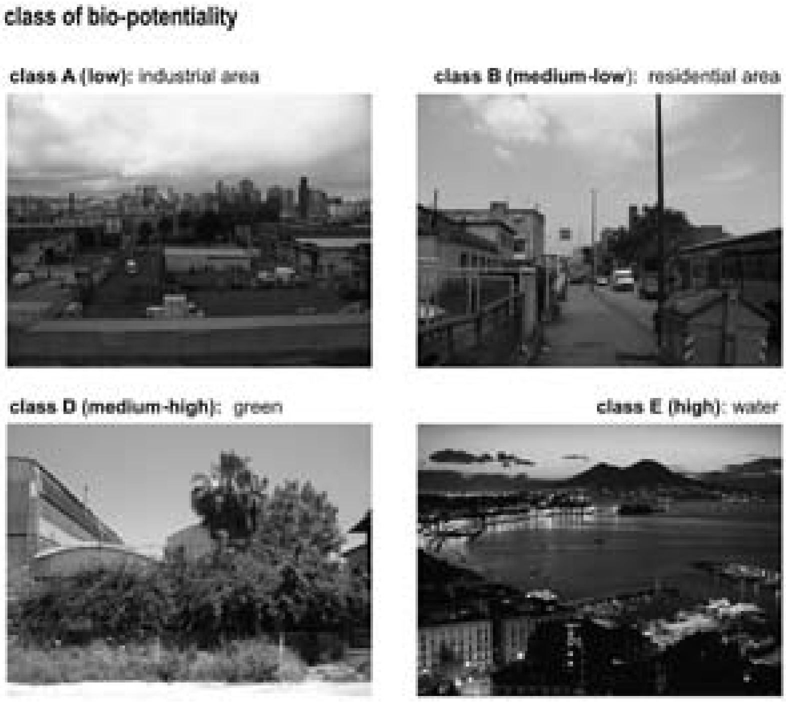
class of bio-potentiality
class A (low): industrial area
class B (medium-low): residential area
class D (medium-high): green
class E (high): water

Fig. 1

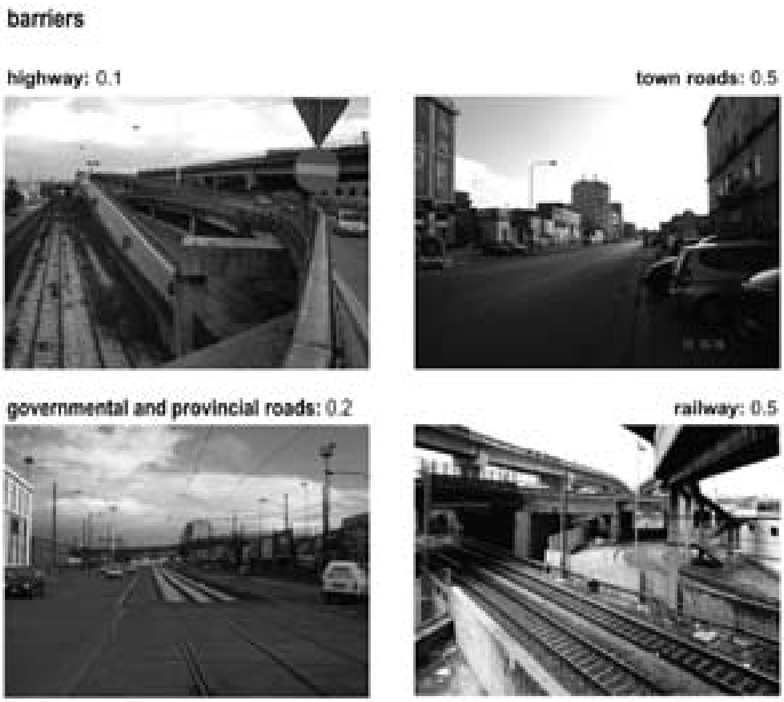
barriers
highway: 0.1
town roads: 0.5
governmental and provincial roads: 0.2
railway: 0.5

Fig. 2

A contribution to environmental sustainability that comes from the development of tools and models "enriched" by a multi-disciplinary input, can help the management of the project, and in inserting the area in a more general system. The "multiplicity" characterizes both the area of study and the intervention itself.

The development of an analytical framework, aimed to environmental sustainability goals, will mainly emphasize the environmental resources involved and the acting processes, distinguished by type (natural, human, etc..), and by their impact on the territory. The methodologies and tools of investigation must be rigorously and strictly chosen in relation with the project purposes.

The Eastern region of Naples (Sub-area 12 "ex Feltrinelli"), mainly a dismissed industrial area, is bounded by three major arteries as G. Ferraris, Gianturco and Marina streets, and by the minors roads of Brecce, Calabria and Sponsillo streets. In addition, the tramway to the south and railway in the east part reinforce the lines border.

The infrastructures (Naples-Salerno motorway, railway - Circumvesuviana, trams and buses) represent in this site a dual physical - spatial value: on the one hand they make it a strategic node within the urban context, though heavily compromise, on the other hand they closed the area contributing to its physical and social deterioration. The presence of residences is widespread along the main arteries crossing the area (G. Ferraris and Gianturco street) and especially along the roads more linked to the old town and Marina street, where there is the Public Housing "Prince of Piedmont" quarter. Some areas were involved, in 1985, in the explosion of Agip's deposits (fuel). The overall image that emerges from the several surveys conducted with students and from the historical and urban investigations, is a total dreadful condition that from polluted underground, result of years of uncontrolled human activities, extends to the people who live, in the majority of cases, in unhealthy, and often, abusive housing. The choice to work on the east area of Naples was born, as well as for methodological and design reasons, also from the awareness that these areas represent a real possibility of transformation, in eco-compatible key, of the land which they are part. As professor Salvatore Dierna noted they are "often forgotten areas, which occupy an "intermediate" role in the working dynamics of the city, but they are significant for the high gradient of potential naturality contained in them".[6]

Starting from the definition of "environmental system" as a combination of landscape – units, different for structure and functions, characterized by different levels of connection and of energy trades, the territorial planar graph, used in combination with a system of differential equations, well draws the value of the "bio-energy" of each landscape-unit in which the area is divided, its evolution in a given period of time, and the connections through the exchange of energy.

The development of the graph covers three different scenarios where it is possible to foresee "the evolution, during a period, of the total bio-energy [of system] from its value calculated at time t = 0. Such study could then allow to assess, in time, the ecological value of the system starting from its territorial current arrangement".[7]

For such a complex system it is not easy to evaluate and measure the changes, but it is possible to check at least the meta-stability. Meta-stability means the precarious state of unchanging, tending to evolve towards a less stable state; meta-stability can avoids the risk of exceeding the threshold of resilience, that is the ability of the ecosystem to return to the starting point after a disturbance, the capacity to suffer damage due to external pressure. Each landscape is composed both of low meta-stability elements, with a little resistance to disturbance, but a rapid recovery capability (high resilience) and good meta-stability elements, with a high capacity of resistance to disturbance, but a low resilience.[8]

The "bio-energy", a measure of metastability in the mathematical model, is indicative of "the specificities of ecological units considered" in the respective scenarios: status quo, Master plan adopted, and meta project hypothesis. A critical point is mainly the process of "adaptation" of the model, designed for a territorial context, to urban project area. The different scale has required, in fact, the change of some choice criteria both of ecological sectors and of types of barriers which define and circumscribe eco-mosaic units, contributing more or less to the energy exchange.

The "mathematical model" adopted has a double value: as a tool of investigation and testing, always oriented to design. In the first case (investigation) it contributes to furnish information, expressed by numerical environmental indicators, in the second (testing) it allows a preventive reading of the impacts of the design choices to allow a possible correction. It has an operational role in two specific moments of the design process: between analysis and planning phase and between planning and designing.

To improve and increase the values of bioenergy emerged by the elaboration of the mathematical model has been necessary to direct the project, in its different hypotheses, toward a greater:

- physical, perceptive and technological permeability
- connectivity among the single systems.

In the degree thesis, through the experimentation of the mathematical model, students have been able to orient the design choices toward a sustainable management of the resources. In each project there is a particular attention to the energetic efficiency of the buildings and, moreover, a strong interest to the use of alive materials such as the green and the water, in order to increase the biodiversity, the physical and perceptive permeability and the connectivity.

The insertion of great quantities of "green", in the project of the Agricultural Park and Urban Gardens, is mainly finalized to improve the value of biodiversity emerged by the mathematical model toward the increase of the:

- biodiversity to urban scale
- climatic comfort
- energetic saving

The variety of selected arboreal kind allows to improve the bio-diversity within the project area. They are been selected following two main criterions:

- autochtonous kind
- kind for the barriers anti-noise function

The green assumes, therefore, a social and educational function to improve local habitants sensibilities in environmental recovery. At the base of design choices there is an evaluation in energetic sustainable key that, starting from the passive and active solar

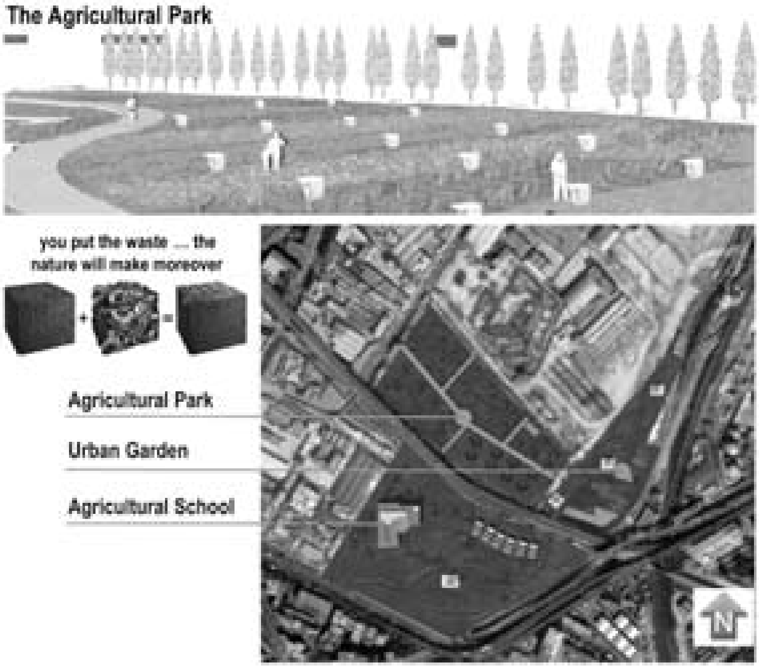

Fig. 3
The agricultural park: Vincenza La Vedova

Fig. 4
The cultural park: Tommaso Fumante

system, comes up to the management of urban waste. The "composting" system is one of the solid waste treatment chosen: the organic materials, biologically decomposed, without negative effects on environment, can be used as fertilizer.

The green, as element to reinforce biodiversity, and the technological and physical permeability are the main themes of the "Cultural Park" project. The "green" has a great influence on the space organization, particularly, the single arboreal essences contribute to increase both the biodiversity and the connectivity among the different areas. The study both of permeable surface, as the system designed for the parking zone, and of permeable barriers, as the different kind of streets adopted, is oriented to the maintenance of the biodiversity. This particular interest to the natural heritage is essential therefore to assure conditions of sustainability to the territory and safeguard the urban ecosystem, as well as to strengthen the urban identity of the city.

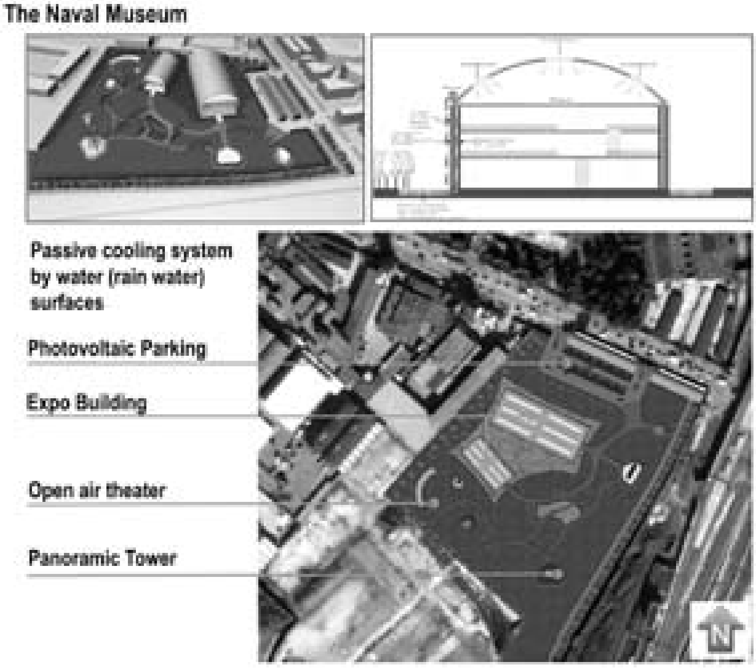

Fig. 5
The naval museum: Ulderico Tornincasa

The Naval Museum aims to valorize the maritime tradition in the east of Naples: the water, in its different shapes and functions, is the main element and with green, as in the other hypothesis, also contribute to improve the permeability and connectivity within the different project areas.

The student paid particular attention to the building passive cooling, in fact, he designed a system based on water surfaces that exploits the capability of the water to absorb heat and to release it during the evaporation. According to our approach of rational management of natural resources, the water used is rain water picked up and also used for the park irrigation: rainwater and its use for landscape watering needs, is a reasonable and realistic way to reduce the use of potable water for landscape irrigation.

In conclusion, the application of the "mathematical model" to urban scale is developing as an experimentation so it would be interesting to research on the introduction of new and more appropriate environmental indicators for urban scale. After verifying the validity of the tool "mathematical model", it would need to work on:

- the mathematical model's implementation in the operational routine and administrative practices through computer system (GIS).
- the normative interface between the actual environmental control tools and the new experimental one so to consider value data, such as permeability, meta-stability, connectivity, usually not directly involved in the decisional making process.

Students:
Tommaso Fumante, Ulderico Tornincasa, Vincenza La Vedova

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Giovanna Franco

Facoltà di Architettura
Università degli Studi di Genova
Italy

"Energy" and Existing Buildings: Chance or Problem for their Architectural Persistence?

The European scenario

About 80% of European citizens lives in urban areas, where the effects of environmental problems are more intensively perceived. Noise, air pollution, vehicular traffic, lacking in maintenance of the built environment, bad environmental management and scarce strategic planning aid the raising of health problems and worsen the quality of life. The planning of high level of environmental protection is one of the fundamental presuppositions to ensure a sustainable urban development.

The heating system and the artificial lighting of buildings absorb the main part of energy consumption (42% in total, 70% for heating) and produce 35% of total greenhouse gas emissions. For these reasons, renovated methods in building design, construction and refurbishment could allow a notable improvement of environmental performances of the cities and of the quality of the life of citizens. Consequently, the protection of the environment is one of the fundamental presupposition to ensure a sustainable urban development.

Assuming European directives, the Italian building sector has been individuated as a priority area of intervention to obtain significant results. The combined application of recent national laws and fiscal incentives will imply, in the next future, a strong acceleration of sustainable refurbishment of existing buildings. Urban renewal and building refurbishment represent therefore an immediate sustainable action. In Italy above 3 million of dwellings (almost 12% of total amount) need radical interventions to solve situations of decay, pollution and energy consumption. A huge challenge for the future passes through the refurbishment of existing buildings, especially erected in the second part of the 20th century, following sustainable principles and criteria. The extension of "energetic certification" to existing buildings, according to the European Directive, will also stimulate a sustainable upgrading.

Practically, refurbishment is more complex than a new construction, because different situations require particular and sometimes complex solutions. Moreover, the attention to existing real estate property will become particularly important after the adhesion of the new member countries.

The attention to these problems is also evident inside European research recently ended or under development that aim to define procedure and sustainable management tools of built environment. Among these research it is possible to remind the INVEST-IMMO project (2001-2004), that was finalised to the construction of a user-friendly software for the sustainable management of residential buildings erected in 20th century (the research did not descend in a detailed technical scale). Among other projects, under development, it is possible to remind DEMOHOUSE "Design and management options for Housing"; BRITA "Bringing retrofit innovations to application in public buildings"; SOLANOVA – "Solar-supported, integrated eco-efficient renovation of large residential buildings and heat-supply-systems" specifically directed to eastern European built heritage.

At the national level, studies and research devoted to sustainable refurbishment did not yet face in a systematic way the real applicability of different techniques of intervention to the built heritage, neither the implications (in terms of costs/benefits) on different aspects of the problem (technical, architectural, environmental, economic, management…). They are also missing studies and researches that integrate, in a global vision, architectural, environmental, technological aspects with knowledge from other disciplines (as building physics and performance control, economy and evaluation…).

In conclusion, sustainable refurbishment represents an open field of research, and has immediate reflections on labour market, especially in our region. For these reasons, the theme is hardly developed also in the teaching activity at the School of Architecture.

Sustainable refurbishment of ancient/recent built heritage and software simulation

In the following rows some reflections are presented about the use of digital technologies - *user friendly* software – mainly addressed to the environmental control of building design during the teaching activity, both at the first level (second year) and third level (that corresponds to the Ph.D. course).

As the teaching activity is mainly focused on the modification of the built environment (cities of the 20th century), one of the main subjects of the work at the school is the improvement of energy performances of existing building, that is one important part of the refurbishment and upgrading of 20th century building stock. In particular, one of the aspects that is investigated – through the use of simulation methods – is the energy consumption monitoring and the testing of possible benefits deriving from the application of insulating systems on the building envelope and innovative technical disposals (through the use of renewable sources).

Didactic at the first level

Working in the education field the first step that could be undertaken by the teachers corresponds to making people - and students - aware of the huge actual and future environmental problems linked also to the building sector. This goal could be pursued using traditional methods (lessons, seminars, courses…) or even involving the students themselves in a more effective way.

Instead of making the student work on case studies given by the teaching, they have to work, as training, on their own home/apartment/house. The main idea is to make the students responsible for the data collection regarding the actual state of the building (technical features and energy consumption) in order to make him/her touch directly the environmental and energy problem (consumption and saving).

During the experimentation, each student has to collect a few technical data and to perform the energy behaviour (in terms of consumption) of his apartment trough a user-friendly tool specifically adapted to attribute buildings to an "energetic class" (tools could be Sacert, Docet, Cened, CasaClima…). These softwares also allow to immediately evaluate benefits of thermal insulation or technical improvement.

The direct involvement of the student (making him working on one's own house) responds to the major purpose of each kind of teaching, that should be the raising of attention in respect to several problems and, in general, the progress in culture.

This kind of attitude, that also directs the practical experimentation on the student's own house, leads the student to:

- the knowledge of problems,
- the correct setting of a technical project
- the responsible choice of the final technical solution, that is never fixed and unique, but could be different from case to case.

Fig. 1

Partial results of the didactic work of the students at the first level: data collection and thermal performance on one's own house.

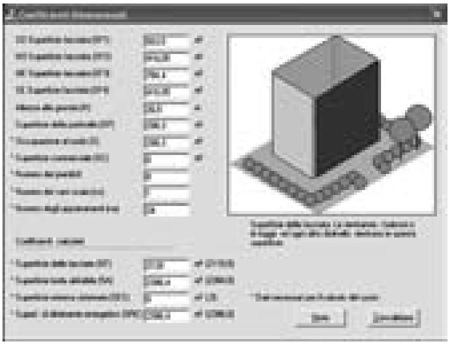

Fig. 2

Epiqr software (result of an European project about energy performance of residential buildings and retrofict actions): general input data. The software is available for 20th century residential buildings.

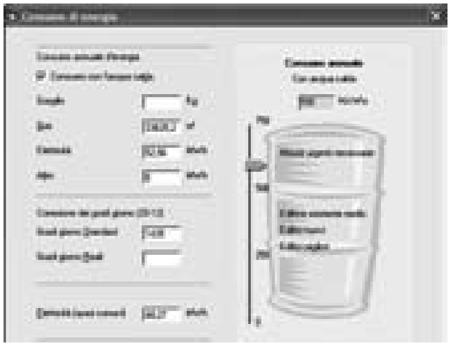

Fig. 3

Epiqr software: input data of energy consumption; on the right a first rough evaluation of the energy performance of the building and the necessity of refurbishment actions.

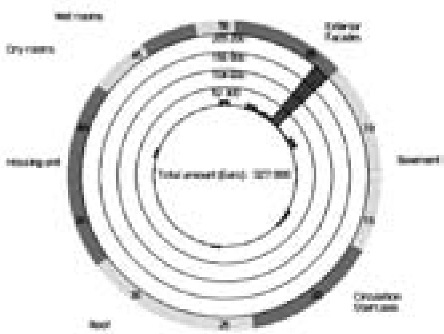

Fig. 4

Epiqr output: cost predictive retrofitting estimation; results graphically show which part of the building (in this case the facades) need urgent intervention.

The involvement of the student on its own house opens to margins of responsibility, implies somehow the individual engagement and aims to give a problematic dimension to principles and decisions. This approach can contribute to the diffusion of the personal interest in the energy saving problem. The student perception of the problem can be activated not only by the comparison of his own data with conventional ones but mostly with the confrontation among the various collected data. Comparing energy consumption of the same building typology and finding that his values are higher than the others, can stimulate the wish to reduce them by identifying the best possible solution.

Didactic at the second and third level

Working with other specialists (mainly professors of building physics) didactic experimentation at further levels allow to introduce the use of more complex simulation and testing tools among which: Ecotect v.5, Epiqr, Design builder, energy plus or other national tools (i.e. Acca Thermus).

Ecotect v.5 allows to perform solar analysis (shadow display, reflection display, solar exposure, shading device design); lighting analysis and thermal analysis. It is possible to check the consequences of orientation, shape and materials of the building in terms of thermal performance but it is not possible to integrate these considerations with technical devices (as heating system).

Epiqr is a specific tool developed inside a European research program, devoted to sustainable maintenance and refurbishment of residential building stocks. Results of Epiqr combine energy saving evaluation (of the actual state and of refurbishment actions) and a rough cost predictive retrofitting estimation.

Design builder – Acca thermus (and other national tools allow dynamic energy simulation to better evaluate the most suitable refurbishment action (in terms of annual energy costs).

Results of didactic experimentation

The workshop represents an important occasion to think about the new possibilities and benefits offered by testing and simulation methods in the design process but, in the meantime, about eventual risks. The large part that teaching activity sometimes devotes to these methods could possibly give rise to a segmentation of the design process, and the student could fall in an excessive reductionism, forgetting that the architectural project – even if under the constructive point of view – is mainly a synthesis of complex knowledge.

As immediate results, students acquire ability and knowledge to enter a labour market under fast development. Anyhow, although this is a very important result, other aspects could be carefully considered.

First of all, in the school of architecture it is possible to use just “rough” software tools and not very accurate. Different calculation methodologies offer a simplified or a more complicated way to reach reliable results. Students are not able to verify reliability of results (that also depend on simplified or more complicated calculation methodologies), and, going deeper with our research (among teachers!) we found that in some cases deep attention must be given to input data because it could not respond

Fig. 4

Epiqr output: cost predictive retrofitting estimation; results graphically show which part of the building (in this case the facades) need urgent intervention.

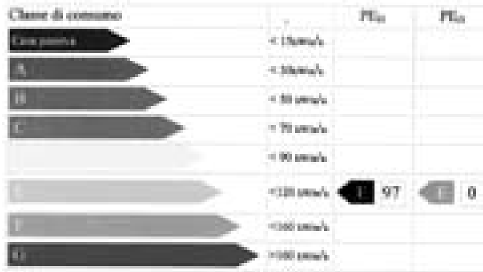

Fig. 5

Energy classification of the building case study applying italian user friendly software.

to reality (model or simplification?). In other terms, simulation tools can give good results if properly used, but in general the students are not able to verify it.

Another significant result (less direct but more significant in cultural education) is that this kind of testing tool could reduce the building to an efficient machine (results are numbers!) and could induce the student to lose a very significant part that is linked to the idea of Architecture. This is happening in Italy especially in the Schools of Engineer-Architecture, much more oriented to energy consumption and energy saving problems, but less oriented to understand complex significance behind the term "Architecture".

Using a paradox, the following question could be: why what is considered at least among scientific publications as "sustainable architecture" has always the same image (at least in the images from web network)? What is more important in an architecture, the thickness of an insulation layer or the building in its whole? Is architectural production going towards the free choice among "globalized" and "pre-fabricated" images? Have digital tools a responsibility in this?

Which kind of professional figure do we have to educate in our Schools of Architecture? Which kind of skill the student should gain during his training? An "holistic" mind, able to reduce single parts to the whole or a specialist, able to go into several technical problems in more depth?

The debate, still opened, in not only referred to technical disciplines but regards nowadays all professors involved in the Italian Schools of Architecture, in consideration of the new teaching reform that has to be applied next year.

Fig. 7

Ina-Casa quarter of Bernabò Brea in Genova, pretty well known for its rationalist character. This building has been chosen as another case study. Detail of the window.

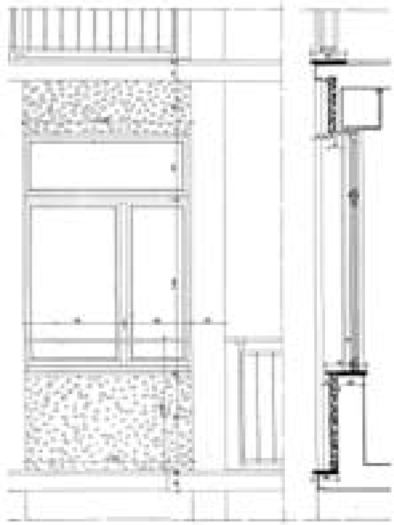

Fig. 8

Genova, Bernabò Brea: original drawing from arch. L.C. Daneri showing the composition of the window frame. How to insulate this part of wall without loosing original characters?

Fig. 10

Copenhagen, west Vesterbro: dialogue between tradition (massive architecture) and innovation (pv cells) added to a new external addition.

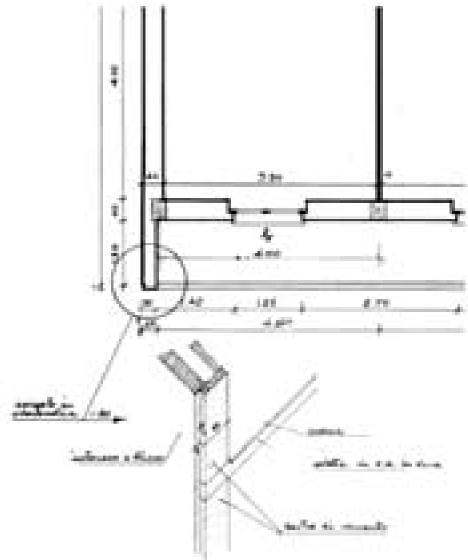

Fig. 9

Genova, Bernabò Brea: original drawing from arch. L.C. Daneri showing the composition of layers in the external wall.

Quality of the project, quality in the project

The actual and future scenario shows us rapidly the following conditions:

- Building design is getting closer to enterprise
- There is a convergence of the design process with construction
- Design team is becoming more and more a sort of trans-disciplinary aggregation
- It is always necessary to guarantee the real feasibility of the project
- It is also necessary to control, in each phase, the building process

As an immediate result, and looking also at industrial production, quality should become a fundamental attribute of design process.

Testing and simulation tools (at least that we use) guarantee the quality of the project, but not necessarily the quality in the project (in other terms as teachers we should aim to lead the student to brilliant results and not just to correct results).

The didactic experimentation in the field of sustainable refurbishment convinced us that more and more it is necessary and appropriate to work with the students on the design or project activity as a complex work, in which it is necessary to dialogue with specialist in the mean time escaping hyper-specialisation.

The way chosen to make the students aware of the complexity of architecture design process and maintenance is to make them working on existing buildings characterized by strong architectural features, in order to better highlight conflicts and contrasts generated by the new possible refurbishment action (for example adding a new insulating layer, substituting Windows, adding solar screen…).

Students are therefore guided to follow some crucial actions:

- the identification of different values and systems
- the compatibility between different purposes
- the identification of constraints and conflicts
- the choice of suitable tools
- the optimisation (and no more maximization) of one system in respect to the others.

Jelle Laverge

Department of Architecture and Urban Planning
Ghent University
Belgium

Modeling Building Physics: a Tool for Integrated Design

Dramatic changes in the environmental balance on planetary scale call for a new energetic consciousness. Various studies have indicated the importance of the building sector in general and architecture in specific in climate action. Now stronger than ever, high (legal) performance standards, for both comfort and energy demand, stimulate fully integrated architectural and engineering design.

Computational modeling can be one of the strategic means to further promote this integrating reflex in architectural practice and education. Simple static 2D models are easy to use and even to build in a spreadsheet. Nevertheless, they provide quick and crucial information on feasibility of design options and architectural detailing, bringing more cohesion to the architectural concept.

On a different level, advanced dynamic modeling can have an even greater impact on the design process since it will provide detailed information on the viability of the whole integrated concept of the building. By introducing modeling early in architectural courses, students have the opportunity to develop skills that enable them to create and interpret these powerful tools.

To achieve fully integrated buildings, attention must also be paid to the execution phase of the building project. A 4 of 5 dimensional approach of modeling, which incorporates planning and technical data, provides robustness to the concept. These models (BIM) are still highly experimental. Not only will applying them in architectural courses facilitate their introduction in common practice, it is a powerful review mechanism to further improve them.

By reviewing a 'Low Energy Building'-seminar and a design project in Masters classes, the advantages and pitfalls of these approaches will be discussed.

The building process: a historical perspective

Without any pretention for accuracy, a short overview of the evolution that has marked the building process throughout history will put the present day situation in a more elaborate perspective.

Since the very beginning of building, it has been a group process. Building involves substantial charges and complicated manipulations that necessitate the involvement of more than one person.

Where it can be assumed that at first the owner himself and a group of helpers constructed the building to their on ideas and possibilities, soon specialization brings about the introduction of the professional builder. The exponent of this all-in-one builder is the medieval free mason. From this point on, further specialization due to increased need for technical knowledge and development of esthetical theory introduces figures like the engineer, the (specialized) contractor and the architect to the construction field.

Although the distinction between the 'designer', the 'calculator' and the professional 'executor' can't be made as sharp as this formulation would suggest, the principal idea of progressive specialization is essential.

The next step involves the appearance of the technical engineer, the acoustical engineer, the building physics engineer, the state agent, the insurer, security advisor, the EPB reporter, urban planning authorities…

The field of people engaged in the building process is ever expanding, as is the number of specialized branches within the process. Each of these actors has his own agenda and expertise. This often introduces not negligible coordination difficulties into the project. Technically, the project benefits from the dense competences that are addressed, but the diversification of actors in the process launches new challenges to the means of communication. On top of that, the growing complexity of the building process renders most projects impossible to handle by the traditional one-man architect. Group practices and partnerships, where every member has his own specialty now represent most of the architectural offices.

Next to the ongoing concentration of the activities around these specialisms, the representations used in communicating the project have undergone considerable technical improvements since the introduction of graphical computer programs and CAD-standards, but the basic form of representation did not change since the medieval realm. The common form of document that is passed on between the different partners now controlling the building process, is still the 2D schematic plan. As buildings become more and more complex due to scientific progress in the field, the shortcomings of this technique increasingly limit the efficiency of the output. Since economical imperatives contrarily require increasingly higher effectiveness, alternatives receive elaborate attention in contemporary literature.

Although their market share is still limited, new 3 dimensional component based virtual models (BIM)[1] steadily gain importance because of the triple advantage they have over the 2 dimensional drawing. Firstly their open platform architecture makes it possible for every user in the project to access and append the same model, which decreases double work and copying errors significantly. It is evident that the mentioned coordination issues are largely tackled by this. Secondly they offer a much more 'tactile' model for the owner to judge the different alternatives proposed by the partners. Thirdly they provide a robust platform for the exchange of electronic information. Due to the ongoing specialization, each task of the different actors has a high level of professionalism and involves progressively more computation. Computer models in fact become the very basis of most of these activities. Resolving compatibility issues between the different models is one of the main reasons for and merits of BIM-development.

Simultaneously with BIM, the classic triangle of Architect, Contractor and Owner is broken and replaced by the 'Building Team'. In the classic configuration, the architect designs the project in relative isolation and the contractor executes the design. This exaggerated but nevertheless meaningful witticism shows the explicit responsibilities of the different parties in the contract. This formalism is legitimize by its 'objectivity'. Since the architect is responsible for the entire design, he will be critical in assessing the quality of the work done by the contractor and since the design is not 'owned' by the contractor, several contractors can be consulted, resulting in the best possible price.

Although these merits are often true, the altered context of the building process reduces their profitability considerably. Not only does it require tremendous amounts of energy to produce a complete and objective file for every project, the useful knowledge of contractor is completely ignored. Because of this waste of knowledge, incompatibilities between certain proposed components are often overlooked, causing pressing problems during execution.

Within the 'building team'-configuration, the contractor and all other partners in the building process are chosen from the very beginning and all of them contribute to the design. This way, the incompatibilities should be overcome. The early involvement of the contractor also makes it possible to reduce considerably the total length of the building process, from initial intent to build to completion. Of course, this also reduces the objectivity of the design. Practical experience teaches that the balance between pro's and contra's of both arrangements is not univocal and should be considered for every project individually. A decisive parameter in this balance is certainly the complexity of the project. The more difficult and the bigger the project, the more the advantages of the 'building team'-approach will dominate the disadvantages.

Generative energetic assessment

Within the building process, energetic and building physics modeling (and by extension all technical modeling) can be implemented in two ways: either it can be a limiting assessment that renders existing proposals 'impossible' or it can be a generative instrument. Although it is clear that the second implementation is preferable, technical 'boundary conditions' are often perceived as limitative. This aversion towards technical issues is plainly visible in the place the engineer occupies in the classic design process. All too often a finished design arrives at his table for him to 'solve'. The implementation of building technology in this design is then repeatedly impossible without spoiling the architectural quality.

When on the other hand these 'boundary conditions' would be approached as possible narratives for the concept, they could possibly add value to the whole in stead. Sufficiently accurate and user-friendly models that offer the possibility to immediately evaluate the performance of a design alternative or a decision. This performance can as well be energetic (EPB)[3] as ecological (LCA)[4] or economic (planning, budget) etc. Here to the recent emergence of BIM and the 'building team'-approach offer additional possibilities. With the use of BIM, the designer receives important feedback on the quality of his concept on various benchmarks. The building team makes sure that the intellectual resources to interpret the results of the benchmarking and put forward realistic goals are present from the very beginning.

The designer can no longer hide in 'perfect isolation' but has to share some of his decision making authority with the other partners. Once again, the 'objectivity' of the design will be less, but when all actors in the process are sufficiently talented, the final concept will be significantly richer because it encompasses different fields, forming a well integrated design.

Pedagogical Background

Collaborative learning is, although already vastly discussed in literature, still the subject of a lot of research in pedagogical science. New models and findings are published frequently. Most of the research agrees that collaborative learning is a high performing setup for a learning environment. The learning results achieved by every group-member are highly dependent on the specific construction of the collaborative environment and the design of the assignment.[5]

Next to more evident criteria like a clearly defined task, a description of expected output etc. the assignment of specific roles to each of the students individually proves to be determinant. To achieve the maximal efficiency, students need to be both dependent on the total result of the group and their own individual work for the final evaluation of the exercise. This makes sure that more perspectives of the assignment are included in the discussion and that each student has to contribute substantially since he of she can not claim the work of someone in an other field.

The roles the students take should be chosen carefully. Most of them will naturally be within the possible positions the student will have to fill once they enter the job market. On the other hand, some 'opponent' roles (like the contractor or the accountant in the building process) can be very interesting since this perspective is usually not included in the process and causes the concept proposal to be imbalanced.

From the teachers side, careful consideration is needed when distributing the roles and allocating students to the different groups. Special attention needs to go to the 'career' of the over successive assignments. Although specialization is normal – students regularly tend to choose the tasks they like or know best – the staff needs to make sure that a sufficiently broad spectrum is covered during the program. This means that sometimes students will need to be forced to take a certain role against their role. The importance of the individual final attainment levels for every role can hardly be overestimate in this matter. This prevents students from altering the description of their role to such extend that they manage to 'escape' the curriculum items they dislike.

To manage the information exchange needed for these assignments, broad research on computer assisted collaborative learning (CSCL) environments has been conducted i.e. by Valcke[6] and indicates that the learning output of the assignment is highly determined by the setup for the communication environment, both in face to face meetings and in CSCL. One again, the quality of the preparation of the exercise by the staff is crucial.

Conclusions for education

From all considerations mentioned above, a few general conclusions for the organization of architectural education can be deduced. The field of the building process is in constant motion, with ongoing specialization and ever growing complexity as thriving forces. Computer models increasingly dominate the activities of the different actors. The emergence of multi-person offices as a new practice-standard in the architectural field was already briefly discussed. Moreover, the ever larger group of people involved in the building process was elaborately touched in the first paragraphs.

With this perspective for his future employment, the contemporary student in one of the disciplines of the building sector, should acquire excellent communication skills next excellent competences in the specific part of the spectrum the program addresses. Within these skills both soft skills and technical skills are included. While technical skills like being able to clearly represent the envisioned proposal in comprehensive drawings, models and schemes for the other partners can be learned individually, soft skills like tact, discussion management, reasoning and judging the value of an argumentation are in essence learned in interaction.

In most educational programs, the need to develop these interactive competences is mitigated by forcing the students to work together in (small) while working on a project. Pedagogical research indicates that this form of cooperative learning is a very powerful instructional tool, but also points out the high context dependency of the efficiency of the technique. The danger lies in the difference of the individual learning curve of the cooperators. To assure that all participants learn as much as possible, the specific design of the exercise and the groups is crucial. More specific for the design project, students need to 'play' the different partners and oponents (or at least some of them) within the building process instead of all being the designer. The final result should also be judged on two 'independent' sets of criteria. This may include different additional jury memebers for each group member that have explicit expertise in one of the roles.

In addition to these formal constraints, and moreover in interaction with them, the contents can focus on the integration of different perspectives sprouting from the discussed specialities, different branches of the art etc. in one rich concept.

Case 1. Design Studio 'Kaaitheater'

In this case, I will try to demonstrate how integration is attempted in a design course in the Master of science Engineering: Architecture program at Ghent University. The course is a classic design studio for the first year master students. The course described took place last academic year in a pioneering tryout.

Students tackle a renovation in a theatre building in Brussels, and get the choice which kind of perspective they want to embody. The possibilities were 4-fold: the classic designer, the technical engineer, the civil engineer and the façade-expert. The last three categories are combined to one 'technical studio'.

In a first stage, design teams with only the designers are formed. They start the project by developing an initial special concept. In the mean time, the different groups in the technical studio each prepare specific proposals for typical issues encountered in theater design. After a short initial period, the results of all groups (both designers and technicians) are evaluated by a intermediate jury, giving them feedback on their opening work. After this, where possible, design teams are joined by a technical advisor of each category. They now form a broad group of different actors within the spectrum of the building process as described above. To prevent that the technical advisors either isolate themselves from the original group or abandon their technical mission, they are subject to two final juries: they are evaluated partially on the total quality of the concept together with all members of the design team and partially on a presentation of their own specific work.

To help them generate as much background knowledge as possible, the technical studio also remains active as a whole after the reformation of the groups. In these meetings with all technicians, they discuss problems they encounter and try to develop a few general models that can be used by all design teams (including the ones that did not get technical advisors). The different groups within the technical studio form 'consulting groups' that offer advise on their own subject to any design group that has specific questions. For each of these 'consulting group' a few workshops with experts in the field are organized.

In this case students used all kinds of models and software to communicate their ideas to one another and to the staff. No specific demands were made. On the other hand, the staff consistently asked for numerical proof of the propositions made by the design teams. Models here had both a limitative and generative function. By eliminating options that performed badly, the overall quality of the design improved considerably. On top of that, the general models developed in the 'abstract' discussions in the consulting groups provided additional input for the design process. The combination of this double function with the heterogeneous composition of the design teams (designers and 3 kinds of technicians) from a very early stage of the course rendered more rich and integrated design concepts. Although all groups could benefit from the more rich competences that were available in the studio by means of the consulting groups, the expected increase in quality was especially significant for the teams that included technicians.

Case 2. IFC-master's thesis programs and elective courses

In the case discussed above, the stress was laid on the context and the organization in which models are used in the design studio, how they are a tool for generating content that augmented the integration of different perspectives in the project and result in a richer concept. In this second case, I will focus on master's thesis programs and an elective course now in execution in the same master's program.

The goal of these courses and projects is the development of a tool that combines the advantages of BIM with the flexibility needed for the design process. Based on the international IFC standard, an international interoperability standard, this tool should both possess intuitive (special) modeling capabilities and accurate, powerful evaluation engines for structural integrity, energetic performance, planning, economic feasibility etc.

This very broad research is divided in several subtasks. The research staff is engaged in the development of the main engine of the whole tool: the conversion of richly labeled geometrical data (ifc)[2] to workable definitions of space, volume… From this central engine, the work both upstream an downstream is taken up by students.

For their master's thesis, 3 students try to link the engine to planning, accounting and visualization software respectively. They focus on the links between these software packages and propose a general strategy for linking the engine to any kind of application. The link should make sure that users of the tool get immediate information about their design and the effect of changes they make. An other group of students works on the link downstream between modeler and engine in a special elective seminar. They try to generate useful data with very simplistic modelers that are suitable for spatial research. Both links should be bidirectional to ensure dynamic interaction between all components of the tool, a crucial quality because of the fast .

Both students and researchers are assisted by a group of students that use this engine in their design process for their master's thesis to try and find bugs and propose additional functionality. They are a first test group for the early versions of the tool.

Further research and intentions

Both cases are presently in full development. For the design studio, the staff recently formulated the intention of reforming the staff from the present rather homogenous group towards a similarly heterogeneous team as proposed for the students. This will again introduce more different perspective and specific expertise to the design process.

Once a fully functional tool is ready, the design studio will be an interesting betatesting group. The effect of using the tool in a real design environment will be investigated further. Remarks and proposals from this test group will then again be incorporated in the further development of the tool.

One of the next functionalities to be incorporated in the tool is producing technically correct drawings and schemes from the simply 'massed' model and all additionally 'labeled' information.

Co-authors

Nathan Van Den Bossche, *Doctoral Researcher at the Department of Architecture and Urban Planning at Ghent University*

Arnold Janssens, *Professor at the Department of Architecture and Urban Planning at Ghent University*

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Jelle Laverge

Department of Architecture and Urban Planning
Ghent University
Belgium

Pushing Architectural Quality further

In this paper, the intentions thriving the implementation of computational modeling of building physics as it is approached in the Architectural engineering courses at Ghent University are discussed.

During the bachelor degree, courses focus mainly on integration of basic building physics feasibility in the architectural conceptualization. During the final bachelor year, students program their own simplified 2D models for internal condensation and thermal bridges in a spreadsheet, based on realistic detailing from buildings they studied in other courses. These models are intentionally kept both simplified and strongly mathematically based to nurture thorough comprehension of the physical background of problematic design options. Additionally, evaluation of energy performance with official EPB-software is incorporated in the courses because of its high relevance as a legal benchmark. All these models, including EPB, are (semi)static and thus offer only limited but nevertheless useful information on physical, legal, hygienic… viability of different options at reasonable complexity. Furthermore, they induce basic modeling skills as a basis for further development.

During the master's degree, the focus shifts from taxation of the feasibility of design decisions towards energetic performance as one of the starting points and validation criteria of the design process. For students who wish to specialize in the matter, elective courses and master's thesis projects on optimization, innovative techniques, passive building standards etc. are offered in which advanced dynamic modeling is used. These models offer an important input for this specific design process as they enable precise, nuanced validation of the robustness and sensitivity for certain parameters of different strategies in a given, very complex, situation.

By developing both innovative, more precise models for the master classes besides more powerful integration of modeling with design software (BIM) and robust predesign templates for the bachelor courses with master's student cooperation, the research team supports these courses in achieving output of the highest possible quality.

Introduction

Architecture and modeling have a very intimate relationship since models, even more than the buildings they eventually represent, are the core object of architectural production. Each building that is built is unique and therefore, in contrast with product design, prototyping and beta testing is unrealistic. Architects employ models to represent and fully understand the different aspects of the project in the planning phase. 'Models' are here to be interpreted as representations in general, so they can be sketches, digital imagery, schemes as well as text, physical scale models and material samples.

Design decisions are based upon data that is derived from these models. A fortiori, the project is even presented to contractors, legal administration and different stakeholders by sole means of this fictive image. Therefore, although some changes can be made during execution, it is crucial that the models, as means of communication, hold as much and as accurate information as possible. Architectural quality is or at least should nevertheless be defined by the aspects of the built object.

Because decisions and evaluations are based on the model, architectural quality in the planning phase is a function of the correlation the architect can establish between the representation and the actual built object. In light of this philosophical paradigm, the task of architectural education mainly consists of equipping students with skills to model their ideas and retrieve interesting information from these models that accurately predicts the future state.

The questions that arise from this simple notion are to what extent computer technology can help develop these skills and in what context it offers the best performing model. Computers, by definition, offer superior computational power, which enables the user to access more, and more detailed, results. Moreover, the reduced calculation time allows for more reflection on the data. The actual impact of these expanded resources on design quality will be determined by aspects and quality of the pedagogical setting in which they are used.

This paper will focus on the implementation of computer models in building physics classes at Ghent University. The goals and the pitfalls of the implementation will be discussed for both the bachelor and masters degree programs. Concluding, further intentions of the research staff for the future developments will briefly be discussed.

Bachelor education

During bachelor degree courses, students are supposed to adopt certain attitudes in assessing their own designs. The ability to present a technically coherent design is one of the specific goals this academic bachelor degree envisages, as stated in the description of the program in the academic educations register of the Flemish government[1]. Two explicit subtargets are given, namely understanding the underlying scientific and practical principles of building and acquiring skills to represent (model) the design both graphically and digitally. This is clearly inspired by the philosophical context presented in the introduction. Through the different classes they start with the simple knowledge that energy supply is limited (fact), gradually forming a concept of a low energy building, relating this concept to energy saving measures and combining these measures in a low energy strategy for a building, thus ascending the taxonometry of knowledge as defined by De Block[2]. The final goal of this path is that they attain a low energy attitude, always reflecting the consequences of their (design-) decisions in an energetic dimension. To achieve this, theoretical courses, practical exercises and a project are given. Within the same taxonometry (De Block), these approaches represent knowing, understanding and applying the matter respectively. The final stage, forming a well developed attitude for energetic reflection, is the achievement the students need to prove in the final design studio. Their design is rated on overall quality, detailing and performance both spatially and energetically.

While building physics is taught in an analytical way, students are asked to demonstrate their understanding of the matter through solving simplified problems during the practical exercises. Here computers are first introduced. During exercises, students use simple spreadsheet programs to calculate the data needed to find the solution. The spreadsheet they develop at the end of an exercise is actually their first rudimentary model. By saving the file, they now possess a template for the calculation of, for example, the one dimensional heat loss through a wall. This may appear trivial and of little practical use since buildings are essentially three dimensional. Contrary to this first intuitive appreciation, this model is of crucial importance, since it is the basis of all more advanced models, including the EPB-tool used for building licensing. The fact that students build this model themselves is essential, since it makes sure that they understand how it relates to the physical phenomena it represents. Adding to this bit by bit, they eventually model a year-long condensation balance in a spreadsheet.

This model is then applied in the project to evaluate and improve the performance of their own design. In close collaboration with the design studio, a framework was created to apply the learned energetic concepts. At the introduction to the studio, the energetic feasibility of the design and detailing is stressed as an essential evaluation criterion. After a short conceptual phase, students get a new assignment, but continue working with the spatial concept and the self-made model in the building physics project to evaluate the performance of their initial proposals. The data generated is used to propose variants with better performance, which are elaborated further in a more technical perspective in a separate project. The final results of this continued development is then picked up again by the design studio and reintegrated in design. That last step has proved to be both the highest hurdle to take and the most decisive moment in the learning process, as students only then fully appreciate the power of the model as a decision making tool and the impact their alternatives can have on the total design.

With the introduction of energy performance directive, the above mentioned strategy was abandoned slightly to give way to a more elaborate training in the legal EPB-software. Students were now no longer required to use their own models but followed an intensive workshop with the legal software. The assignment for the project was essentially the same. Although the now used software is much more elaborate, results of the project appeared poorer. The projects now featured a myriad of exotic techniques, but often lacked a coherent concept or a detailed analysis of the problem. In their oral presentation, students also proved to be less capable of explaining the fundamental physical processes determining their design.

Although these findings are purely subjective and not statistically analyzed, they indicate the importance of the tool. Architecture can essentially be described as a 'wicked problem' as described by Rittel and Webber[3] for which Munneke et al.[4] among others described the influence of different representational techniques in interactive argumentation. In the context of the EPB-software failure, the findings of Suthers[5] that students may lose themselves in the exploration of a complex tool, seem to apply.

Masters Degree

The strategy for the bachelor degree layout, as discussed above, is designed to ensure that students produce architectural output of high (technical) quality, in accordance with the goals stated. Although the contemporary situation of the construction sector can only benefit from this benchmark, this is not sufficient to answer the acute need for innovation in building physics sprouting from energetic developments on planetary scale. The skills required to tackle this more fundamental branch are tackled in the master's program. Students are free to explore one of the many fields touched in the bachelor program more profoundly and specialize themselves in this matter. Since an academic master's degree presumes a capability to critically reflect and innovate existing knowledge, the mission statement of the masters includes developing the ability to conduct autonomous research in the field of the chosen specialty.

As discussed above, experiments in bachelor degree courses pointed out that high quality output and the related high value engineering skills are only feebly triggered by simply using preformatted software. Better learning results are achieved when students program their own models based on their theoretical knowledge. In future projects the latter will obviously be preferred.

In light of the intentions of the masters program[1], the focus there is shifted towards more innovative research. Students are now expected to be capable of understanding the physical background of innovative systems and cooperate with the research team in different projects. Two main tracks of participation exist: either through elective courses or through the master's thesis. Both focus on specific subjects like passive house standard offices, modeling the influence of surface treatment on efficiency of natural night ventilation or qualifying thermal comfort in a building.

Entirely different computer models are used for the various assignments. The models and the way they are approached can again be categorized twofold.

In the first category, models of a certain research component do not exist or are still highly experimental. The goal of the project then consists of developing, testing and validating the model. Since the models used in this particular context are very complex, individual students are no longer expected to program them themselves each time. Either they are responsible for the development of one part of the model in close cooperation with research staff and fellow students, or they validate the model that others created against available measurement data. Special attention in this particular stage goes to compatibility of the model with existing software environments like the academically well known TRNsys.

In the second category, the performance of certain techniques is validated. Here the weight of the investigation moves from the component to the building or system as a whole. The impact of certain components in the system and the sensitivity of the system to its characterizing parameters are qualified by modeling the whole of the system or building in a simulation suite. Rather than developing the model for the physical process, the goal is to build a model for feasibility. For this, the students can rely on data produced with earlier developed models for input. Here the use of elaborate and easy to use software environments in the preparatory stage is evident since this phase must be as short as possible. Nevertheless, experience with similar self-made models in the past is crucial to analyze the produced data correctly.

The emphasis that is put on innovative research and highly specialized modeling is of great value to the students as future architects and engineers with an appetite for the field of building physics, because it enables them to further nurture their recently acquired energetic attitude and familiarize themselves with state of the art technology. Evidently, their work is also beneficiary for the department as a research team, the scientific community and for society at large.

Next to this specialized research, which interprets the use of computer models essentially in the way described by Schmitt[6], new initiatives are deployed in the design studio of the master's program. The expertise based on the results of the specific research teams will in the future be implemented in the design studio of the masters program by means of a 'consulting group'. This group of researchers and professors with more technical background will assist the design studio sessions. Their task will be to confront students with technical issues in their design concept and relay them to the students and researchers who are working on that subject. This way, students benefit directly from the expertise and the models that are developed as described above. Interesting new concepts that arise from studio work, can of course also be a subject for deeper research. Next to this 'catering'-facility, a special type of specific research is conducted in the field of modeling itself. A special research project, in cooperation with the laboratory for information technology, now combines two essential models: the graphical representation of the design and the analytical model for energy performance.

This coupling, established in the international IFC-standard[7] is one of the steps that brings effective Building Information Modeling (BIM)[8] one step closer. Four Master students are now using the beta version of this software in a design process to assess the possibilities and problems of this setup. If these test runs are successful, this software will be introduced in the design studios of the different programs for large scale testing of the impact this linked model can have on design output.

It is expected that, since the graphic model now gives important feedback on the energetic performance of the design, overall quality as described in the introduction will improve significantly.

Still, this in no sense lessens the importance of the model know-how acquisition process as it was introduced above. Although the model will report energetic inconsistencies, these can only be tackled by the student if he or she has thorough insight in the process that the data provided evaluate.

Complementary to this project, a new laboratory is initiated that will focus on computer generated physical models. The object of this research is the possibility to incorporate robotics in the construction process of a building. In the long term, the intentions are that students will be able to use the CAD-CAM technology in this laboratory in the design studio.

Framework

A last important issue that has proven to be essential in the success or failure of the use of computer technology based models in both the bachelor and master's program is the supportive framework for students. None of the described projects are possible without student access to the technology and the software. Therefore, again in collaboration with the laboratory for information technology and the university ICT department, wireless internet access in the building of the architecture department, free access to modeling software trough a remote access application and bilateral agreements with software developers are established for all students. Although this provides access, these measures alone proved to be insufficient. Lots of student projects failed to deliver the expected output within the provided timeframe because of unexpected hardware problems or problems with the software functionality. A test during the academic year 2005-2006 proved that the presence of a staff member specifically skilled to deal with these problems had a significant impact on the results. Therefore, the department has decided to appoint a new staff member as soon as possible to attend to this need.

Conclusions

In the introduction, modeling was described as one of the essential activities within architecture. In the corpus, intentions and implementation for computer models in the bachelor and master's program for architecture at Ghent University were discussed. The argumentation was presented to push architectural quality to a higher level, the focus should be on continued development of better and more precise models. The mission of education in this context is twofold: equipping students with skills that enable them to actively take part in this continued research and help them develop an attitude to incorporate energetic reflection in every part of the design process. The underlying idea is that using computer models is only efficient when the user thoroughly understands how the model works. Only then can he of she interpret the produced data correctly and base decisions upon them. Several examples were given of practical organization of this approach in courses and within a broader practical framework. Future research will try to assess the effectiveness of the proposed measures with statistical data.

Co-authors

Nathan Van Den Bossche, *Doctoral Researcher at the Department of Architecture and Urban Planning at Ghent University*

Arnold Janssens, *Professor at the Department of Architecture and Urban Planning at Ghent University*

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Tom Pawlofsky
Oliver Fritz

School of Architecture
Liechtenstein University of Applied Sciences
Liechtenstein

Cardboard-Buildings 1:1

introduction - industrial production nowadays

For most people mass production is seen as an endless chain of standardized products, such as cars leaving a factory. But for many industrial sectors, reality is quite different by now. To be able to react to the constantly changing markets, to the latest fashion and the latest technology, industry has already built up an infrastructure, that mostly uses computer controlled machines and therefore allows the production of lots of varieties and small numbers of items. Within this context the chair for architecture and digital media at the Hochschule Liechtenstein is focusing on the question, how the design process can be adapted to profit from these possibilities by using digital tools consistently. In the summer of 2007 the architect Oliver Fritz, who occupies this chair as an assistant professor and the author Tom Pawlofsky, who is a product-designer, arranged a series of full-scale experiments. In order to get important experiences and face all the consequences of a real set-up, two experimental buildings, made of corrugated board, were realized. The result of this series of experiments is a 55 sqm building, that serves as an additional space and can be used as a studio for the students.

From design to machine (Fig. 1)

These experiments are part of a research project, that examines the realization of curved surfaces in architecture with the support of computer technology. Already at the very beginning, this project showed, that it is very important to close the gap between the data, that are used for design and the data that are needed for driving the machinery. As long as these data are delivered, computer-controlled machines can produce unique items for the same price as they do for producing a large number of identical items. A laser-printer illustrates this very well: printing 500 different pages is just as expensive as one page, that is printed 500 times.

During these projects, a computer-controlled plotter is used to perform the labeling, the creasing and the cutting of corrugated board. To get the data for this machine easily, the design-process has to follow some simple rules regarding line colors and layer-management. This will allow a self-programmed command, that is integrated into the CAD-software. It converts the design-drawing directly into the machine-data. As a consequence the machine data for hundreds of items are generated with one click, without any gap or the use of any additional software. Therefore it is possible to mass produce unique items.

Mission

In recent years the institute for architecture and planning suffered from a limited working-space and required an additional and external workshop for model-making. For this purpose a temporary building was permitted on the ground next to the back entrance of the university. In the context of the described research project, the idea was born to realize this building with corrugated board because on the one hand it was common knowledge within the team how to handle cardboard, on the other the material would underline the temporary character of the building.

Fig. 1

Research project 'computer-aided curved surfaces in architecture', concrete-prototype, size 2.5 x 4.5 m

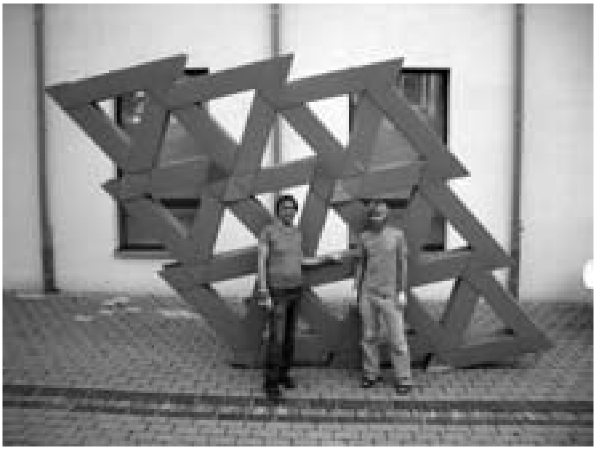

Fig. 2

One of the first models, Oliver Fritz (left) and Tom Pawlofsky

Fig. 3

Preliminary study, pavilion made of 450 elements

Preliminary study (Fig. 2, 3)

To gain the necessary experiences concerning material and logistics, a preliminary study was set up:

The students were asked to design a temporary shop for a shoe company within one semester. This project was also important to find out, if the construction of a 1:1 scale building in cardboard could be achieved in teamwork with the students, mostly without external help. At the beginning a lot of models in different scales were used to explore the possibilities for the construction. Later the final pavillon was made of 450 similar but unique elements. As this experiment was meant to last only for some days, a few weeks at most, the weather-protection could have been an experiment too. It was done with liquid packaging board.

Design - Educational framework

This first, and mostly pleasant 1:1 experiment, was a great help to set the framework requirements for the final building and answered a lot of questions. It showed, that it is a big advantage to have arched cross sections, for it is quite difficult to handle tractive forces within a cardboard-construction. Furthermore a curved shape allows a construction out of elements that are all the same hierarchy, regardless whether they belong to the wall or the ceiling. Additionally, the finally curved body was predefined mostly by two factors: The ground plan had to respect an existing, untouchable tree and the final outbuilding shouldn´t sheet the windows of the main building.

The final design is a curved cardboard structure out of 600 different but similar elements with a base area of 55sqm. The building is installed on a wooden platform that serves as the foundation and is equipped with electricity, water and wastewater. The construction is covered with a translucent foil to be protected against the weather.

To realize the final outbuilding a two-week course during the summer holiday was announced and six students signed in. As it was obvious, that the complete work couldn't be done within this time-span some design-decisions and some steps of production had been anticipated.

From shape to cardboard (Fig. 4, 5)

All steps - from designing the shell, the 3d cardboard-geometry, the 2d-patterns and the generation of the machine-data - used a digitally drawn geometry to transfer the data to the next step, regardless if it been done manually using a 3d software or using scripting technology. Therefore each step could be developed as a independent procedure and the result could be controlled visually at any time.

At the beginning the shell was designed by a 3d software (Rhino3d). This shell got triangulated with a manual method, that enlarges the concept of geodetic spheres as it is commonly known from Buckminster Fuller. The aim was to create nearly isosceles triangles of almost the same size. Furthermore each knot normally touches six triangles. But to realize the curvature some knots only touch five triangles.

After fixing the positions of the 400 knots on the shell, all further steps were taken with single, independent scripts. As there are more than 600 elements, it is nearly impossible to draw them manually - even with the help of a computer. Those scripts can

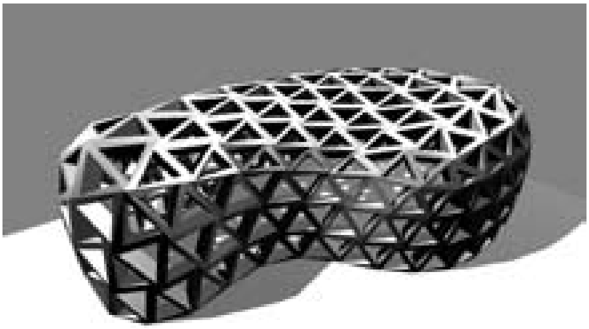

Fig. 4

Generated cardboard structure for the final outbuilding

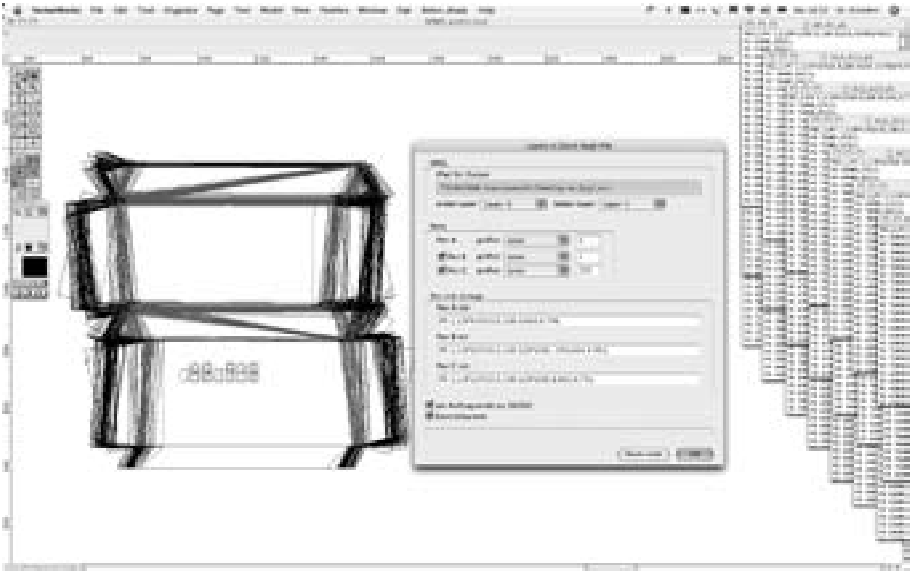

Fig. 5

Self-programmed command: generate 200 machine-jobs with one click

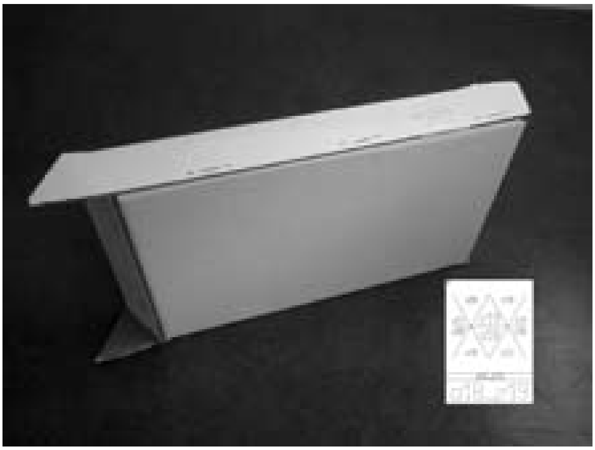

Fig. 6

One of 600 elements, cut and creased on a CNC-machine, assebled and pasted up with a sticker, detail: the sticker used as a non-central plan be compared with a batch process or with the mail-merge-functionality offered by some text editors.

The first script generated the triangulated surface and converted it into a cutting pattern for the skin. Then the geometry of the cardboard was generated in 3d, already containing all the details such as joints. The next step was to unfold the cardboard geometry and to organize the naming of the parts. Then the 2d geometry for the skin and the cardboard were transferred into the data for the plotter. The last script generated stickers that were printed and attached to each element.

The entire scripts can be regarded as a toolbox that handles all the steps from the design to the machine within some minutes and without any careless mistakes. But as this toolbox consists of single tools, which all take a drawn input and generate a geometry as an output, all the scripts or tools can be changed or affected very easily.

Non-central plan (Fig. 6)

After all the parts had been signed, creased and cut with the process above, the set-up began. Unlike a common master plan it was organized with a non-central system. The sticker of each element carried the naming, its position and its neighborhood. This system of intelligent puzzle-parts was used successfully for the set-up. An overall plan was only required for welding the foil that is used as a weather-protecting skin.

Set-up (Fig. 7, 8)

The main structure consists of non-rectangular cardboard boxes, where each element is aligned to the edge between two triangles. Each element is slightly different from the other and has a predefined position inside the triangular grid, that is approximating the doubly curved surface of the shell. The corrugated board is coated with paraffin - normally used for fruit trays. Therefore it offers a higher consistency against humidity. At each knot the joints are realized with overlapping flaps, that are glued and fixed with a clamp to the neighboring element. The circular overlapping results in a windmill-like arrangement. To be assembled more easily, each triangle got a black strapping. The elements got pre-fabricated inside the university. To start the assembling outside, a wooden plinth with a ridged top edge was connected to the platform. It is used as a splash guard and as a positioning device.

Finally, the assembled cardboard construction was covered with a customized tarpaulin to protect it against rain. Its fiber-reinforced, but translucent material is based on PVC. The single parts were welded together by a professional company. The distance between the tarpaulin and the cardboard was established with old tennis balls. Fortunately the tarpaulin had been attached just one hour before the first rain fell. At last at the opening party, everyone was happy about the final result and the comfortable ambiance inside the new "Modellbauwerkstatt".

Perspectives (Fig. 9, 10)

It should be emphasized, that these projects did not only focus on the set-up of an outbuilding for the university, but that they also examined how to give the students an understanding of the latest production-technology. In former times, maybe a bricklayer-internship was sufficient. Nowadays, however, it has become more complex to

Fig. 7

Preassembly inside the university

Fig. 8

Final set-up situation: the wooden platform, the untouchable tree, the riged plinth, the cardboard structure, the tennisballs used as spacers

Fig. 9

Indoor view, the opening party

Fig. 10
The new 'Modellbauwerkstadt' at night, Hochschule Liechtenstein, summer 2007

transfer the latest technological development into a readily available example. Hopefully these experiments show how the creative power of CNC-production can be transferred into the context of a university and offer the students the necessary experience. It should also be possible to transfer the gained knowledge to other materials or other computer controlled methods of production.

Hopefully the know-how that includes the full workflow from the idea up to the machining permits the backward influence: architects can be aware of the full potential and broaden their understanding of what is possible.

The projects have only been possible because of the beneficial support of some commercial partners. We want to thank:
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Session 3

Form and Structure
- Testing and Simulation

Chair: **Ramon Sastre** *UPC, Barcelona, Spain*

Maria Vrontissi

Department of Architecture
University of Thessaly, Volos
Greece

Modeling Structural Behavior from an Architect's Point of View

A dynamic design process to deal with the 'living' building entity

Recent developments in material science, advanced structural engineering and manufacturing techniques possible through advances in computational technology shape a new reality directly linked with the creation of architectural form[1].

New, but differentiated, interest in tectonic culture, in materiality and in manufacturing processes and production systems is developing, while the traditional concept of the building as a fixed static entity is confronted with the emerging idea of an interactive intelligent living entity, shifting from an organic to a hybrid structural morphology, from a fixed static building envelope to a dynamic responsive building skin[2]. Classic notions of structure, envelope and boundary are challenged and new terms such as performativity have been introduced, while the notion of interactivity has found a whole new meaning.

While the interrelationship between form, structure and skin, materials and processes is acknowledged, structural efficiency, material performance and environmental behavior become of key importance as powerful design parameters.

In this context, the need for a dynamic design process is arising, so is the need for the right tools and techniques, in order to aggressively engage these parameters into the design process. A dynamic process should take into account the active nature of the design parameters and allow possible interaction during the design process, the construction phase or even the (final) use. It should support more elaborate controls and be open to feedback, investigate modifications by checking results and identifying errors, promote experimentation by testing alternatives. Such a process demands and enables thorough knowledge of design parameters and overall building performance.

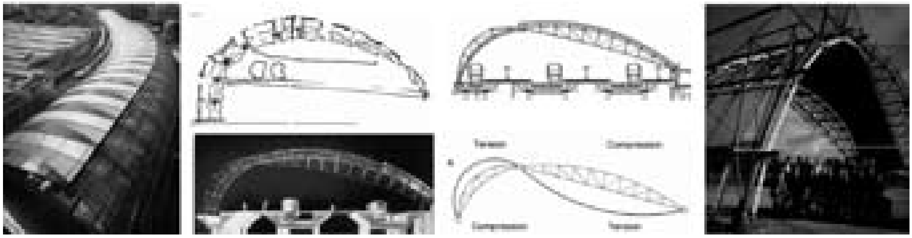
The concept of the active living building entity, where design, construction and use interact in a constant dynamic process[3], demands description methods based on simulating behaviors and performance rather than (re)presenting characteristics and properties.

Traditionally, drawings, diagrams, formulas, technical descriptions and physical models have been the descriptive means of (re)presentation containing information about structural and geometrical configurations, material and constructional choices (picture 1). The more interactive tool being the physical model (picture 2), either in the form of an accurate structural model in scale or in the form of a full-scale mock-up, not only containing geometrical and morphological information, but also able to indicate structural, material and environmental properties in scale or in full range[4].

On the other hand, digital technology applications, for long associated with analytical tasks, have only recently been used for architectural representation purposes or even for elaborate morphogenesis studies, as well as communication and collaboration means, yet still without exploring their full capacities as design investigation tools.

Structural behavior modeling tools: analytical, digital and alternative models

In an educational framework, structural issues are usually approached in an analytical rather than a synthetic way. Structures courses, usually taught by structural engineers,



Picture 1

Descriptive means of building (re)presentation (Waterloo Station, N.Grimshaw, T.Hunt)

Picture 2

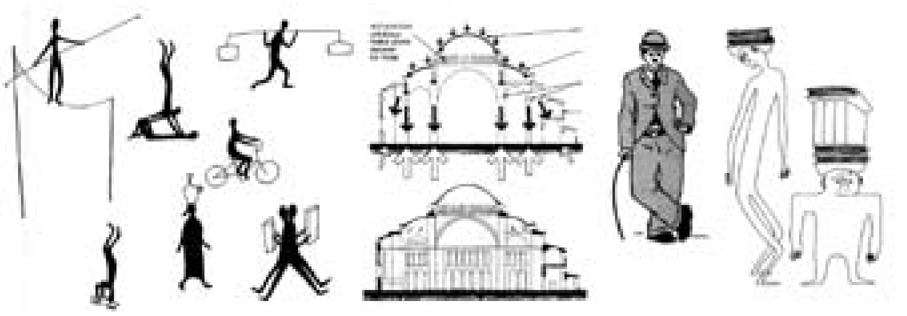
Physical models (re)presenting geometrical, structural and material characteristics: in scale structural model (Sacrada Familia, A.Gaudi) or full-scale mock-up (IBM Traveling Pavilion, R.Piano)

focus on the development of basic analytical methods and tools, hardly discussing structural design in a conceptual level, mostly emphasizing on the detailed analysis of primary structural elements with few references to their structural function within the whole structure.

Modeling the structural behavior and material performance of a building structure or component, usually consists of segregated pieces of analysis and preliminary sizing (defining the material, type and dimensions of the cross-section), performed and presented in a theoretical, nonfigurative, quantitative way.

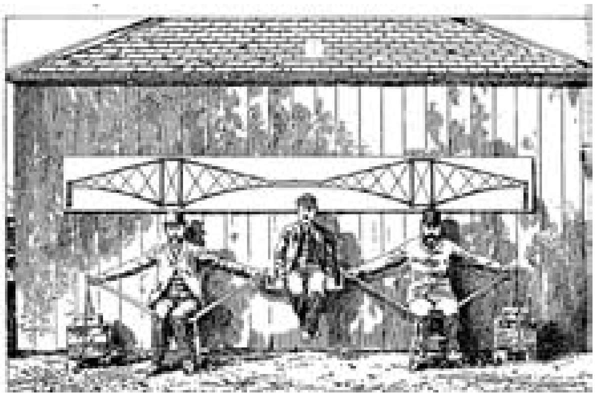
Based on applications of static laws and strength of materials principles, abstract calculation formulas (calculations usually performed by hand), tables of data, static structural diagrams and technical descriptions, this approach is believed to effectively build up systematic knowledge and to promote inter-disciplinarity. However, it barely develops conceptual awareness of structural and material characteristics[5,6] or enhances interactive design. Furthermore, the focus on primary elements is ineffective for the understanding of the overall structural behavior and is somehow narrowing the design vocabulary developing uncertainties about more complex structural forms[7].

Historically, qualitative approaches developing conceptual structural and constructional awareness within a creative design scope can seldom be found. Only in individual cases, alternative models discuss simple or elaborate structural concepts in vigorous ways emphasizing on visualization methods (picture 3). Structural configurations, material properties, loading conditions or end constraints, as well as force and stress distribution, are presented in alternative structural models (B. Baker (picture 4), M. Salvadori[8], F. Wilson[9], A. Zannos[10]), in conceptual structural diagrams (F. Moore[11]) or



Picture 3

Alternative structural models emphasizing on qualitative visualization methods (F. Wilson, F. Moore, M. Salvadori)



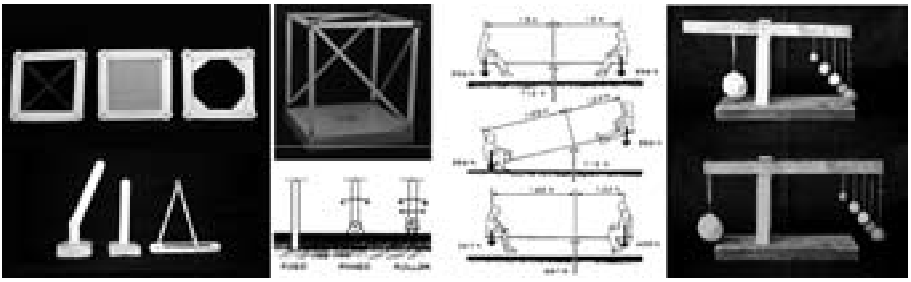
Picture 4

Alternative structural model representing structural behavior (Firth of Forth Rail Bridge, B. Baker, 1890)

in minimal physical structural models. Though static by definition, these qualitative approaches imply some degree of interaction, preceding contemporary digital simulation tools and techniques by suggesting behaviors more than simply describing characteristics.

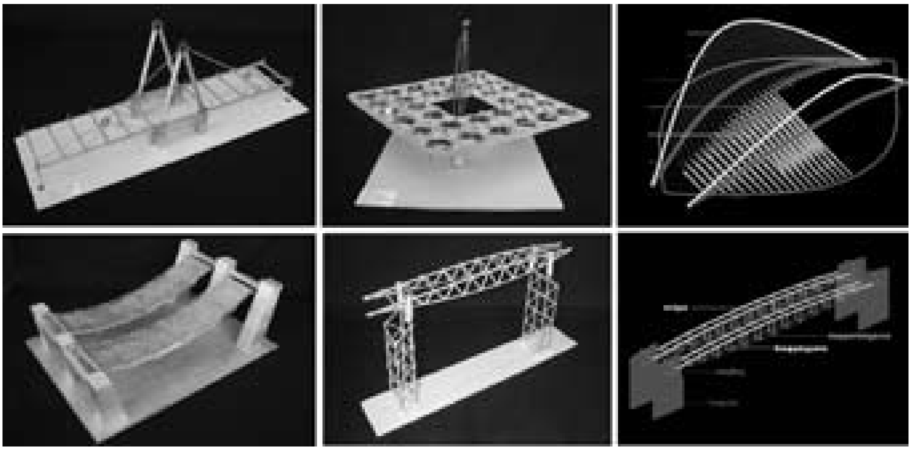
In this tradition, alternative teaching methods enhance conceptual understanding based on an experimental approach simulating structural and material behavior in scale (O. Kuenzle[12]). Hands-on exercises with simple elements study basic structural concepts (picture 5), while structural physical models and qualitative analysis diagrams of a bridge or building explore the force and stress distribution within the structural components (picture 6).

In the education of structural engineers, digital technology has moved on from analytical tasks to more comprehensive operations, sometimes even substituting the structural design process[13]. Advanced digital tools and simulation techniques, interactively modeling structural forms, configurations, properties and performance, can be used in structural design studies for optimization or control purposes.



Picture 5

Hands-on exercises exploring basic structural concepts, such as rigidity, balance of forces and moments, types of end conditions (Structures Courses, Department of Architecture, University of Thessaly)

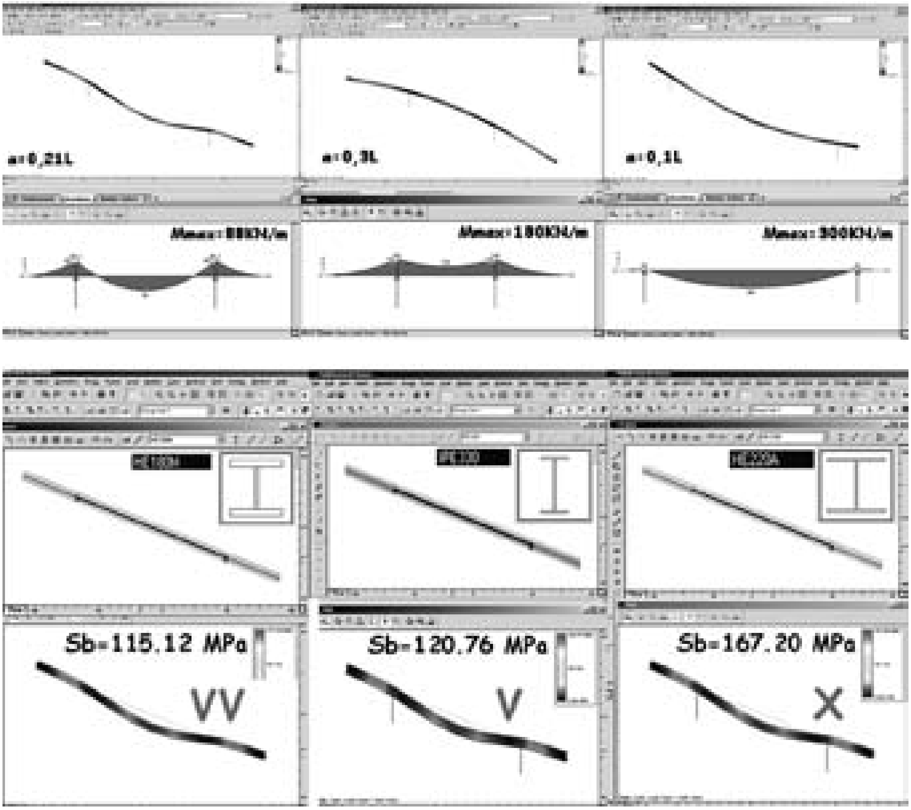


Picture 6

Structural physical and digital models providing an insight on how structures stretch, bend or deform in order to carry loads to the ground (Structures Courses, Department of Architecture, University of Thessaly)

In architecture education though, the use of digital technology in structural issues remains exceptionally limited, in a rather ill-defined framework, where the architect has neither the need nor the competences to deal with structural decisions. While this is a major discussion, incorporating methods and tools of digital analysis of structures, next to the traditional calculations by hand, is possible and should be welcome in an educational level.

The example of Multiframe, an open-source structural engineering software testifies such possibilities in simple exercises for geometry optimization or optimization of cross-section of structural elements (picture 7). Through a highly visual interactive interface combined with conceptual, analytical and design capabilities, digital applications can assist in an overall real-time conceptual understanding of the structural



Picture 7

Studies on geometry optimization and optimization of cross-section of structural elements using Multiframe engineering software (Structures Courses, Department of Architecture, University of Thessaly)

Picture 8

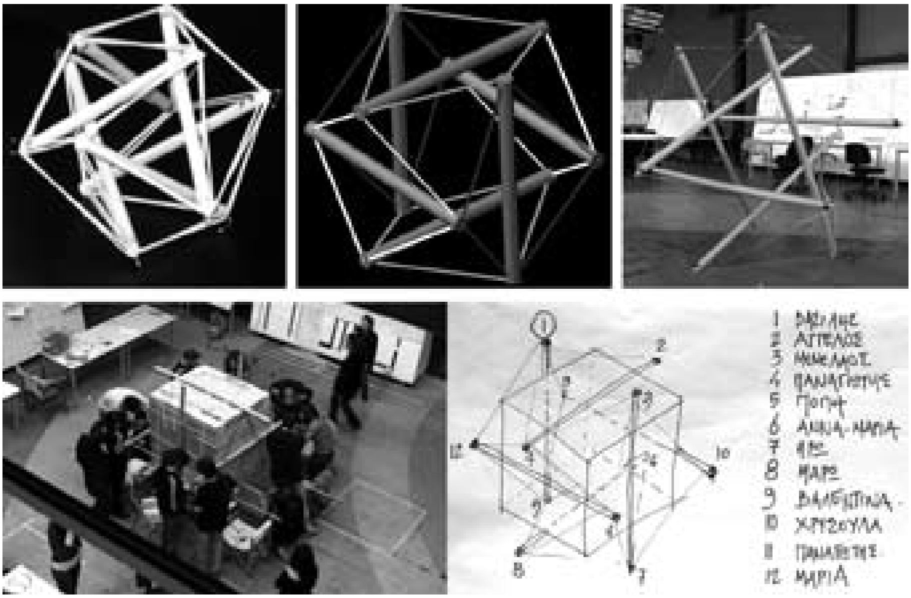
Tensegrities Workshop, Department of Architecture, University of Thessaly, Volos, March 2007, Professor: M.Vrontissi behavior and material performance of the structure. However, the use of such tools requires careful implementation always combined with traditional methods, otherwise it can become very problem specific resulting to automated answers and solutions and removing the result from the process, or even misleading by disconnecting from the physical characteristics of the structure and limiting conceptual understanding of design parameters.

And while a structural awareness needs to be developed in a conceptual level, systematic knowledge and thorough understanding of structural behavior and material performance is required in order to correctly interpret or, even more, resourcefully translate features such as structural configurations, loading conditions, end constraints, cross-section properties, material characteristics, force and stress distribution.

Reliability of experimentation tools: the case of a design-built workshop

The case of a design-built workshop underlines the sometimes misleading role of digital modeling and emphasizes the power of and, therefore, need for simulation techniques if used in all their magnitude and not only for the formfinding process.

The workshop theme was the design and construction of several full-scale tensegrity structures (picture 8). The geometric complexity, the exceptionally 3D character and intrinsic characteristics of tensile structures led towards an object oriented design[14]. While the traditional methods (paper based design) and representation tools (sketches, 2D drawings,…) proved to be inadequate, the 3D model was the only and interactive basis for design studies. The 3D model in several versions (picture 9), each version contributing a specific, yet somehow interactive, information component, in-



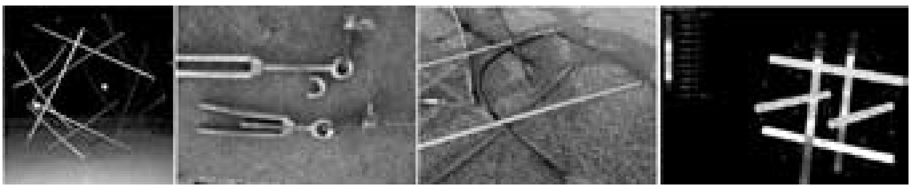
Picture 9

Tensegrity Icosahedron: design studies based on the 3D model: physical, digital, 1:1 scale models and erection sequence diagram dicating behavior patterns and suggesting possible alterations in a non-linear design and construction process[15]: data sheets to describe coordinates and calculate mathematical relationships between parts, digital model to define geometric forms, physical models to understand force distribution, and, ultimately, 1:1 scale mock-ups to deal with complex 3D details and construction sequence issues, as well as construction management diagrammatic models to 'direct' the construction phase.

The need to test the theoretical output of these studies, led to an immediate trial-and-error approach, looking for a reliable experimentation tool. While 2D drawings were insufficient and physical models had limited efficiency for scale and accuracy reasons, the digital model was initially helpful to define geometric forms. However, the specific digital model proved to be inadequate for testing purposes, as it contained no information about materials, cross-sections, force and stress distribution, being basically a static descriptive representation tool unable to simulate structural and material behavior.

Picture 10

Tensegrity Needle Tower: experimenting with the 1:1 scale mock-up (S.Bagiartaki, P.Doudesis, E.Kostopoulou, N.Theodoulou)



Picture 11

Buckling failures and joint components breakdowns from shear or tensile forces due to lack of advanced simulation tools

The 1:1 scale mock-up proved to be still the only available reliable experimentation tool to understand the physical characteristics of the architectural form (picture 10). Geometries, detailing and construction sequence was decided based on hands-on experiments on the 1:1 scale mock-ups, while preliminary sizing (selection of material, type and dimensions of cross-sections of elements) was performed based on intuition, rules-of-thumb or on-site testing.

Failures resulting from axial buckling and non-axial bending stresses, as well as joint components breakdowns from shear or tensile forces could have been avoided if more elaborate modeling tools and simulation techniques were to be used (picture 11). A comprehensive detailed digital model containing information about geometrical and topological characteristics, structural and material properties and performance, as well as information about construction sequence and detailing issues could be an ideal tool for the design and construction process of such complex structures.

In the case of experimental structures though, one should point out the difficulties and uncertainties in the simulation process, regardless the capabilities of tools and techniques, due to limited data input (custom materials, elements or components with non well-defined, non-tested or perhaps non static properties).

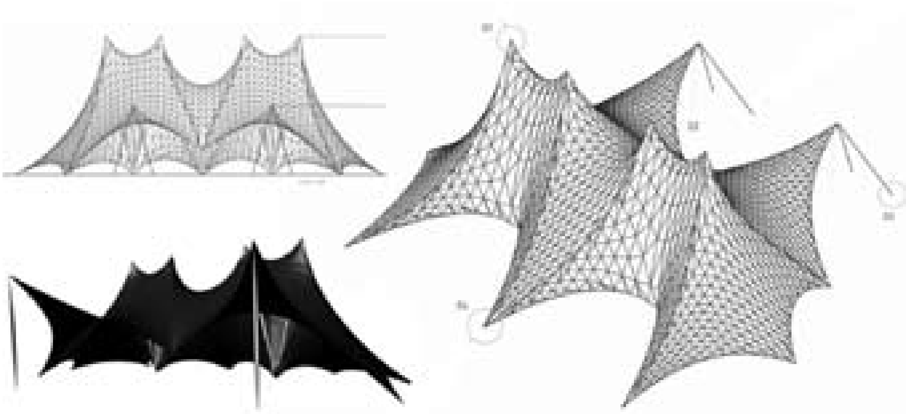
The all-inclusive digital model: the case of tensile membranes

The case of tensile membranes is a unique precedent of significant educational value to introduce the 3D model based design, to develop awareness of the importance of structural and material performance as form generators, to present the interaction between design and manufacturing process.

In the design of tensile membranes the substantial use of digital technology (yet always next to traditional methods) in a broader and more profound way than in other architectural typologies, has produced a particular professional environment (multidisciplinary approach), a singular working process (object oriented design) and a differentiated product (highly customized manufactured architectural product with an enhanced information component)[16].

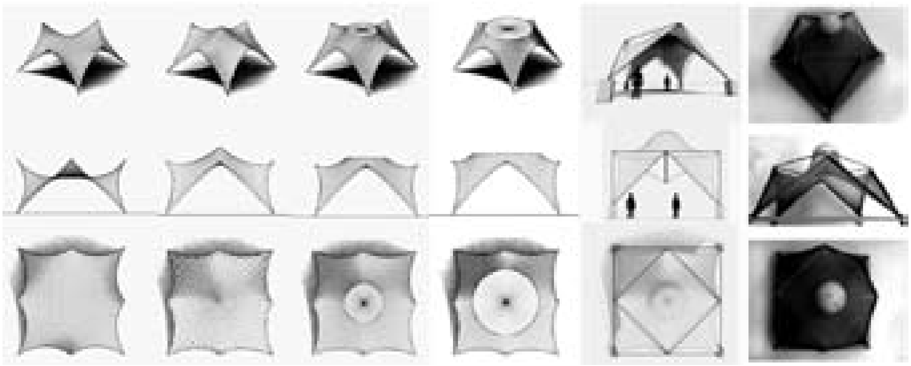
Shapes, geometries, structure and materials are interrelated, form BEING the structure. Internal forces and material properties interact with the design as well as the manufacturing process in a differentiated design and making approach. The whole process is directly based on the 3D model (traditionally physical, now digital) containing all information about form, forces, material properties and cutting patterns, therefore being a crucial tool in formfinding, engineering analysis and manufacturing production (picture 12). Design investigations take place in a constant trial-and-error process, once performed with accurate physical models, now carried out using advanced simulation techniques to give immediate feedback about structural behavior and material performance, digital technology becoming a reliable design tool, when used to all its extent (picture 13).

Digital tools for the design, analysis and manufacturing process of tensile membranes usually consist of three separate modules, all based on the same digital 3D model.



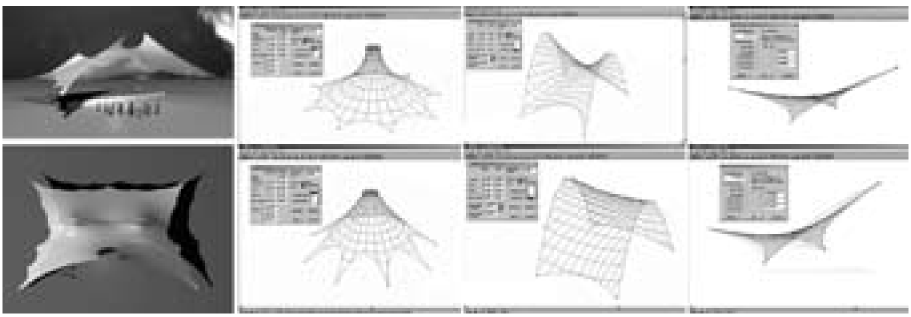
Picture 12

Tensile membranes: the all-inclusive digital model – student project: C. Miralles, P. Segado



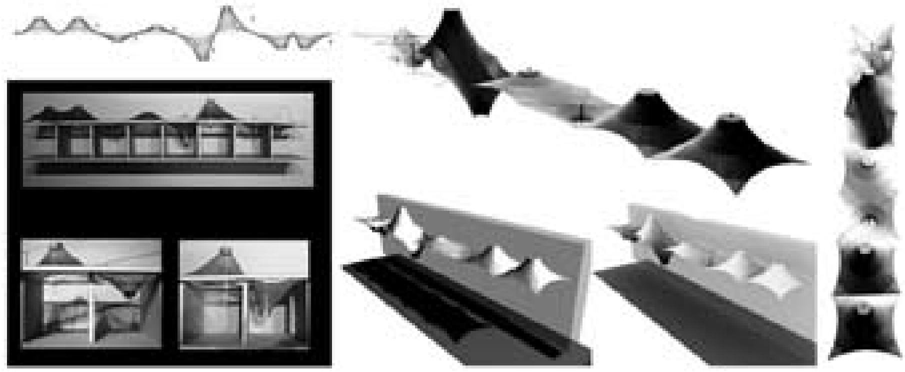
Picture 13

Design investigations on tensile membranes – student project: P. Nikolakis, G. Tzotzis



Picture 14

Design studies on tensile membranes using CADISI formfinding software – (Building Technology Courses, Department of Architecture, University of Thessaly)



Picture 15
Digital simulation tools next to physical models enhancing interactive design – student project: V. Karga, Ch. Chelidonaki

ISIMEM, an open-source engineering software, is a simplified, yet typical example of digital tool for the formfinding, engineering analysis and manufacturing production of tensile structures (textile, pneumatic,…). The CADISI module provides force-equilibrant surface formfinding capabilities together with surface geometry exporting options, therefore allowing further design experimentation with the surface itself or the supporting elements (picture 14). The subsequent load-analysis module provides tools for non-linear analysis with design-specific force and stress visualization methods, while the manufacturing module provides tools for high precision detailed cutting patterns.

Projects dealing with the design of a small to medium membrane structure are based on the CADISI formfinding module always accompanied by physical models to indicate structural and material behavior, the load analysis and cutting patterns modules requiring the knowledge of advanced mathematical tools and methods beyond the typical architectural background. Even in this limited application, digital simulation tools offer a more comprehensive understanding of the physical characteristics and performance of the structure than a typical rendering architectural design digital representation tool, since the model itself dynamically contains information about characteristics and properties and simulates behavior interactively, as the formfinding process is associated with force and stress distribution (picture 15).

Interactive modeling tools to support a dynamic design process

Digital technology offers a new design approach through a model enhanced with an information component essential to the design, engineering and manufacturing process.

The digitally possible interactive model is a tool to aggressively incorporate powerful parameters such as structural efficiency, material performance, environmental behavior and manufacturing constraints in a dynamic design process, while advanced simulation techniques can be used as design investigation tools for form queries to load analysis studies and material properties investigation providing significant feedback.

Dynamic by definition, digital technology applications can provide all inclusive information about characteristics and properties, but, mostly, they can allow for interaction with the living building entity by simulating patterns of behaviors and performance, enabling a non-linear open process, where design, analysis, construction and use are interrelated.

And while the type and form of the information contained in the digital model is yet to be defined, differentiated kind of input and skills is anticipated by the designer in order to maintain control of the design process and the final design product. While the use of such modeling tools and techniques demands special skills and systematic knowledge of design related fields, additional competences need to be developed, emphasizing on conceptual awareness and analytical thinking, promoting visualization methods and tools, enhancing communication abilities.

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Nathan Van den Bossche

Department of Architecture and Urban Planning
Ghent University
Belgium

Why do we use Simulations today?

Is it simply because we have the knowledge to do so, or do we really need them to meet the current standards in building practice? First of all we can make a distinction between building physics and structural engineering.

When we look at building industry today, we cannot describe the purpose of buildings with the word 'shelter' any more: the list of demands has grown longer and longer in the last decades. While the building envelope has become very outstanding in its job, our responsibility in controlling the indoor environment has proportionally grown and so does the weight of building physics. The building envelope is getting airtighter, watertighter and better insulated, so we can not count on a natural balance between the indoor environment and the outdoors anymore to provide for a healthy environment (just one example is the rise of ventilation systems in the 20^{th} century). Add to that the fact that today we have very high performance standards, the margin to control the indoor environment has become quite narrow. Who was complaining about overheating 50 years ago? Today we want to walk from our air-conditioned car to our air-conditioned office and we get sick because our body can not cope with the sudden temperature differences when it's too hot outside. We have strict demands towards the indoor environment and especially for new buildings we assume it will meet our expectations. A typical phenomenon in that area is that people will complain about noise nuisance in new buildings, while people in old buildings with the same acoustic performance apparently experience no discomfort because they have other expectations.

When it comes to structural engineering we have to consider a different approach: the performance standards have not changed that much over the last decades. Simulations are primarily used to save time (for calculations which also could be done manually) and to solve structural problems which require more complex calculations (e.g. seismic analysis and machine vibration are often calculated with linear elastic model analysis). The use of simulations offer new design possibilities to architects and engineers all over the world, just look at the buildings of Calatrava or Foster.

Next to the architectural and artistic design of a building the architect is also responsible for the solutions for technical problems and for creating a healthy and pleasant indoor environment. The client does not buy a pile of concrete, bricks and steel just put together, he buys a whole system, a clockwork that guarantees a good indoor climate, protection against noise, rain, sun, cold, heat, earthquakes etc. Depending on the scale of the building a number of engineers will be consulted to achieve those goals.

Looking at the jurisdiction there is also an interesting trend that explicitly affects the architectural practice today and in the future. As the architect is the supervisor and coordinator of a project, in the past he was expected to employ every possible means to successful realise the project, no more, no less. The last decades there is a shift in the legal obligation of the architect towards a contract that is performance-bound (absolute result required by the contract). The client who wants to build something has become a consumer, and the architect and contractor have become the company that will be held liable when needed. But can we rise up to that expectation? Which architect would stake his head on the fact that his design complies with every applicable standard and guideline? In Belgium a quick search brings us to a total of 2800 standards concerning building practice, and approximately 200 mandatory guidelines. More and more standards allow simulations to prove the building will meet the demands.

So we know we have a bigger responsibility concerning the indoor environment, and the expectations of clients are higher than ever before. To meet these expectations we can use standards, which often admit the possibility to use simulations. The demands will probably never decrease, our responsibility will only get bigger, so one could expect that the importance of simulations will only grow in the future. On the other hand it is not unthinkable that simplified calculation methods will be developed that cover most of the current problems we solve with simulations today, or that some problems might be covered by extensive databases. Aware of the fact that we are more and more evolving into a performance-bound jurisdiction the latter scenario may be unlikely.

Building simulation in the architectural education

Here we get to what is a crucial aspect of building simulation with regard to architectural education: can we really expect that an architect can perform all the simulations to guarantee that the building will meet whatever standard there might be? Where does the work of the architect stop and the work of the engineer begins? That boundary is also important to determine: what we have to add to the curriculum of the architectural education.

At the University of Ghent the students with a bachelor degree of engineer-architect can choose between a master in urban design and architecture, and a master in architectural design and construction techniques. Both degrees give admission to the profession of the architect, but have a different point of view. The master in architectural design and construction techniques focuses on the simultaneous design of space, construction and detailing, and the students also receive a bigger package of building engineering sciences like acoustics, advanced construction calculations, and rehabilitation techniques.

Concerning computer simulations in the curriculum we distinguish two paths: on the one hand there are certain abilities every student should master, those are the integrated subjects which every architect can use and we try to interrelate them with the design studios (with varying success). Because every student should acquire these skills, these aspects are dealt with during the bacheloryears. Typical programs we use for that are Powerplate and Powerframe (structural engineering), EPB (building energy software), Trisco and Kobra (thermal bridge simulation) and home-made models.

On the other hand we want to offer the possibility to the students to go deeply into specific fields of interest. These students can choose for 'particular assignments', where teachers focus on specific topics in history, art, urban design, building physics or building construction. In the latter two the students can improve their simulation skills with the programs already mentioned above and lay the foundation for a senior thesis. The following programs have been used for particular assignments and senior theses (next to those already mentioned above): Beam, Capsol, Comis, Concrete, Connect, Contam, Cpcalc+, Delphin, Dialux, ECO-Quantum, Fluent, PHPP, Solido, Therm, TRNSYS, Voltra, Wufi, simulation models created at our university…

Multidisciplinary design

In the senior bachelor year the students have to focus more thoroughly on integrated design. The design studio is organised as follows:

- Week 1-6: The students have to design a building on a confined scale, like a youth centre or a day care centre.
- Week 7-12: The design has to meet the current standards in energy performance of buildings, which has to be tested by using the EPB-software (building energy software). At this moment they have to determine the structure of the different building components. The condensation risk evaluation has to be made for one roof based on the glazer-method. For another course the engineer-architect students have to work together with bachelors civil engineering which act as a structural engineering consultant. Together they have to develop a structural concept and aim at a full integration of architecture and structure. The students civil engineer have to calculate the posts, beams, plates etc, while the architects will use the results and dimensions to draw up their design.
- Week 13-18: Based on the previous step the students are now able to inquire into the different building envelope interfaces. Thermal bridges can be avoided by the use of thermal simulations programs. Next to that they also have to solve the different problems concerning material properties, weathertightness, fastenings and construction. At the same time they have to develop a HVAC concept and dimension the heating and ventilation system for that building.
- Week 19-24: The design that was made during the first 6 weeks is resumed, but completed with the additional knowledge in building physics, building construction, and technical installations. The impact of the different analysis must be processed within the design concept strategy.

During week 7-18 the counselling is organised by experts in the different topics which are not associated with the actual design studio, and during that period the students have to design another project parallel to the technical counselling. That way the students are confronted with the impact of technical preconditions, but also with the impact of particular design decisions. Another aspect is the process during which they are confronted with different people who are dealing with different aspects of the building. The importance of a multidisciplinary approach will become clear along the way: almost every student has to alter the initial design to meet the various requirements. Sometimes it can be a hard nut to crack for students but it's necessary one…

It is very likely that every practicing architect will be confronted with these issues, however much depends upon the scale of the project they are working on. For small projects we assume an engineer-architect has been educated thoroughly enough to achieve those capabilities and expertise to master all facets in the design process (including structural engineering, HVAC-design, acoustics and energy performance). As the scale of a project increases, the number of involved engineers and consultants will follow. Generally the complexity of the subtasks will go up with the scale, by which we don't want to say that all small-scale projects are plain and simple.

Future

For large-scale buildings the architect will coordinate the different subtasks and communicate with the involved parties. Three aspects are crucial in that regard: for one thing the architect needs a broad-based education to fully understand all issues the consultants are dealing with to assure a high-quality discussion, for another those consultants need to be involved at a very early stage in the design process. Otherwise there's nothing left but to suggest ad-hoc solutions that satisfy neither party. A typical example is the impact of acoustics on the construction of building components: simulations point out that the noise nuisance will be too high, so the construction has to be altered on the spot, alas. If the different requirements are listed in an early stage in the process, those issues can be dealt with along the road.

Last but not least the architect needs to organise and streamline the information that is supplied by the consultants. We can not just continue to pile up those various paper plans in the digital area. Architecture, heating, ventilation, air conditioning, water supply, sanitary fittings, electric circuits, structural engineering and material finishing schemes should all be united in one database, as different layers that can be switch on and off. Even today al lot of projects worth several millions of euros still don't use the opportunities at hand. The use of IFT-technology can help the matter along. The CAD-software industry has a major responsibility in that, because all too often companies protect their systems that much that mutual exchange of information between different software-programs is either impossible or very roundabout.

Nicolas Tixier

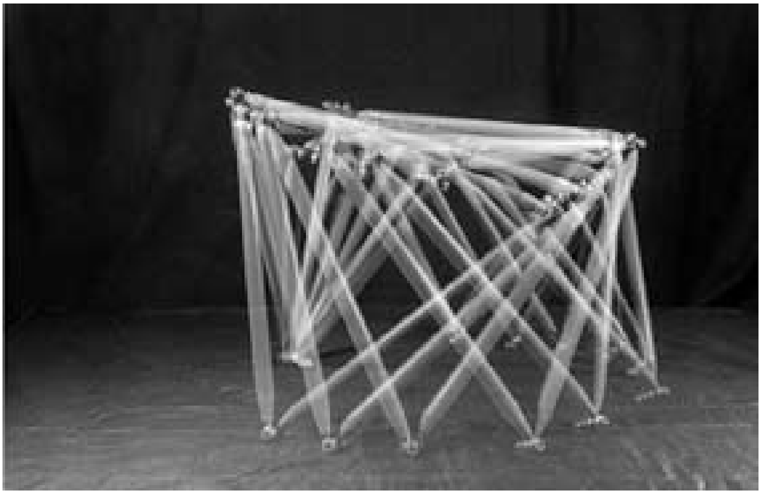
Laboratoire Cresson
Ecole Nationale Supérieure d'Architecture de Grenoble
France

Des Spaghettis à la Sauce Isostatique

En dehors de leur qualité culinaire, les spaghettis sont aussi appréciés dans les maquettes de structures. Des concours de ponts et de tours sur Internet, aux tests de résistance filmés et analysés, les spaghettis sont utilisés par de nombreux enseignants dans des exercices de conception des structures.

L'exercice présenté ici est simple et nécessite peu d'ingrédients. Prendre des spaghettis, ajouter du fil, un tube de colle de type gel, un socle et facultativement une feuille calque. Disposer d'une journée complète et d'étudiants en 1ère année de licence.

Expliquer dans une séance précédente les principes d'isostaticité et de contreventement, en différentiant traction et compression. Insister sur la relation «Nombre d'éléments de la structure x 3 = nombre de paramètres de liaisons» pour valider la pertinence d'un schéma statique.



Maquette hypostatique [F. Broggini]

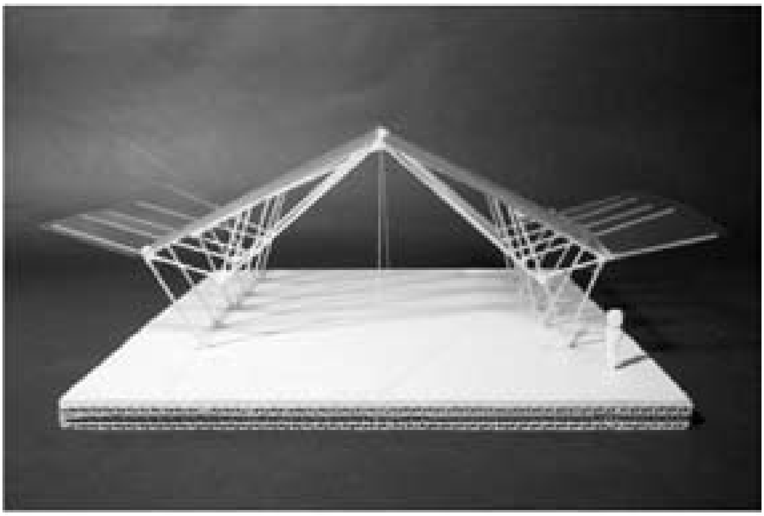
Passer en permanence du schéma statique sur le papier en deux dimensions à la matérialisation en 3 dimensions par la maquette. Un schéma statique élémentaire peut par de simples variations géométriques générer des volumes complexes.

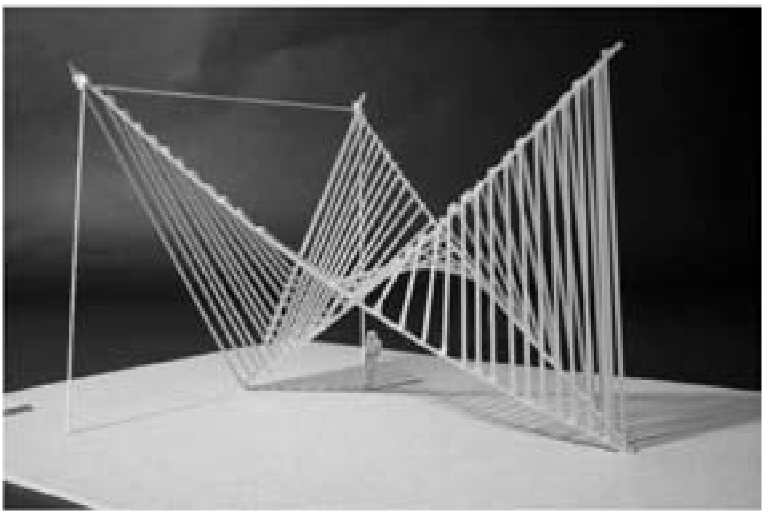
Utiliser le fil pour les éléments qui ne travaillent qu'en traction et laisser la possibilité de représenter la toiture et de mettre un personnage pour donner l'échelle et du sens au projet.

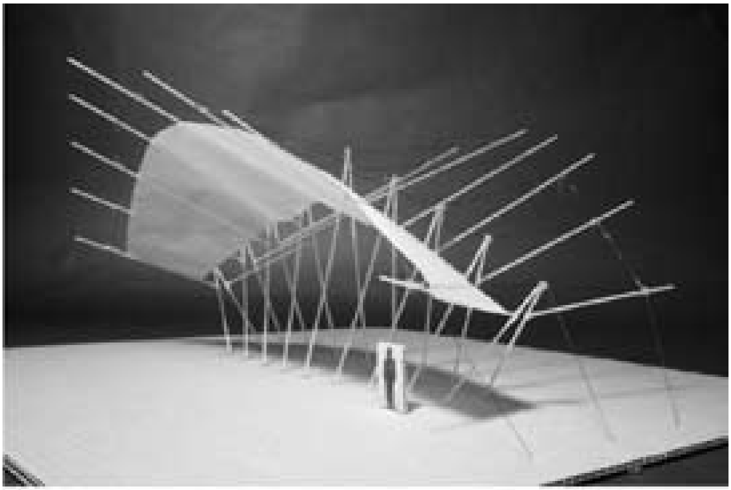
Laisser sécher. Prendre en photo.

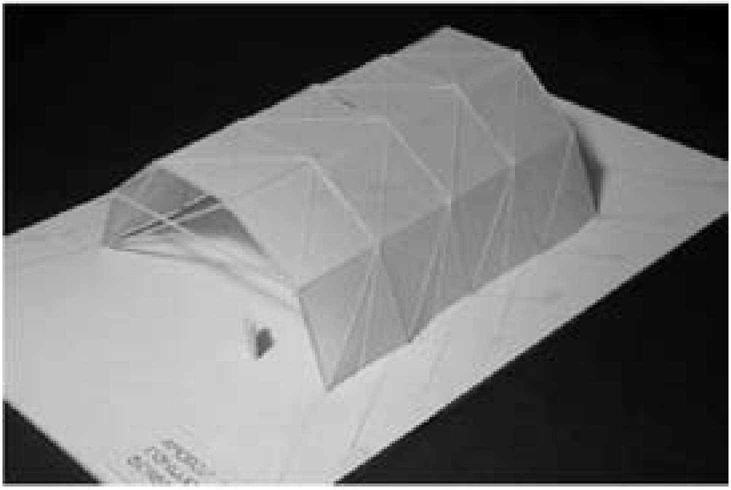
http://www.grenoble.archi.fr/enseignement/cours/tixier/tixier.html

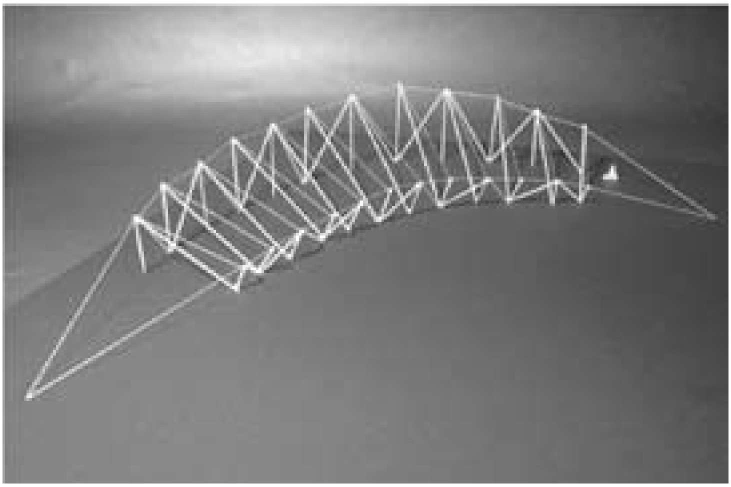
Projets issus des travaux étudiants 2005 – 2006 – 2007

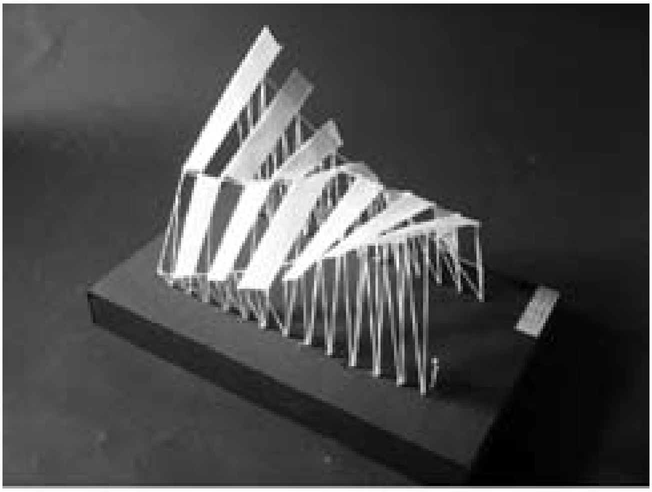


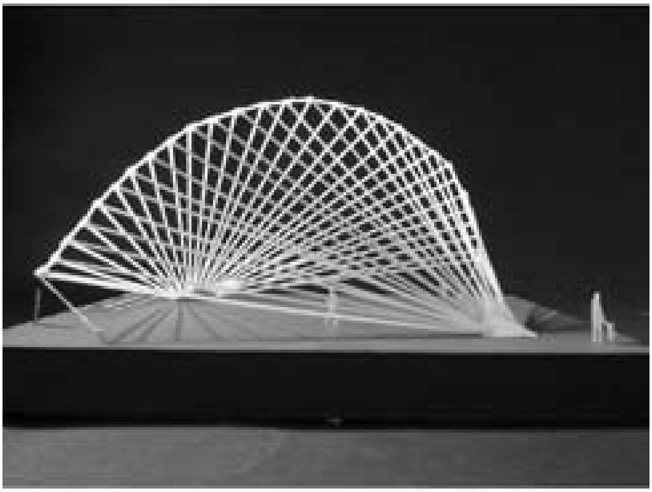


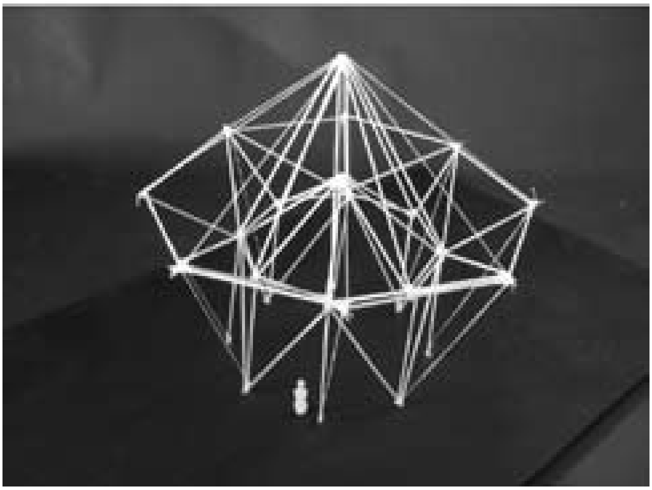


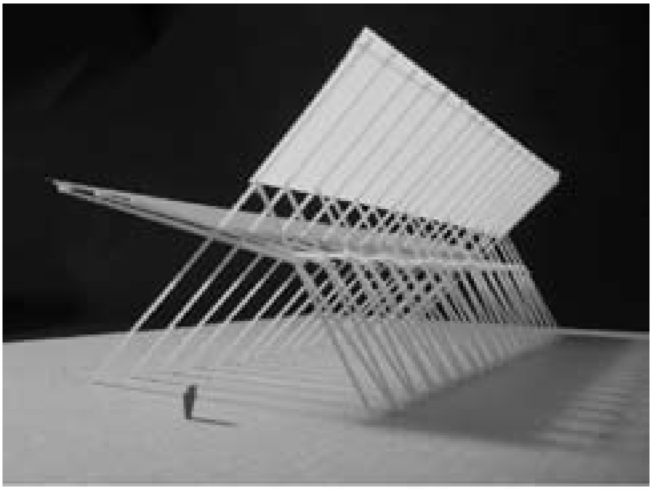


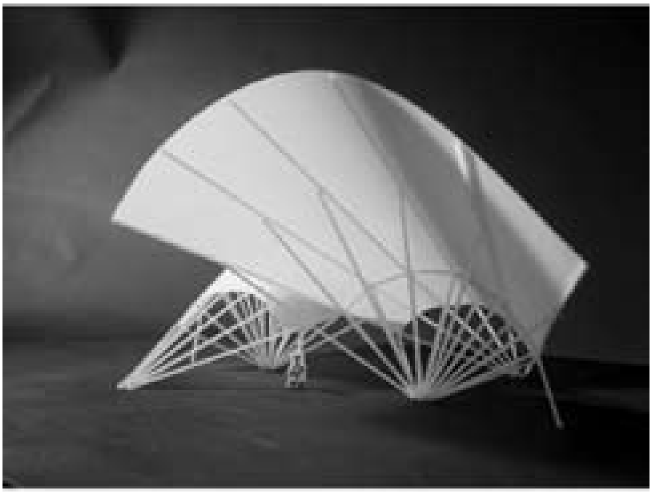


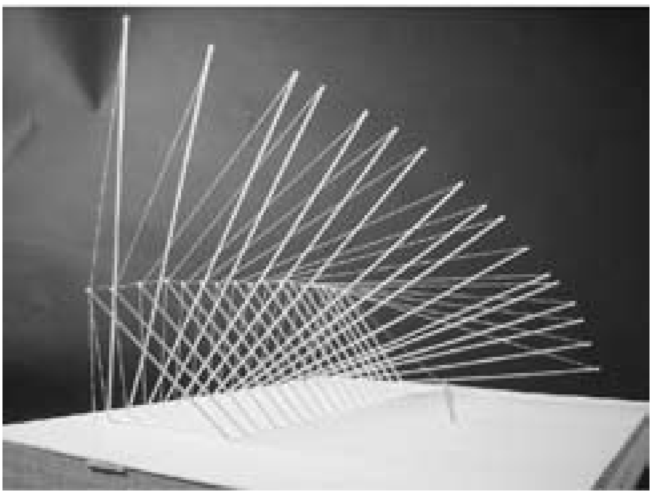


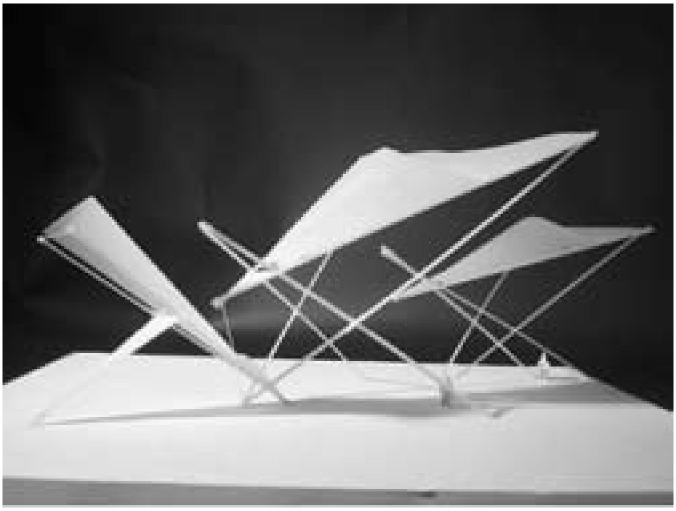


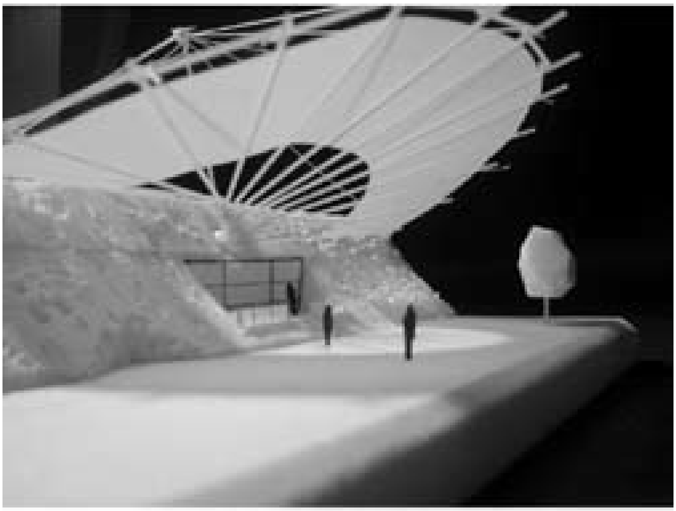












Karl-Gunnar Olsson[1]
Pierre Olsson[1]
Jonas Lindemann[2]

[1] Chalmers University of Technology, Göteborg
[2] Lund University, Lund
Sweden

Form Finding Based on Virtual Force Paths and the Computer Tools PointSketch and ForcePAD

Structural tasks and form finding

The proposed approach to form finding begins with a definition of a structural task formulated prior to the introduction of any material structure. Structures are generally designed to accommodate several different load cases or structural tasks, but in the present approach the idea is that a selection is made of one or two such tasks that are regarded as being major ones. A structural task, as defined here, involves a load case and a set of supports. Four common structural tasks are shown in Figure 1, those of spanning a space, reaching out, lifting up, and expanding. It can also be the case that two tasks represent the extremes within which a structure acts, as in the case of settling (ranging from none to complete settling) or a local damage (ranging from none to complete). This latter use of the approach has been employed in investigations of the design of historical roof trusses in which the capacity for horizontal support shows marked variation over time or due to differences in local design.

When a particular task has been formulated in terms of external load and specific supports, a structure resisting the applied load can be developed. This can be done either by connecting free points in space or by a reshaping of a continuous material (Figure 2). In either case, each stage in the shaping or reshaping process has an inherent displacement or stress state that can serve as a guide for the next step of the shaping or reshaping process. The parallel nature of the two approaches is evident in the similarity of the respective stress patterns produced, as can be seen in Figure 3.

For the example of a structural task shown in Figure 3, different load paths are possible. As long as the design process continues these load paths are to be considered as virtual. In the upper row in Figure 3, the load paths emerge through the connecting of individual points. These points can be chosen freely in accordance with some spatial require-

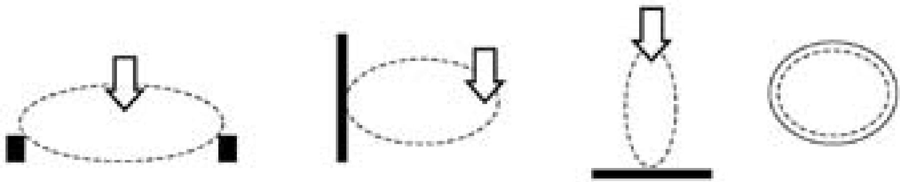


Fig. 1

Four structural tasks: Spanning a space, reaching out, lifting up, and expanding.

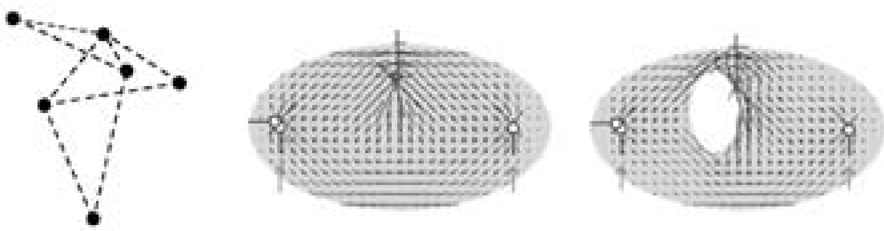


Fig. 2

Creation of structure: Linking material points or reshaping a continuous material.

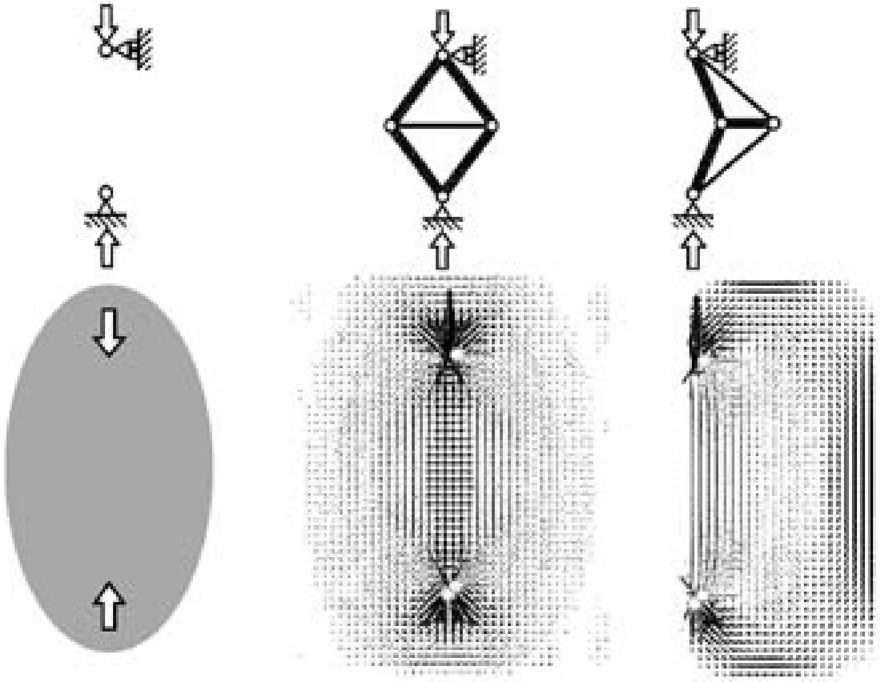


Fig. 3

Structures carrying a vertical load (blue = compression, red = tension)

ment or form of architectural expression desired. The load paths can also come about through experimenting with the distribution of material stiffness within a continuous space. At the lower left in Figure 3, a possible load-carrying space is outlined. In the middle, the applied force and the resisting support create a line of symmetry in the space, whereas the diagram at the right shows a load-carrying space on one side of the force-support line. The force patterns in the two diagrams at the right in Figure 3 can be compared with the shape of the trusses of Waterloo International Terminal drawn by N. Grimshaw, Figure 4.

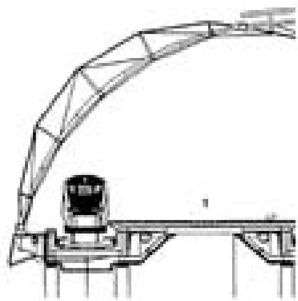


Fig. 4

Waterloo International Terminal, Nicholas Grimshaw.

The concept of stiffness

The concept of stiffness plays an important role in evaluating the distribution of internal forces. Certain guidelines for this can be drawn up. In efforts to improve the structural efficiency, one can note that shapes that resist external loads by bending are less efficient than shapes that resist loads axially. The global composition of a structure, its local geometries, its material stiffness, and the distribution of internal normal forces within it, all contribute to creating a stiffness distribution. In statically indeterminate structures, the efficiency of parallel load paths can be measured and compared in terms of stiffness. The fact that different types of stiffness are interchangeable opens the way for creativity in the design process.

Canonical stiffness is a new mechanical concept used here for detecting structural mechanisms and for detecting and ranking weak deflection patterns. From the assembled stiffness of a structure, a set of deformation patterns can be computed and ranked in terms of stiffness (canonical stiffness). These deformation patterns can be translated into static load cases directly and be interpreted as such. The deformation patterns corresponding to the lowest canonical stiffness thus represent the load case that result in the largest deformations of the structure.

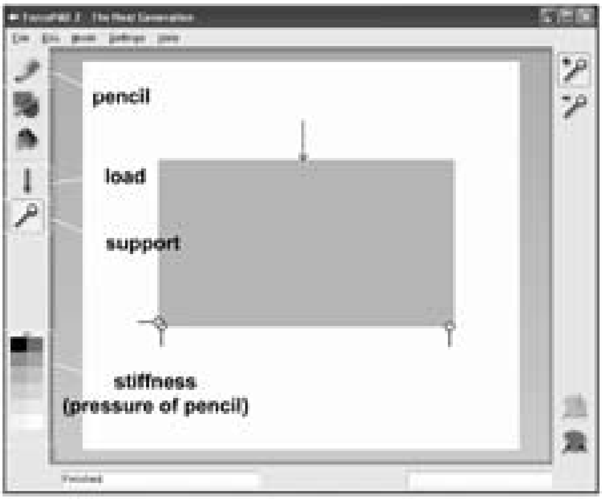
A method termed 'Sketching with stiffness' that facilitates visual experimentation in structural design provides the basic approach used in the computer program ForcePAD. By adopting the architectural manner of creating space and form, in which sketching is essential, and replacing matter by stiffness, the architectural exploration of the interplay between structural form and space, light, etc. can be extended to also involve an exploration of the interaction between structural form and mechanical action. Letting the lead marks produced by the pencil designate stiffness rather than simply matter, allows load paths to be drawn, the pressure exerted on the pencil corresponding to the load carrying capacity involved.

Transparent layers and computer tools ForcePAD and pointSketch

The organization of transparent layers of material, as employed in the computer representation of the structure, allows different aspects of the design to be studied parallel with each other. The interchange between layers makes the least common denominators of the different aspects of the design visible, facilitating a common and broaden understanding of the design task. This approach has been employed to some extent but not fully in construction of the two computer programs referred to. ForcePAD, for example, possess the possibility of hand drawn sketches (studies of form) being imported into the drawing board for further mechanical exploration.

The two computer programs ForcePAD and pointSketch[1] are aimed at clarifying the approach described. The two programs have in common that they involve use of virtual load paths in a manner allowing both architectonic and mechanical qualities to be explored and examined. Through the pictures they present, the programs can act as sketching board for ideas to be evaluated and developed further, as well as providing a common language for the engineers and architects alike who are involved. The programs are designed to allow the following overall goals to be achieved:

- Provide knowledge of the limited set of actions and of basic variables that govern the structural behaviour involved.
- Promote sketching with load paths as a method in the exploration of form.
- Enable form (cause) and action to be shown simultaneously.
- Present pictures that show global qualities such as stress and deformation patterns in a way allowing the efficiency of different designs to be compared.
- Offer a possibility of working at different levels of precision, from qualitative to quantitative levels.



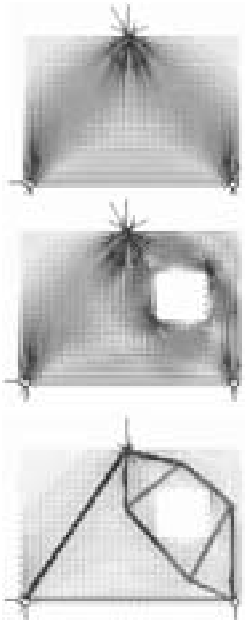


Fig. 5
ForcePAD

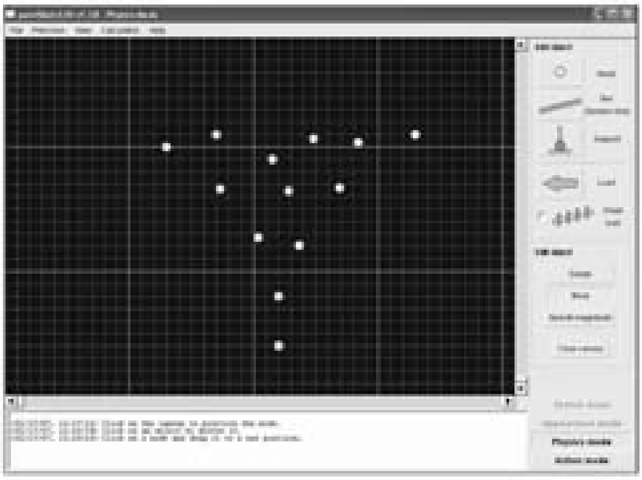
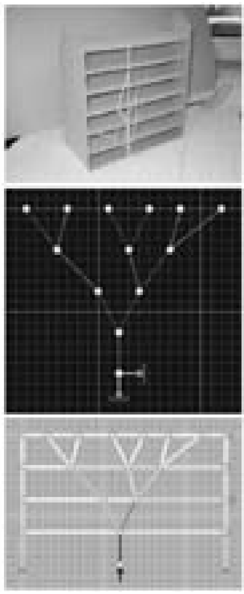



Fig. 6
pointSketch

Figure 5 shows the drawing board of ForcePAD. In the left-hand column the pencil (representing stiffness), the point load and the support given in one direction (degree of freedom) represent the basic tools one can work with. By touching the stiffness palette the pencil can be employed to express different degrees of stiffness. The upper part of the column at the right shows that the support button has been activated allowing new supports to be added or old supports to be removed. Two buttons in the lower part of the right-hand column allow a change from the Physics mode (modelling) to the Action mode and vice versa. These two modes can also appear parallel to each other in separate windows. At the right in Figure 5 the effect of a void in a wall is studied. In the diagram at the bottom a set of concentrated load paths is shown.

Figure 6 shows the drawing board of pointSketch. In the column at the right, the point, the line (representing stiffness), the support in one direction, and the point load represent the basic tools available to work with. Touching the appropriate buttons allows the actions employed to be changed from add to delete or to move. At the bottom of the right-hand column there are two buttons that permit a change from Physics mode (modelling) to Action mode and vice versa. Here too the two modes can appear parallel to each other in separate windows. At the right in Figure 6, snapshots from a design of a load-carrying wall are shown.

Five different parts of the approach described can be distinguished in physical and mathematical terms:

1. An interaction occurs between the external load acting at the material of a particular point and the surrounding material that resist and redirect this force. This is described in mathematical terms by the differential equation which expresses the local equilibrium.
2. An interaction also occurs between the complete set of external loads and the external supports. This interaction represents the global balance of the structure, and is in mathematical terms achieved by the introduction of a volume and of boundary conditions necessary for a global equilibrium to be obtained.
3. The material load paths that are present need to be sufficient for a stable structure to be achieved. In mathematical terms, this means the existence of a unique solution.
4. There are two types of patterns, the one being that of a structure which consists of moving parts, further parts needing to be added in order for stability to be achieved, the other being that of a stress in which the active load paths of the structure are shown. In mathematical terms, the first of these is expressed as the zero eigenvalue solutions of the eigenvalue problem, and the second as the solution of the differential equation expressed in terms of the principal stresses, the existence of zero energy modes and the minimization of the strain energy providing the respective physical interpretation of the two patterns.

The two programs were developed collaboratively by the Department of Architecture of Chalmers University of Technology and the Division of Structural Mechanics of Lund University. They have been used successfully in both architectural and engineering education in the Scandinavian countries.

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1 Structure, Architecture and Engineering, 2007
http://structarch.org/software.htm

Caterina Tiazzoldi[1]
Chris Whitelaw[1]
Nicolas Tixier[2]

[1] Nonlinear Solutions Unit Laboratory
Columbia University
New-York, USA

[2] Laboratoire Cresson
Ecole Nationale Supérieure d'Architecture de Grenoble
France

Applied Responsive Devices

In the last 15 years in architecture, the frequent use of design instruments such as, algorithm, dynamical relations, *parametric systems, mapping, morphogenesis, cellular automata, bifurcation with broken symmetry*, shows clearly how contemporary thinking in mathematics and physical sciences, dealing with complex dynamics, non-linear systems, chaos, emergent properties, resilience, etc., has changed the way we think about design and the life of today's cities.

In a complex-structured city in which the interactions among parts intensify; in which the number of decision makers and cultural scenarios overlap, interconnect, and sometimes collide; in which the temporal dimensions of the citizens are dissimilar; in which local and global, physical and virtual dimensions co-exist; it is necessary to respond with new typologies, new complex urban organisms and new production systems. Architects have to face different realities, in which building typologies and space-using modalities are continuously put into question. It becomes crucial to define a set of complex adaptive tools which are able to suitably manage these complexities within the system.

In the first phase an architect's interest focused on the direct transposition into the architecture of digital tools deriving from other scientific fields. The use of such tools led architects to discover forms that were inconceivable with traditional procedures. Nevertheless, the lack of control of tools that were not specific for architecture, in the mid 1990s, engendered a drastic reduction in the initial interest for such an approach.

The motivating hypothesis at the basis of the interdisciplinary research Lab Non Linear Solutions Unit at the Graduate School of Planning and Preservation at Columbia University is to challenge, consolidate and promote the research in the field of complex systems in architecture.

The pilot model, Applied Responsive Devices, is a methodological approach in the modelling and simulation of architecture and engineering scenarios.

Applied Responsive Devices questions how to enhance the organization and transfer of architectural knowledge by activating a strong interaction between analogue and digital modelling. It analyzes the different possible applications of a model (to demonstrate, to analyze, to discover) and the properties that it should embed (robustness, repeatability, resemblance) in order to be efficient.

Applied Responsive Devices is conceived as an educational and professional decision aid tool giving assistance to the decision maker to fix the priorities related to a formal, functional, technological or engineering problem.

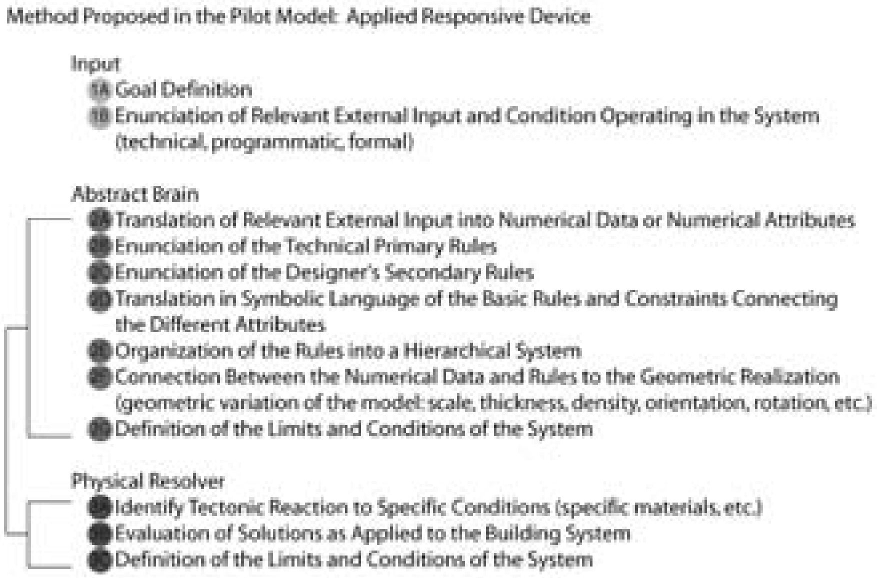
The project *Applied Responsive Devices* is finalized to achieves the following tasks:

- Supports architectural reasoning through time based simulations.
- Develops and refine the research tools through computational methodologies.
- Defines a strategy that allow an easy tracking errors and mistakes.
- Provides conceptual and instrumental platform and a service to the scientific, architecture and engineering community.
- Contributes to the science of learning by providing an innovative methodology.

From a methodological point of view, the project makes use of developments in other scientific fields (for example, research developed by John Holland of the Santa Fe Institute (Holland, 1992)). In fact some architectural problems can be managed with a classifier system, consisting of a set of rules, each of which performs particular actions every time its conditions are satisfied by a specific informational attribute. Applied Responsive Device innovation includes also the way in which quantitative and qualitative parameters (i.e. social, physical, sensorial, cultural and economic) are aggregated in order to emphasize the concept of formal adaptation.

The interest is to embed sets of constraints within the modelling process that affect the decision making of the designer.

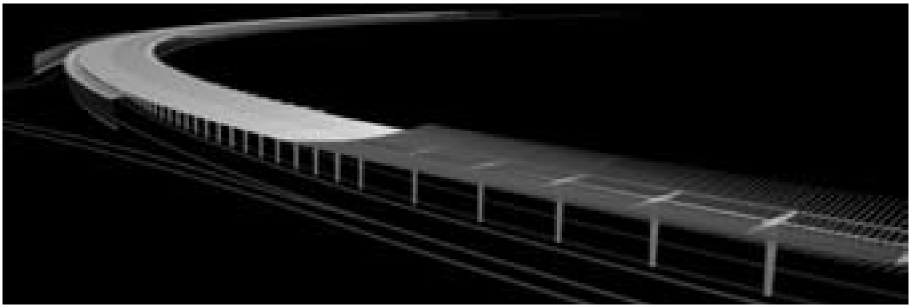
Such an approach leads to the architecture students' and researchers' heightened control of an increasing level of complexity in the design, engineering and production processes.



Logical model of the APPLIED Responsive Devices: definition interaction between the analogical and digital dimension of architecture. Image courtesy of NSU.

The research *Formal Modulation for Acoustic Performance* starts from the projects "Ceresiosaurus", "Desailopontès" and "Runninghami": works by Pascal Amphoux (Contrepoint Urban projects, CRESSON), Filippo Broggini (BlueOfficeArchitecture) and co based on an exploration of the problem in order to engineer a formal solution for highway bridge acoustic panels in response to a given set of requirements. [Runninghami: http://www.design-public.net/article.php3?id_article=44]

The researchers developed a morphodynamic design to 1) optimize noise reduction in the area surrounding the structure 2) provoke a perceptual experience for the drivers and for the habitants and 3) render possible new uses of the spaces in immediate proximity.



Ceresiosaurus [Amphoux, Broggini]

The original proposal consisted of a formal modulation based on acoustic performance obtained by means of manual interpolation between engineering data and acoustic tables.

The project *Formal Modulation for Acoustic Performance* was developed in a collaboration between NSU and Cresson. The rsearch carried out at the CRESSON laboratory focuses on the issues of environmental perception and on architectural and urban atmospheres. CRESSON advocates a qualitative and dynamic approach susceptible to facilitate or influence design strategies and processes.

The real case study *Formal Modulation for Acoustic Performance*, was conceived to verify the validity of the methodological hypothesis analyzed in the Pilot Model Applied Responsive Devices. The goal was to evaluate which tools have the capabilities to respond to formal, managerial, structural problems arising in the architectural domain.

In order to achieve such a result acoustic and perceptive constraints were integrated in the digital modeling process. At any moment, basic relationships required by the empirical acoustic evidence are satisfied.

The project was developed following a chronological sequence of phases:

1. Propedeutical preparation: Collection of Data and Survey.

   Researchers used data (survey of the site and acoustic requirements) provided by Cresson and by BlueOfficeArchitecture.
2. Definition of the predominant factors influencing the formal response to acoustic requirements of the site.

3. Subdivision of the problem, into a system of elementary units: attributes and building blocks.

   Fragmentation of physical and conceptual problems into attributes and building blocks. Reduction of the problem into a set of elementary units.

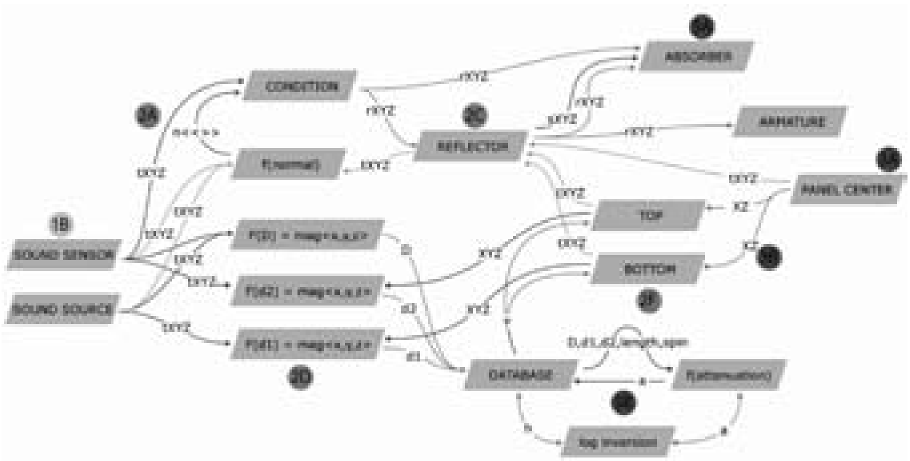
   All partners defined a set of technical, acoustic, economic and social factors influencing the different elements formal requirements. They established a checklist that the designer and students used to collect information.

   Analysis of the conditions in which formal and performative requirements and performances can be represented through sets of numeric data.

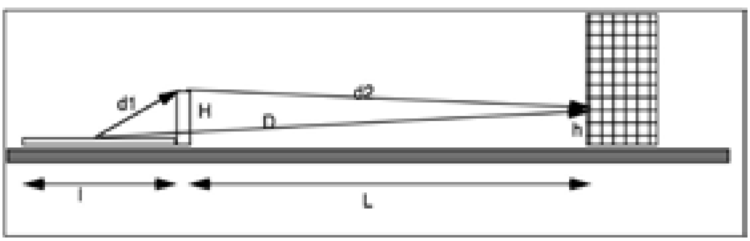
4. Expression of architectural principles through a set of dynamical relations: Articulation of the project in a set of relations and translation of input in abstract symbolic language.

   Guidelines relating acoustic performance and other factors:

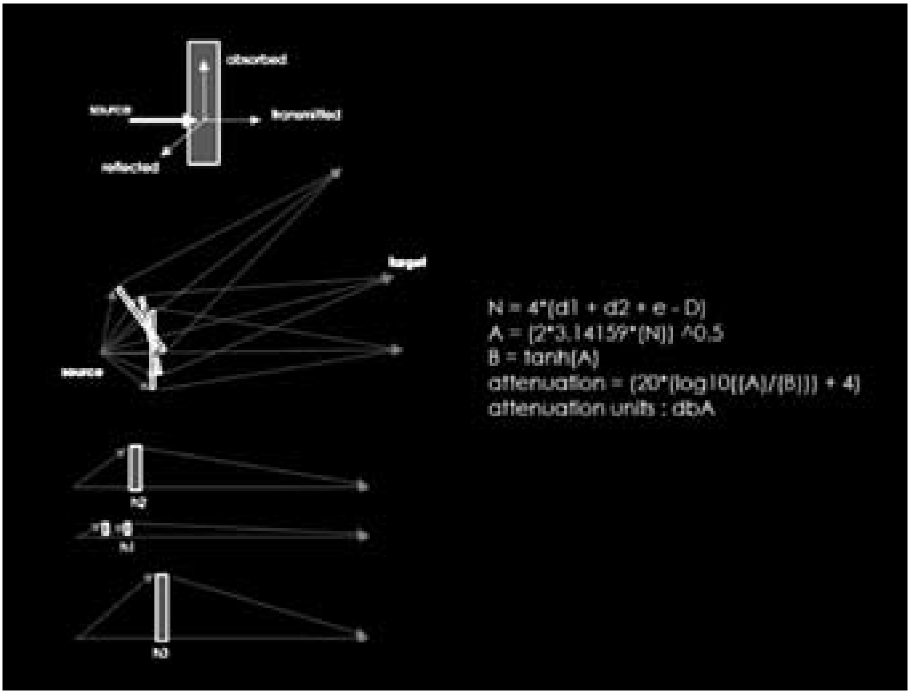
   Definition of formal aspects and of acoustic criteria. Based on the analysis of the results of the this task was aimed to define the parameters and the rules describing the formal response of the different panels on the basis of sound/acoustic requirements.



The volumetric model was linked to the acoustic parameters and proportional requirements by the empirical performance formulas affecting the definition of the form.



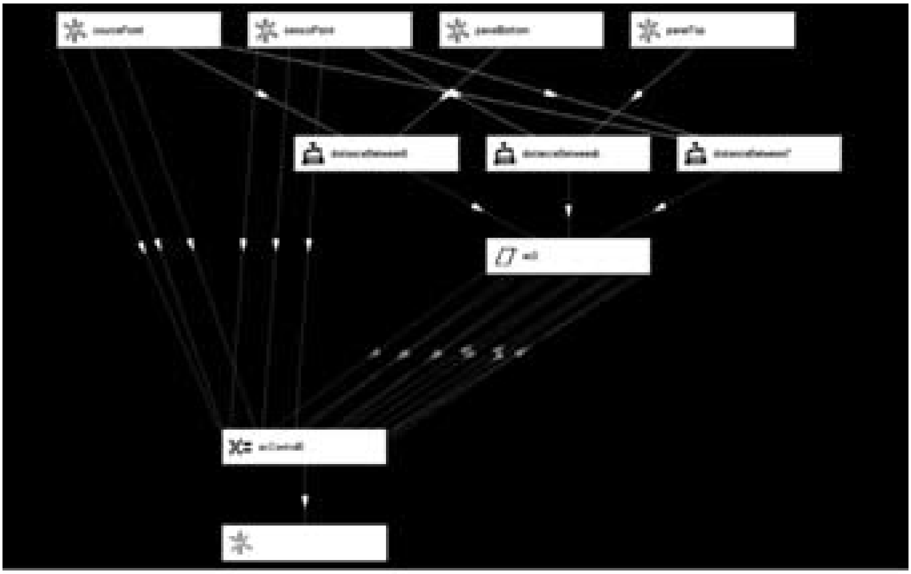
Attenuation calc Scheme [JJ Delétré - Cresson]

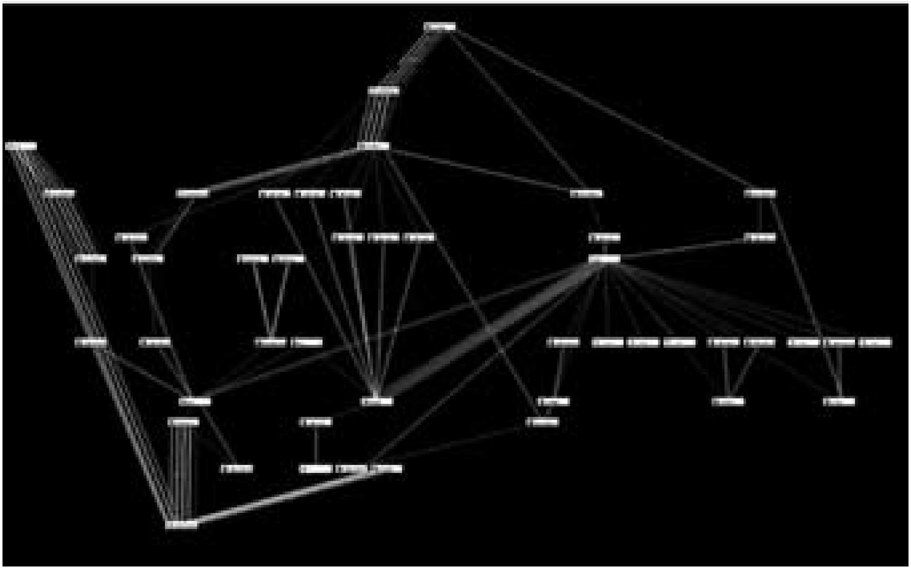


Extension of model data and method implementation. (the algorithms of the model were incorporated into a software application). Initial data resulting from the survey were complemented with additional data sources according to the simulation model requirements. The entire database was defined to identify and develop correlations between the acoustic requirements, the influencing factors and the formal attributes of the solution.

The project achieved to investigate the possibilities that opened up by the modulation between the combinatory potentialities of the different performance criteria with their design intentionality. The project unfolded sets of formal solutions through rule-based modelling and programming. The project challenged and enhanced architecture's capacity to respond to specific acoustic and environmental requirements with its adaptable physicality.

From an epistemological perspective the tool operates as an heuristic device aiming to challenge the boundary existing between the Measurable and Non-measurable dimensions in architecture.



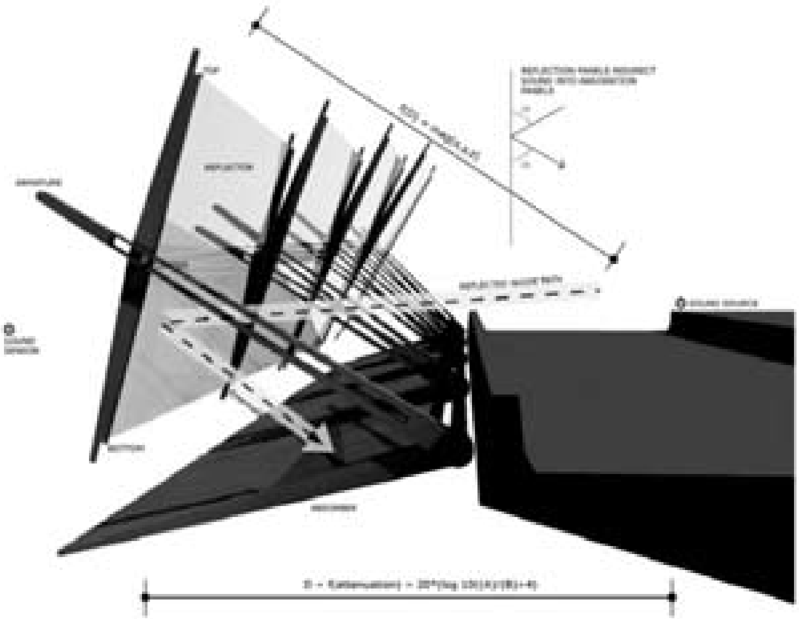


The results were formulated into a set of user-friendly guidelines

Method Implementation

The algorithms of the model were implemented into a software application and delivered to users.

Maya interface developed for the case study Formal Modulation for Acoustic Performance. The tools developed allow to connect a specific sound source to an acoustic panel and a site to isolate.



Session 4

Case Studies
- Testing and Simulation

Chair: **Karl-Gunnar Olsson** *Chalmers University of Technology, Sweden*

Jorge de Novais Bastos

Faculdade de Arquitectura
Universidade Técnica de Lisboa
Portugal

The Model Span Competition - An American Experience Applied in a Portuguese School of Architecture

Introduction

Although human mind may have a sharp perception of the physical phenomena usually "small details" may lead into different conclusions. The current teaching trends within most Portuguese Schools of Architecture are still largely based on the Fine Arts heritage. The experimental methods – laboratory and/or full-scale tests running up to ultimate conditions, which are the basis of the modern contemporary scientific design concepts is usually not implemented due to a multitude of different reasons, e.g; excessive costs, lengthy procedures, and lack of interest and curiosity.

Prof. Mario Salvadori's approach as an "educator" to the early human brain development stages, mainly with high-school children, has revealed to be a lifetime investment for our Society. At the University of Texas at Austin, the author's experience as a Fubright-Hays graduate student, under unique teachers' excellent classes, e.g., Prof. J.A.Yura's "Structural Steel Design" course, was worth being implemented. The Model Span Competition - a course requirement, was adapted and used at the Lisbon School of Architecture undergraduate student's program.

A "Renaissance Man" – Prof. Mario G. Salvadori

Prof. Mario George Salvadori made unique contributions to the art of teaching construtionscience both in the engineering and architecture fields. A native Italian born in Rome in March 17, 1907, he received his undergraduate degree in Rome in 1925. He went on to earn also from the University of Rome both doctoral degrees in civil engineering (1930) and pure mathematics (1933). In 1939, just before the beginning of WW II, he came to the U.S. through an invitation of a fellow countryman, Dr. Enrico Fermi, living in Chicago. A few months later he joined the Faculty at Columbia University and, in 1961, he became a founding partner of Weidlinger Associates in New York City that grew up to become a very large and well-known design / consulting firm both in the U.S. and overseas.

In 1975, at the age of 68 he established the SEBCE – "The Salvadori Educational Center on the Built Environment", established at the N.Y. City College, Harris Hall, N.Y. City, where he was able to demonstrate his unique ability to transform rather complicated concepts into simple ones through demonstration and hands-on work. The innovative Salvadori methodology was based on the following principles , Fig. 1 [1]:

"1. Students can understand the abstract concepts of mathematics and science through a focus on the concreteness of their familiar built envirromment;
2. Problem-solving skills can be taught through rigorous and compelling hands-on activities;
3. Small-group learning and peer teaching are fruitful ways for students to explore mathematics and science while acquiring essential collaborative and communication skills;
4. The history of mathematics and science can be used to reinforce the discovery method of learning by showing students that scientific inquiry is a collaborative process in which they can successfully engage; and,

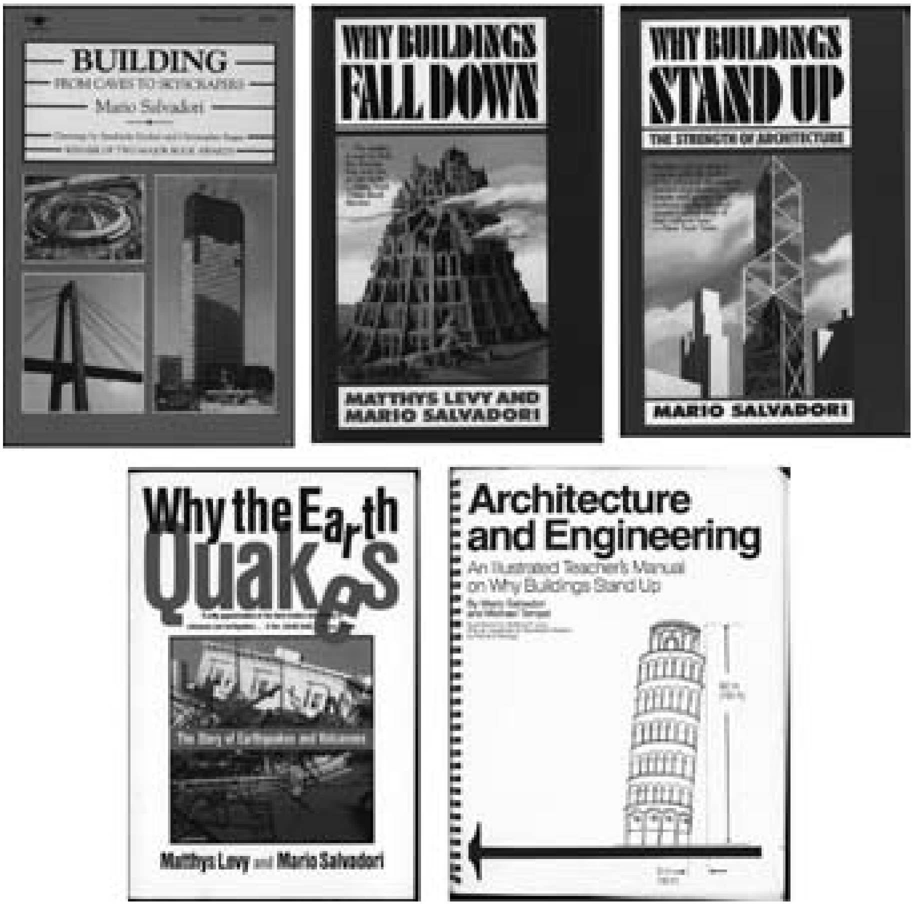


Fig. 1
Prof. Mario Salvadori's Landmark Textbooks

5. Learners can be motivated and challenged with glimpses of more advanced topics and their important real-world applications."

One of his early texts [2] published in 1979, Fig. 1, writen to motivate inner-city children to grasp the principles of science and mathematics got two major book prizes - the N.Y. Academy of Sciences Children's Science Book Award and the Boston Globe - Horn Book Award for Non-fiction. Other publications were also able to interest standard citizens into the art of building concepts - "Why Buildings Stand Up [3], "Why Buildings Fall Down" [4] and, "Why the Earth Quakes [5].

On May 20, 1997, during one of his last U.S. visits , the author was able to locate Prof. Mario Salvadori – first at Columbia University, next at the N.Y. City College and, finally, at his home near the U.N. building. During the meeting that lasted about 1 ½ hours the author was astonished with the vivid mind and real-life interest on other people activities and cultures. On June 25, 1997, at the age of 90, Prof. Mario Salvadori regrettably passed away in New York City. He achieved the James Renwick Prof. Emeritus of Enginneering and Prof. Emeritus of Architecture at Columbia University, he became Weidlinger Associates firm honorary chairman, he received the most coveted Hoover Medal from the A.S.C.E. and he was the first person to become an honorary member of both A.S.C.E. (1980) and the A.I.A. (1979). However, his best achievement, that hopefully will endure, is his legacy to the middle-school children, the real place where student achievent in mathematics and physics has been shown to drop off rapidly. He strongly believed that the real solution must become an environment for problem solving, hands-on exploration and cooperative learning. As an "educator" one of the best advice he gave about the education of engineers and architects regarding what he called "a reciprocal ignorance" was for engineers to become architects and architects to become engineers.

The Model Span Competition – an American experiment in the Lisbon School of Architecture.

The US tradition

The designer is usually faced during the different project phases with a set of difficult decisions in order to optimize his solution. This fascinating mind-boggling subject has occupied the mind of any serious "constructor" along the history of mankind. With the advent of computers and the development of numerical analisys the task of exploring several different solutions by varying critical parameters, e.g., volume of materials, deflection control, strength capacity in order to find an optimum level has become easier [U. Kirsch (7), P. Samyn (8), Lord Baker and J. Heyman (9, 10)].

At the University of Texas at Austin – College of Engineering – Dept. of Civil Engineering and Architectural Engineering, one of the most challenging contests in the Prof. J. Yura's Structural Steel Design class was the Model Span Competition that attracted students from other states and neighbouring countries (Mexico, Canada). The challenge of using an economic set of materials – balsa wood, epoxy glue, sand paper, that anyone could afford to buy (US$10.- 20.) was very appealing. The design phase that would take one to two weeks with extended discussions with fellow classmates [the Salvadori's "discovery method of learning"(1-6)], followed by the construction phase ["the hands-on activities"(1-6)], finally culminated with the load-up to-collapse test ["small group learning and peer teaching" (Salvadori (1-6)]. The optimal design R, is calculated through the ratio between maximum collapse load P_{ult} (lbs, kips, N, kN, kgf) by the total weigth, $W_{tot.}$ (ounces, grs.).

The LNEC Model Span experiment

The Lisbon School of Architecture originated from the traditional XIX th century Fine Arts Academy didn't have the required loading apparatus to carry out this Model Span Competition. Therefore, through a joint cooperative program and mutual understanding regarding the valuable educational investment on future practising architects, the Author was able to organize a technical visit at the well-known L.N.E.C. –"Laboratório Nacional de Engenharia Civil". The Ceramic and Plastics research unit had a state-of-

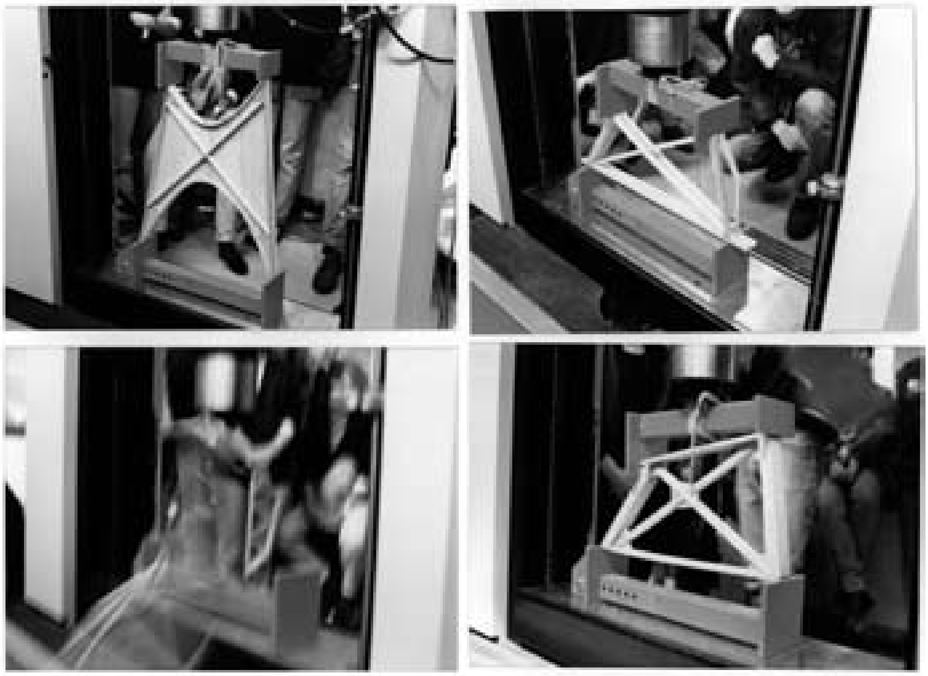
Fig. 2
At the LNEC Main Entrance

the-art universal loading apparatus ("INSTRON"), with load and displacement control monitoring and a real time data acquisition system.The student's enthusiasm was able to convince the most skeptical laboratory personnel to help us carrying out the tests. During several sucessive years, collapse load tests on all different types of balsa wood models supported in two points and loaded either in one point (junior student classes) or in two points (senior student classes) were performed enlightening successive generations of students, Fig. 2.

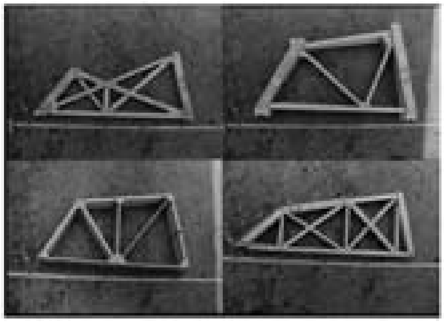
This experiment main objectives were to foster: (a) teamwork and solidarity; (b) sequence planning and economic design; (c) workmanship and a hands-on experience; (d) to evaluate actual design conditions by predicting the maximum expected load and where the collapse will occur. This tests were carried out, not only with native Portuguese students, as well as, with other European students (Italy, Spain, Belgium, France) under the Socrates-Erasmus exchange program. Real life results were able to leave most people astonished with both their scientific and technical skills, Fig. 3 - a maximum collapse load $P_{max.}$ = 8950 N (895 kgf) was reached with a minimum balsa model weigth of $W_{min.}$= 155,6 grs, and an efficiency ratio of nearly $R = P_{max.} / W_{min.}$= 5750 times.

A Lifetime Experience

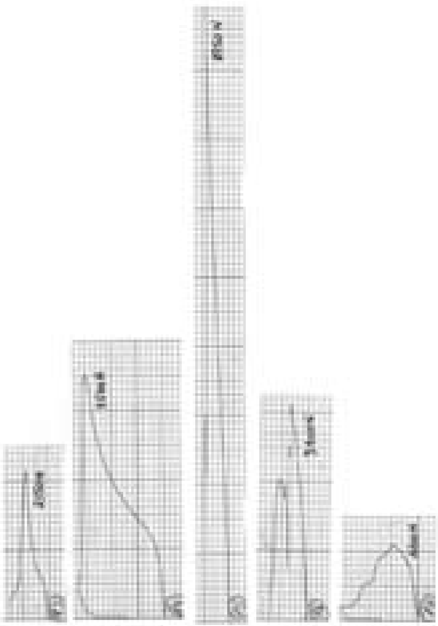
One of the experimental learning process most important aspects is curiosity. From an initial negative student's attitude with this out-of-the-routine exercise up to an excitment stage with the best and most impressive results. The author was able to observe all these different reactions, after his return from the U.S. Fulbright-Hays Program nearly twenty years ago while organizing these technical visits to the L.N.E.C.. The subsequent attitude during the after test days of: (1) where and why did I failed?; (2) how can I do it better?; (3) where teamwork decisions didn't match?; (4) where planning,



a. Tests Setup



b. After Collapse Tests



c. Experimental Data

d. A Joyful Team

Fig. 3
A LNEC student visit

craftmanship, material quality could be improved, are all pertinent questions that will remain through the years in those young minds and, hopefully, will lead to better architectural practioneers in their lifetime.

Aknowledgements

The Author is sincerly grateful to his home Institution and the Magnifico Rector of The Technical University of Lisbon to allow the participation in the Mons(Belgium) meeting. He is greatly indebted to the L.N.E.C. to host with patience and enthousiasm, during several years, successive generations of young architectural students, that used their expensive equipments and the human resources help, with a great generousity. The Fulbright-Hays exchange program allowed more than 25 years ago to understand that the pursuit of excellence his gift that must be encouraged through the free access to information. Last but not least, to Prof. Maria Voyatzaki (The Aristotle University of Thessaloniki, Greece) and our host Prof. Ing.-Arch. Alain Sabbe (Faculté Polytechnique de Mons, Belgium), for their energy and hospitality.

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Dariusz Masły

Faculty of Architecture
The Silesian University of Technology
Gliwice
Poland

Reflections on Simulation Methods and Techniques in Architectural Design: the Polish Experience

Introduction

The focus of the paper is on the use of different simulation methods and techniques at various phases of building life cycle. The aim of the paper is to review the potentials of simulations in architecture for improving the quality of the built environment.

The paper is divided into four main sections. The first section reviews simulation vs visualisation. The second section reviews various phases of building life cycle at which simulation is crucial, pointing out the specific industry wide advantages that could build up from implementation of simulation at these phases. The third section reviews selected case studies where various simulation techniques were used. The last section reviews available tools for simulating the concepts of a physical form at various stages of architectural design and the functionality they offer.

Simulation vs Visualisation[6]

Simulations result from a human fascination with the replication of real-world context. Now 3D computer modelling and animation are commonly used by architects to visualise their ideas. Popular, commercially available CAD software like AutoCAD, Architectural Desktop, ArchiCAD allows architects to create a complete replica of their designs and look at them from virtually any point of view. Designers simulate how built environment affects them and the surroundings. In a way they experience the space.

So where is the border line between simulation and visualisation of a physical form? In Wang's words images, photographs, architectural models "remain representational unless they are included in a larger research program in such a way that the manipulation of specific factors results in useful data that can be applied back into the real-world context under study." [6] Simulation takes place when a model of a real-world contains dynamic interactions, when it enables manipulating of analysed factors and collecting data on these interactions.

But the computer technology has blurred the differentiation between representation-visualisation and simulation. Almost every architect changes shapes of his 3D model dynamically in everyday practice and applies the outcomes of his studies into the real-world building. In my opinion now the key to differentiate simulation from visualisation may be interactivity available not to the architect but to the user. A simulation of a physical form begins for users when they are able to experience an analysed design interactively.

Simulation at various phases of building life cycle

In many countries even new buildings are characterised by poor quality. Disaffection by developers, building owners, facility managers and building's users is widespread. There are several problems that lead to poor buildings' performance. But the crucial one is the misunderstanding and inappropriate assumptions in the area of building's quality.

Quality of the built environment is the ability of a building to satisfy the needs of its users.[2,12] Therefore needs of building's users have to be recognised to deliver a high quality built environment. Traditional approach to handling information on users' requirements and its communication is an important contributor to the problem of low building quality. An innovative approach to the design of buildings is based on feedback and evaluation at every phase of building life cycle.[10,11] Building evaluation identifies the various activities, requirements and needs of occupants, processes and interactions present in analysed buildings. Information fed back through continuous assessment leads to better and more informed user-oriented design decisions.

Buildings go through a complicated evolutionary life cycle process. It comprises planning, programming, design, construction, use, demolition or adaptation for a new purpose and recycling. In my opinion simulations should be especially used at phases of building life cycle at which feedback from users can be gained.

They are:

- programming,
- early stages of design
- and post-occupancy assessments.

Simulations can be used for studying people behaviour in relation to built environments before the environments are erected. The studies allow the future users to participate in the programming and design process. They also allow researches, architects, designers to understand what aspects of a built environment influence people's preferences.

Case studies – the use of simulation techniques

Three examples, selected case studies undertaken at the Faculty of Architecture in Gliwice will be presented in this section. The methods of creation for all of these simulations are quite similar.

3D models were made in AutoCAD, Architectural Desktop or Autodesk Viz, then they were animated in Autodesk Viz. Interactivity to rendered pictures was added in Adobe Flash software.

Development of Faculty of Architecture in Gliwice

The aim of the project was to create an architectural program[3,4] and conceptual designs of the new Faculty of Architecture building. The architectural program consisted of:

- site analyses;
- results of quality analyses of the existing facilities;
- organisation's structure;
- detailed spatial requirements;
- users' needs;
- concepts and sketch designs.

A few simulation techniques were used during this project. First shadow studies were created to make sure how existing buildings would impact future building. (Figure 1) The Daylight System tool in Autodesk VIZ together with animation tools were used to make studies of the building's shadows over time. The Daylight System tool enables to set sun position and the location of an analysed building. Then we can study the movement of shadows across the ground and on the elevations of analysed building.

The next step was to create concepts of a new building to study a physical form. Realistic views of the design proposals aren't needed to make better decisions as we progress through the programming process. The crucial functions and tools that we need as designers at the architectural programming phase are to construct simple geometric forms, basic building blocks. At the programming phase the 3D model must be simplified, efficient and dynamic to increase the speed of data processing. It should be a low polygon model. Figure 2 shows two concepts which were created to study a physical form. One of these concepts was selected for further studies.

Finally there were created animated walkthroughs to analyse the building's outward appearance. A walkthrough is the mean to generate a more intimate look at a design. We simulate the view of a building as we walk along a path. Walkthroughs are meant to give the user a sense of what the space is really like.

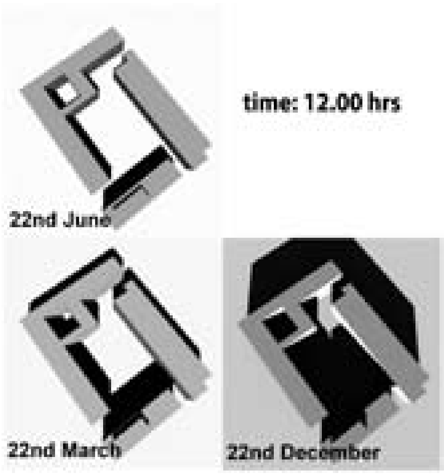

Fig. 1

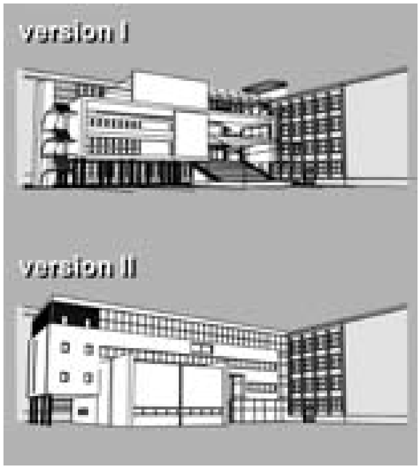

Fig. 2

Quality assessment of an office building

The second example is the quality assessment of an office building located in Warsaw. We collected systematised data describing the quality of the office building and checked the performance of the building from the point of view of its users. At the end of the research process we invited the users of the building – the people who really know about the building in use - for discussion. We presented to them the research outcomes which had been prepared in the form of 3D visualisations.

The performance quality of the following categories were showed:

- the impact of structural solutions on the flexibility of space arrangement;
- efficiency of floor area use (Figure 3);
- behavioural quality of workspace.

During discussion users were given the opportunity of commenting on these issues.

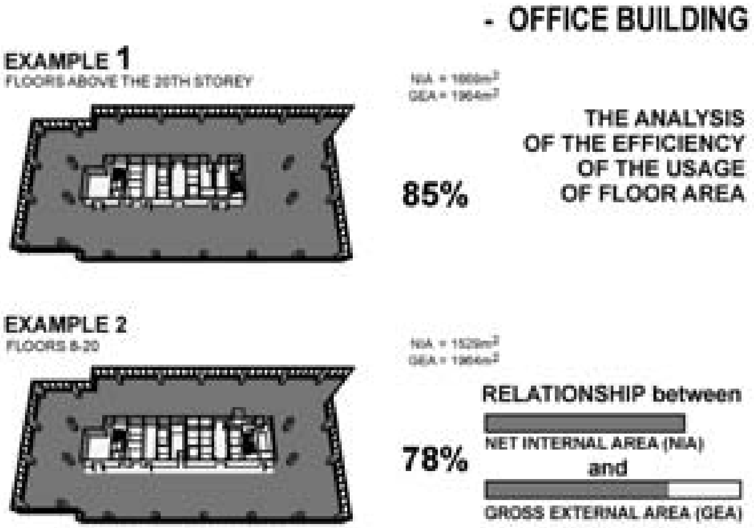

Fig. 3

Quality assessment and programming of office facilities
at the Faculty of Architecture

The main objective of the case study was to assess the quality of the existing office facilities of the Chair of Office Buildings Architecture and Design Strategies. The next objective was to devise the functional program and design concepts. An interactive presentation of the results of the analysis was prepared.

The interface of the presentation enabled displaying the data collected in the course of the quality analyses and the worked out results. For example there was possible to display the following data:

- comparison of the sizes of floor areas of the analysed existing office space and the proposed arrangement (Figure 4);
- pictures of existing office facilities;
- arrangement of the new workplace by pointing at text or pictures visible on the screen.

Simulation methods, techniques and tools

In the last section the common technology is reviewed which can help make our simulations as real as possible. The following methods, techniques and tools are described:

- modelling the behaviour of light;
- creating panoramas;
- RPC – Rich Photorealistic Content;
- Virtual Reality;
- rendering to texture – "baking";
- game engine technology.

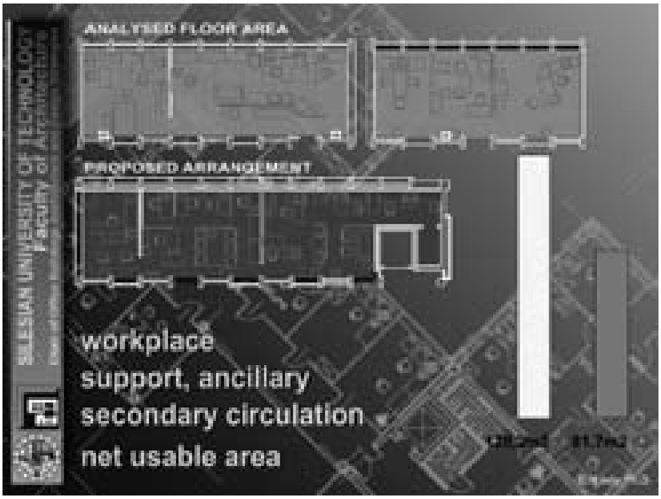

Fig. 4

Modelling the behaviour of light

Today there are many tools to model the behaviour of light. They are crucial to create stunningly realistic images. Not only can they create a physically correct lighting simulation, but they can also render all imaginable visual phenomena like caustic, reflection and refraction. The most popular tools are Autodesk Mentalray, V-ray and Brazil.[16,17]

Rendering the behaviour of light has got one critical disadvantage. It takes a long time to render such images. It is common that a single detailed photo-realistic scene requires even overnight to render. Not to mention a rendering of a short animation. The rendered frame size in most animations is relatively small but we have to render 30 frames for every one second of animation. To make things worse the HDTV is being launched and one of its characteristics is significantly higher resolution than of traditional TV. Rendering networks sometimes called render farms are the solution to this disadvantage.

Creating panoramas[9]

There are many software packages available which create an image-based panorama. It is called also a "wraparound panorama". The panorama offers a 360-degrees view of a space and our point of view is in a fixed location. An example tool to create panoramas is the Panorama Exporter in Autodesk Viz. Two spherically distorted images are shown in the Figure 5 which can be displayed in a wide array of panorama viewers. The most popular to view panoramas is Apple's Quick Time VR format. Panoramas can also be efficiently published on the World Wide Web.

RPC – Rich Photorealistic Content[14]

RPC – Rich Photorealistic Content is an plug-in used to create high quality items such as people, cars, furniture and plants. RPC uses a single plane with an image applied to

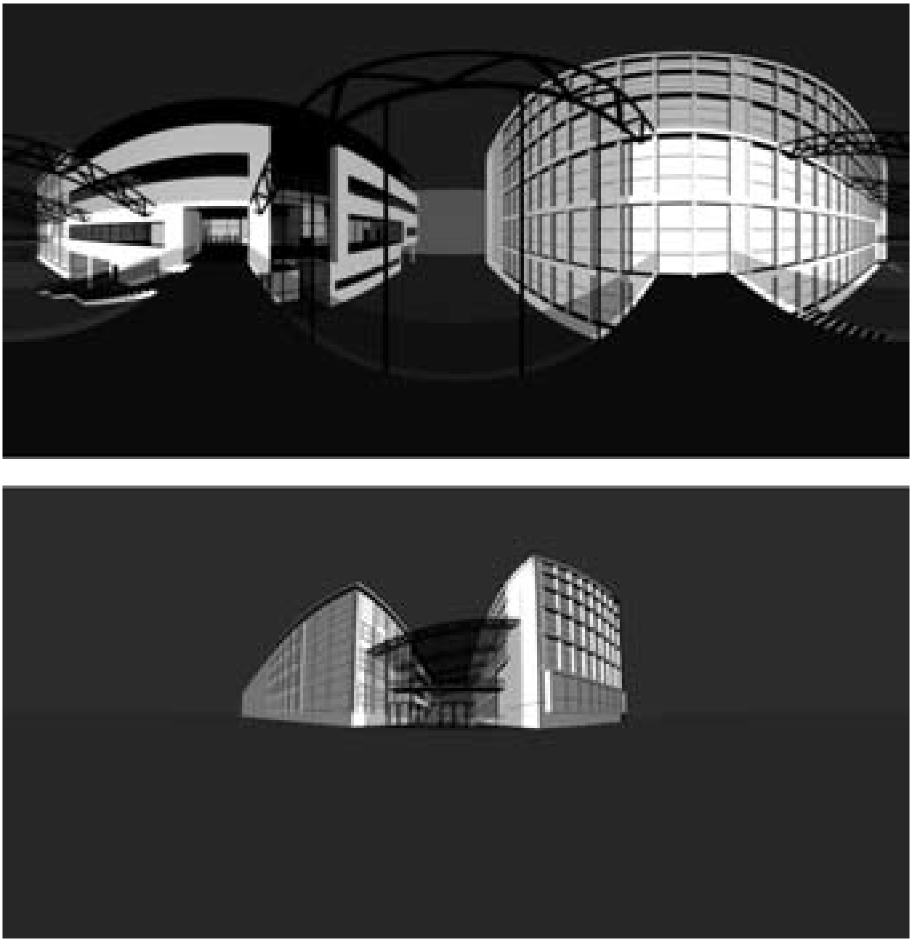

Fig. 5

its surface. It looks like a cardboard photo. But RPC objects are useful with animations as well. The plug-in changes the displayed image when the point of view changes, so we see an illusion of the 3D object.

The two main characteristics of the RPC objects are that they render noticeably fast and files are small in size. But the objects have also one meaningful weakness. An image of a tree textured onto plane doesn't bounce light in the same way as a 3D model of the tree. So RPCs aren't useful when you want to model the behaviour of light.

Virtual Reality[5,9]

The alternative to the traditional rendered still images and animations is Virtual Reality. It is any computer generated environment in which you can place your "avatar" (point of view) and freely move around a three-dimensional space in real time. The most important quality of real-time technology is allowing users and designers to be "in" the built environment which exist only in architect's imagination. We can interactively visualise and experience spaces in time. We can interact in real time.

Through the two most popular programmes Macromedia Director[13] and WireFusion[15] virtual reality became easily accessible to the design industry. The software offers means of conveying 3D worlds through the Internet. We can also interactively change colour, texture, form of our models to see how variations affect the design.

Rendering to texture – "baking"[9]

"Render to texture" or "bake" is a tool which enables creating bitmaps with advanced lighting data, such as the results of active radiosity, mentalray or v-ray. We render bitmaps with shadows, reflections and shininess. When the advanced textures are mapped onto an objects' surfaces we can remove light sources from the model and the objects look like they are still lit.

Models with "baked" textures can be displayed really efficiently, because graphic display cards need less time to display "baked" textures than to calculate lighting information in real time.

Game engine technology[9]

The most efficient in simulating Virtual Reality are now real-time game engines using DirectX and OpenGL technologies. Technology is finding its way into architectural simulations too. Macromedia Director and WireFusion are good examples[13,15].

But the significantly impressive development is seen in a multibillion dollar worldwide computer game market, partly driven by graphics card manufacturers. The fact is that the reality of 3D worlds in games will probably always be at the highest level than the reality of the built environment created in CAD or a common modelling and presentation software. Everyone who has played a modern console game knows how addictive moving around architectural spaces can be.

Of course we can always export our models to a real-time game editor and prepare the simulation there. (Figure 6)

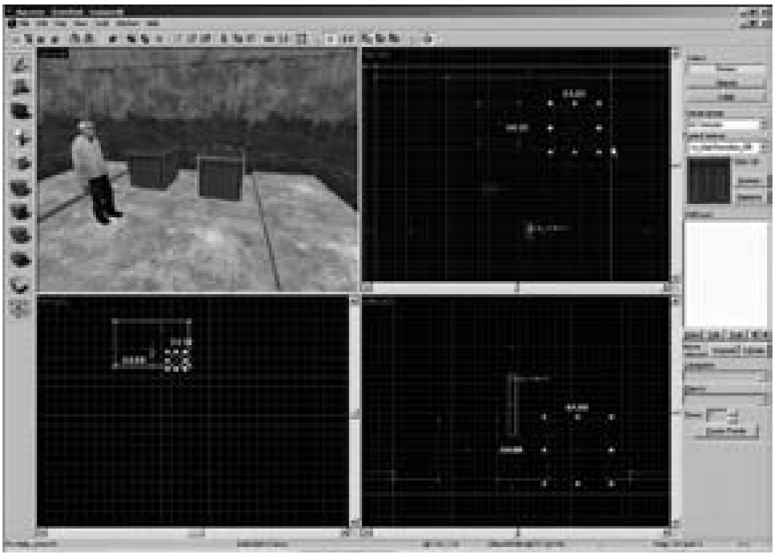

Fig. 6

Conclusions

Simulation methods and techniques are making their way into an architectural design practice. They can help test design ideas in terms of how a physical environment can affect users' life. An architect and a client are now able to experience space before the building is even constructed. Simulations can also generate data which would be returned to the real world context for its benefit.

Moreover there is a general and growing recognition of the need to address the issue of the users' participation in the delivery of high quality facilities. Unfortunately there is one significant obstacle. There isn't any recognition that tangible benefits could be derived from the participation and from building quality evaluations particularly.

Wide incorporation of users into the design process for better quality of the built environment could be the core focus in the employment of simulation methods and techniques in architectural designs and researches. But the widespread adoption of simulations at early stages of design and the anticipated associated improvement in quality of the built environment will only be possible when the building industry is willing to agree on the practicability of the building quality evaluations.

Therefore the plans are to render the practicability to create a model of a simulation tool which would allow the occupants of the future spaces to take part in the research process at a programming, design or occupancy phase. Such model would incorporate virtual reality, questionnaire surveys and would work on the Internet.

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Aimilios Michael
Marios Christodoulides
Marios C. Phocas

Program of Architecture
Faculty of Engineering
University of Cyprus
Cyprus

Construction Workshops in Schools of Architecture

A Case Example

'Construction' as meaning and its role in architecture education

As a meaning, 'construction' remains unaltered expressing the means and the process by which the intellectual thought of the architect takes shape. The development of new coordination technologies preceding the construction process has led to the eventual sidestepping of on-site construction techniques. This has led in many instances to their relegated importance of the latter from a primary holistic role, to a limited field of operation, directly related to the material characteristics, the appropriate assembly and finally the realization of the design intent.

Nevertheless, contemporary construction experience and architectural practice has been characterized by an ever increasing complexity and a continually growing number of material choices. These bring back the act of 'construction' to the center of architecture production, highlighting its cohesive and indivisible presence. The direct correlation of architectural design with the potential of realization, the connection of construction methods and detailing with contemporary aesthetic expressions and the movements of the twentieth century, highlights the importance of construction in the making of contemporary architecture.

Teaching construction at a newly established academic program

Following from above, the newly established Architecture program at the University of Cyprus, has developed the teaching of construction courses in such a way as to support and reinforce a unified and Integrated Architectural and Construction Design.

Through construction courses I, II, and III which are organized in thematic groups according to the primary construction material – wood, reinforced concrete and lightweight-steel respectively – the intent is to highlight the distinct characteristics of the different construction materials and how these can affect or determine the building structure and envelope.

The courses are conducted in the context of architectural design studios and construction studios (micro-studios), with the design exercises aiming to utilize the technical knowledge that has been attained through lectures, and also to develop an understanding of structure and the appropriate construction processes through the process of architectural design. The intent is to emphasize that the design of the structure supports the integrated approach, which is derived from the parallel development of the programmatic requirements, architecture form, and the process of construction.

Timber Construction Workshop. A Case Example

In Schools of Architecture a holistic approach to design construction and manufacture may be achieved through workshops of specific educational contents and aims, which can function as complementary to the individual respective courses of the curriculum. With the primary objective being the implication of students in the pragmatic process of conception and implementation of an architectural idea, the Department of Architecture of the University of Cyprus organized in cooperation with the Cyprus Architects Association, the Timber Construction workshop, with the participation of twelve students from four architecture schools throughout Europe, the University of Cyprus, the National Technical University of Athens, the University of Thessaly and the University of Manchester.

The development of the architectural idea and the process of realization

Methodology

The Timber Construction Workshop is attempting to utilize the knowledge and experience students have also gained from a more intimate contact with architectural practice.

The design requirement remains consciously simple for enabling an understanding of the basic principles of the structural systems, the particularities of the design and the final design products. The entire process is based on the integration of structure and construction in the design process, with the aim to boost the approach of integrated architectural design. The students are asked to arrive at a specific design intent, evaluating the potentials and shortcomings of the selected site, the available materials, and the timeframe in which they would have to operate.

Materials and tools of production

The workshop team has at its disposal wood studs 5 cm x 10 cm x 600 cm and marine plywood panels 244 cm x 122 cm and 22 mm thick. In addition metal ties, metal wire, bolts, and other metal accessories for wood assemblies can be used. Also, for the construction phase, a number of electric tools are available for handling raw wood materials.

Schedule

The entire process has been divided into three interrelated sections that include design, construction, and transportation (including site assembly and installation) with a time frame of three, four, and two days respectively.

Project site and conceptual thoughts

The process is initiated with a site analysis, and an evaluation of the different possibilities, so as to select a specific location for the installation. The first conceptual thoughts are developed with a clear correlation to the urban structure of the square (in reality

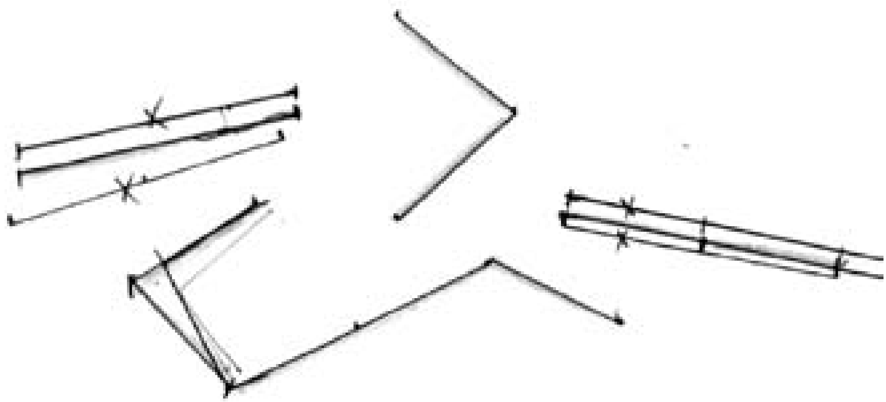

Fig. 1

Initial concept, directly related to the urban structure of the square it's a network of widened sidewalks that frame a main vehicular route, which defines the 'square' more as a major artery than as a place to stop), the historical importance of the place, both in political terms since it served as the nucleus of one part of a divide city, but also since geographically it does connect the old walled city with the new city.

Concept development, design of structure

The design suggests the construction of a double wall with a geometry that has references from the bastions of the Venetian walls of the city. The arrangement of the two sections of the structure results both in a passage and a place to stop, able to guide passersby and offer seclusion in an urban space that is not so clearly defined.

The conception is carried through with a series of sketches and study models that begin from an early stage to show evidence of the formal and tectonic intention of the final structure. For the tectonic realization, a structural system is chosen that includes tilted surfaces with rigid joints connecting them.

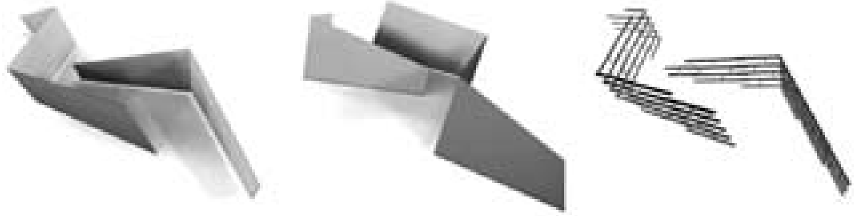

Fig. 2

Concept development, design of structure

The use of digital design as a vehicle for exploration and as a tool for tackling the different layers

The process is carried though in a digital environment, that allows the multiple and simultaneous exploration of the different parameters of design, form, constructability, structural system, detail development and the entire production process, which is developed consistently in stages and constitutes an important tool during the realization of the project. Also, the cataloguing of the different parts of the digital model enables the classification of the different elements which include the rectilinear members, the

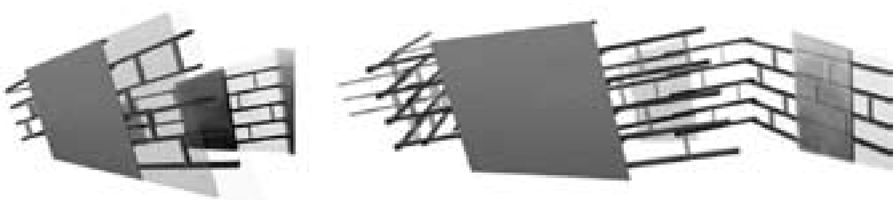

Fig. 3

Exploration of different parameters of design panels, and the parts that connect them. The digital model constitutes throughout the process of design and construction, the primary tool for exploration, development, and organization of the work. However it's also complemented by the construction of a scaled physical model, at a scale of 1:10 with the appropriate information so as to facilitate the coordination of detailing and construction.

Construction

According to the 'list of parts' of the project, all the different elements are assembled as they are being prepared. Issues are resolved that are related with the anchoring of the structure on the concrete paving of the square. The structure is first assembled at the department, and then disassembled in the appropriate parts so as to accommodate their transportation.

Fig. 4
Manufacture

Transportation-assembly

The different parts of the structure are transported to the final installation site, where they are assembled, anchored on the solid paving of the square and assume their final shape and form within the space.

Fig. 5
Transportation to the final installation site

Supplementary architectural interventions

A black angled stripe is painted upon the structure, transversing its different surfaces and continuing upon the ground plane of the square, extending the reach of the structure beyond that of its wooden surfaces. A series of black and white photographs representing moments from the city are attached on selected nodes along the black stripe, reinforcing the association of the structure with the space in which it resides, the past, the present and the future of the city.

Fig. 6
Supplementary architectural interventions

Interacting with the urban fabric of the city

The architectural product, after having gone through the various equally important and interdependent stages of design, construction, transportation and assembly, was installed at Eleftheria square.

The resulting structure, along with the inherent possibilities or limitations of its material, attempts to convey the potential of the architectural process, a potential that through the conditions of design and construction becomes an urban reality, incorporating form, color and texture. Through its material presence, the structure initiates a spatial condition, through which it transforms the spatial experience of the square as a whole, and attempts to respond to the challenges of the build environment and co-exist with the everyday reality of the inhabitants of the city.

Furthermore, the entire process allowed the integration of all the workshop activities in the area of the walled city, successfully energizing the public and achieving its integration into the process of architectural creation.

With the introduction of the prototype in the most predominant public space of the city, the workshop also aimed indirectly at the regeneration of the city core through a revitalized stimulation of the people's experiences and understanding of architecture.

Fig. 7
Cross influence with the urban fabric of the city

All the above assume more meaning, when referring to the city of Nicosia, where the attempt to halt the process of degradation, a result of abandonment and organizational deficiencies, is of a major and constant concern in the local authorities and citizens minds.

Educational Outcomes

Such workshops offer to the participants the possibility of learning the properties of the materials and the specific requirements of the construction techniques, as well as the basic design principles of the structures. Through the development of the designs and the process of realization, construction and manufacture are experienced in real terms, while these individual thematic sections are interdependent with no clear boundaries and with substantial overlaps among them. The works of the particular workshop aimed at the investigation and promotion of the role of the structural and construction elements in architecture per se, as well as in the creation of the built form.

An important outcome has been the gathering and actual cooperation of architecture students from different academic backgrounds, a matter which is highly important in architectural education at university level.

Conclusions

The present paper examines the introduction of construction workshops in the architectural education at University level, with regards to the building technology component and its interrelation with the architectural design. The required development of a temporary structure addressed all stages of design and manufacture, including the phases of conceptual design, construction design, prototype construction, transfer and erection of the structure at the central square of the city. In relevant courses of technology, the objectives should aim, among others, at the best possible integration of technology and the practice of basic principles of architectural design through a holistic, interdisciplinary approach. To achieve the above and capitalize on the educational benefits, the authors propose that in addition to studio based courses, such practical outdoors activities occur on a regular basis, complementing the design research that occurs in the studios. The case study of the timber workshop 2007 is presented herein for clarifying the aim of teaching and applying the syntax of construction design in the frame of architectural design.

Henk de Weijer

Academie van Bouwkunst
Amsterdam
The Netherlands

Complementarity

Interoperability and the necessity of a proper bookcase

An architect is not a hermit living on a lonely island. Architecture is neither the outcome of individual activity nor does one, and only one, particular field of science support it. Furthermore: architecture is neither Art for Arts' sake nor a branch of science. It is influenced by so many ideas, possibilities, demands, requirements, fields of knowledge and a workable metaphor of an architect is a juggler who, in the smooth and dynamic flow of his performance, tries to keep all balls in the air. Each ball follows a path that is in harmony with the flow of the designed show. Uncontrolled, bouncing balls only evoke disaster. A juggler needs to have a good feeling about the influence of gravity, light, weight, distance, timing, size and texture of the balls, about temperature and air-friction. But the moment he/she starts thinking about one of these items in particular the magic is broken and the specific performance is over. Essential is the overall view of the juggler and his/her ability to design unexpected movements, rhythms, speeds and items, while playing with the limits of his/her human potential and the laws of nature.

Two thousand years ago Vitruvius wrote the following in *De architectura libri decem:*
"So, one could say that a person amply complies with the norms, when he, of the various branches of science, has superficial command of those branches and their theories, that are indispensable for tectonics, by which he will not fail when the need arises to pass a critical judgement on these matters and artistic forms. However, when a person by his very nature is endowed with such highly giftedness, acuteness and memory that he is capable to qualify completely in mathematics, astronomy and other studies, he will rise above the sphere of actions of an architect and will become a mathematician."

If architecture is controlled by many not completely predictable opinions, directions, interests and influences, how will an architect stay in tune with an inherent order that asks to be followed before the essence of the structure he/she tries to build will be allowed to come out? No one can tell what is the essence of a specific project or how to bring it out until the level of every detail, it has to be dis-covered by hand. Peter Zumthor writes: *"Details, when they are successful, are not mere decoration. They do not distract or entertain. They lead to an understanding of the whole of which they are an inherent part."* For me one thing is clear: not before a building has been allowed to be itself, complete and undivided, will the Essence come out. Even when an architect possesses the sensitivity and skill to let this happen, there is every chance of misunderstanding and improper or inadequate application of new information and insights. Unfortunately or luckily: the path does not unfold in one continuous, unilateral flow, but is distinctly multilateral and wavelike in character. Sometimes we follow a smooth road, sometimes it seems to be filled with only rocks. Moreover to some extent path, as well as outcome is blurred. The outcome is not completely predictable, but on the other hand a certain amount of freedom to move is built in.

A good amount of stability is needed, not in the last place because other users of the same road: engineers, advisors, contractors and subcontractors all have a valid interest in practical and clear information. If the various interests are properly recognised and dealt with while following a constructive and fair approach, they work out complementary and synergetic, instead of in competition.

The movement requires a backbone and, like in a human body, it needs to give stability, as well as allow for flexibility in the different levels of action.

The first level is a clearly defined developmental procedure. Although in the various European countries this procedure varies basically, in all countries the period from first sketches until completion is divided into four, incremental stages. The design stages are clearly defined, but not disconnected: each summarising activity is conclusive as well as open ended and in this way they operate as concept for the next. This approach will allow for a maximum amount of future space, which in return catalyses ingenuity and skill of present and future partners, paving the way for serendipity.

The second level is a competent architect, able to co-ordinate and integrate the various discovered possibilities and necessities - brought forward by competent consultants - into a visionary, stable, synergetic and visual model.

The third level, the sharing of different forms of information, is in itself not a new item. What is new is the precision and speed offered by scientific software and continuously faster computers. Speed and detailed precision have tremendously increased, as a result of which more potential models, following different parameters can be compared during the process, thus allowing for more conscious decisions and more precision in design. Not only that: CFD (Computational Flow Dynamics) programmes have become capable to perform highly complex geometries, which allow accurate insights in situations concerning aerodynamics and energy, fire resistance and safety, as well as structural stability.

However precise, fast and reliable these new models may be or capable to serve the interests of various consultants in the design process, they are field-specific and not general programmes, fit to improve the exchange of information between the various participants. The present data models for information and communication are anything but universal, informative and complete. To give one example: a structural model could be copied from the, already existing, architectural model, but in almost all cases a structural engineer starts on blank soil. In order to achieve vertical integration, costs-reduction, less miscommunication between building-parties and lower failure costs a new building model is being developed and promoted. For this basically two solutions exist. A first possibility is the all-in-one model; a digital master, capable of solving all architectural, organisational, scientific and other needs. It is clear that such a model would be too coarse, unwieldy and expensive. The second possibility is a general, universal and transparent, 3D based, data model that serves as a basis - and not more - for the requirements of all specific programmes, like a bookcase for books (Fig. 1).

Such a non specific Building Information Model (BIM) will allow information sharing and interoperability of intelligent, digital building models, developed in object based systems, throughout all phases of the building life-cycle.

In BIM a design model -covering geometry, spatial relationships and geographical information- and a database (IFC-Industry Foundation Class) go hand in hand. BIM incorporates 'parametric object based design' where every object inside the model po-

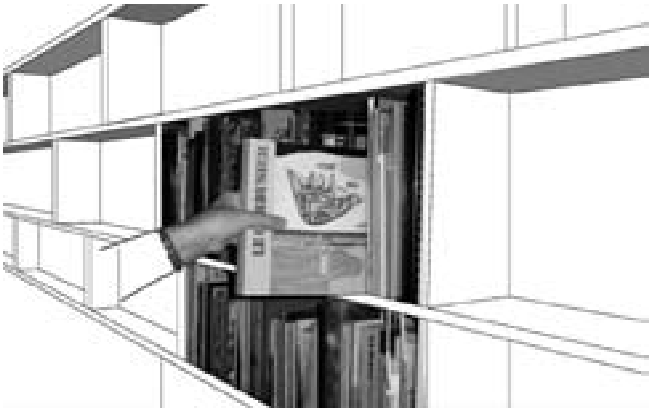

Fig. 1

tentially contains many levels of information. A wooden window-frame not only gives information about form and size, colour or required amounts of paint, but also about glass, insulation, moment of delivery or even Facility Operation. BIM provides the potential for supplying virtual information from the Design Team (Architect, Structural and Civil Engineers, Mechanical and Electric Engineers) to Contractor, Subcontractors and Owner. Each discipline is allowed to add specific information to the basic model, in this way openly influencing it. This IFC is developed and controlled by the IAI (International Alliance for Interoperability). IAI is an alliance of organisations - software companies, building product manufacturers, information publishers, owners, designers, and builders - in AEC (Architecture, Engineering, Construction) and other industries. The various CAD platforms, like ArchiCAD, Revit from Autodesk, Vectorworks from Nemetschek or StruCad from AceCad Software, use this IFC archive file format as the basic general software for their own specific drawing software. Certification of these specific products is done by IAI. In Europe, architectural companies -who usually bring the needed (BIM)bookcase with them- and their designers are waking up for this big operation. USA and Scandinavia are a bit ahead. This change will be bigger than the transition from the paper to the digital model. It will initiate a different way of working, thinking and designing.

A last level is the level of demands, requirements and expectations. Many of these are relatively objective, like functionality, economy, sustainability and flexibility, while others are relatively subjective, like humanism and beauty. Objective or subjective components alike, they all need to be integrated into an architectural form that serves its intended activity in the most direct and simple, yet multilayered way.

Do these various levels have absolute and exclusive value? No, they only have relative value and are complementary to each other.

Creativity

The general and the various specific virtual models are complementary to each other and need integration, but what about virtual reality itself? Is it one and complete in itself or is it a counterpart of another reality? One way to look at is to watch where it came from. Virtual reality no doubt is the result of thinking, of our mental capacity. But is our mental capacity independent and self-supportive? Somehow we got created in an evolutionary process that took 13,7 billion years. The first forms of life maybe organelles, maybe single cells like amoebae, only possessed an automatic response to their environment called instinct. In the course of time higher animals developed simple attraction and rejection, sentiment. Still more complex creatures, including human beings, know all the previous subtle layers of the mind but now including thoughtful reactions and emotions. Finally with the potential of creativity and deep thinking, new horizons opened and the human recognition of the existential core brought us completeness (Fig. 2).

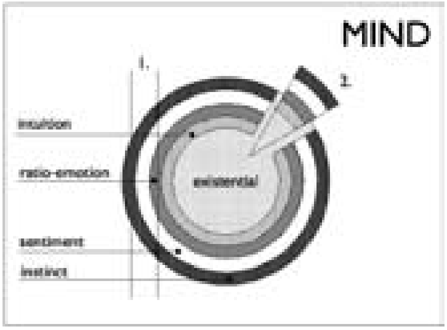

Fig. 2

Ultimately, mental experience cannot do without physical experience. They are tied together; virtual reality cannot be seen without a physical sensation, although the process of the influence of both knows two directions. One is physico-psychic (physical reality catalyses mental activity), the other psycho-physical (mental activity results in actions towards physical reality). During the act of designing it is only natural to use all acquired characteristics. Physical activities are not waiting to find shelter in virtual reality. On the other hand, the quality of a physical shelter can be raised tremendously by adequate use of intellect and virtual models. After completion all promises, intuitions, ideas, virtual and other models of the design team are forgotten, to the users (but not only to them) it is only the real building that counts. After eating the used utensils go back to the kitchen, they have lost their function for this meal. In much the same way a mother doesn't love the virtual image of her daughter, she wants to talk, play with her child and hug her because of undeniable emotional and deeper needs. Multi-layered, meaningful buildings are rich, while single-layered decisions and architecture are poor, independent of the budget. However intellectually advanced approach nr. 1 in fig. 2 seems to be, its outcome is shallow and dry. On the other hand, approach nr. 2 of the same picture, in principle uses the full human potential.

Creativity and the urge to search for new, unknown connections are catalysers for new insight. But creativity can only be optimal and effective when both rationality and skill are developed and at the same vision is directed towards something new and essential.

In the process of creative action three elements are essential: Reflection, Analysis and Construction, the last one being physical or digital (Fig. 3). It should be perfectly clear that the presence of all three is what matters, the order in which they occur, clockwise or counter-clockwise, is less important. Reflection, the internal search for a certain direction, may directly be followed by the Construction of a model, provided that at some moment an Intellectual Analysis will be carried out. Also a first analysis of the

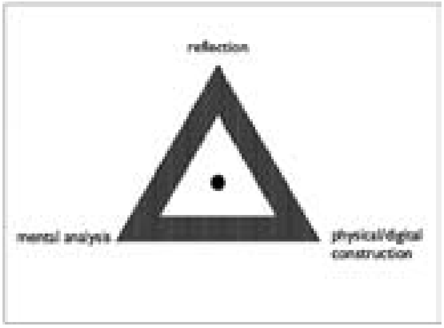

Fig. 3

programme may directly be followed by deep internal Reflection and brooding about an appropriate form, after which a digital or material model be made. There is no way to determine which is the 'better' approach; it is a purely individual choice. It is my experience that a usable creative flow only comes out during active involvement and commitment. One doesn't win a competition by reading a book about architecture.

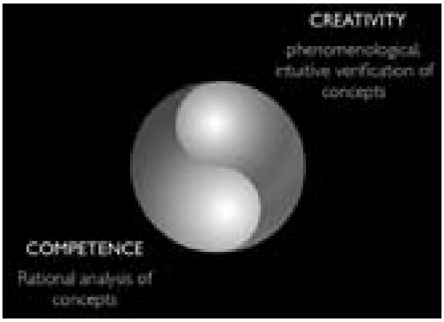

Fig. 4

Again, different realities are complementary, the virtual and the material; reflection, analysis and construction; as well as their basis: the human physical, mental, creative and existential potential. Not only that: meaningful architecture, and the teaching of it, will find its strongest expression when a precise, rational analysis of concepts is balanced with the phenomenological, intuitive approach (Fig. 4).

Let me give one example of such a creative approach. For young people in Firminy-Vert Le Corbusier sought to unite sport activities with more intellectual pursuit in the library. He united two functions in one material concept, a gallery made of concrete, both with the same geographical orientation, but one outside in the stadium and the other one inside a cultural centre (Fig. 5, 6).


Fig. 5

Le Corbusier, *Firminy-Vert.*
Outside: a gallery for sports ...


Fig. 6

Le Corbusier, *Firminy-Vert.*
... and inside: a gallery for reading.

Examples of pluriformity in approach

In the architectural practice the use of different techniques is state of the art. The final choice depends on the required information itself, economy, availability of specific resources, time involved, background and skill of the responsible instigator. Material models occur in addition to 3D renderings and handmade sketches (Fig. 7), physical tests alongside CFD models. Nothing is excluded in advance. As a matter of fact, all models not only have their own capabilities, but possess limitations as well and it is only but relevant to continually be aware of this and weigh their pros and cons. So far no fire brigade will accept CFD models, so a physical test is the answer to questions related to fire resistance. Much in the same way questions related to the ageing of a material can only be answered by physical testing. The presentation of a preliminary design may be accompanied by 3D renderings, but in general is best served by a physical model, because physical models don't have a backside. Structurally occurring complex elements like facades may be analysed by architect, subcontractor and contractor, but only a one to one model, a mock up (Fig. 8), will clearly show all positive and negative consequences. The need to make choices continues from first sketches until completion.

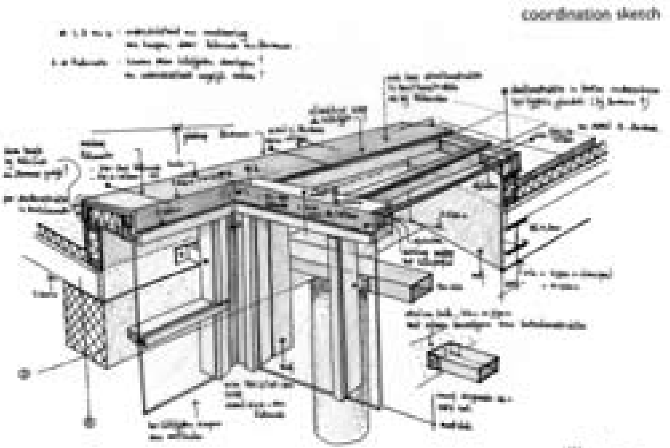

Fig. 7

Co-ordination sketch.

Fig. 8

Herman Hertzberger, *Amsterdam*.
Mock up for a facade of the University of Amsterdam.

Fig. 9
Moshe Safdi, *Yitzak Rabin Centre, Tel Aviv*.
A physical model.

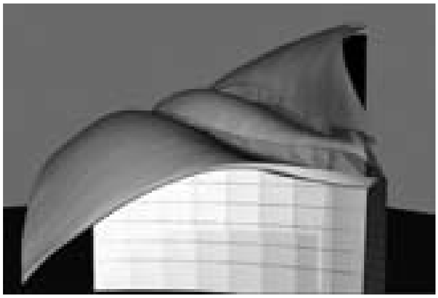

Fig. 10
ibid,
A 3D model by Moshe Safdi.

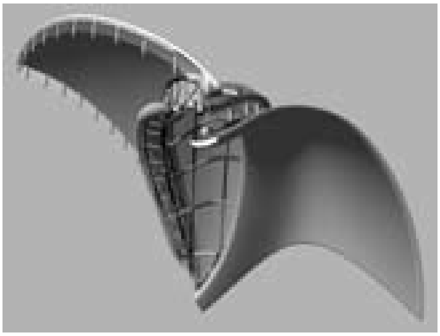

Fig. 11
ibid,
A Final Engineering 3D model by Mik Eekhout.

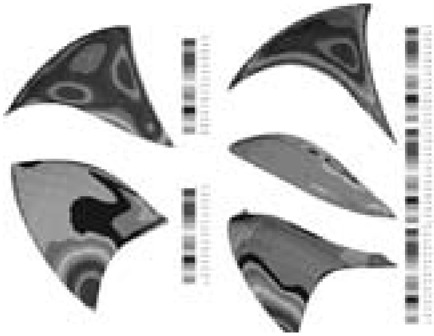

Fig. 12
ibid,
A CFD model.

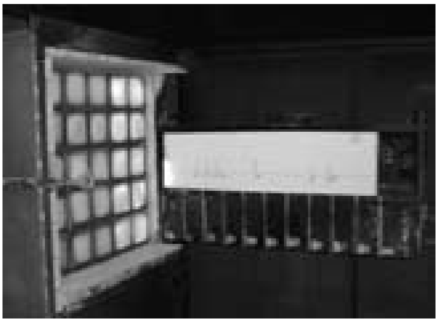

Fig. 13
ibid,
A fire resistance test.

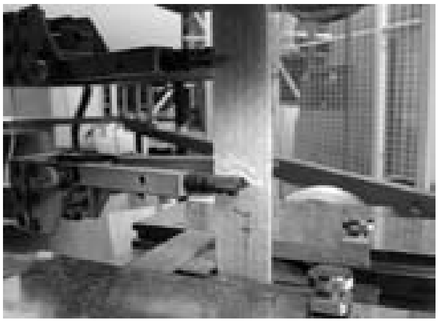

Fig. 14
ibid,
An ageing test.

The first examples all follow the design stages of the Yitzak Rabin memorial in Tel Aviv, designed by Moshe Safdi. The two wing-shaped elements were engineered and produced by Mik Eekhout and Octatube in the Netherlands, after which the various were transported and assembled on the site in Israel.

Do architects, with the wide range of new scientific programmes and CFD models, all at once have total control over a project? The consequences of proposals can reliably be brought to the surface but final decisions are made by a team of consultants, each with a specific interest. Some interests are complementary, but sometimes they conflict and a loss can only be accepted by psychologically and philosophically developed persons!

Teaching

Teaching can only take good notice of and implement the above mentioned attitude and approach. Teachers need to assist the students in developing their skill to work with virtual reality, at the same time learning that its counterpart is physical reality and also discover this reality while working on a one to one basis. So in the preparatory (Fig. 15) and part of the first year they only work with paper models. After that they are pushed towards a digital presentation of their assignments. It is even more important for them to discover that a, sometimes hidden, polarity is an essential characteristic of Nature, of architecture. Each of the counterparts has its own value and denial of one results in incompleteness and stagnation. Learning about the nature of Nature can only be done by giving a lot of energy to construction and analysis only after that they will be kissed by Nature and discover new visions and coherence. We teach our students to be precise, critical and creative, never to be satisfied with easy answers or worn out answers from the past.

Fig. 15
Final presentation in the preparatory year; student: Bob Gibson.

Conclusion

Every step in the path from programme to design and completion needs lots of energy, commitment, alertness, rational approach, but the essence of this all goes beyond ratio. The goal of all our efforts, of all our texts, sketches, meetings and models is not to make virtual reality, but real buildings where we can take shelter 'in the folds on construction' like Louis Kahn once said. It is a situation where the virtual and the real have blended. Or, in the words of Steven Holl: *"Our challenge is to make spaces of a serenity and exhilaration that allow the modern soul to emerge"*. If each contribution, each mental construction and each model was directed at the same goal, the path has been paved for experience and the subtlest of all, experience of experience (Fig.16).

Fig. 16
Herman Hertzberger, *museum of modern art, Apeldoorn.*

Jean-Marie Bleus

Saint-Luc de Wallonnie Institute for Architecture
Liège
Belgium

General Context

General Context

The following text presents some current reflections. They are the fruit of :

1. Numerous debates that we have been lucky enough to have in our institution where daily contact between teachers of various disciplines enables the development of what I call a trans-disciplinary approach.
2. Frequent contact and work over the last ten years with the teachers JP Franca and JM Perin from the Paris La Villette School of architecture where they have been working on a model of the global architectural project for the last ten years.
3. Contributions from the 5 previous AEEA construction group seminars.

The above points have been listed in order of importance with regard to the time spent on them.

In education, the approach of architecture leads, from the students' first steps, to an immediate awareness, of the colossal number of parameters which have to be considered when working on a project. This great complexity is part and parcel of the word of architecture, even more so when considering the particular parameters studied in "related" architectural disciplines.

From this point of view, certain teachers believe that the technical factors are elements whose study can be postponed until the conception planned in the teaching phase of the project. Some teachers of architecture even speak of teaching "pure architecture". Our position is obviously completely different. We can say that this proposal can be considered as a postulate or a basic axiom in our search for pedagogical coherence.

From local to global approach

If we address the more precise subject of this colloquium, "simulation and tests" we can easily imagine that current computing tools enable us to realise increasingly complete models of mechanical, thermal, waterproof or acoustic performance and properties as shown in certain works on completed construction. Although these tools are of interest for the studies, they present some disadvantages:

1. They are generally mono-disciplinary and do not allow an estimation of the interaction between various disciplines during the conception phases.
2. They supply us with information once the conception has been completed and do not provide us with direction or orientation of choice during the reflection process.

Taking that into account, we believe that simulation or tests in the conception phases can only be taken into consideration if we take a more in depth look at the fundamental notion of the *model*.

Generally speaking, a model is an instrument which accompanies any consideration when it comes to human thought processes, even more so when it involves concrete projects. For this part of our presentation, we shall use the classification adopted by Alain Badiou in his book 'le concept du modèle' (The model concept) , where he distinguishes between the formal sciences (logic and mathematics), the empirical sciences and the hermeneutic sciences.

Yet it appears inevitable that, in order to organize thoughts of any complexity, we should proceed by Reduction, otherwise it could lead to a degree of confusion. Nevertheless, a certain ambiguity arises as soon as such words are used. It is then advisable to base oneself on the categories of sciences expressed above and note that the model is similar to a system which relies on a type of inadequacy (Fig. 1) In fact, we can speak of a thought model and of a representation model which gives rise to two distinct elements.

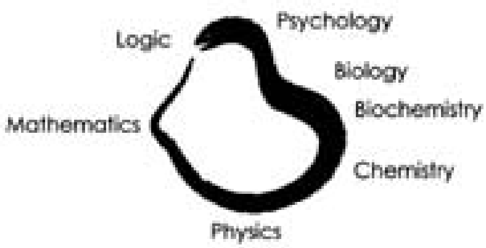

Fig. 1

As a result, we will take a look at the conditions upstream of the simulations and the tests realised in the conception phases of the architectural project and consider the integration of the initial technical constraints as elements inherent to the first phases of the project.

The necessity of reduction shown in Franca and Perin's plan in their model (Fig. 2) developed in Paris La-Villette.

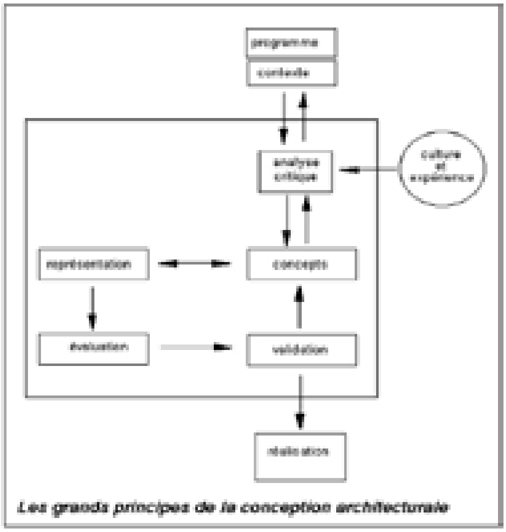

Fig. 2

is made up of loops applied to various stages of the project, through time and with a perpetual 'bottom-up' and 'top – down' movement.

In addition, during projects carried out in the workshop on the conception of empty space, geometry makes up the interface between materialism and space. Consequently, three categories of scientific disciplines already mentioned appear on the model (Fig. 3).

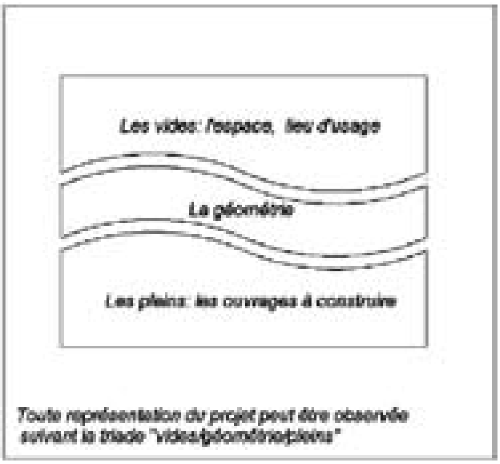

Fig. 3

With the rigour that models need to provide from images

This reflection allows us to use the rigour of the sciences in order to obtain coherence between the parameters defined at every level. The search for coherence leads us to be more critical of sketches and therefore to detect notorious incoherencies such as those found in Santiago Calatrava's drawings and watercolours below. In the first, the transparent part of the eye corresponds to the sphere of the building which appears opaque while the transparent part of the building (around the sphere) corresponds to the white but opaque part of the sclera (Fig. 4).

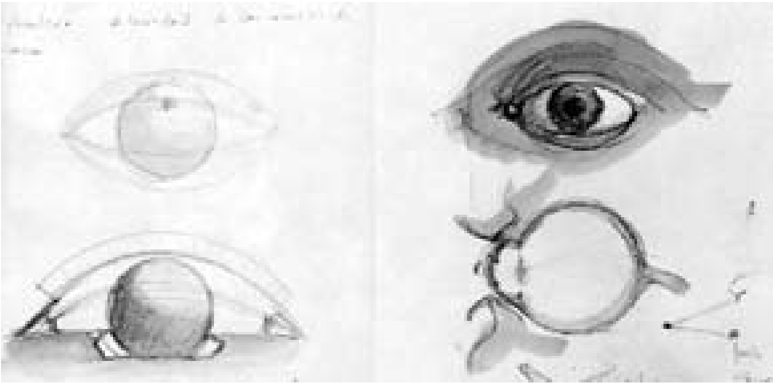

Fig. 4

In the following drawing, taken from the book 'Introduction à l'analyse des structures' (Introduction to analysis of structures) - the static model which corresponds to the "horse" possesses an articulation in the place where the horse's thigh muscle is at its most rigid! Here the assembled model has nothing of a horse other than a certain visual likeness.

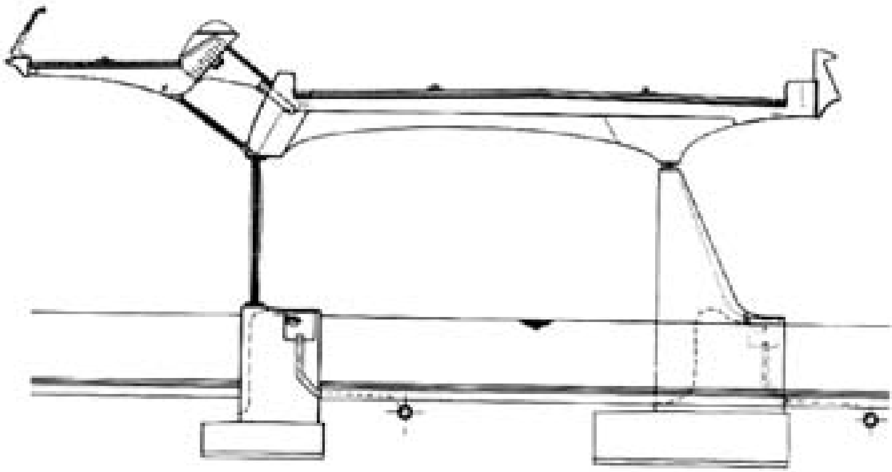

Fig. 5

Troughout time

With regard to examples of the reality- the approach of complexity by our students - in Baccalaureate year 1, we ask students to develop the idea of associating - when presenting elementary volumetric models - geometrical considerations, light, thermal and structural considerations. (Fig. 6)

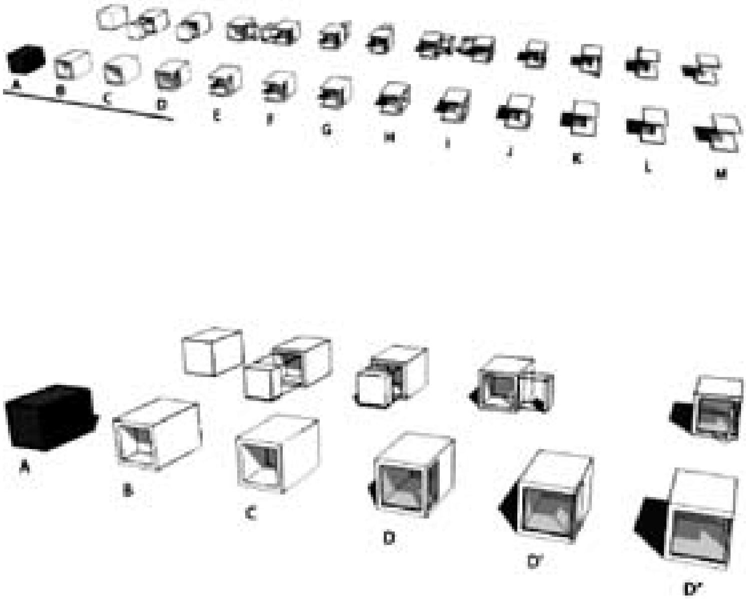

Fig. 6

This exercise, which touches on reduced complexity, allows us to work with students with little training enabling them to simultaneously consider elements which are usually separated when it comes to analysing their performances.

The idea of generating a multi-criteria code of performances, even of a limited order, follows on automatically.

In the 2nd Baccalaureate year, student works on bridges (Fig. 7) enabled the students to introduce themselves to relations, forms, materials, and mechanical performances. Through the process of manufacturing their models, testing the material and its behaviour in accordance with geometry and the planned loads, the students progressed significantly even when working with reduced complexity.

Fig. 7

In their 3rd Baccalaureate year, one of the students' tasks in the studio of architecture is directed at the conception of volumes in housing, an exercise centred on empty space

as the element of composition (Fig. 8). The integration of this initiative in the structures lesson enables us to introduce students to reflections on doubts concerning potentialities, necessities and resultant performances.

In the 2nd Master's year, in 2007, a fruitful experience (Fig. 9) integrating the structures lesson in a micro-architecture workshop (teachers: Fabienne Courtejoie and Norbert Nelles) allowed us to work on the integration of geometrical parameters, spatial complexities, materials, costs, and auto-construction.

Fig. 8

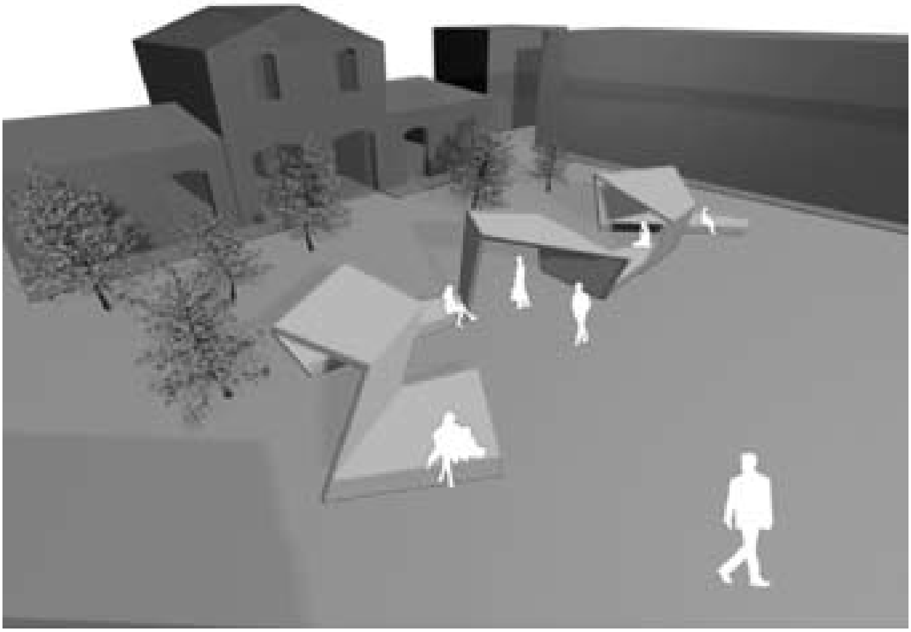

Fig.9

The evolution phases of the project were carefully listed so as to make best of the pedagogical opportunities and allow us to identify the imperatives of structure and construction. We believe that this analytical stage constitutes a worthwhile exercise of association for sometimes divergent parameters which require in depth study of a choice among recognizable and required criteria.

In this case, even if the students and the teachers do not make a choice considered relevant by the whole workgroup, the main aim of this experiment is to make everyone aware of the parameters of influence on the result. Far from being an exercise in obtaining optimal results, the objective is to avoid shortcuts too often used in architecture of images, appearance, or shape without foundation. I would like to remind us of a sentence that Victor Hugo could have used, "The shape is the foundation which comes to the surface".

Fig. 10

A second exercise, carried out by a second team of students in the same workshop (also developed to answer our school's needs), was designed and constructed during the 2006-2007 academic year based on a geometrically less complex concept. It is already used as an example in the structural analysis lesson in the second Baccalaureate year.

In conclusion, some elements seem important when debating the interest of simulation and tests in the learning process of construction in the school of architecture:

1. The simulation has link to a more general context, that of the model.
2. For fundamental reasons, due to the specificity of the conception which is multi-criterion, the context must be thought of in a broader, more global way than the peculiarity of the local performances of such elements in the context restricted by its own discipline.
3. The model used to estimate the performances can then give all its sense in the global context of any project of architecture.

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Iconographic Sources

Fig.1 comes from Hubert Reeves "*Malicorne*"

Fig. 2 and 3 come from JP Franca & JM Périn, *Le processus de conception* p3.

Fig. 4 comes from the book *Santiago Calatrava Libro Segreto,* Mirko Zardini, *Il planetario della citta delle scienze by SantiagoCalatrava* p.21 Motta Architectura 1995

Fig. 5 comes from *Introduction à l'Analyse des Structures* Studer M-A & Frey F.

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Nina Juzwa
Aleksandra Witeczek

Silesian University of Technology
Gliwice
Poland

Form versus Structure in the Computer Age

Regardless of the time of creation of an object, the architect's convictions, style or direction of thought, the building's form, construction and matter remain in an inseparable relationship, however, for the shaping of architecture, form is of fundamental importance. The form defines the architectural style of a building, it identifies the time of its creation, author and the cultural setting. Before the form takes a material shape has an intentional character, i.e. it is a thought in the mind of the architect-creator.

Already for Vitruvius, the idea was the basic fabric of architecture, although an idea alone does not constitute architecture. A design presented in the form of a drawing or a model is still a thought; such a presentation is a supporting activity indispensable for converting a thought into a material object. There exists a very close relationship between the idea and the material form of the work being created. During the design process, the architect sees their idea as if it were real. However, between the design and the executed object, there exists a huge gap similar to that one that exists between the conceived object and its drawing or model. The choice of the method of building, construction, materials, colour and texture is made by means of a drawing, model or a finished design.

The role of a design is to convert an idea into reality – such reality which will create new impressions in the mind of the user, similar to those that were the inspiration for the building's creator. The ways of capturing an architectural idea, i.e. the various abilities of the tools supporting the design of architectural buildings have an enormous influence on the shaping of the architectural form of a building. Over centuries a pencil, a set-square and a ruler were the basic set of tools which enabled the architect to present images which were conceived in their mind. When the images were connected with a creative thought, the tools enabled the execution of magnificent sketches of forms and constructions including gothic churches or the Sydney Opera House. Actually, all modern architecture of the Western civilisation has been created with the help of these tools and consequently the influence of tools on the design has been often neglected.

Design in the Computer Age

Recent years brought on extreme civilisation changes. Frequently, our time is called the computer age, digital age or liquid modernity – terms that refer to our changing environment. The changes also concern engineering and technology of building construction as well as shaping of our architectural environment.

In the process of architectural design, digital technology has expanded the set of tools available for the architect-designer. The spread of computers at the end of the 20th century caused a huge influx of new tools which have dominated the design process and replaced the classic drawing tools. As a result of the application of computers, not only does the time and manner of design change, but also the way and range of collaboration with specialists. A design is often created with the omission or reduction of the number of drawings and sketches; this phase of design is often taken over by a three-dimensional model. Computerisation frequently encompasses the manufacture of building materials as well.

The most important effect of the computer age on shaping of the architectural form are the new possibilities of shaping space. The new possibilities unlock architects' imagination by changing their outlook. The previous boundaries are called into question. There are still areas difficult to access, however the thought of architects explores ever new dreams which until recently were impossible to fulfil.

Currently, architecture gains new qualities which lead to the creation of a new paradigm of space. On the one hand, modern architectural space emphasizes intelligent environment; on the other the form of a modern architectural object explores instability, variability of elements, ignores rules of Euclidean geometry and searches for convex spaces or experiments with materials.

Fig. 1

Airport Barajas, arch. R. Rogers, 1998-2005, Madrid, Spain.
All the new material possibilities and construction techniques gives lots of freedom to the designers. Computer supported design process open up a whole area for the creation of a non linear architecture.

Form versus Structure

The teaching undertaken by our research group concerns architectural design of buildings with research or production function. The experience gained in the process of teaching as well as in the recent years conducted research in the area of shaping the architecture of industrial buildings has led to the reflections we are presenting here.

The spatial layout of an industrial object most of the time consists of several buildings which are usually weakly connected with one another. They are frequently arranged freely reflecting the technological processes. In addition, often a characteristic object is the production hall; it is the architecture of this building which in many cases determines the impression of the whole complex.

Production functions connected with the engineering and technological features require a high, spacious interior which is free for development. The space of the hall is characterised by adaptability. Design requirements result in the fact that modern production halls most of the time consist of two main elements, namely the construction, sometimes of large width, which functions as the internal structure of the object and the casing which is the external envelope of the object. These two constituent elements are the basis for shaping the architecture of the building.

Our research concentrated on 60 objects (industrial plants) selected by means of professional literature research; the objects were subjected to an introductory investigation. For the second stage, i.e. closer investigation, 35 objects were selected. The research examined the dependence between structure and form as well as the construction and building skin of the industrial halls. The objects were analysed with the application of functional schemes and described – each object was labelled with data concerning the technology and function of the object, the surname of the architect, building year, localisation, site planning and spatial configuration of the complex and layout of the plot. The spatial relationship between the production hall and the remaining buildings was described, as well as the main construction principles. Most of the illustrations were executed *in situ*.

Fig. 2

Some examples of analysed industrial plants - our research involves the results of analysis of 35 examples, built after 1980 in Europe.

The research allowed us to formulate general rules which govern the shaping of a hall object.

The main characteristic of a production hall is the size of the cover which often requires the employment of a construction with a width exceeding standard values. The choice of construction and the manner of its application usually determines the formal solution for the object's architecture. Our research allowed us to distinguish three different solutions which determine three different concepts of the architecture of an industrial hall. The difference is determined by the tectonics of the elevation:

- *Tectonic expressive* - the load-bearing structure out-sizes the building's skin and determines the formal impression of the object.

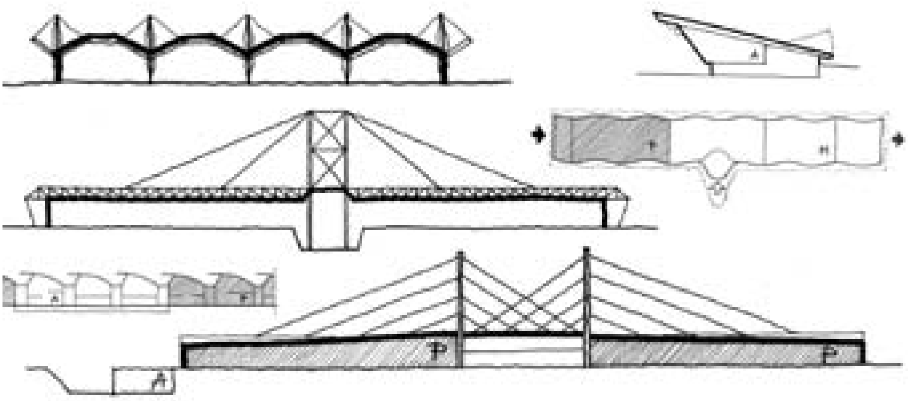


Fig. 3

Tectonic expressive – examples

Fig. 4

Renault Distribution Centre, arch. N.Foster, 1982, Swindon, UK. – an example of TECTONIC EXPRESSIVE [Photo: www.fosterandpartners.com]

The leading trend on the beginning of eighties and nineties was to show the structure.

- *Tectonic fragmented* - the building is divided into parts and the load-bearing structure is invisible.

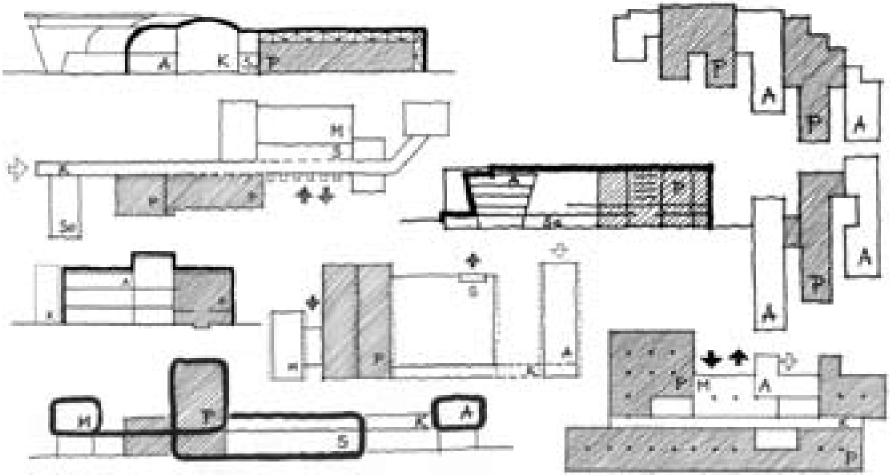


Fig. 5

Tectonic fragmented – examples

Fig. 6.

The Glazed Factory, arch. Henn Architekten, 2002, located in the edge of the historic town centre of Dresden, Germany – an example of TECTONIC FRAGMENTED.

- *Tectonic hidden* - the construction is covered by the building's skin.

  The building skin, "envelope", is separated from the load-bearing structure and becomes a curtain. The fixation on the surface, the use of ornament and decoration is increasing nowadays. Often a structural drawing on the elevation or the texture of the used material is the only idea for the aesthetics of the casing.

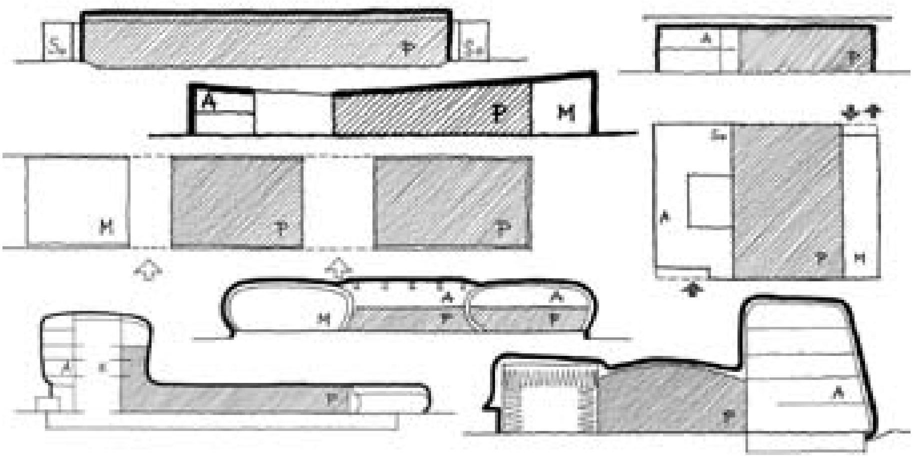


Fig. 7

Tectonic hidden – examples

Fig. 8

The Experimental Factory, arch Sauerbruch & Hutton, 1998-2001 in Magdeburg, Germany – an example of TECTONIC HIDDEN

Similar principles apply to non-production buildings which require an interior of a large volume. It is important to note, that objects created for the industry are often strongly defined by the economical aspect and do not allow such a creative freedom as objects created for public retail or services. However for the purpose of our research, production halls are an equally useful example. Especially that many of the investigated objects were designed by well known architects. We find the works of Eisenman, Hadid, Ghery, Herzog & de Meuron operating on basis of having been "liberating" from the constructive constrains.

The majority of the large volume buildings are supported by a steel or concrete frame and protected by a non – load-bearing multilayered curtainwall. Many of the more recent buildings underline the idea of continuous uniform or stillness of a more abstract volume. Thanks to the new composite materials such as carbon fibre products, glued structural profiles will be very light weight, insulating, non corrosive and at least as hardy as steel. It opens the possibility to express structures inside and outside

It seems that in recent years some large-scale objects move towards solutions where the load-bearing structure is an increasingly integrated form. In the case of Olympic objects, we can talk about *tectonic integrated*. In particular, this is applicable to the Watercube –National Swimming Centre called "Bubble Building" or National Stadium "Bird's Nest" in Beijing.

Fig. 9

National Stadium "Bird's Nest", arch Herzog & de Meuron, 2003, Beijing, China – an example of TECTONIC INTEGRATED [Photo: E. Trocka-Leszczyńska]

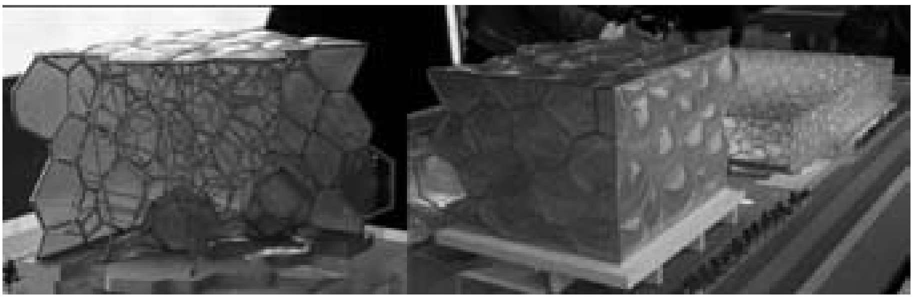


Figure 10

Watercube –National Swimming Centre, arch. PTW, 2003, Beijing, China – an example of TECTONIC INTEGRATED [Photo: E. Trocka-Leszczyńska]

Miodrag Nestorović
Ivan Rašković

Faculty of Architecture
Beograd
Serbia

A Novel Approach to the Development of Structural Systems and Space Structures at the Faculty of Architecture in Belgrade

Man discovers gradually the secrets of nature which reach the essence of creation in realms of its laws and structures, which also have the same distinctions as structures created by man for his needs.

The most recent research of the secrets of nature in assemblies of inorganic and organic matter confirms that principles and forms of creation should be sought again in the building art of nature.

Like all organic structures, of plant or animal origin, which fulfill their purpose superbly (armour of radiolarias, spider web, honeycomb of bees, snail shell), the structures created by man are adequate to their task and form his ambience and living.

In the last three decades the matter of structure systems and space structures at the Faculty of Architecture in Belgrade was developed in educational and research domains, which testify designs, models and papers of students. Their research essays lean mostly on the matter contained in the books of George Zloković The Coordinated System of Constructions and Space Structures, as well as on the master and doctoral works of Miodrag Nestorović in domain of integrally tensioned (temerity) structures.

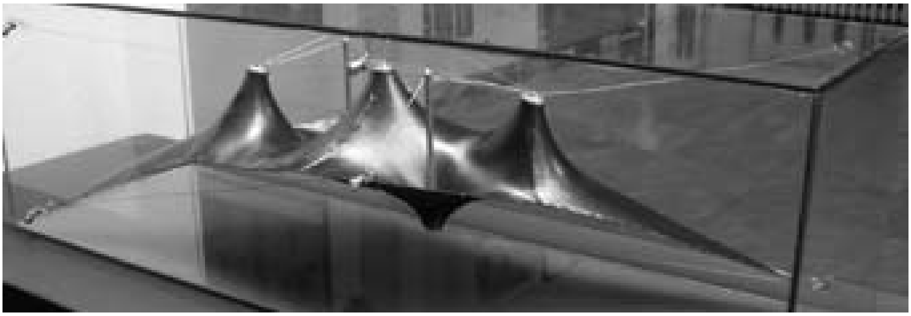
The research was conducted with the aim to obtain new rational structural forms and to reduce necessary amounts of material, energy and construction costs, as well as to find new adequate building technologies, mounting, dismounting and transport. It gave novel solutions which, in regard to conventional structures, provide great advantages in the richness of various forms, construction technology, speed of erection and economic performances, as well as many new properties: expanding and folding, packing into a small space, an extremely small weight and easy transport.

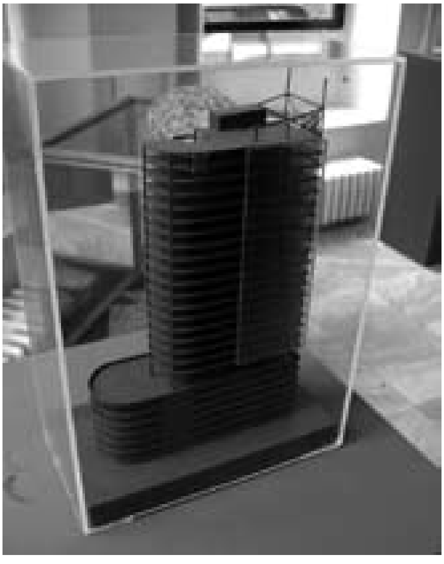
The students' projects and models from structure systems and space structures from the Faculty of Architecture were shown to public in seven exhibitions from 1963 to 2007.

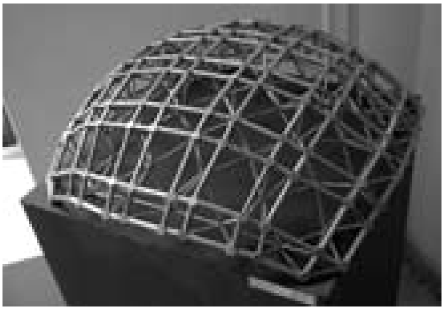
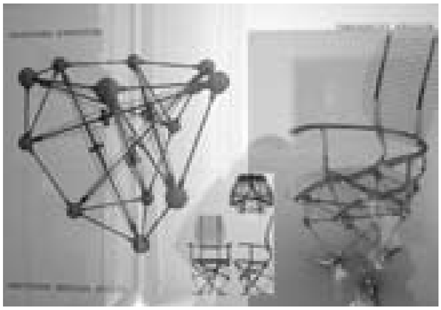
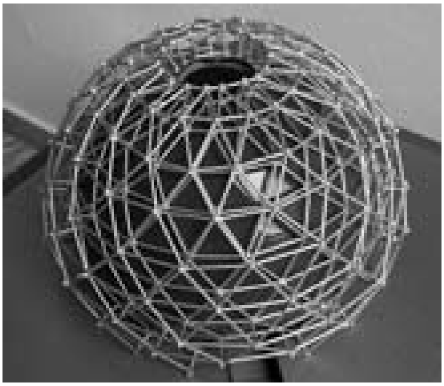
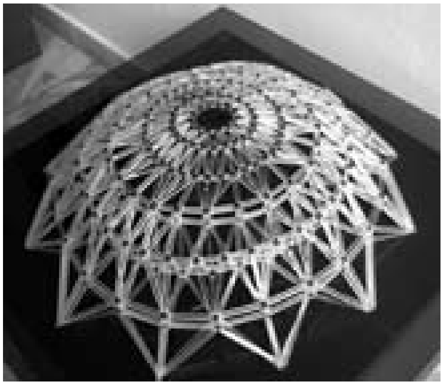
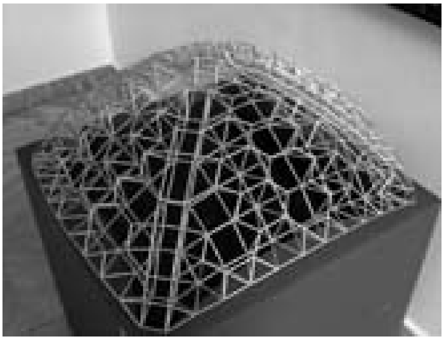
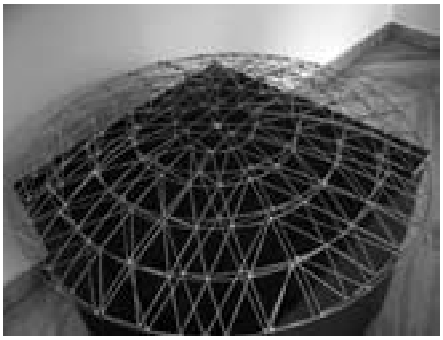
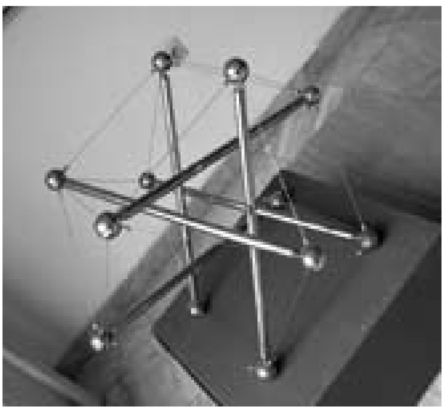
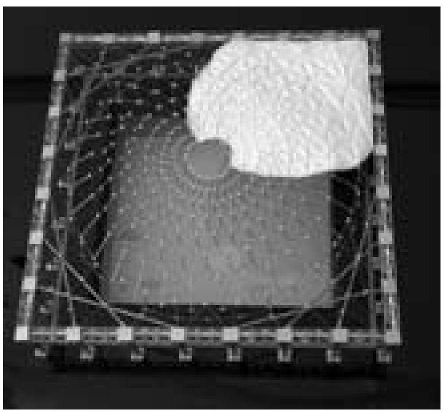
Maintaining a high level of scientific and teaching work, coordinated with the criteria of world leading institutions, with an inexhaustible creative potential of young professionals, woven into forty five years practice of Structure Systems and Space Structures, are the best guaranty to the assuredness that with fruitful and successful work will be continued also in the future.

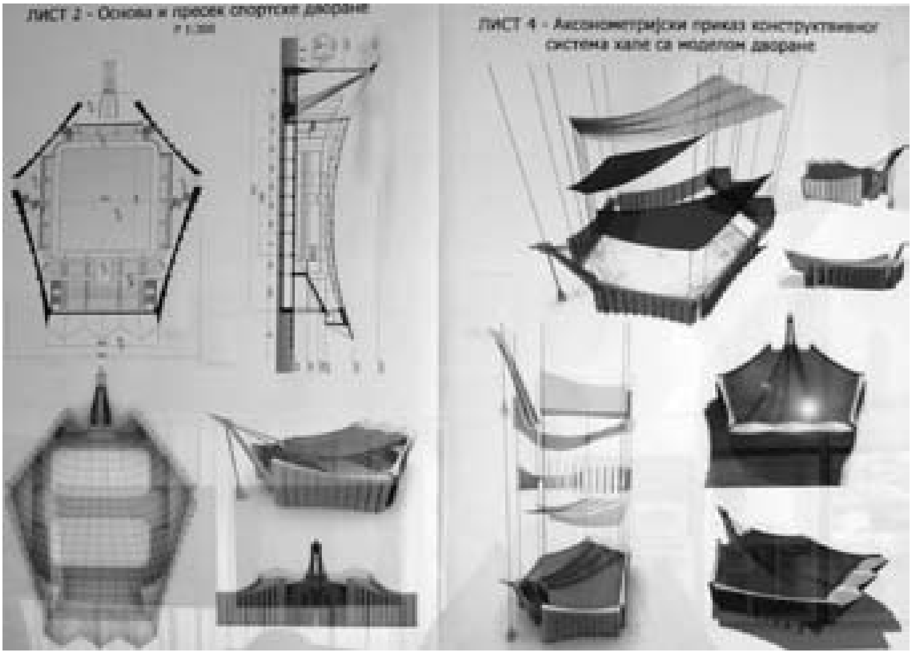
High criteria instigated at the same time are affirmation of the potential and the affinity towards an engineering line in architecture. The inspirational influence on students' work and attachment to the subject was inherent in the educational method of Professor Zloković who, by examples of concepts and solutions of structure systems of his sport halls in Serbia and Montenegro, was showing the genesis of these objects from design to realization, pointing to the importance of technology, economy and speed of construction. Characteristic qualities of education in the subjects Structure Systems and Space Structures, it is necessary to emphasize again, is the synchronization and contemporariness with world currents and influences. The fifties of 20th Century represent a definite turning point. Architecture is in a great expansion on all continents with a great number of new tasks (universal halls, societal centers, office buildings and the like).

A program established as a synchronized planning of objects and formation of a corresponding structure system presumes an active engagement of students in educational process, study of research papers and analytic choice of solutions of their own. The subject Structure Systems and Space Structures are established as a general course during two semesters, at a higher degree logically, the subject Space Structure







is studied including the static computer analysis too. As facultative, by its concept, this subject enables a more liberal, creative approach in modeling novel structural forms and solutions, which requires very ambitious and self-creating work of students.

Teaching methods, actually, often call for some kind of the check of subject by tests that are to be studied.

A classical approach to structure forms relays mostly on simple standard shapes with narrow field for expression for a subject that is studied or designed. Deficiency of such a method is that one remains outside the enormous field of more abstract forms of the subject, the forms that describe the subject from particular important aspects and angles. Designer is usually in the situation to define its structure or building only within forms of expression numbered. Their content and has evaluated through time in respective "language" that is able to foresee future structure completely.

Real model, on the other hand, acts as a sort of simulation that is to show how the subject in question is to respond to various influences and conditions. Models of more or less simple shapes and forms are suitable for one to become familiar with basic natural and physical processes within material structures as well as with a number of building design principles. Besides that, interaction that occurs between creator and a model is valuable as a learning process. One is to experience a difference between design concept, project, drawings, computer analysis etc. and real structure that possess own, specific characteristics of material artifact.

Modeling of a subject, designed as the peak of the design process, could be coupled within method of simulation where information technology acts as a connecting tissue. Thus, the possibilities to foresee the future "life" of structure design emerge limitlessly as never before within the history of building and technology.

Debates

Debate on the presentations of Session 1

Chair:

Jelle Laverge

Department of Architecture and Urban Planning
Ghent University
Belgium

Jelle LAVERGE, Ghent, Belgium
It is about the building up between the models, the computer models and the physical reality or another tension building up between the knowledge of the students and the possibilities of all different programs and even tensions coming from programs that interact and how they interact in the studio.

Hosin BOUGDAH, Canterbury, UK
I teach architecture. I was trained as an architect, but my subject is technology and Integration of technology into design. I have a comment and two questions for the contributors. My comment is that, yes, simulation, modeling, all these are tools and techniques we use and we encourage the students to use, but I get a little bit nervous, when I see that we concentrate on numbers all the time. I think students should be encouraged also to get a feel of what they need and not just the number crunching. I also get nervous when I hear things that designers don't create or do not create anymore by simplifying forms and just look at this form which was found but not created, as it looks terrible. Two questions, one for Marios Fokas, is that right? Marios in your presentation you referred in the program, in the architectural program, to two different types of design, environmental design, Integrated design and architectural design and their courses. Is there a difference between the three? And my question for Jerzy. You said that sometimes the students, for example, are exposed to all the disciplines such as building physics you mentioned and they can learn about energy efficiency for instance, but that does not find its way into their design. Why is that? Shouldn't it find its way to design?

Hosin BOUGDAH, Canterbury, UK
In your presentation, the courses you refer to environmental design, integrated design and architectural design, as well as structure and, I think, construction. You describe design with three different words in your syllabus, is that right?

Marios FOKAS, Cyprus
The construction courses?

Hosin BOUGDAH, Canterbury, UK
Yes.

Marios FOKAS, Cyprus
Or the technology courses?

Hosin BOUGDAH, Canterbury, UK
The course over the ten semesters. You have got various courses, you have got five: construction, technology, Integrated design, architectural design and environmental design. I have got these three. In the table?

Marios FOKAS, Cyprus
Ok, now I understand.

Hosin BOUGDAH, Canterbury, UK
My question is what is the difference between the three designs? Integrated, environmental and architectural.

Marios FOKAS, Cyprus
In the frame of the technology courses or of the technology area there is actually no difference between architectural design and integrated design. Actually, integrated design is the methodology followed for practicing or for developing architectural design. There is actually no difference. Now environmental design is maybe that was the wrong word I used. I meant the area of Technical System Support of the building. This specific course and energy efficiency of the buildings.

Jerzy GORSKY, Warsaw, Poland
The question was why these two parts, technical and architectural did not work. First of all, I think, because of the organization of the school. Traditionally, it still is divided into small departments and all the departments do their own work and this co-operation is difficult to organize. Hopefully the ambitious students can make the connection in their heads. Let's hope so. We tried from time to time to organize this working together, but I think that a teacher of architectural design, a studio teacher is not negative, but also is not positive. Which means they are not interested very much in practical co-operation, of course when we discussed it they said that structure is important and construction is important and sometimes they complain that students do not know much about our subject, but without stressing to students from the designing studio's point of view. These problems are important, it is difficult to force the students to do it properly and that is one side. On the other side there is the traditional thinking of the student. Sort of "School type" thinking of students. They have subjects and when they have passed the examination of the subject, it is assessed, the forget about it. Sometimes when I remember some construction exercise, I remember the students and then I talk to them afterwards, when they come for consultations for the design studio, because we try to make this co-operation, I ask them: " Did you do this three years ago?" And they say: " It has been a long time and I do not remember". Altogether it is still a sort of traditional way of teaching in our schools. This is the main problem. I also want to add something else, on the simulation theme, not for this thermal calculation, but for something else. To make simulation even on the architectural form. We discussed during the break some problems with some people that there is usually a presentation of final design. These students are really good at this. It is like a live building or something, but still they are coming to this final result by traditional methods, so they make this final picture, but I think that it is not the way of the task. The task should be simulation, for example checking the elevation. How the shadows are changing from the morning to the evening or how it will look according to the materials and how they change their traits. Even to simulate changing of the form and still when I cannot find this sort of new attitude in the design studio.

Fulop ZSUZSANNA, Budapest, Hungary
I saw a lot of different methods and simulation programs of different point of views and I have a general question: "How can we evaluate the results of these simulation

methods together?" This should be evaluated together because the final result of this calculation of building one construction and one building and I would like to ask you: "Have you got a special method for this evaluation in your practice and how can we solve it?" I do not know if you are able or not to understand my question, so as a result of these simulation methods, they should be evaluated together. And independently, for example, the simulation method of the daylight and the acoustical simulation methods must be evaluated together, I suppose. And I would like to ask you, how our lecture can evaluate these results in their practice? From our colleague from Leuven, from Israel, it is a general question. Our colleague from Leuven, I have heard especially about these simulation methods.

Stefan BOEYKENS, Leuven, Belgium
I think the question is right, because the difficulty of evaluating over different simulation aspects is that many of the teachers, you have only your own experience, your field of experience, your expertise and it is usually not in all the aspects. If you compare in general contexts, out of a teaching situation. This usually requires different consultants for different fields of expertise to unify all these simulations, I think it is very difficult, because of the lack of underlying technical knowledge in these different fields, so I am not sure how we could easily solve this. We can have a global qualitative evaluation based on different aspects, but usually lack experience in the other fields. I am not really sure how we could solve this.

Nathan Van den BOSSCHE, Ghent, Belgium
I do not think that every architect should use every kind of an evaluation program. I think that all architects should have insights in simulation programs and the results and on the other hand, we have to use the programs to improve their designs. I think that an architect should have a fundamental education, to communicate with different engineers and then understand and explain what he wants and what an engineer means. I think an architect needs a base for communication, but on the other hand, concerning simulation programs, I think actually, it is quite limited, because if you really want to understand it, you have to have a direct view on every aspect of it, like a lost representation you have to understand almost everything. That is just not possible for acoustics and day-lighting or construction and all those other programs. I think that an architect should master some specific elements concerning environmental design, because it is very critical and the base of our design process and on the other hand you just have to communicate with other people.

Jelle LAVERGE, Ghent, Belgium
I would like to add something to that. It is true that an architect, in the modern building process, is the communicator who communicates with all the different specialists, but I also said, that he should not only find the results of his concept. He should make his concept himself and then validate it to all these different fields, but that does not mean he has to know how to do it. As Nathan has just said, he has to have the means and that has to be another tool. He has to have the means to communicate with his ideas and what he thinks the result should be. I think, that is another aspect.

Maria VOYATZAKI, Thessaloniki, Greece

I will try to clarify something that may appear a bit technical or technocratic to start with, that will improve, I hope, as I go along. When I was writing this text on simulation, I was trying to think of what it is when a student develops, through simulation and I will use three terms, that distinguish a competence of an architecture student. In the general framework of looking at architectural syllabi in the European Union, in order to understand the different versions in the spectrum of architectural curricula, the competence is a tool is a way of understanding. Competences can be distinguished in three categories: 1) to know, 2) to understand and 3) to be able to. 1) To know: is associated with knowledge, 2) To understand: is obviously making sense of a situation and 3) to be able to: it gives you the capacity to be able to do something. With simulation, I think it is very difficult to say it is one or the other. One of the three. It is a combination of all the things at the same time, the way I understand it and therefore, when you look at a software or familiarizing students with simulation as a way of developing an understanding or enriching their knowledge or the capacity to be able to do something. You should look at it as a tool to facilitate these three different elements of the same competence. Therefore, I would agree with the people who talked just before me, that it is a way of developing certain skills one should have as a generic framework within which one gains insight into the several things, but to designate or to construct a school curriculum, where what you do is to have a student who is "literate" to use Ramon Sastre's term in the positive way. Literate in simulation and acoustics, or structure , I think we are looking for the impossible. I also think, that it is very important, since I mentioned Ramon, that his contribution to this forum is associated with our job which is to facilitate in many ways students' literacy on simulation techniques. Therefore, our job is firstly to stress the importance of simulation to students and then to simplify, if we can, because I'm not a programmer, but maybe in a School's staff team there is someone who can simplify simulation to familiarize students, with simulation as a concept but to grasp the importance of simulation and to become aware of what can be simulated and in what way. As a kind of a preparatory course for the programs with which they might work themselves or they might have to understand, when someone else who is a consultant or a member of the same team when they design in practice is dealing with the design or with Nathan's work to improve their designs. It is not our task to educate them to either write, understand or simulate.

Avraham MOSSERI, Tel-Aviv, Israel

I think that we are living in an era of crisis of integration, which is an outcome of the information revolution and I think we shall have to overcome this crisis. It will take us a few years and I think that we should have two different tools. We shall have strategic tools for rough estimation and for architectural understanding more precise tools, which now we have more of this kind, the problem of integration at the human level and the technological level. I think we have to educate for interdisciplinary thinking and going back to the model of integrating personality, that has the ability to integrate knowledge at a strategic level. We lost it in this era. In the future it must be in my challenge. We do not have to give up and we have to believe that it is possible to have the ability to integrate knowledge from many fields and this integration has to be at a strategic level. It is very important to stress this point. An architect has an ability to create an acoustical concept. He must have the ability to create a structural concept and to check it with strategic tools. The experts can do the more precise process later and I think we lost it in the last few decades. I am sure that if we take it as a challenge, we can go back and be part of an integrative profession, in the future.

Henk DE WEYER, Amsterdam, The Netherlands
I have a small question for Prof. Stefan Boeykens. You were talking about the element method and about including the cost of the environment, regarding the environment anyhow. Now my question is that we are talking about interdisciplinarity also. How long do you have, there is a group of people who are thinking about the same issue and they call it the forbidden cost. The hidden environmental cost. Is there any relation to those ideas that you were discussing? We are sitting here altogether thinking about, how to reinvent the wheel, or is there any communication and exchange of ideas among other members of the same profession in Europe?

Stefan BOEYKENS, K.U. Leuven, Belgium
A partial difficulty for me is that the actual research on these aspects is by my colleagues and not by me, so I am not able to give you a partial answer to that, but in a sense most of the way the element method is applied, originated uniquely from financial cost, economical calculation of the building construction, but it was found out that the actual methods, the actual logic to do that, could be extended towards the total building cost. The building lifecycle of cost, from the original material and the environmental impact until the final demolition of the building. In the last several years, a part of a research group has focused particularly on extending the cost into the total building cost. It is actually an interdisciplinary approach to this research. I think what you are saying is partly complementary with different research groups, different research approaches. I am not sure if that really answers your question.

Adrian Gabriel VIDRASCU, Ion Mincu, Romania
I am teaching technical science in our University. I also had previous experience in teaching just architecture, that is for coming in to complete the affirmation. Our colleague from Poland had already introduced on the relations between the design and architectural teaching and the teams, that are dealing mainly with the technical problems, but now I will come to my questions. Honestly, I had two questions. One of which I have already heard from our colleague before. Mostly, I would like to ask our colleague from Leuven, about this integration of the cost. Saying cost means not only financial cost but say in the perspective of the system developing, we are not only speaking about the financial problem, but about the social and the environmental problems and all three together are coming to build a system future. What are the tools that you are planning to use and are using and developing in your research? Not only as tools to work with, but also as tools to form the future of architects, to be aware of the things that they are designing from the very first moment of design and the impact of this design process on the future building. You gave us the first answer, but I would like to keep in touch, to keep the contact, so that we know more about this, because we are also interested in this aspect. And the second question I had was

for Mr.Spiridonidis or as for Mrs.Voyatzaki and for Mr. Mosseri, we already spoke before. My question is: How can we plan a kind of group, that we can supervise the evolution of our students and integrate their process for the formation and information process, in a way that the possibilities of testing and simulation in the construction teaching should go further in a kind of a co-operation program? Like in a social teaching program, because this is a networking platform in the end, and I would be interested in managing to make a kind of group of independent consultants, or whatever so that we can keep in a kind of permanent contact. In your presentation as you said, you have this classical way of doing, the teaching or the computer system. Teaching when you have the on-line and off-line Internet, and also of database. How can we do this in a larger scale, in a larger environment together, so that we can make a social teaching tool? I do not know if this is the right term, but it is just a first idea. How can we build this for the future experience, that we may have in teaching architecture and technical sciences in our Schools?

Stefan BOEYKENS, K.U. Leuven, Belgium
It is obviously a long question. I suggest that you could contact us later on the Internet, because I can forward you to the right people with more specific knowledge about its total building cost and its approach to that. But what is important was that, as part of this research, because it is developed throughout a research project and the total building cost is the focus on that, is to derive in a certain way to measure different designs and to have to be able to evaluate them on the same level and that I think there are the interesting aspects, because it is like the financial cost which is only a single aspect of the total building cost, which obviously is an important part, because the building owner is the first who should pay in the end and that is important too. In a teaching context that students should understand that a building, represents not only a financial cost for the building, but a complete and environmental cost and for such aspects it is interesting to connect the simulation tools, to derive quantitative information, build in a more simplified method, to be able to apply it in a design. It is a combination of searching for appropriate algorithms to derive information that is accurate enough to be useable in a design without the burden of a complete technical calculation that requires the knowledge that the student does not have or in many cases the teacher does not also possess or not at a sufficient level. The part is refining those tools and that can be part of the research aspect but applying these tools into the design process is a next step, that is something that is still ongoing, but is in the last few years that slowly some of these aspects are becoming the tools, such as a cost evaluation or a total building cost evaluation tool is some kind of a spreadsheet to fill in with very rough numbers, but with the limited amount of understanding the subject can be directly applied and that makes it interesting. An additional step would be the combination of beam, software or a tool to describe something digital and then to be able to connect with these simulation tools, because most of the information that is required has already been provided in the construction of the digital building model. The additional step of integrating this simulation is much smaller than using a very specific and sophisticated simulation program which requires a complete re-entry of all the information and an informative user usually does not directly understand.

Avraham MOSSERI, Tel-Aviv, Israel
Two years ago, I had connection with the University of Delft and we thought about the possibility of creating a pilot study in a few places. One pilot study in my University, one pilot in your University and the third one in Germany. It was only the beginning of an activity. For many reasons we did not continue, maybe we should continue this process, but I think it is a good idea if in a few places, we should be able to make a little pilot study, using a data base for case studies and to have the conclusions to share them. I think it can be very interesting. In some Universities that I know, most of the teaching is still traditional and there is not advanced usage or utility of the digital resources. We still have cases, where supervisors tell the student: "Please go to the library and bring me this and that book." It is very important and I think we should continue reading books, but in parallel I think we can use digital resources and with this laptop we can have channels around the world, a large amount of information. Maybe the idea of building a few pilot studies in a few places can be a good idea. You can think about this.

Jelle LAVERGE, Ghent, Belgium
First of all I would like to thank you all for your comments, your questions. I would like to thank the speakers, for their lecture. I hope the discussion that has started will continue over the next days of the Workshop.

Debate on the presentations of Session 2

Chair:
Miltiadis Tzitzas
School of Architecture
National Technical University of Athens
Greece

Hosin BOUGDAH, Canterbury, UK
Thank you very much to all the speakers, this morning with the presentations. I have not got a question. It is more of a comment, which is probably valid for all the presentations. We do use simulation, various types of simulations, such as teaching tools as well as research and design tools, but my worry is that maybe we are giving simulations probably the importance that they do not deserve in the design process. We should not make simulation a be all and end all. Simulation is only a tool, like every other tool. For a young student, they may think, that if it is coming out of the computer, then it must be right. However we know, that what you get out of the computer is only as good as the output, the input you put into it. Let's be cautious and we need to explain to our young students and future designers, that actually, yes they can get good results from a model, but at the end of the day it is how it will actually work out in practice. Finally, I was a little bit concerned when you said that architecture is equal to modeling. I think architecture is a lot more than modeling. And also knowledge is not just theoretical. I tried to tell a three year old girl, who was skipping with a rope in the play yard. She never had a lecture on how to skip with a rope, she has seen some other girls skipping a rope and she can skip it, so we do not have to actually impart. Knowledge can be imparted without theoretical concepts. People can learn even from practice.

Miltiadis TZITZAS, Athens, GREECE
Well, thank you very much for all the comments, but actually from the last one which was a little bit provocative about architecture being a model. Would you like to make a comment?

Jelle LAVERGE, Ghent, Belgium
Of course, I recognize that the statement was very provocative. As I also stated in my presentation it was just a way of trying to present architectural practice not that architecture cannot be seen as a part of physical realization of that architecture, but what you do as an architect is that usually you do not build yourself. You need to tell somebody else how to do it. You actually need to know exactly how he is going to do it. Otherwise you cannot tell. In that case you are absolutely right. Practice is extremely important, but what you need to learn is how to state what you produce, in that way that somebody else can understand it and can execute it for you and that is what I meant by saying that architecture is like modeling. It was really a part of simulations or it can be anything. It can be a drawing, it can be words, it can be a story. Or you can even show how to lay bricks, but modeling needs to be understood in a way that it is a communication and a simulation of some kind of something that somebody else has to do and how you interpret it. I hope that clarifies something.

Hosin BOUGDAH, Canterbury, UK
That goes a long way towards sort of answering. Although it is not a question, it was a comment I was making. But my point is that architecture is more than just the building itself. Otherwise, we will end up by sort of rephrasing the building as it was mentioned as an efficient machine. Surely, there is the human side of it. There is the social, the psychological and every other aspect. So, yes you are right. The building can be modeled,

can be made efficient, can be optimized, but there is also the experience of the space, that we cannot model. It is only when you are actually in the space and you must not forget that, because students, or prospective developers, whoever can see the model, can see the scheme, can see the nice picture. But it is actually only when you see it in reality and when you experience the space. Some of my students do not know what it means when they see the C temperature. They don't know what it means 75 db, when I say to them that the road traffic noise is 75 db. They do not know what I am talking about. It is sometimes very difficult to almost rely on the model to deliver that. But yes, the model will actually help. It makes you, or it gets you to show at least one side of the solution.

Henk DE WEYER, Amsterdam, The Netherlands
I would like to give an additional comment to that. I think somehow I agree with you, with the idea. I can find myself with the idea of modeling. It is very important after having made the model as a student, but not only as a student as an architect and designer also, to make a model and then, after say the rough scratch of the modeling has been made, to step back and to see what you have been working on, for maybe weeks or maybe months and then decide whether what has been made as a model, is actually worthwhile continuing to make progress after that. The moment there is always the reflexion that is needed just to make a first concept working out in detail, the modeling is not enough. It may lead to a completely new approach, after you see what you actually did. After this reflection you may make huge changes. I think that is essential with modeling.

Jean-Marie BLEUS, Saint-Luc, Belgium
I would like to ask Tom Pawlofsky a question. Could you tell us how long it took you to make the white structures you showed us? How many people did you have in the teaching group, for how many students? It am very interested to know, because it is a fine product.

Tom PAWLOFSKY, Fürstentum, Liechtenstein
For the first study, we did the one, the survey version the students had one semester and for them it was a small session. They worked for fourteen weeks. Each week for hours, together with us and for the final model, the white one as you call it, we worked in a team of four people for about one month fulltime and then together with the students for two weeks. And in the first course, there have been nine students and for the final Workshop, we have been about six students with both Oliver Fritz and me.

Ramon SASTRE, Valles, Spain
I want to ask a question, maybe in general or particularly to Tom or Giuliana, about when you make a simulation sometimes then we are talking about the results or we can trust the results. For a long time we have been calculating instructions about the programs we have been simulating and we trust the results. When we build an object or when we make a simulation program, testing is very important. I suggest not to finish the experiments by just building, but then testing and simulating at the same

time and checking the results. In this way you can have a program of simulation and you can trust it. Your colleague said, not to calculate, but my opinion is that you have to calculate. You have to calculate and then change the parameters you put in the program of calculation to obtain the results you get with the model. So, you have to calculate with the program, you have to simulate and at the same with the other programs over the future. Maybe when you have a simulation for the future fifty years, it is very difficult to wait fifty years to see if the program is good or not, but you can check for a stage to find the result for this year, for each year and then change the simulation program just to adjust to the results, because whether simulation is easy or not, you do not only trust it in the program.

Klio AXARLI, Thessaloniki, Greece
I agree that we have to make calculations and I think that it is a common process, before using a simulation program, you must validate it for your conditions. Of course you use simulation programs that are reliable, but if you want to use them in your local conditions, in your climatic conditions or in your other conditions encountered in your project, you have to validate them first. Make some measurements and after that, if you are sure that you have a valid program then you can use it as a tool to help your design and have it as a reliable tool for you.

Tom PAWLOFSKY, Fürstentum, Liechtenstein
I think that we use different kinds of ways of talking about simulation. For me, the buildings we set up are kind of a simulation of the process from the idea using modern technology up to a building, like how we can simulate this full process that might change the way of the design. How can we kind of shorten it and bring it to the University? This is the way I see the simulation within this project. You are talking about this real engineering simulation. There are some simulation programs for cardboard, because cardboard itself, is only there like for packaging. I have a company, you can ask them about a simulative fruitbox in a digital way and they can tell me that it will be, for instance, up to 200 kg., but cardboard itself is on its own quite complex. You have all these problems of inaccuracy. You have the problem of the glue. There is a difference between refolding a cardboard and folding in the digital, because cardboard is never folded in exactly the same way. There is one student who tried to put it into a simulation program, so we will see if we can see the result or not. For us, it was important to have like a real experience and I think that it is also very important not to forget that you have to develop a feeling, whether something is working or not. Because on the computer we output a lot of garbage as well. Imagine how long you need to find the right way, to make a 3-D rendering and look how to position the light and how to change parameters from the material. How much experience you need, until it really looks real. Then you see that simulation has always big problems. And therefore, it is always good to know whether you can stand on this bottle or not. Everybody of us can judge it, whether I am standing on it or not, by putting this glass on top, I do not need a simulation program to see whether it is working or not. I think it is always important to decide whether you need the simulation or not. And of course the project we did is real. It might be useful to use the simulation or it might not, in a way of technical terms to simulate studied models. Does this answer your question?

Giuliana LAURO, Naples, Italy
Simulation is really a tool to develop some knowledge. I mean the graph that is geometric. At a base there is a work of investigation of the conditions of the site. While you are playing with geometry, I am talking about the students and not only the students of course. The properties of the site all from an environmental point of view, but also practically concrete. I mean you are maybe right when you are talking about differential equation that leaves the behaviour of the solution, but that is really a research subject, because it is the first time that we have applied this kind of equation to this. There is an internal coherence, so if the results obey a coherence requirement, then you can have a first check. If, for example, the permeability increases then there is an internal coherence in constructing this model, but one can check, because one can check also in the practice. You can apply to the situation which is already exploited and use some situation already existing, to check the validity on that reality and then you can foresee. Of course we are talking about two different types of models. Let's say that the model has a continuation in the project so concrete, but they are inspired by this criterion. I believe that it is so important to take care of the environment, for all of us of course. That is why I am happy to integrate these two approaches in a project, that is then concrete.

Ivan RASKOVIC, Belgrade, Serbia
I would like to put a question to the colleagues in front of us, all the colleagues. What is their opinion about the relationship between the ideas they have presented to us, methods, concepts, and the tradition? And when I say tradition, I think about the tradition as a whole, coming from national heritage, heritage in building, in vernacular architecture and coming to the everyday life. Every day life manners, every day designing and architectural practice. As I see the ideas are really advanced in a concept. What do they expect when the students see that such ideas come to every day practise and face the traditional way of living?

Caterina FRETTOLOSO, Naples, Italy
I will try to answer, although I may have missed something. According to the first interventions, I think that you see that my way of thinking and my mind is very similar to the traditional one. I am not so young, as I seem. When I first studied architecture, computer and design did not exist in Italy and that shows someone's affection for the hand and the mind. I know that we are living in a digital world, but I think that the homos analogous is the mind that gives inputs to the instruments. In fact, I think about the connection with tradition. First of all, I would like to stress again, that simulation tools, or computer and design, or digitalisation are tools. Architecture is not a tool to me. Architecture is an aim. I do not want to make a direct comparison between aim and tool, because to me, like in the tradition, there are two different things. Tools are instruments to reach an aim and they do not correspond. In this way, I stress the students, students of our School of Architecture, did not become famous, just became architects, common architects, at least some of them, I don't know. I would like to stress this importance of human mind. Also, using user friendly tools. Just to give an example and explain, that this stress in my phrases, that I did not have the intention to make a joke with words, but when I said that, the quality of architecture is some-

thing and the quality in architecture is something else. I believe that, that quality of design process is different from the quality in architecture. Just to give an example, probably using your example your master thesis. You said that you were working on traditional architecture. That is why, I would like to explain again, what is the research in architecture, and not the research of models. In your case, research in architecture is the materiality of architecture and the connections and the conflicts between new materials, insulation materials and old architecture. How can we do them? How can we respect the architectural values, but at the same time energy performance, if it is necessary? This to me, is to make a research in architecture and these are my didactic purposes. And I try to make the students work on these conflicts and on this idea and on the materiality too. Because architecture is also a material and space.

Miltiadis TZITZAS, Athens, Greece
It is getting very interesting. I would like to make a comment as well. I will go on to your project, Tom. It helps me give an example. I would like to clarify something first. After the machine has cut the cardboard, how do you assemble it? By hand?

Tom PAWLOFSKY, Fürstentum, Liechtenstein
Yes.

Miltiadis TZITZAS, Athens, Greece
And you glue it?

Tom PAWLOFSKY, Fürstentum, Liechtenstein
Yes.

Miltiadis TZITZAS, Athens, Greece
Then we have a component that has been designed and cut by the machine, which is high technology. And then it is glued by hand and then put together, but not so successfully, right? In some joints. You needed some extra tools to make it stronger. And then you said a phrase, which I liked very much, which was a combination of high technology and hand 'crafts-machine' the foil you put on top of it. Right? I think it is a very good example. Not to be extra careful, in words that are a bit sophisticated. In using simulation and using this technology, while we can, I am not referring to your example now and not trying to go onto all levels. We do not need to go to all levels. We use this technology to help us design something. I am going back to Ramon Sastre's question yesterday, that sometimes we get a lot more information that we do not need. Especially, when we are talking about students in their first years of study. All the presentations that were made this morning were very interesting. But they are not helpful for the students in their first years of study. Afterwards, when they get more experienced in designing, when they get more confident in doing things, all this is very useful. Its difference, its simulation difference, in which levels we can use it and which scales are adapted. For instance, Caterina Frettoloso, in all the urban scale, simulation was in an urban scale and that was very useful. Calculations etc. But we are talking about urban scale and then we are talking about buildings. In checking something afterwards by people that can translate the results, it works, but for a young

student, for his/her first or second year of study, the first steps in designing, we can have tools, of course. They must be simple tools. And I find it very difficult for myself writing with this (showing a pen) and with that (showing a computer "mouse"). That is so difficult as well, but I have a knowledge of this by drawing by hand. I can use the computer and I am using the computer, but in a different way. And I am exploiting all the technology advantages, that I can have, because I know how. But when a young person starts, and the computer is his only tool, there are some things that he is doing and he does not understand them. That is why I think that physical modelling, referring to my presentation yesterday and models and I do not mean architectural models, but I mean making models and then working with them for months and then stand back and see how it goes. Working with my own hands, gives a different sense to me, because it is a direct expression of my thoughts through my hands and that cannot be, I think, re-valid by the machine. But I think your experiment and Oliver's experiment, which was very interesting, makes the students working with that, gain a lot of experience. And after that, they get more confident and they can do things.

Klio AXARLI, Thessaloniki, Greece
In my presentation, I stated another concept, where simulation is used as a tool. It is a tool in the hands of the teacher, to make his lecture and his presentation more interesting and more interactive with the students and then the students can understand better how the building envelope behaves. When the sun changes position and when the climate changes. Just a tool to teach. A teaching tool. I can see simulation as a two fold. As a teaching tool and a tool for students to validate or to make their drawings better. It is good for the students who have teachers in their first year, who use simulation as a tool, as a teaching tool. It makes the lecture more interesting and students understand and realise better what happens to the building envelope.

Maria VOYATZAKI, Thessaloniki, Greece
I will probably repeat what I have talked about in previous Workshops. I do not mean to oppose to Miltos, but as most of you know, recently I have been diving into children's psychology for my own personal purposes, but being a teacher myself, helps me a lot, because it does not really matter, whether you teach infants or whether you teach eighteen year olds. There are similarities to certain things. And because we have been talking in the last six Workshops about this, we will be talking for life for this unique relationship between the hand, the brain and the eye. I want to submit to you some ideas that I have been recently familiar with and they might be useful to this conversation on the natural reaction to the eye and the brain. The Italians will maybe know better than me, Maria Montessori, and educationalist, that has been the founder of the Montessorian system for infants up to the age of ten. The work of Maria Montessori, as a school teacher was that she worked closely with psychologists and psychiatrists on the neurones and the brain system of the human being and the best time of absorbing information. She came up with a term, that she used extensively in her bibliography, that she called "Windows of opportunities". I will not draw an analogy of architecture of the mouse or the eye, but mostly about what Montessori came up with, that you may end up speaking as good English as any other person that has learnt it naturally, but there will always be an accent, a case in point, that you

have. And there will be points where you will be tired and there are other things in your brain, your mother language will come in first. Your know which your mother language is. It is the one you count in. The language in which you dream and so on. What I am saying by that is that there is a window of opportunity from the age of two to the age of six, that someone becomes familiar with something being a language, a mouse or a computer. After this long introduction, I feel that the people that have this strong feeling between the eye, the brain and the hand, are the people that are educated in this system. Our students live a different reality. They educate themselves in digital tools from the age of zero. And I mean that, because I am very familiar with toys, that children use and look at the adolescents that enter the School of architecture the way they can draw tables on their mobile phones, it is a metaphor really. We feel that it is their unique window of opportunity that we are familiar with, since they were acquainted with architecture, is a wrong impression. Physical modelling perhaps is valuable and as close to our hand, eye, brain relationship for us people, educated in that system. These contemporary people have different windows of opportunities and they are perhaps better at dealing with those tools than us dealing with those tools and visa versa. As Giovanna said, the aim is architecture, whether you achieve it by exploiting your window of opportunity to be digitally literate or physical moderate literate is a different issue. But they are not two comparable things. It is a reality, we have to come to terms with. Our students belong to this generation. Now, whether our aim at the end of the day is to trying to persuade them that they belong to a different era, is a wrong exercise, I believe. We are just aiming at the wrong thing, I mean we are just pointing at the moon and they are looking at our indexes and visa versa. We have to realise their reality. They have different windows of opportunities and this is to be computer literate, from a very young age. A two-year old can easily, trust me I have my own case study, manipulate a DVD back and forth setting up the apparatus, to watch a DVD and we are talking about an 18month old toddler. In other words, they are capable of doing other things, than our generation. My children are not interested in wooden toys. They do not like piling them up together. And we have made this distinction with my husband, that the architects, friends of ours, buy us the wrong toys. We buy our children 'wrong' toys for their liking. No matter how much we have to press, the societal pressure is such that from a very young age people have to be digitally literate. Much more than being handcrafted and being able to use their hands and put things together and make better sense of it. We have to accept this.

Tom PAWLOFSKY, Fürstentum, Liechtenstein
I would like to comment it. I will try to. I am not sure if I have got everything. But I think, that there is a big difference between using all those toys or using the computer and understanding the background. For instance, let's talk about baking. If you just go to a shop and you pick out a package for a chocolate cake and you put water in and you mix it and you put it in the oven, you get 100% success. But if you really want to be creative and know how to bake, then you really have to know about the ingredients and you have to know the background. I think, that this is a big problem, that you talked slightly to the point. I would like to formulate it in a different way. There is a lot of knowledge that is transferred to the computer, but that is hidden behind the interface. I can give two examples: when I first printed out my first picture from the

computer, it had horrible colours and then I took the photoshop help and read printing problems and it was my first contact to colour spaces. I never had a lesson in the University, that taught me about colour spaces. I have got a problem in relation with the computer program or when we are talking about modelling, as I told you I am a designer, if you ask a student six different possibilities of how to design this corner (showing the corner of a laptop computer), they will say that they are like two possibilities that I can have these options in the computer and the modelling program, but they are not about the geometrical background that there are millions of ways, of how these corners can meet.

Maria VOYATZAKI, Thessaloniki, Greece
I will not disagree with you at all, but I will just bring another example to make my point clearer. I think it is a shift of a development of skills to write an sms or to write a note to your friend which are more or less aiming at the same thing to communicate an idea or a message to someone. Contemporary generation knows the structure of the language, knows the letters that you are talking about, the ingredients of your cake and they are much faster texting than stirring the cake. And in fact when they text an sms much nicer, because they are effective each time and you can read it nicely. Look at us the more we write on the computer, the worse is our handwriting. In other words, my feeling is that there is a shift of skills and priorities and as you say, the structure, the letters, the alphabet, the language, the syntax, the grammar are there. But you use different tools to do the same and is a shift of skills you develop from the first example to the second. From the handwriting to the second. And if we think that we are still belonging to this unique thing between the brain and the eye all we do, because we do not practise it on a daily basis, we do not do it nicely at all. I am sure that everybody in this room had better handwriting like classical architects, who used to write very nicely, but not so much in these days, because you do not practise handwriting very much. If you go back writing on a drawing, I do not think you will like it. This is my case and I have known many people that have experienced this. They do not write as neatly as they used to, as architects anymore. And I do not disagree with you, please do not get the wrong end of the stick of what I am saying. That is a shift of skills, and we have to accept this.

Jean-Marie BLEUS, Saint-Luc, Belgium
Perhaps Maria, I do not understand everything that you say, because my English is not very good. It seems to me, that using computer or an sms, there is something left. There is a global view of the things, because time is getting in little part and no time put in together. With an sms, you have a small text and you can go through and you never see the global things of the text. That is my point of view. And in the computer it is the same. Now it is completely wrong, that people, students come with the computer and ask to show them at this computer with the glass and the sun. Horrible. And you cannot see the global things. Or you take the role and you go through it and through and out and through and out with the time cutting in small pieces. Time is something that flows.

Maria VOYATZAKI, Thessaloniki, Greece
This discussion can go on for life. I do not mean to be a supporter of computers, but I sound like one. Just to say to Jean-Marie, what is unique about computers for example, and I am talking about simple software these days, for example Autocad: you work one to one, whereas on a piece of paper you only use one scale. With a computer, you can bring it close to you, you can put it at a distance, but with a piece of paper you only work at one scale. In this case, I do sound like a defender of the computer, but I can twist the argument the other way and we can go on forever.

Ivan RASKOVIC, Belgrade, Serbia
I am sorry to take your time, but when I hear this interesting discussion I have to say that I am supporter of the computers and I became a supporter one year ago, when I experienced a situation I have to express. I had two students, they are both now married and the boy was in love with the girl and the girl was not interested in him. He was trying to impress her. He was very computer literate and he asked her for her mobile phone, she gave it to him and he printed in his phone number, but instead of his name he put, I love you, so whenever he called her, the first thing she saw on the screen, was 'I love you'. Such thing could not be expressed by a classical letter, a love letter. When I saw that I started to believe in computers. Computers and advanced technology are not obstacles to romance, to emotions. And I do believe that computers and software are very simple tools and my brother's son started with computers. Listening to what Maria said about wooden tools. This boy, he is about ten now, he is completely uninterested in movies. Why? Because he has got a lot of software where he can make his own movie, by playing. I think it is a natural process, that we should accept. Not, of course to forget to draw by hand.

Miltiadis TZITZAS, Athens, Greece
I would like to close the session, by thanking all the speakers this morning. It was very interesting. Thank you very much.

Debate on the presentations of Session 3 and 4

Chair:
Karl-Gunnar Olsson
Chalmers University of Technology
Göteborg
Sweden

Maria VOYATZAKI, Thessaloniki, Greece
I will give the floor to Ferenc, just to ask questions on the last session we had and then I will go back to this session and pass the word to the other speakers too. And of course at the same time you can give us your insights of the session.

Ferenc MAKOVENYI, Budapest, Hungary
I would like to thank Professor Maria Voyatzaki and Professor Constantin Spiridonidis for being the heart of our Workshops for years. I will come to the fourth session, but I think that our future is more important and I have a suggestion. I think that this Network is so important and I think that we underestimate this network, that we are participating in now. There are about 200 schools of architecture in Europe and in each school there are construction teachers and construction departments. This Network could work and give added value to companies as well, but let me get at the simplest way that I suggest. The book of proceedings, which comes out each year, is a very important resource, which we can refer to. If we go for what is only a newspaper named "Detail" in Europe, which is about construction and there is no referred newspaper there, you can give in your findings, your contribution. I think that, if we split this book and we say that every month there will be an issue for this construction network, for sure my school will buy at least 10 – 20 issues and this is about four thousand. For sure we need referred newspapers, referred journals and this does not exist and here is the possibility and this is an enterprise. It could be an enterprise, because it has an absolutely different field of activity than detail, because detail is much more about analyzing an existing building and what we do is more based on research. Based on education and on a general level, which does not exist. We are not speaking about a company, but about our profession. And if we do not do what other professionals will come and say: Are you serious you do not even have a referred newspaper in your subject on construction or architects? I think it may be an enterprise and of course this network has to apply for E.U money. If we apply together with companies, I think that we can get a better chance.

Maria VOYATZAKI, Thessaloniki, Greece
Would you like to continue or would you like Jelle Laverge to carry on and then Professor Miltiadis Tzitzas? I have some remarks in front of me, from Professor Henk de Weyer, who is still here. He could tell us his thoughts or I could read them out if you want. Then, I have Professor Karl Gunnar, who will go back to Sweden, so I can read his feedback and then we can close the session. I have to say that Jelle is here for his first time and probably one of the youngest people that have been around this table. I think his contribution is unique in that sense.

Jelle LAVERGE, Ghent, Belgium
I think this maybe gives me another perspective and I have been teaching for a very short time. I see it from another perspective and from another era. To come back from the first session, that I chaired, there were many presentations about tensions and problems and limits of simulations that came forward, due to applying them and teaching and I actually have two thoughts about it. The first of them is: Although, most of us are engineers or architects, in the first place we are teachers and that is why we

are here at this conference and teaching in itself is a design science on its own, that is related to a subject to architecture and engineering. But, teaching has its own rules and its own problems and in teaching simulations are only a tool. Just like research is also a tool to become a better teacher. You do research to find out more about the subject. If it is unknown and if you need it to convey it to your students. And you even do research in totally different fields. Asking: Who are your pupils? Who are the students that are sitting in front of you? In many discussions that I had with some of you, the thing that struck me the most, is that there is no clear view. A question that is absolutely not answered, even not specifically by everyone individually. What do we want our students to be? What will their position be? If you remember one of my presentations I presented, in the whole building crew, there is an architect, a contractor, an engineer, a lawyer and an insurer. And most of us and even myself do not have a clear view on what the students that we deliver at the end of the course should be. What should be his core competence? That is one of the most fundamental questions handled in the next Workshop. I think this Workshop should still exist, because there are still questions that are not answered.

Maria VOYATZAKI, Thessaloniki, Greece
Was it in 2005, that we discussed about competences and skills? I do not remember by heart but there was a Workshop dedicated to that. I have to make reference to that, but I cannot claim that that covered the issue. But there was a discussion. I think it was back in 2005, just before the Workshop in Venice.

Jelle LAVERGE, Ghent, Belgium
The idea of this session, is that it was more about the future of the teaching and how it would evolve. But I think this question has a different aspect altogether.

Maria VOYATZAKI, Thessaloniki, Greece
It is about the profile of the architect that we deliver through our teaching.

Jelle LAVERGE, Ghent, Belgium
What will the role of the architect be in society? How will teaching affect him, and what will he be? The idea with the journal, not only annually contributing, but building up a volume of thoughts through a year that can simulate the Workshop, could be even getting this to another level.

Miltiadis TZITZAS, Athens, Greece
Referring to session 2 rather quickly, which was testing a simulation and environmental control, but in a different presentation, the first part of it was the simulation and it was presented by colleagues as a tool for teaching, which was very helpful. It was extremely helpful for larger scales, as upper interventions for coordinating all the necessary data, in that scale. But also in a building scale, when I was using for reference to some buildings and then you knew that for existing buildings having it as an evaluation for existing conditions. More or less, in the first part, simulation was used in a very productive way, but it was used as a tool for teaching, from the part of the teachers and also as a tool for students, which had already acquired some experience. At least,

students that were not in their first year. The second part was quite interesting, because it was different. We had it from your presentation (talking to Jelle Laverge) and then Tom and Oliver, from Liechtenstein University, that showed us that kind of cardboard buildings as an experiment, which in a way was no more that the execution in a one per one model of design, which is constrained. I am not down, because it was very interesting that, when they found out that after they have cut the cardboard in a specific way, the machine and everything else was drawn on it. They have to glue it by hand and then when they tried to put all the units together, they had some problems in the joints. And they found it interesting, because it was a mix of a very high technical drawing part and then the craft that was needed to do that. And I have to go back to the very interesting first day keynote session, by Fabio Gramazio and Mathias Kohler of the ETEHA, which I have to say that actually there were two young persons, two young colleagues. They are architects, they are enjoying their work but they are researchers. Researchers in a way that they go further on to what they exist, used as a tool meaning that what they were using, the roboting control arm with the changed front part of it, put on bricks one on top of the other. They realized that they have achieved in a better way, by hand of course, but they were using elements in a way, that the same way, that our hand, a human hand can put it on top of the other. But they realize that this machine could use very accurately, larger pieces of bricks or larger pieces generally, heavier pieces. And put them very accurately and then start going further on, in an evolutionary way of an existing high technology. I think that it is a very interesting point, in which architects are experimenting themselves on an every day business basis and are using tools in a very productive way, of course. But also as architects, in a designing way. I really mean architects, going on from the construction point of view to the developing new point of view. Not ideas, but new ways of seeing things, in an open-minded way. And this is a privilege, that they do have in a younger generation and I think that in this network we do have it. I think it is the first time Professor Maria Voyatzaki, that we have such young people, with us. That is a very good sign for this network. And I will go there further more, saying that I think the six years, that I think this network exists, for me it has been five years. We have had bad times and good times and finally just look at it as a result.

Maria VOYATZAKI, Thessaloniki, Greece
For those that have been around the Workshop for quite some time, know that there have been arguments at times, around the room. I do not know whether this is a healthy thing, but in that respect we were not healthy enough in this current workshop.

Miltiadis TZITZAS, Athens, Greece
Professor Constantin Spiridonidis said that we have to change the way of seeing the whole thing, if you want to apply for the continuation. Since, what we have done all these years, is sort of mapping the situation where different schools exist in the network, but I think personally and I think most of us, even though we sometimes think, that I have some presentations and I believe that my way of thinking is quite good. I know that a radio is not contributing more, but whatever, it gives me an idea of what has happened in that school. For us, in our school at least, it is good to have. It is very

helpful to know what happens to other schools. How we implement the same ideas in a different way. Sometimes, because of the different cultures or the different situations in the architectural education and also in the profession as well. And I feel that the idea of having a sort of newspaper or making a broader diffusion of the things that are happening in those Workshops, because it is a Workshop actually, it is not a conference. It will be very useful and it is a good idea, I think this one and maybe we can move on over that. But, finally I do not like what I am seeing now, of course, because we are not as many as we started. And this is the first time that it happened so unsuccessfully. And I am also talking about myself. I mean I lost the last session in Lyon. I mean to say that this congregation is very useful for me, for younger people and for younger schools as well, that have started now. And this network should however be continued.

Maria VOYATZAKI, Thessaloniki, Greece
The thing is that even though I tried to put some structure to the discussion, we are discussing about the past, present and future at the same time. That would not bother me, since we live in multi-layered, multi-faceted times in the history of the humanities. Therefore, to be mixing up issues maybe is not that inappropriate. In that sense, therefore, I would like to grab onto some notes I managed to make, during the event and for the first time, my overview or synthesis of what has gone on is a kind of jigsaw or a puzzle of parts that eventually, despite the very different profiles of the keynote speakers seem to fit together very well, because their approaches are very different, their profiles are very different, but they have touched upon issues that intertwine, or in some kind of way, correlate in the best of ways. And therefore I want to talk about the papers themselves, but the things that the presentations have mentioned as I said, fit in very well with the way that the keynote speakers talk about things. It is the third year or fourth year that we accept that there is a new reality of a dominance of what we would like to call tools or partners or instruments used today and I guess words are not innocent. They relate to the way we look at things. Therefore you call it an instrument if you can be an acoustician, therefore you call it a tool you can be whatever and when you when you call it a partner in giving birth to forms again you are another profile of an architect. Accepting this reality of the dominance of whatever you would like to call them and I am talking about digital reality, I found very interesting the point where Mathias Kohler and Fabio Gramazio put forward, which is taking something that exists, which is in this particular case a brick and transcend through the tool or the instrument or the method. It is common given and conventional value. I thought for me, that was something that was left and I found it very crucial for this discussion that you do not necessarily have to go for, that is not to say that you should not go for, but there is something which is called, what Professor Logothetidis spoke about last year in Venice, about nanotechnology and the new sort of ways of designing the genetic code of a material to fit the needs that we look for, which is a possibility and we have to exploit it, but I found very important that a brick can do many things and many more than Luis Kahn put it as. It is certainly a golden brick that can do all sorts of things for tilting, doing grapes, filtering light and so on. I think that the insight that they offered in a very impressive way through robots and so on. I think notionally and philosophically for me is a very important one. Then, I

would dwell a little bit on two things that Hanif Kara put forward. I think the one thing was that we do not pretend to be anything and everything. But we should learn to cooperate with people that know things better than we do. And I think that this is something that has been going on in architecture or architectural education and other debates on design. And someone like him who is one of the leading sort of innovative forces at the moment in the UK and the world talks about cooperation and other people that know better. And he does not pretend to be an engineer that writes scripts and understands computers better than a computer specialist. That is another thing that we have to keep in mind or perhaps convey both to our practice as architects or as engineers, but mostly in our educational practices. The other thing I liked very much and when I saw his title I did not quite understand the way he looks at tools and weapons. But in his lecture you understand what he says is a tool is on your side and a weapon is not on your side, because it turns against you. And this is how I understood this concept about tools and weapons. Tools and weapons are not the same thing. The same thing can turn against you, if you do not know how to use it properly. And that is another thing I guess we have to keep in mind. Then Philippe Samyn's lecture might have been at first reading about lightness and structural efficiency. But, I think it is mostly about a sustainable use of tools or the use of tools in order for us to be sustainable as a profession, as architects, as people conscious to the environment, to the use of materials, to the way we teach. And I would also pick on the issue, about simplifying notions in order to convey things to students, even though to tell you the truth I did not make much sense of his lecture when he got into engineering staff, because my background would not allow me. I mean it is my handicap. Not his problem. Then I would speak from Pofessor Vincent Servais one of the engineers of the longest bridge in the world that connects Sweden and Denmark. What I found interesting about his lecture was that, to most people's perception, the new tools or instruments or generative machines are interconnected exclusively with new forms and new architectures. I found out from his lecture that three quarters of it were dedicated to how you do restoration through computers. And I think that this is a very fresh insight and suddenly in Schools of architecture, where conservation is taught, people have to be taught programming. They have to understand the software that will help them restore the old listed buildings through computers and software and do simulations of how a building can survive time and age and I found that very interesting. And he talked about examples on Tournet and then what can come to mind is what Marc Barry does at Sagrada Familia. Last but not least, a lecture by Professor Tzekakis on the last one, I guess many people were put off by the title and left perhaps, because they thought it was going to be exclusively heavy going staff on acoustics and those who stayed on did not regret a minute of it, because they discovered that it was a vehicle, where simulation can actually be a case in point where form generation, when designing a form or a building with very special needs, beat light, acoustics, condensation or special needs. Then the design and the simulation of that particular issue go hand in hand and you do not have any sequence. There is back and forth. An iteration of the same thing in order to achieve the form that serves the purpose. In other words, since we live in times where special requirements in buildings is not something extraordinary, but something common, then simulation has to be seen as a way of understanding, what exists. We have been working together for years and years at the same University and it is the first time that I hear him speak about his staff, that for a long time I thought I could never understand. And it is a very revealing point in our collaboration and I will thank him for that. From the other presentations on simulation there are two or three issues that are at stake, as far as I can understand it. One is the reliability of results, which is something very important. There is yet another tool that can kill. Remember what Mathias said about the robot. He says we have to be careful with the robots. Everybody would dream around this room, to have a robot in their Schools, but it is not as simple as that. Robots kill. Kill brains. Kill students. Kill ideas. And this is something I guess, we have to be very careful about. Professor Tzekakis also spoke about the body of special knowledge, as this is transferred to us by the sciences and the computer sciences in particular, which is a different cattle of fish. We are in a very different situation, where people talk about the shift of responsibility. And there I would connect it to what Professor Henk de Weyer put into his presentation. How you certify the ISO of a product we design. How you certify the ISO of the architects we produce. How you certify the ISO of the education we offer to our students. And this is something to think about in the future. I would close with all these thoughts that were generated during the meeting. I would leave the thanks for the end. And I would like if I may, would you like me to read it out? To read two things that have been submitted. One, by Professor Henk de Weyer, from Amsterdam, who is still here and can add to this.

Suggestions, thoughts for the Workshops of construction teachers.

General points:
The Workshops make my focal points of teaching sharper. Our sense of direction, analysis, methodology and elements of teaching. They mean a big inspiration and force to me, to think and rethink about what and why I teach what I teach. Take notice of what is going on in Europe. If broad members have spent enough time on the organization of the Workshops, the same amount of members could be added doing the essential amount of thinking, organization and planning. Present members function as peers, if possible. Second point: What is the methodology you teach? How to include, improve knowledge skill and creativity? How do you approach basic questions of knowledge regarding new thoughts and possibilities and the need of society to achieve higher quality, more sustainable projects, more freedom of use, more influence of known and unknown clients, affordable constructions? How does your approach show in the results of your students? When and how do you include new digital approaches? What is your freedom as a teacher? Third point: Give one example of an essential exercise. Why did you give it? Analyze the aims and contents. Show outcome, your remarks and analyze your remarks. Fourth point: What are your limitation? How do you work to overcome these?

Karl-Gunnar Olsson from the University of Technology, Sweden, Stockholm, with an engineering background has left us this note. I am giving you this feedback information, because that will connect to his proposal. The generic title when we discussed it before he wrote this was an evaluation. How do we evaluate the project on construction, he said and then he wrote the following: On span and space, exploring structures in architecture about how we, as construction teachers act in critics, in the studio. One of his colleagues creates a model that spans a field between object and space and gives examples of how a critic of space can be performed with the structure of object as a frame of reference. We discussed this topic in the Northern countries and I believe that this discussion can be broadened to the European group of construction teachers. I think the core of our profession as teachers is in this.

I would like to clarify a few things that have been put forward and I can answer immediately. We have to make a very clear distinction between a referee journal and a newspaper. Newspaper is by default, something which is lighter in terms of academic rigor to a refereed journal. A newspaper takes less work, is more accessible, but easier to contribute to, but less well – valued by any serious academic body that judges research. If we are to do something about this, then a) we have to look at who funds it, because that is very important. In other words as Ferenc says, his school will buy some. We need to do a kind of survey before we dare do something like this around the Network and ask if people would support such initiative. If it were to be put forward. Personally, I think the newspaper these days is our website. If you are very keen on learning of what is going on in our network then the website can do this. I think we are really heading for a refereed journal, but there we have to start thinking around this table for a scientific committee, that is going to sort us out. That is to say, that if we want to be serious about what we are doing, you have to have a committee of specialists. Therefore we have to open up an invitation to people around the Workshop and around the world, who would be interested in reviewing the input. Then you have to come to terms with nasty criticism, because what you get back from a scientific committee of a refereed journal, believe me is not nice most of the time. They basically channel you, to write your paper, even though they have given you instructions on the format, after you write it, then they tell you what you should have done. You have to be open to this criticism and accept that this is the situation and another thing also, we have to have at least two issues ready, before we publish it. That is to say we have to set up the committee and make sure that before the first issue appears, we have already enough publications to sustain for a whole year, if it is for me I think it should be a quarterly one, it should be two a year maximum. And the third point, forth whatever: We should not replace, as far as I am concerned the book of proceedings that we produce with refereed journals, because they serve a different purpose. The book of proceedings, a) counts for our research record, b) it is easier to contribute, because it is not as harsh c) it is faster to produce in the sense, that you know it is once a year and it takes less work so you might find out that you know, it is not that demanding and these meetings have to be recorded anyway. If I personally or I guess we as a group want to have credibility on the work that we produce, it is important that when we get together there is a record produced and you keep it in your bookshelf and you know, you have an ISBN and a publication already there with page numbers and so on, as we have done all these years. As far as the referee journal, newspaper, website is concerned. According to Professor Henk de Weyer's points the second year that was 2003, this was exactly the very thing we did. Maybe we need to put the presentation that I did in Ankara on here to show people. That is maybe useful, because it was the theme of the second year that you were not at. It was Ed

Melet from your school that appeared, but I truly believe that this is something he will return to, because if you maintain a Workshop after five years of having shown the exercises you do the assignments you give to students. Not just to demonstrate the outcomes, but you talk about the methodology, the brief you set to the students and you give people an idea of the duration of the exercise, the outcome, the people you teach with and so on. I guess five years down the line this has changed and also the people around this room have changed. To return and look at it from a fresher angle would be a useful exercise anyway. I think we have to think of ways of accommodating your idea, because it is an important, an interesting one. This is from the different points. Also I think Gunnar's proposal about assess,emt/evaluation is a very interesting point, but maybe difficult to discuss, but again we can include it in one of the sessions. How we assess? This is an internal and perpetuating problem of design teachers. You know that. How you evaluate a design? In other words, how do you ISO quality? That is a valid question too. I will stop the monologue and give you the floor, because I think enough has been said from me and take reactions from you people.

Henk DE WEYER, Amsterdam, The Netherlands
I was wondering whether you, as a board of the committee, are slowly getting tired of having to do all these time consuming things and I was wondering if that was maybe the reasons of the follow up of the next Workshop!

Maria VOYATZAKI, Thessaloniki, Greece
If this is a personal question, I get tired when I sit down. When I do not have interesting things to do, say or act. Then is when I get tired. Give me a project and I will be there, but there has to be a project and perhaps repetition is too tiring. Therefore, maybe there is a score for this to go on the same form or format. Maybe there are more ideas or other ideas around this room, that might make it more interesting, but as far as I am concerned and I guess the same goes for many of you. If there is something interesting to undertake then I am happy to continue. I need feedback for that.

Hosing BOUGDAH, Canterbury, United Kingdom
The points I was going to raise is with regard to research. I suppose I am being selfish here, because I lead a double life. I teach students in the day and I am doing research in the evening and weekends. That is the life of sad academics. I think the outside world of architecture profession as well as academia will take these form seriously, if something along those lines, refereed journal.

Maria VOYATZAKI, Thessaloniki, Greece
I knew that this point would come from a British school, because I taught there for twelve years and I left just before my school submitted for the RAE exercise. British schools get huge pressure from what is called for them the RAE or the research assessment exercise. Schools are funded on the basis of research outcome, which is very rigorously judged by a committee. Canterbury school or any British School I think that will spread. It will be contagious and it will spread in Europe. It will happen eventually. That we will all need to hold very serious research record to attach our lives to. And this is in fact what I meant when I talked about ISO-ing our lives, because it is

about certifying the quality. We will have to quantify quality and qualify quantity, in contemporary life and it will have at the end of the day to be broken down to numbers. There are so many publications and so many journals, that have ISBN's and page numbers and so on. I am fully aware and this is why I put it on the table. Because maybe it is not so much of a pressure in other European schools of architecture, but since the British have this magic power to spread their staff around Europe, I can see it become contagious in most countries in Europe, if you look at the three plus two and the Bachelors and the diplomas.

Hosing BOUGDAH, Canterbury, United Kingdom
It does not have to be paper based. It can be on-line journal. Two issues a year. I do not know, if anybody knows about the CBE, the center of building education environment in the UK. Although it is built environment, it is more than architecture. It deals with all aspects of the environment. They have transactions, which like every other conference, on line. As well as journal. It is a referee journal and it appears twice a year, two issues and you do not have to deal with the paper. Money becomes less costly.

Jelle LAVERGE, Ghent, Belgium
I could add that in Belgium, the same process that Professor Maria Voyatzaki described, is already taking place. It seems that it is already spreading.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
I can give some information about the framework and probably that will create ideas for this new proposal. In case that we will submit it at the end. We are running as you know, the sixth year of this thematic network that includes these projects. The thematic networks are projects that are funded for three years. At the end of the three years, we have to submit a new application, which is practically a new project. I mean that we have to submit everything from the beginning. There has to be someone who has to describe what has happened before, but the logic is that you enter in the competition with all the other proposals. New proposals submitted, every year. Of course we have the disadvantage that we have these six years behind us already. And probably the commission will decide to support other initiatives and probably new networks that will emerge in areas, which are more attractive or they are much more focused in the objectives that the commission every year puts for the selection of the projects. We have the advantage that it was a very successful network. I mean we always received very positive critics and the range of activities is really very broad. You have to imagine that in parallel to your Workshop, we have run three Workshops on architectural design. We will have three Workshops in architectural theory. We have already three Workshops in architectural conservation and we have six meetings of Heads of Schools of architecture. In parallel we have run many inquires trying to map what is happening in our days in architectural education in Europe and we collected very interesting data regarding the state of the art and the conditions of architectural education. I think that there is a very significant material produced, which will be of course a positive reference for the new application. But of course in order to have a new application, you must have a new project. You must have objectives. You must have aims, you have to fulfill and you have to argue with an application that you go

through different steps in order to achieve some goals. The interesting thing and the main question is what our objectives will be. If we say, that we are asking money in order to produce a scientific journal, that is for sure that they will not support it, because they will say that this is the work of the academy and it is not in our perspectives and you know very well that in such a kind of project you always have to cover their own objectives and through their covering of their own objectives, you have to achieve your own goals. All these inputs that you described are very interesting and very significant. But we have to find something that will be attractive for the persons who fund these projects. This is the main question and this is the main difficulty. Of course there are some ideas behind that. I mean we are thinking, not only in the framework of this event, but in the others as well. That probably we will find some references, which will give us the possibility to continue such a kind of discussion. But in the same time we will be closer to the European policies. I would like very much to give you an idea concerning the direction towards which we are actually thinking. This is not a definite decision. But probably that will be a direction towards, which we have to continue. In the last five years or three years there is a kind of emerging tendency from the world of academia, which was also supported by the European Commission to implement, legitimize or institutionalize a shift of para times that someone can recognize in the domain of higher education. This concerns a different view of what higher education means. Emerged through the last three years, mainly from the Universities but supported by the European Commission. In order to make it clearer, I would like to use an example from the experience that we had in this room. Mathias and Fabio presented to us this case of their laboratory in their school, which I think represents something that definitely happens in the domain of architectural profession, which is the following. We have a robot, we have a machine and the architect is working in order to change every time the head of the machine, as they told us. The work of the architect is to change the head of the machine. We can see a person who feeds the machine with bricks and this is the work of the worker. And also we saw another worker smoking a cigar, just carrying out the product that the machine made and to implement it in the real construction site. The work of the architect appears to be a work on the brain of the machine or in the brain of the computer. But in order to do this work, this architect has to collaborate with other professions. He must be in some kind of interdisciplinary teams, working in interdisciplinary teams to be able to make decisions, to be able to manage his time or her time. To have the possibility and the capacity to communicate his or her thoughts. That is to say to have some competencies that we never teach to our students, because our educational system is mainly based upon the knowledge that we have to transmit. But we never or almost never care about the skills that someone must have, knowing what he or she would know and the understanding that this person will have, what he or she knows what we are trying to transmit. It means that it is not enough to transmit knowledge, but also we have to ensure to our students to our graduates, critical thinking, capacity to collaborating in the interdisciplinary teams. Capacity to manage time. Capacity of decision making. Capacity to properly express ideas on architecture. Capacity to work autonomously. All these capacities are not the center of our educational system. Are not our preoccupations as teachers. Or if they are, they are side effects of different exercises that we apply. But on the contrary, the practice that is emerging in front of us, as we saw in the previous examples, is mainly based on such a kind of capacities. If we want to generate or produce graduates that will be able to deal with the new conditions in the professional practice, then we have to incorporate our educational system, broader spectrum of competencies on the pages of which the educational system has to be developed. This approach of a competences based education, appears to be one of the very significant priorities that the European Commission wants to promote and of course it is one of the main interests raised by the academic system, taking into account the University association, that supports these efforts and of course the program Tuning, which was the initial project on which this discussion started and emerged three or four years ago. We think that if we will raise such a kind of issues, then it will be possible to continue the discussions we have. We will be in a position to produce new material regarding the teaching practices and also we will be in a position to rethink all these issues that we developed during the six years of this project. This approach is not of course something that will be imposed. It is such an idea which will create a new ground for discussion. More or less some references appeared in the discussions, but I think that in the near future main Institutions will be directed towards this way of understanding education. Since, this is much more student-centered, as you already mentioned, because this is looking to the student and not to the teacher. It is looking towards the capacities that the student will have at the end and not towards the capacities of the teacher, when he/she has started implementing a course. The objective is the student. We are speaking about the student-centered education.

Jelle LAVERGE, Ghent, Belgium
I think, posing the question in that way, as I argued makes you think in a new way about the teacher. Like you say the question comes from the student so, what a teacher does has to start there. It gives a whole new perspective about what a teacher is and what he does.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
I completely agree with what you say. It presupposes a different conception about education, because if someone will say that I want to achieve as a product the capacity of the student to collaborate in an interdisciplinary team. Then I have to organize the exercise in a way that this will be achieved. I will also be in a position to prove that I achieve this objective. I mean that I followed some steps in order to have some real proofs that the student has the capacity to do that.

Maria VOYATZAKI, Thessaloniki, Greece
Could it be a proposal on the contemporary exercises that develop certain competences? Some kind of combination of two previous Workshops in a contemporary context?

Constantin SPIRIDONIDIS, Thessaloniki, Greece
It could be a possibility.

Miltiadis TZITZAS, Athens, Greece
I would like to go further back and forth of the experience we gained in those six years. You said at the very beginning that there are other Workshops going on with teachers. Design teachers. Not construction teachers only. You said at the beginning, that there are other networks.
They were discussing design. In the very first sessions we had, there was a debate among our selves, in which some of us, construction teachers are more designers. Perhaps more structurally oriented. There was among ourselves a kind of debate, which should be the right way, or which should be the proper way. All the things you proposed now Professor Spiridonidis, some of them are in the new role, like of a teacher. We have to see first how we combine with the designer teachers. Teachers that teach design, where most of them are totally isolated from the construction perspective of the point of view of making what they are designing.

Maria VOYATZAKI, Thessaloniki, Greece
Or the opposite, or they coincide in some schools.

Miltiadis TZITZAS, Athens, Greece
There are times when they coincide, but in all of them. I think it is a very fine line, if you like in between. It is worth to experiment and research that fine line.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
I think that you touch one of the most interesting issues, that during the six years these Workshops try to raise and to give, some kind of answers. I would like to say that in the very beginning, when we prepared the very first application for this network, there was a magic word that was running around in our brains and of course from the experiences that we have with the meeting of Heads in Chania, where these issues were discussed. And this magic word was integration. All of the people were speaking about, the way to integrate. Not only construction and design, but theory and design. Fine arts and design. Urban design and architecture. Environment and theory. That was the main preoccupation. The strategic idea in the proposals was that we will start from the subnetworks of construction, design, urban design, restoration and theory. Not to reinforce their isolation, but on the contrary to take measures against this isolation. Even for the very first meeting and I am sure that you remember, we try to bring those aspects together. And there is no reason to repeat what happened over the years. But, I believe that we never managed to arrive at something coherent, as a proposal or an operational idea that will answer to this issue. There are two aspects or two possibilities. The one possibility is, that we do not want to answer. The second is that we cannot answer. We either do not want, or we do not know how to do it. The result is that after six years this issue remains a burning one, but an issue that is discussed in these kind of Workshops and I would like to tell you that in this May, we had the design teachers meeting in Lisbon, where the theme was more or less the same with this one and the previous one. The question was in this new conception about the world and architecture, what would be the teaching of design. There, the designers made references about working with construction teachers, but of course under the dominance of the designers. And this is the same thing, happening here. I think

that if we will insist on that, I agree that this is the most significant theme, but I feel that in order to overcome this we have to stand a step above that and to say, instead of saying how we will bring designer and construction teachers together, we will ask which will be the necessary competences for a student who will work in the lab of Mathias Kohler.
Then the designer and the construction teachers can easily show this capacity for the student in their courses. In common or in separately.

Maria VOYATZAKI, Thessaloniki, Greece
This is where I have a slight difficulty Professor Constantin Spiridonidis, about the construction teachers and the designers. There were many people around this room, that asked me earlier if we have ever attempted to put designers and construction teachers together. I will try to make a point, through a very far-fetched angle, starting from misusing perhaps a cult proper sort of track of thinking, about scientific truth that is valid until the data that can prove it can be refuted. That is to say that only the results that we drew from previous workshops were that design and construction are integrated. But when you put the word integrated, you automatically imply that they are two different things. What I am saying by this is that the contemporary example, the way I follow it from the people that come from very innovative schools is that these people are the same person. There is no artificial distinction. The same way that there is no artificial distinction between design and manufacturing through continuum and processes that start parametric design that lead to the manufacturing of elements for something to become a built form. The same happens in teaching, since teaching as I said right in the introduction of this workshop is about simulating reality. To put artificial barriers and say, let's put the network of designers and the network of construction teachers or put construction teaching together, it is as if we have accepted from the start that they are two separate species. I believe that maybe we should reconsider what we talked about five years ago, which at the time was a valid finding for that, as before that design and construction were two different things. But we experience two different realities and this is something that we have to consider. In other words, when we discuss competences of our graduate, we should not be discussing them as two different entities, but as one a the continuum. If you look at the people around this workshop, what are Mathias and Fabio, as teachers? Are they designers or construction teachers, when they are in their school? What is Professor Maria Vrontissi in her School? A design teacher or a construction teacher? What is Professor Emilios? Is he a design teacher or a construction teacher? I am sorry to mention young people or young looking and thinking people, because there is no objective age. Age is in the mind. I think it is important to realize this new reality, that these people are not too different to try to get together. They are the same people. You can see that. It is very interesting. We have this thing automatically. When people walk into this room and happen to be here at the introduction. I look at them, I try not to, because I have to concentrate on what is happening here. I look at the door. You can see that these people have design in their genes to look at things. When Professor Ramon Sastre came in, being a specialist in retractable structures, he walked directly on the bridge and went to see how the room is split. When Prof. Tzekakis came in, do you know what he did first? He looked at the reflectors, then looked at the absorp-

tion and the diffusion and then looked down to us people. In other words, I am sorry I observe people. It is part of my bad habits. But what I am saying is we always have something from our education and our genes to look at things in a certain way. This is the way we were educated and the way we think. But the new reality has it, that we are in a new era, where we redefine the contemporary profile of the homo universalis, but they are the same person. Nowadays, we have to rethink whether their teaching is the same or it should be the same and to look at the construction of the teaching of construction through this new angle.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
The discussion becomes much more general, but I would like to say that we have to rethink the whole story. Not only the construction and design. This is what we discussed with Jean-Marie Bleus, that every period of history used to cut the world in smaller pieces, in order to understand it and in our case we have a cutting of our knowledge about architecture into smaller pieces, which are theory, design, construction, restoration. It is a way of splitting. But every time the way that we split knowledge, we use, we apply a number of criteria. That is to say a number of values. It is a value system, that produces a certain cut. I believe that we are in a new era and value systems are completely different from those that are used in order to make this split. If someone will say for example that our subject as teachers in schools of architecture is to teach our students how to design architecture, how to make, how to create architecture or generate if you want, then probably we can apply another split, which will be the way of thinking about the design, the way of creating, the way of evaluating, the way that we use. I mean other themes not necessarily the construction, because in each of those steps all of the existing aspects about architecture and construction is one of those, can be useful in order to have a better insight to that. I think that we need to invent a new split of knowledge. Of course this is not something very easy. You have to understand that it is organized and based upon power structures. Already etsablished conditions in schools of architecture, that cannot happen tomorrow. But on the contrary I strongly believe that with a view on competences it is possible to find some kind of missing links between the split subject areas, which will be useful and a very interesting investment for the future. Those things do not change overnight, but they have already started. It is very interesting to note the shift in terminology from students to learners. It is a different thing to think of the other as a learner, to think that a person is learning in a process. Not as a student who is a passive receiver of information of knowledge that the teacher possesses best of all and can convey to the others.

Jelle LAVERGE, Ghent, Belgium
I think that you touch something that is very valuable, but because you can say that you can split architecture or whatever designing other categories, but I think you must not forget one other thing which is some sort of meta-category. Now you split the subject, but there is something else that you have to talk about. How do you teach this? The conditions that rise from teaching this subject and how the specific problems that occur. The specific aspects of teaching itself has also value in the system you are describing there. That is maybe another category that goes along.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
I would like to say that last year we run an inquiry in the European level asking the professionals about the graduates of the schools of architecture according to their view, how those competencies are prioritized. We gave them a list of twenty-eight competencies and we asked them to rank them. We also asked them to evaluate the degree to which, each one of those competencies are covered by the educational system of their country. We had answers from about six hundred and something professionals all over Europe and the interesting result of this inquiry was that the competencies which referred to knowledge were always last. On the contrary, the most significant competencies for them was critical thinking, was the 'learning to learn' capacity. Their capacity to express their views in written and textual, graphic, digital forms. Their capacity to make decisions. The time management skills. All those competencies appear as much more significant than the capacity to know history or the knowledge of other aspects of architecture. It was evident that those people are expecting, knowing some knowledge, to be able to do it. We never ever, in our educational system, try to ensure such kind of competencies, which of course presupposes a completely different structure of the curriculum, which is the one level and a completely different teaching process in order to achieve. We have to work in the future in the two different levels. The one will be the structural one. How a curriculum could be organized, that means how we will split the knowledge into smaller pieces, years and classes and I do not know what else. The second level is how we will develop new teaching approaches and tools in order to ensure those capacities. The interesting thing in this inquiry was that the most significant for the professional's competencies were the less covered, or to a smaller degree covered in the educational system. To our question to grade our capacity to create or to generate architects with critical thinking, the grade they gave us was 5.5/10. And what was interesting was, that the average of all the competences covered by the Schools arrive at 553 or 535, I do not remember exactly, but it was under six. It was pass of course, but a bare pass I am afraid. So, I think that there is a ground of thinking and developing different approaches.

Miltiadis TZITZAS, Athens, Greece
I think we have to be extra careful on that. There are two things running in Europe generally and especially in our country nowadays. Some people say that students should be educated in a way of getting a job, being good workers. That means that we could be easily accused of preparing a generation of workers, architect workers. That is one thing. The second thing, is that we educate people in order to become architects. We should give professional skills, in order to communicate with other disciplines. If we just grasp this very difficult problem and start thinking about it, discussing about it, doing something about it, then we might just keep in truck, that we might be turning around in some schools. In the UK it is happening now. Architectural education is turning into a more practical thing. They are educating some kind of workers. Not all schools, but it comes from the definition of the governmental policy. They put money into the schools, according to the research they do. But the research they do is not something that they decide as schools of architecture, but what is implemented sort of well. Not implemented, but suggested by what is in the profession. If we start being independent of all those things, we can start a discussion about it.

Constantin SPIRIDONIDIS, Thessaloniki, Greece
First of all, I want to say that I completely agree with what you said and I never meant that we have to take this model as a guide. It is a kind of reference, which someone has to take seriously into account. Of course not the profession will define the way that we will teach architects. It is beyond any kind of question. But the problem is there and we also have to rethink this distinction that you very correctly mentioned. There are schools that educate architects and there are schools that train architects. This distinction is a very typical one. There is a third category, which is the schools that cultivate, it is more or less the academies of art that are closer to the artistic aspect of architecture or the beaux arts schools that have departures of architecture, where they do not train architects and they do not educate architects, but they develop a spirit of architecture. These are three completely different strategies of education. But beyond these differences, I think that the relationship with the real world of profession, which is out there, is something we have to keep alive and a communication to be very serious on both sides and we have to feel up to which degree we can cover this demand of the profession. To which degree after a lifelong learning process probably we have to continue to cover it, which is of course another level of discussion.

Miltiadis TZITZAS, Athens, Greece
That is what I mean Professor Constantin Spiridonidis. To give quality to that perspective. Not to leave it to the politicians hands.

Jean-Marie BLEUS, Saint-Luc Liege, Belgium
If we have a new regard of what we have done through these six years, the first step of the idea of architecture would be the term "ethic". Political of ethic. Because everywhere we are talking about sustainability. Sustainability is to be placed in regard of the system in which we live everyday. If we have time I would like to show a short example. One teacher, in the first year in the studio in our School, was discussing with another one. The first one said, if I have to make a house, a passive house for people who have to drive one hundred kilometres with two cars to the work. I do not work on the passive house. I do not want to design it. Would you change where you live? Would you be in a proximity of your work place? The other one said, that it is not the question we had, to question us, if we have to have a passive house, I will design a passive house. What is the consideration we have to the system we are in to validate the first step of what we are designing changing opposite systems. In this way, we have to question the industrial people who are open to have architects. They are very glad to have an architect choose new material, but only with the one thinking is making money.

Maria VOYATZAKI, Thessaloniki, Greece
I would like to thank you for having the patience and the stamina to be still here and above all to thank Professor Alain Sabbe for being such a warm effective host for being with us until the last minute. Thank you very much.

List of Participants

ALEXANDROU Eleni
National Technical University of Athens (N.T.U.A.)
School of Architecture
42 Patission Ave, 106 82 Athens
GREECE
Tel: +30 210 6892927, Fax: +30 210 6892927, e-mail: gcharoni@hol.gr

AXARLI Kleio
Aristotle Univesrity of Thessaloniki
School of Civil Engineering
University Campus, 541 24 Thessaloniki
GREECE
Tel: +30 2310 99 56 16, Fax: +30 2310 263632, e-mail: axarli@civil.auth.gr

BASTOS Jorge de Novais
Universidade Tecnica de Lisboa
Faculdade de Arquitectura
Polo Universitário do Alto da Ajuda - Rua Sá Nogueira PT- 1349 - 055 Lisbon
PORTUGAL
Tel: +351 96 250 6492, Fax: +351 21 364 7066, e-mail: jnbastos@fa.utl.pt

BLEUS Jean-Marie
Institut Superieur d'Architecture Saint-Luc
Bulevard de la Constitution 41 4020 Liege
BELGIUM
Tel: +32 499 698 313, Fax: +32 4 263 70 90, e-mail: jmbleus@skynet.be

BOEYKENS Stefan
K. U. Leuven Department of Architecture
Kasteelpark Arenberg 1 3001 Leuven
BELGIUM
e-mail: Stefan.Boeykens@asro.kuleuven.be

BOSCH Lola
Hogeschool Sint Lukas Brussels
Paleizenstraat 70 1030 Brussels
BELGIUM
Tel: +32 (0)2 2501183, Fax: +32 (0)2 2501134, e-mail: lola.bosch@sintlukas.be

BOUGDAH Hocine
Canterbury School of Architecture UCCA
New Dover Road CT1 3AN Canterbury
UNITED KINGDOM
Tel: +44 12 27 81 73 93, Fax: +44 122 7817500, e-mail: hbougdah@ucreative.ac.uk

BULLO Sandra
Università IUAV di Venezia
Dipartimento di Costruzione dell'Architettura
Dorsoduro 2206 30123 Venice
ITALY
Tel: +39 335 8456530, Fax: +39 041 522 3627, e-mail: bullo@iuav.it

CONTI Calogero
Mons Faculty of Engineering
9, rue de Houdain B-7000   Mons
BELGIUM

CRUNELLE Marc
Institut Superieur d'Architecture Victor Horta
U.L.B. - C.P. 248, Boulevard du Triomphe 1050 Brussels
BELGIUM
Tel: +32 375 53 60 99, e-mail: mcrunell@ulb.ac.be

DE BRUYCKER Sandy
W&K Dep. Architectuur Sint-Lucas
Hoogstraat 51 B-9000 Ghent
BELGIUM
Tel: +32 9 2251000, Fax: +32 9 225 8000,
e-mail: sandy.debruycker@architectuur.sintlucas.wenk.be

De WEYER Henk
Amsterdam Academy of Architecture
Waterlooplein 211 1011 PG Amsterdam
THE NETHERLANDS
Tel: +31 (0)20 53 18 218, Fax: +31 (0)20 6232 519, e-mail: hesuweijer@planet.nl

DELPIRE Denis
ISACF - LA CAMBRE
19 Place Eugene Flagey 1050 Brussels
BELGIUM
Tel: +32 2 643 66 63, Fax: +32 2 647 46 55, e-mail: cecile@lacambre-archi.be

FRANCA Jean-Pierre
Ecole National Superieure d'Architecture Paris la Villette
144 Avenue de Flandres 75019 Paris
FRANCE
Tel: +33 14 82 49 024, e-mail: jpfranca@club-internet.fr

FRANCO Giovanna
Genoa School of Architecture
Stradone di Sant'Agostino 37 16123 Genoa
ITALY
Tel: +39 0 102095753, Fax: +39 0 10295790, e-mail: francog@arch.unige.it

FRETTOLOSO Caterina
Second University of Naples
Convento di San Lorenzo ad Septimum
via San Lorenzo 81031 Aversa (Ce)
ITALY
Tel: +39 081 8902920, e-mail: carerina.frettoloso@unina2.it

FRITZ Oliver
University of Applied Sciences
Institute of Architecture and Planning
Furst - Franz - Josef - Strasse 9490 Vaduz
LIECHTENSTEIN
Tel: +42 32 65 11 38, Fax: +42 32 65 11 21, e-mail: oliver.fritz@hochschule.li

FULOP Zsuzsanna
Budapest University of Technology and Economics
Faculty of Architecture, Department of Building Construction
Muegyetem rkp.3 II em. 27/A H-1111 Budapest
HUNGARY
Tel: +36 1 463 1306, Fax: +36 1 463 3949, e-mail: zsfulop@epsz.bme.hu

GKOUZKOUNIS Anastasios
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
University Campus 54124 Thessaloniki
GREECE
Tel: +30 2310 619836, e-mail: angkouz@arch.auth.gr

GORSKY Jerzy
Warsaw University of Technology
Faculty of Architecture
Ul. Koszykowa 55 00-658 Warsaw
POLAND
Tel: +48 602710443, Fax: +48 6283236, e-mail: 104jg@arch.pw.edu.pl

GOULIELMOS Francis
National Technical University of Athens (N.T.U.A.)
School of Architecture
42 Patission Avenue 10682 Athens
GREECE
Tel: +30 6945 684430, Fax: +30 210 675 4304, e-mail: F.Goulielmos@arch.ntua.gr

GRAMAZIO Fabio
ETH Zürich
Department of Architecture Hönggerberg
HIL F56 Zurich
SWITZERLAND
Tel: +41 44 633 28 39, Fax: +41 44 6331171, e-mail: gramazio@gramaziokohler.com

HEISTERCAMP Marcel
W&K Dep. Architectuur Sint-Lucas
Hoogstraat 51 B-9000 Ghent
BELGIUM
Tel: +32 9 2251000, Fax: +32 9 225 8000, e-mail: marcel@heistercamp.be

HOYET Nadia
Ecole National Superieure de Versailles
5 Avenue de Sceaux 78000 Versaille
FRANCE
Tel: +33 06 87 27 35 03, e-mail: nadia.hoyet@wanadoo.fr

JANSON Ulf
Chalmers University of Technology
School of Architecture
SE-41296 Goeteburg
SWEDEN
Tel: +46 70 308 8400, e-mail: ulf.janson@chalmers.se

KARA Hanif
2 Farringdon Road
EC1M 3HN London
UNITED KINGDOM
Tel: +44 20 7336 7143, Fax: +44 20 7608 1549, e-mail: hk@akt-uk.com

KOHLER Matthias
ETH Zürich
Department of Architecture
Hönggerberg HIL F56 Zurich
SWITZERLAND
Tel: +41 44 633 28 39, Fax: +41 44 6331171, e-mail: kohler@gramaziokohler.com

KONIORDOU Laura
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
University Campus, Box 491 54 124 Thessaloniki
GREECE
Tel: +30 2310 995589, Fax: +30 2310 994241, e-mail: lkoniord@arch.auth.gr

LAURO Giuliana
Second University of Naples
Convento di San Lorenzo ad Septimum,
via San Lorenzo 81031 Aversa (Ce)
ITALY
Tel: +39 081 5064176, e-mail: giuliana.lauro@unina2.it

LAVERGE Jelle
University of Ghent
Jozef Plateaustraat 22 B-9000 Ghent
BELGIUM
Tel: +486 776132, e-mail: jelle.laverge@gmail.com

LUYTEN Laurens
W&K Dep. Architectuur Sint-Lucas
Hoogstraat 51 B-9000 Ghent
BELGIUM
Tel: +32 9 2251000, Fax: +32 9 225 8000,
e-mail: laurens.luyten@architectuur.sintlucas.wenk.be

MAKOVÈNYI Ferenc
YBL MIKLÒS Faculty of Architecture and Civil Engineering
Thököly ùt 74 H-1146 Budapest
HUNGARY
Tel: +36 203890920, Fax: +36 1 2521278, e-mail: makovenyi.ferenc@ymmfk.szie.hu

MARTINSSON Lina
Royal Institute of Technolgy
School of Architecture
Östermalmsgatan 26 SE - 100 44 Stockholm
SWEDEN
Tel: +46 0 76 29 86 265, e-mail: lina@akt-uk.com

MASLY Dariusz
Silesian University of Technology
Faculty of Architecture
Ul. Akademicka 7 44-100 Gliwice
POLAND
Tel: +48 32 237 24 18, Fax: +48 32 237 24 18, e-mail: dariusz.masly@polsl.pl

MICHAEL Aimilios
University of Cyprus
School of Engineering, Architecture Programme
Kallipoleos 75 1678 Nicosia
DEMOCRACY OF CYPRUS
Tel: +357 22 892960, Fax: +357 22 660834, e-mail: aimilios@ucy.ac.cy

MOREL Philippe
EZCT ARCHITECTURE & DESIGN RESEARCH
72 Rue de Amelot 75011 Paris FRANCE
Tel: +33 1 48 07 57 56, Fax: +33 (0) 1 43 14 94 61, e-mail: philippe.morel@ezct.net

MOSSERI Avraham
Tel Aviv University
The David Azrieli School of Architecture
P.O.B. 39040, Ramat Aviv 69978 Tel Aviv
ISRAEL
Tel: +972 4 6290838, e-mail: mosseriavi@bezeqint.net

MUSTO Manuela
Second University of Naples
Convento di San Lorenzo ad Septimum,
via San Lorenzo 81031 Aversa (Ce)
ITALY
Tel: +39 081 5567985, e-mail: manuela_musto@libero.it

OLSSON Karl-Gunnar
Chalmers University of Technology
School of Architecture
SE-41296 Goeteburg
SWEDEN
Tel: +46 703 088 350, e-mail: kgo@chalmers.se

OUDATZI Kyriaki
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
54124 Thessaloniki
GREECE
e-mail: arch.museum@sportmuseum.gr

ÕZMEN Fulya
Gazi University
Department of Architecture
Celal Bayar Bulvari, Maltepe 06570 Ankara
TURKEY
Tel: +90 312 2352157, +90 312 2317400, Fax: +90 312 2308434,
e-mail: efozcan@gazi.edu.tr

PAWLOFSKY Tom
Hochschule Liechtenstein
Fürst Franz Josef Strasse 9490 Vaduz FÜRSTENTUM
LIECHTENSTEIN
Tel: +49 8331 750 9339, e-mail: tom.pawlofsky@hochschule.li

PERIN Jean-Marie
Ecole National Superieure d'Architecture Paris la Villette
144 Avenue de Flandres 75019 Paris
FRANCE
Tel: +33 06 24 49 66 90, e-mail: jmperin@freesurf.fr

PERTRESCU Vlad
Bucharest University of Architecture
Strada Academiei 18-20, Sector 1 010014 Bucharest
ROMANIA
Tel: +40 723 337 166, e-mail: vlad_petrescu@yahoo.com

PHOCAS Marios
University of Cyprus
School of Engineering
Architecture Programme
Kallipoleos Str. 75 1678 Nicosia
DEMOCRACY OF CYPRUS
Tel: +357 22892969, Fax: +357 22660834, e-mail: mcphocas@ucy.ac.cy

POOLS Denis
ISACF - LA CAMBRE
19 Place Eugene Flagey 1050 Brussels
BELGIUM
Tel: +32 2 643 66 63, Fax: +32 2 647 46 55, e-mail: cecile@lacambre-archi.be

RASKOVIC Ivan
Belgrade University
Faculty of Architecture
Bulevar Kralja Aleksandra 11000 Belgrade
SERBIA
Tel: 011 32 35 713, +381 063 88 68 174, Fax: 011 32 35 713, e-mail: agm-am@Eunet.yu

SABBE Alain
Mons Faculty of Engineering
Department of Architecture
9, rue de Houdain B-7000 Mons
BELGIUM
e-mail: asabbe@mac.com

SASTRE Ramon
ETS Arquitectura del Vallès
c/ Pere Serra, 1-15 08173 Sant Cugat del Vallès
SPAIN
Tel: +34 934017880, Fax: +34 934017881, e-mail: ramon.sastre@upc.edu

SIEM Jan
NTNU
Alfred Getz Vei 3 7492 Trondheim
NORWAY
Tel: +47 99 45 94 53, e-mail: jan.siem@ark.ntnu.no

SPIRIDONIDIS Constantin
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
University Campus 54 124 Thessaloniki
GREECE
Tel: +30 2310 995589, Fax: +30 2310 99 4241, e-mail: spirido@arch.auth.gr

TIXIER Nicolas
Ecole National Superieure d'Architecture de Grenoble
Grenoble
FRANCE
e-mail: Nicolas.Tixier@grenoble.archi.fr

TSOURAS Vassilis
National Technical University of Athens (N.T.U.A.)
School of Architecture
42 Patission Avenue 10682 Athens
GREECE
Tel: +30 210 6719281, Fax: +30 210 6724287, e-mail: vtsouras@central.ntua.gr

TZEKAKIS Emmanouil
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
University Campus 54 124 Thessaloniki
GREECE
Tel: +30 2310 995501, Fax: +30 2310 995504, e-mail: tzekakis@otenet.gr

TZITZAS Miltiadis
National Technical University of Athens (N.T.U.A.)
School of Architecture
42 Patission Ave. 10682 Athens
GREECE
Tel: +30 210 7723914, Fax: +30 210 80 41 123, e-mail: miltis@central.ntua.gr

VÄISÄNEN Päivi
Helsinki University of Technology (T.K.K.)
Post Box 1300 FI-02015TKK Helsinki
FINLAND
Tel: +358 40 523 1543, Fax: +358 9 451 3960, e-mail: paivi.vaisanen@tkk.fi

Van de VREKEN Koen
Henry Van de Velde Institute
Department of Design Sciences
Mutsaardstraat 31 B2000 Antwerp
BELGIUM
Tel: +32 0473 30 14 82
e-mail: koen.vandevreken@telenet.be

Van den BOSCH Nathan
University of Ghent, Department of Architecture and Urban Planning
Jozef Plateaustraat 22 B-9000 Ghent
BELGIUM
Tel: +32 9 264 39 27, Fax: +32 9 264 41 85, e-mail: Nathan.vandenbossche@ugent.be

Van den BOSSCHE Adrian Gabriel
"Ion Mincu" University of Architecture and Urbanism
Strada Academiei 18-20, Sector 1 010014 Bucharest
ROMANIA
Tel: +40 723 271111, e-mail: ancadrian@ancadrian.com

VANDENBOSCH Lut
Provinciale Hogeschool Limburg (PHL)
Campus Diepenbeek, Gebouw E, Agoralaan,
Universitaire Campus 3590 Diepenbeek
BELGIUM
Tel: +32 0 11 249 200, Fax: +32 0 11 249 211, e-mail: lvandenbosch@mail.phl.be

VIDRASCU Thomas
ISACF - LA CAMBRE, 19 Place Eugene Flagey 1050 Brussels
BELGIUM
Tel: +32 2 643 66 63, Fax: +32 2 647 46 55, e-mail: cecile@lacambre-archi.be

VOYATZAKI Maria
Aristotle University of Thessaloniki (A.U.TH.)
School of Architecture
University Campus, Box 491   54 124 Thessaloniki
GREECE
Tel: +30 2310 995544, Fax: +30 2310 994241, e-mail: mvoyat@arch.auth.gr

VRONTISSI Maria
University of Thessaly, Department of Architecture
Pedion Areos 383 34 Volos
GREECE
Tel: +30 6974 328 383, Fax: +30 210 8042 887, e-mail: mavrontissi@post.harvard.edu

WILQUIN Hugues
Mons Faculty of Engineering
Department of Architecture
9, rue de Houdain B-7000   Mons
BELGIUM

WITECZEK Aleksandra
Silesian University of Technology
Faculty of Architecture
Ul. Akademicka 7 44-100 Gliwice
POLAND
Tel: +48 601 172 261, e-mail: aleksandra.witeczek@polsl.pl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