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Teaching construction thinking in architecture through materiality and craftsmanship

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ABSTRACT: In the field of architecture education design thinking today is often focusing on the powerful tools of modern technology. This comprises both the increasing technological possibilities in construction and materials allowing for more complex and tolerant structural performances and the broader geometric modeling tools which not only reduce formal limitations but also call for complexity with distinctive parametric translations of any given shape. Especially the teaching of design thinking is increasingly connected to growing technological opportunities, options and visions rather than to limitations. This tendency has intensified when even architectural and constructional models are no longer build but printed omitting the only part in standard design practice which is inherently connected to the process of making. The natural translation process of a formal geometrical idea into a physical object, once incorporated in the design process as a matter of course, strongly guides the design itself. This paper presents examples of teaching construction thinking in architecture through materiality and craftsmanship to architecture students at ETH Zurich. Focusing on simple tools and basic principles students explore material systems such as natural timber, simple glulam, or ferrocement without reproducing traditional techniques but to extend their experiences to possibilities of architectural expression and structural effectivity. This has been done in different cultural contexts in mixed groups with students of other schools to also discuss different approaches of dealing with materials in construction and different scales. Four different cases will be discussed in depth to reflect the potential of experimental design and the empirical study of forms and forces.

1 INTRODUCTION

Materials and material thinking play an essential role in both the daily design practice of architects and the basic architectural education program. They form an important foundation in the later phase of the conceptual design when ideas and forms find their way to scale and more concrete geometries and also an early understanding of their physical presence connected to a material expression. In architectural education, these phases of conceptual form development on the one hand and constructional exploration of materials, fabrication and construction on the other are very often discretely disconnected – the form considered the design phase, the material the practical construction. This schematic understanding of architectural design is strengthened through modern technologies on both of these sides. In the early design and often also the more detailed design phase digital design tools allowing for a multiply controlled design process and form development considering many more contextual aspects, whereas on the construction side new hybrid materials allow for increasingly complex applications. Both are redefining the tolerance in which material and contextual design limitations have ruled and stimulated the holistic design process. Instead, freer from constructional conditions and material thinking, formal approaches are applied projecting various schematic concepts of material optimizations and its figurative, often diagrammatic formation.

In a new construction-focused course, a very basic material thinking has been tested in the realm of architectural education. This course was offered as an elective for third year bachelor and master students at the architecture department of ETH Zurich throughout the last three years. It aimed for a complete design and build process where al steps had to be considered and taken by each student individually. In each case, a material was given and a design task focusing on the production of simple object which is both structurally meaningful and interesting, such as a piece of furniture like a chair. The goals of this course were very simple: First, raising the awareness of the architectural potential of designing and working with construction materials during the entire development of a certain semester project (Clifford 2011); secondly, to explore an explicit architectural language based on the very conditions of the particular material; and, thirdly, to use materials to think about design aspects and the overall characteristics of an object just like a drawing or writing process would do (Goldstone 1998).

2 WOOD AND TRANSFORMATION PROCESSES

Connected to a larger research project into the character and constructional logic of new timber products and applications (Rinke & Schwartz 2014), a first hands on workshop within a one-semester course was initiated in spring 2015 as a collaboration of the architecture school at ETH Zurich, Chair of Structural Design, and the Lucerne University of Applied Sciences and Arts, Object Design program, comprising 16 students, 8 from each school. As often practiced for practical workshops, there was a partner from the industry involved: ERNE Holzbau from Laufenburg, Switzerland, provided practical knowledge on contemporary timber fabrication. The students were given an abstract design task which was to design and built a sitting object for themselves. Developing a consistent and rich construction language based on wood, no steel connectors such as screws and bolts were allowed. Using standard contemporary wood products, both natural and industrial, all design processes had to explore the architectural and technical material properties of the material of choice.

Traditional and contemporary fabrication and construction were studied to set up a broad basis for all design decisions. The students mostly developed their design concepts on the basis of connection principles they found for their materials and the desired function. Pushing the limits of contemporary applications of tools and fabrication techniques, surprising new constructional forms of wood evolved. The project “Stuhl: Holz, gesteckt“ (chair: wood, plugged) is based on the general understanding of the classical chair providing a comfortable surface to sit and read (Fig. 1). The desired form is developed through a combination of three overlapping linear elements using the

Figure 1. Daniel Itten, “Stuhl: Holz, gesteckt“, spring 2015 (Photo: Andri Stadler).

principle of reciprocal frames to achieve fixed connections between them. In the overlapping zone of each pair of elements one stick is placed on either side so to block their movement, i.e. to fix it. In order to lock not only the members they are touching but also to fix them just in the position where they are, these sticks are shaped according to the concept of dovetail joints. This way, they can be slide in sideways but cannot move perpendicular to the members. To provide better comfort through a curved sitting area, the connecting sticks are curved. The fabrication of these curved and dovetail-shaped sticks is based on the principles of modern glulam fabrication and adopts these for the scale and assembly of furniture (Saxer & Rinke 2015).

Another workshop in spring 2017 picked up the concept of material-based construction but widened the spectrum of formal references. Set up as a collaboration of the architecture school at ETH Zurich, Chair of Structural Design, and the architecture school of the Southeast University in Nanjing, 16 students from each school joined the two-weeks course in China. Extending the focus from the object to an architecture scale, the students were asked to design a "space divider", a structure that can be considered a furniture with a designated function but placed and integrated in a concrete location at the campus of the Southeast University. This way, their respective project was an intervention architecturally reacting to a certain situation which was precisely modified to provide an additional or different quality that was felt needed. As for the furniture scale, these structures should be crafted, and the design of all its parts would relate to a particular logic of joinery and their arrangement reflect a clear idea of tectonics. Consequently, the design concepts start with a vague idea of the function and its spatial setting but, more concrete, on a basic idea of joining which would eventually lead to a characteristic pattern of all parts involved.

During the first week of the workshop, the group studied traditional timber buildings such as temples or palaces in the city of Nanjing but mostly in the preserved traditional villages of Hongcun and Xidi, located in Yi County close to Huangshan City in south Anhui Province. Different construction techniques were analyzed through sketching, photographing and small-scale modeling. Comparing these techniques with those typical for central Europe, which have been studied by the ETH students in Switzerland before the trip, allowed for a contextualizion far beyond a common study practice of colligation where very different aspect of construction are subsumed under concepts like "Western" and "Asian" timber construction. By looking at the basic conditions of the constructional context, i.e. the client and the representative demand, the material and its journey to the site, the local formal and constructional references, the labor and their background, the construction knowledge involved etc., the entanglement of basic formal aspects and constructional principles in "West" and "East" can be made visible and used for a broader understanding of 'traditional' use and combination of wood as a constructional material.

During the second week, developed their design concepts for their space divider. For the purpose of knowledge exchange and reflection, groups of 4 students were formed consisting of two students from each school. Firstly, they chose a location and a functional scenario, and went on to try out various constructional principles they found interesting and which would contribute to their overall design concept. Secondly, the student studied their design in a series of small scale models and, in parallel, learned to work their particular timber joints by themselves, guided by tutors and, partly, by Chinese carpenters. For their projects they were provided with a limited number of timber elements with two sizes. The only tools used for their timber work were simple wood saws and chisels. The final goal of the week was to demonstrate the concept by showing the constructional features such as the worked members and the crafted joints but also indicate the volume of the overall project. Eventually, the 8 groups developed very different projects focusing on particular techniques to enhance the architectural expression of their space dividers.

Back to Switzerland, the ETH students were then asked to reflect what they have learned both from the critics on their projects and their own work with the material and the tools. The two ETH students from each workshop team reworked their design concept and improved joint detailing and the precise, effective use of tools. This generally led to much lighter structures and more homogenous patterns.

The space divider shown in figure 2, for example, plays with idea of regular patterns using the same type of layering resembling a scarf joint in the same general angle but with different orientations to generate zones of different grades of transparency. The space divider here works like a

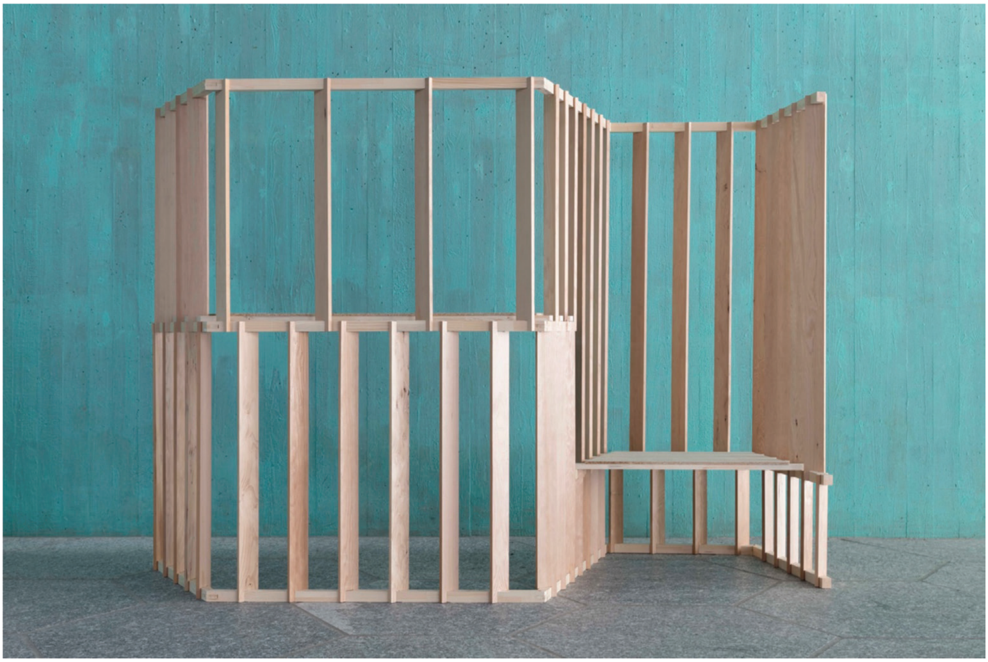

Figure 2. Tamara Blanc and Sarina Meier, “Space Divider”, spring 2017 (Photo: Andri Stadler).

screen to create a new space within its larger context and, in particular, offers smaller spaces within the screen structure for resting or reading alone on a small bench (on the right) and to stand and enjoy a coffee in a small group on a higher board (on the left). Therefore, the density of the pattern emphasizes privacy or openness and visibility. The sum of the many layered joints together with overall spatial arrangement of the screen result in a very good overall stability of the structure.

3 WOOD AND MANIPULATIVE OPERATIONS

As a continuation of the first workshop on wooden furniture in spring 2015 another workshop was set up in spring 2018 focusing on the manipulation of component shapes and their connections. Like for the workshop in spring 2015, the design task was to design a sitting object for personal use. This workshop was done again in collaboration with the Lucerne University of Applied Sciences and Arts, Object Design program, this time comprising of 28 students, 10 from ETH and 18 from Lucerne. Again, an industry partner was involved which was Artek from Finland, part of VITRA. Artek provided a comprehensive input on contemporary timber technology in furniture fabrication and followed the design process of the students closely throughout the semester giving specific feedback on their individual projects.

The starting point of the workshop was the legendary l-leg of the Artek stool, an l-shaped wooden leg that was made of several layers of veneer bent in shape and glued to make a continuous form of the wooden component. A veneer manufacturer was visited in the first week of the semester to better understand the nature of the material and the immanent manipulation techniques. Based on the knowledge of the history of wood bending and common contemporary manufacturing technologies, the students were provided with simple tools and equipment for their work. The students again began to develop their concept by working with the logic of the material itself. Different layering techniques were studied and very often the layering led to the concept for the joints. Like in the other workshops before, a strong focus was put on the consistent material concept which allowed other materials only if necessary and in line with the overall character of the object. This artificial restriction led to a more – at first sight – complicated connections but mostly proved to be in concert

Figure 3. Ziu Bruckmann, “Reading chair”, spring 2018 (Photo: Andri Stadler).

with the actual fabrication method of the components. The goal of the course was a full-scale prototype that showed all joint details and indicates the fabrication technique for the components.

There was an enormous variation of formal approaches based on a few constructional principles. Many students were interested in extending the concept of bending the members in different directions in space. The project “Reading chair”, shown in figure 3, exemplifies this idea. Three complexly but precisely curved components are arranged to make one robust framework ^which looks like a continuous wooden ribbon. Two of these three touch at specific points and ensure this floating expression: one of which is ending, the other runs continuously to the next meeting point. All joints are glued and no further metal connector was used. Working with different models and scales ensured a multi-level material design: small scale concept models to try options and combinations, full-scale test models to verify proportions and comfort, and full-scale components to test precision and strength.

4 FERROCONCRETE AND MODELING

Another design and build workshop focused on another material. Transferring the methodology of working with wood to ferroconcrete allowed for a detailed check of the teaching concept beyond the material. In spring 2018, basically parallel to the wood workshop running the full spring semester, a compact one-week workshop was given in Rome, Italy, in cooperation with Tor Vergata University. The material ferroconcrete is closely linked to Italy and, more specifically, to Rome. The Italian Engineer Pier Luigi Nervi (1891-1979) developed and patented the concept of “ferrocemento”, where thin prefabricated concrete panels are manufactured by pouring or spreading the thin concrete on a wire mesh lightly reinforced with steel bars. By applying the concrete directly on a given form constructed as a metal cage working as both a form and load carrier, the resulting reinforced concrete (ferroconcrete) panels can be very thin and light but, more importantly, can be given a more specific shape free from conventional concrete formwork.

There were 12 students participating from the architecture school at ETH Zurich, Chair of Structural Design, and 4 students from the engineering school at Tor Vergata Rome. Groups of three, two ETH students and one from Tor Vergata, developed a concept for a sitting object for their own functional scenario, i.e. sitting alone, together in a group or separately on the same object. During the week in Rome there were two days of inputs and site visits and three days of working time. Visiting selected some buildings form Pier Luigi Nervi helped to understand the initial idea, its advantages and problems in different scales of applications.

On the first day, the students developed concepts using paper models representing the materiality of flexible, continuous forms strongly associated with ferroconcrete in Nervi's work. Later, in a second step, they made extensive material tests producing ferroconcrete in different compositions by themselves. This way, they made important experiences about the basic properties of concrete by handling and mixing all ingredients but also the nature and limits of the resulting hybrid material, i.e. the curvature, stiffness, weight or density. On the second day, each group focused on the fabrication of their objects by preparing the wire mesh and, by doing so, setting up the form of the object. The mesh itself consisted of two layers with a distance holder between them to make the actual thickness of the concrete. By adjusting the flexible mesh where needed, the first physical layer of the object serves as an immediate interaction tool to both check and remodel the actual object form. Therefore, the fabrication stage here is not following the design phase but it is part of it. Several steel bars were added where additional stiffness was felt necessary and, finally, the concrete was applied directly on the mesh. A first concrete layer was brought in between the mesh layers, a second to make and control the final surface.

As the form of the concrete is determined and limited by the mesh, which holds it, and which can be bent and curved unlike a planar formwork which is usually determining the form of the concrete, a very unique expression can be achieved through ferroconcrete modelling (fig. 4). Also, there is ideally no external element at all allowing the concrete to be cast; the mesh as the form carrier is inside the physical object. Form control, material control and usability control go hand in hand in the process of fabrication which is an extraordinary experience for the students placing their understanding of designing an object not outside the process of making and vice versa.

Figure 4. Nick Däschler und Alexander Nikolas Walzer, "Lounge bench", spring 2018 (Photo: author).

5 GENERAL METHODOLOGY

Throughout all design and build workshops a general teaching methodology is used to ensure a thorough learning process. A basic principle in teaching set up is collaboration in the teaching team itself to bring in different aspects of design and to stimulate transdisciplinary design thinking. Therefore, structural engineers and architects should be involved as well as designers from other fields such as product design. A main focus is put on the early production of physical models in different scales to allow for a continuous design process, to question, modify and verify both the form and the general character of the design object but also to understand and incorporate the physical behavior of the material (Meister & Rist-Stadelmann 2016). The early identification and adoption of constructional problems challenges and strengthens the underlying technical thinking throughout all variations of the project.

6 CONCLUSIONS

The natural translation process of a formal geometrical idea into a physical object, once incorporated in the design process as a matter of course, is often the leading approach in the architectural and structural design. Instead, an integrative methodology can be used to bring design and fabrication together using physical models in all stages of the design process together with a parallel development of formal and constructional concepts (Popovic-Larsen 2016). This paper presents examples of teaching construction thinking in architecture through materiality and craftsmanship to architecture students at ETH Zurich. Focusing on simple tools and basic principles students explore material systems such as natural timber, simple glulam, or ferrocement without reproducing traditional techniques but to extend their experiences to possibilities of architectural expression and structural effectivity. This has been done in different cultural contexts in mixed groups with students of other schools. Four different cases have been discussed in depth to reflect the potential of experimental design and the empirical study of the relationship of forms and materials.

For the successful performance of the students, a few major aspects have been identified which were used as a guideline for all workshops. It is important to choose design tasks which the students can easily connect to, such as common objects of their daily life. The objects they are developing should become eventually personal objects resulting in a much better identification with the design scenario and a greater overall commitment. Also, the scale of the objects should be in some way relate to the human body which allows for more intuitive design process and a permanent possibility of functional verification. The tools must be well understood to incorporate their rules and potentials as a design guidance. In the overall process, the continuous exposure to physical models and materials can allow to extend digital design concepts through a thorough material thinking, which will not limit but deepens the conceptual design thinking. Studying historical construction practices and techniques not to reproduce or hail them but to contextualize the materials, products, tools and techniques we are using today contributes to the broad understanding of necessities, rules and constructional conditions. Eventually, teaching construction thinking in architecture through materiality and craftsmanship raises awareness and reflection for a more competent material design and a deeper and more complex general design thinking.

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