STRUCTURE & EXPRESSION

Urs Meister,
Carmen Rist-Stadelmann,
Machiel Spaan (eds.)

PARK BOOKS

1 CRAFTING THE MODEL

2 TECTONIC REFLECTION

3 TWELVE WOOD STRUCTURES

4 CRAFTING WOOD HANDS-ON

Foreword

Erasmus+ is the European Union's most successful education programme. 'Strategic Partnerships' are projects in which at least three organizations from three different programme countries work together. In addition, non-university organizations can also participate in a Strategic Partnership if, by doing so, they generate added value towards the implementation of the project objectives.

The European Community promotes Strategic Partnerships in order to improve the quality and efficiency of European education systems.

> *Academic freedom is the freedom to learn as much as one desires.* (Rudolf Virchow)

In this spirit, the project 'Wood: Structure and Expression' has put into effect an interdisciplinary cooperation between universities and building praxis so as to establish innovative and creative partnerships between these two realms over the long term. The project partnership consists of three university partners, the Amsterdam Academy of Architecture, the Norwegian University of Science and Technology (NTNU) in Trondheim and the University of Liechtenstein, as well as two creative timber construction companies from Liechtenstein and the Netherlands.

The specific expertise of the three partner universities in the fields of design and architectural theory, combined with the partnered timber construction companies' practical know-how of building construction and assembly, enriches the project and offers an important breadth of knowledge and experience. This transfer of knowledge, achieved through the interconnection between praxis and universities and the resulting holistic approach, which combines architectural, constructional, cultural, economic and ecological issues with aspects of the encounter between differing cultural spaces, adds another important facet of innovation to the Erasmus+ project 'Wood: Structure and Expression' for the higher education sector.

The project was implemented to a very high standard, and we at the national agency responsible for Erasmus+ education in Liechtenstein honour the strengthening of ties between education, research and innovation that was brought about by the project 'Wood: Structure and Expression' at the University of Liechtenstein.

Dr Stefan Sohler,
Director of the National
Agency for International
Educational Affairs

Mag. phil. Clarissa Frommelt,
Head of Erasmus+ Higher
Education

Introduction

Roughly, by a complex system I mean one made up of a large number of parts that interact in a nonsimple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole.[1]

Carmen Rist-Stadelman,
Urs Meister

Wood is considered to be one of the most original materials with which man began to build dwellings. In depictions of primitive huts, we first encounter trees interwoven with branches that are still rooted and used as supports. In later representations, trees are felled and trunks, branches and twigs are used to construct primitive skeletons and eventually to build roofs and walls, and joints were knotted with fibres and cords. Even if we know that these archetypes of building correspond to a retrospective view and the didactic pretensions of the architectural theory of the Renaissance, we can still argue that timber construction and later carpentry developed from this basic taxonomy of joining building components, which used a limited number of tools to furbish beams and boards out of a tree trunk in order to erect structures and enclose space. The principles are still the same today: stick, connection and structure are the central elements of a game, in which stability, economy of means and the pursuit of congruence and beauty must be kept in balance. The laws of interaction of the parts must not only be observed, but constantly redefined in order to obtain a whole that is more than the sum of its parts. Persistent work is required to give the building inner tension, complexity and ultimately radiance. The design process follows less the architect's will to form than his ability to deal with the logic of the material and its properties.

This has become a leitmotiv and recurring theme in the methodology of the design studios of the three schools of architecture throughout the whole process. In this three-year Erasmus+ programme, students and lecturers from Amsterdam Academy of Architecture, the Norwegian Technical University in Trondheim, and the University of Liechtenstein focused on designing structures in wood. In the focus of the partnership, the three design studios were run in parallel and were complemented by joint workshops. The implementation of a special session at the International Congress for Structure and Architecture 2019 in Lisbon and a symposium held in Amsterdam in 2020 made our experiences and results accessible outside the project partnerships and positioned the programme in the European discourse. Today, wood is one of the most up-to-date building materials and offers an incredible wealth of possibilities. Modern timber construction with the currently available means bridges the gap between solid carpentry and complex digital manufacturing processes. Hence the future of timber construction is open to complex developments, which we should aim for in our schools of architecture. We would like to express our sincere thanks to all those involved for their great commitment and the diverse support we have received over three years.

1 Herbert A. Simon, *The Architecture of Complexity*, Pittsburgh 1962

1 CRAFTING THE MODEL

Tectonics in Education

Carmen Rist-Stadelmann

Materials influence the design and appearance of our built architecture. It is therefore important to consider materials as a whole, as a unity of form and construction, and to make them understandable for students as a driving force, as the origin of form and construction in the design process. But how do we offer our students a way to understand the meaning of these aspects? We can achieve this through a tectonic discourse that promotes a sensitivity to materials and generates a sense of joy in and curiosity about the interaction between materials, design and construction. In other words, the symbiosis between art and technology in design and realization. The practice of working at full scale at the University of Liechtenstein over the past ten years has contributed to the tectonic discourse about various materials in the teaching of architecture in Europe.

The culture of joining

> *Tectonics is therefore the study of joining individual parts together to make up a whole, to create an object of architecture, if you will: it is the study of the inner structure of an artwork. Tectonics, as the aesthetic expression of laws of construction, demands a structural design that cannot be easily separated from the work of the architect who designs it, nor can it be considered separately from the artistic mastery of building.* (Kollhoff, 1993)

In order to fulfil today's requirements of technology and building physics, we must layer the various construction materials. Or to use Gottfried Semper's terminology, we must use them for cladding. Layered materials lead to a packaged architecture involving many participants and professionals. As a result, our understanding of the material-specific joint has been lost, and this can be seen in the often questionable use of materials in contemporary architecture where they are no longer used because of their properties, but primarily because of their appearance. The art of joining the materials logically, proceeding from the individual piece to create a new whole, has been lost over the course of history, starting with industrialization and continuing with computerization today. We miss this art now. Due to this loss, we no longer see an interplay between design and construction based on the properties of the materials. That is why it is important to revive the culture of joining and the interaction between art and technology, bringing it back into the discussion and raising awareness of it.

Tectonics, with its implied hierarchy in construction, from coarse to fine, is directly suitable for achieving this. For Gottfried Semper, the joining of rigid, rod-like parts to create an immovable system is indisputably the most important and, at the same time, most difficult task, as he explains in *Style in the Technical and Tectonic Arts* (Semper, 1879a). Here he divides the purposes of tectonics into four tasks. These include the frame with corresponding filling, the lattice as a complicated framework that is made by joining rod-like structural elements to form a system that creates a surface, the supports and the structure, which is formed by an integration of the supports with the frame (Semper, 1879b).

In Gottfried Semper's understanding of tectonics, based on these four tasks, construction is by nature multi-layered. For him, it is important for tectonic joining that architecture always supports structure plus cladding, whereby the use of materials depends on the construction, thus making design and construction come together as one entity. Thus the appearance corresponds with the technology used. Adolf Loos wrote the following on this subject: "The principle of cladding, which was first articulated by Semper, extends to nature as well. Man is covered with skin, the tree with bark." (Loos, 1898a) This analogy between tectonics and human anatomy shows that the skin as cladding is always joined constructively to a person's insides; it is part of our body. That is why it is important for Loos that the cladding may not be confused with cladding materials. "The law goes like this: we must work in such a way that a confusion of the material clad with its cladding is impossible." (Loos, 1898b)

Semper's definition of tectonics or Loos's analogy with the human body, however, do not tell us how this tectonic interaction can be resolved. They refer to the secretive relationship between constructional joinability and appearance and involve the connection between the built object and our perception. The 'how' remains unexplained between art and technology. However, it is precisely this lack of clarity that enables a creative space for construction and design that should be taught more strongly, rediscovered and placed at the focus of the design and construction process when training architects. In order to join very different materials in this complex design process as understood in tectonics, we require basic knowledge about the materials to be used.

Material consciousness

> *Every material possesses its own language of forms, and none may lay claim for itself to the forms of another material. For forms have been constituted out of the applicability and the methods of production of materials.* (Loos, 1898c)

All of the efforts by an architect to do high-quality work ultimately depend on his or her curiosity about the material to be used. This requires material consciousness and, more than anything else, knowledge of their properties and the possible ways they can be implemented. Because, as Loos accurately said, not all materials are alike.

We can achieve this necessary material consciousness by promoting a sensibility to materials when teaching architecture and, besides imparting theoretical knowledge, by holding the material in our hands, and by working and designing with it. In his book *The Craftsman*, Richard Sennett divides material consciousness into three phases. He describes the first phase as metamorphosis—when the material changes. For him, metamorphosis takes place by developing the material further into a type form, establishing a judgement about its use in a combination of forms and reflecting about its area of application (Sennett, 2008a).

He identifies the second phase of material consciousness as presence. This comes about for Sennett through in the processing of materials by leaving behind trademarks or by marking the material or by making production processes visible. That is, how the material is processed and how we ultimately join materials to one another (Sennett, 2008b).

The anthromorphosis, the third area of material consciousness, is described by Sennett as what happens when an unprocessed material is ascribed human qualities. When we speak of real material or beautiful material, that is, when built objects are assigned human traits and properties (Sennett, 2008c).

Material consciousness according to Sennett—when it finds its way into teaching architecture—means that students become familiar with different materials and their different physical states during their

Figure 1–5
Construction process of the model workshop, Liechtenstein, 2017

architectural studies. They must know how different materials can be processed, how they can be developed further and joined tectonically from the small to the large. In brief, students should learn how materials should be used in building in accordance with their properties and how this interplay ultimately influences the appearance. In this process, the marks of production, influenced by the choice of tool for each material and visible in the way the material is joined to the building, also play a significant role. However, these marks are not restricted merely to the traces left by tools but can also include structural marks. This means that marks are also created by a multitude of steps carried out as part of the different requirements and that these are connected to one another while building. The production process includes a specific combination made up of empirical experience and intellectual reflection, and these can hardly be separated from one another. Here, the hand carrying out the work is important, as it processes the material with the respective tool or machine. The tool is therefore an extension of the hand, which brings us to an important point: the interaction between hand and mind.

Interaction between hand and mind

> *For the sportsman, craftsman, magician and artist alike, the seamless and unconscious collaboration of the eye, hand and mind is crucial. As the performance is gradually perfected, perception, action of the hand and the thought lose their independence and turn into a singular and subliminally coordinated system of reaction and response.* (Pallasmaa, 2009)

When this collaboration between hand and mind comes to bear with material consciousness in combination with tools in architecture, the result is highly interesting in terms of materials and construction technique. In the study of architecture, theory and praxis come together through hand and mind. This happens when everything that is taught as theory and is stored in the mind as knowledge, beginning with material consciousness right up to construction requirements, is put into practice using the hand and the tool.

The hand touches small objects with the thumb, cradles them in the palm and grasps them with the entire hand. The fingers touch, the hands grasp and feel, and the collaboration between hand-wrist-lower arm acts as a whole. The exchange of information between eye and hand is strengthened by repetitions. The hand first of all has to be sensitized by the tips of the fingers. After that, it can turn to the problem of coordination, then comes the integration of the hand into wrist and lower arm. Once the interplay of knowledge, which is made up of theory and praxis, has been learned, when eye and hand are familiar with one another, what results is an invaluable aspect in the teaching. Thanks to this dialogue, long-term design habits develop, and these habits lead to a switching back and forth between solving and finding problems, which supports the symbiosis between construction and outward appearance, or to put it in other terms, the unity of art and technology.

And when this interaction is transferred to the design process, what is achieved is an interplay among sketch, models, building at full scale and drawing. This fruitful inclusion was part of the three-year Erasmus+ project 'Wood: Structure and Expression'. In this project by the University of Lichtenstein, headed by Dr Carmen Rist-Stadelmann and Professor Urs Meister in cooperation with the architecture department at the Amsterdam Academy of Architecture and NTNU Trondheim, research was carried out into joints made of rod-like timber elements, and these were tested in a real design. The starting point was the long tradition of joinery, which has taken on different forms in different cultures, but always has the task of dealing with the transfer of forces in timber structures. Here, we concentrated on purely timber joints without considerable steel reinforcements in order to enrich the structures influenced by our culture with experiences and discoveries from other cultures.

With the basic knowledge acquired in this way, and by developing our own connecting nodes at a scale of 1:1, the students first created a spatial load-bearing structure that could form a roof to protect the prehistoric rock drawings made by Vikings near Trondheim in Norway from further erosion and which—together with several infrastructural buildings—can welcome visitors from all over the world to an open-air museum. Joining and thinking tectonically was therefore provided for in the task itself. As the design process involves using the material itself, the result is a material consciousness in the three phases outlined by Sennett. The hand executes what the mind thinks. Theory and praxis are brought together, and the students learn through the experience they have gained.

Learning through experience

But the result is the student's own experience and possession, because it has been learned rather than taught. Learning is better than teaching because it is more intensive: the more we teach, the less students can learn. (Albers, 1982)

Students can learn and gain a good understanding from their own experience when they build at a scale of 1:1. In other words, when they work hands-on. Working in this way offers students plenty of opportunities to gain experience, something that became apparent when we built the model workshop for our university. Many years of experimenting with building at a scale of 1:1 at our university have shown that just having contact with the material is enough to gain a new understanding of it.

While building the model workshop, we noticed that wood was the material that was driving the design and the subsequent manual labour. The design process began with a five-day workshop as part of the Erasmus+ programme, in which eight load-bearing structures were developed and then built on site at a scale of 1:1. The parameters for the load-bearing structures were set in advance, as the tunnel-shaped form best complied with the existing building regulations on the designated site.

Of the eight supporting structures, the two design studios of Dr Carmen Rist-Stadelmann and Professor Urs Meister analysed four structures as the next step. These were then further developed with the students and built as prototypes. From these, a small jury of lecturers and students selected the structure that was ultimately to be realized. The selection criteria that were decisive were that the supporting structure formed both wall and ceiling constructively, that the structure was developed from the material, and that the tectonic approach was fulfilled. The structure also had to be built and realized by the students themselves, without specialists and without much computer work, and that the expectations of craftsmanship and artisanal aspects were also satisfied.

For the fabrication process, the students built moulds into which the long and narrow timber boards could be inserted and then fixed together into segmental arches. With a tectonic understanding, these prefabricated segmental arches were joined on site to create a new whole. The segmental arches are hinged at the crown, rest on a timber sole plate and are interwoven with one another. The timber sleeper is, in turn, held by the floor beams, which are designed to withstand tension. The finished floor on the floor beams provides information about the floor construction through its laid timber formwork. It thus visibly unites construction and appearance.

The model workshop was an ongoing process in which the students resolved different structural parts in different teams. The project was developed further in joint presentations while construction proceeded simultaneously. In a 1:10 scale model that one student group built during the construction process, it was possible to assess all decisions and then to build them on site at a scale of 1:1 and vice-versa, thus resulting in an interesting interplay between theory and praxis using both the model and reality.

The construction process was carried out as teamwork involving 62 students and 3 lecturers. After 15 weeks of intensive building, detailing and designing, the model workshop was ready at the end of the semester, meaning it could be opened ceremonially. In addition to relocating and connecting the machines, participants carried out the last work during the summer holidays, so that the workshop could go into operation for the 2017–18 winter semester. The model workshop has proved its worth so far and enjoys a high level of acceptance among students.

The fascinating thing about this way of learning through experience gained by working on a real object was seeing how strongly the students identified with the construction task and how this increased as the process went on. It was also exciting to see how they gained experience and confidence in working with wood as a material as construction progressed. And how they naturally switched back and forth between the different scales to check construction details and aspects in real life. Their learning was learned and not just taught.

The tectonic ambition

Technology, when spoken poetically, leads to architecture.
(Auguste Perret)

The use and application of materials influence the design and appearance of our built architecture. So it is of great importance to gain more in-depth knowledge of how to handle a material in its form and construction, beginning during one's architectural studies. It is all about really living the tectonic discourse, promoting a sensitivity to the material, in short, about generating a sense of joy in and curiosity about the interaction between material, its design and construction, that is, the symbiosis between art and technology in the design and realization process.

In addition, it is important to perceive of material as a whole, as a unity of form and construction, and to make it understandable for students as a driving force, as the origin of form and construction in the design process, and it is increasingly important that this be cultivated in teaching architecture. Tectonic joining plays an important role in this process. To achieve this, we must be able to join parts together to form a whole and in this way gain an understanding of the materials used to make them. Put briefly, we must be able to master the interplay between art and technology. This can be achieved if our expectations of tectonics are already experienced while we study architecture, and appearance and construction can merge again to become a whole, to achieve unity.

References

Albers, Josef. 1982. Josef Albers. In *Rainer Wick, Bauhauspädagogik*: 159. Cologne: DuMont.

Kollhoff, Hans. 1993. Über *Tektonik in der Baukunst*: 7. Braunschweig; Wiesbaden: Vieweg.

Loos, Adolf. 1898a. Das Princip der Bekleidung. In *Adolf Loos, Gesammelte Schriften*: 140. Vienna: lesethek.

Loos, Adolf. 1898b. Das Princip der Bekleidung. In *Adolf Loos, Gesammelte Schriften*: 141. Vienna: lesethek.

Loos, Adolf. 1898c. Das Princip der Bekleidung. In *Adolf Loos, Gesammelte Schriften*: 139. Vienna: lesethek.

Pallasmaa, Juhani. 2009. *The Thinking Hand*: 82. Chichester: John Wiley and Sons.

Semper, Gottfried. 1879a. *Der Stil in den technischen und tektonischen Künsten*: Vol. II: 199. Munich: Friedr. Bruckmann Verlag.

Semper, Gottfried. 1879b. *Der Stil in den technischen und tektonischen Künsten*: Vol. II: 201. Munich: Friedr. Bruckmann Verlag.

Sennett, Richard. 2008a. *Handwerk*: 162–176. Berlin: Berlin Verlag.

Sennett, Richard. 2008b. *Handwerk*: 177–184. Berlin: Berlin Verlag.

Sennett, Richard. 2008c. *Handwerk*: 184–196. Berlin: Berlin Verlag.

A Universe of Wood Joinery

Machiel Spaan

All down the centuries, collections of details, material properties and building techniques have inspired architects and designers to improve their craft and innovate their products. It was with this goal in mind that the German architect Gottfried Semper documented the four most important building materials in his book *The Four Elements of Architecture (1851)*: stone and masonry work, wood and joinery, textile and weaving, ceramics and moulding. Semper classified the four materials according to construction technique and architectural appearance. His classification offers insight into the mutual relationship between materials and their deployment, thereby offering a platform for renewal.

In *De wetten van de bouwkunst* (2009), architecture historian Petra Brouwer discusses the 19th-century knowledge revolution in relation to architecture books from the period. According to Brouwer, we should not view these textbooks as a reflection on the architecture of the period, but rather as vehicles for renewal. The books gather together material properties, building techniques and construction principles and reveal the relationships among them. The collected knowledge improves our understanding of the craft. The catalogue of classified examples reveals not only the qualities and rules but also the limitations, thereby increasing insight and encouraging improvement. Current conditions and requirements, as well as the desire to do things better, led to unprecedented solutions that expanded the catalogue. The book *Wood and Wood Joints* by Klaus Zwerger is a collection of imaginative wood structures from all over the world. “Only when one can observe and study a building as part of a larger group of comparable buildings, one's findings will be informed by the bigger picture and thus more meaningful.”

Compiling references is a form of collecting and an aid in grasping the structural and architectural principles of wood construction techniques and accompanying joints. Classifying references allows us to reveal the origins and logic of the joints so that we can analyse the architectural principles of each of them. The expertise of the craftsman is encapsulated in every joint and detail. The sharpness of the saw-cut, the ingenuity of the dowel, the clever assembly, and especially the efficient transfer of forces. That said, every joint is also rooted in contextual conditions such as topography, culture and civilization.

Is this act of collecting a valuable aspect of architectural education? And do collecting and cataloguing enhance our understanding of the craft? *A Universe of Wood Joinery* explores these questions by discussing two *Crafting Wood* educational projects in which we analysed and designed wood structures and accompanying details. First during an analysis and design exercise where we drew wood joints in a uniform manner, and second during a hands-on workshop where we made wood trusses.

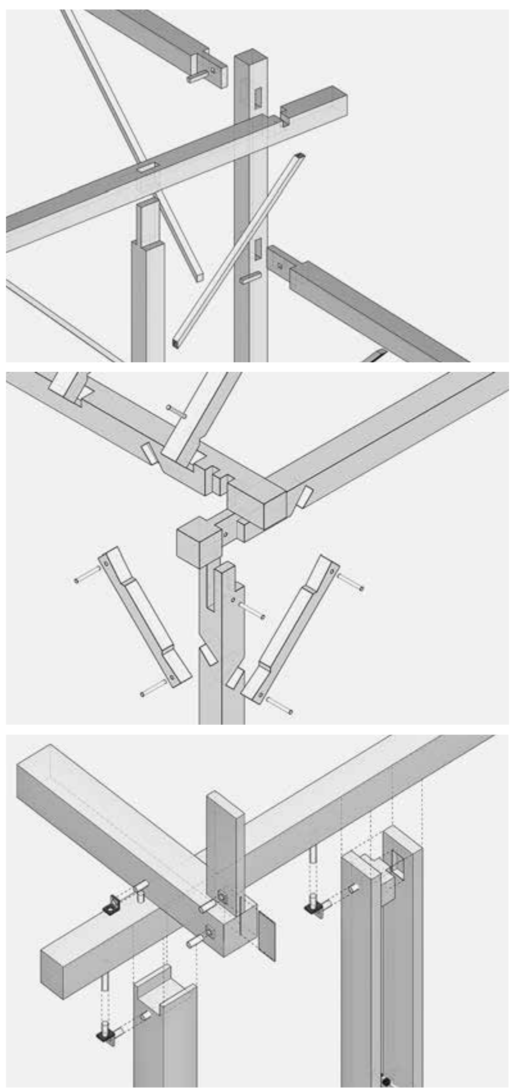


Figure 1–3
Wood joints drawn by students

25 wood joints

Part of the *Crafting Wood* project involved analysing traditions of wood construction. In the spring of 2018 a group of students studied wood joints from the Netherlands, Norway, Japan, Switzerland and North America. We drew the joints of selected structures in a uniform style, namely an isometric at a 30–60 angle. We then drew the structures designed by students in the same way. The act of drawing helped us to study the details and explore the world of wood joints. We drew, made and analysed joints. We searched for the identity and essence of the joint, the language of the craftsman. We zoomed in and out and compared traditions. That process taught us about the balance between authenticity and universal values. A uniform drawing technique allowed us to compare construction, building technology and atmosphere.

The result of the drawing exercise was an elucidating ‘matrix’ of wood joints. The classified joints told us about context, form and assembly. We learned about the differences and similarities. It was no exhaustive and scientifically underpinned catalogue but an associative compilation that inspired further study and design. The catalogue was a personal and subjective representation, a starting point for further reflection on new solutions and possibilities. “Every new experience is measured against past experiences and assessed in relation to it. That results in standards that are subjective and that—as discussions with colleagues from academia and craftsmanship alike reveal—are continually changing or are being substantiated,” writes Klaus Zwerger in his book *Wood and Wood Joints.*

The completed drawings revealed differences between the hierarchically composed American, Norwegian and Dutch constructions, the stacked structures from Switzerland, and the ingenious Japanese ‘puzzle constructions’. But there were also similarities between the restrained Japanese, Norwegian and Swiss joints.

A series of student designs was based on structures with flexible joints that move in response to horizontal forces such as the wind, which can be very strong and unpredictable in Norway and the Netherlands. The joints in roofs are composed in such a way that the whole construction can sway with the wind. History teaches us that this technique goes back to the construction of Viking ships, which boasted flexible and moveable joints that could withstand the force of the waves. Many Norwegian carpenters also came to the Netherlands during the Golden Age to craft roof trusses and ships' hulls.

A number of student designs consisted of stacked joints. Beams and/or planks were alternately stacked and connected to one another with the help of overlapping notches. Sturdy walls on the inside and outside supported the roof beams. In the Alps, the vertical loads of thick layers of snow are carried to the ground by these stacked structures. Communities in mountainous areas were often small in number, so wood structures had to be simple and easy to construct by a limited number of people. In the Netherlands and Germany you can see a tradition of solid wood constructions that originated in the Alps.

The Japanese tradition of wood construction is timeless. Joints are made in such a way that they are completely hidden from view. All that is visible are the beams that are held together. Every single connecting piece, wedge and notch is concealed. The joints of the Stave Church in Norway look similar to these Japanese joints. Students designed joints of ingenious and precisely made forms inspired by Japanese traditions. These inventive joints, which can support forces acting in a number of directions, have their origins in a tectonic phenomenon. Earthquakes in Japan inspired the development of wooden structures with a high degree of elasticity to withstand vibrations and ensure stability. Japanese joints do both. They move with the vibrations without falling apart.

A number of wood joints are also based on techniques of prefabrication, a form of construction that is widespread in America. These ‘loose’ construction principles stimulated the students. Prefabricated trusses and components are assembled on site.

A remarkable example of prefabrication is the Thorncrown Chapel by architect E Fay Jones. This open and layered structure is set in a pinewood forest. The construction consists entirely of components

Figure 4
Workshop Trondheim, 2018

that can be handled by two people. The limited dimensions and the quality of the wood determined the construction: a series of pine columns, beams and diagonals. Larger components were assembled on site and then hoisted into position.

Classifying wood construction from all over the world helped students to explicitly adopt a position of their own in relation to design. Compiling and comparing examples gave each wood joint a fixed position within the collection. In any setting, a wood construction results from a combination of individual preferences and contextual and cultural background. Topography, climate and civilization influence the nature of wood joints. “Only by looking at the elements under a wide lens can we recognize the cultural preferences, forgotten symbolism, technological advances, mutations triggered by intensifying global exchange, climatic adaptions, political calculations, regulatory requirements, new digital regimes, and, somewhere in the mix—the ideas of the architect that constitute the practice of architecture today,” writes architect Rem Koolhaas in *Elements of Architecture,* an inexhaustible compendium of relevant architectural elements from the history of architecture.

The classified drawings offer insight into contextual differences and similarities. In addition, the exploded isometric drawings show all components of the construction and the way they are combined in a joint. Both the shape and form of assembly are illuminated in an intuitive manner.

6 roof frames

A second relevant project in this regard was a workshop held in Trondheim in the summer of 2018. The starting point for this *Crafting Wood* workshop was the wooden roof structure of the *Haltdalen Stavkirke* from the 11th century. Thirty-two students from three schools constructed six wood trusses that together formed the spatial structure of the chapel. We worked in two specialist workshops, each with its own space, tools and skilled craftsmen. A variety of joints were made and tested at full scale in both workshops. The joints of three trusses were made with saws and chisels according to traditional techniques; the details of the other three trusses were made using modern saws, drills and milling machines.

Students worked in groups to design and make the wood joints that appealed to them. The joints were then gathered in a central space so that students could touch and test them for strength and manipulability. The students could reflect on the nature of joints within a universe larger than the individual detail or product. In plenary working sessions, students compared and shared their understanding of the details on the table: on how they were made, the tools used and the efficiency of the transfer of forces. All the details became part of a shared collection and classified according to the insights of the students. This exchange ‘on the table’ was repeated a number of times, and the collective exchange of views made it more efficient, precise and easier to design the wood joints. The details were refined from sketch model to well-considered mock-ups and then incorporated into the collection.

Work then moved to the construction site, where the details became part of a truss 4.5 metres wide and 4 metres tall.

As stated, we worked in two workshops, each with its own tools, equipment and drafting techniques. The way of working in the manual workshop differed from that in the machine workshop, and each had its own learning curves and results.

The manual workshop was also the actual construction site, where components were sawn to size and assembled. The relationship between joint and structure was explored repeatedly on the spot, initially through sketches, and then by laying out the whole truss on supports and positioning the elements to be connected on top of and beside each other. In this way, we could see the joint in relationship to the whole structure. The slow character of the manual workshop—it simply takes a long time to make a detail—ensured that the focus was put on the material. It became a matter of crafting the wooden beam

as best as possible with the available tools. The craftsmen present shared with the students their knowledge of working with the saw and chisel—handling the material, holding the chisel, moving the saw, supporting the beam. When sawing with a handsaw, the hand and arm directly encounter the changing grain and knots. Bit by bit, the tool becomes an extension of the hand. A narrative and intuitive handbook with the dos and don’ts that apply in the craftsman’s workshop: the realization that the forces acting parallel to the wood fibre of the pinewood beam can be far greater than those acting perpendicular to it. That a dowel cannot withstand large forces but can only keep components in place. And that the dovetail joint can absorb forces acting in various directions.

In the machine workshop the students worked with electrical equipment, such as circular saws and drilling and milling machines. Machines make it possible to test an idea in reality quickly and without too much difficulty. This allowed the students to think in terms of variations and part solutions. They could compile their own collection of mock-ups and choose from them. The machine workshop was located some distance from the construction site. Prefabricated components were prepared in the workshop and then transported to the site for assembly. The wood we worked with in the machine workshop was Gluelam. The grain in the composite beams was multi-directional because of the criss-cross way they were glued. As a result, the uncontrollable nature of the knots in the trunk was eliminated. The wooden beams were exact in their dimensions and the direction of forces could be easily predicted. Computer drawings are mostly used in the modern-day workshop. From the drawing of the whole truss, students could zoom in on the individual joint.

In the machine workshop, attention shifted from materials to tools. Machine tools create a distance between the hand and the material. Technology moves fast, and safety instructions, gloves and googles increase the distance further. Caution is therefore advisable. The machine comes between the hand and the material. As a result, mastering the material ‘just like that’ is not so easy.

After the construction site had been tidied, what remained was a wood construction consisting of six trusses featuring more than 30 classified details of joints in wooden beams. Together they constituted a narrative about tradition and modernity, craft and the machine, slowness and speed, strength and beauty. The collection offered insight into the intentions of the designers.

Figure 5
Seven Trusses, Trondheim, 2018

The trusses made in the traditional workshop were exuberant in their use of materials and expressively artisanal joints. Half-lap and dovetail joints were embraced and formed the starting point of the construction. Ornaments were added to each truss: a carved dragon, a decorated tip of a beam, a candleholder. Traces of the saw and chisel revealed the process of making and lent the trusses an artisanal quality.

The three trusses made in the machine workshop were based more on concepts, such as minimizing the use of materials or creating an asymmetrical, abstract or balancing construction. What mattered most was the form of construction, reflecting a desire to innovate and push back boundaries, as expressed by the joints. Flying in the face of tradition, the dowel was deployed to connect elements in a number of places. The cuts of the circular saw and the rounded corners of the milling head indicated the materials used.

The six trusses encouraged innovation, the first three fed by respect for tradition and the way traditional solutions can inform future solutions. The machine-made trusses were informed by an urge to deploy tools optimally and thus arrive at new smart solutions.

Collecting and classifying

The drawing exercise speaks to both the design approach and research approach of the student. Analysing existing wood joints and allotting them their rightful place in the collection is a valuable lesson. Every discovered wood joint becomes part of the collection, inspiring the designer and providing pointers for design.

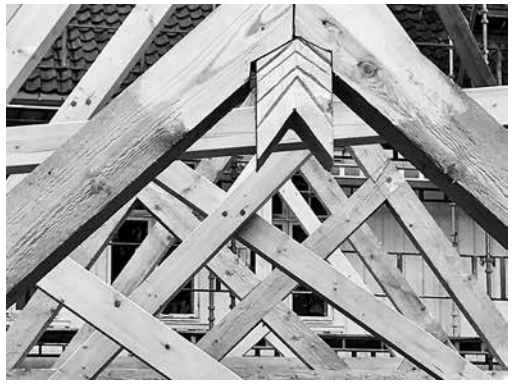


Figure 6
Wood joints, 1:1, Trondheim, 2018

The making exercise goes a step further. Here the student steps into the shoes of the craftsman. In addition to a knowledge of form and assembly, the student is also challenged to master the material and its characteristics such as weight, grain and so on. Actually working with the material makes it clear that the tools at hand help determine the design and finished product.

Through the act of drawing, students collected and classified wood joints. These constituted a coloured representation of reality, offering insight into a wealth of ways to use wood. They broadened the horizon and provided opportunities to explore new perspectives. Moreover, the drawings provided a good form of representation because they facilitated every idea. The pencil allowed us to explore the collection and each individual joint, without having to take gravity into account. Imagination was given free rein.

The reverse was the case in the making exercise. The act of making confronted us directly with the resistance of the material. We explored the properties and possibilities with our own hands. We engaged directly with the wood. Imagination made way for physical contact. The intrinsic knowledge of the craftsman helped us to refine our understanding of the material and tools. Here the collection was not committed to paper but shaped by hand through the material.

The 'living' collection of wood joints made during the process helped everybody to adopt a position and refine their own design. In the end, the six trusses constituted a collection that enabled us to reflect on the role of the workshops, tools and materials in design.

In designing, an architect balances technique and beauty, crafts and arts. In *De wetten van de Bouwkunst*, Brouwer describes how the handbooks of Vitruvius address both the theoretical and practical knowledge of architecture together. "Manual craftsmanship is the continual and repeated training in an activity that involves shaping by hand the sort of material that is required, until it complies with the intended design. Intellectual reasoning can illuminate and explain the objects crafted." The process of collecting and classifying the drawn wood joints stimulated this intellectual reasoning. And the collection of wood joints made with one's own hands forms a 'manual' for mastering hands-on craftsmanship. Seen in that way, collecting and classifying are welcome tools in learning to understand the use of materials and craft and their significance in design.

Connected Knowledge

Bjorn Otto Braaten,
Jan Siem,
Arnstein Gilberg

The development of computer numerical controlled (CNC) milling machines has renewed interest in traditional carpentry joints. The use of machines to make complicated timber joints paves the way for large-scale production of timber structures in a modern industrial context. An interesting question is how these digitally produced timber joints, untouched by the human hand, relate to the understanding of the properties of wood, structural concepts, cultural identity, aesthetic aspects and individual experience of traditional craftsmanship. What characterizes the difference between them? What is gained and what is lost in this development?

Some aspects in this discussion concern measurable and objective facts. Others can only be studied as part of a continuously changing, subjective and intersubjective cultural context. Very often, this kind of discussion tends to be polarized between a seemingly non-value-based, rational and 'objective' position, and a value-based ethical or aesthetical 'subjective' position. In this paper, we will present and discuss a method called the Four-Quadrant Model, which helps us investigate these matters in a more balanced way through different perspectives and ways of understanding that include both objective and subjective positions.

Four-Quadrant Model (FQM)

Through a series of books, the American philosopher Ken Wilber has developed and presented a map for human knowledge called the 'Integral Approach'. It attempts to be comprehensive, balanced and inclusive, and embraces science, art and morals. Its vision is to establish a comprehensive, all-inclusive or integral map that includes the best elements of knowledge, experience, wisdom and reflection from all major human civilizations: pre-modern, modern and post-modern.

The Integral Approach consists of five main elements: 'Levels', 'Lines', 'States', 'Types' and 'The Four Quadrants'. 'Levels' refer to the developmental stages of the phenomena. 'Lines' refer to the different areas of development, and 'States' refer to different states of temporary character (like states of consciousness: deep sleep, dream sleep, awake, altered, etc.). 'Types' refer to different aspects such as gender, personality types, etc. 'The Four Quadrants' refer to a way to investigate a phenomenon by differentiating four perspectives and then recombining the information (Wilber, 2001).

Though all these elements work together as a whole, we will, in this context, focus on the Four-Quadrant Model (FQM).

The FQM (figure 1) may be seen as an upgraded version of the tripartite classical model of Ethics, Aesthetics and Science, or 'the Good, the Beautiful and the Truth' (Wilber, 2000).

To understand the architecture of the FQM, we can divide it into its different building blocks. On the right side, the two quadrants (Upper Right and Lower Right) deal with everything that can be measured or positioned in time and space. These are the objective aspects of facts. However, these facts are not fixed 'truths' that don't change. History

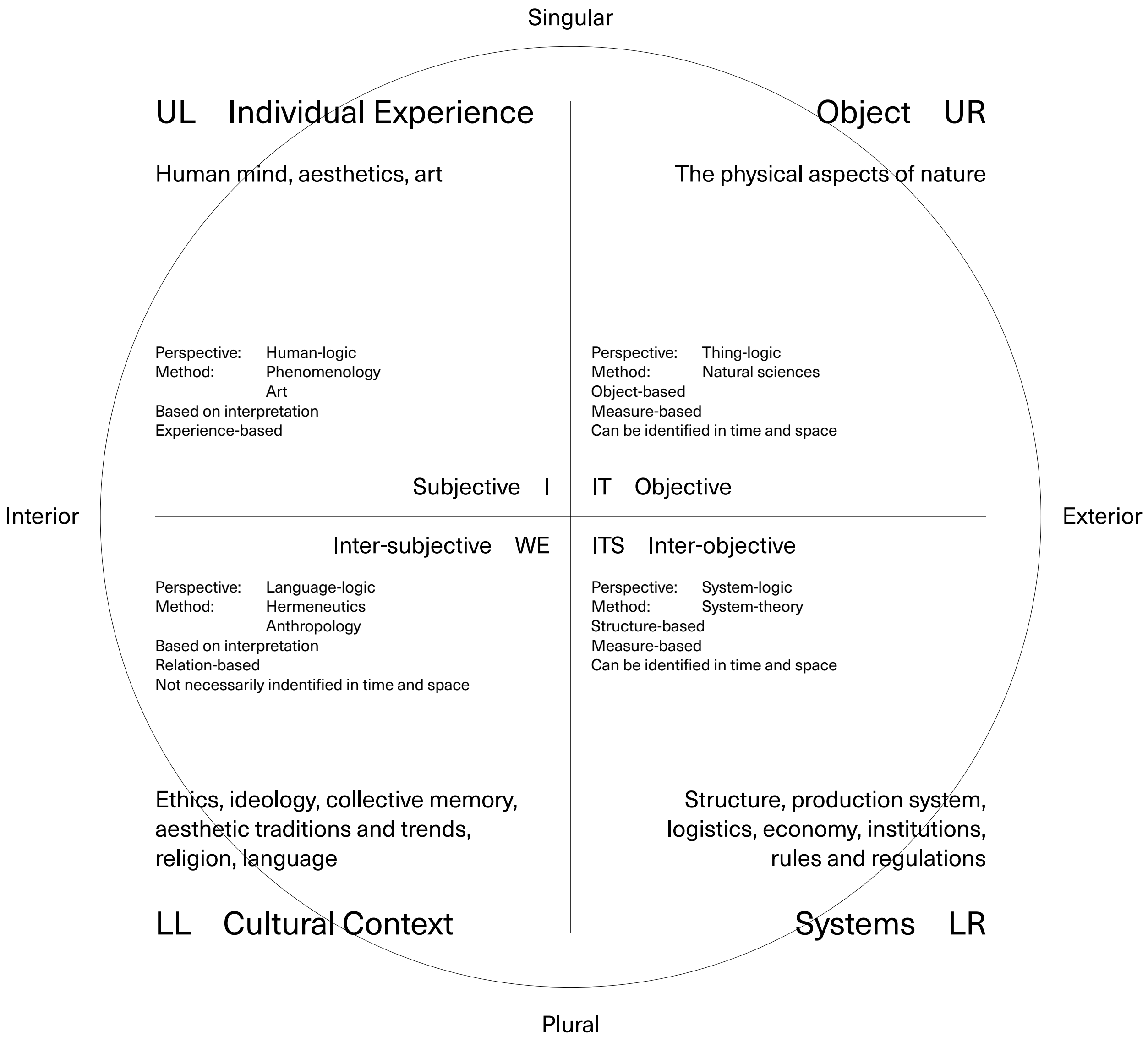


Figure 1
The Four-Quadrant Model (FQM). This version of the FQM is adapted by the authors for this specific context (see 'Adapting the Model to Our Cause')

shows that development of better equipment for measuring or studying the phenomena at hand may fundamentally change the way we understand or see the object. (This, however, is an example of the aspect uncovered by the 'Levels' category in the Integral Approach). Upper Right (UR) is the behavioural aspect of the phenomena, or its nature as an object that can be observed. This is the field of the natural sciences. Lower Right (LR) is the objective plural aspect of the phenomena, the system aspect. Here, structures and links that the phenomenon at hand is part of may be discovered if they are not easily visible in the upper right quadrant, where they are studied as a singular entity. This is the field of system theory.

On the left side of the model, the perspectives are fundamentally different. The Upper Left and Lower Left represent the subjective aspects of the phenomenon. They cannot be measured, observed or defined in time and space like those on the right side. These perspectives are defined either by subjective individual experience (Upper Left) or by shared intersubjective experience based on interaction and dialogue (Lower Left). Hermeneutics, the science of interpretation (Gadamer, 1975), is an example of a method of the lower left quadrant, while phenomenology (Husserl, 2013; Heidegger, 2010) and the arts are methods and ways of investigating the Upper Left quadrant.

On basis of this, the Upper Left can be seen as an 'I' perspective (internal, singular, subjective); the Lower Left a 'We' perspective (internal, plural, intersubjective); the Lower Right as an 'Its' perspective (exterior, plural, inter-objective); and Upper Right an 'I' perspective (exterior, singular, objective).

As noted in the introduction, the FQM offers a set of methods that includes both objective and subjective perspectives. Now it is easy to see how the different quadrants are part of the whole, how they represent different perspectives, and how they are interconnected. A phenomenon observed in one of the quadrants will automatically inform

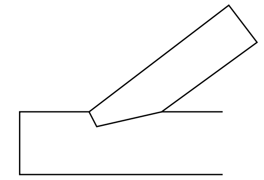


Figure 2
The single-step joint

and influence the three others. Something observed as a 'fact' in the Upper Right will, for instance, always be seen within a cultural context, through epistemological, ontological and language-based concepts in the Lower Left. When these change, the fact may be translated and understood in a different way.

In terms of using the model, it is important to be aware of three different steps that need to be taken. The first step is to separate the phenomenon we want to investigate into the four quadrants. The next step is to isolate the investigation in each of the quadrants, so that the potential of each perspective is fulfilled. To stop here, however, will quickly lead to some kind of reductionism, subjective or objective. The last step, recombining the information and seeing how the different perspectives inform each other in a new complete picture, is therefore crucial.

Adapting the model to our cause

The Integral Approach and the Four-Quadrant Model is used to discuss and analyse a multitude of phenomena in different contexts like medicine, education, economy, politics, etc. (Wilber, 2001). In discussing structural wood joints in this context, we have chosen to make some small adjustments of words headlining each quadrant. In the Wilber model, the headline for the Upper Right (objective exterior / it) quadrant is 'Behavioural'. In our model we have chosen to use the headline 'Object' to make it clearer that this is how the phenomenon appears when externally observed as an object. The headline for the Lower Right (inter-objective exterior / its), 'Social', is here called 'System' to emphasize the system-logic perspective. Lower Left (intersubjective internal / we) is changed from 'Cultural' to 'Cultural Context', and Upper Left (subjective internal / I) is changed from 'Intentional' to 'Individual Experience' to make it easier in this context to understand the profile of the quadrant. However, the concepts, perspectives and content of the four quadrants remain unaltered from the Wilber model.

We will now show how the Four-Quadrant Model can be helpful in discussing the qualities of a timber joint. As an example, we will use a joint that is common in traditional Norwegian structures and traditional Japanese buildings, and is now also available for industrial production by 3D milling machines: the single-step joint (figure 2).Following the previously mentioned procedure, we start by separating the different aspects of the joint: the object perspective (UR), the system perspective (LR), the cultural context (LL) and the individual experience (UL).

1 The object perspective (UR)

In this perspective, all the things that can be measured, weighed and observed will be taken into account. In addition, how it works as a singular structural element is important information. 'The single-step joint: a traditional carpentry joint with new possibilities' is an in-depth paper on the way this joint works (Siem, 2017). It describes failure modes and how forces are distributed, the importance of the fibre direction in the wood, and the consequences of variable angles between the horizontal element and the inclined compression element, etc. Other important aspects of the joint are what kind of wood is used and what part of the tree is used and its percentage of humidity. The precision between the two connected structural elements can be measured and, if put into a laboratory, the capacity to take forces can be documented. All this is information that belongs in the Upper Right quadrant.

2 The system perspective (LR)

If we look at the single-step joint from a system perspective, the focus shifts from looking at the joint as a singular, isolated element to seeing how it works as part of a system. This could be many different systems. First, it is the structural system that can tell what specific function the joint performs in a building. Then there is the system of production that tells if it is made in a small, local workshop or part of large-scale industrial production. How does the joint relate to an economic system? How much does it cost to produce? What are its characteristics within a sustainable system? Is it transported over long distances or is it 'short travelled'?

The system perspective helps us to better see the function of the joint in a bigger context. Things that would remain hidden if it is only studied as a singular object become clearer, and sometimes surprisingly so. For instance, can the extreme refinement of traditional Japanese carpentry be understood better by seeing its function in the simple structural systems of the traditional house, where the joint represents a negotiation between structural stiffness and flexibility? Instead of rigid diagonals that would cause serious damage in the event of earthquakes, the joints fitted together with wedges may be shaken but easily mended by tightening the wedges.

3 The cultural context (LL)

What is good and what is bad, what is important and what is not, what generates knowledge (epistemology) and how we understand our world (ontology), all belong in the Lower Left quadrant. Because this deals with human values and culturally defined worldviews, it cannot be measured, weighed or even identified in time and space, as with UR and LR. For an orthodox natural scientist, this is the muddy and unpredictable field of meaning, belief and interpretation. Still, it is quite obvious that even a natural scientist does not observe objects outside a given cultural context which will influence what is seen and the way the facts are interpreted.

Because this quadrant deals with the cultural value aspect, this is also where different points of view concerning what is 'good' and what is 'bad' about the joint belong. It is, in short, where the ethics of the joint are highlighted. Some may be surprized that it is possible to discuss the ethics of a joint, but we will see that the value-perspective between traditional carpentry and industrial production of joints can be quite different. This is of course a complex matter, so in this brief presentation of the simplest way of using the FQM, we will just bring out a couple of examples.

Within the context of producing timber joints, whether traditional or industrial, there is a shared attitude that 'wood is good'. However, even if the human-made and machine-made step-joint is equally strong and functions in the same way, there are some important differences concerning the production. Sustainability is an important ethic factor in our time, and even if wood is regarded as a sustainable material, large-scale industrial production may not be seen as sustainable owing, for instance, to long-distance transport.

Industrial production will provide the product, but not the human act of making, since it is made by milling machines. In a society and cultural context where global industrial products are plentiful, some will say locally handmade products in general, and traditional craftsmanship in particular, have a value in themselves. The act of making, is, by some within the field, actually seen as important as the product, because the knowledge is in the hand; it is an embodied experience, not just a question of cognitive knowledge (Godal, 2018; Greve and Nesset, 1997). If this 'silent' knowledge developed by the act of doing disappears, a way of thinking that is not based purely on reductive production logic and instrumental thinking may disappear. On the other hand, the potential for new understanding and new ways of making very intricate timber joints through new production methods may also be the 'lifesaver' of the timber joint in modern house production.

4 The individual experience (UL)

The Upper Left quadrant is based on how each individual experiences the phenomenon in question and is, by definition, subjective. This does not necessarily mean that this experience is limited to the individual, because many people will experience the same thing in a similar way. On the other hand, we will never exactly know what each one of us experiences, because we all have a different background, different sensibility and so on. To acknowledge, in this context, the individual experience of the specific single-step joint is therefore crucial. All objective aspects, system aspects and cultural context aspects are ultimately filtered through a person, with his or her level of understanding, sensibility, prejudice, preferences and knowledge.

The aesthetic experience of a specific single-step joint has not only an intersubjective aspect related to norms and preferences within the cultural context, but also an individual, subjective aspect in the way each individual experiences these aesthetic properties. If the joint is made by a 3D drilling machine, how for instance do the rounded corners fit with the rest of the formal qualities of the structure? If it is made by hand, is the precision of the craftsman's work using traditional tools satisfactory? If there are rough edges, do they give a sloppy impression or are they expressions of functional understanding?

The individual experience of the single-step joint may be based on both physical aspects, emotional aspects, cognitive or knowledge-based aspects, and intuitive aspects.

5 Recombining the four quadrants (UR/LR/LL/UL)

By differentiating how the single-step joint works in four different perspectives, we get a wider picture. Each of the quadrants may contain true or truthful information about the single-step joint, but only partly, reductive truths. By recombining them, we can acknowledge the contribution of each perspective and achieve a more balanced discussion.

In this case, the discussion about aesthetics may be informed by how the single-step joint was produced (by whom, with what tools, where, production cost, etc.), if the aesthetic expression is focused on a slick surface or a more unpolished consequence of the forces working within, and finally, what values it represents as a cultural artefact.

It is now possible to see how the analysis of the forces working within the joint and the production process (whether industrial or traditional) are connected to explicit intersubjective paradigms and individual preferences.

Using the model

When recombining the four perspectives of the Four-Quadrant Model, we come to understand that there are potentially many different aspects and factors that could be included as part of the investigation. For those used to discussing or investigating phenomena mainly from one or two perspectives, this model may seem quite complex. On the other hand, to use the FQM without taking into account the four main elements (levels, lines, states and types) of the Integral Approach may be seen as a drastic simplification.

This is a classical dilemma in dealing with matters of complexity and depth. How can complex matters be discussed in a manageable way without missing their complex nature? Using the Four-Quadrant Model can be seen as a first step in solving this dilemma. The next step would be to take into consideration and identify the different levels of each of the four quadrants, from gross to subtle and causal. After that, the discussion or investigation could develop into states, lines and types.

However, to be able to use the FQM as an operative tool, we need some training. During the spring of 2018 the FQM was presented and used in the master level theory course Timberstructures B (7.5 ECTS) at the Faculty of Architecture and Design at NTNU in Norway. (This course was closely linked to a 15 ECTS architectural design course called Timberstructures A.) During the five weeks of the course, the 14 students would submit an essay where they used the model as tool for discussing a specific joint system. The students would use a freely chosen building or built structure as a case to discuss the context of their specific joint system. In addition to a text of at least six pages (maximum 50% pictures or diagrams), the students were encouraged to fill in key-words of their analyses into a graphic representation of the FQM. The essays are available as an internal NTNU booklet entitled 'Joint Systems: A Collection of Student Essays' (Siem, Braaten and Gilberg, 2018).

Information about the model was provided through articles to read and a lecture. In addition to presenting the Integral Approach, the lecture focused on how the FQM could be relevant to discussing architecture and architectural elements like joint systems.

As a typical transdisciplinary topic, the architect's way of working is a very good example of an integral way of thinking in practice. Designing a building is a complex negotiation of technical, economic, ethical and aesthetic elements, and the architect needs to be trained in considering all these elements and their interrelationships simultaneously. The students in this master-level course were, through their previous years of studying and designing architecture, well prepared for the multi-perspective thinking represented by the FQM.

By studying the 14 essays, we became aware of some aspects of using the FQM by beginners that seem to be typical.

The overall impression was that almost everybody managed to use the model in a relevant way. This means that they discussed their joint system based on the FQM in the text. All 14 essays show an ability to differentiate between the objective (UR/LR) and subjective (UL/LL) perspectives in the model. Two essays did not strictly follow the form by putting the discussion into the quadrant headlines. One of them, probably because of discomfort with the rather formalistic structure, and the other interestingly integrated the FQM into a more 'essayistic' text. This last one in particular was a highly competent text where the author fully understood and expressed the intention of the FQM through a more literary form.

As with all models, the quality of its use depends on the skills of its user. A couple of texts showed just a rudimentary understanding of the model and its intentions. This may have been because they felt the form to be restrictive and were unable to break out of the form or to develop enough skills and understanding to use it in a more elaborate way. It must be pointed out that the time to develop this skill and understanding was limited to five weeks. However, at least four or five of the essays show exemplary use of the model, where the separate perspectives were understood and the relationship between them was discussed in a concluding section.

A very good example in using the model is an essay where the student first briefly introduces the built structure by explaining its history, building process and use. The structural joint system is steel dowels, and the author describes different stages of development in using dowels and steel plates in bigger timber structures and how the forces are distributed through the joint (UR). Through the system perspective (LR), the author describes in depth the nature of the building's structural system and how torsional and bending forces are working, based on the dowel joints. In discussing the cultural context (LL) of the structure and joint-system, the author explains the specific interest in the area for using timber in new and inventive ways that point to the future and back to regional traditions. A very relevant and interesting story of the relationship between cultural identity and development of wood as structural material in large buildings is told. The author also clearly explains his close relationship with the building (UL) from early age, and how he enjoyed the appearance of the visible steel dowels which made him understand, in a simple way, how the structure actually worked. Finally, in the recombined part the author discusses how the structural system and the use of dowels are rooted in a tradition where timber structures and regional identity are closely linked. He points out how the joint system (UR) combines influences from the other three quadrants and is not a purely technical detail with a strictly functional meaning.

What seems to be the most challenging quadrant for many students is that of cultural context (LL). Even if many of the descriptions of how the forces work in the joint-system (UR/LR) are somewhat superficial, this is probably not because the students don't understand it, but because detailed information or laboratory tests have been hard to provide in such a short time.

However, discovering and understanding the relationship between the objective facts of the technology perspectives (UR/LR), and assessing these within a cultural context, seems to be an even bigger challenge. It is crucial for an architect to understand how the language we use (LL) and the way we conceptualize objective facts (UR/LR) consciously and unconsciously implies valuation, moral positions and ideology. This is very evident in the discussion between 'traditionalist' and 'technologist' concerning the different qualities of a handmade and robot-made wood joint. What is 'good' and why it is 'good' is just partly a question of objective, measurable facts. It is also a matter of intersubjective valuation of what is important, of aesthetics, and of the construction of identity. This is exactly where the FQM is very helpful, because it clarifies the nature of this interrelatedness.

Another aspect that shows it takes some time and effort to integrate the way of thinking that the FQM represents is the quality of the graphical abstracts the students were asked to make. All of the graphical abstracts showed general topics and categories related to the four quadrants, rather than visualizing specific and detailed information about the joint system. The potential of the graphical abstract was thus not fulfilled. This, however, is important information for the team of teachers. Since it was the first time this specific task was tried out, the students had no template to use as reference. Next time around, this will be provided, and hopefully the result will be improved. It also informed the team of teachers that even if the students could reflect surprisingly well in written texts about the joint system using the FQM, it perhaps requires a higher level of understanding to extract the most relevant information in a graphical abstract. This makes the graphical abstract even more interesting as a tool for developing understanding of how the FQM works and skills in using it.

Since the architect's role in the design process is clearly not only to take care of the aesthetic aspects, but also to be the one who recombines all the different elements of the building process into an architectural whole, it is important to have tools to deal with such matters of complexity. The FQM provides one such tool, and the students in the course specifically expressed that they saw the benefits of having such a structured way of conducting analyses and discussions. Through the course, they not only improved their technical knowledge of the properties of wood, but they were also able to discuss these matters in a way that is relevant for them as practicing architects.

Connected knowledge

All building processes in a modern society are based on interdisciplinary work. At its best, it is a fluent flow of information, knowledge, creativity and decision-making among competent representatives of the different disciplines. Too often, however, interdisciplinary groups are bothered by misunderstandings and bad communication due to different disciplinary traditions, ways of thinking and interests.

Among the small group of teachers (consisting of one engineer, one architect and one architect/craftsman) that for some years have been developing the master course 'Timberstructures' at NTNU, there is one specific aspect of interdisciplinary work that is crucial for good cooperation. This is the willingness and openness among participants, not only to acknowledge each other's competence, but also to learn and develop some basic knowledge in the different fields. This willingness to dig into and integrate the perspective of another discipline is probably one of the most important elements in transdisciplinary work. If this does not happen, the situation will often be that each member of the group remains in the somewhat simplistic position of thinking that things would be better if only their specific discipline's view was dominant.

This is where the FQM becomes a helpful tool, because its concept is to structure a discussion about a phenomenon around four basic perspectives and that, as isolated perspectives, they all carry potential truths, but only part truths. It is the combination and cross-connection of the quadrants that provides the bigger picture. To learn to use the FQM is to develop competence and a willingness to see things from different points of view. People who have developed this skill to a certain level, in combination with a high level of competence within their field and some basic training in group-work dynamics and self-knowledge, are carriers of what is here meant as 'Connected Knowledge'. These individuals would be very attractive partners in interdisciplinary and transdisciplinary work.

In the discussion about revitalizing the wood joint as part of a new area of timber structures, there is a huge potential for combining knowledge and skills among several professionals, among them architects, engineers, craftsmen and building historians. By using the FQM as a structuring and helping tool in the research, we can ensure that the best of each professional field could together pave the way for new inventions and higher quality production in the field of modern timber-based architecture.

References

Gadamer, H-G, 1975. *Truth and Method*, translated by G. Barden and J. Cummings. London: Sheed and Ward.

Godal, J.B. 2018. Om det å lafte. Fagbokforlaget.

Greve, A. and Nesset, S. (ed.), 1997. *Filosofi i et nordlig landskap*. Universitetsbiblioteket i Tromsøs skriftserie Ravnetrykk nr. 12.

Heidegger, M. 2010. *Being and time: a revised edition of the Stambough translation*, State University of New York, Albany.

Husserl, E. 2013. *Ideas: General Introduction to Pure Phenomenology*. Routledge.

Wilber, K. 2000. *A Brief History of Everything*. Shambala, Boston.

Wilber, K. 2001. *A Theory of Everything*. Shambala, Boston.

Siem, J. 2017. 'The Single-step joint—A traditional carpentry joint with new possibilities'. *International Wood Products Journal*, 8: sup 1, 45–49. Taylor and Francis Group, UK.

Siem, J, Braaten, B.O. and Gilberg, A (ed.), 2018. *Joint Systems: A Collection of Student Essays*. NTNU.

Models 1:100
1:10
1:1


1


2


3


4


5


6

During three workshops in Trondheim, Amsterdam and Vaduz, students of the participating studios made models of structures and details of selected buildings and their own designs. The analytic model stands for different building traditions: the Norwegian wood tradition that goes back to the Vikings, the Dutch wood tradition and its relation with shipbuilding and the urban vernacular of the traditional wooden buildings of the Rhine valley near Liechtenstein. Large scale models were finally used in the design studios in order to transport the knowledge of the previous research phase into the project work of each student and to cultivate the power of hand drawing as a design tool.

The models were essential in helping students to gain insight into the qualities of the façades and the used materials and joints. We came to understand that working at a large scale echoed the difficulties of working with wood as a building material. In the process, we discovered the value of modelmaking as a crafted object unmediated by the computer. The selection underlines the role of drawings and models as instruments of knowledge that fuse the conception and construction of buildings and offers a fundamental insight into the crafting of wooden façades and making a handmade model.

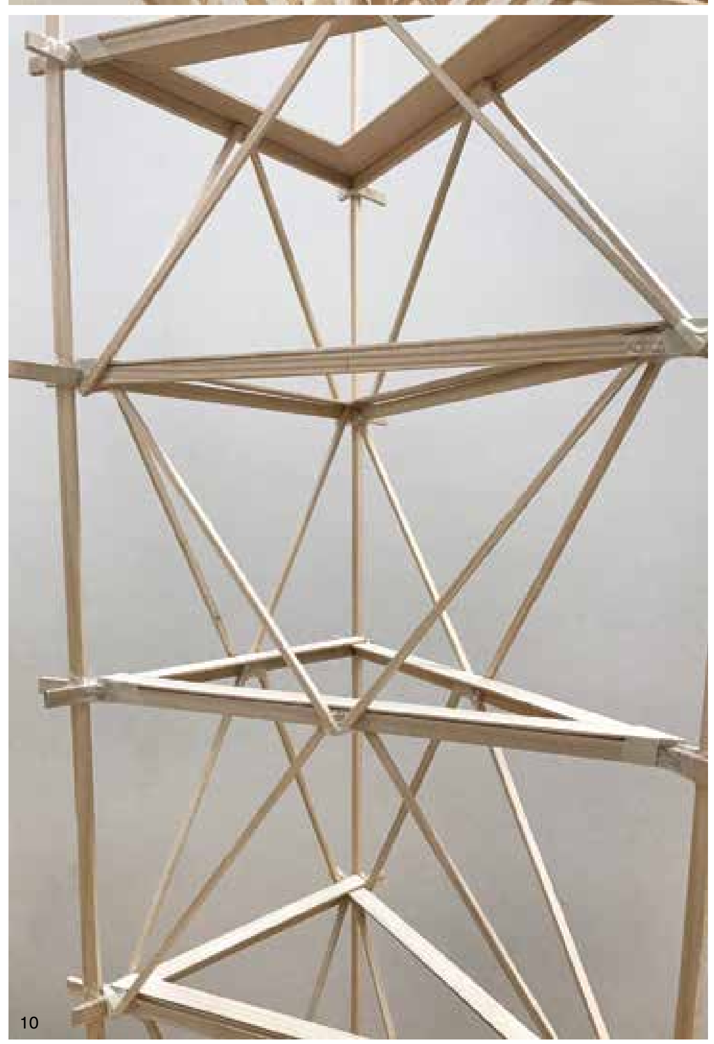
Bell shaped roofs

1 Tom Vermeer, Richard Doensen
2 Daria Dobrodeeva, Charlotte Mulder
3 Tom Vermeer, Richard Doensen
4 Evie Lentjes, Anouk van Deuzen
5 Sung-Ching Lo, German Gomez
6 Laurien Zwaans, Anne-Roos Demilt


7

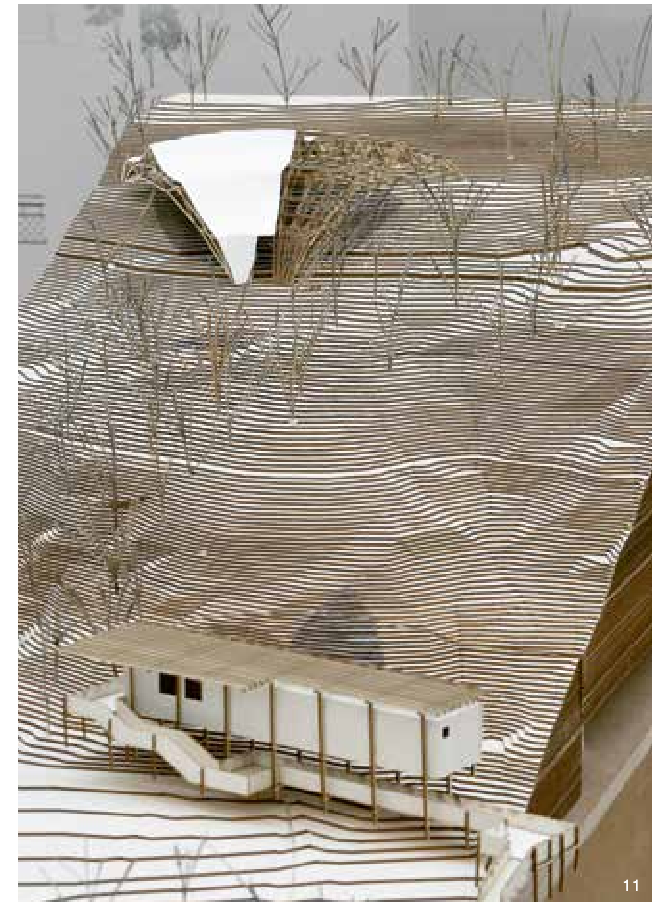

8


9

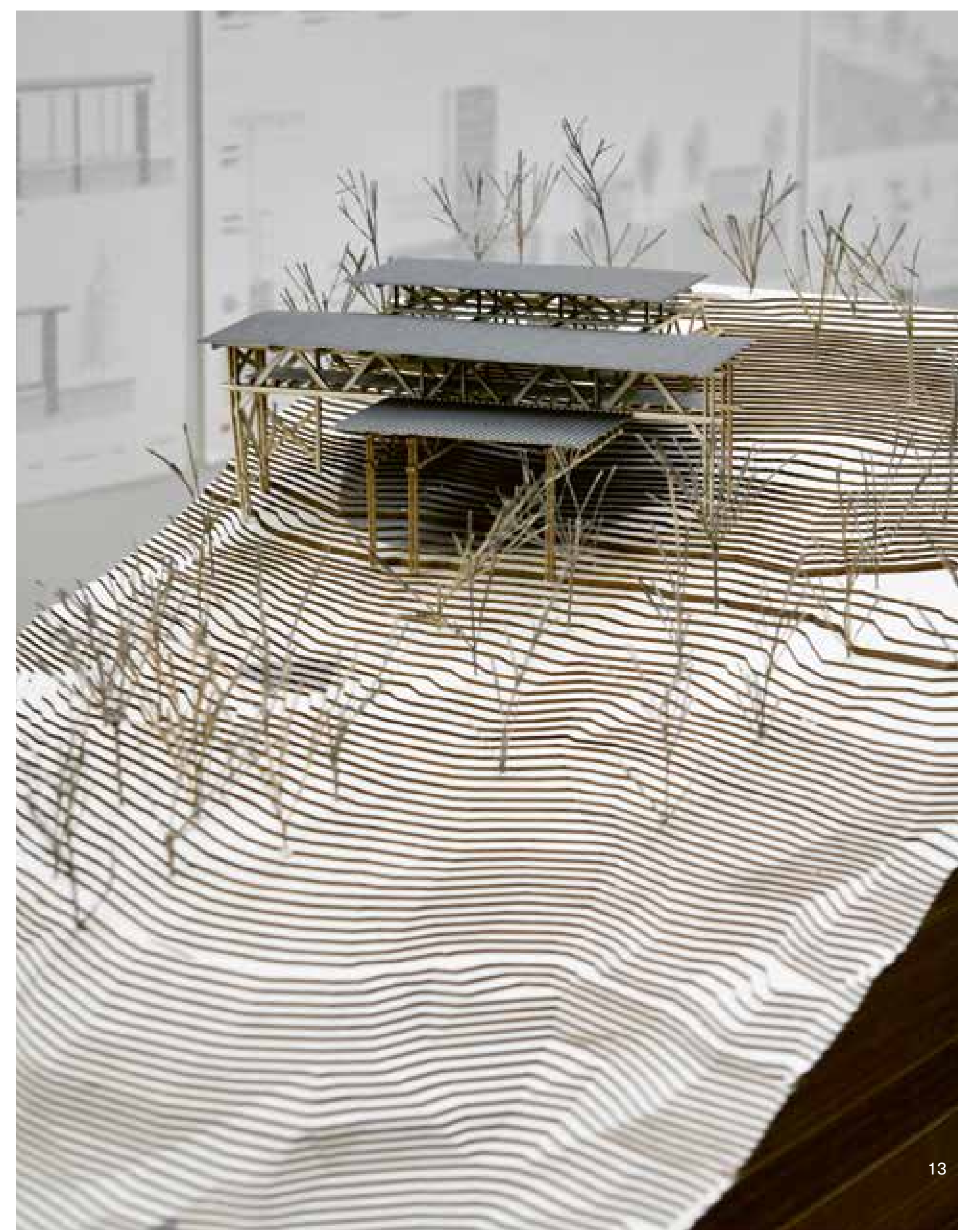

10

Towers

7 Shefket Shala, Anna Prüller, Bertille Bourgarel
8 Danny Kok, Sandra Oeler, Arthur Rundstadler
9 Evie Lentjes, Rikke Jensen, Arno Wust
10 Anne-Roos Demilt, Bunjamin Sulejmani, Alex Escursell

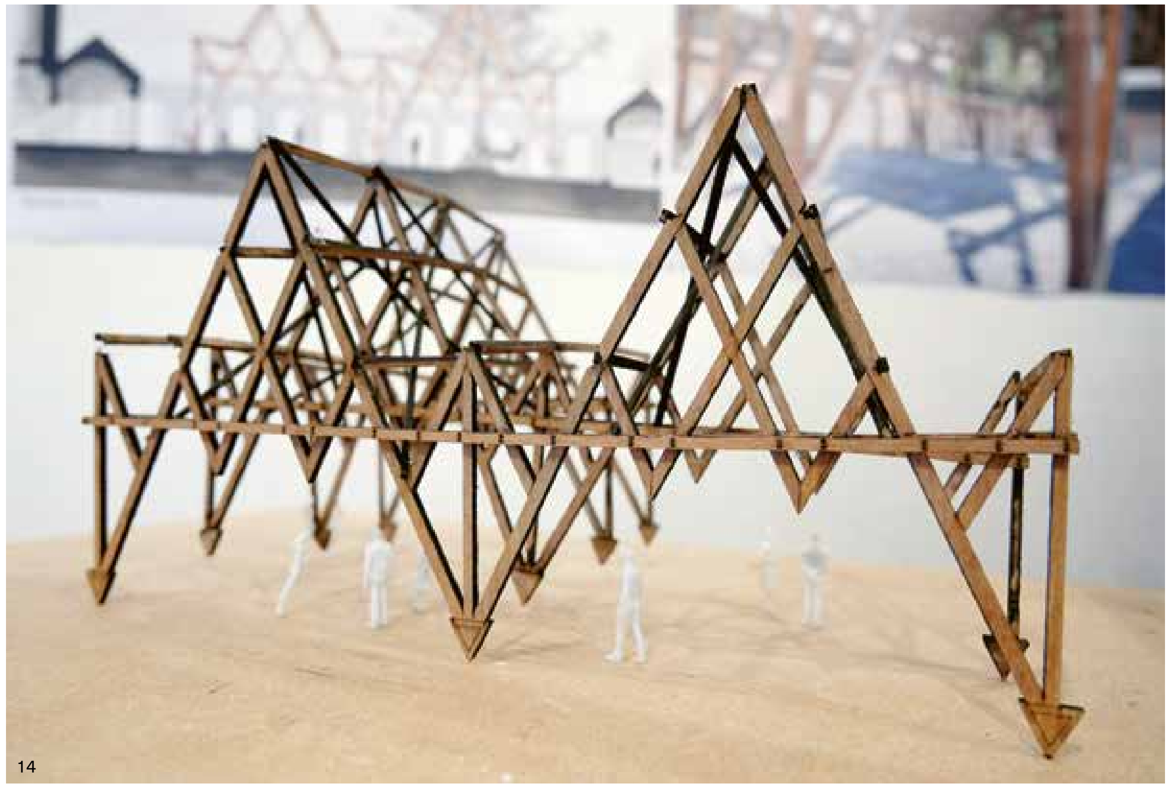

11


12


13

Roof frames

11 David Kerle
12 Jakob Fliri
13 Andreas Negele



14

15

Roof frames

14 German Gomez Rueda
15 Martynas Solovejus
16 Thea Cali
17 Niels Hulsebosch
18 Ayla Azizova

16

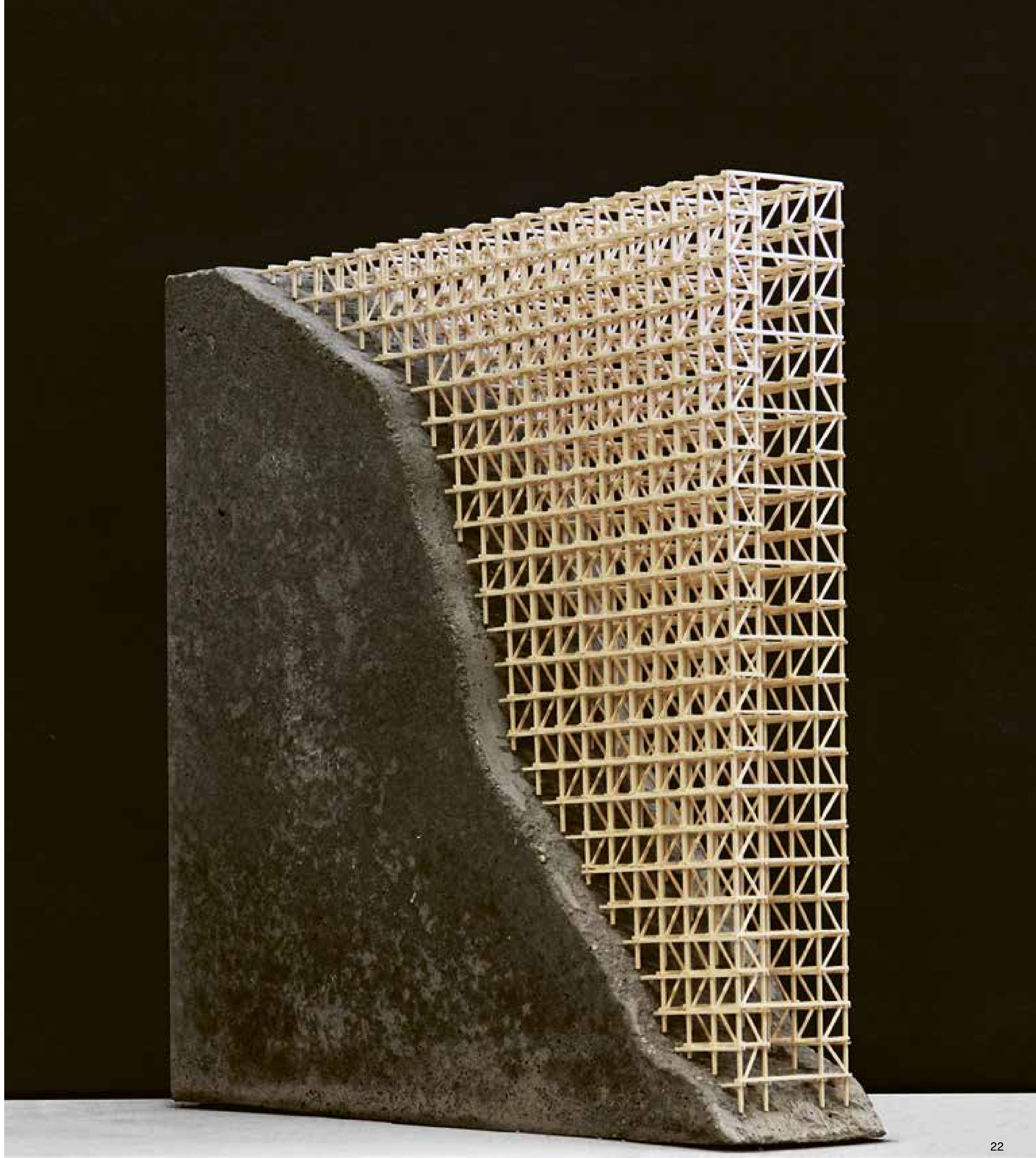
17

18


19


20


21

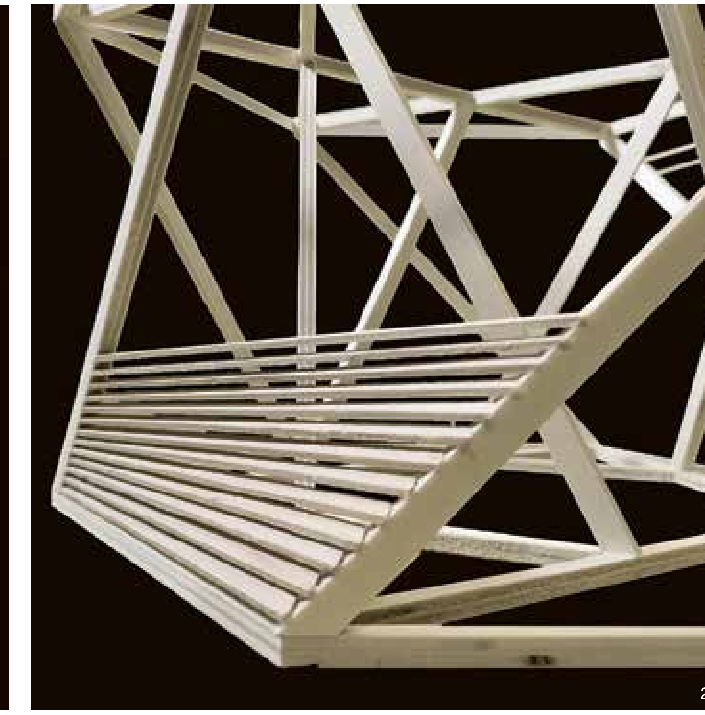

22

Towers

19 Jannik Oslender
20 Alina Koger
21 Tobias Oswald
22 Alex Carrasco Escursell, Gilles Gasser, Luis Martín Cea, Iñigo Villanueva Gutiérrez


23


25


26


24


27

Towers

23–24 Ben Quinn, Júlia Ros Bofarull, Mar Gonzalez Campos, Silvia Doherty Riubrugent
25–26 Gebhard Natter
27 Charlotte Mulder


28


29


30


31


32


33

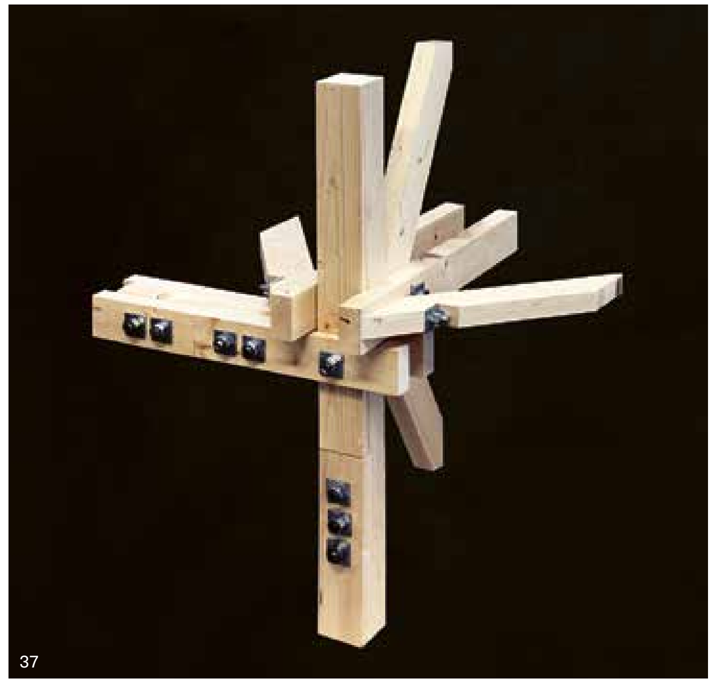

34


35

Bell shaped roofs

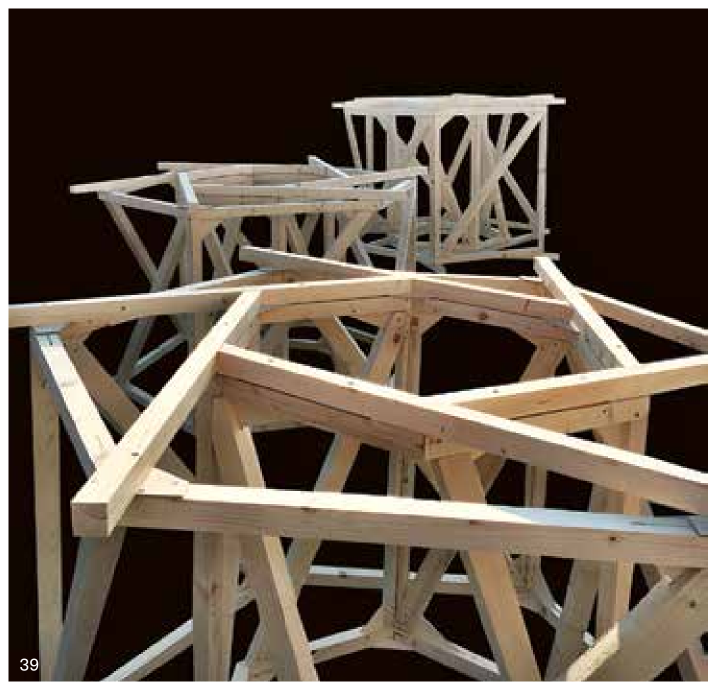
28–29 Danny Kok, Ayla Azizova
30–31 Anne-Roos Demilt, Charlotte Mulder
32–33 Evie Lentjes, German Gomez
34–35 Noury Salmo, Anna Torres

36



37

38



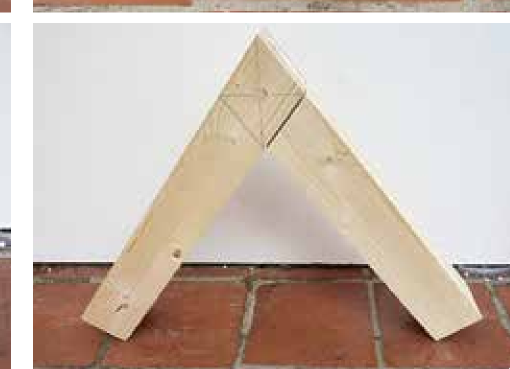
39

40

41

42

43



44

Nodes

36 Gebhard Natter
37 Alex Carrasco Escursell, Gilles Gasser, Luis Martín Cea, Iñigo Villanueva Gutiérrez
38–39 Gebhard Natter
40 Final result, Workshop Trondheim, 2018
41–44 1:1 mock-ups of details, Workshop Trondheim, 2018

45

46

47

48

49

Pedestals

45 Tata Zakaraia, Giorgi Evsia
46 Herolind Elezi, Zaal Siprashvili
47 Kelvin Au, Shona Beattie
48 Nick Ulrich, Lars Gassner
49 Carlos Vazquez, Roberto Villaseñor


50


51


52

Towers

50 (background) Danny Kok, Sandra Oeler, Arthur Jean-Pierre, Henri Rundstadler, Anne Roos Demilt, Bunjamin Sulejmani, Alex Carrasco Escursell (foreground) Edwin Frei, Bejan Misaghi, Silvia Daniela Doherty Riubrugent, Shefket Shala, Anna Prüller, Bertille Beatrice Agnes Marie Bourgarel

51 German Gomes Rueda, Christian Meier, Ben Quinn, Attila Truffer, Agathe Philippine Cheynet, Iñigo Villanueva Gutiérrez

52 Noury Salmi, Aline Rabea Koger, Esteban Vincent, Roger Borteele, Ayla Azizova, Gebhard Natter, Berenice Lea Marie Aubriot

53

54

55

Towers

53–54 Anna Tores, Luis Martín Cea, Mar Gonzalez Campos, Evie Lentjes, Rikke Jensen, Arno Léon Oreste, Alfred Wust

55 (foreground) Anna Tores, Luis Martín Cea, Mar Gonzalez Campos, Evie Lentjes, Rikke Jensen, Arno Léon Oreste, Alfred Wust
(background left) Adan Carnak, Júlia Ros Bofarull, Gilles Benjamin Theo Gasser, Charlotte Mulder, Maik Goop, Anna Garcia Molina, Pia Weber
(background right) German Gomes Rueda, Christian Meier, Ben Quinn, Attila Truffer, Agathe Philippine Cheynet, Iñigo Villanueva Gutiérrez

56

Towers

56 (foreground) Noury Salmi, Aline Rabea Koger, Esteban Vincent, Roger Borteele, Ayla Azizova, Gebhard Natter, Berenice Lea Marie Aubriot
(background) Danny Kok, Sandra Oeler, Arthur Jean-Pierre, Henri Rundstadler, Anne Roos Demilt, Bunjamin Sulejmani, Alex Carrasco Escursell

2 TECTONIC REFLECTION

The Age of Timber

Machiel Spaan

During the Wood Symposium held at the Academy of Architecture in Amsterdam, several speakers argued for the use of more timber in construction.

> *Only when one can observe and study a building as part of a larger group of comparable buildings, will one's findings be informed by the bigger picture and thus be more meaningful.*
> (Klaus Zwerger in *Wood and Wood Joints*)

In a distant past we built our houses from wood sawn from the trees of nearby forests, or from trees the rivers carried to us from German and Swiss forests. Architects and carpenters were one with the grain and hardness of all kinds of wood. Woodworking skills were passed on from master to apprentice. In our post-war efforts to rationalize construction, we ended up in a world of concrete. Building traditions, skills and knowledge of wood gradually disappeared; woodworking techniques were no longer developed.

Now that the climate debate is catching up with us, it seems time for a change. Dutch architects advocate the use of much more timber in construction. Timber is made available to us by nature, it stores CO_2, and it provides a healthy indoor climate. In addition, timber structures are easy to assemble and can be dismantled and reused. How practicable is this idea of building with timber to the concrete-loving building sector of the Netherlands? And what is involved in this seemingly simple shift from concrete-oriented to timber-oriented thinking? We will have to renew timber applications and constructions to make them suitable for today's circumstances and regulations. And how can traditional knowledge contribute to this new step towards an 'Age of Timber'? These were the questions that arose during the Wood Symposium held at the Amsterdam Academy of Architecture on Friday 22 November 2019. The four speakers presented four perspectives that gave attendees plenty of food for thought.

During an impressive argument, Klaus Zwerger of the University of Vienna showed that in timber construction, innovation is of all times. It is a consecutive and continuous process that involves adapting to circumstances, improving techniques and availing oneself of new possibilities. Development processes in the Dutch timber construction tradition came to a standstill some 70 years ago. Timber construction and knowledge of structures and connections were no longer passed on to the next generation. Artisans with knowledge of wood properties and joinery are now scarce. Dutch engineers lack the expertise to calculate the efficient complex constructions necessary to create dimensioned and sustainable timber constructions. How can we remaster the necessary knowledge, skills and traditional methods? Is it possible to reintroduce the master-apprentice structure?

In an ecological structure, we use timber in a material-specific way: tensile forces in the direction of the grain, pressure forces perpendicular to the grain. Because of its properties, timber lends itself well to assemblage. Swiss structural engineer Mario Rinke presented smart and efficient timber constructions that can be assembled as well as disassembled: ingeniously curved trusses composed from slender, tension-loaded slats and a dome construction made of pressure-loaded beams. Bespoke steel joints ensure that the structures are easy to disassemble. Rinke compared them with laminated joists, glued constructions that cannot be disassembled and reused. Wouldn't using the latter mean: creating a new kind of 'timbery' concrete? We can remaster the knowledge of timber assembly and apply it in today's construction technology.

Where do we get our building materials? What is locally available and what can we grow and harvest on the spot? The Zestien Eikenschuur by Hilberink Bosch Architecten in Berlicum is an inspiring example.

It shows that trees can provide many building materials: not only beams and planks in different shapes and sizes, but also residual wood, shingles and bark can be used as building materials. One-third of Dutch forests comprise pine trees for paper production. Two-thirds comprise oak, Douglas fir and larch; the latter two are widely used for construction. If we better manage and diversify Dutch forests we will be able to extract even more and higher-quality local timber. If we earmark wood varieties for the purpose for which they are most suitable, we can handle our stock efficiently and ecologically. This way, dozens of dwellings will grow in the Dutch forests every day. What is the best way to organize this learning process? Who has the space and time to experiment? If we want to innovate, we have to facilitate experimentation. And things may go wrong. Who will take responsibility?

Architect and lecturer August Schmidt presented construction workshops with students from all over Europe in Trondheim. Students learned how to build and design with the material and playfully discovered new ways to stack, connect and span—and learned from each other's traditions. The design and construction of Schmidt's own house are experimental as well. Connections and constructions are tried and tested on the spot. His own house is a laboratory to develop timber detailing and assembly techniques. The coming of the Age of Timber may be a matter of time, but starting it is easier said than done. Innovation requires the remastering of knowledge and skills of the material and its applications. This intrinsic knowledge belongs to the designer and the builder. We have to attune legislation and regulation to its use. Experience shows that it takes more than a decade for rigorous innovations to penetrate the capillaries of the building sector.

Designers, builders, the industry, government and education can join forces to develop a new vocabulary together. Being open to new ideas helps. In Europe, there is a lot of useful knowledge about timber constructions, and this can inspire and accelerate our timber construction transition. In this process, experimentation will play a crucial part. It is at the joinery works, the building site, the architect's self-built house and the experimentation site that we can pass on the craft by hand and discover the future. Not at the drawing board!

Three Projects

Sixteen Oak Barn

Berlicum,
The Netherlands
Hilberink Bosch
Architects

Plugged and Stacked

Andelfingen,
Switzerland
Rossetti + Wyss
Architekten

Sponhuset

Trondheim,
Norway
Arkitekt August
Schmidt AS

Sixteen Oak Barn

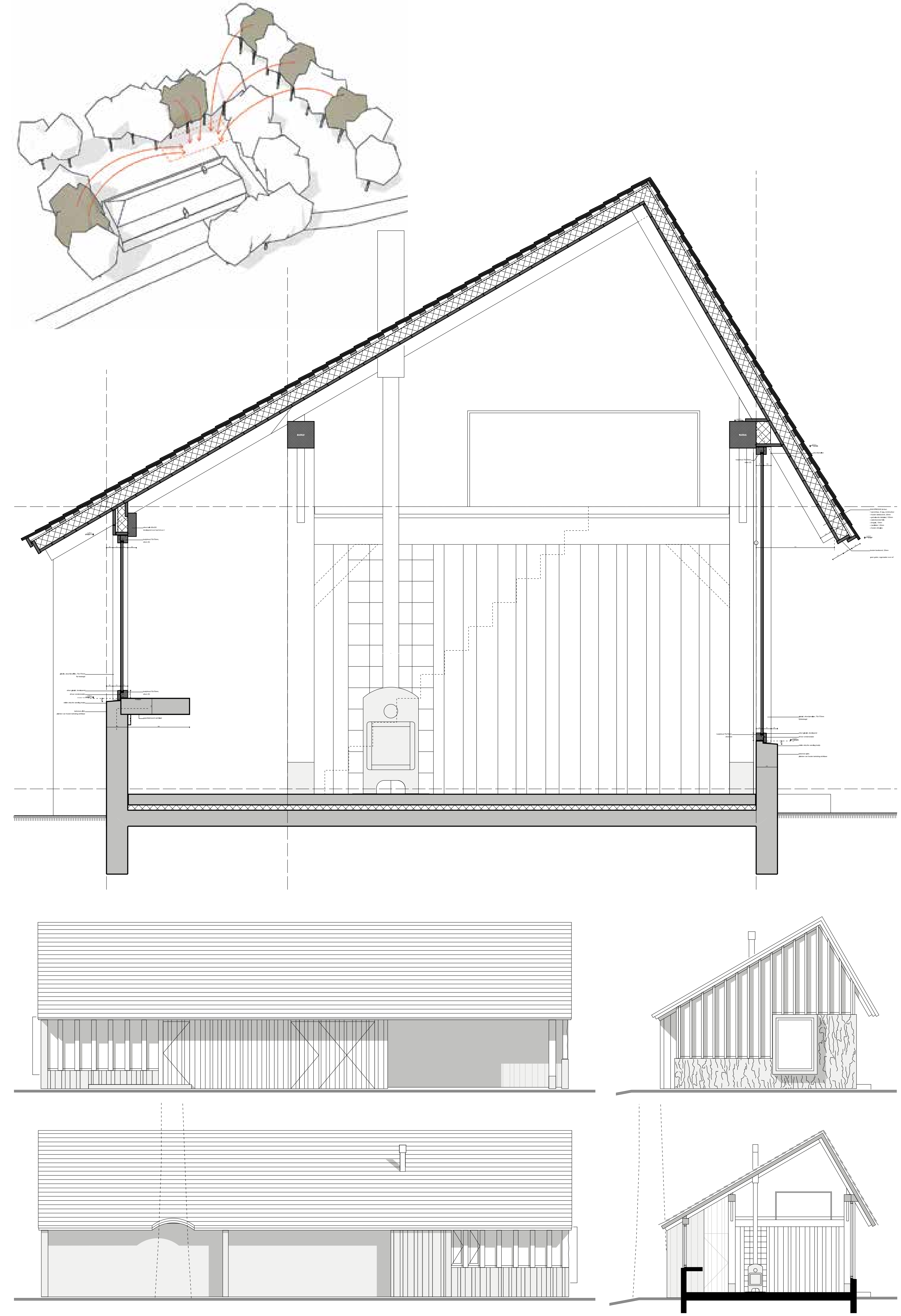
In 2017, seven century-old oak trees on a farm appeared to be in poor condition. To breathe new life into an old tradition, the architects used the wood from the oaks and traditional timber construction techniques to construct a new shed on the site, where a motley collection of run-down structures needed replacement. Along with nine additional trees, a total of sixteen trees were sawn with a mobile sawmill into beams for the bearing structure and planks for the exterior walls. Beams containing pieces of phloem were processed into slats, while bark and soft sapwood were added to the poured concrete. Short lengths of oak were cut into tiles for the roof.

Chance is an important aspect of the building's aesthetics. It lends the contemporary shed a vibrant appearance in which old and new work wonderfully well together.

Annemariken Hilberink

Berlicum, The Netherlands

Project contributors:
Architect: Hilberink Bosch Architects, Berlicum
Structural engineer: Raadgevend Ingenieursburo van Nunen, Rosmalen
Timber construction: Zandenbouw b.v., Aarle-Rixtel
Photographer: René de Wit, Breda











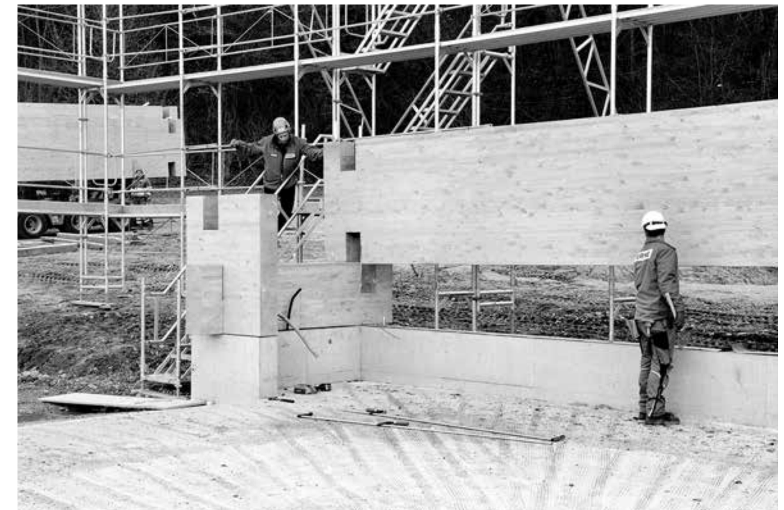

Mario Rinke

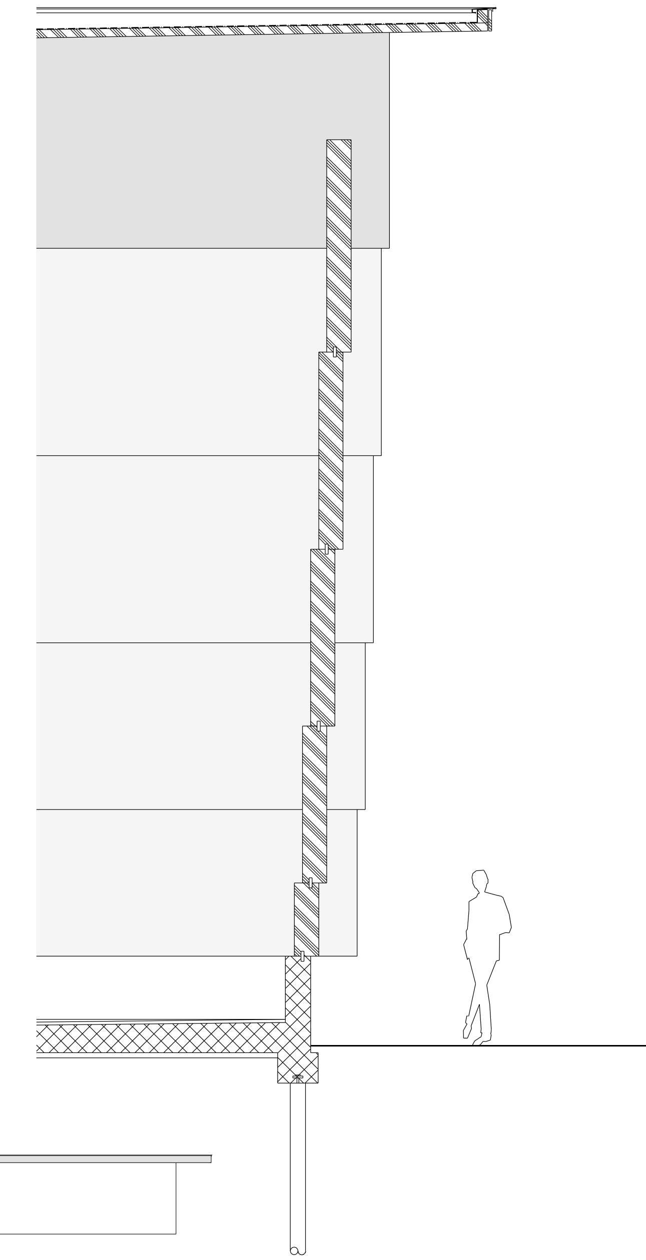
Plugged and Stacked:
The Maintenance Depot in Andelfingen as Modern Industrial Log Construction

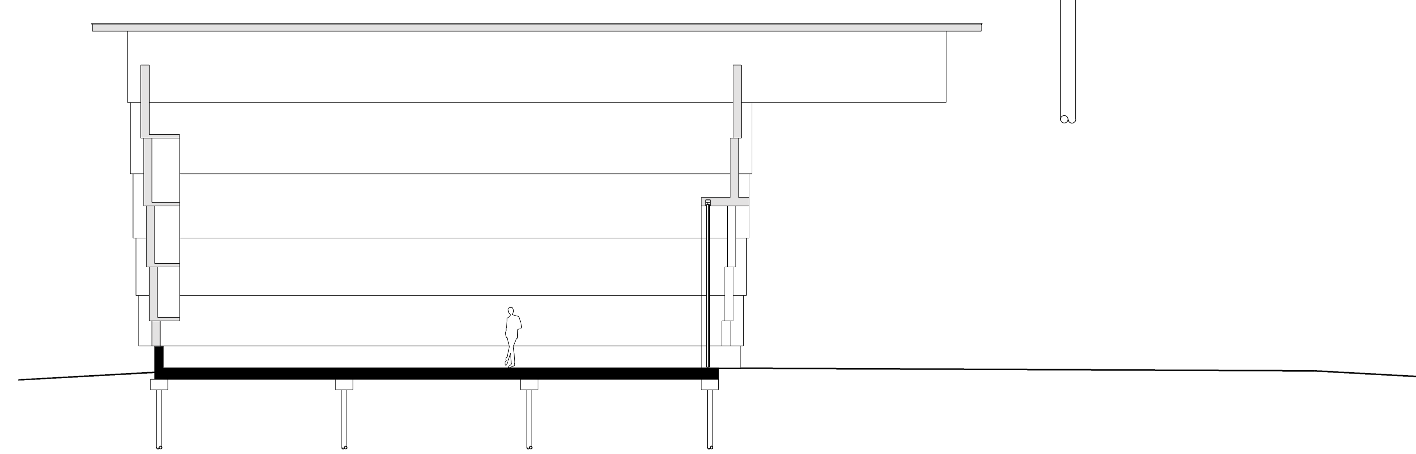
In 2015 a new maintenance depot for utility vehicles was built in Andelfingen (Canton Zurich, Switzerland). The building is 16.50 metres wide, 30 metres long and 8 metres tall, and was to be constructed in timber. Inspired by the simplicity of a kit of parts, planar components were developed for the roof and walls to integrate both the loadbearing structure and the building envelope, and to facilitate fast and simple assembly. This was possible because of modern industrial fabrication techniques that allow traditional log construction to be transferred to a large-scale industrial building type. The process of stacking and plugging two-metre-high laminated timber components along the length of the entire building, and then slotting the roof beams into the walls and the multilayer boards on top, made it possible to erect the building with just a few additional iron fasteners in just four days. The Glulam wall components are completely straight and can even be used for another building later, embodying the concept of a material bank for future construction cycles. Only through close cooperation between architects, engineers and contractors could such a strong relationship between the materials, construction principles, structure and architectural expression be achieved.

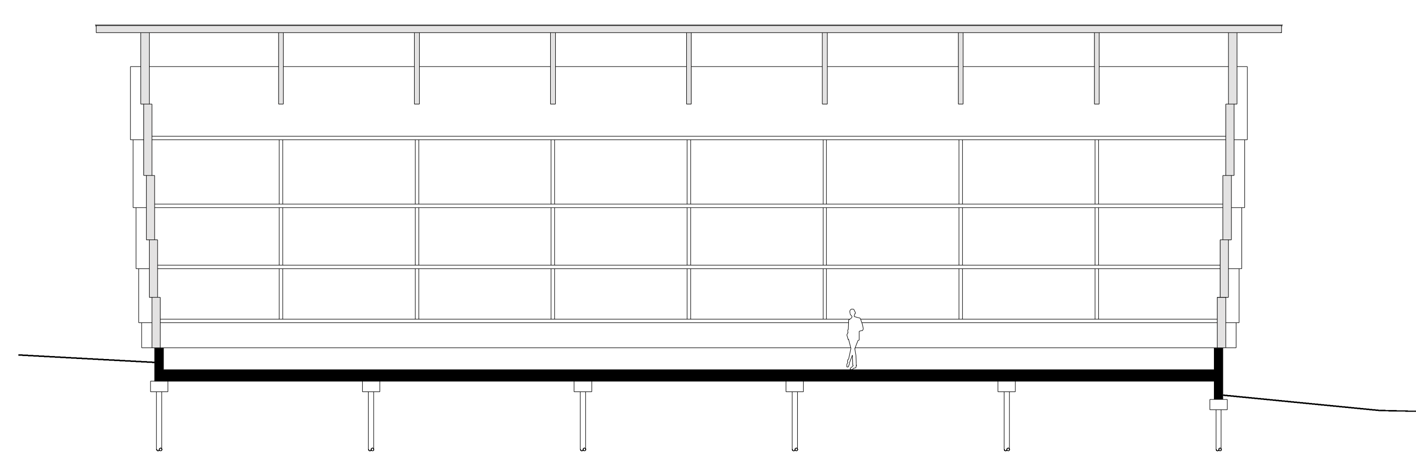
Andelfingen, Switzerland

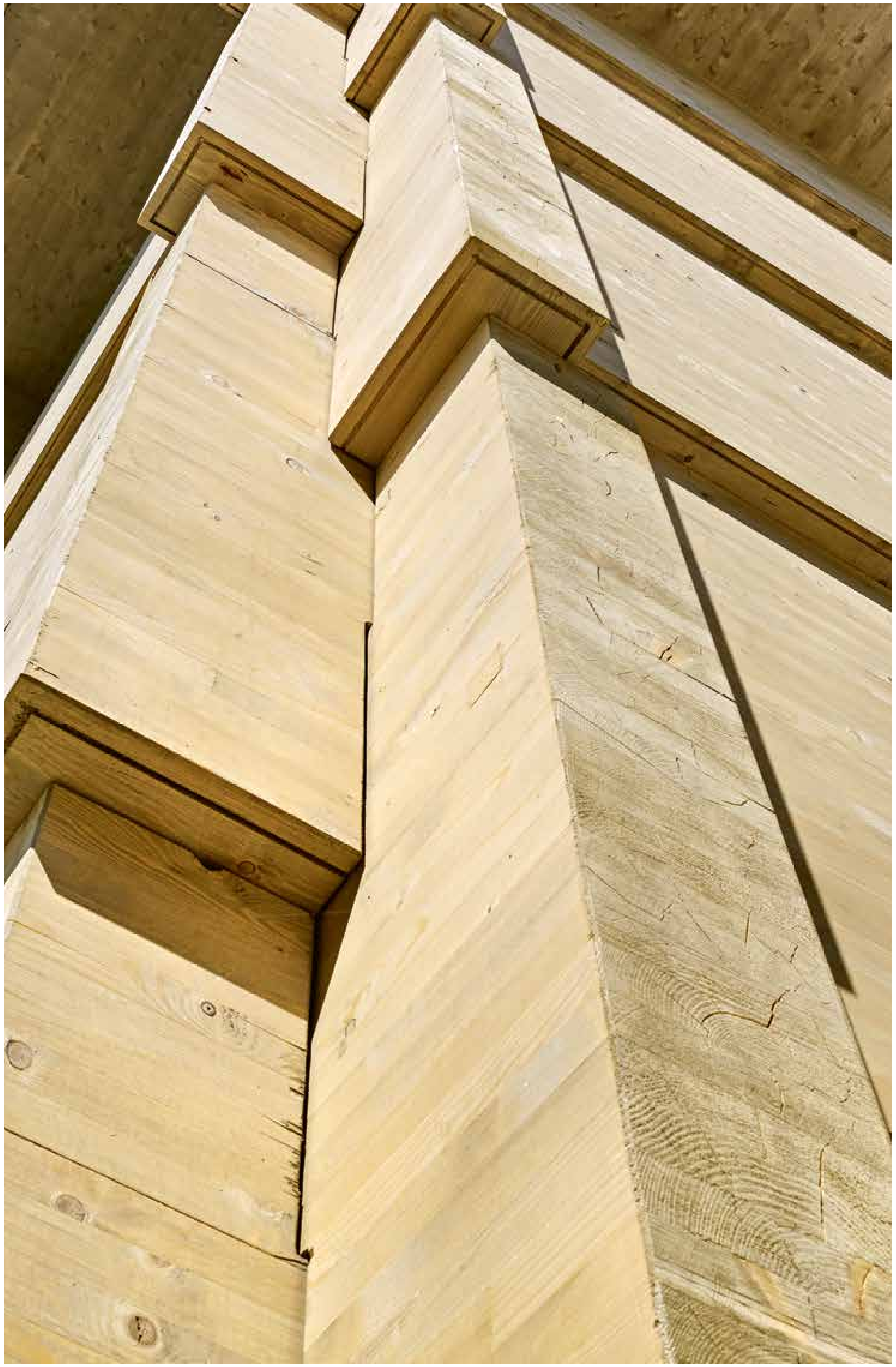
Project contributors
Architect: Rossetti + Wyss Architekten AG, Zollikon
Structural engineer: Dr. Lüchinger und Meyer Bauingenieure AG, Zurich
Timber construction: Erne AG Holzbau, Stein
Excavation and concrete construction: Landolt + Co. AG, Kleinandelfingen
Glulam components: Hüsser Holzleimbau AG, Bremgarten
Photographer: Jürg Zimmermann, Zürich











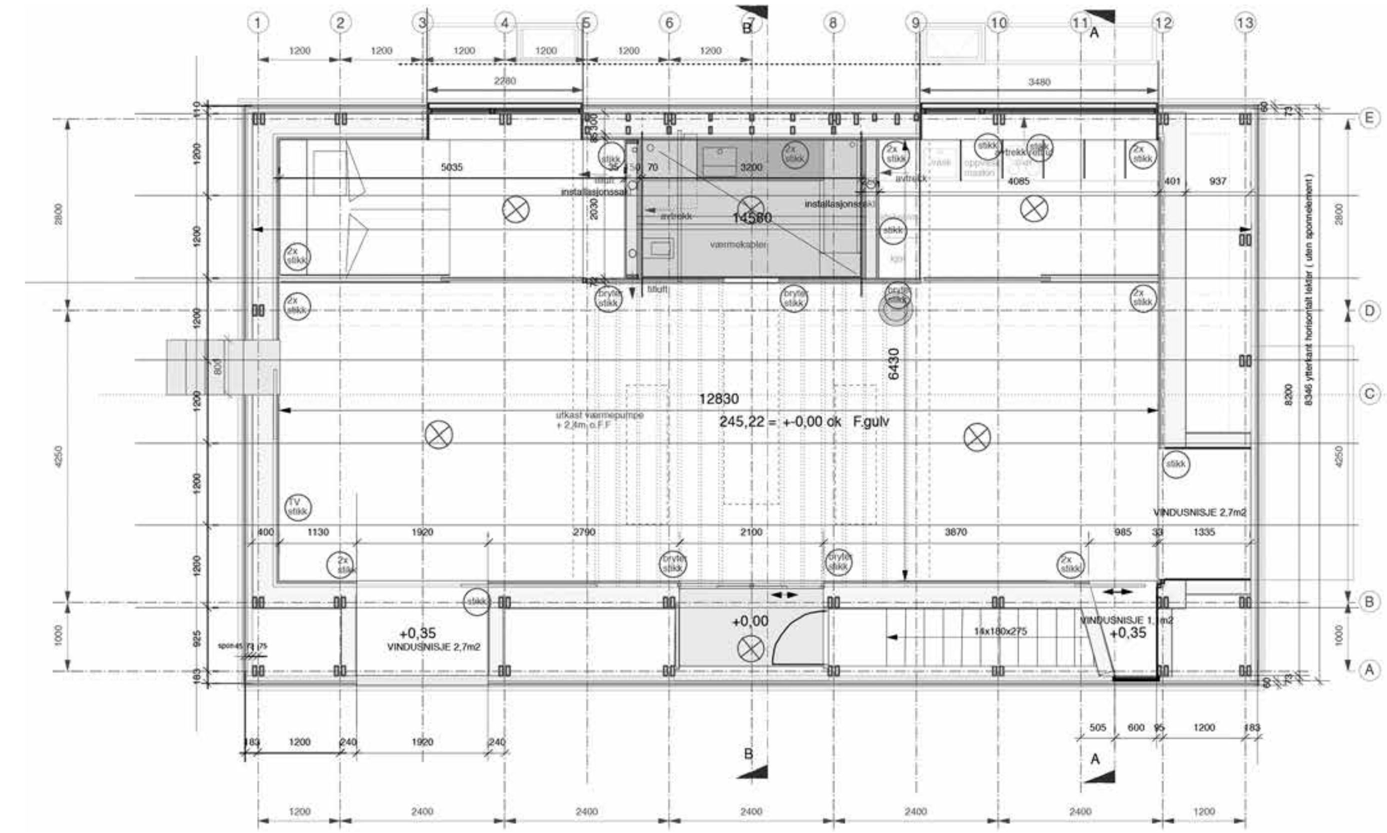
August Schmidt

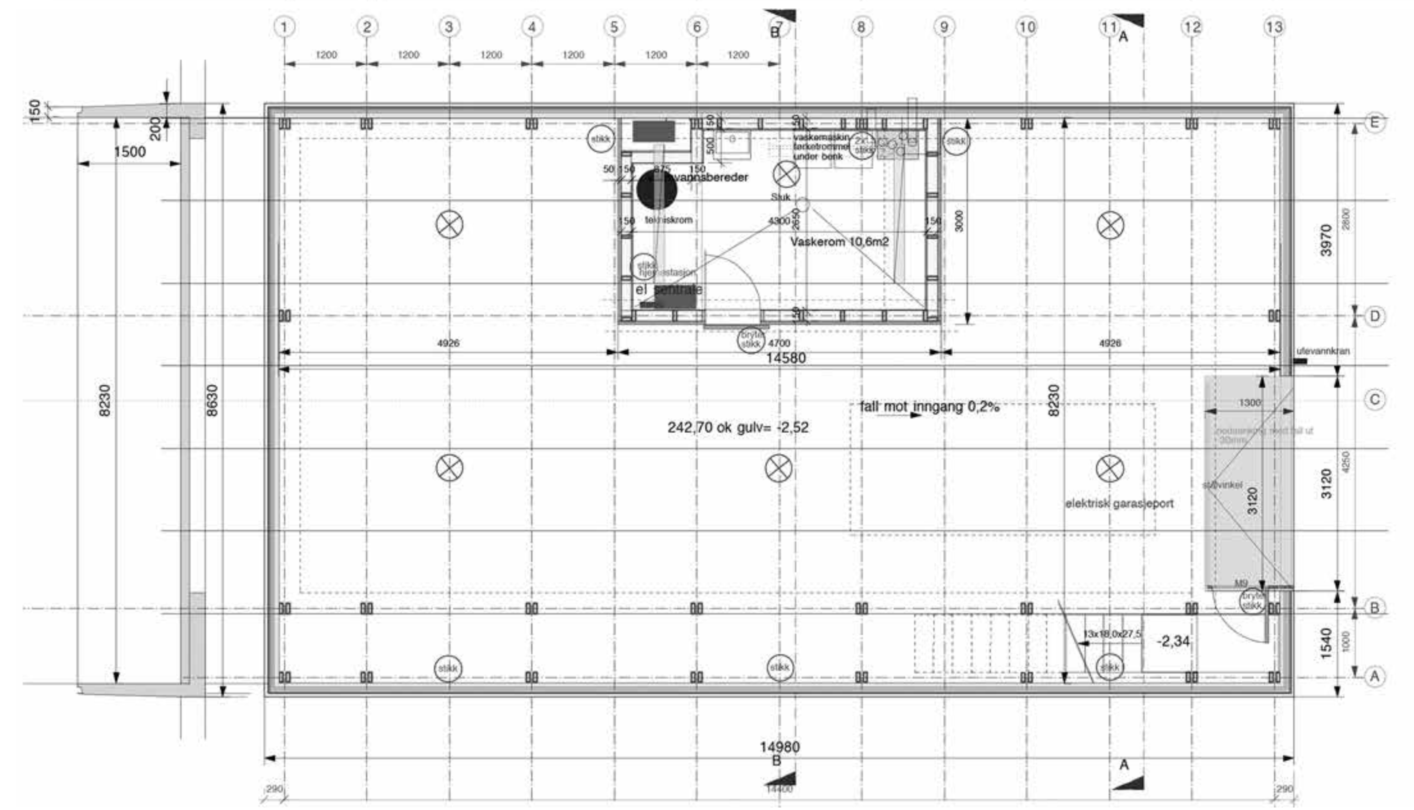
Sponhuset

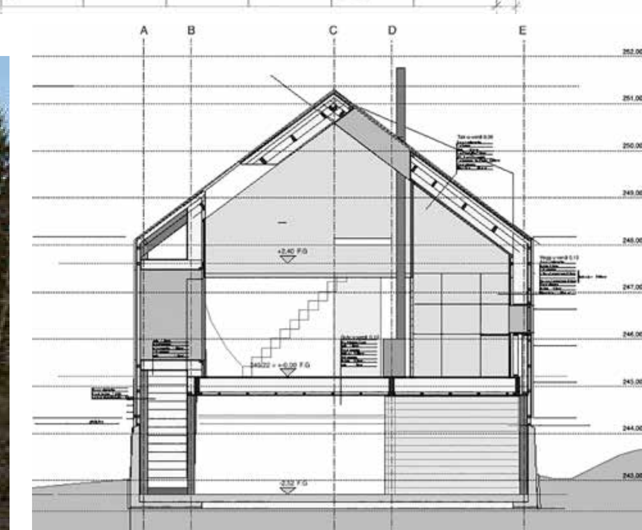
Dikehaugen 12 is a small one-family house situated among trees on the outskirts of the city of Trondheim, Norway. The complex comprises three saddle-roof volumes (dwelling, sauna and annex), all constructed in timber and clad in pine shingles.

Energy efficient and environmentally sustainable, the house is compact but its flexible floor plan creates plenty of living space. Natural materials allow the sturdy construction to breathe. The low-maintenance building includes unpainted exterior surfaces that can age with the weather and untreated indoor surfaces that do not require surface treatment. The distinctive design and layout of the volumes allows the complex to blend into the natural surroundings.

Made of timber, plant-based and recyclable materials, the house features simple and sound solutions, and its clear architecture is designed to ensure a long lifespan. Heated floor space is limited, and there is more unheated multi-purpose space to provide plenty of flexibility and facilitate activities during snowy winters and wet summers. The building binds CO_2 in its construction. At the end of its lifespan, the building will produce a minimum of non-recyclable waste.

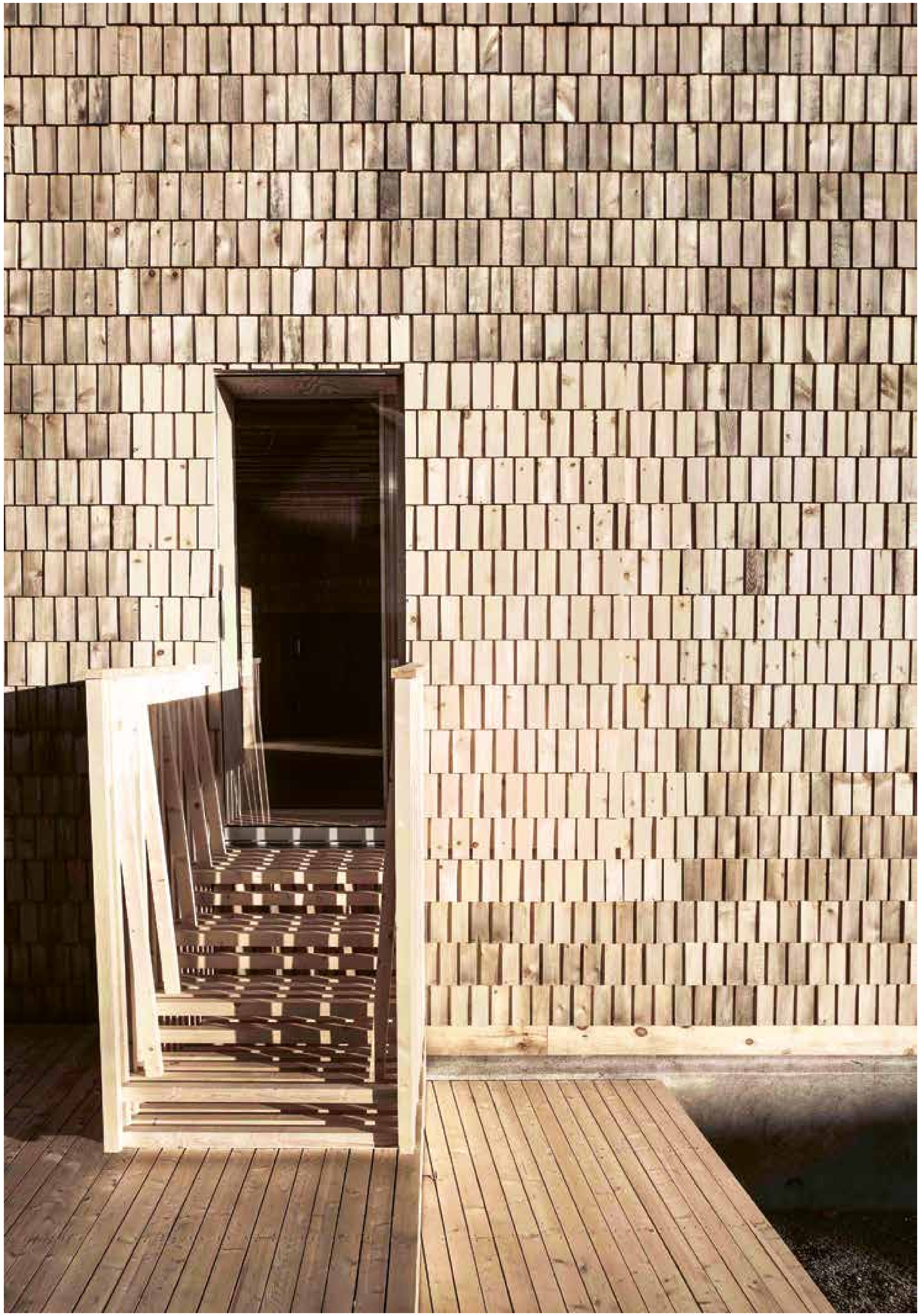






Trondheim, Norway

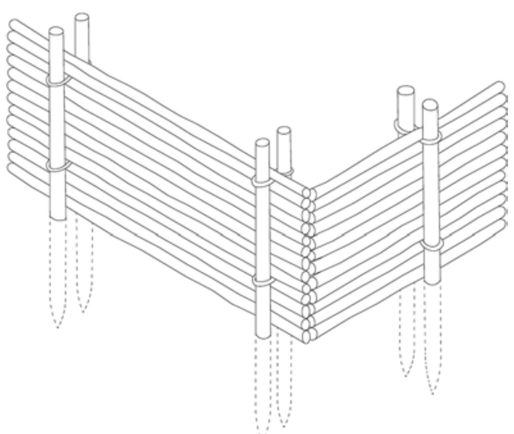
Project contributors:
Architect: Arkitekt August Schmidt AS, Trondheim
Structural engineer: Dipl. Ing. August Schmidt
Timber construction: Artic Nord Bygg AS
Photographer: Pasi Alto



Evolution of the Wood Joint: ‘How Did Tradition Stimulate Innovation in Historic Wood Architecture?’

Klaus Zwerger

Summary of lecture by Klaus Zwerger at the Amsterdam Academy of Architecture on 22 November 2019, by Machiel Spaan



Palisade, drawing by Klaus Zwerger

‘Can tradition stimulate innovation?’ Klaus Zwerger answered this question with a resounding yes. To him it isn’t even a question; it’s a given. He immediately posed a follow-up question: ‘How did tradition stimulate innovation in historic wood architecture?’ A professor at the Faculty of Architecture and Design at the University of Technology in Vienna, Zwerger is an expert on the development of historical wood architecture. He has documented in words and images countless examples of timber structures encountered on his travels and categorized them according to theme and development. A selection of his discoveries can be found in his publication *Wood and Wood Joints*.

Making something without any basis in knowledge that has been passed down is simply leaving things to chance, said Zwerger. There is little chance it will result in successful innovation. Developing tradition further on the basis of trial and error leads to progress much more often. Zwerger cited in this context the American sociologist Edward Shils: ‘The tradition of empirical knowledge embraced both the knowledge of how to adapt an inherited model of a tool or a machine so that it would be appropriate to the better performance of recurrently given tasks and the knowledge of how to use the tool efficiently.’[1]

Zwerger continued his introduction more quotes from Shils: ‘Mastery of traditional empirical knowledge is [...] capable [...] of becoming detached from the tradition through efforts to see how work could be done more efficiently.’[2] And importantly: ‘It is the tradition which permits the discernment of the opening to invention.’ According to the English architects and researchers Robert Brown and Daniel Maudlin, we can discuss the development of historical wood architecture from the angle of the value of tradition ‘as a creative, adaptive and reflective process within modernity.’[3]

The palisade wall

The first image that Klaus Zwerger showed was a drawing of a palisade like that built by Roman soldiers to defend their strongholds. Such walls were strong but temporary, because they derived their strength from the resistance of the piles driven into the ground, which rotted away over time. It took some time before a better solution was devised, because traditional ways of working and construction methods did not change without a reason. It wasn’t easy to convince a builder or craftsman to adapt their way of working. Often, a tradition was only revised if external conditions forced a reassessment. For example, if changing climate conditions or material scarcity forced people to reconsider the use of materials. Or if the social development from an agrarian society to a society of employees changed the requirements for living and working conditions. Farmers used their houses in a very different way to people who leave home in the morning and return in the afternoon to eat, watch television and go to sleep. Even today, when we spend a lot of time in front of the computer, new conditions are imposing themselves: interior spaces are better insulated and sealed off from the world outside. This leads to new timber construction techniques and details.

Innovating is not a recent phenomenon. Ever since the palisade, timber construction has undergone extraordinary development. Conditions have continually led to modifications and improvements to construction methods and details. During his lecture Zwerger presented ten examples to demonstrate that innovation is anything but a contemporary phenomenon. Quite the contrary, it has a long tradition.

1 Shils, Edward. 1981. ‘Tradition.’ The University of Chicago Press.
2 Ibid.
3 Brown, Robert and Maudlin, Daniel. 2012. ‘Concepts of Vernacular Architecture.’ In *The Sage Handbook of Architectural Theory*, edited by Greig Crysler, et al., 340–354. Los Angeles, et al.: Sage Publications.

1 Corner joints

A sturdy corner makes a house so secure that it can be raised off the ground, supported by stone foundations. Over time and in response to local conditions, woodworkers developed methods to prevent beams from sliding out of position and to protect their ends from the weather. Various dovetail joints (through, half-blind, secret and overlapped dovetails) demonstrate the inventiveness of the maker, each in its own way.

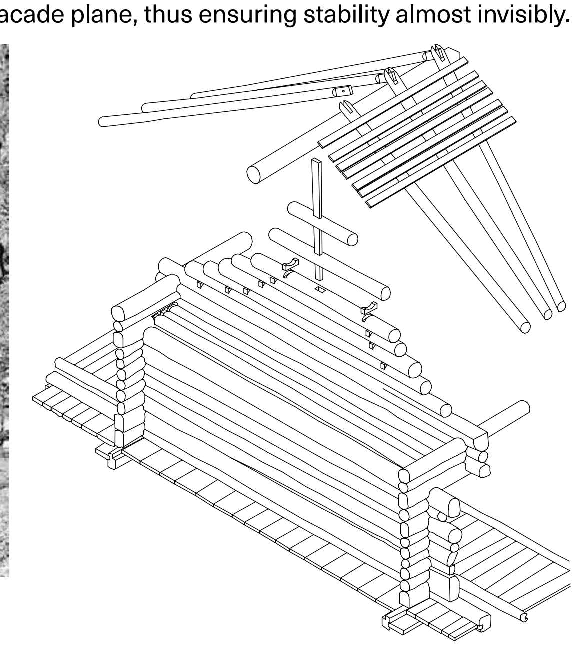
Sibiu, Romania

Molzegg, Austria

2 Pagan support pincer and sword

The triangular facade plane beneath the pitched roof above the log structure does not stay upright all by itself. Craftsmen developed details to keep the beams in position. Several pincer constructions are clearly visible. A sort of sword driven vertically through all beams forms part of the triangular facade plane, thus ensuring stability almost invisibly.

Reichenbach, Switzerland

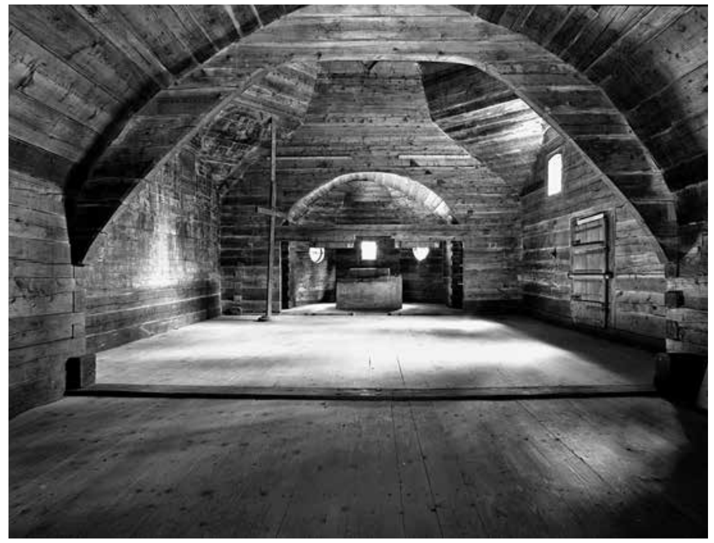


Gressoney St. Jean—Obro Lommato, Italy

3 Round shapes

When it comes to log construction we usually think of rectilinear shapes. But curved walls and roofs on timber sheds and chapels can also be functional and lend such buildings additional structural stability. Turning each successive beam slightly inwards results in a curved roof shape that makes a structure much stronger and more stable.

Nadasa, Romania

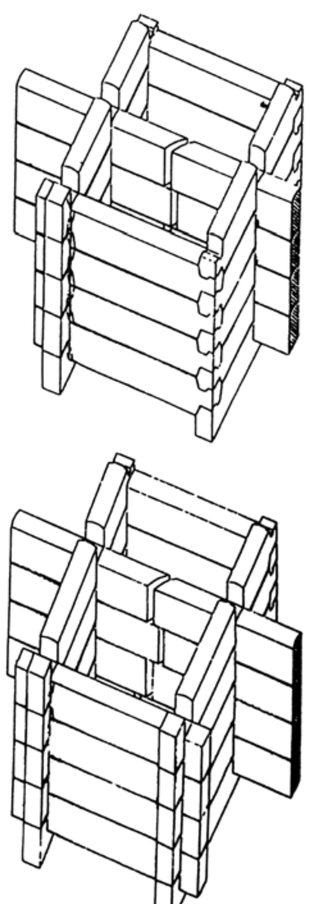


Ulucz, Poland

4 Columns of stacked wood

The walls of log buildings are limited in length owing to the maximum length and stability of available wood. Stability was achieved by placing cross-walls perpendicular to the outer wall, but these sometimes stood in the way. So smart woodworkers came up with hollow columns made of stacked wooden beams. These columns ensure stability, strengthen the walls close to the roof edge and strengthen and protect the logs joined lengthways. In churches they served as significant supports to dissipate the roof load.

Pihjalavesi, Finland



Drawing from: Lars Pettersson; Templum Saloense; Helsinke 1987: fig. 261–3, 4.

5 Forked columns

Placing the house on columns lifts it clear of the ground, protects it against water and vermin, and allows the floor structure to dry fully. But such ‘pillars’ also make a structure vulnerable; if one of them fails or collapses, the house will also collapse. Woodworkers devised forked columns to prevent them from sliding and, at the same time, strengthen the base layers of the structure.

Lijiazui, China

Stübing, Austria

6 Anchor beams

The growth of urban populations also increased the need for taller buildings. Longer beams allowed for the construction of houses with multiple floors after carpenters had introduced anchor beams. Long beams facilitated their construction, specifically their reinforcement. But irregular bracing determined the position of wall openings and impaired the appearance of facades.

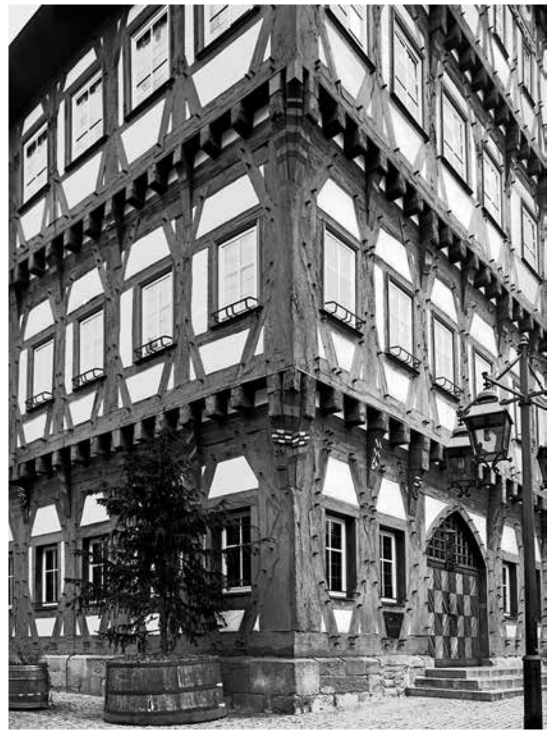
Quedlinburg, Germany

Marburg, Germany

7 Frame construction

As wood for construction becomes scarcer, declines in quality or decreases in dimensions, traditional methods of construction no longer suffice. The one-storey frame structure designed in response to these limitations offers a number of advantages. A different window arrangement can be made on each floor, and floors can be stacked in a staggered manner to create cantilevered volumes.


Rothenburg, Germany


Markgröningen, Germany

8 Hammer beam roof

A scarcity of materials also leads to innovative roof structures. An example is the 'hammer beam' roof, consisting of a number of short beams. By constructing the roof structure out of a series of rigid triangles, builders could achieve a relatively large span without depending on tie beams that require long and straight material. For the proper execution, skilled woodworkers were needed. Decoratively executed details visibly expressed an appreciation of churches and other representative buildings.


Woolpit, England


Tarrant Crawford, England

9 Hanging pillar

The need for large column-free spaces increased with large buildings for large numbers of people. To avoid the use of columns in spaces, all sorts of smart structures were devised to divert the forces acting on the central part of the truss to the walls rather than vertically downwards. The search ultimately led to a beam structure that distributes the forces to the eaves' walls directly or via the inclined roof-shaping structural members. This 'hanging pillar' ingeniously disburdens the previously heavily burdened horizontal beams.

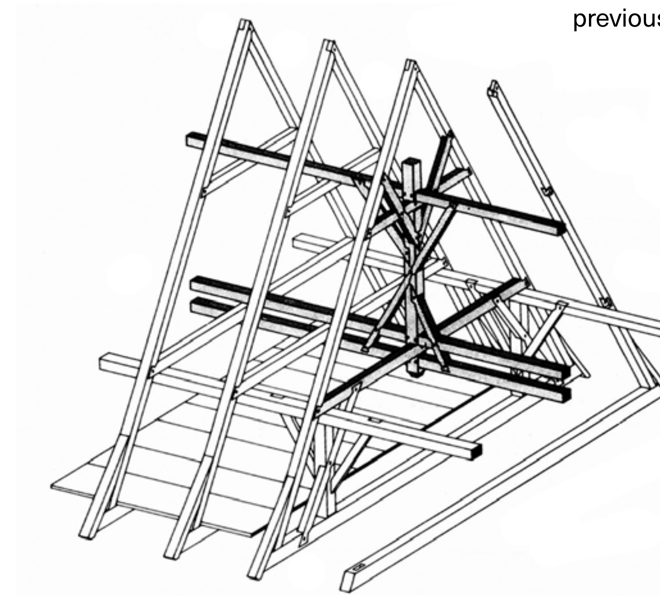


Image from: Albrecht und Konrad Bedal; Dachstühle im Hofer Land vor 1650; In: Beiträge zur Hausforschung I, 1975: 126–173.


Égreville, France

10 Natural protection

Protecting the timber structure of buildings from the weathering effects of the sun, rain and snow extends their lifespan. That can be achieved with cladding, conventionally using boards and shingles, or using greenery. The leaves of espaliers planted in front of the facade offer protection from both the rain and sun. Green facades also produce oxygen and create microclimatic cooling.


Eidsborg, Norway


Lupitsch, Austria

Timberdutch! Considering Dutch ‘Conceptional Wood’

Tibor Joanelly

Mind the gaps! Not so long ago, the Franco-Swiss architects Bakker & Blanc refurbished a huge old barn in the picturesque valley of the River Saane in Fribourg, lying at the foot of the medieval town. Since the 16th century the barn has been called Le Werkhof, a designation that carries meanings of necessity, bustle and skill in its name. The barn was erected for the production of boats, and after a devastating fire some years ago, the architects launched a concept for its reconstruction, mainly based on references to ships and shipyards.

The story behind that story is simple: Fribourg, in the 16th century, was well known for the production of wood for construction, mainly from oaks and beech trees, some of which was even shipped to the Netherlands. There the wood was processed for the housing and shipping ‘industry’ of the time. The geographic gap between the hilly heart of Switzerland and the plains of Holland was closed with the simple force of water and difference in altitude.

Talking today about the past and future of timber construction and the hopes that it implies—hopes that are guided towards a sustainable use of resources—seems to unravel a whole bunch of gaps. There are gaps between places of cultivation, processing, manufacturing and the use of wood or timber products for the building industry. There even are gaps to be acknowledged between industry and craftsmanship in general and between engineering calculation methods and traditionally transmitted knowledge in particular, which give rise, among other issues, to problems around the provision of warranties. More than that, there are gaps to be found between different modes of thinking, between tacit knowledge and conceptual thinking—and also between academia and practice. If they were not enough, there are, besides an apparent gap between past and present, gaps to be discerned between good examples and the large mass, between rural areas, and between small buildings and large estate development. And on and on.

It may be worth staying a bit longer with history. Amsterdam, the brick city par excellence was, at least until the 15th century, constructed in timber. Some brick facades within the inner ring today are, in fact, only facades covering a timber structure. Brick was introduced after large fires 1421 and 1452, but some buildings were only masked—a detail that can be verified by finding facades where upper stories project, because that is only made possible with an underlying traditional timber structure.

These remnants seem to tell us a lot about the proverbial Dutch pragmatism. They also tell us a lot about the conceptual possibilities of composite constructions that are able to serve different masters. And they explain how timber constructions could convincingly find their way back into dense cities, at least in terms of architectural expression.

Of course, this would need some further gaps to be bridged. In doing so, one has to start with a new assessment of fire regulations, as was successfully undertaken in Switzerland in 2015. The new regulations propelled innovation in the timber construction industry. Another area of assessment is the development of reliable calculation

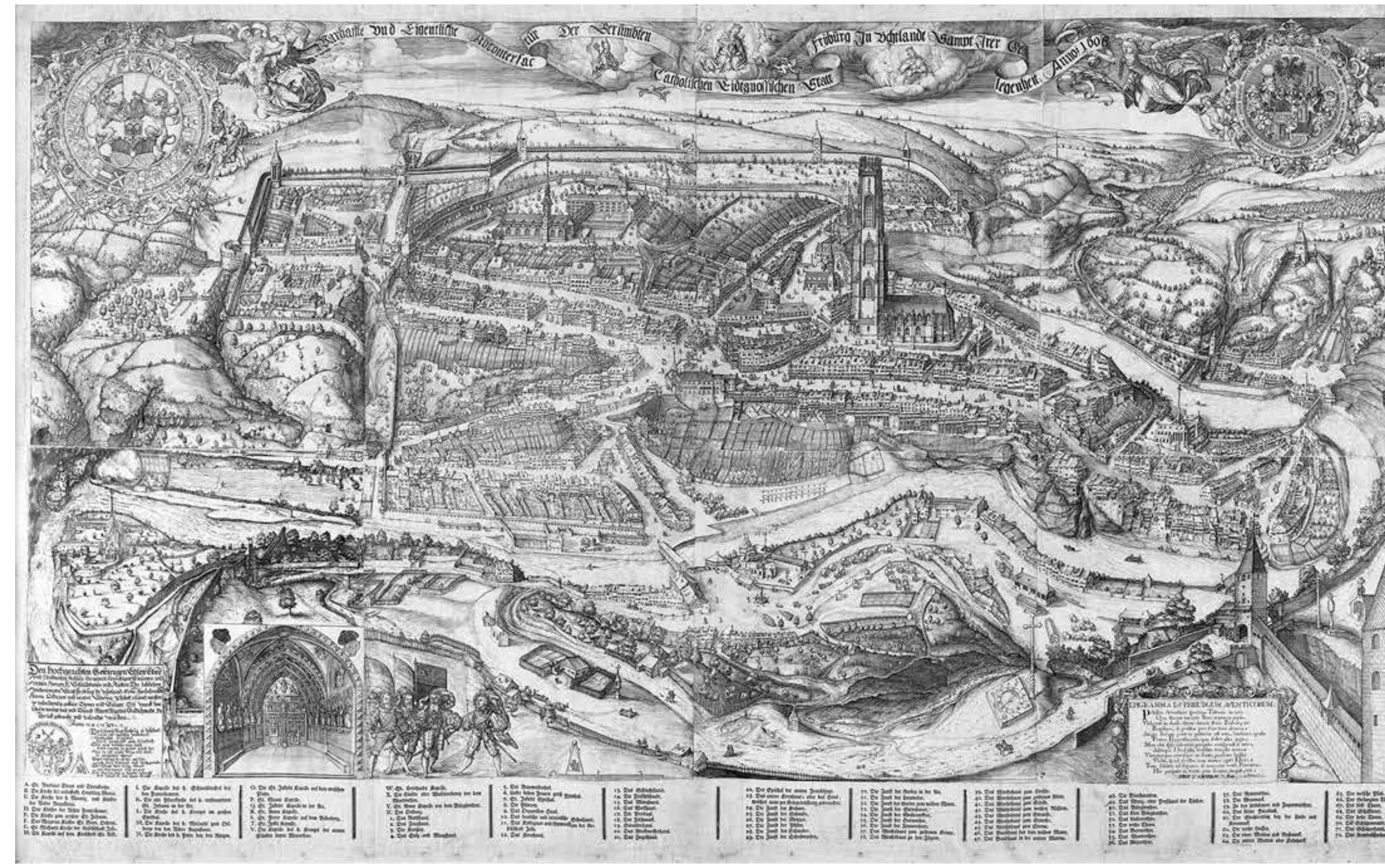


Figure 1
Le Werkhof in Fribourg/Switzerland, a barn from 1555 where boats were built to transport timber downstream.
a *Martiniplan*, Martin Martini, 1606
b Detail
Picture credits: Courtesy of Musée d’art et d’histoire Fribourg

models that allow for more efficient structures, since the financial aspect implicated here is crucial for a broader proliferation of timber construction systems. It seems that the notion of efficiency is something that is promising for both stimulating new technologies and fulfilling the thrifty and therefore sustainable use of such systems.

Efficiency is not something that has been only requested for the benefit of investors. Another look at history—or tradition if you want to call it that—makes this obvious. But the historic perspective also has its pitfalls. The Grubenmann family in Switzerland had acquired a knowledge of wide-span timber structures that allowed them to use similar structures to bridge valleys as well as large spaces for churches. Their implicit knowledge led in the 18th century to spans of more than 60 metres or 36 × 21 metres respectively—without the type of calculations that would be required today!

Unfortunately, the Grubenmanns were unable to offer proof in terms of scientific knowledge, and so they were no longer allowed to build. For today, it would be interesting if it were possible to develop state-of-the-art calculation models for timber structures that are easy to apply and bolster intuition—and could also provide structural proof.

Viewed conceptually, composite structures like those we find in some old Amsterdam houses have the potential to bridge another gap that has already been mentioned: the gap between city and countryside. Building in a dense environment calls for different construction systems, not only due to fire regulations or height, but also due to standards, regulations, costs, comfort and the like.

Even under the paradigm of sustainability, building in the countryside implies detached houses, or at least settlements with only a few storeys to provide forms of privacy or spaces that accommodate different needs from those in the city. And it also implies a different metabolism of construction materials. Besides the fact that most people still live outside cities, for instance in Norway, building in the countryside engenders different construction systems as well as different solutions regarding the adaptability or reuse of structures. Timber, in any case, can provide fruitful solutions—or to put it differently: there is no ideal and generalizable construction technique.

Of course, bridging the gap between good will and reality is no easy task. And it doesn’t happen by itself. Let us return to Fribourg. Not long ago the canton and state of Fribourg launched an architectural competition for a police administration building. One of the constraints that the architects had to respect was the use of the state’s own wood.

Figure 2
'Tara-Space' at Le Werkhof in Fribourg/Switzerland, representing the shipping and trade connection to the Netherlands. Some remains of the old oak structure are still visible. Photo: Bakker Blanc architects, Marco Bakker

Figure 3
The material of the wooden structure for the administration building of the cantonal police in Fribourg by Deillon Dellay Architects was obtained from the communal forests. Photo: Mélanie Rouiller

(It should to be noted that many communities in Switzerland still hold their own wood resources.) The winning and now realized project is an interesting concept with a completely timber internal structure and an aluminium shell that is reminiscent of car bodywork, perhaps because the plot is situated between highways and car infrastructure.

Stimulating the use of wood requires subsidies and even state pressure. One good example is Norway, where wood technology was pushed by the government in the lead-up to the 1994 Winter Olympics.

And in the Netherlands? In December 2019 the Dutch Supreme Court upheld the decision by a lower court that forced the government to reduce CO_2 by 2020 at a rate of 25% compared to 1990. Such efforts may not happen without courageous changes in the building industry and without legal compulsion.

Without going too much into sociological or philosophical details, change is only possible if structures are bound not too tightly. Or to put it differently, there has to be, in every relationship, be it human or among things or even between notions, a certain degree of freedom to allow for the unexpected to occur, to allow for surprise. And here, of course, the gap plays a crucial role. A gap exactly marks that field of underdetermination and uncertainty where new things can occur and change is possible. Gaps should therefore not be bridged too firmly. In relation to the above discussion, it becomes clear that solutions may well be situated between construed oppositions, such as tradition and modernity, academia and practice, or city and countryside. Mediators can develop enormous efficiency.

Historically, 'Superdutch' was such a mediator. The now widely discredited architectural 'style'—or better, the attitude towards architecture implied by the term—can be seen as an attempt to bridge architecture's aim for autonomous expression and the realities of neoliberal policies and markets in the 1990s. The 'closing of the gap' was made possible by raising conceptual thought to the realm of architecture, striving for a strong assertiveness of architectural ideas.

But we all know about the affirmative outcomes of this experiment—and about the aesthetic, economic and political consequences such as arbitrariness, massification and populism that paralleled architecture as it framed unbridled growth. So, maybe 'Superdutch' really has lost credibility. But what about reconnecting to the spirit of the 1990s? What about combining Dutch conceptual thinking with what has been set up by craftsmen in remote Swiss valleys and Norwegian fjords? I would like to propose here a new 'thing-in-between-the-gaps': Why not talk about 'Timberdutch'?

The Ecology of Timber Construction

Cathrine Johansen Haanes
and Haakon Haanes,
Nøysom arkitekter

The renewed relevance of timber

Building with timber is increasingly becoming the new standard for sustainable architecture, and not without merit. As a building material, timber has lots of qualities that mark it out from its competitors.

Timber is a renewable material, when harvested sustainably. In Norway, for example, productive forests are growing faster than they are being cut down. In 2017, numbers from the Norwegian Institute of Bioeconomy Research (NIBIO) showed that the volume of Norwegian forests has tripled since the 1920s, and the forests are growing twice as fast.[1] There are several reasons for this, such as the regrowth of traditional cultural landscapes, longer growing seasons due to climate change, and more intensive forestry.

Timber is a climate-friendly material when used locally. As trees grow, they capture CO_2, which is then stored in building materials made from wood. When timber is compared to other building materials, this stored CO_2 is often counted. In addition, wood is soft and malleable, and normally does not need much energy to process into building materials.

Timber has benefits for indoor climate. The internal structure of wood allows for moisture to pass through its body, which evens out temperature and relative humidity levels. Its complex structure creates a good acoustic environment, and the visual, tactile and olfactory qualities of wood provide a subjective feeling of comfort and warmth.

Finally, wood has properties that make it easier to recycle or reuse than many other materials. It can be downcycled as bioenergy or components for fibre boards or other composite products, or preferably, it can be reused directly.

All these qualities make wood from local forests that are managed and harvested properly the obvious champion of sustainable building materials by today's standards.

However, from an ecological perspective, most of the qualities noted above have less to do with the actual sustainability of timber as a material than with its role in minimizing a building's negative environmental impact. Being a renewable material with less negative impact on global warming, and with fewer human health and ecological disruptions than its competitors, does not make wood a sustainable building material in itself.

To go deeper into the sustainability of timber as an architectural building material, we have to go into the ecology of timber construction.

The ecological benefits of building with wood

From an ecological perspective, sustainable development can be defined as 'the goal of fostering adaptive capacity and creating opportunities'[2]. The study of interrelationships in nature teaches us that the capacity to adapt to changing circumstances and create opportunities is crucial to healthy ecosystems, and a rich and diverse nature. Human beings are part of nature, and have adapted to nearly every climate on

1 Dalen, Lars Sandved (2017, 28. Aug) Nye rekordtall for skogen i Norge. From https://www.nibio.no/nyheter/nye-rekordtall-for-skogen-i-norge)

2 Holling, C.S. (2001) Understanding the Complexity of Economic, Ecological and Social Systems. From https://link.springer.com/article/10.1007/s10021-001-0101-5

earth, but we seldom think about how we are reorganizing our contemporary environments to increase or decrease our ability to continue to adapt and create opportunities.

Looking at the tradition of timber construction, we can see that wood as a material has been a central building block of human adaptation to a diverse range of circumstances. This is due to qualities of wood that are seldom mentioned in a sustainability context; the simplicity, versatility and understandability of timber as a building material.

Wood is simple in that it follows the logic of all carbon-based life forms. The wood we use is dead, but it still needs to breathe and move, or it will rot, twist, turn and disintegrate. You can cut through it using simple tools, but so can insects and rodents. Many species have evolved a capability to digest wood, and if the living conditions are right it will be home to life forms like fungi and bacteria. It will burn if you set fire to it. It will change colour if exposed in the sun. All these qualities are often seen as a problem with wood, but they have been predictable and understandable for humans through the ages. As a life form adapted to its different environments over millions of years, trees and wood are an integral part of many ecosystems, and for better and worse, they always have a role to play.

The versatility of wood is also due to many of the properties listed above. Modern humans have marvelled at how enormous structures of stone and marble have been erected without the technology we have today, but few have done the same with wooden structures. A tree can be processed into building materials using only manual labour and simple tools. It can be transported easily, as it floats on water and glides on the snow. Wood as a building material is strong, but weighs little. It can be combined in a variety of ways, from carefully constructed joints to crude nails hammered into it. Untreated wood is not particularly (though wood dust can be carcinogenic) harmful to work with, neither for you nor for other living organisms. Different species of trees, and the different parts that make up trees, provide a variety of benefits to constructions and buildings, and traditional knowledge of timber construction has found uses for most varieties.

The result of the simplicity and versatility of timber is its inherent understandability as a building material. One of the oldest building materials we have, timber has been shaped into a variety of forms for various purposes. Logs have been stacked on top of each other, sticks have been lashed together, and columns, beams, joints and other components have been shaped, formed and combined into a multitude of structures that can be used and reused in a variety of ways, inspiring creativity and embracing the unexpected. The traditional and intuitive understanding of timber as a building material has made it the material of choice where trees grow, sparking artistic, inventive, useful and robust architecture. When it comes to sustainability in an ecological perspective, this is the greatest merit of timber as a building material.

The complexity of modern building materials

The evolution of timber structures based on material availability, tradition and creativity, is long and rich, but at some point it changed its course, leading to the way we often build with timber today. The question is whether many of the qualities that made traditional timber structures sustainable have been lost in the process.

There has always been a conflict between the natural qualities of timber and our need for a controlled environment, but in recent decades our ability to change the properties of timber has increased greatly. When constructed correctly and with high-quality timber, structures can be left untreated without adverse effects. This was the norm in countries like Norway up until the 19th century.[3] Timber can also be treated in ways that preserve its inherent qualities, such as the ability to transport humidity. But for the sake of ease and economy, a wide variety of synthetic treatments have been invented to alter the natural qualities of timber, transforming it into something else. Timber treatments to avoid susceptibility to fire, rot, insects, bacteria and fungi and discolouration have environmental impacts that go beyond altering its properties. Naturally, most substances that prevent timber from

transporting water through its cells, being eaten by bacteria or fungi, or catching fire, are harmful to nature and people.

Timber as a building material also has natural limitations when it comes to structural strength and durability, and the quality of wood differs within a single tree, between individual trees, and between species. As wood increasingly became a commodity, the ability to grow fast, providing steady and reliable income, became the favoured property of trees. With the decline in our understanding of which trees, and parts of trees, were best suited for different purposes, the evolution of timber construction became a matter of finding ways to use trees that grew fast in large plantations, like spruce. As a result, a range of complex composite materials have been invented, partly by physical reorganizing the material and partly by adding products like glues, bitumen, cement, metals and plastic films to the mix. Many of these materials are harmful to the environment and/or energy intensive in their production.[4]

One of the main challenges in contemporary architecture is that neither users nor specialists, like architects, really understand what new buildings are made of. A timber building, for example, is not always what it seems. A study by the VTT Technical Research Centre in Finland, referred to in Lars-Erik Mattila's article 'Reclaiming expertise' in *The Finnish Architectural Review*[5], claims that the timber content in new timber structures in Finland is only 16–32 per cent. The jungle of composite materials is not made easier to navigate by the fact that product names have replaced the names of materials, and that the architectural design process, more often than not, revolves around choosing products from a catalogue or computer database, and importing them directly into a building information model. The model contains all the specifications of the materials, making the architect's job easy, but that makes it difficult to understand the ecological impact of the building they have designed. The sticker 'wood' attached to a variety of composite materials becomes a trap for both professionals and laymen, alienating us from our built environment.

From building blocks of innovation to specialized elements

Another major development in modern timber construction is the rise of prefabricated components. Until recently, the versatility of timber structures had been preserved with modern innovations, at least in Norway and other parts of the world where timber frameworks have been, and still are, the most common way to build small buildings. Modern stud-frame construction can be seen as the pinnacle of this development, with the sawn planks available at every building store providing versatile building blocks for an ingenious, simple and economic construction system that stimulates creativity and problem solving for architects, carpenters and self-builders.

The versatility of the stud frame makes it ideal for self-building, which has been a common way to build homes in Scandinavia as a result of municipal schemes and individual efforts. It wasn't until after the Second World War that self-building stopped being a tool for providing affordable housing. Concrete and steel became the materials of choice for mass housing in cities, and industrial construction methods and eventually prefabrication gradually became the norm for efficient building. For many people, this efficiency and ability to stack hundreds of people on top of one another in itself is synonymous with sustainability.

When the timber industry discovered that it could produce cross-laminated glued components that could combat reinforced concrete, it was perhaps rightly seen as a revolution in timber construction. A revolution that is still gathering steam, under the pragmatic call to descrease the environmental impact of the building industry. However, in the process the versatility of timber as a building material seems to have been abandoned. Huge prefabricated elements constructed in a factory can carry heavy loads, providing the opportunity to build towers of timber, but the timber used is highly specialized in its function, and almost impossible to reuse. In its current form, it can compete with concrete, but only by becoming like it.

3 Berge, Bjørn (2001): *The Ecology of Building Materials* (English Edition) Architectural Press, p. 434

4 See for example Berge, Bjørn (2001): *The Ecology of Building Materials* (English Edition) Architectural Press

5 Mattila, Lars-Erik (2019): Reclaiming Expertise. *Arkkitehti / Finnish Archietctural Review 5–2019*

The evolution of timber construction is not over. We need to reinvent contemporary timber construction to make it simple, versatile and understandable again. In an ecological perspective, without these qualities, timber materials will not continue to be the sustainable building blocks for innovation they once were. In a world that is increasingly turning to smart technology to solve our adaptation, too often we forget that we are also smart and adaptable. Timber is traditionally a material that takes our intelligence seriously and facilitates the creative adaptation of our environment through simple structures. Whether through the rediscovery and renewed appreciation of the genius of existing methods of timber construction, or through new ways of adapting traditional techniques of timber construction to new challenges and new settings, the future will show whether we can reinvent contemporary timber construction in a way that conserves the ecological qualities of building with timber.

3 TWELVE WOOD STRUCTURES

Studios

Rock Art at Leirfall	Alpine Towers	University of the Crafts
02.2018–06.2018 Stjørdal, Norway	02.2019–06.2019 Schaan, Liechtenstein	02.2020–08.2020 Landgraaf, The Netherlands

All participating students worked on the same topic in our design studios. Each of the three project partners was responsible for the content and organization of one design task, which was then carried out jointly. By choosing wood as the main material, we clearly focused on regional traditions of timber construction in the three countries. Each country developed its own traditions, crafts and sources that shaped local building methods and specific details. In addition, the sites and topics relate to specific tasks in the three countries. The integrated workshop with a hands-on component enriched the studio projects. The collaboration with lecturers from the three participating universities in the fields of design, construction and structural engineering deepened the studios and offered a wide range of knowledge and experience throughout the whole project.

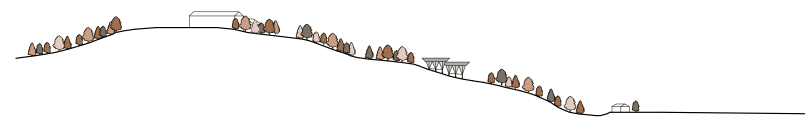
Leirfall in Stjørdal is one of the biggest rock art sites in Norway. There are several groups of carvings on the site, and the largest group is on a rock surface about 22 by 20 metres in area. The carvings mainly date from the late Bronze Age (1800–400 BC in Norway) and consist of geometrical patterns and the representation of footprints and boats. Most well-known, however, is the procession of thirteen human figures arranged in a line. At the head of the procession, a much larger male figure with a pointy face seems to hold a sword. Two of the figures in the procession are carrying something between them. This procession is unique in rock carving sites in Norway, and probably depicts some kind of ritual. The site is a steep slope at the northern edge of a cultivated field, where you arrive from the flat river valley. It is open to the public and guides can be arranged on a daily basis during the summer months. From October to May the rock surface is covered with thick carpets to protect the carvings.

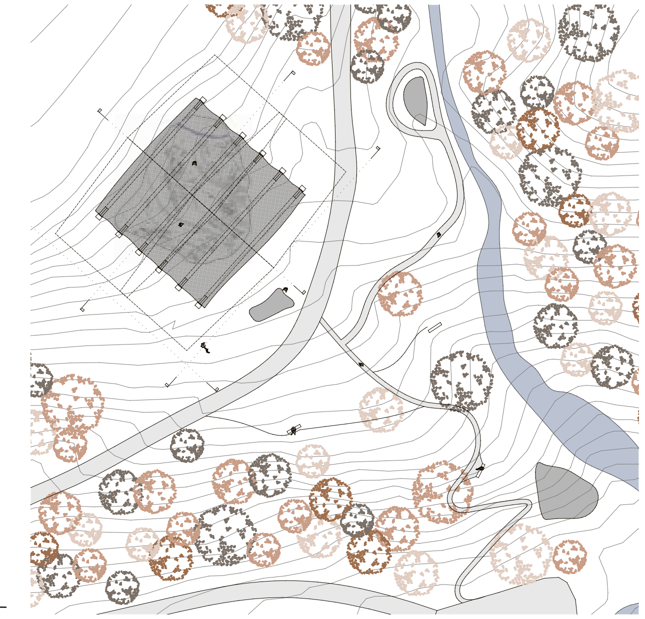
The rock carvings were discovered in the early 19th century and are already showing signs of erosion and damage. If they are not physically protected, they will disappear within a relatively short time. The assignment was to design a timber structure that provides shelter for the rock art at Leirfald III.

02.2018–06.2018
Stjørdal, Norway

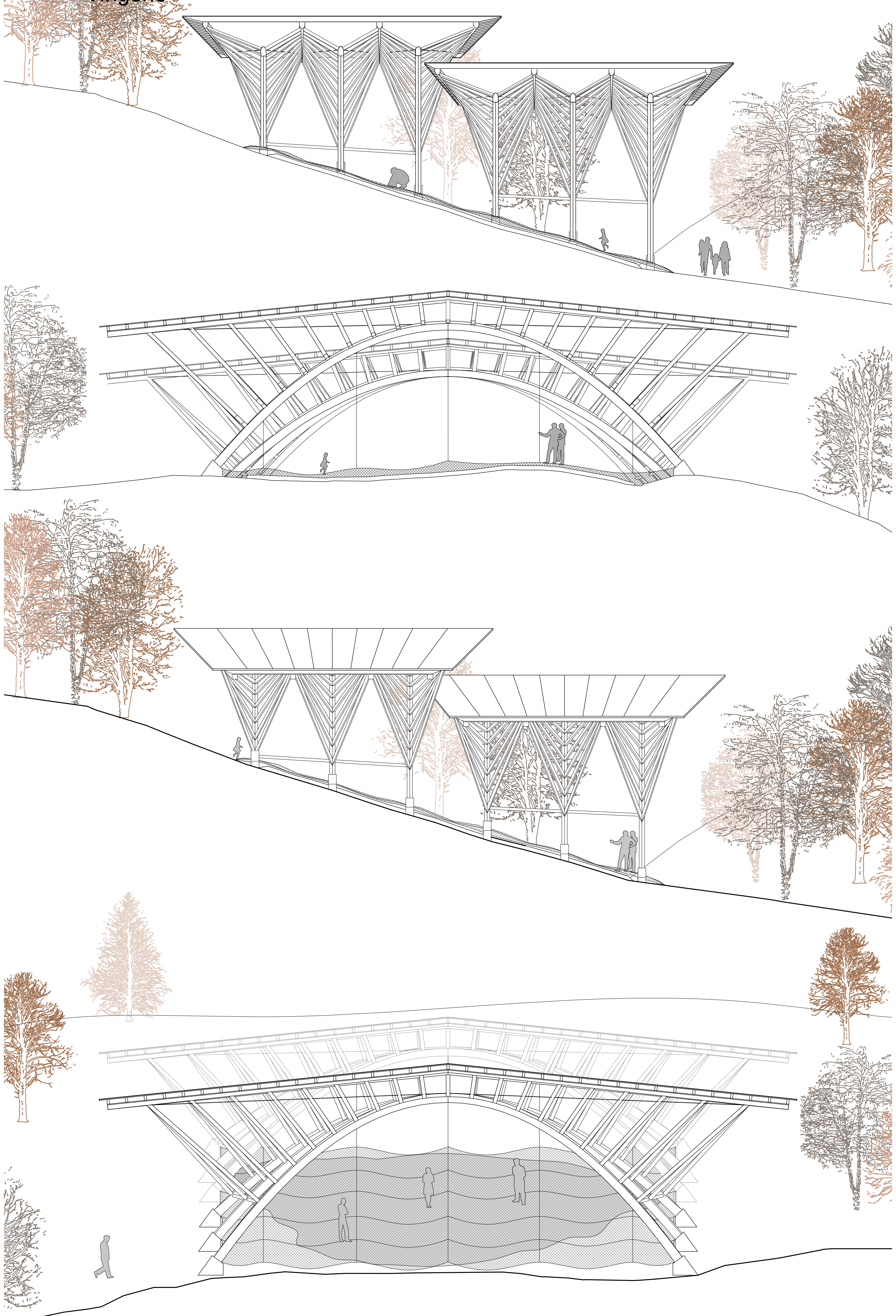
1 Vingene, Constantin Frommelt
2 Felsenshelter, Julia Mair
3 Rock Art Shelter, Lucie Thamas
4 Petroglyph, Michelle Schmidt

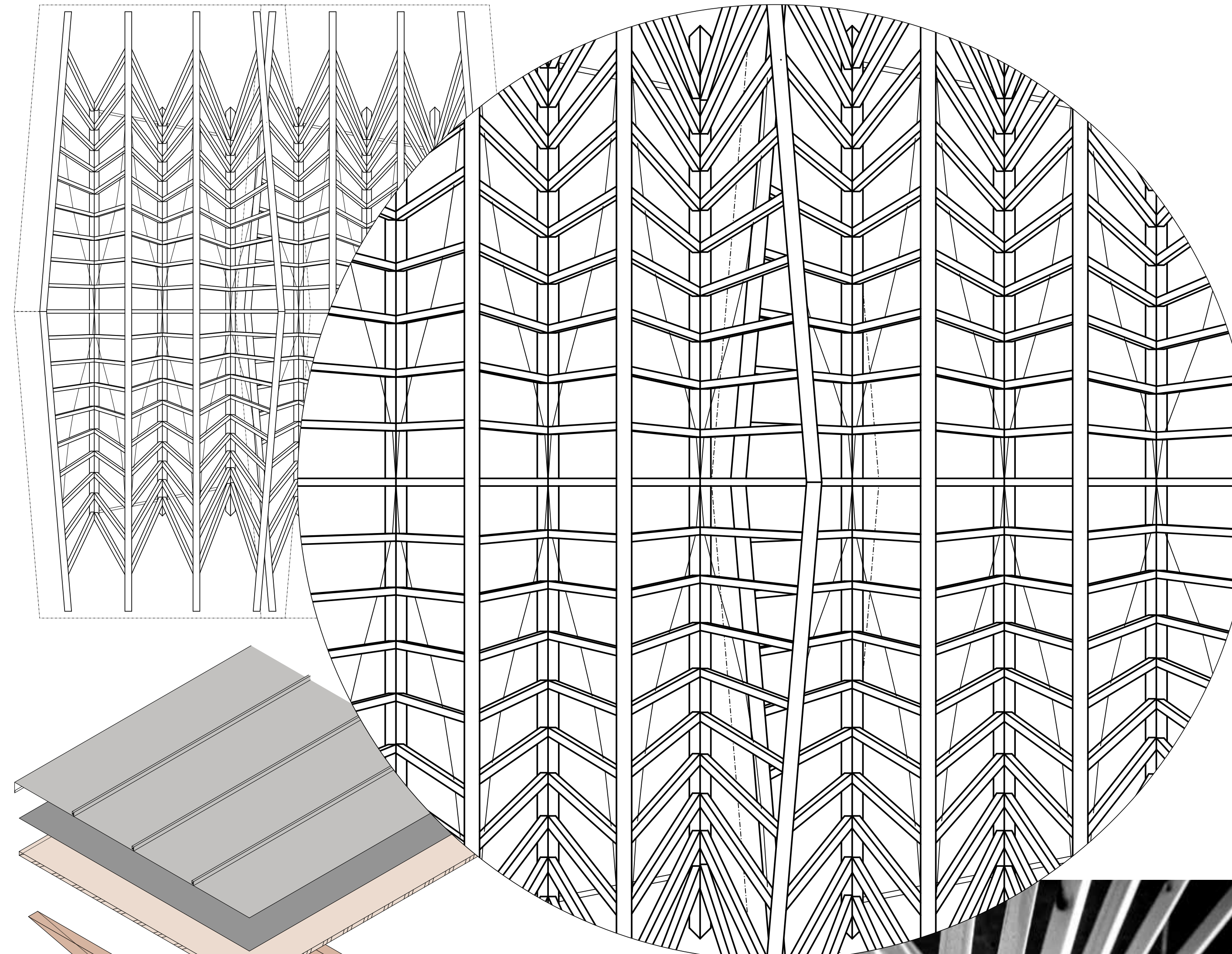
Vingene

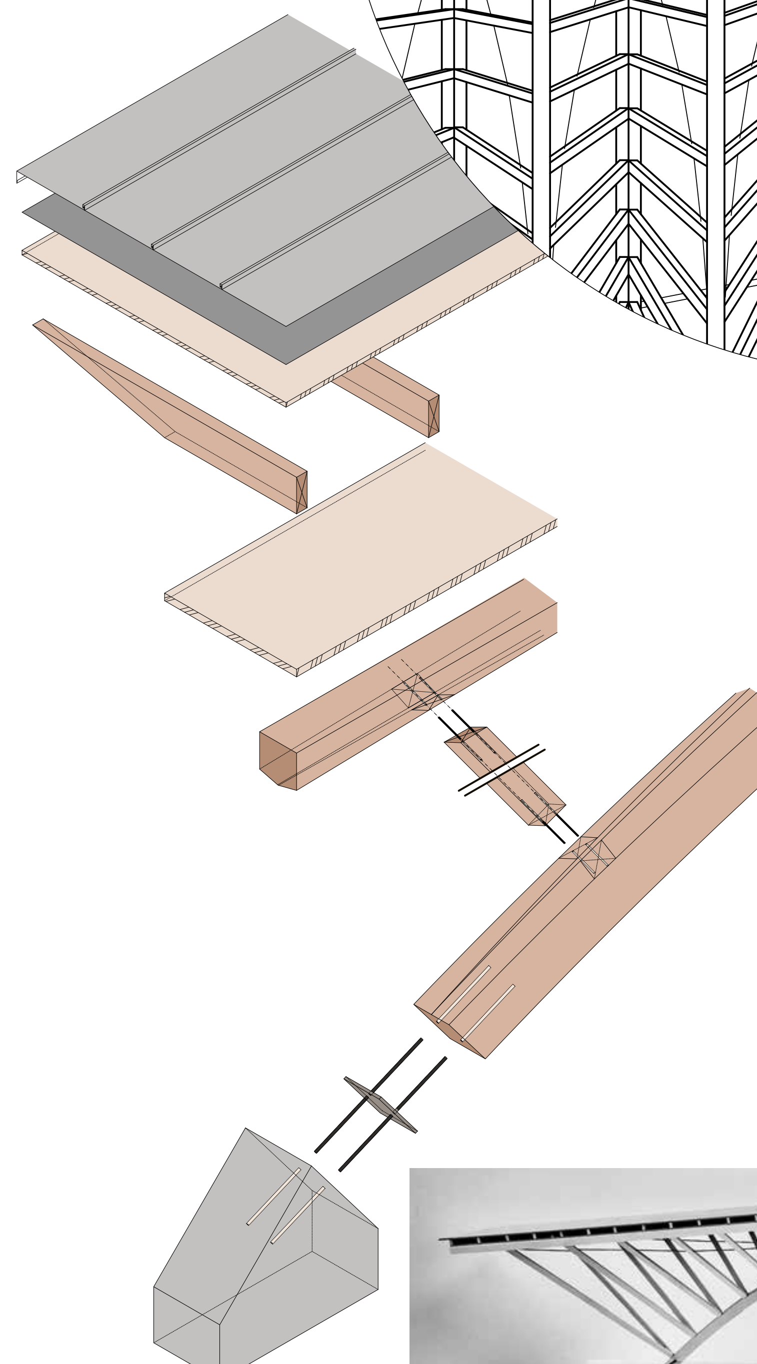


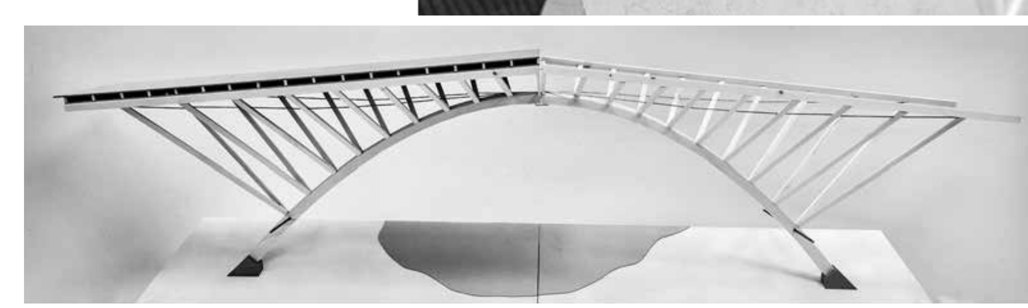


Vingene

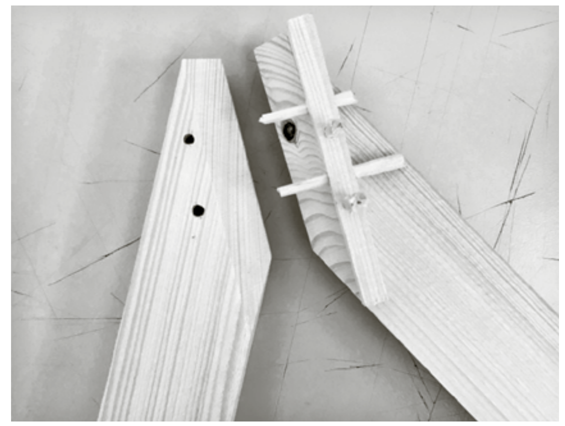


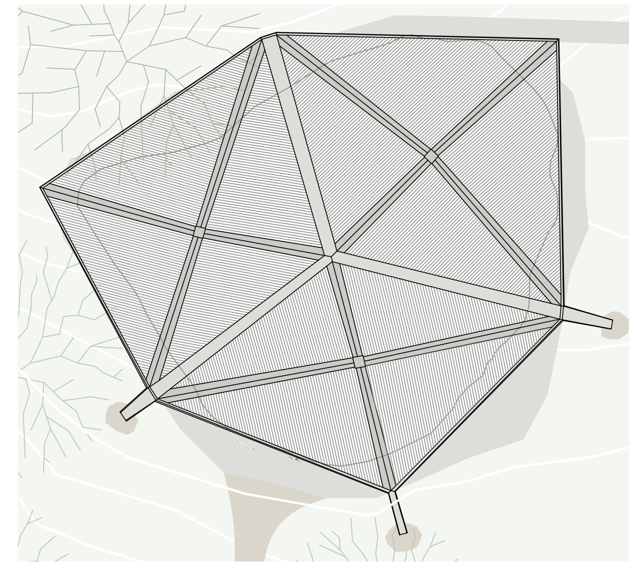


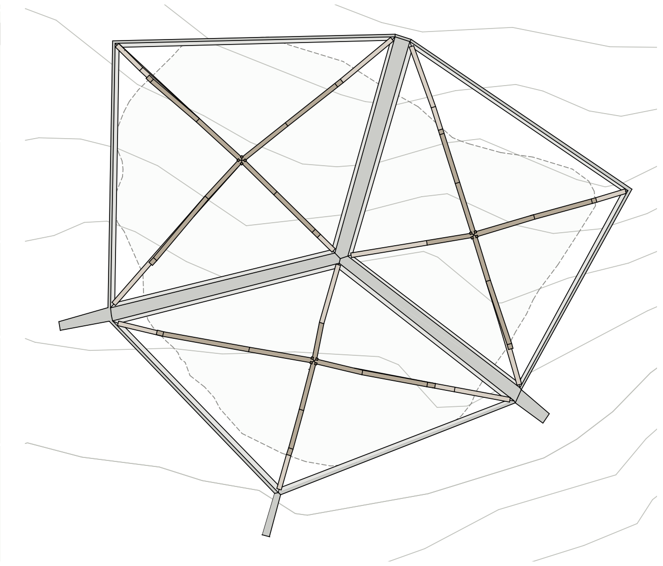


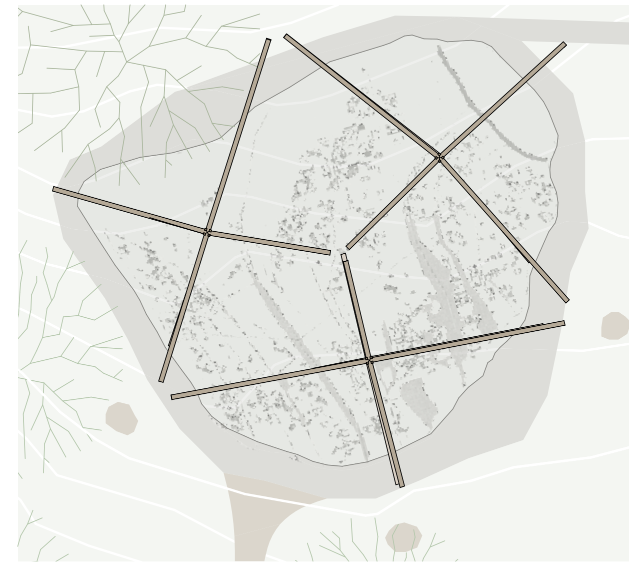


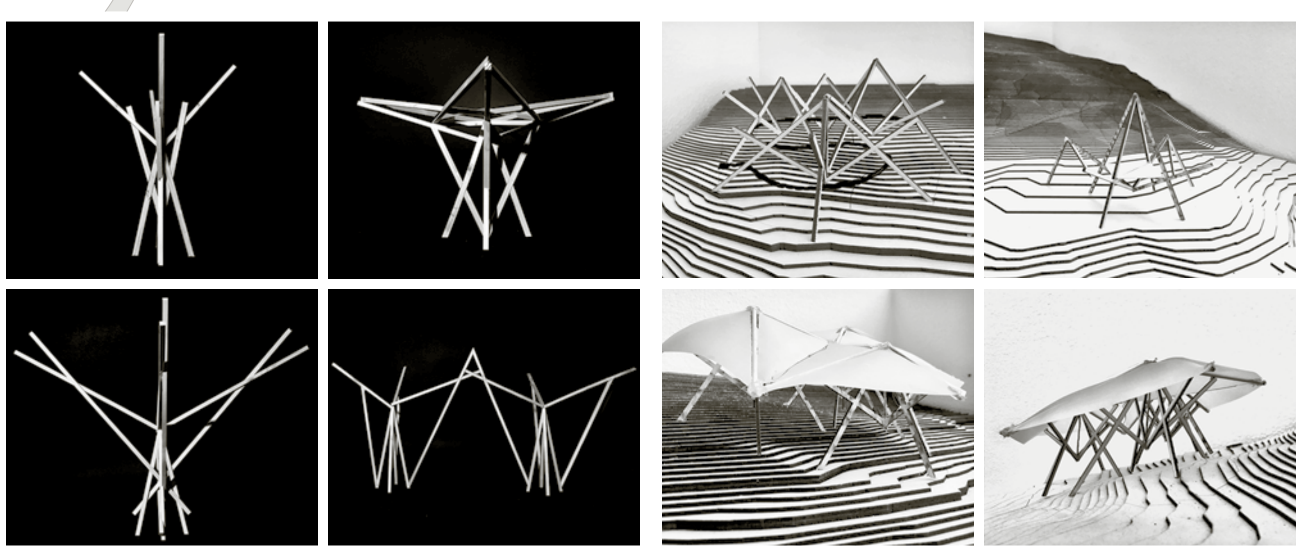
Felsenshelter

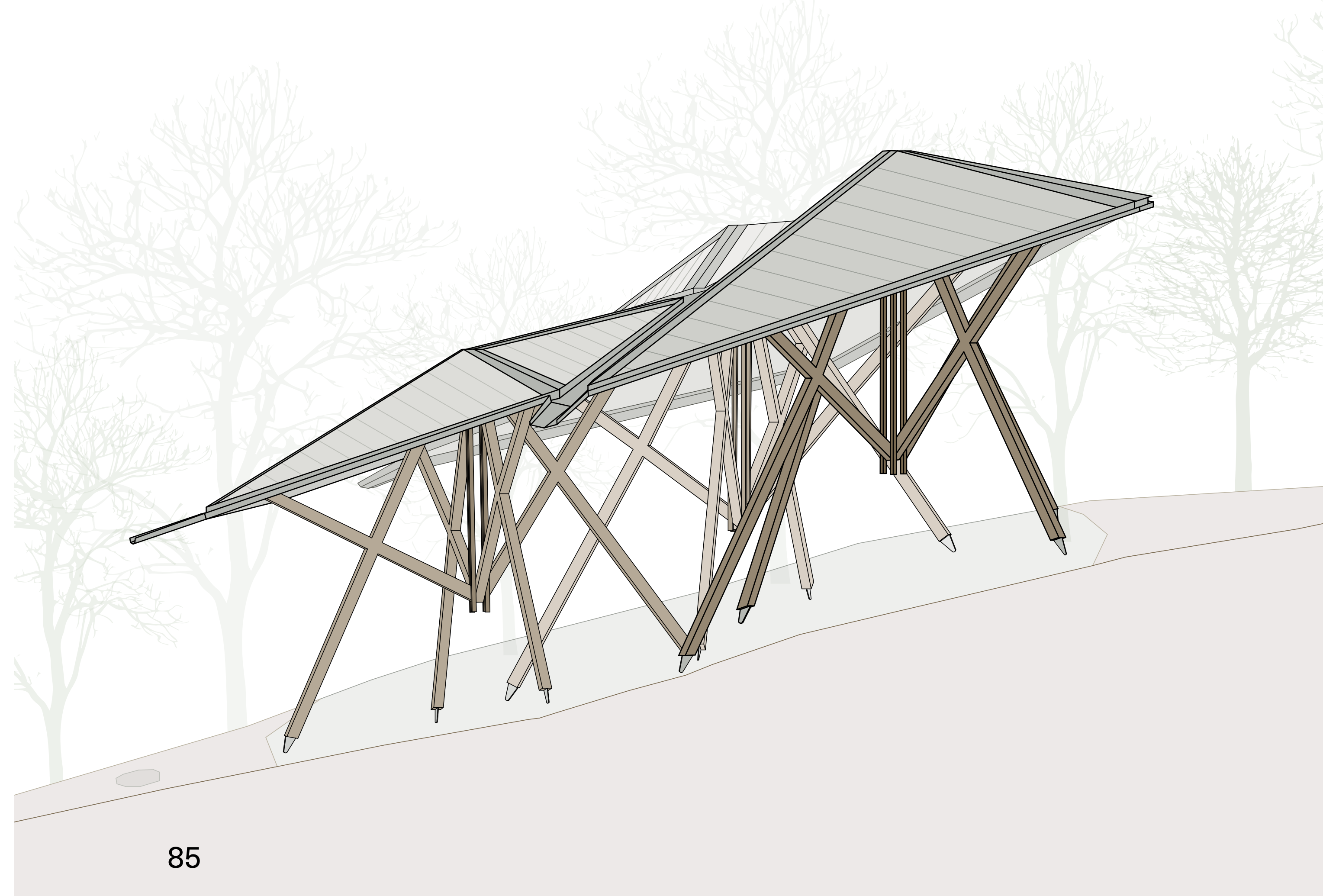




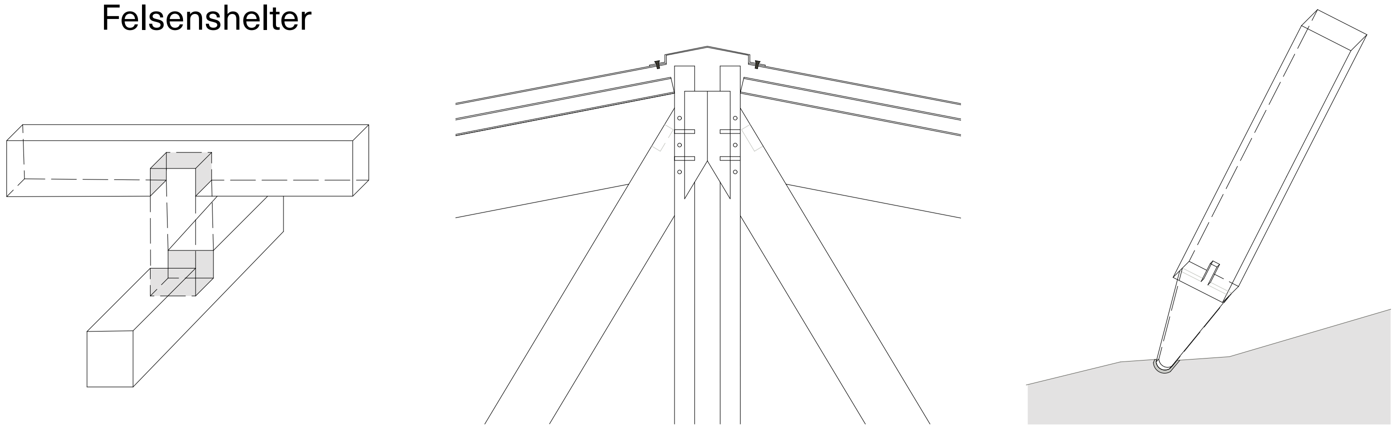


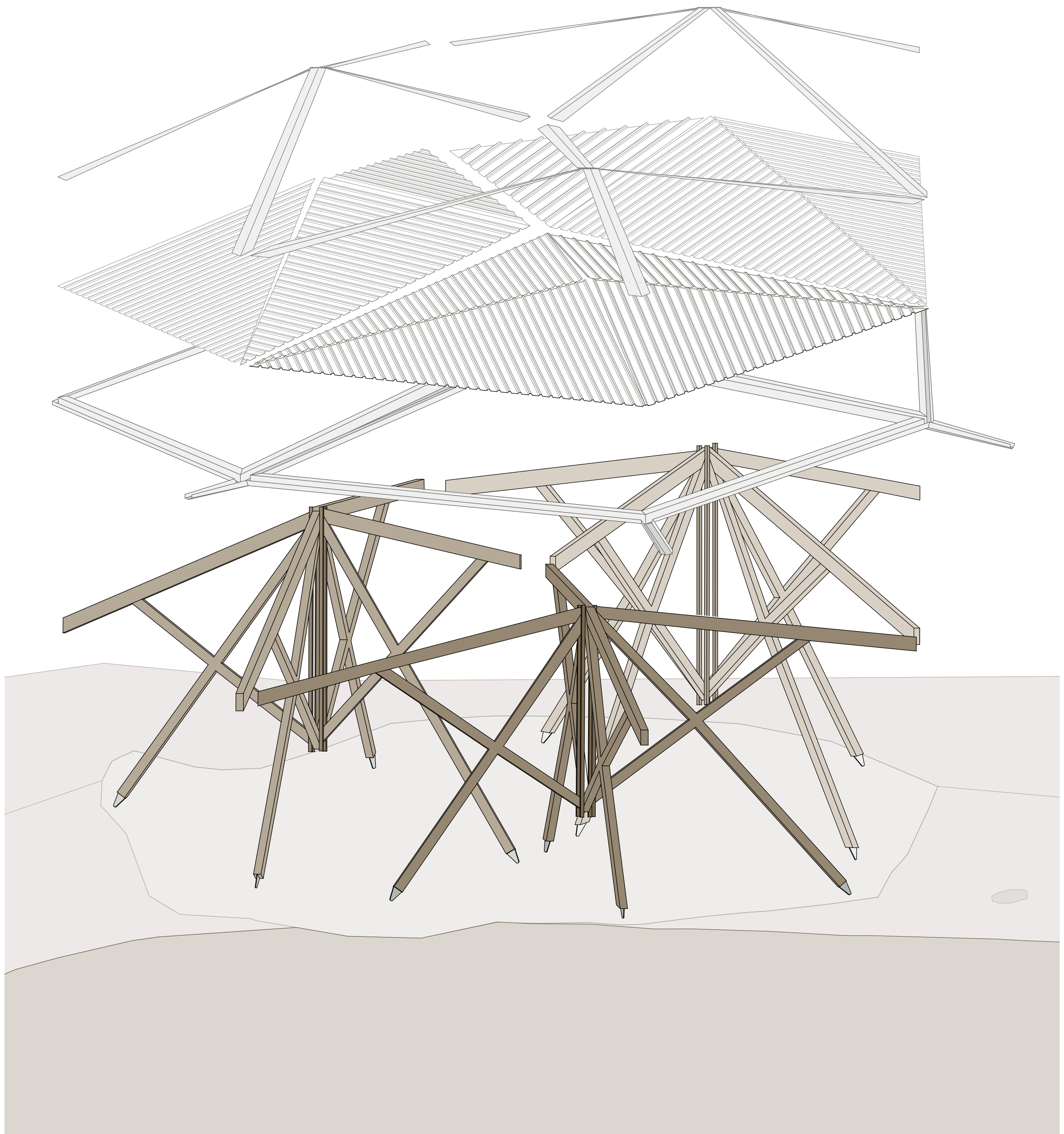




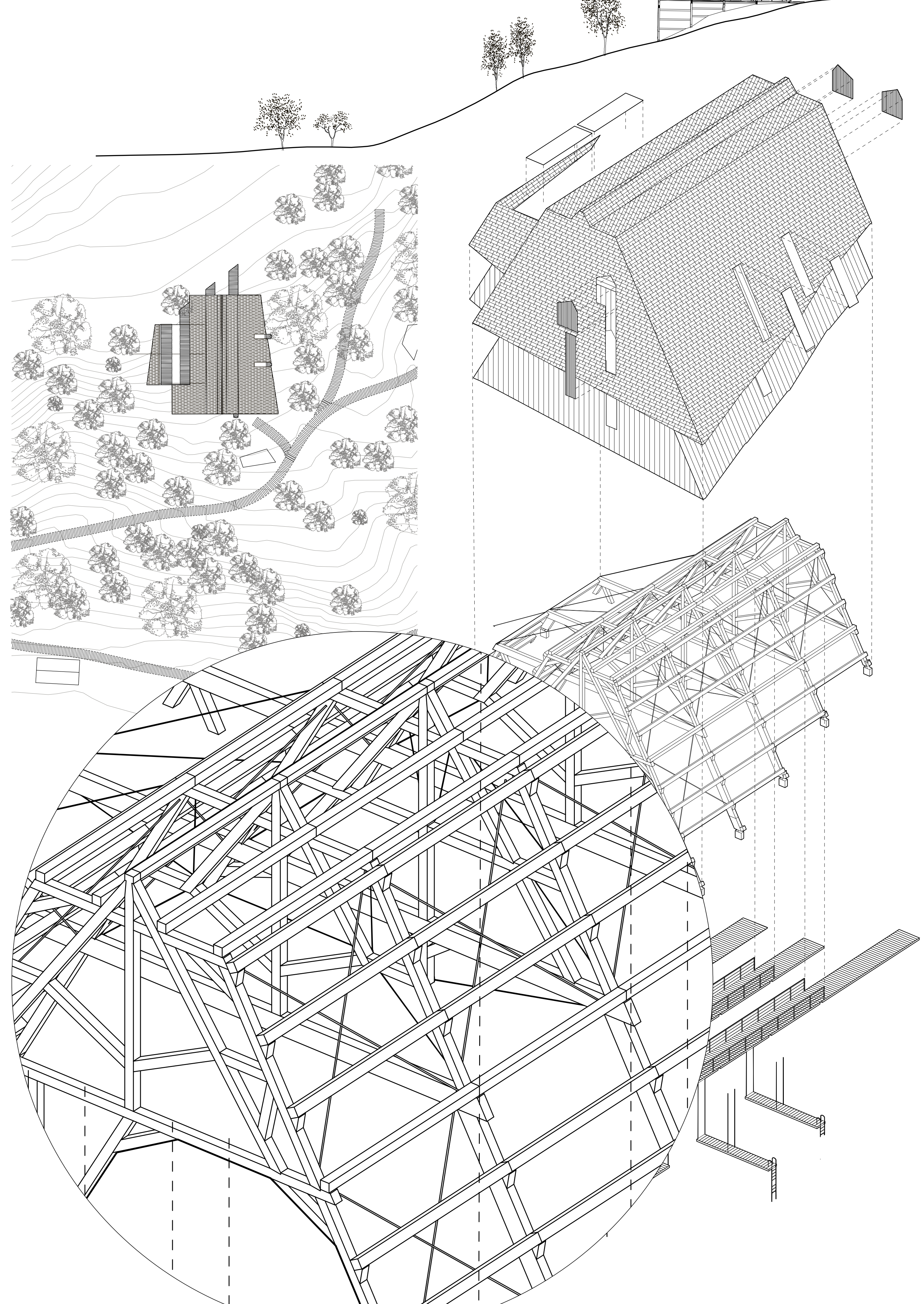


Felsenshelter

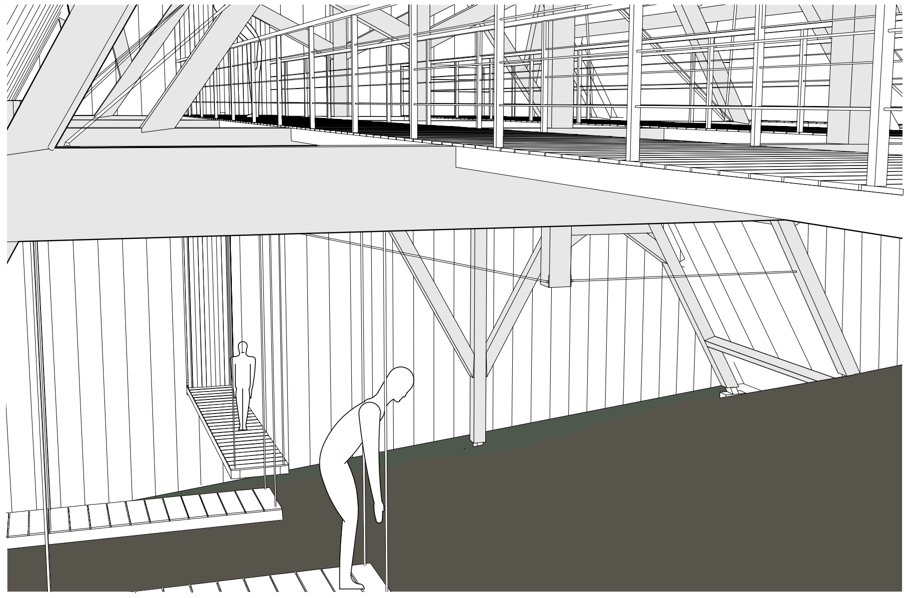


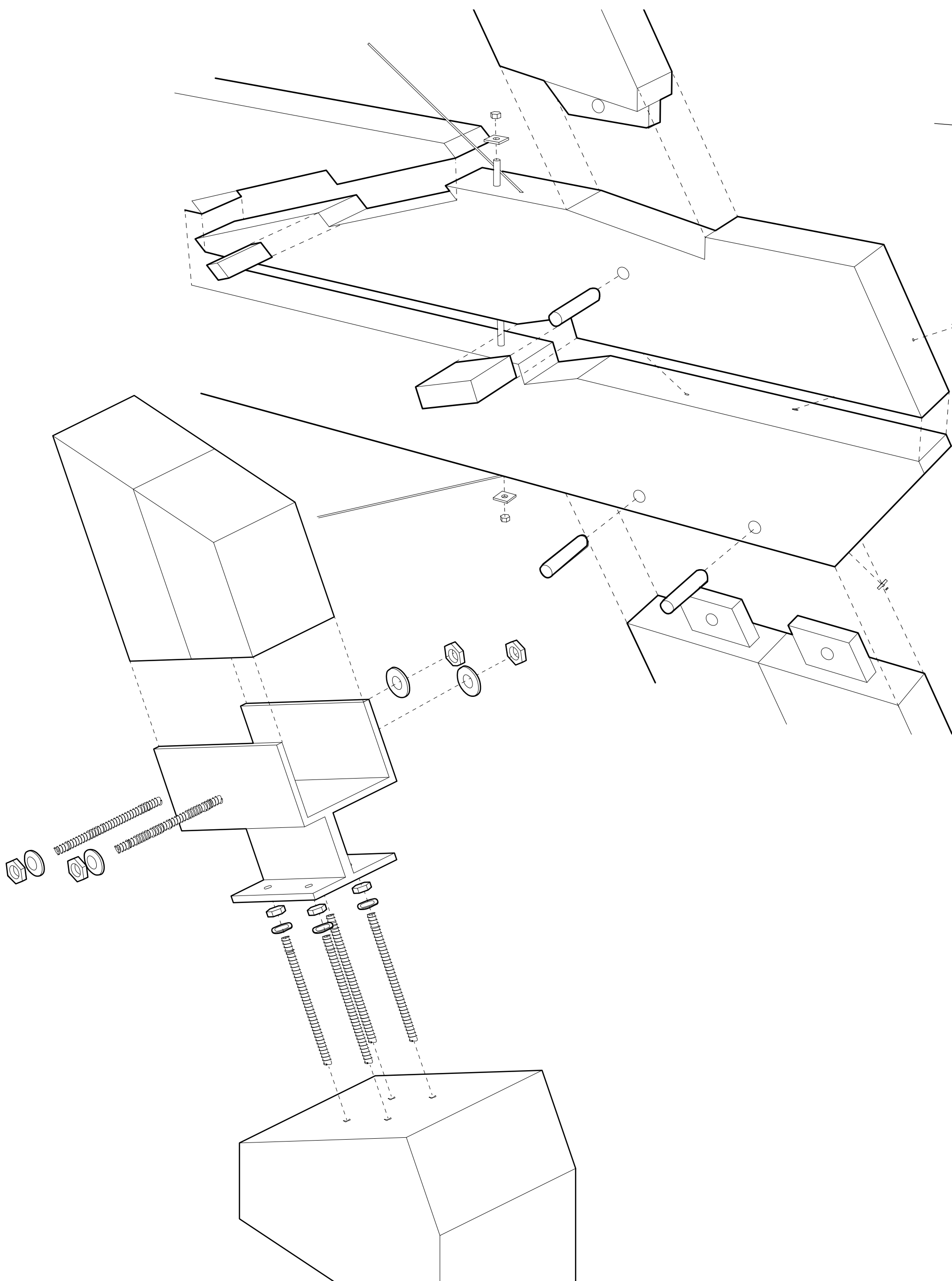


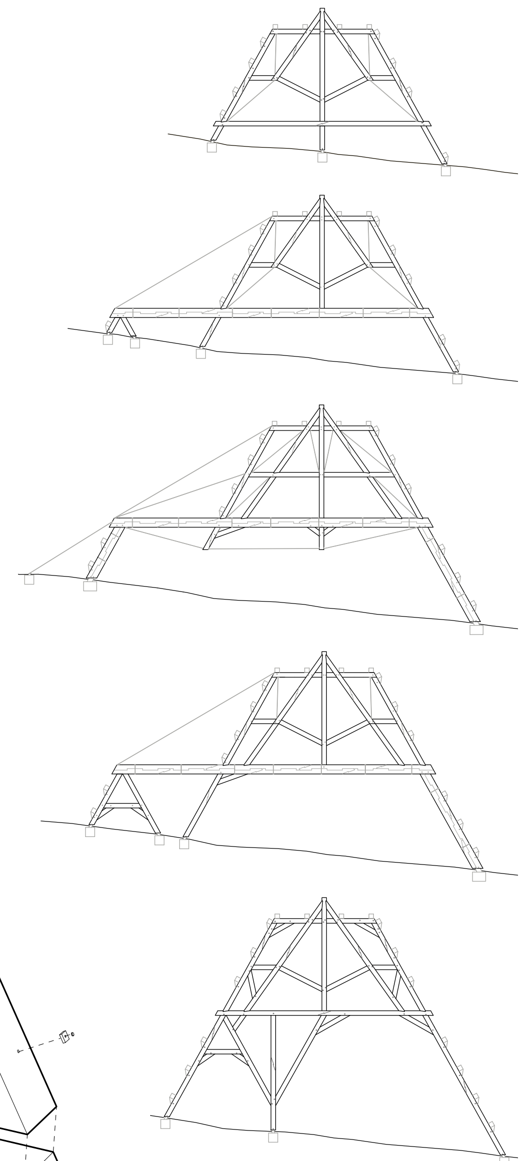
Rock Art Shelter

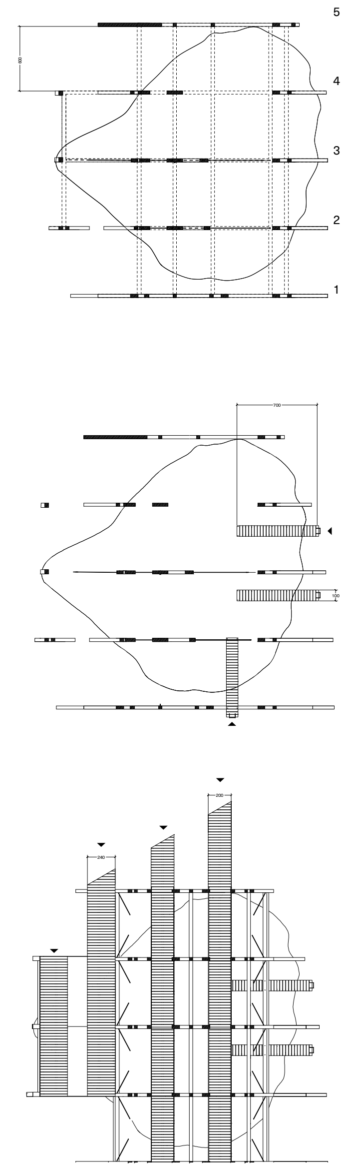


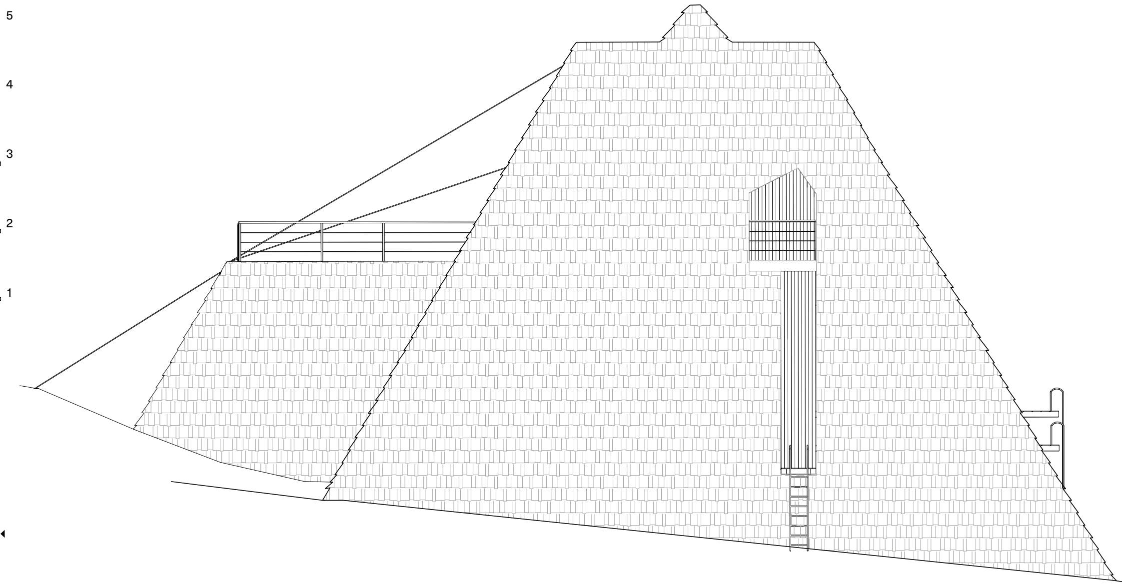
Rock Art Shelter

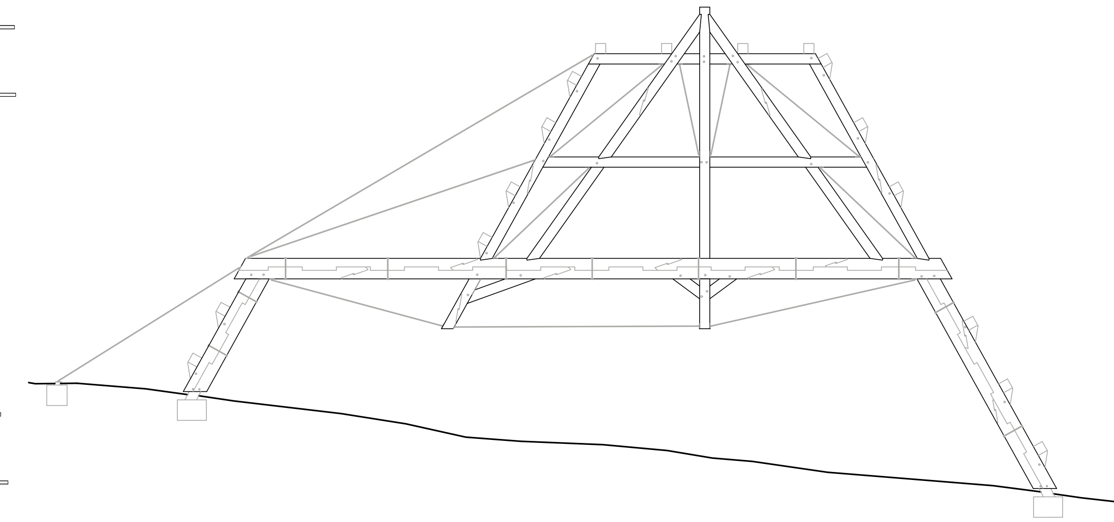


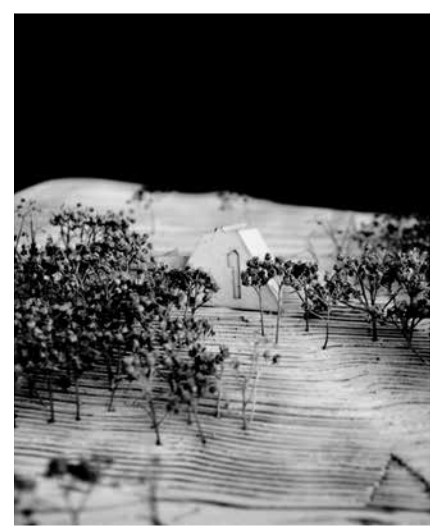


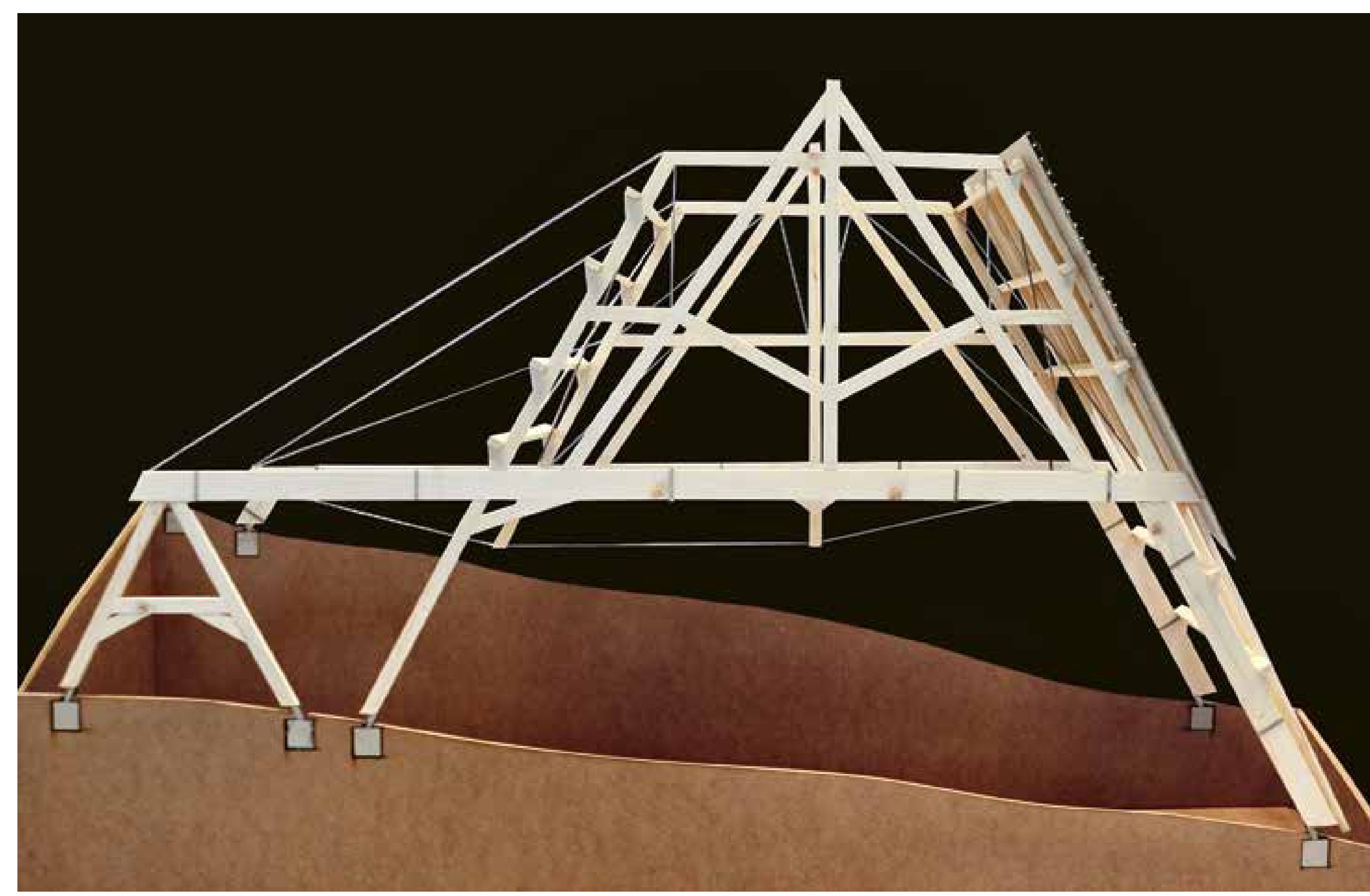




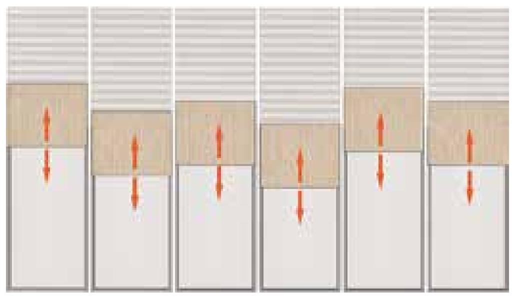


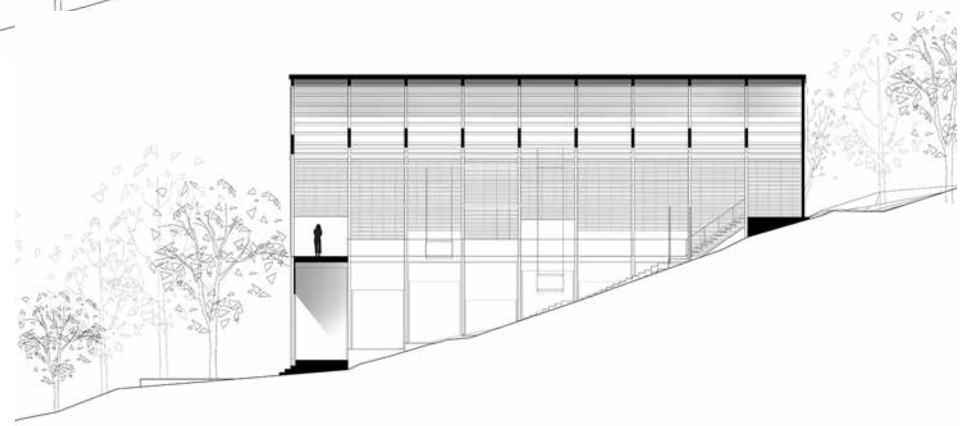


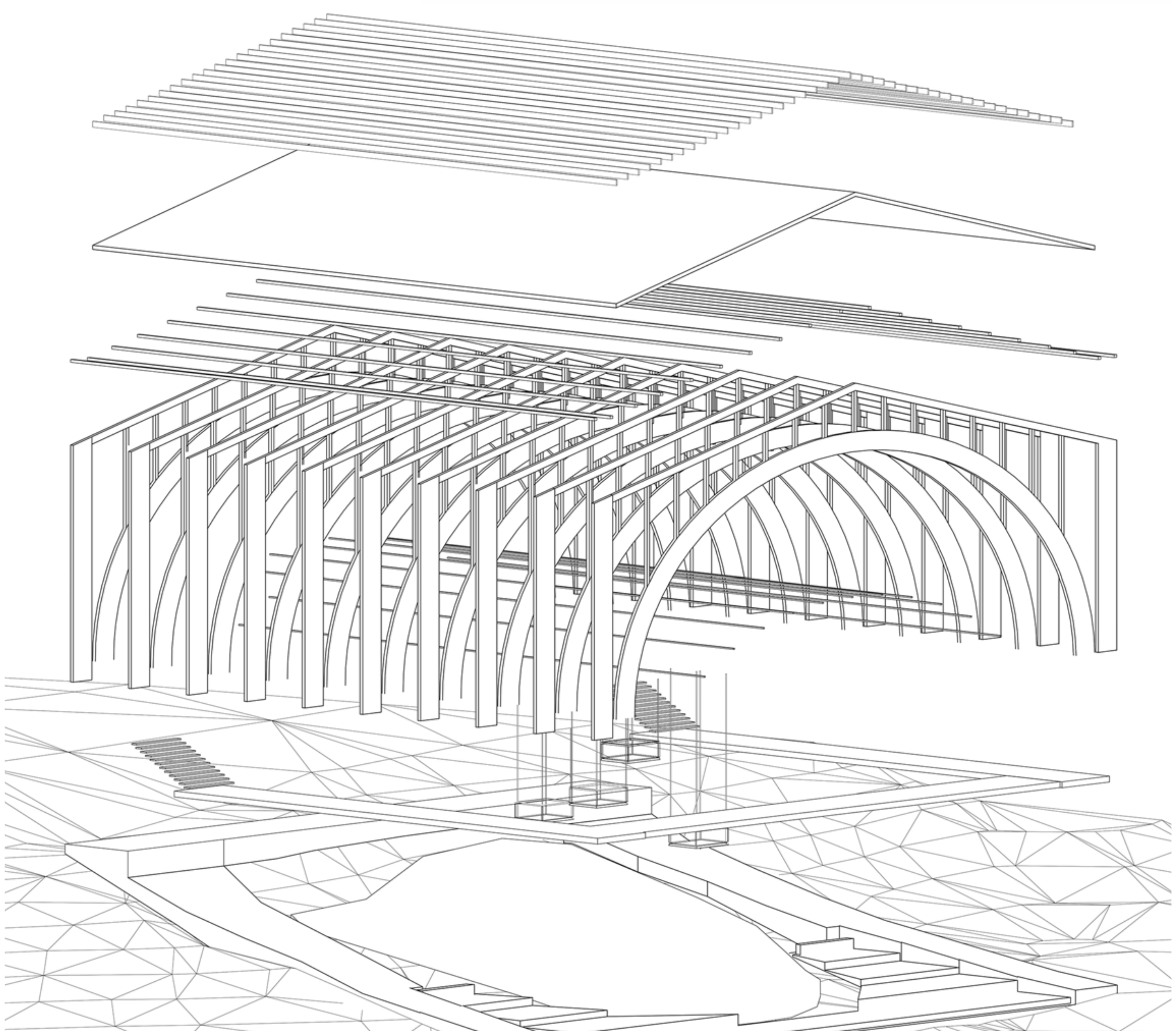


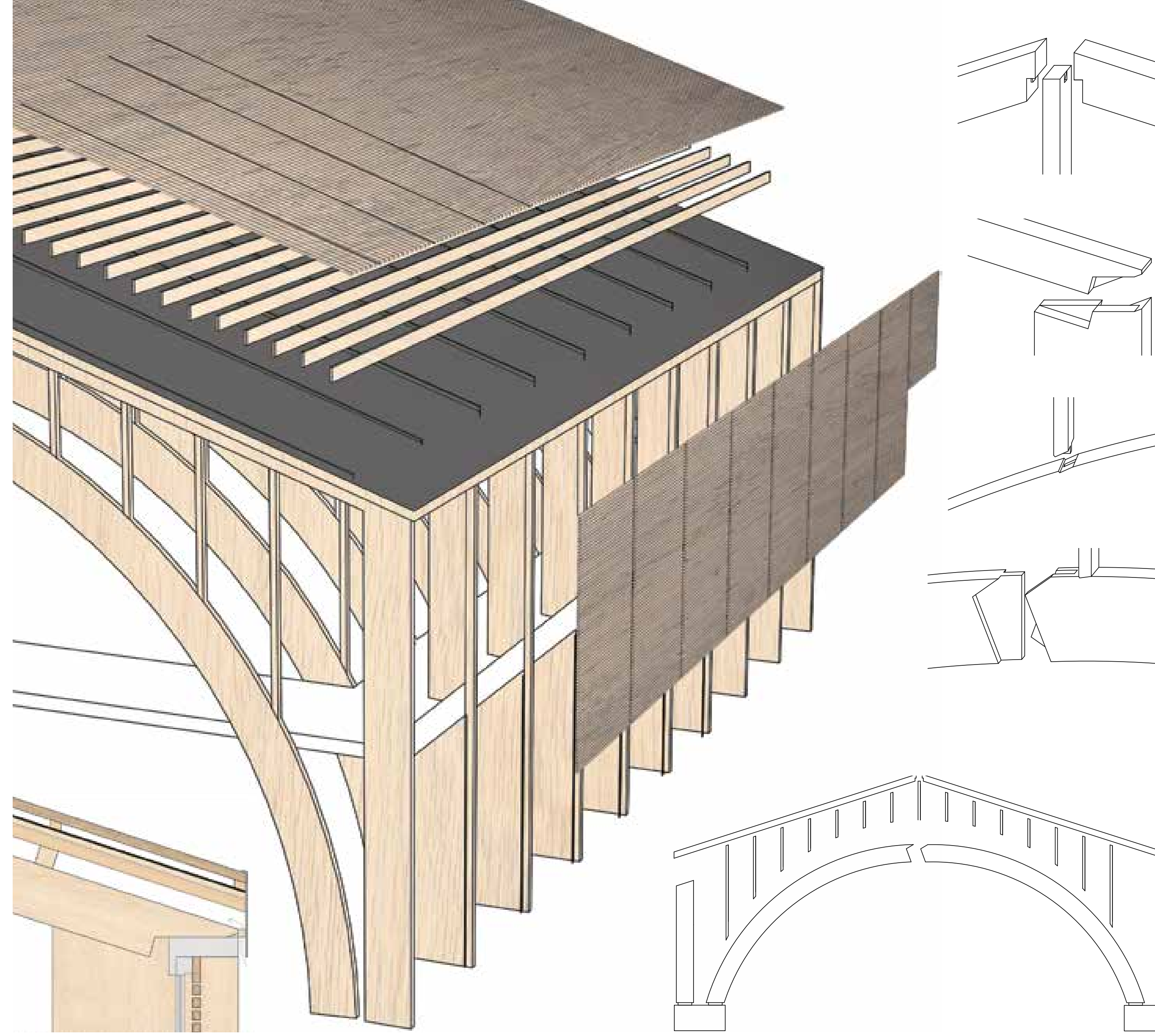


Petroglyph









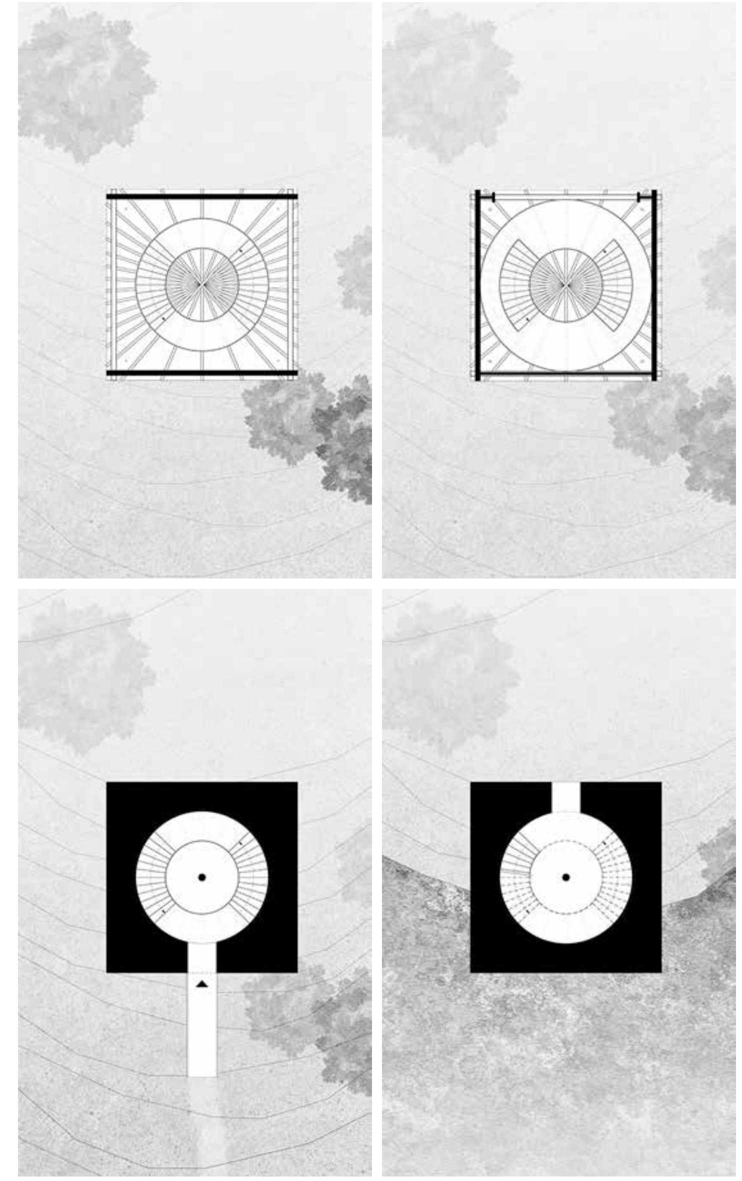
Two wooden observation towers are planned in the forest above Schaan. Wood is the obvious material for rural buildings, especially for a tower in the forest. The construction will reach a height of about 35 metres, allowing visitors to enjoy a view over the treetops. The careful connection to the existing paths and surrounding area is also part of the project. Wood occupies a central position in the alpine building culture of recent centuries, particularly in the region of the Rhine Valley. Students analysed this culture. The tradition of timber bridges by the Grubenmann carpentry dynasty from Appenzell in the 18th century and the later translation of the typology of the covered timber bridge into the efficient framework system of Howe in the Vaduz-Sevelen Bridge across the Rhine are just as much part of the investigation as the construction of the Norwegian stave churches and the suspended column structures of Eastern European bell towers.

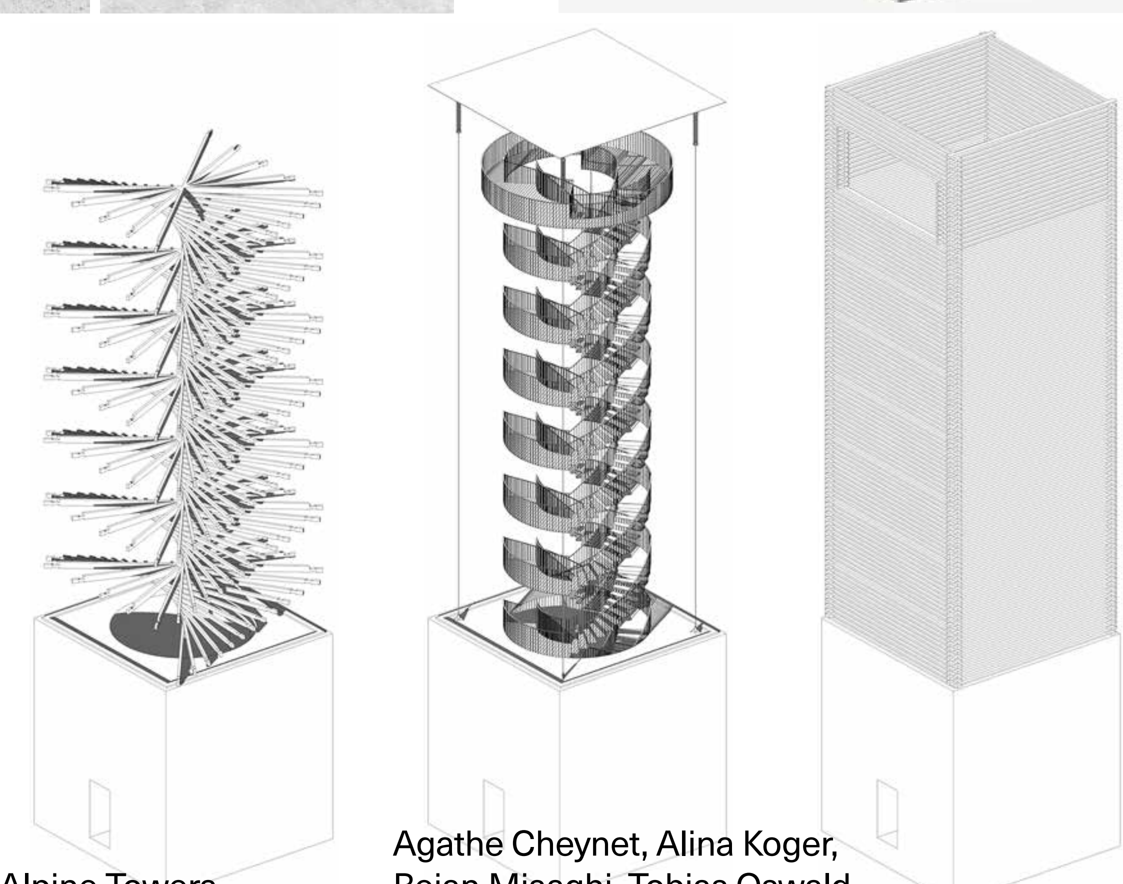
Against the backdrop of the discussion about sufficiency and creation of regional value, we are interested in the tectonic properties of the solid material and its intrinsic suitability for tectonic elements. The joining of individual parts regains enormous significance. Modern mechanical processes can create timber connections that were previously made by hand. The use of locally grown hardwood also adds new themes. In the interplay between traditional knowledge and modern technology, a new 'hybrid timber construction' is postulated, lending new meaning to the classic theme of carrying loads. The conception of a handcrafted timber structure, developed for modern production techniques, should offer an alternative to standardized, industrially produced timber structures. Thus, 'archaic' and 'advanced' techniques are both used to reinterpret the richness of traditional timber with today's manufacturing techniques.

02.2019–06.2019
Schaan, Liechtenstein

5 Spiralis, Agathe Cheynet, Alina Koger, Bejan Misaghi, Tobias Oswald
6 AXXXV, Christian Meier
7 Intertwined, Anne-Roos Demilt
8 Rotation Entgegengesetzt, Gebhard Natter

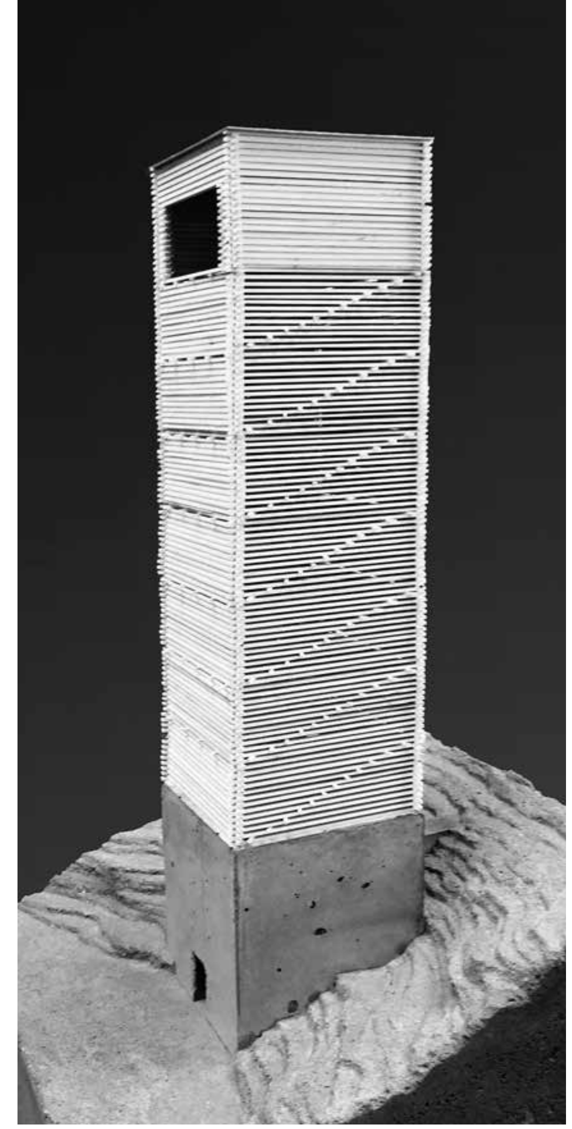
Spiralis

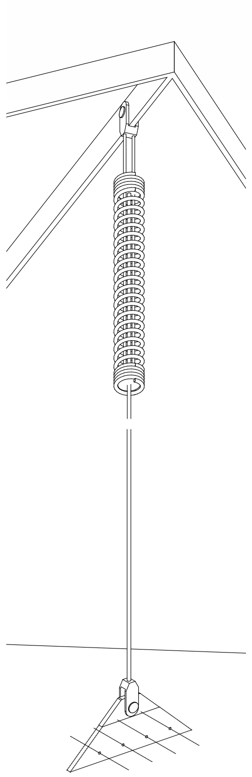


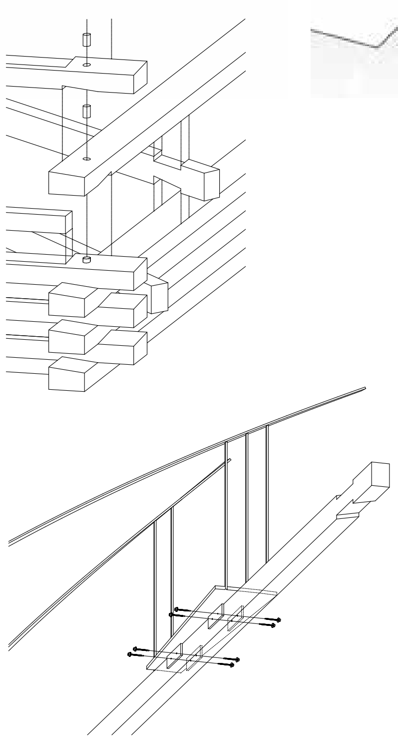


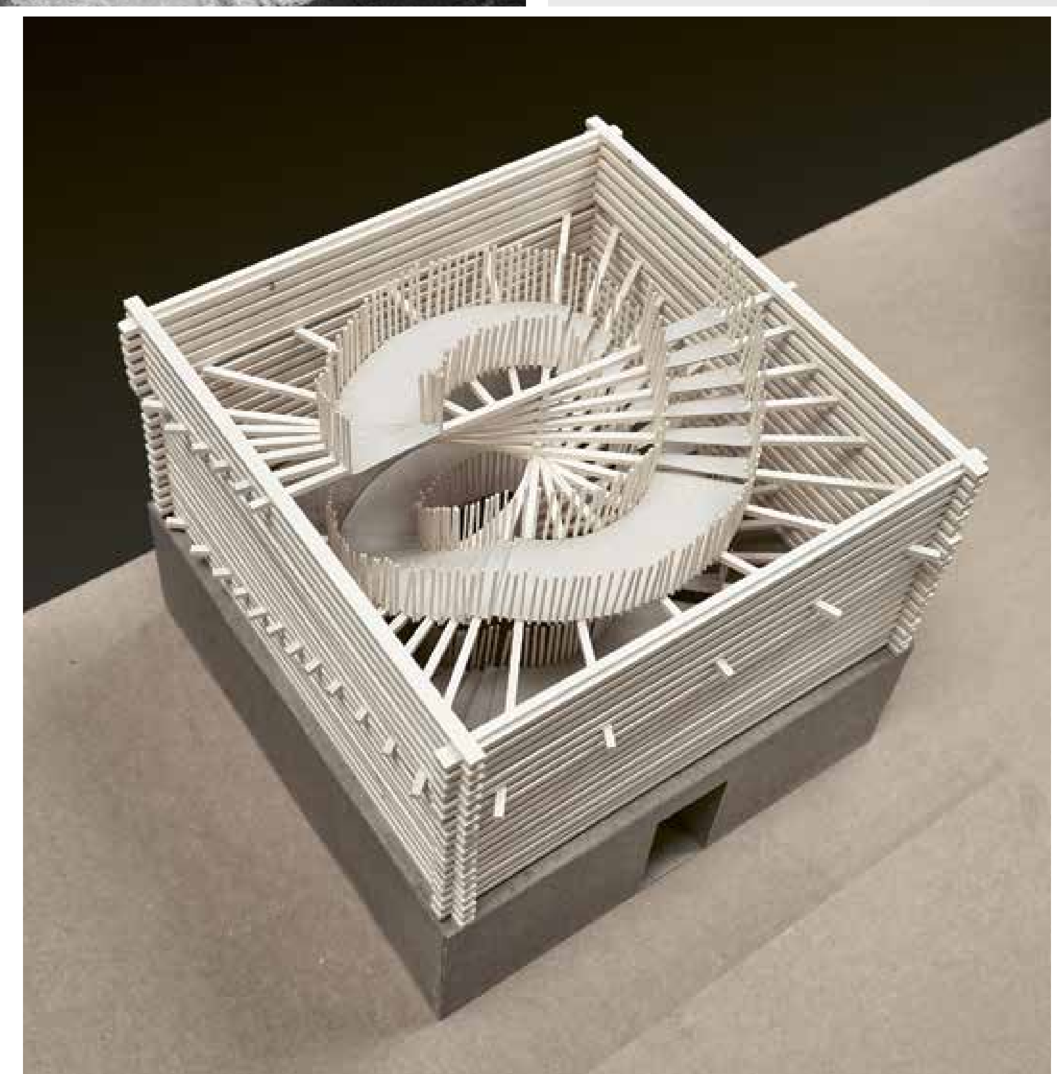
Agathe Cheynet, Alina Koger, Bejan Misaghi, Tobias Oswald

Spiralis



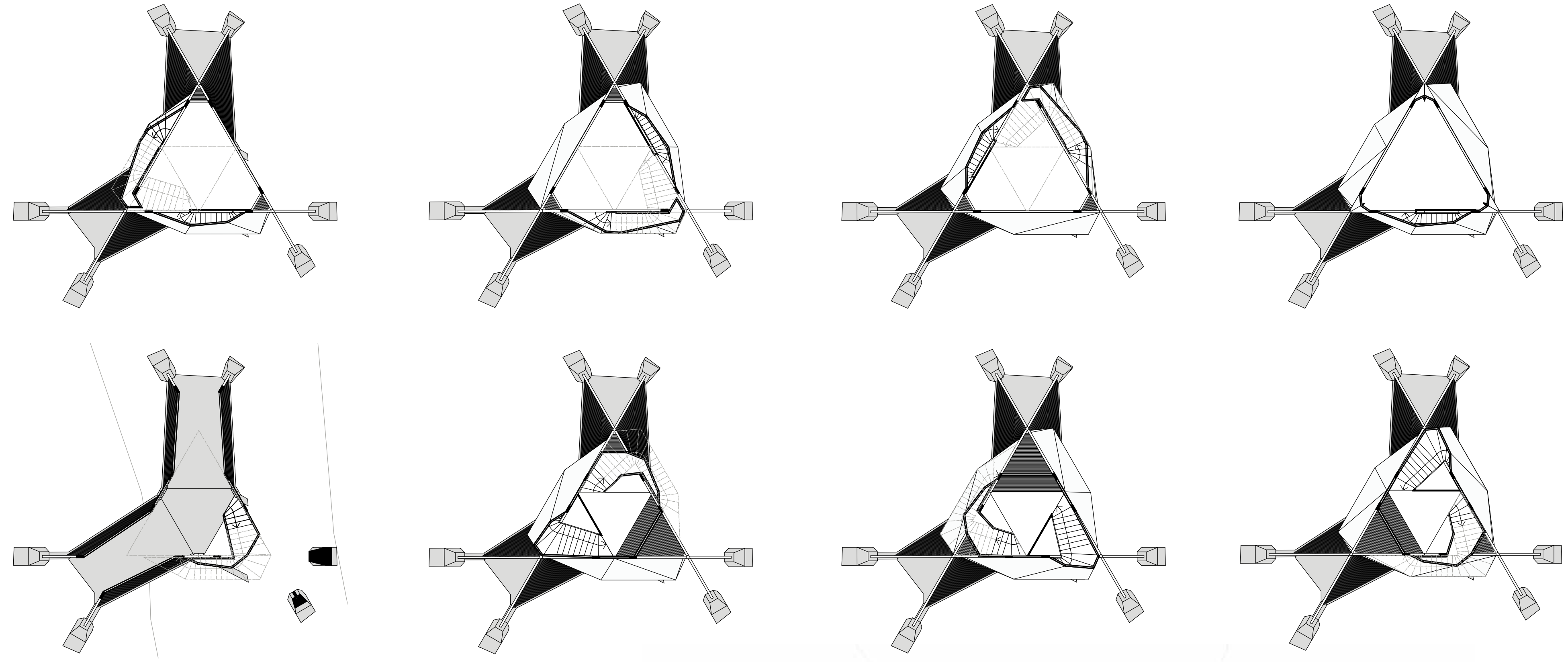


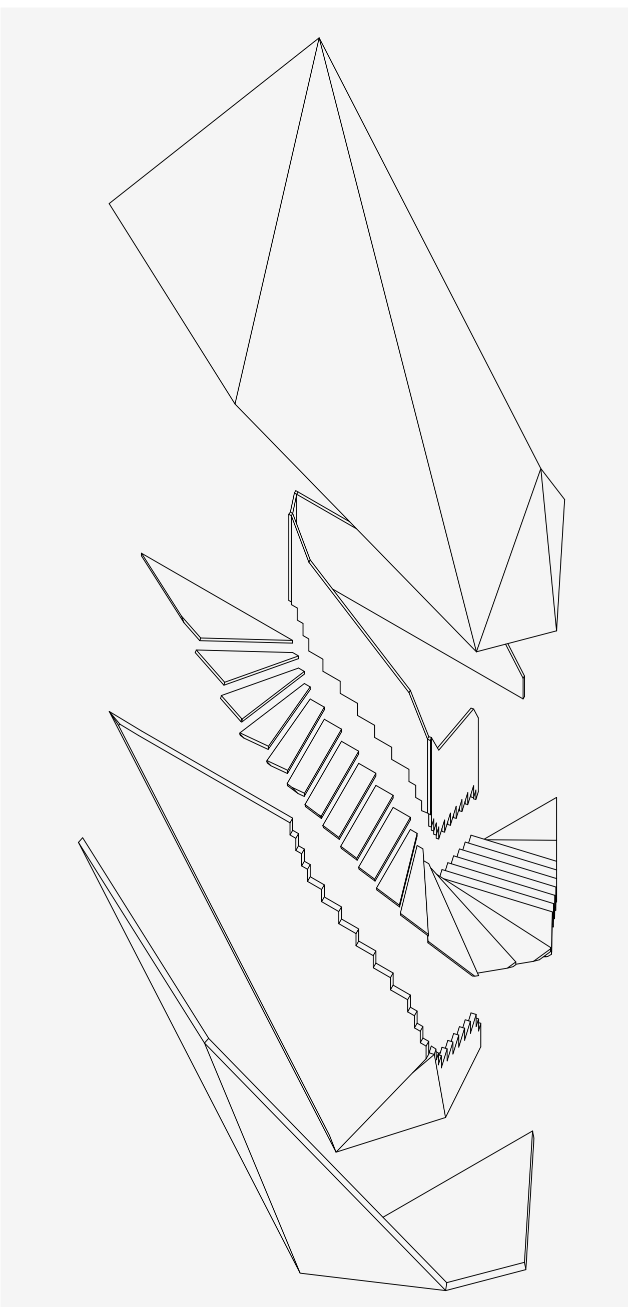


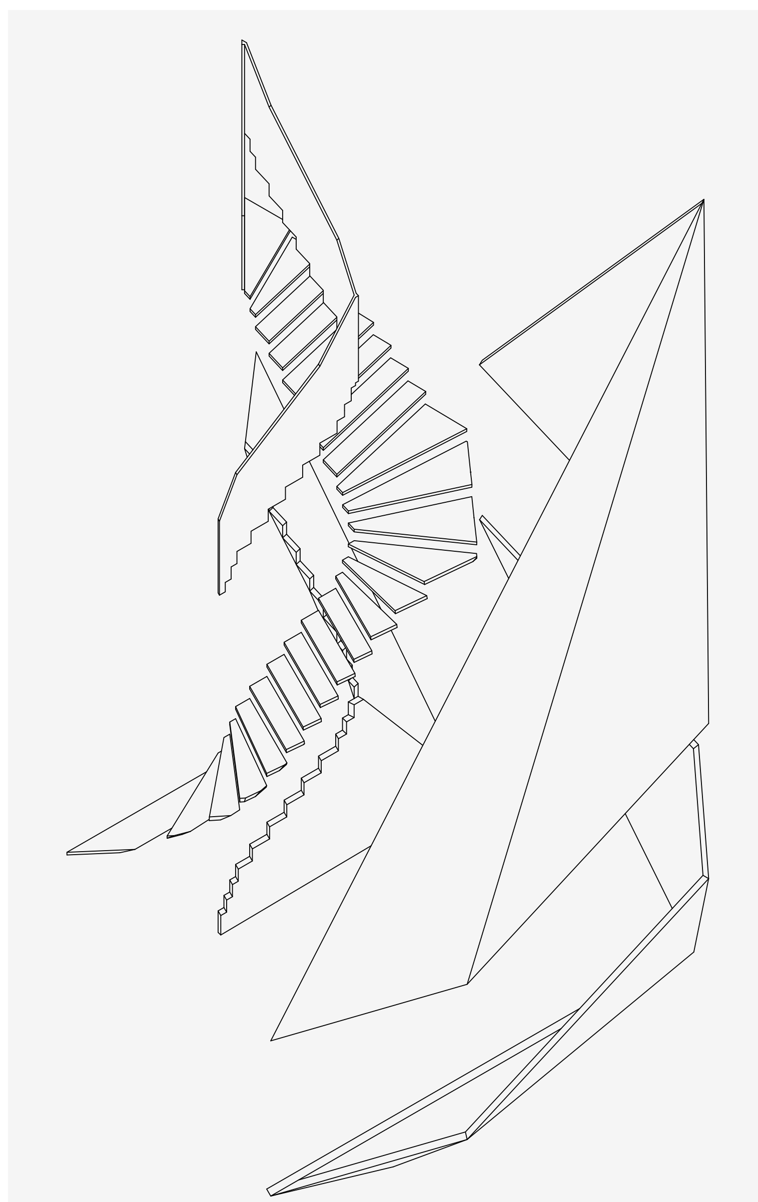


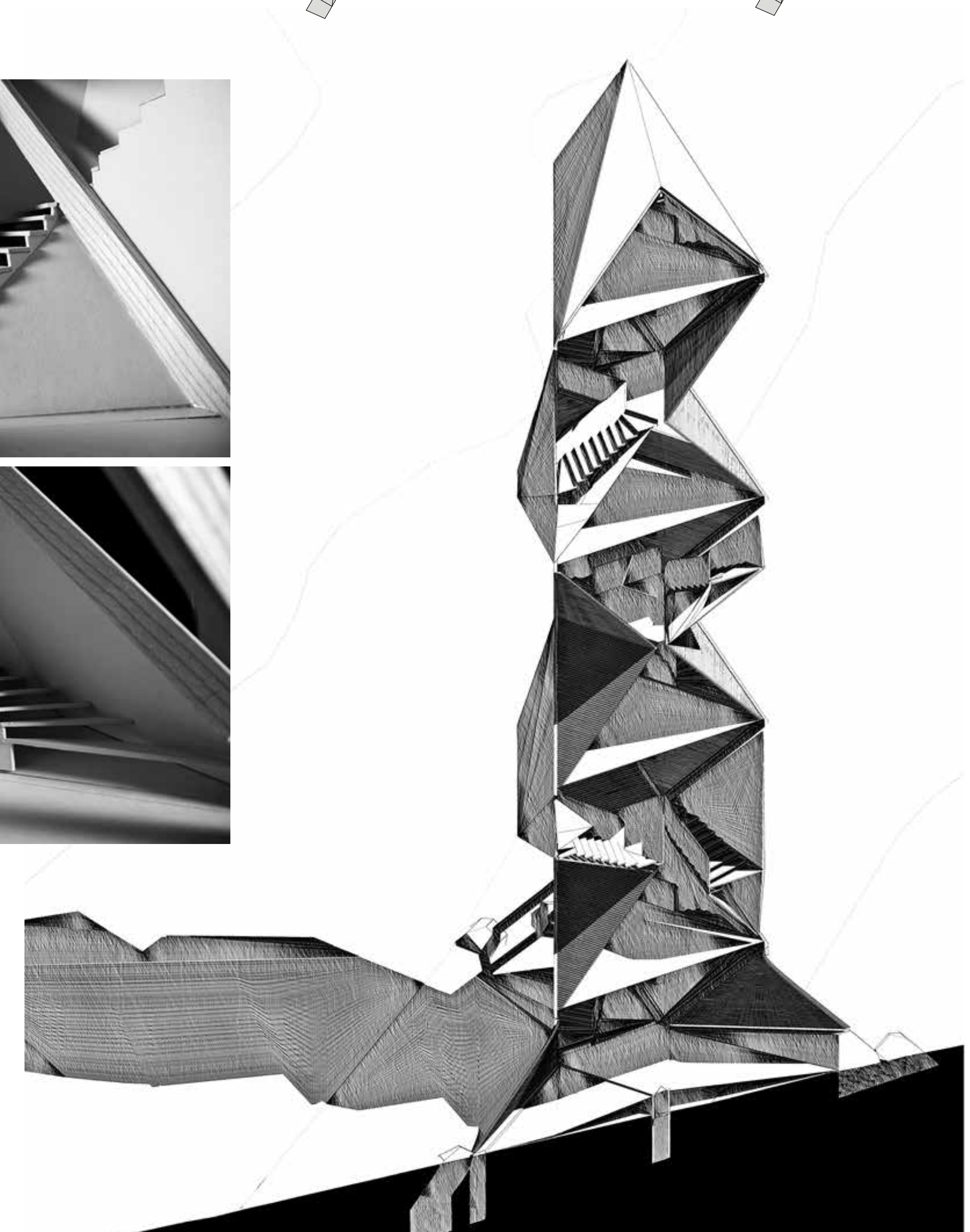
Agathe Cheynet, Alina Koger,
Bejan Misaghi, Tobias Oswald

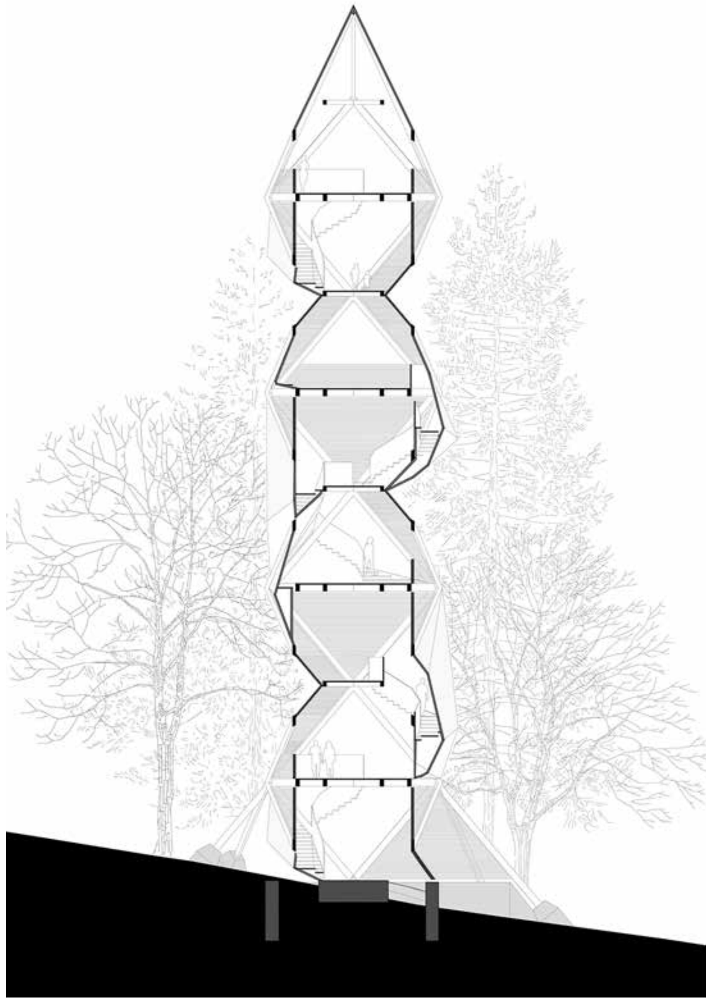
AXXXV

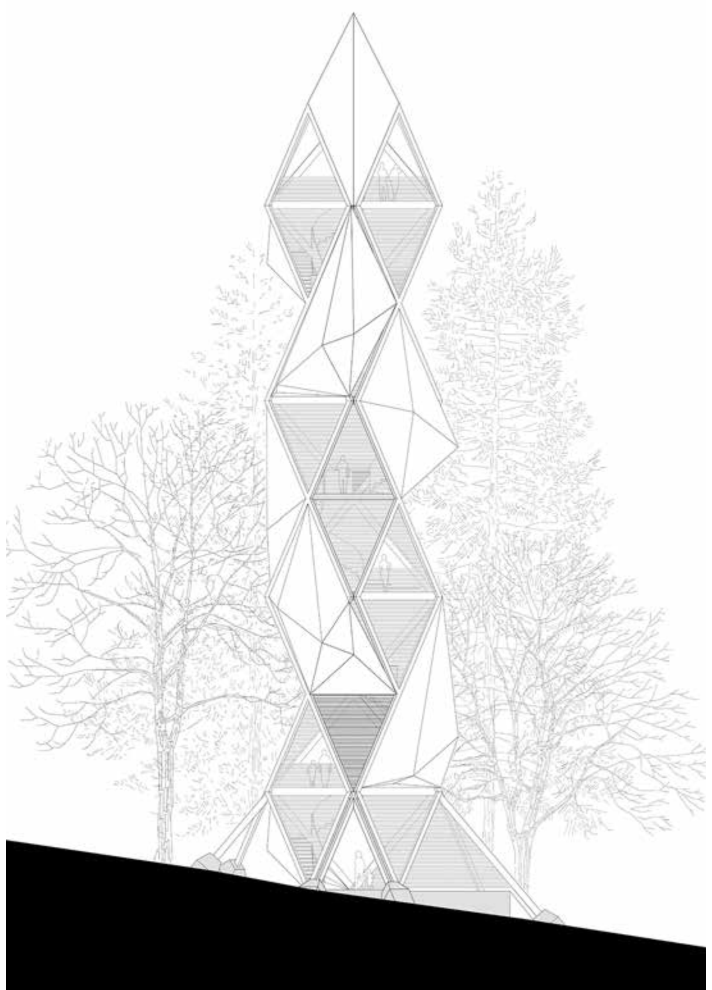


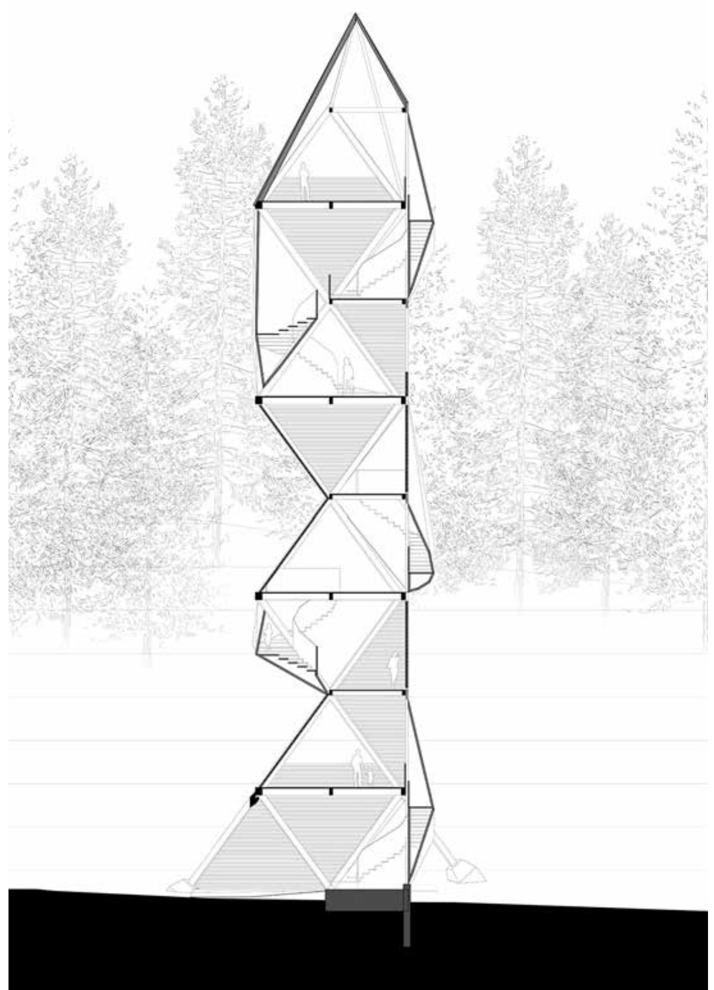




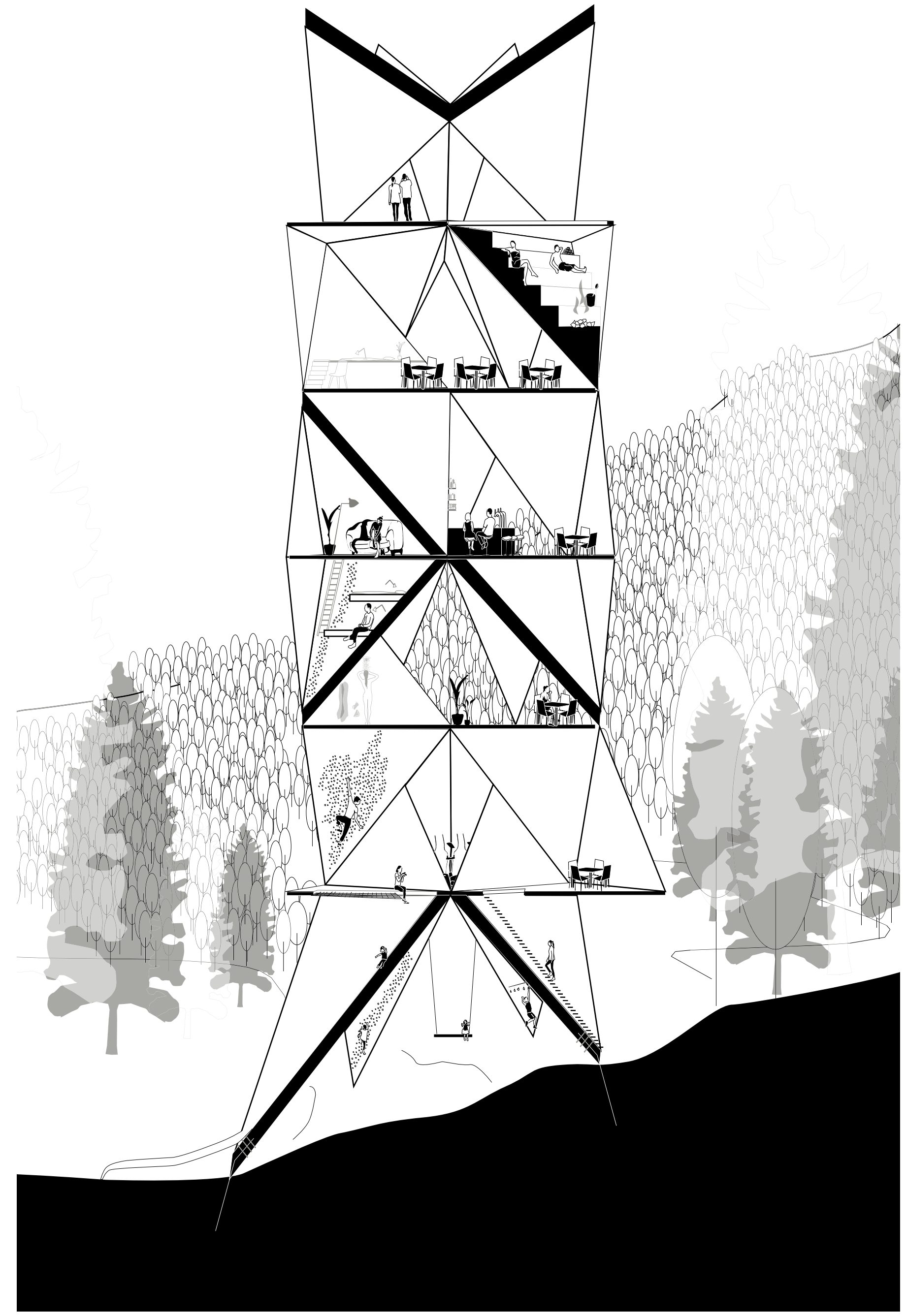


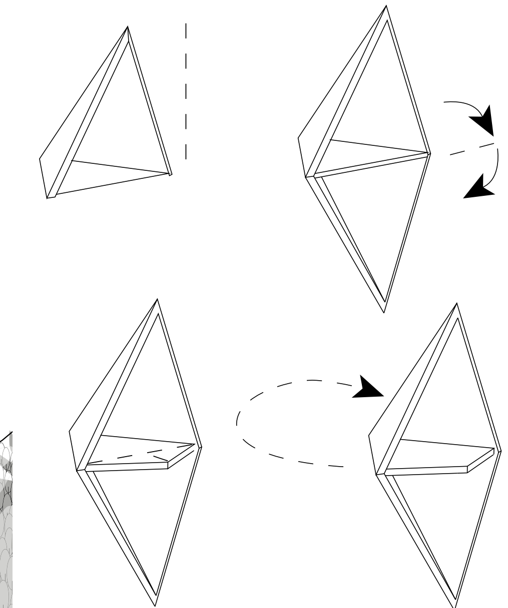


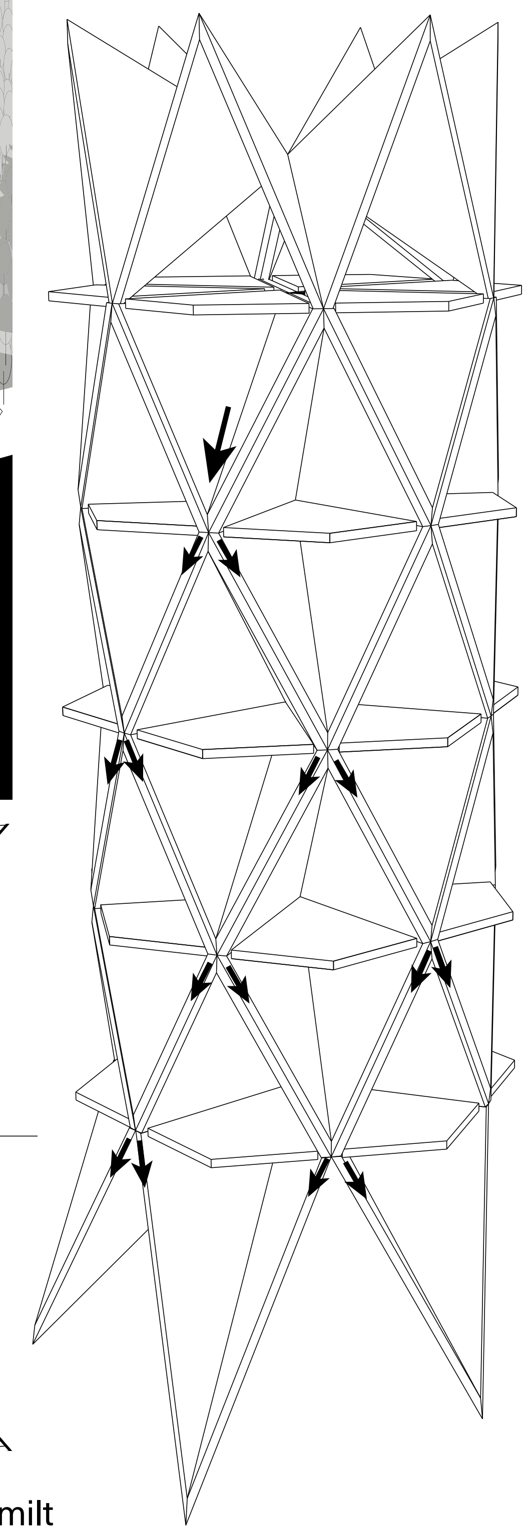


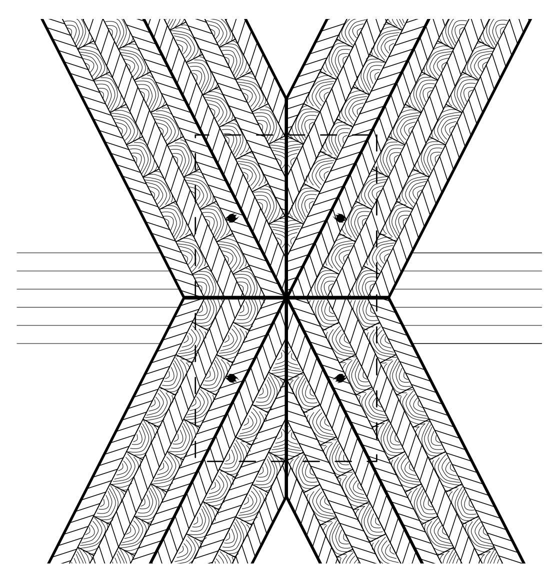


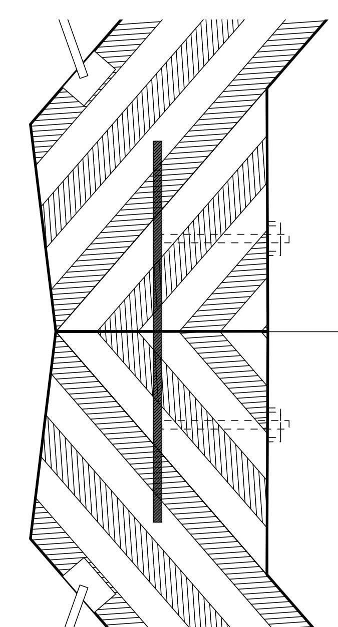
Intertwined



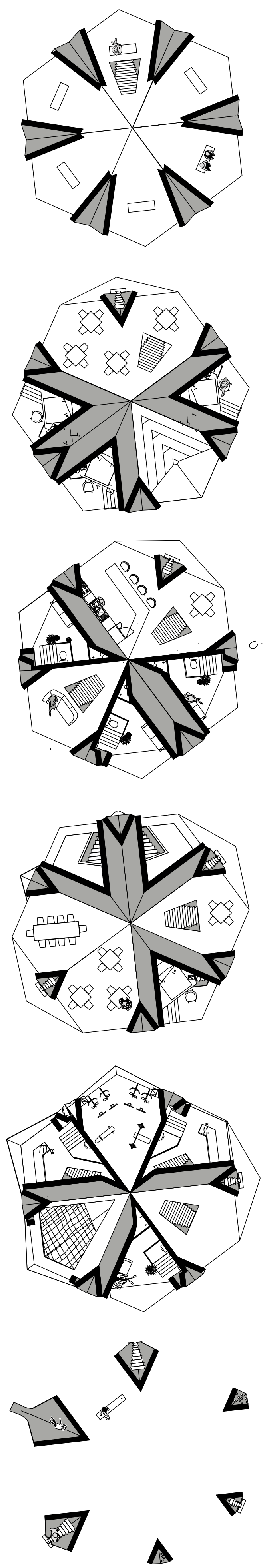


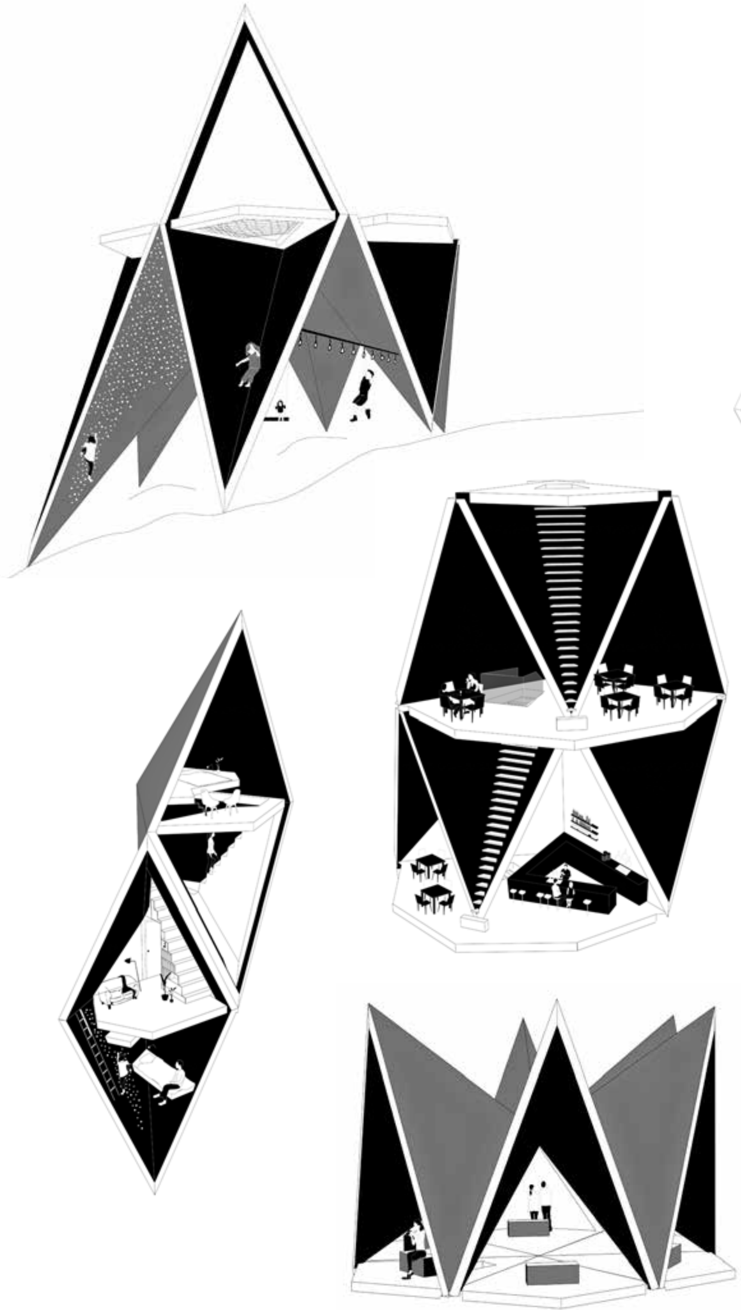




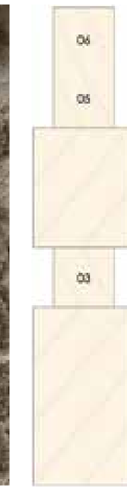


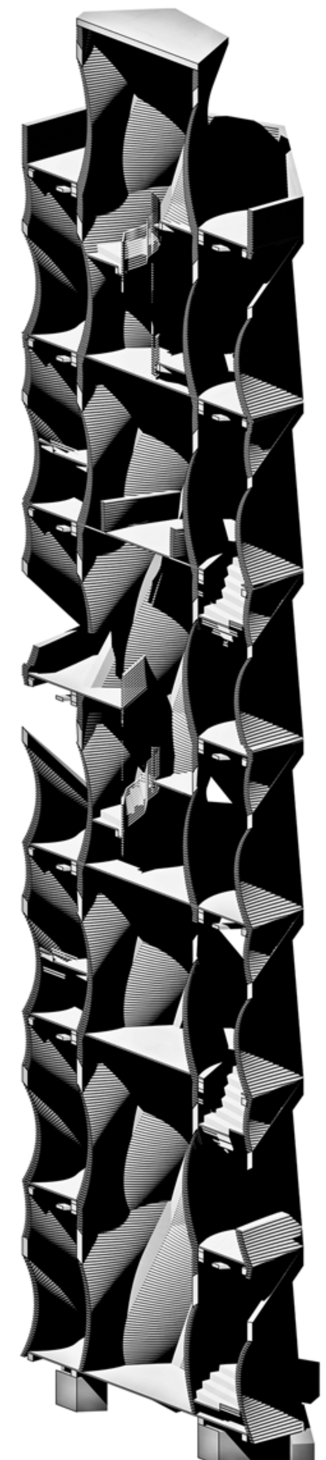
Intertwined

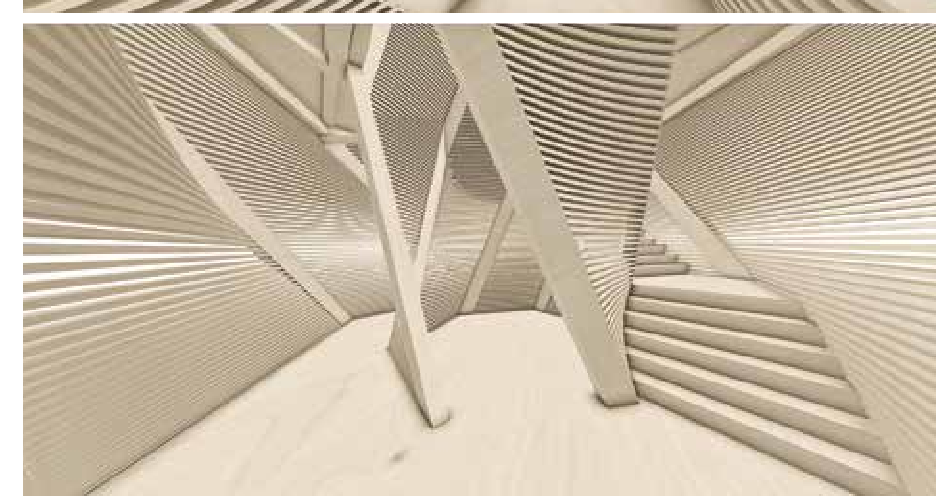




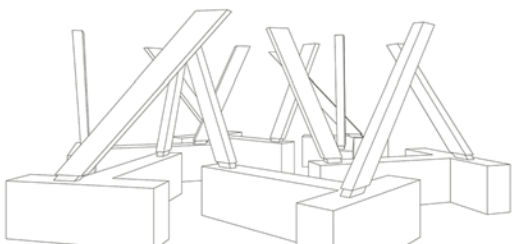
Rotation Entgegengesetzt

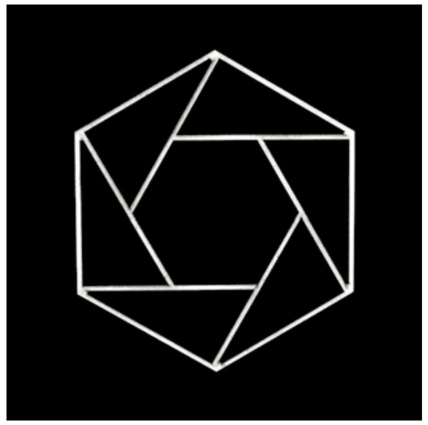


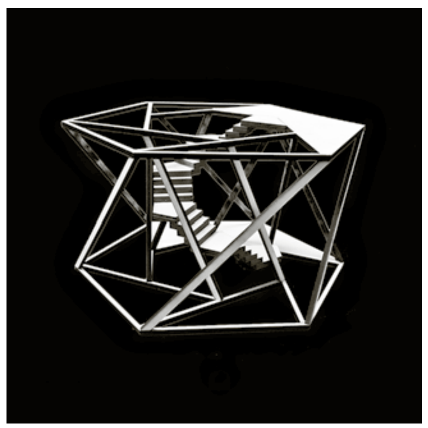


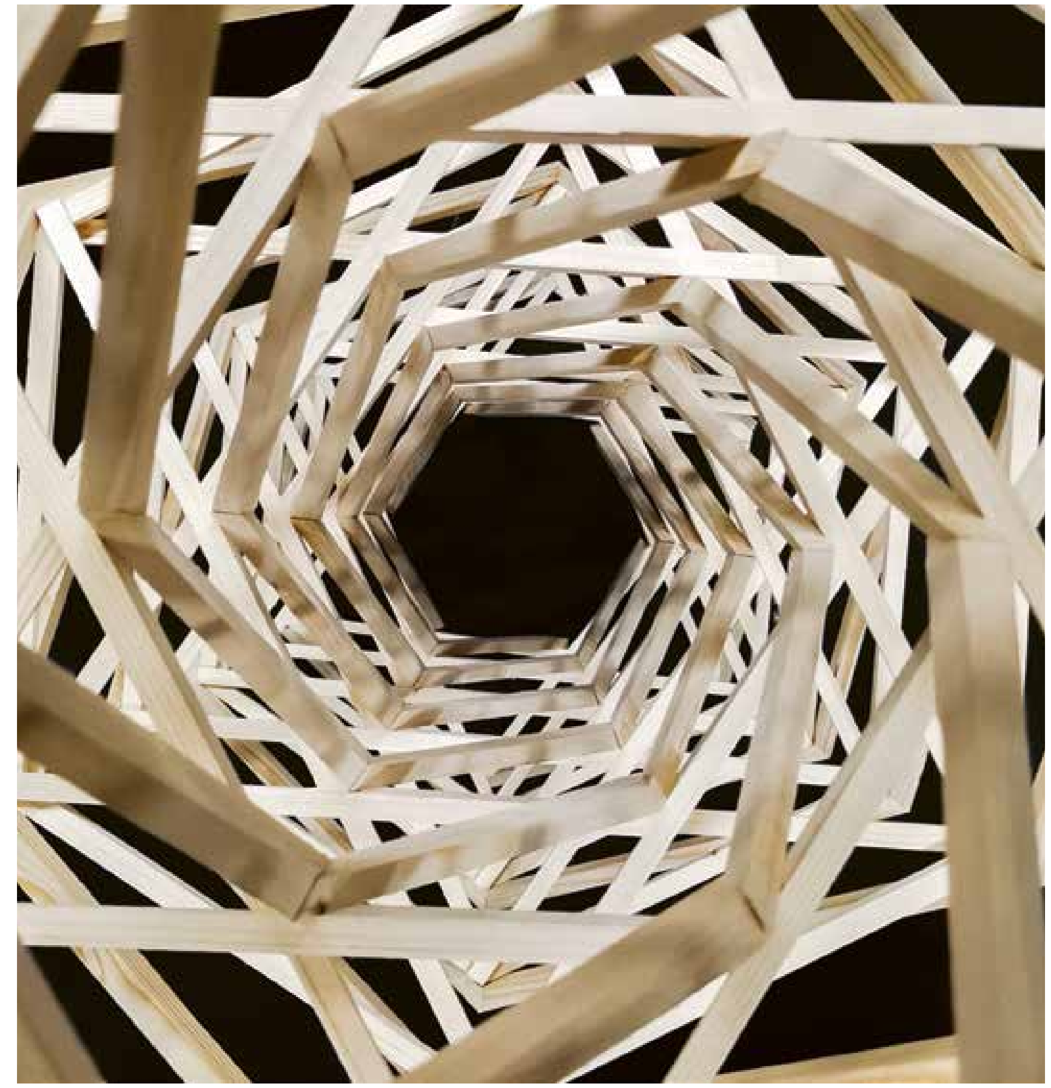


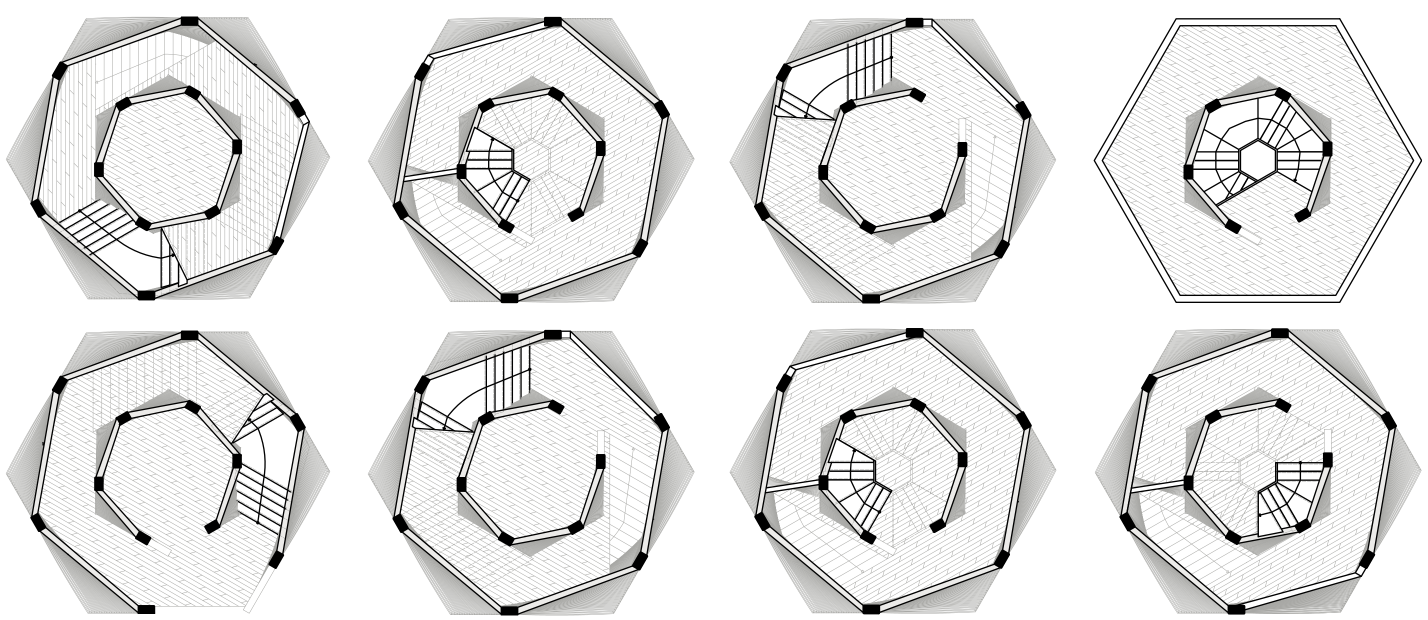
Rotation Entgegengesetzt

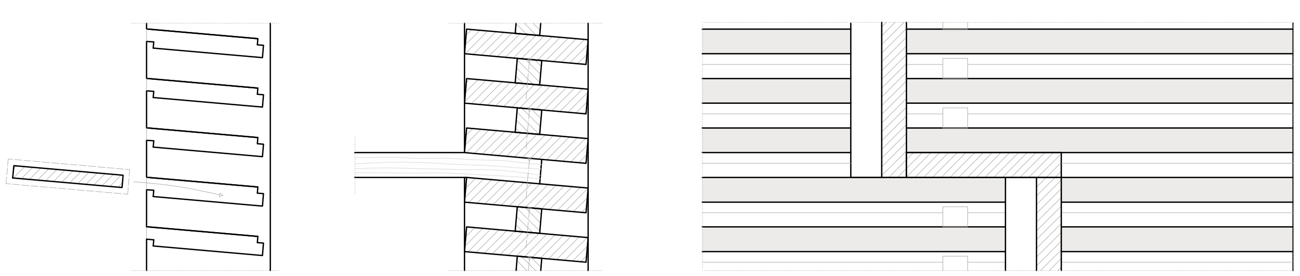


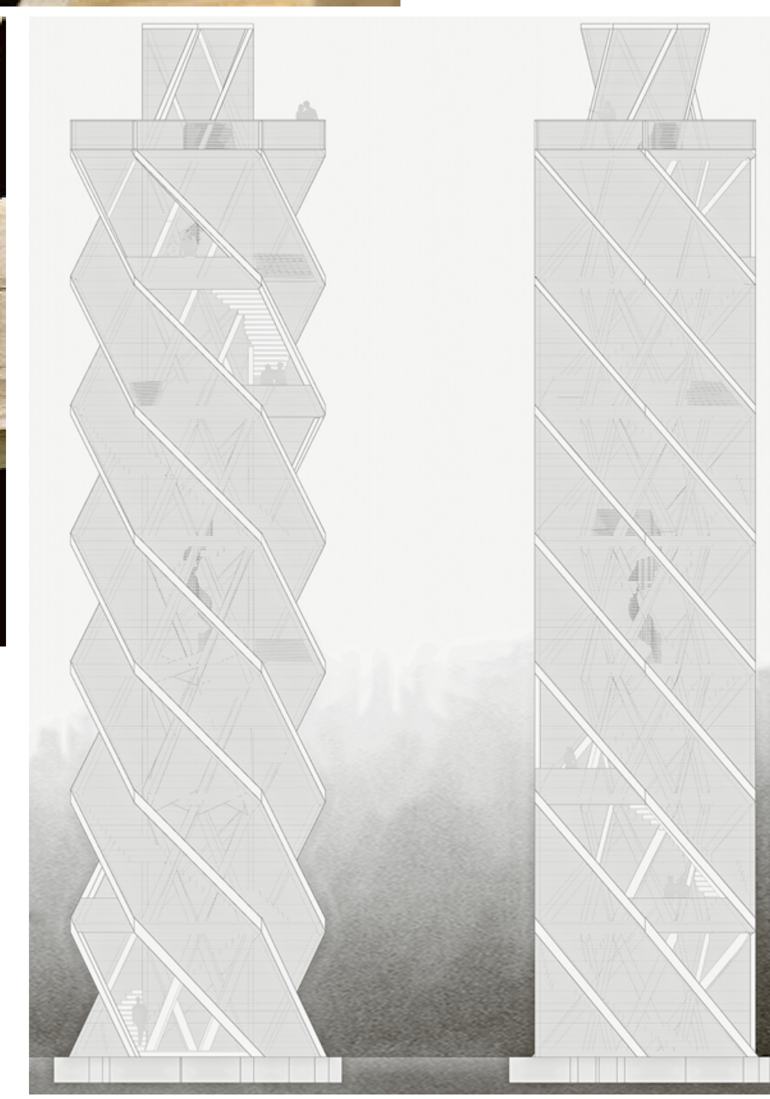












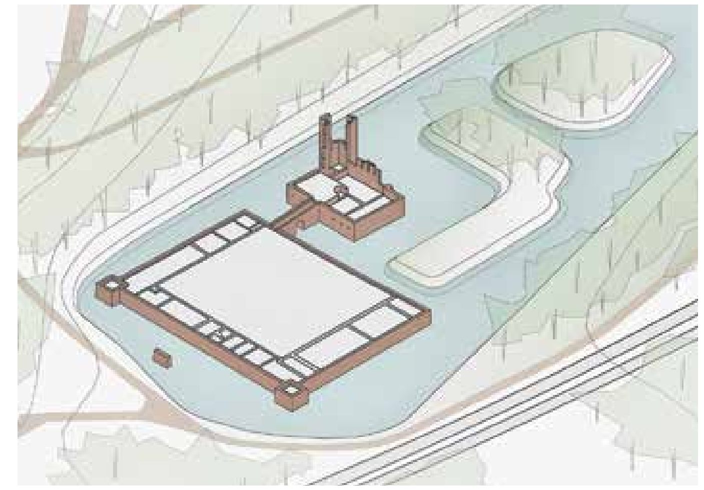
The assignment was to design a University of the Crafts on the historic site of Schaesberg Castle in Landgraaf. The *Landgoed Slot Schaesberg* Foundation wants to rebuild Schaesberg Castle and the associated *Slothoeve* in a historically and scientifically responsible manner and to redesign the surrounding area. The castle is both a cultural-historical attraction and a location for education and training to promote craftsmanship. The University of the Crafts consists of workshops for the development of traditional building-related crafts, labs for innovative techniques, and a research centre with documentation, library, exhibition and other facilities. The new building will be part of the historic ensemble of the castle site and should relate to the existing artefacts of the castle.

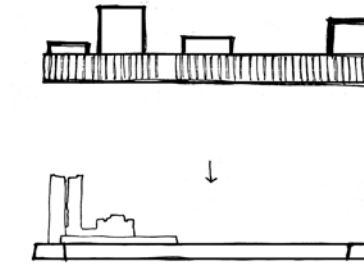
Design themes included the tectonics of the materials used, the merging of old and new crafts, historic and modern architecture, restoration and transformation. Local wood was an important building material for the construction, cladding and interior. From the first to the final week, students utilized spatial design and communicated with scale models, ready-mades and mock-ups. In *The Craftsman*, the sociologist Richard Sennett argues that old and new crafts are a crucial part of our daily lives. Archaeologist Langland writes in *Creaft* that our surrender to machines actually leads to decline. At a time when we are becoming increasingly cut off from the world around us, that is not only tragic but downright dangerous. A craft is a profession in which something is made by hand. We should become a *homo faber* again, the kind of person who makes things. That could be our salvation

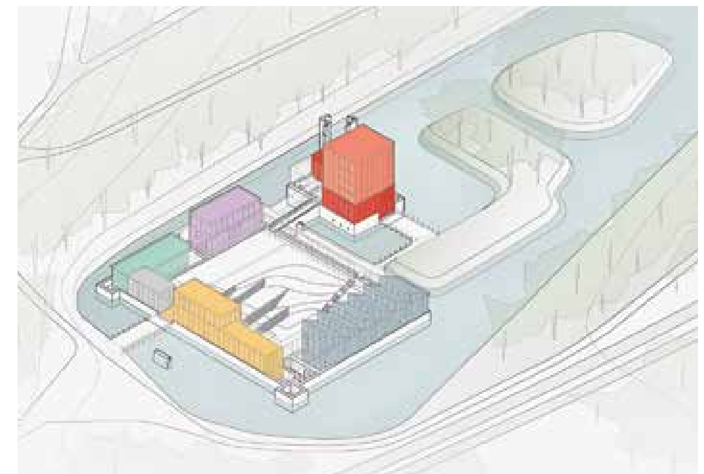
02.2020–08.2020
Landgraaf, The Netherlands

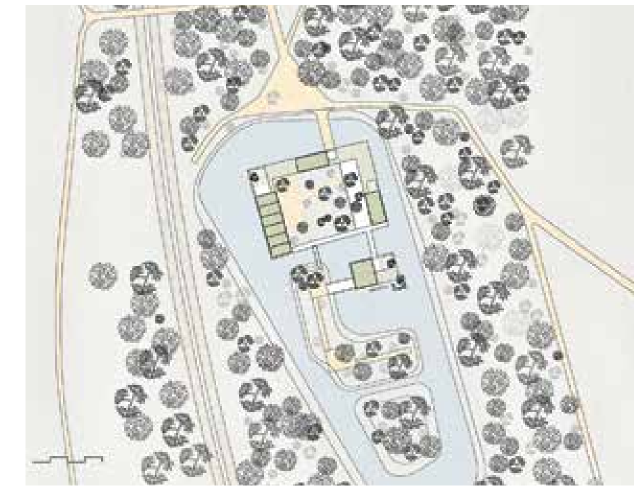
9 Craft Forum, Bart Jonkers
10 Horizontal Promenade, Clément Molinier, Laura Villaverde Díaz, Xavier Granados Esteve
11 Momentum–Reaction, Morten Bjørn
12 Craft Village, Tom Vermeer

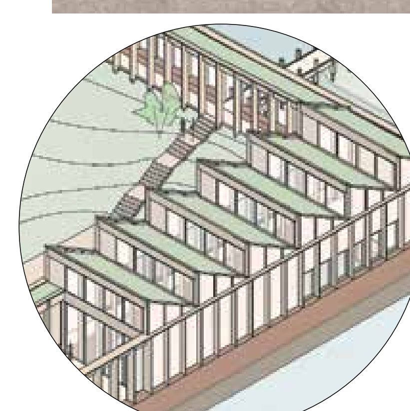
Craft Forum

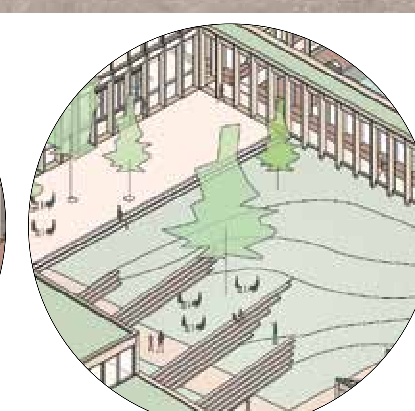


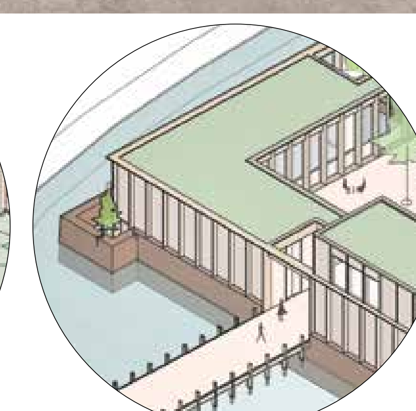




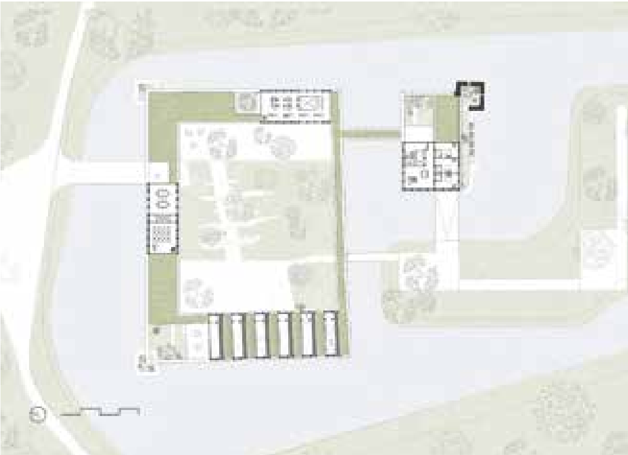


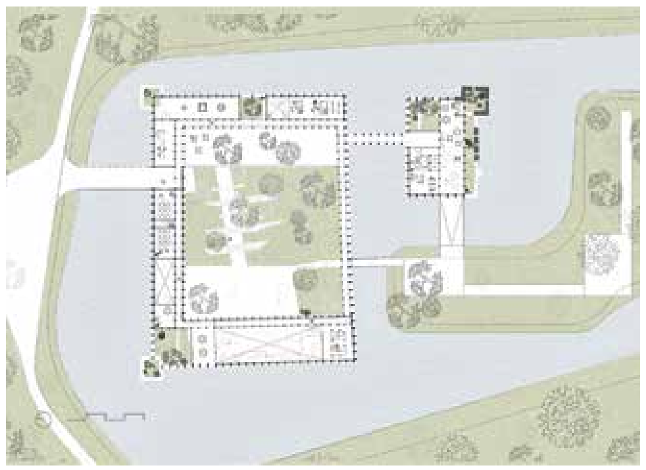


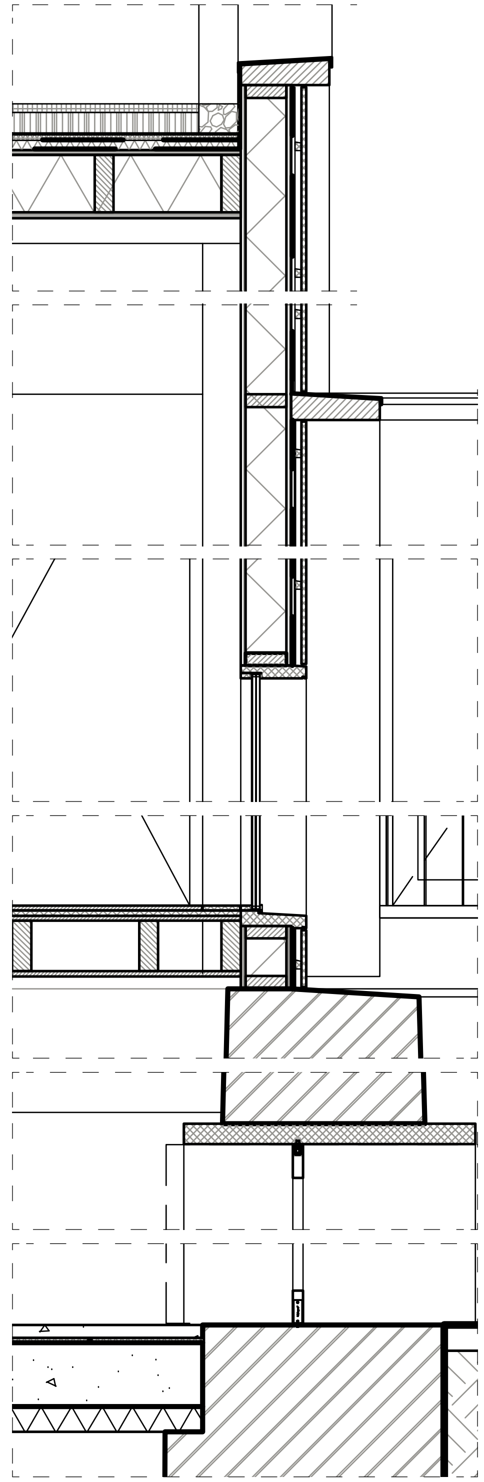


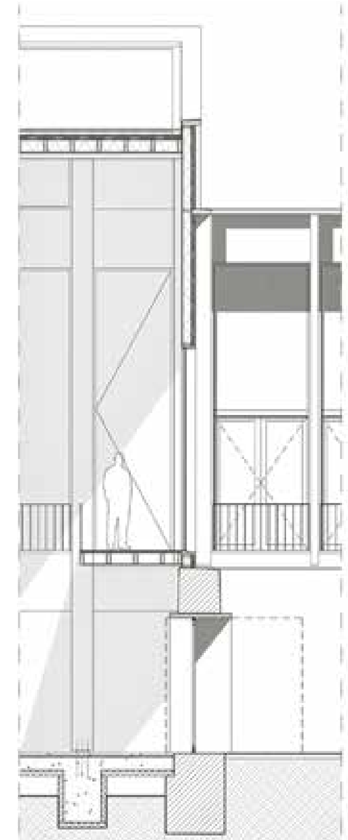


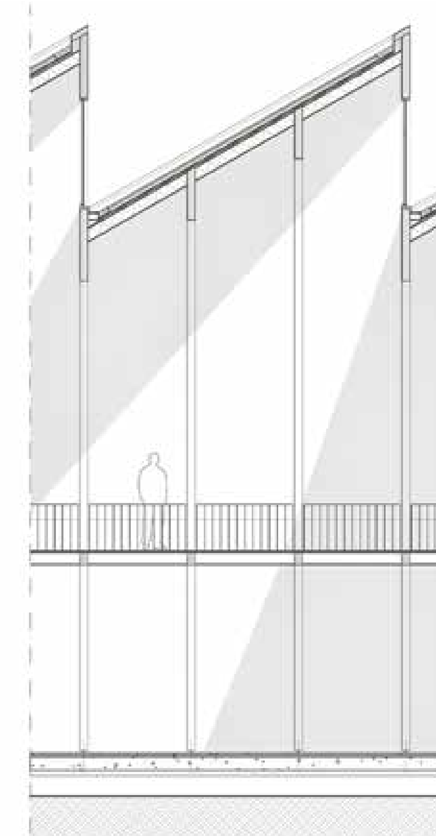
Craft Forum

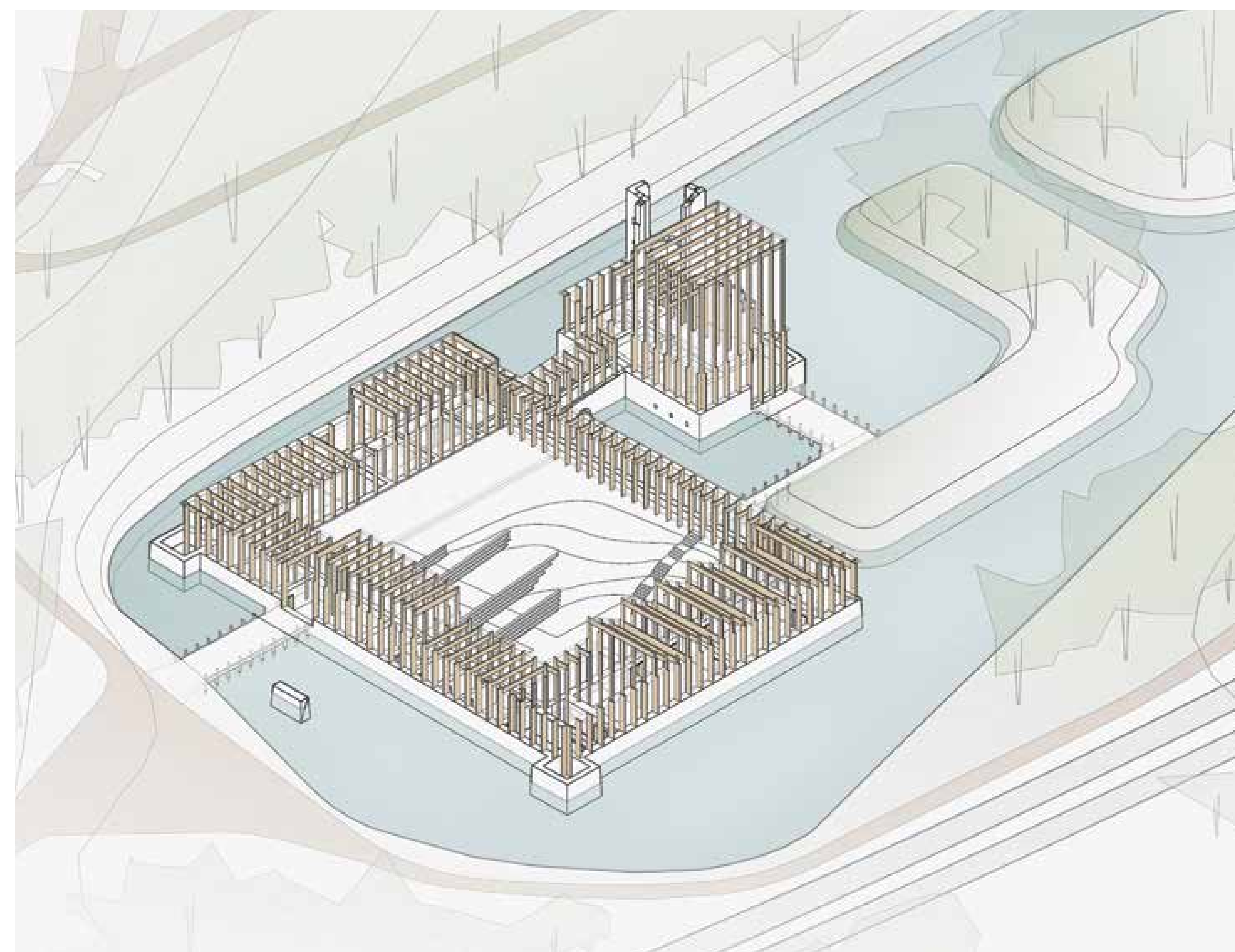




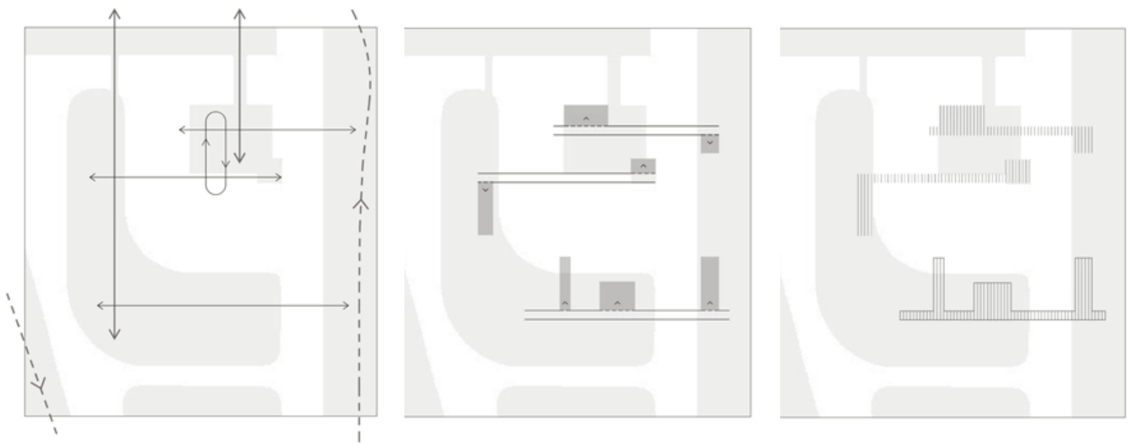


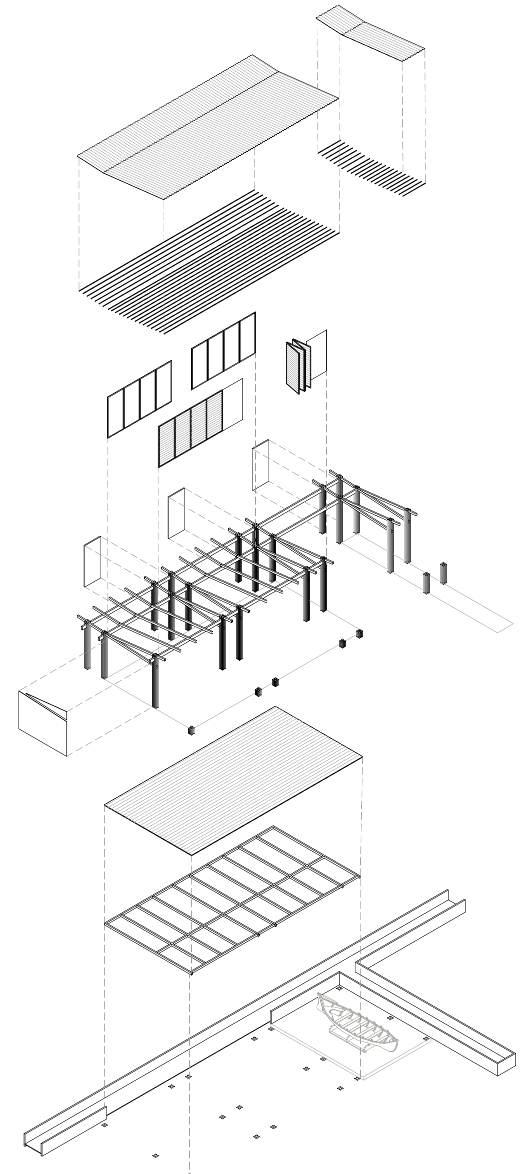


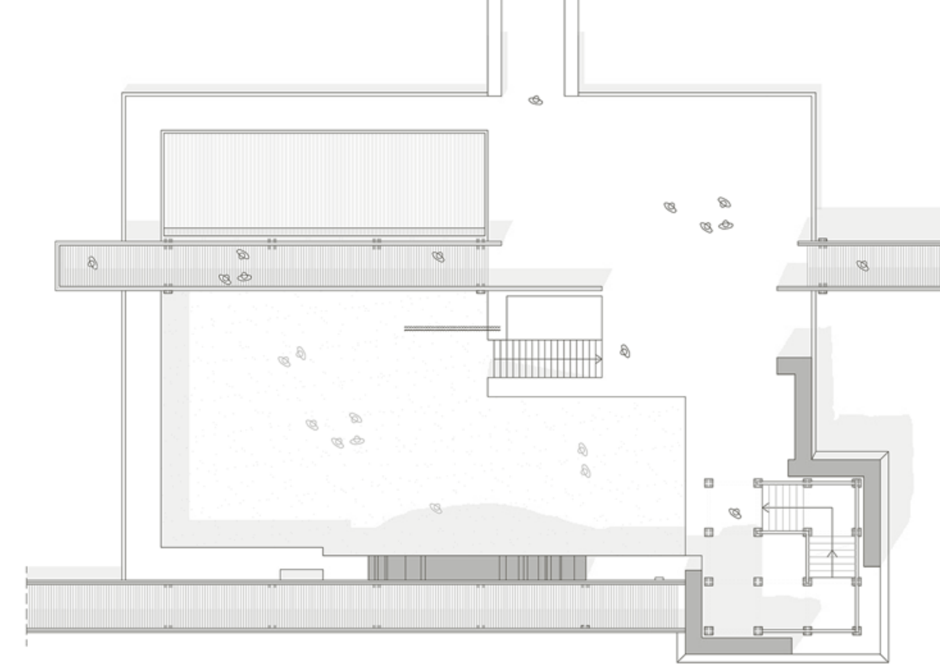


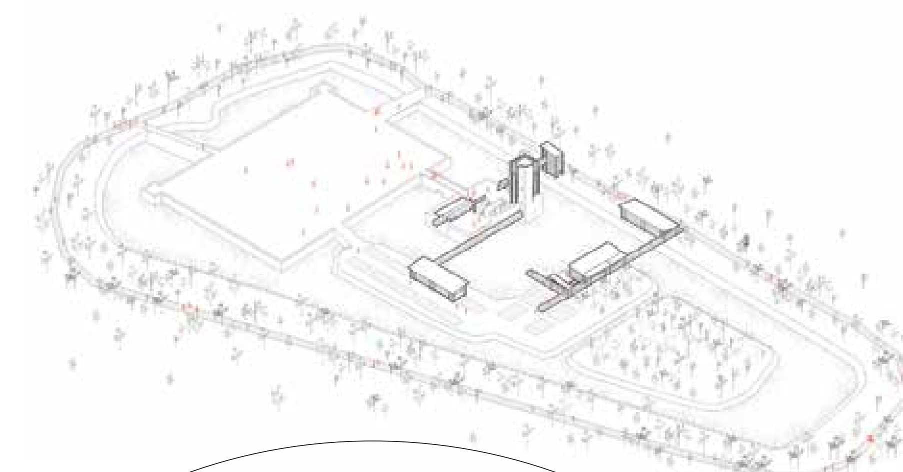


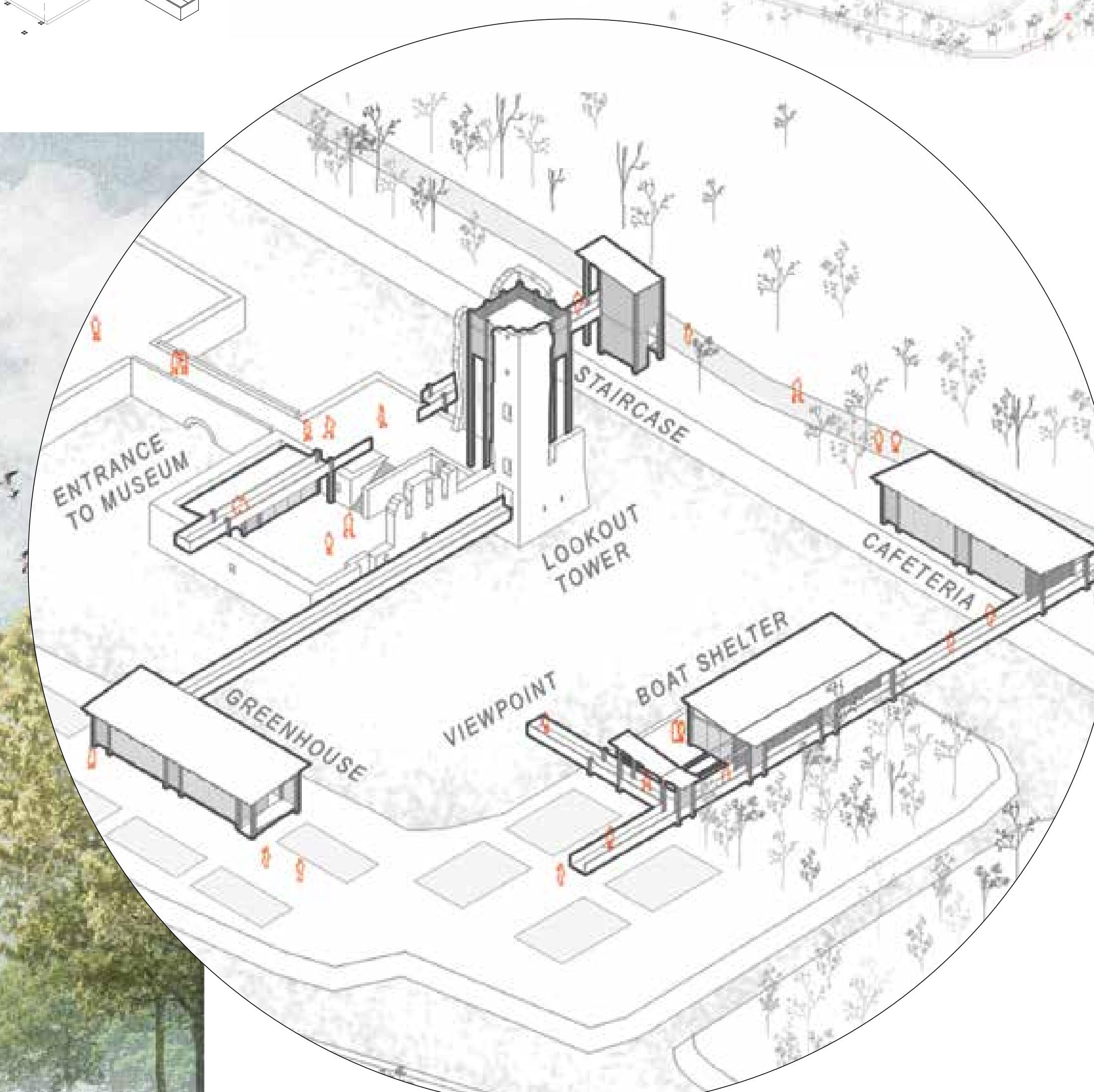
Horizontal Promenade





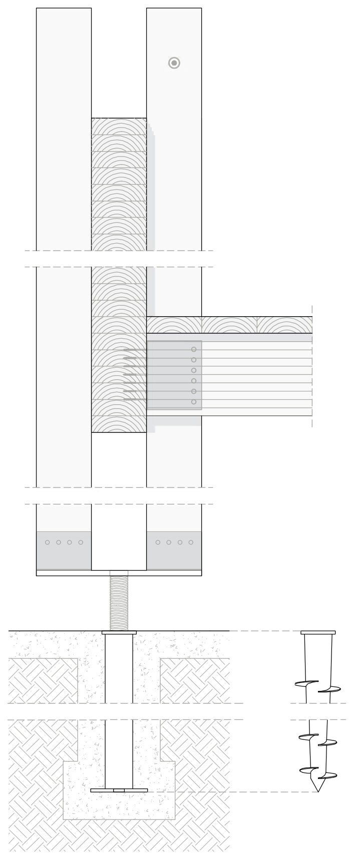


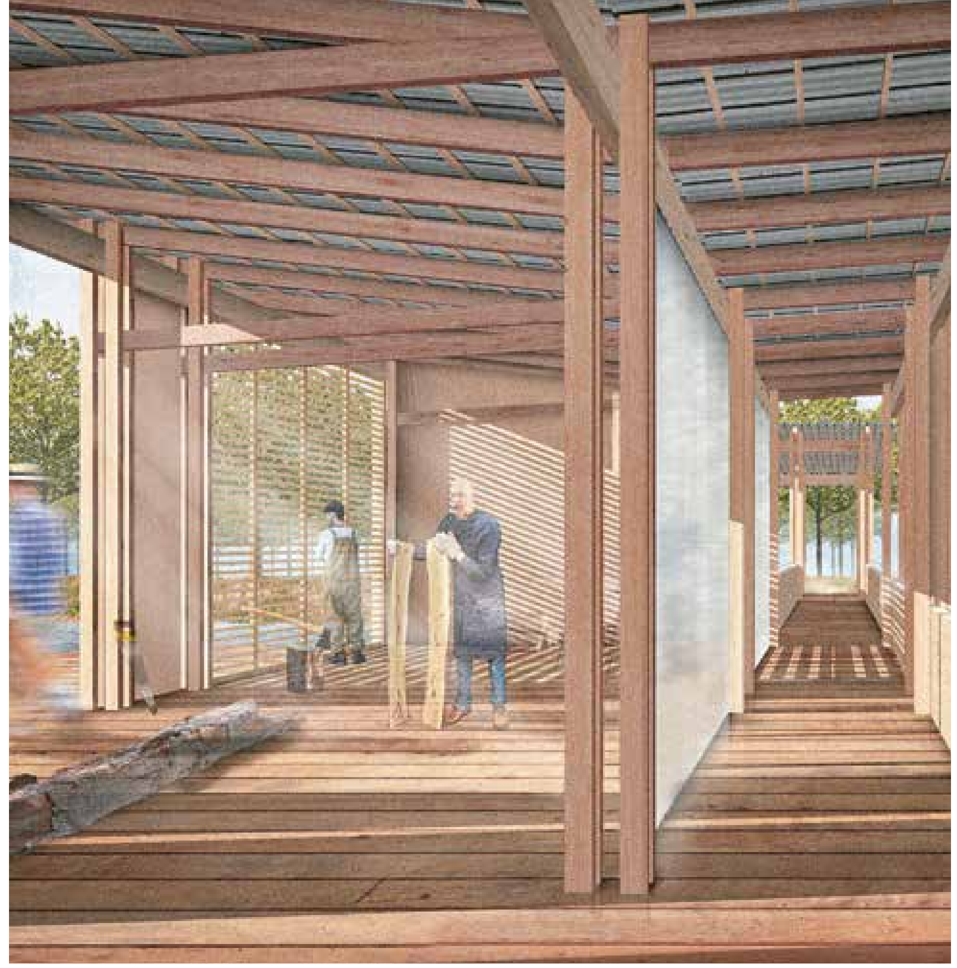


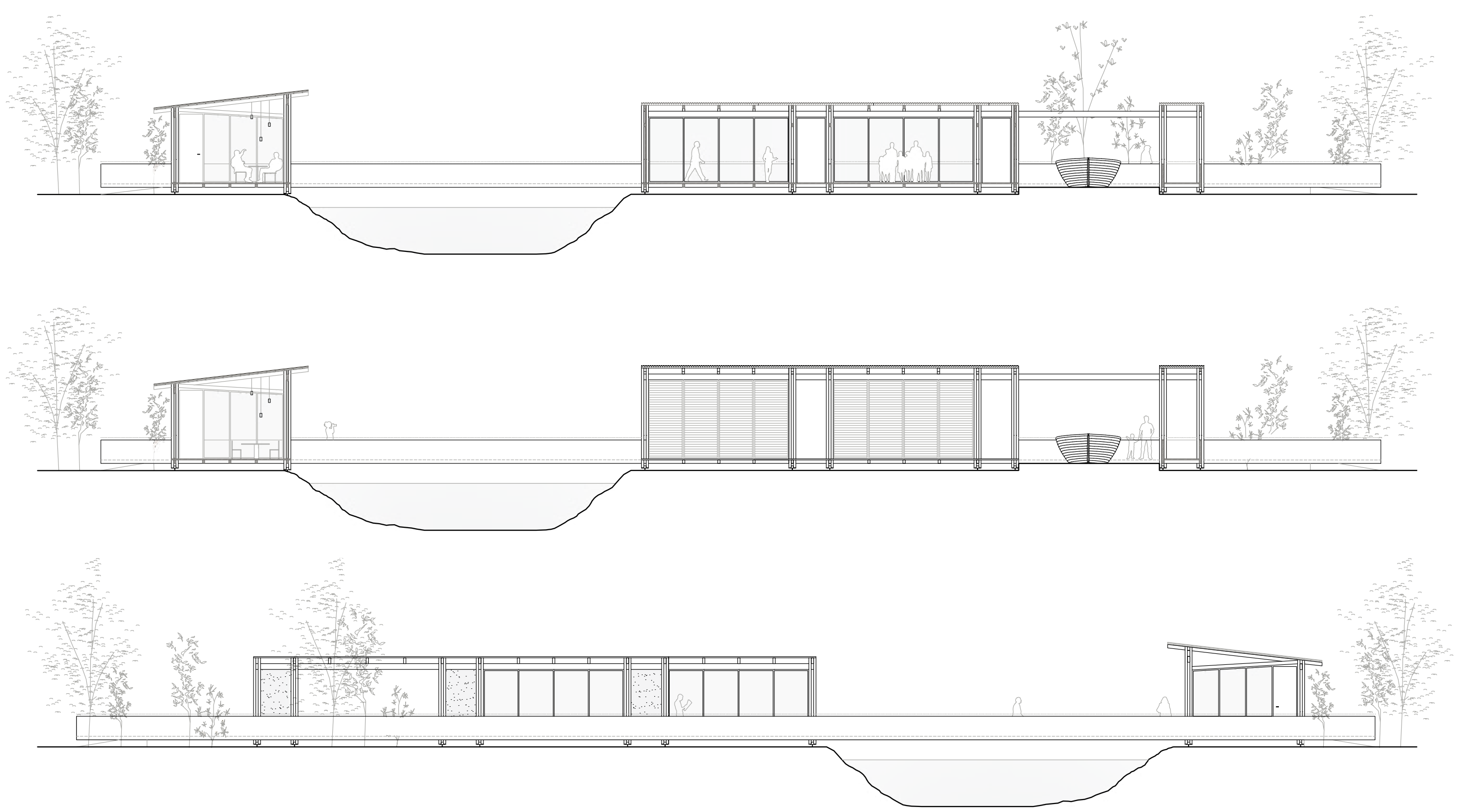


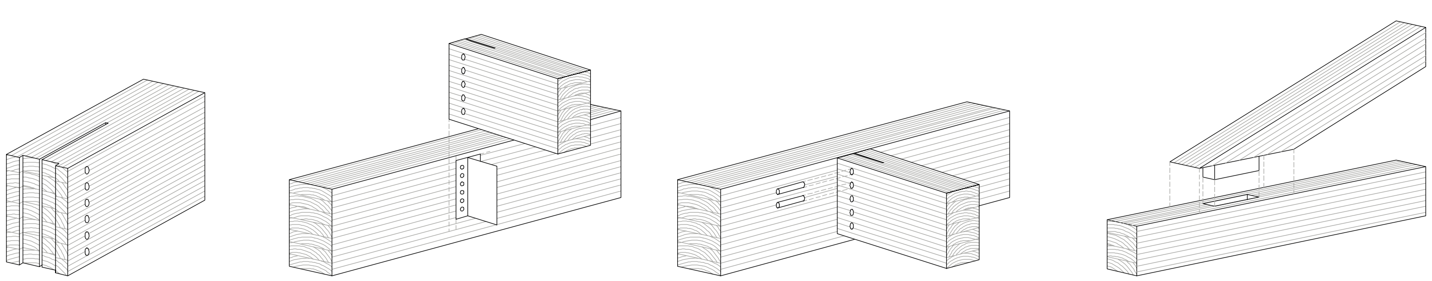
Clément Molinier, Laura Villaverde Díaz, Xavier Granados Esteve

Horizontal Promenade

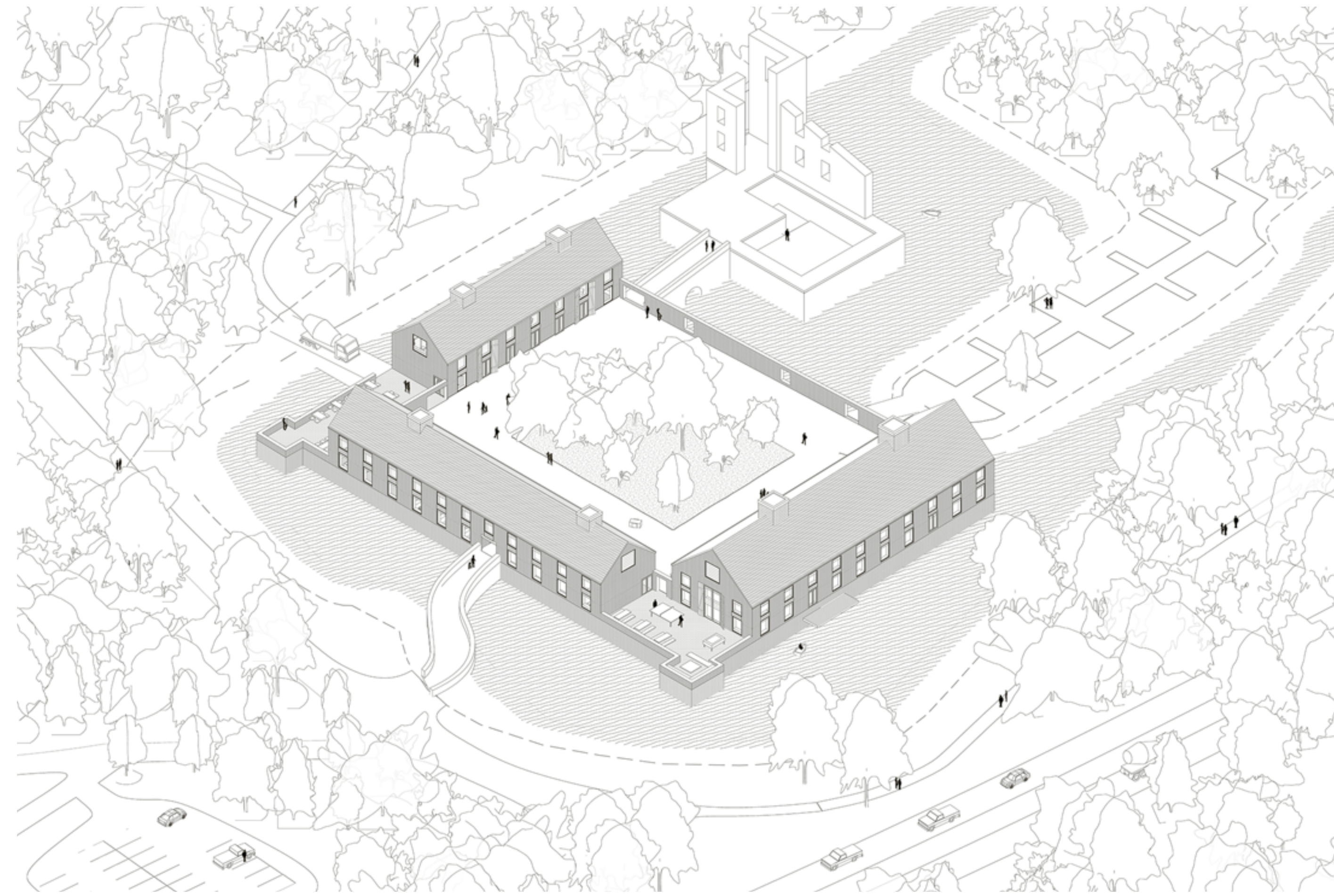


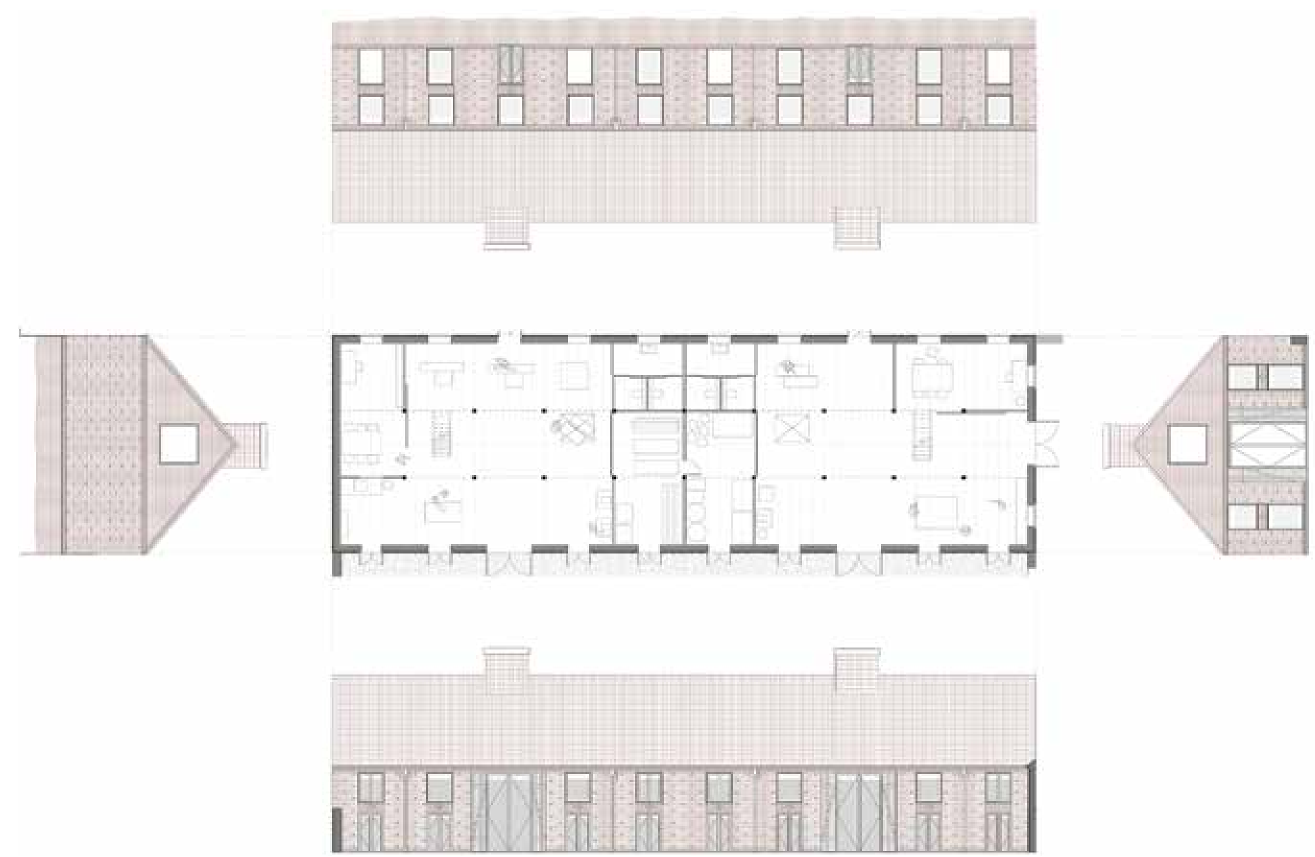






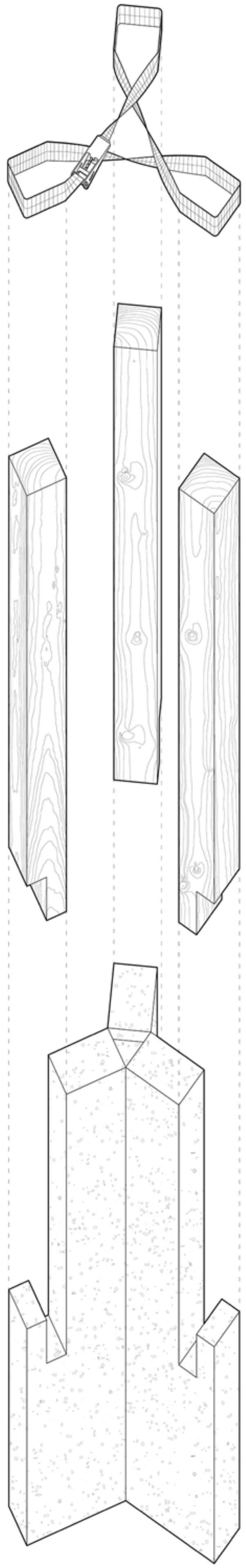
Momentum–Reaction

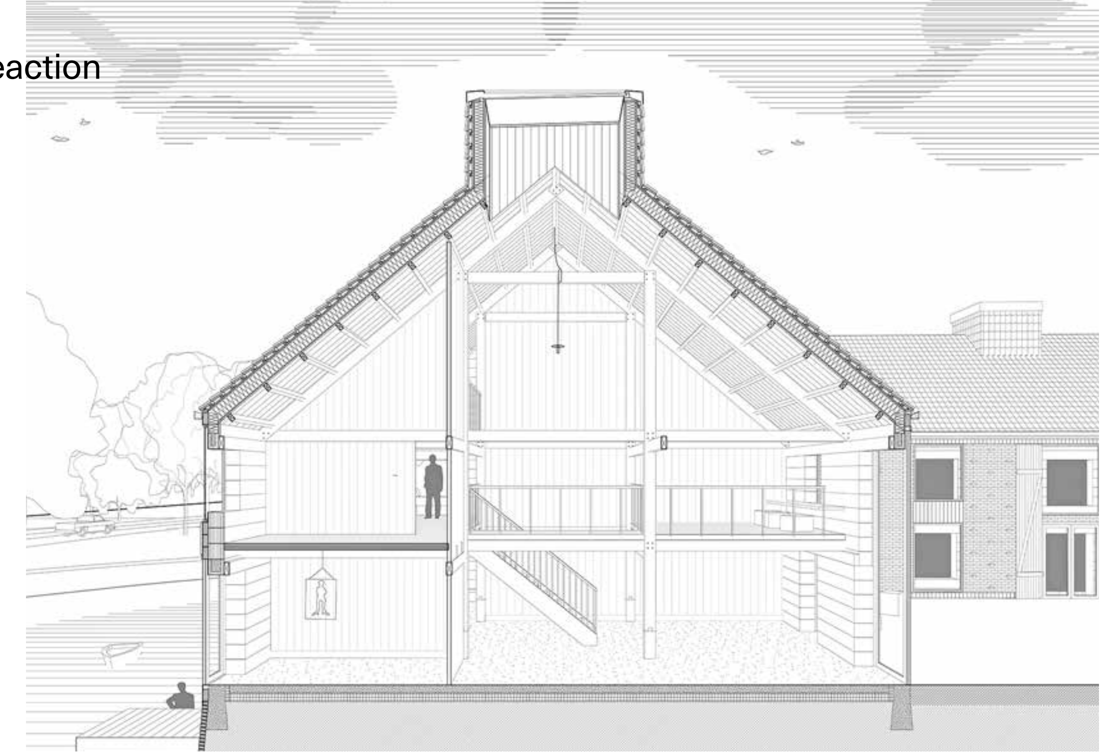




Clément Molinier, Laura Villaverde Díaz,
Xavier Granados Esteve

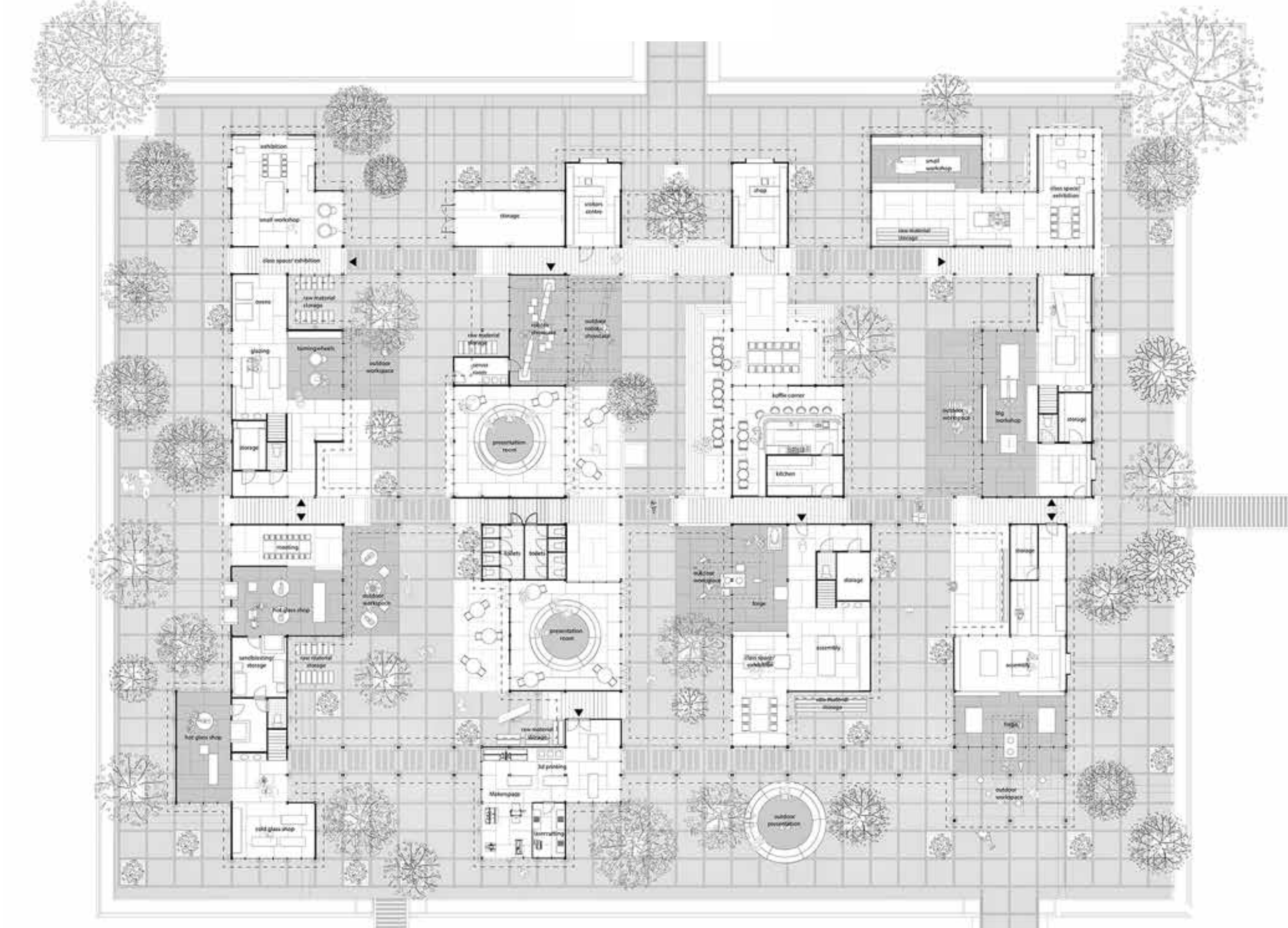
Morten Bjørn

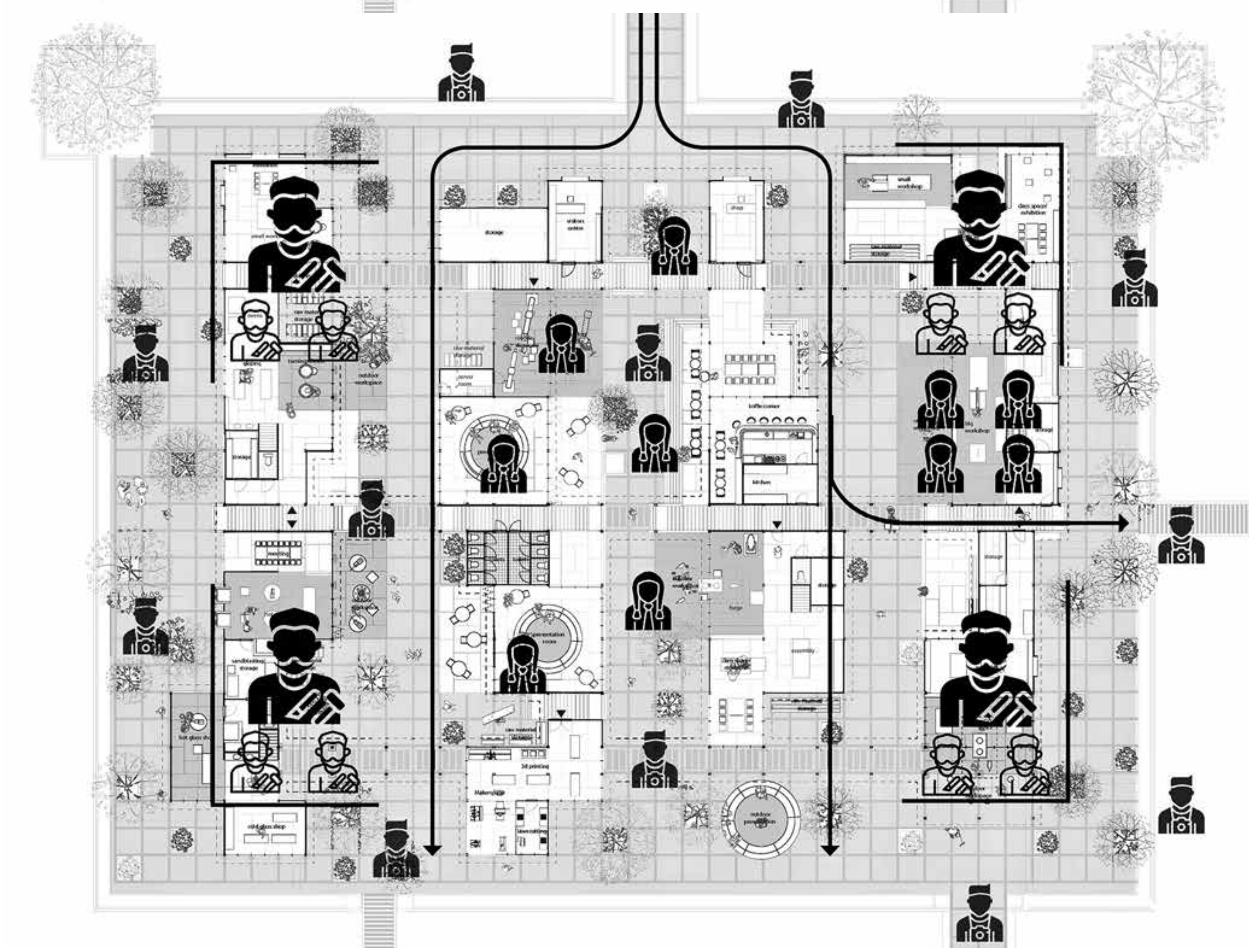




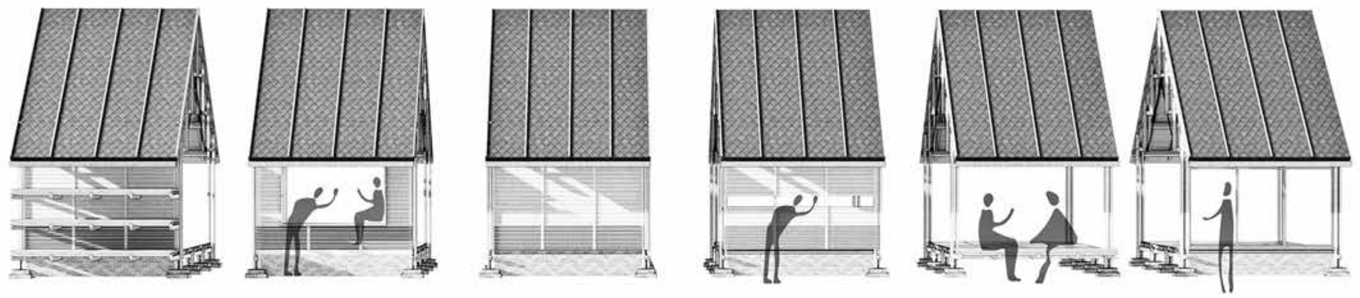

LEER KANTOOR

Craft Village





Craft Village



4 CRAFTING WOOD HANDS-ON

Full-Scale Timber Architecture as an Educational Tool

Jan Siem,
Bjorn Otto Braaten,
Arnstein Gilberg

The Faculty of Architecture and Design at NTNU in Norway has used full-scale building as an educational tool for several years. In one of the series of courses, designing and building a permanent project for a client has been the driving force for developing knowledge and skills in timber architecture and timber structures. In this paper we present three of the projects, sum up our earlier dissemination about pedagogic methods we have presented at ICSA conferences, and show how the Four-Quadrant Model (FQM) can be used.

At ICSA 2013 we presented a birdwatching tower (figure 1) and discussed the pedagogic methods we used to help students to gain increased insight into the development of architectural concepts, and the inherent properties of materials, structures, workmanship, fabrication, erection of structures, collaboration and communication (Siem et al, 2013).

Figure 1
a Inside, front screen to the right
b Upper platform
c Front screen

At ICSA 2016 we presented a Star Cube (figure 2) and discussed the pedagogic methods we used to inspire and guide students in developing individual projects, working in groups on chosen projects for further development, and working as an architectural studio to develop one project in detail (Siem et al, 2016). A multi-perspective model based on the 'Integral Approach' developed by Ken Wilber was introduced. This model, called the Four-Quadrant Model (FQM), is adapted for discussions and research within the field of architecture and architectural structures (Braaten et al, 2019) and used to discuss a specific joint in the structure later in this paper.

The third project, called 'The Change Observatory' (figure 3), focuses on the changes in the area the installation is built. When arriving at the site, you are guided by a bridge into the building. Inside, you can choose to go up the stairs to enjoy a wide view of the area, or you can continue walking to an opening into the dark core of the structure, where you can observe the water underneath the building. Inside the core is a stairs down into the water. When you look at the building you can see four steel legs entering the water. These are welded to steel piles in the ground.

The project is built at the mouth of the River Orkla. On the site, the variation in water level depends on amount of flow in the river and the tidal water in the sea. Underneath the structure, it can be dry land or almost two-metre-deep water.

In this paper, we want to use the FQM (Braaten et al, 2019) to discuss one of the details in the presented full-scale project where the structure and structural detailing is an important part of the architecture. By using the model, we will discuss the detail from a technical, cultural and aesthetic perspective.

The chosen detail is shown in figure 6 and based on the same joint system as shown in figure 2.

When using the FQM, you must be aware of three different steps that need to be taken. The first step is to separate, or differentiate, the

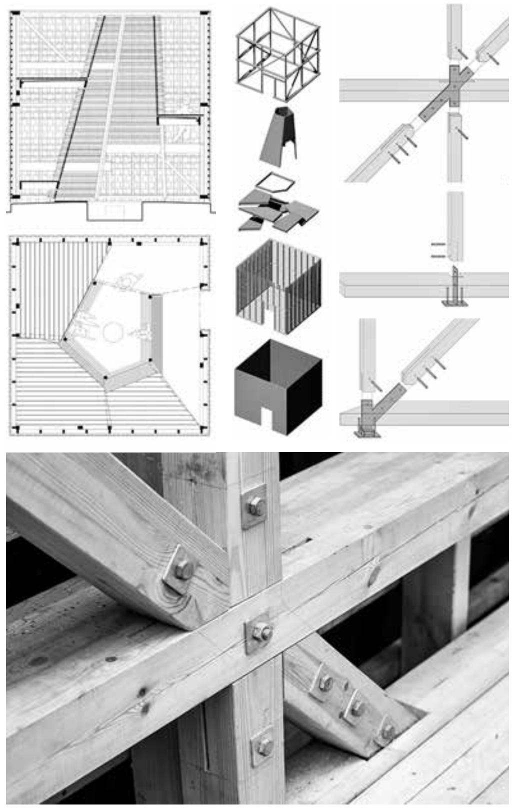


Figure 2
Star cube

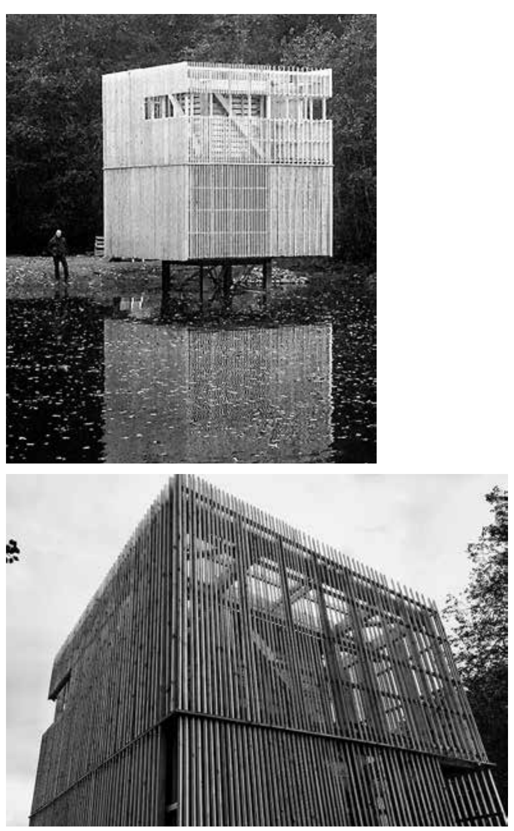


Figure 3–4
The Change Observatory

phenomenon we want to investigate into four categories of perspectives (the four quadrants). The next step is to isolate the investigation in each of the quadrants, so that the potential of each perspective is fulfilled. The last step is to recombine the information and see how the different perspectives inform one another in a new, complete picture. This last step is important, because without it the separation and isolation steps may lead to subjectivist or objectivist reductionism.

Separation into four quadrants

When discussing a topic, people often think they are discussing the same thing, but they are unaware that they are actually discussing different aspects of a phenomenon. To help make the discussion clearer, the separation into the four quadrants shown in figure 5 is a good start.

The quadrants contain an objective natural scientific perspective of the detail (UR), an inter-objective system perspective (LR), an inter-subjective cultural context perspective (LL), and a subjective individual experience perspective (UL). The details of this will be discussed in the next chapters.

Isolating the four perspectives

1 The physical aspect of the detail (UR)

The detail chosen for discussion is a joint where five structural elements in a truss meet, as shown in figure 6. Technically, a slot is cut into the timber elements as shown in the centre image, and a steel plate is inserted into the slot. On this picture, just three timber elements are shown. On the picture to the right, we see all the elements in the K and the bolts with steel washers. The drawing on the left shows numbers positioning the steel plate and the bolts in the joint.

To design a joint like this, it is important to understand the design criterion based on the inherent orthotropic material properties and the possibilities of the production process. Through international joint research, design rules are developed and formulated in Eurocode 5 (CEN, 2004). When axial loads are transferred from one structural element into the joint, the forces pass from the timber element through the bolt into the slotted steel plate and then in the opposite direction into the other timber element. Many parameters influence the chosen design. The force value affects the diameter and number of bolts needed. The number of bolts in a row, the distance between them, the distance to the end or the edge of the timber element, and the thickness of the timber are all important elements that determine the capacity of each bolt. There are many possible design solutions when considering timber geometry and limitations in production methods.

2 System perspectives (LR)

The system perspective helps to see the aspects of the joint in a bigger context. By shifting the viewpoint from the joint as a single point to part of a structural system, production system, economic system, etc. we may see hidden characteristics. Let us take a closer look at the structural system, production system and logistics.

Figure 7a shows the core structure in timber. The darker parts indicate the steel plates in the joint. The figure shows how the joints and the timber elements create a stiff core with an opening into the centre which can carry the horizontal wind loads, and transfer the vertical loads down to the four supporting columns. The strong and stiff joints make it possible to choose a system with cantilevered platforms (figure 7b).

The production system and economic system make it rational to use the joint system in the trusses in the core, but not in the platforms. In the core, with its large loads, it is necessary to use the strong and more expensive system.

Our workshop contains modern equipment for producing timber details, components and structures. The workshop makes it possible timber prefabricate complicated full-size structures with the discussed detail at nearly furniture quality. Hand tools are used on site, so it is

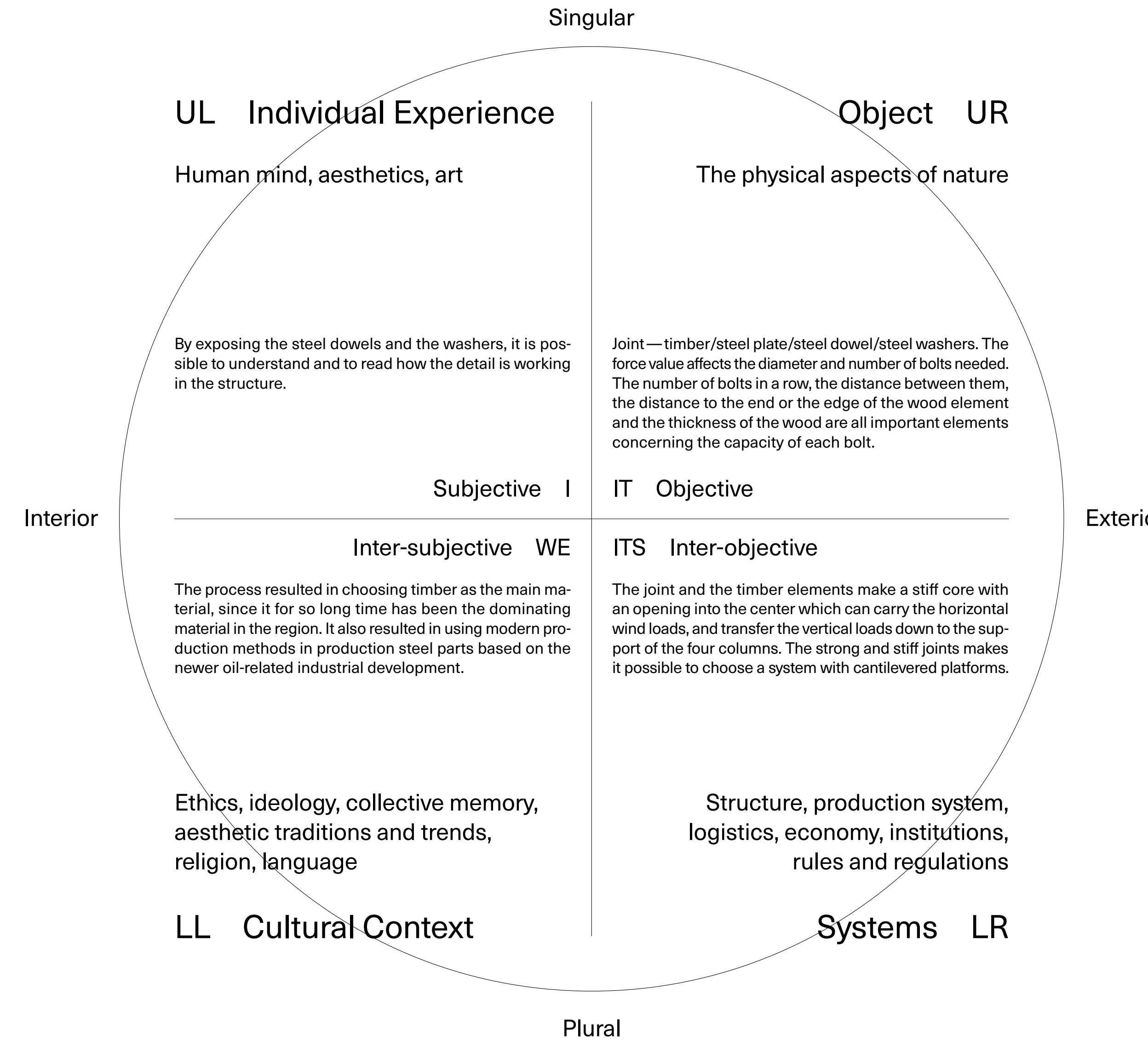


Figure 5
The Four-Quadrant Model (FQM) for the detail in the Change Observatory

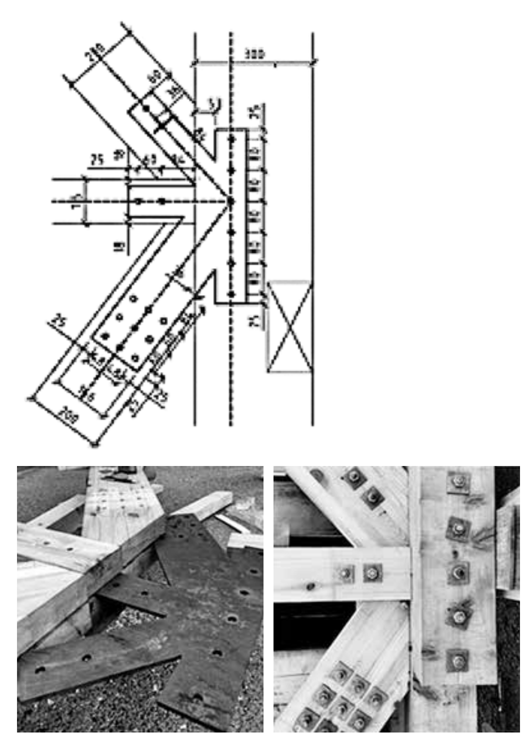


Figure 6a–c
Joint in the Change Observatory

not possible to produce the discussed detail. These possible production systems affect both the prefabrication system and the transportation system. It is necessary to produce volumes that can be transported by road and assembled on site.

The digital drawing system makes it possible to study 3D digital models of the structure, and to transfer geometry to the engineering calculation programmes and to the laser-cutter system for producing the steel plates with holes as shown in figure 6.

3 The cultural context (LL)

The building project was a collaboration between NTNU and the municipality of Orkdal, an industrial community close to Trondheim. Orkdal has an impressive industrial history, strongly connected to the local industrial inventor and architect Christian Thams, who started producing prefabricated timber houses for exportation worldwide in the early 20th century. He later initiated large industrial companies and thus created the basis for a solid industrial culture in the area. Today Orkdal is the largest industrial municipality along the Trondheim fjord, now focusing on oil-related business.

The municipality wanted us to cooperate with local industry and develop a built object appropriate to the cultural context of the area. We arranged meetings with local producers so that the students became aware of the local possibilities. The process resulted in choosing timber as the main material, since it has been the dominant material in the region for a long time. It also resulted in using modern production methods to manufacture steel parts based on the newer oil-related industrial development.

When Norway was preparing the Winter Olympics of 1994, Glulam was used as a structural material for the largest arenas. This led to a process whereby a new production technique was developed to produce

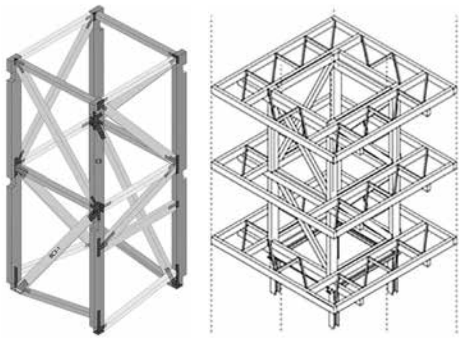


Figure 7
a Core structure
b Core and platform structure

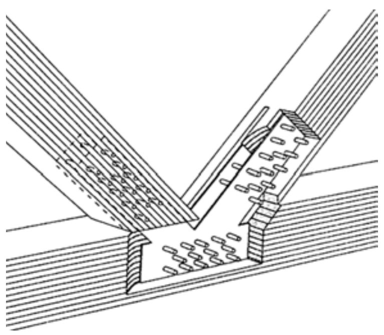


Figure 8
Dowel joint

stiff and strong joints for transferring loads. Figure 8 shows a typical K-joint and a section of the arena with the highest loaded joint. To produce joints, slots are cut in the timber and holes are drilled, steel plates with holes are inserted into the slots and dowels are pushed into the holes. The principle was well known, but was not previously used in large structures in Norway. Since then, the joint principle has been used in large-span sports arenas, the largest timber bridge span in the world, and largest timber building in the world. The joint can now be characterized as an important part of Norwegian culture in building large-span timber structures.

4 The individual experience (UL)

Individual experience is by nature subjective, so the description of a detail through this perspective will vary from person to person. For this reason, some tend to dismiss this perspective. Two things about this perspective are therefore important to remember. The first is that even if we talk about individual experiences, we often share these experiences in an intersubjective way, meaning for example that aesthetic experiences are based on shared cultural references and context. The second is that, at the end of the day, the perspectives from the three other quadrants are interpreted through the senses, emotions and minds of individuals. To not acknowledge this perspective is therefore to supress or hide important information. This may soon result in conflict in discussing the interpretation of the objective facts in the UR/LR quadrants.

Typical aspects of the joint in this quadrant would be how an individual responds to the aesthetics of the joint. Is the steel plate slotted into the wood in a precise way? If the steel washers have a quadratic shape, are they positioned precisely in parallel order? As we can see in figure 6, the washers on the vertical timber element are not parallel. Some will see this as a lack of aesthetical quality; others will not pay any notice to it at all. By exposing the steel dowels and washers, we can understand and read how the detail works in the structure. For some, this is a quality. Others would maybe prefer to hide this so it looks more like a traditional timber joint without steel.

Aside from the aesthetics, there is an aspect of individual emotional response to the production process. Some may take pride in the local industrial history and identity and therefore appreciate the combination of timber as a traditional material and the high-tech steel plate system. Others who interpret local tradition and identity more in relation to traditional timber craftsmanship may see the joint as a hybrid and an expression of pragmatic modern industrial technology.

Recombining the perspectives

All these four perspectives represent important aspects of the joint. Individually, however, each of them represents reduced information about a complex matter. This is maybe hard to see, because it is almost impossible not to unconsciously make connections between the quadrants. For example, we may automatically assume that because of the strength of the steel dowel joint, it is 'better' than a traditional timber joint without steel. The objective fact is that it is stronger (UR), not better (LL). Depending on the context, a weaker traditional timber joint may sometimes be a 'better' solution than a stronger steel dowel joint.

Recombining the reductive perspectives of the four quadrants in a conscious way is therefore important in getting the big picture. Only in this way will the FQM work as a helpful tool for a balanced discussion of the various phenomena.

Looking at what the different aspects of the quadrants provided in terms of information, we observe that some combinations work harmoniously. The physical properties of the joint and the way it contributes to a large-scale Glulam timber structure in an industrial production system align well with local identity and intersubjective values focused on industrial history and contemporary high-tech. If individuals experience the mix of tradition and the high-tech solution of the joint as beautiful and maybe even identify with the industrial tradition on a personal level, the joint in this context can be seen as strong (UR), effectively organized (LR), good (LL), beautiful and meaningful (UL). However, a different view of local identity or a preference for pure timber structures, may give a more conflicted picture.

Conclusions

We have now tested how the Four-Quadrant Model contains an objective natural scientific perspective (UR), an inter-objective system perspective (LR), an intersubjective cultural context perspective (LL) and a subjective individual experience perspective (UL).

So what is achieved by using the FQM? By recombining some vital aspect of each quadrant, we can see more clearly the interplay between the wider context, the aesthetics and the technical specifics of the joint. This balances out any tendency for one specific perspective, objective or subjective, to dominate the discussion.

Dealing with complex matters like architecture without making drastic reductions into technological, cultural or aesthetic reductionism calls for a way of thinking that considers the bigger picture without losing the complexity of the combined aspects. The FQM provides a tool for balanced communication and discussion between the various participants within the building industry and the field of architecture in general.

Within architectural education and structural engineering education, the FQM represents a map to train students in complexity thinking and in understanding the importance of connected knowledge. For the teachers, too, the FQM structures the components of knowledge in a way that one-perspective thinking is avoided. At a time where the building industry really needs to change practice and promote production and solutions that are drastically more sustainable, this is crucial.

By our brief and preliminary testing of the FQM on a specific structural joint, it is also necessary to ask what is not achieved?

As noted in an earlier paper on the subject, 'Connected Knowledge' (Braaten et al, 2019), the FQM represents one of five main elements in the Integral Approach. For those not familiar with this approach, our experience is that using the FQM is a manageable first step. The Integral Approach, however, covers a much more comprehensive and complex field. The simplifications (though complex enough for beginners) achieved here by focusing on the FQM without 'levels', 'line', 'states' and 'types' (the other main elements of Integral Approach), have been made purely for pedagogical reasons. The next step could be to include 'levels' in the FQM, which would provide differentiations between developmental stages in each quadrant.

A model and a method are never better than the way they are executed. Also, the FQM may be used in a way that doesn't align with the full potential or the basic intentions of the Integral Approach. Training, discussions and knowledge seeking are the best medicine in developing the use of the model in a constructive, intelligent and comprehensive way. When this is achieved, the FQM may have an important impact, not only within education, but also within research and sustainable industrial development.

To develop the use of the FQM within our own pedagogical context, the next step would be to test the model on more groups of students, so that we can better see the thresholds in the learning trajectory and support the students properly through the rapids of multi-perspective thinking. An interesting test would also be to use this model to support a real 1:1 social context with various participants in the next full-scale construction project.

References

Siem J., Braaten B. O., Alto P., Manum B. and Gilberg A. (2013) *The advantage of full-size construction as an educational tool in architecture education*, ICSA 2013.

Siem J., Braaten B. O., and Gilberg A. (2016) *Full scale in four months—Objectives, methods and results*, ICSA 2016.

Braaten B. O., Siem J. and Gilberg A. (2019) *Connected Knowledge*, ICSA 2019.

CEN (2004) *Design of timer structures—part 1-1: general common rules and rules for buildings*, Standard no EN 1995-1-1, Brussels: CEN.

The Aspect of Craftmanship: Innovation and Expression

Urs Meister

Today, the wooden house is produced by machines in factories, not by the craftsman in his shop. A traditional, highly developed craft has evolved into a modern machine technology.
(Wachsmann, 1930)

Konrad Wachsmann's introduction to his 1930 book *Building the Wooden House: Technique and Design* reads amazingly up to date against the background of the rapid technical development in contemporary timber construction. While Wachsmann purposefully focused on the systematization of elements in house construction only to subsequently suffer failure with General Panel Corporation, which he founded in the USA together with Walter Gropius, his research remains a milestone in 20th-century industrial construction. "Each technically pure construction has its own characteristic forms. Hence, the new method of working wood does change the external face of the building. A new form has to emerge." (Wachsmann, 1930) Wachsmann illustrated this in his book with cubic, modern wooden structures in the style of the *Neues Bauen* ('New Building') à la Giedion, which had little in common with traditional wooden houses. The "face of the building" ought to evolve in a modern sense from the construction, and a new working method would ideally lead to a new architectural expression.

Today, modern timber construction is no longer characterized by the will to mass produce, but lies rather in the contrast between classic craftsmanship and digital production. In recent years, this has led to a multifaceted discussion in architecture, which is again experiencing a strong orientation towards exploring craftsmanship and the artisanal. In addition to the utility of innovative technical solutions, this is reflected in the effort to offer more importance in varying degrees to the legibility of production and thus of craft. Today it is also interesting to see how a 'craftsmanly expression' can be realized and deployed as an instrument of design. In the spirit of Gottfried Semper, construction that results purely from the material and its statics requires an exaggeration for an expressive power to emerge and the building to become architecture. This exaggeration requires a creative will to make use of the varied options offered by traditional craft, to do so freely and to use new technologies to make an innovative contribution to the expression of craftsmanship.

Self-evident knowledge

A look at books written for carpenters gives us untold new clues as to how structure and materiality can advance production methods for timber construction. The manifestation of traditional timber structures draws its energy from the immediacy and impact with which the constructional elements interact. Each component is legible, be it in solid, post-and-beam or framework construction. Even with the interior wall panelling of rooms or the facades of timber buildings, the beams and boards are largely recognizable and give the architecture a profoundly human scale and grain, regardless of the building's size.

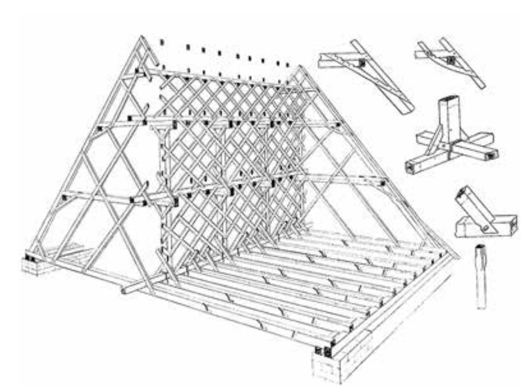


Figure 1
Roof structure of the church in Baar, 1645

As the carpenter was one with the architect until the Baroque period, at least for timber buildings, "conception, design, sizing and execution all lay in his hands" (Zwerger, 1997). The tasks of the architect were wide-ranging, extending to the practical work of the handcraft itself. It is not for nothing that the German word for carpenter (*Zimmermann*) implies the creation of space in that it contains the word for 'room' (*Zimmer*), and conversely, that the *tektōn*—Greek for an artisan, especially a carpenter—is hidden in the word architect. In Japanese, lastly, the word for carpenter is *daiku*, literally 'great artisan' or 'master builder', and actually even takes on the role of cabinetmaker. "As the age of the Baroque dawned, a development took place which was to change the whole nature of building. Designing and planning, the creative act, hitherto the result of practical experience, was to be theorized by and for more and more specialists." (Gerner, 1986). The divergence of craftsmanship and conception in timber construction has advanced inexorably since industrialization. Bringing these loose ends back together is our duty, and the place where this can happen is within architectural education.

It is revealing that carpentry originally scarcely defined itself through drawings. The regionally cultivated tradition of timber construction helped to ensure that a skilled carpenter could rely on his experience for the conception of buildings. "In Russia drawings only started to appear at the end of the 17th century. When working drawings eventually started to be used, these were frequently the work of artists whose familiarity with engineering sometimes left much to be desired." (Zwerger, 1997). Zwerger describes this knowledge as self-evident, as being *taken for granted*. The rules for making timber joints were learned in an apprenticeship, enlarged upon in the journeyman years and finally mastered in one's own work, and thus handed down via oral but above all manual dissemination.

This *self-evident knowledge* is described by Josef Killer in his book about the Grubenmann family of master builders, in the description of the famous roof truss of the church in Baar from the year 1645: "Particularly worthy of mention is also the craftsmanship of these roof trusses. All the connections are not only lapped or mortised, but also secured with wooden nails of oak or beech. Age-old construction principles, which had always been passed down and improved, formed the basis of every wooden structure. Since at that time there was not yet any means to make a structural calculation of the roof structures, all the dimensions were established on the basis of experience, in many cases even based purely on intuition. After all, certain rules governing the normal execution of the work emerged over time, and these could be continually improved by observations of the built structures." (Killer, 1942)

The loss of this traditional chain of knowledge has taken place over a short time: "In hardly 100 years the knowledge accumulated over some 1,300 years, constantly extended, refined and adapted to new tasks, has been allowed to seep away," notes carpenter Nishioka in regret about this development in Japan (Zwerger, 1997). The traditional cultural heritage can only be maintained in niches today, as the economic pressure of industrial production has become too strong. In order to counteract this crisis, it is necessary in architectural education to emphasize an understanding of the culture of construction and the importance of craftsmanship.

Structure and expression

We seek to anchor the cultivation of an experimental and nevertheless practical interpretation of artisanal approaches to timber construction with interdisciplinary architectural projects. As part of the Erasmus+ project 'Wood: Structure and Expression', three architecture schools from Norway, the Netherlands and Liechtenstein are working together with local craftsmen to achieve this goal. In so doing, the contemporary European discussion on designing with wood is supported and new paths with regard to structure and expression are presented. Within this framework, a timber observation tower in the forest above Schaan, Liechtenstein, will be designed and constructed in 2019. The structure will reach a height of about 35 metres and allow views out over the treetops. In an international workshop on site and in the carpentry workshop, the potential of the raw material will be explored in models and prototypes up to a scale of 1:1. In the individual universities, different projects will be developed from these approaches. Ultimately, a tower project will be selected from the students' designs and then, over the summer, it will be developed further and detailed. The construction of the forest tower is planned for autumn 2019 and will be realized with the help of students from the University of Liechtenstein.

Timber is the obvious choice for a building material for rural utilitarian structures, especially for a tower in the forest. But timber also occupies a central position in the Alpine building culture of the past centuries, particularly in the region of the Rhine Valley, Liechtenstein, Eastern Switzerland and Vorarlberg. This will be researched by the students in analytical work. The tradition of the 18th-century timber bridges by the Grubenmann family of master builders from Teufen and the later interpretation of the typology of covered timber bridges in the efficient Howe Truss system (Birrer, 2011) in the Rhine bridge between Vaduz and Sevelen are part of the investigation, as are the construction methods of the Norwegian stave churches and the king-post structures of Eastern European bell towers.

Natural acumen

Covered timber bridges were common in Switzerland since the Middle Ages and provided protected routes for transporting goods and people between north and south. The roofs provided protection for the structure and formed a shaded space in the open landscape above the river that can still be experienced today in the surviving examples. However, the quantity of supports required in the riverbed made the structures highly vulnerable to floodwaters. Starting in the 15th century, larger spans were sought and hanging trusses up to 30 metres were built. The master-builder family Grubenmann from Teufen initiated a veritable boost of innovation in bridge construction in the 18th century. Jakob Grubenmann's family first ran a carpentry business, whose initial work was to cover the roofs of church steeples but soon moved on to building entire roof structures. These were often designed as hanging trusses or strutted frames. With this knowledge, the field of work soon extended into bridge construction and timber structures with increasingly long spans were built. An apex was reached by Hans Ulrich Grubenmann with the construction of the Schaffhausen Bridge in 1758, which soon achieved international fame: "As a monument to the ingenuity of an Appenzellian carpenter, Hans Ulrich Grubenmann of Teufen, who has through his own efforts managed to achieve a new level of architecture, the timber bridge over the Rhine at Schaffhausen is a worthy object of universal admiration." (Storr, 1784) And still further: "Considering the magnitude of the plan and the daring of the structure, it is astonishing that the master builder is a common carpenter without any scholarship, without the slightest knowledge of mechanics and utterly inexperienced in the theory of mechanics. This extraordinary man is named Ulrich Grubenmann, a common rural man of Teufen, a small village in the canton of Appenzell, who was very devoted to the drink. He has a tremendous amount of natural acumen and an astounding affinity for the practical part of mechanics, and he has by himself made such extraordinary progress in his art that he is rightly counted among the most inventive master builders of the century." (Coxe, 1792)

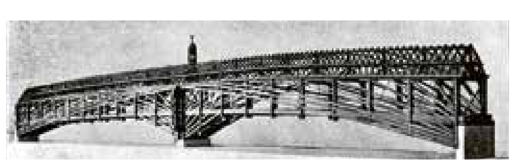


Figure 2
Model of the Grubenmann bridge in Schaffhausen

Emphasis is given to the background of the unstudied carpenter, who developed his means of construction entirely on his own. Grubenmann later took the knowledge he gained from building bridge structures and transferred it to long-span roof trusses for church buildings. His impetus to apply his knowledge of design and materials to create wooden structures with ever-greater spans is due to an investigative spirit that is not academic but rather craftsmanly. Grubenmann also participated in the international competition for a bridge over the River Derry in Ireland and sent a model of his design. The client had to be convinced with both drawing and model; the models were made to a scale of 1:40 and constructed in precision work. Even the interlocking

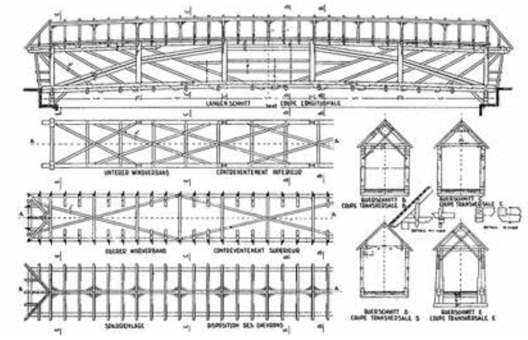


Figure 3
Construction drawing of the Kubel Bridge over the Urnäsch at St. Gallen, 1718

of the timbers in the arches and the bolted connections of individual slats were built. Even today, the impressive drawings and models have hardly lost any impact as communication tools.

Construction languages

In 1871, a good one hundred years after Grubenmann's Schaffhausen Bridge was erected, a toll bridge over the Rhine was built between Vaduz and Sevelen with a span of 136m, and it still survives today as the last of what was once seventeen covered wooden bridges in the Alpine Rhine Valley. Although it is reminiscent of the hitherto familiar covered wooden bridges, its means of construction has little to do with the hanging truss bridges of Grubenmann. The Liechtenstein state technician Peter Rheinberger used the efficient Howe Truss system, a radically simplified timber structural system that was combined with steel elements. The construction system was originated by the American design engineer William Howe, who in 1840 developed a trussed framework of timber beams with pretensioned vertical iron rods. This in turn was based on the lattice truss bridges of the American engineers Stephen H. Long and Ithiel Town. Their trussed systems, which were still built purely of wood and spanned up to 60 metres, subsequently served as models for the iron lattice bridges in Europe.

The sides of the bridge each consist of two paired Howe Trusses that function as vertical longitudinal girders with vertical tie rods and a series of diagonal timber compression struts. The bridge still captivates onlookers today with the elegance of its length and its imposing, enclosed interior where the tight rhythm of the diagonal struts creates an expression of strength. The timber structure is exceedingly adaptable and has already survived diverse modifications and repairs, with measures to the load-bearing structure only needed in isolated locations. The shingled roof and the board facades were conceived as wearing surfaces that are also replaced on a regular basis. The construction of the wide-span bridge can be attributed to the development of steel construction and the idea of rationalization. Despite all its discernible craftsmanship, the bridge's simplification to an elementary and repetitive structure of latticed trusses gives it a distinctly industrial character. The bridge as a system could be stretched considerably further, with its extent limited only by the number of supporting piers anchored in the riverbed. Hence, as a system conceived for mass production, it is exceedingly American, can be executed with a minimum variety of wood joints and stands out clearly from the delicate carpenter construction of Grubenmann.

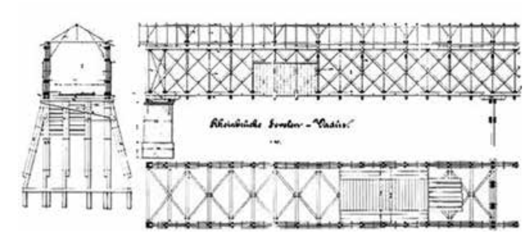


Figure 4
Sevelen–Vaduz Bridge over the Rhine, 1871

The developmental advances in the construction of timber bridges that were decisively driven by Grubenmann and Howe were mainly due to the pursuit of longer spans with greater material economy and the premise of utilizing available timbers. The elaboration of their systems can be characterized as a *construction language*: "Just as languages emerge and develop into entirely different forms as a function of varied boundary conditions, construction languages also emerge and develop in dependence on different factors (…). The history of construction technology can be written as the rise and fall of ever-new construction languages that find their expression in the continual production of ever-new 'texts' in these different languages." (Lorenz, 2005) Language is something that is in flux and must continually evolve. A driver of change is the will to innovate. Yesterday and today alike, the basic driving forces in constructing with wood, aside from fulfilling a clearly defined task, are specifically the search for expression from the design.

The soul of things

How can simple means be used to obtain maximal expression from the construction? A roof structure that is unique in this regard is the barrel roof structure of the Zollinger roof developed in the 1920s. Nearly forgotten today, this lamella construction constitutes a reticular shell structure consisting of relatively short boards, which are held together

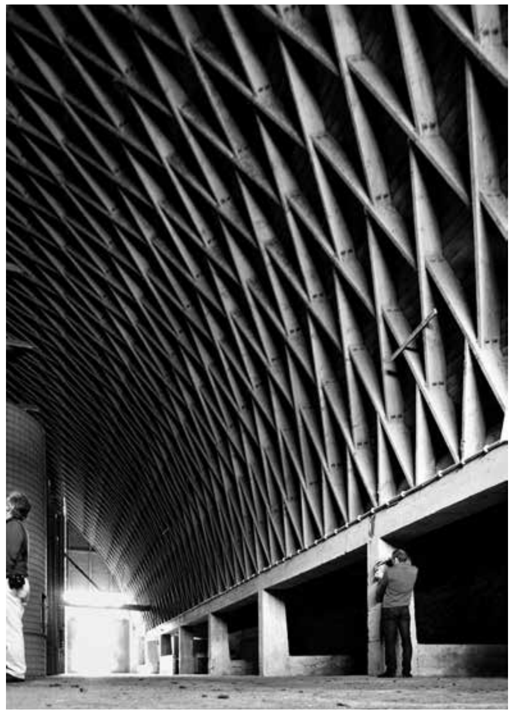


Figure 5
Gut Garkau, Hugo Häring, Scharbeutz, 1926

Figure 6
Construction of the model workshop at the University of Liechtenstein, 2017

at the junctures with steel screws and can be installed together with the wooden cladding with skilled manual labour. With this small-scaled timber construction system, it is possible to produce impressive structures of industrial dimensions. Hugo Häring built the famous barn at Gut Garkau in 1926 using the Zollinger construction method. Not only does the expressive form of its cross-section embrace its organic formal vocabulary, but in the purity of the repetitive and diamond-shaped wooden slats that set the rhythm of the structure, Häring doubtless also recognized what he called the "essence of the object": "He (like the great American architect Louis Kahn later) ascribed to things a 'design will', which the architect helps to assert as an act of empathetic aid. Thanks to his assistance, the soul of things builds its enclosure by itself, so to speak, and differentiates it according to the specifications placed upon it." (Pehnt, 1982). Without planks or rafters, the principle developed by Friedrich Zollinger in 1921 offered not just savings of timber but also the advantage of prefabrication in a sawmill, and it was used for a wide variety of functions—from market halls to hangars to church spaces. The industrial type was also well suited for centrally managed sales and distribution by proprietary companies.

A place of production

The Zollinger roof served as a reference for another project, in which three schools of architecture worked together as part of the Erasmus+ project 'Crafting the Façade' (Meister, Rist, Spaan, 2018). The three-year programme explored the potential of stone, brick and wood as building materials based on their regional significance. In a one-week workshop on the topic of wood, students from the Glasgow School of Architecture, the Amsterdam Academy of Architecture and the University of Liechtenstein worked in teams to develop models and prototypes for the construction of a model workshop. These designs embodied the starting point for further development in an experimental process in which the students, working in close collaboration with a carpentry business, took up the structural concepts and developed them all the way to the realization of the entire building. The load-bearing structure of the model workshop consists of curved boards that have underspanned in an undulating pattern. Despite the delicacy of the boards, this counter-tension ensures sufficient static height and leads to an innovative system with few references. The assembled, additively arranged structure is extremely delicate and elegantly demonstrates the internal stresses intrinsic to the wood. In the design and production of the model workshop, the concept of craftsmanship did not only apply just to the actual work done by hand, but was understood much more as the experimental engagement with the logic of joining the board lamellae into a characteristic expression. The continual change between the level of detail and its tangible reality, on the one hand, and the entirety of the building on the other, in a kind of reverberant design process, seems to us to be crucial for the achievement of innovative architecture. The constant sharpening and honing in a process with changing perspectives and varied distances to that which is being designed increases not only the constructive precision, but also the quality of the design as a whole.

Vertebrae and spinal discs

When studying multi-storey wooden structures, you cannot ignore the Asian pagoda towers. The 67-metre-tall octagonal tower of the Fogong Pagoda (Wooden Pagoda of Yingxian) is regarded as the oldest existing specimen in China and is also the tallest historical post-and-beam structure in the world. Built over four decades and completed in 1095, the building consists of two interlocking octagonal wooden pillars. Sacred figures are centrally positioned on multiple storeys. The passage between the inner and outer octagons is accessible, as are the outer verandas, which offer views of the city and landscape. Radial beams, brackets and supporting pillars interconnect to form a stable trussed framework per storey. The cylindrical void in the middle of the

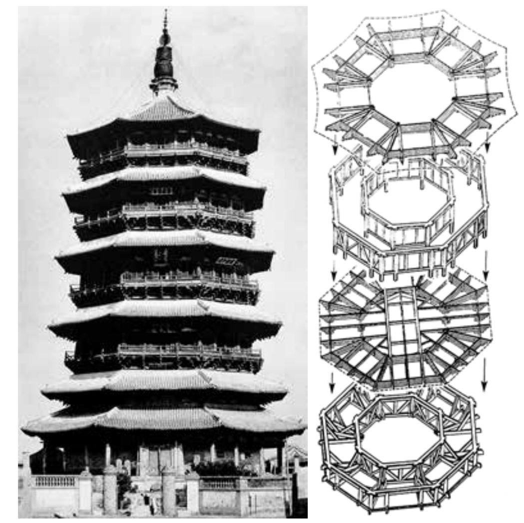


Figure 7
Cross-section of the wooden Fogong Pagoda in Yingxian, 1095

pagoda results from the stacking of the constructional rings and replaces the central mast of earlier pagodas. "The stacked, alternating rings function like the vertebrae and discs of a spinal column. Nature combines sturdiness with flexibility in this structure, while also minimizing material and weight." (Ledderose, 2009). This also makes the building more resilient, which provides greater resistance to earthquakes and storms. The curved roof forms set atop one another are a reflection and expression of a complex timber construction.

The master builders opted for smaller components in most cases. The characteristic projecting canopies are supported by complex bracketed systems and the total number of timber parts adds up to about 30,000. It is not surprising that a high degree of standardization was sought, and thus the ratio of height to width of the individual elements remains constant at 3:2. This high level of pre-industrial standardization is reflected in the Yingzao Fashi, a collection of Chinese building standards compiled by construction official Li Jie that was published in 1103. The manual primarily aimed to rationalize public buildings and established not only dimensions, but also labour hours for the individual elements as a basis for calculating the total time needed for construction. The system could easily be disseminated, making its application economical, and thus the manual reinforced the specific strengths of a modular system. The Yingzao Fashi not only created the basis for the standardization of building parts, but also represents a milestone in the history of mass production in China (Ledderose, 2009). In the European context, such approaches were as unthinkable at that time as the quantity of timber structures that could reach heights over 100 metres. Today we can only marvel at such buildings and at their longevity. Together with their beauty and strength, they radiate a will to innovate that should inspire us.

Production as driving force

If the physical skills of craftspeople had central importance in tradition as a driving force in the choreography of production, and this has meanwhile become obsolete for industrial timber construction, then a new way must be found in contemporary, hybrid fabrication processes to derive creative potential from production. It must also be possible today to process the material by hand to varying degrees and to ultimately leave a visible imprint of the manual work done on it. Craftsmanship does not solely refer to the activity done 'by hand' with hand tools, but extends to include a vastly more diverse selection of production methods that are used in the artisanal sense. These days, the range of tools that serve in handcrafted production as an extension of the human body is enormous, and this allows for the emergence of entirely new expressive profiles.

Against the backdrop of the discussion on sufficiency and regional value creation in the construction sector, we have a reawakened interest in the particularities of solid timber and its inherent suitability for clear-cut, tectonic elements. The joining of the individual parts thereby regains significance, as today's mechanical processes make it feasible to make timber joints that were previously made by hand. The use of locally grown hardwood adds additional new themes. In the interplay of traditional knowledge with modern technology, a new *hybrid timber construction* is postulated that will give new meaning to the classic theme of bearing loads. It is the idea of handcrafted timber construction that has been developed for modern production techniques and which will form an alternative to standardized, industrially produced timber construction. Thus, both 'archaic' and 'advanced' techniques should be used equally to reinterpret the wealth of traditional timber joints with today's production techniques (Lorenz, 2016) Thus, the relative importance of industrial fabrication and craftsmanship must be renegotiated in the search for a timber architecture whose production processes intertwine in a future-oriented way.

References

Birrer, P. 2011. Geschichte. In: *Die alte Rheinbrücke Vaduz–Sevelen. Entstehung und Umgang mit einem Kulturdenkmal*. Vaduz: Gemeinde Vaduz.
Coxe, W. 1792. *Briefe über den natürlichen Zustand der Schweiz*, *Vol. II, pp. 1, 2*. Zürich: Orell, Gessner, Füsslin and Comp.
Gerner, M. 1986. Das Zimmerhandwerk, in Schadwinkel, H., Heine, G.; *Das Werkzeug des Zimmermanns*. Hannover: Th. Schäfer.
Killer, J. 1942. *Die Werke der Baumeister Grubenmann*: 69. Zurich: ETH Zürich.
Kocher, L. 2016. Holz auf Holz. In: *Werk, Bauen 11–2016*. Zurich: Verlag Werk AG.
Ledderose, L. 2009. Ten Thousand Things: Module and Mass Production in Chinese Art. In: Nerdinger, W. (ed.) *The Art of Timber Construction: Chinese Architectural Models*: 40. Berlin: Jovis.
Lorenz, W. 2005. Archäologie des Konstruierens—Eremitage, Walhalla, Neues Museum Berlin. In: Jahrbuch Ingenieurbaukunst in Deutschland: 172. Hamburg.
Meister, U. Rist-Stadelmann, C. Spaan, M. 2018. *Crafting the Façade: Stone, Brick, Wood*. Zurich: Park Books.
Pehnt, W. 1982. Ruhm durch einen Stall: Dem Protagonisten des ‚Neuen Bauens' zum 100. Geburtstag. *Die Zeit*, no. 21. Hamburg.
Storr, G. K C. Alpenreise, Leipzig, 1784, quoted in: Killer, 1942.
Wachsmann, K. 1930. *Building the Wooden House: Technique and Design*. Transl. by Peter Reuss. Basel, 1995. Originally published as Holzhausbau—Technik und Gestaltung. Basel: Birkhäuser.
Zwerger, K. 1997. *Wood and Wood Joints: Building Traditions of Europe, Japan and China*: 57. Basel: Birkhauser.

Experiments with Glueless Laminated Wood

Niels Groeneveld,
Werkstatt

Modern timber construction consists of a broad range of techniques, many of which originated in old crafts and traditions. Carpenters used to explore forests in search of trees with the right curve or trunk shape so that they could create structural elements that optimized the direction of the grain. Special timber joints were designed to take up specific forces (pull, push, torque, etc.). Carpenters could 'read' the quality of wood by examining it closely. Even today, a solid knowledge of past techniques remains essential in bringing timber construction forward and truly innovating. In these modern, competitive times when labour is expensive, it is increasingly hard to work with traditional techniques. To maintain and nurture a 'timber building culture', old techniques must be adapted and further developed, while radically new techniques must also be found. Within the framework of the 'Crafting Wood' research project, the goal is to bridge the gap between old and new craft, strengthening continuity of knowledge about timber architecture. Three projects centred on this theme, each of them relating to a specific case: the curved timber roof structure of the gate tower at Schaesberg Castle. All three projects searched for an alternative, contemporary reconstruction of this timber structure.

Schaesberg Castle gate tower

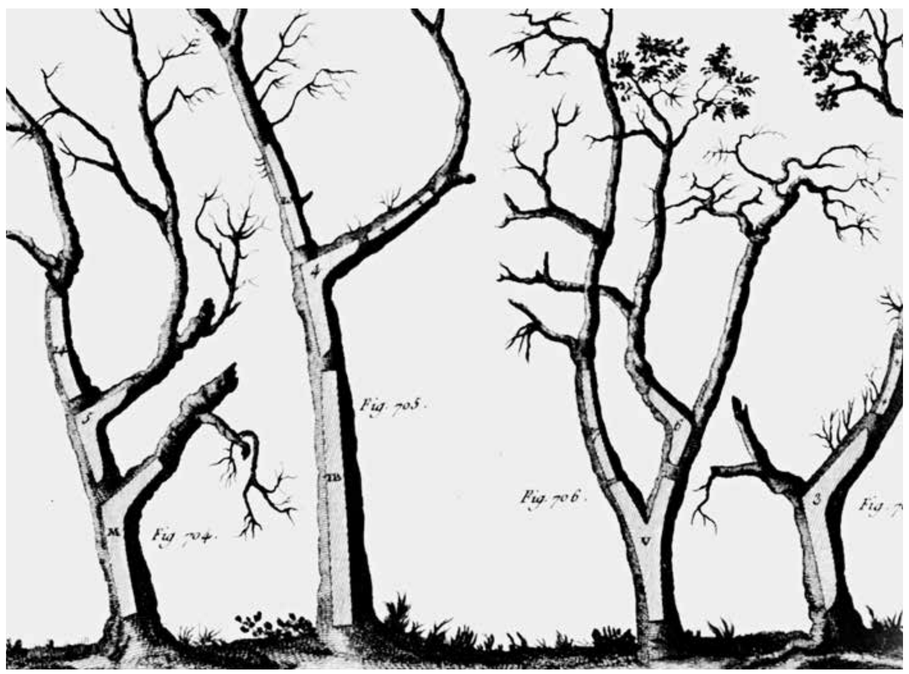
The architecture office Werkstatt and Machiel Spaan initiated three research projects together with students from the Amsterdam Academy of Architecture to achieve this goal. They focused on an analysis of an alternative reconstruction of the former central tower of Schaesberg Castle in the province of Limburg in the south of the Netherlands. This ancient stone tower had an eye-catching, slate-clad, 'bell-shaped' roof, supported by a timber structure. The original tower structure remains something of a mystery, because the original plans were lost. An analysis has been made based on the few sketches, measurements, photographs and comparable structures that still exist.

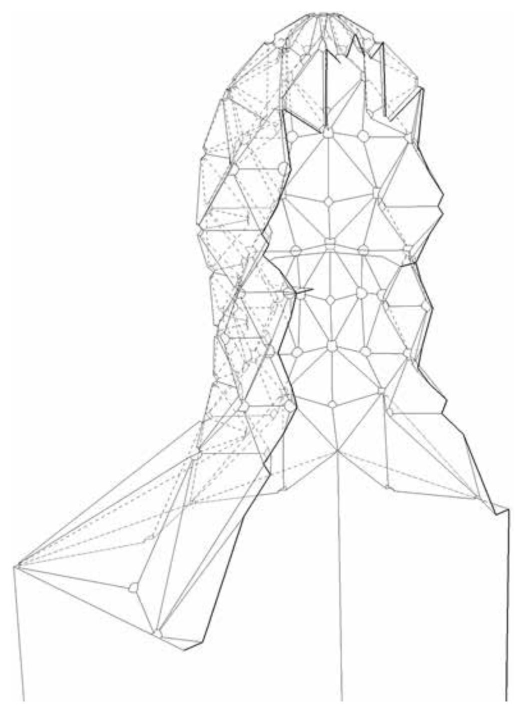
The remarkable bell shape is clearly visible in photographs of the exterior. Only one interior image reveals some information about the tower's octagonal loadbearing structure. It does, however, reveal something interesting about the structure: a 22.5 degree vertical rotation of the tower's central cross-shaped main structure relative to its square stone base. This is the result of the octagonal horizontal section, which makes up the facetted bell shape, consisting of eight single-curved surfaces. Heavy solid oak members were used for the main structure. The structure's overall height of approximately 9 metres is at the limit of what is possible with single members. The structure was likely composed of multiple members to reach the total height.

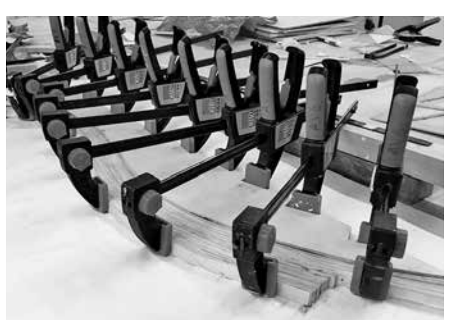
Tower of Slot Scheasberg, Landgraafa

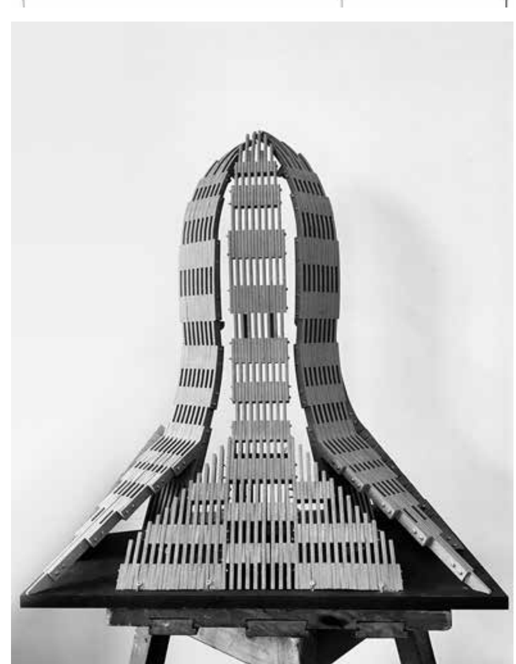
O4 research studio—Amsterdam Academy of Architecture

The goal of the O4 research studio was to understand the differences and similarities between traditional and high-tech methods, and to apply this knowledge to a design assignment: the complex roof structure of Schaesberg Castle's central tower. The O4 studio explored two traditional and two contemporary techniques of joinery and construction. Seventeenth-century shipbuilding methods provided interesting insights into creating curved geometries, by harvesting and applying pre-curved timber beams from curved trees. The use of naturally grown 'Y joints' from tree branches also provided insight into benefiting from nature's most efficient joinery skills. In contrast, digital methods such as CNC milling and laminating show the current state of the timber industry. CNC-milled cross-laminated timber structures have succeeded in combining 'skin' and 'structure', creating possibilities to 'open up' spaces that were formerly occupied by loadbearing structures. And of course the technique of laminating makes it possible to create precise and efficiently curved structures by using fast-grown softwood available locally. The aim was to apply a combination of these techniques to create 'contemporary' fragments of the curved roof structure, thereby generating valuable insight into the future role of wood in organic architecture.


'Krommers' to build the hull of a ship, 16–17th century







Erasmus Wood workshop—Amsterdam Academy of Architecture, with the Universities of Trondheim and Vaduz

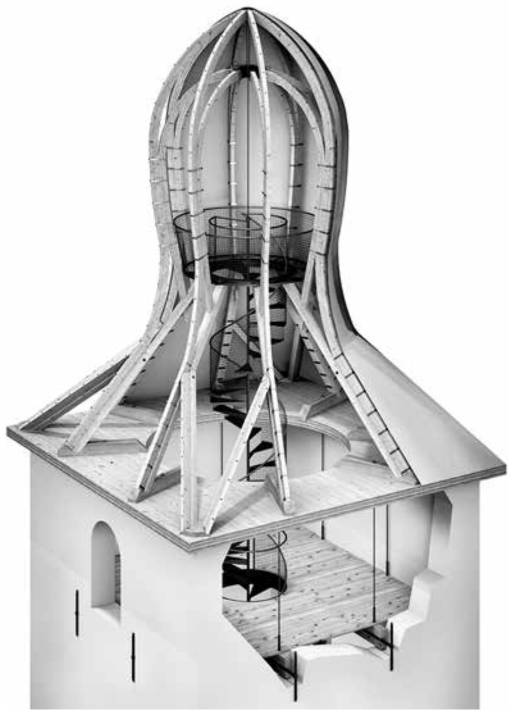
Designing with wood requires specific knowledge about the material because of its natural, anisotropic properties. The only way to truly understand this is to work with the material at scale 1:1. The curved shape of the Schaesberg tower structure provided a valuable starting point. The structure's complex geometrical facets posed multiple challenges for this physical exercise. The aim of the workshop was to create a 'pavilion' or roof structure, consisting of curved timber trusses, derived from the shape of the tower's cross-section. The top side of the trusses had to follow the exact curve, while the bottom side and supports could be designed freely. Giving students certain restrictions in terms of shape, dimensions and quantity of material yielded an interesting collection of ideas. The result was a diverse collection of timber trusses, together embodying the wealth of solutions offered by timber construction.

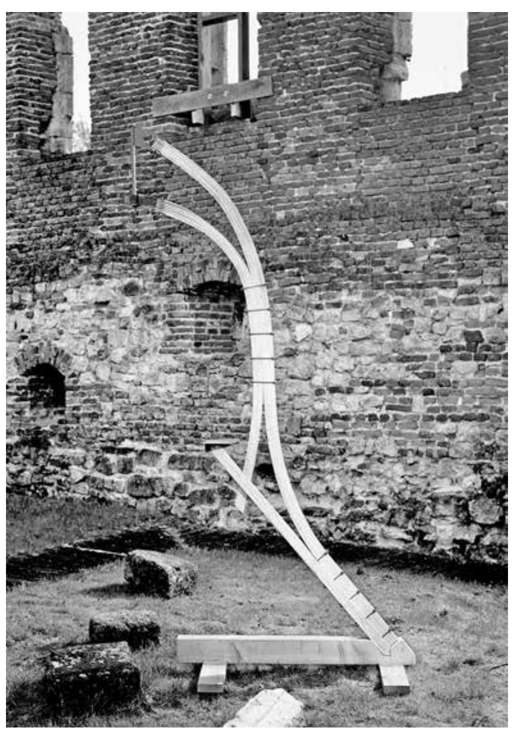
Slotlab—Research by Werkstatt

The O4 studio and Erasmus workshop ran parallel to the Slotlab research project initiated by Machiel Spaan and Material Sense Lab for the IBA 2020 (Internationale Bauausstellung) in Parkstad. Slotlab invites young designers to reconstruct parts of Schaesberg Castle using modern, innovative methods. Architecture office Werkstatt was asked to reconstruct the traditional bell-shaped roof structure of the castle's central gate tower using innovative timber construction techniques.

The original structure that supported the remarkable roof consisted of solid beams sawn from big oaks that are now scarce in the region. These big structural beams made the space beneath the roof impenetrable. Werkstatt wanted to free up this space so that visitors could experience the roof structure up close. In addition, there was a desire to make use of wood harvested locally. This mostly comes from smaller trees that call for different construction methods. To this end, Werkstatt investigated the ideas of the very first timber engineers who in the early 19th century built innovative timber structures out of composite timber, also called 'laminated timber structures'. Numerous thin layers of timber are pressed to form a strong, thick beam. Structures of this kind are increasingly common today, but a lot of glue is involved. In the past, they featured smart connections of steel or timber. That makes it possible, in theory, to dismantle the structure and reuse the timber. This aligns more with the current tendency to consider the sustainable use of materials and circularity. Unfortunately, midway through the 19th century, this pioneering work by a handful of timber engineers was overshadowed by the arrival of wrought iron. Today, the use of timber in construction is on the rise, because it has a positive CO_2 footprint, in contrast to steel and concrete. In the new design for the top of the tower, Werkstatt sought to achieve a high level of material efficiency by resisting the wind load and gravity with a combination of curved and straight timber components. In this way, structural material can be added where the forces are greatest, and material can be minimized in other places, resulting in an elegantly slender structure. Space is kept open in the centre of this structure for a spiral stairs and a round platform to allow visitors to experience the tower to the full. In addition to a fully digital model, one rafter was built at a scale of 1:3. Freshly sawn Douglas fir from the locality was laminated and fastened without the use of any glue, with just mechanical connections of steel and timber. In this way, assumptions and expectations could be physically tested and confirmed: the structure turned out to be very strong and stable, retaining its exact shape after the removal of the mould.

Werkstatt picked up where the 19th-century engineers had left off, combining their ideas with the most modern timber construction techniques. And thus the new tower roof was a homage to more than two centuries of innovation in timber construction, bridging new and old.





Workshops

Seven Trusses

25.08–2.09.2018
Trondheim,
Norway

Alpine Towers

14–24.03.2019
Vaduz,
Liechtenstein

Pavilion at
Slot Schaesberg

19–21.08.2020
Amsterdam,
The Netherlands

During the whole programme, three workshops for all participants ran in the three countries. The goal of each workshop, which was an essential part of the project studio, was to become familiar with wood, with its properties and with the culture of wood construction of the region. In the workshops, participants first surveyed historical and recent wood constructions, and then worked in teams to build models by hand at scale 1:20 or 1:10. In the second part, students studied and experimented with structural elements at scale 1:1. During the final days of the workshop they built a structure at full scale.

For centuries, carpenters have crafted wooden joints and the production methods have been bound by traditions. Many cultures developed their own joinery traditions, and in cultures such as the Chinese or Japanese, these traditions have been especially strong. In Europe, the traditions for structural joinery are closely related, but with regional differences. Today, the development of digitally controlled milling machines has provided renewed interest in structural wood joints. It is now possible to produce them effectively and economically with high precision. Therefore, the design needs to be informed both by industrial parameters and by traditional carpentry knowledge.

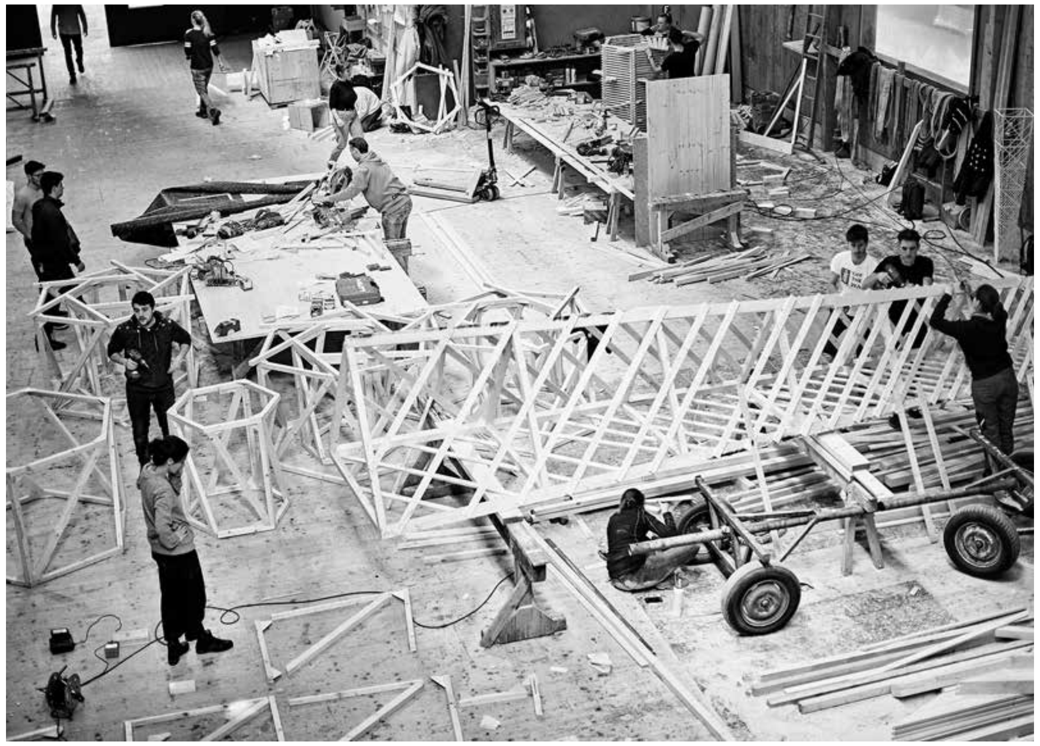
The task of this workshop was to develop and build a timber roof structure. The discussions included architecture, space, structure, joints and timber as a material. An important focus in the discussions was on the detail, and the differences found between structural wood joints made manually by hand and electrical hand tools, machines and robots. By making structural details with different sets of tools, the participants learned about the properties of wood and how wood can be used in inventive ways. By bringing the detail back to the centre of the architectural design, we can enable architecture to regain the important synthesis of structure and expression.

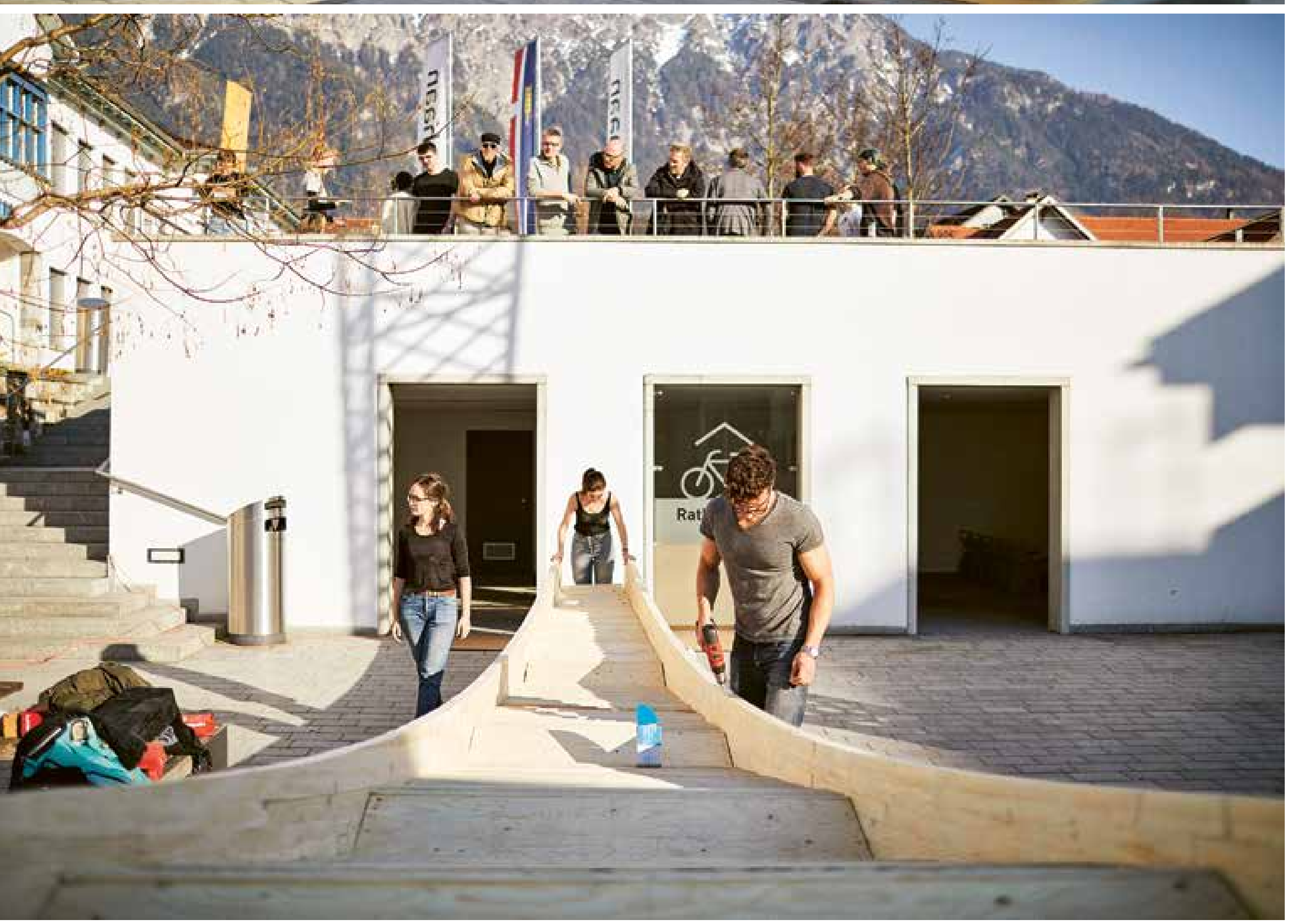



During the workshop in Liechtenstein, the students started with building towers of wooden slats at scale 1:20. Structures that defy gravity and absorb horizontal forces were sketched. The models never lie: by pushing and pulling the slats, we understood the distribution of forces and were able to increase the stability. In this way, twelve structural principles for a 35-metre-high tower at the base of the mountain in Liechtenstein were created over time.

In groups of students from the different schools, we elaborated six chosen structures. The scale was then increased to 1:5, which resulted in models of seven metres tall. The glued or adhesive joint of the 1:20 model had to be replaced by 'real' structural joints. The weight of the material and the precision of the saw cuts were important factors in the execution. Twelve hands worked resolutely on one tower, designing while making. Connections arose via the experiment and were refined over the course of the days.

After four days, the six seven-metre-high wooden structures were transported to the village square in Schaan and hoisted, assembled or stacked on top of each other. The structures formed an inspiring ensemble of six towers, each with a character of its own. Six different structures, each with its own story, delete laws and connections. They demonstrate the creativity of the designer and the workmanship of the craftsman. Thinking and doing formed a stimulating field of tension which was assimilated in unique creations, showing that a fascinating voyage of discovery full of setbacks and successes lies hidden between concept and reality. These prototypes underline the experimental approach of the whole project and mark the starting point for the building of a tower in Liechtenstein, which will be built in collaboration with the students.

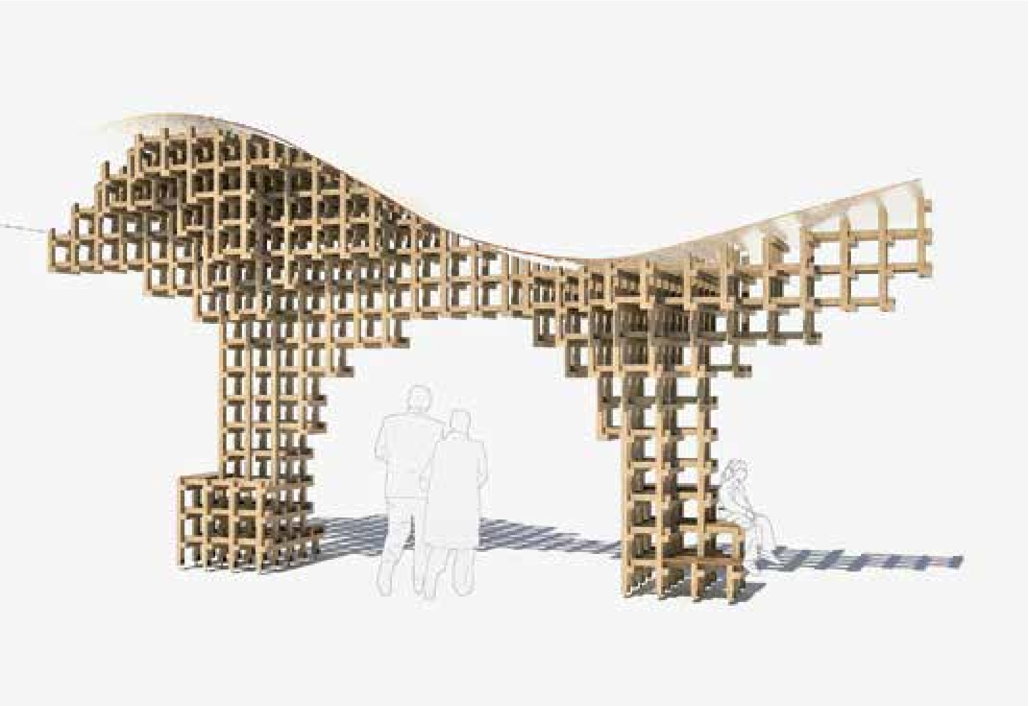


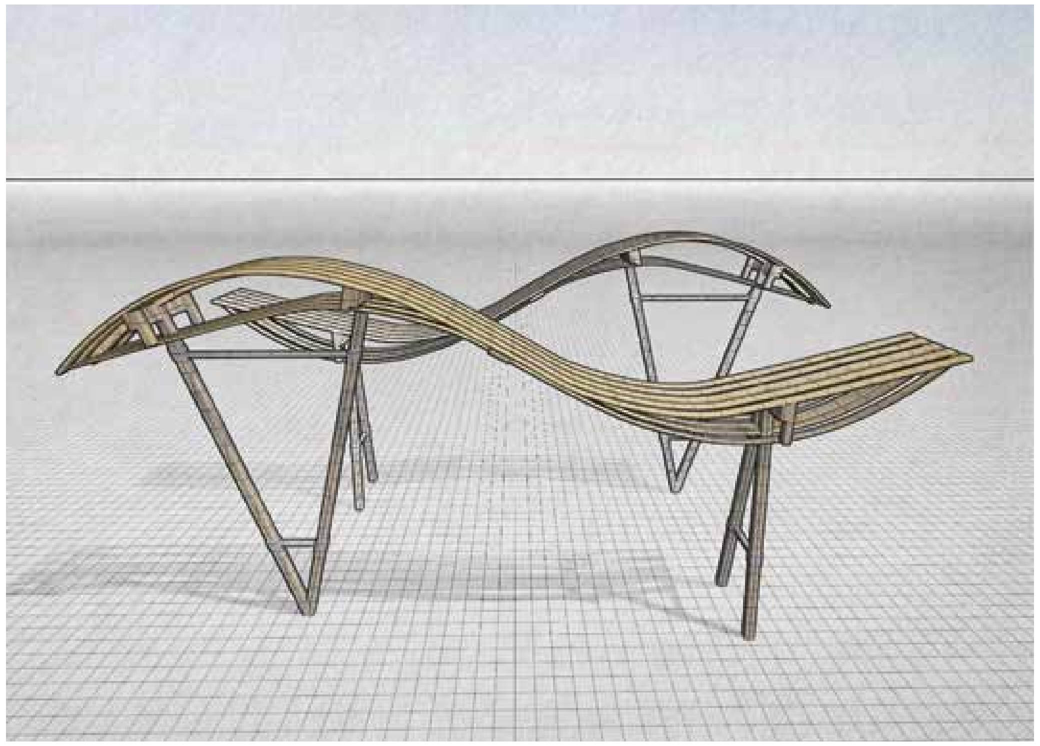


The goal of the workshop was to get in touch with wooden structures and to strengthen a tectonic approach towards both tradition and innovation of wooden structures. In combining traditional craftsmanship and industrial production, the workshop aimed to research solutions that develop new ways to use wood. During the workshop, students experimented with structural elements at scale 1:10. With wooden laths, constructions that are capable of forming members of the structure of an expo pavilion were developed.

The location for the pavilion is the square in front of Slot Schaesberg for the Slotlab exposition for IBA Parkstad. The pavilion is an experiment in making a temporary and removable wooden roof structure, whose elements should be easy to dismantle and to transport on a small truck. The pavilion is a temporary structure assembled with wooden joints, constructied with as little steel as possible and no glue added.

During the workshop we investigated different structures and systems. First at scale 1:10, thereafter with mock-ups and finally at full scale. The starting point was the shape of the pitched roof of the castle tower. The final designs, unique in shape, structure and joints, express an ambitious attitude towards the innovation of the craft.





Participants

Erasmus+
Workshop Wood

Trondheim
25.08–02.09.2018

NTNU Trondheim

Ragnhild Skoglund
Marte Midtlyng
Lars Gustav Rogne
Juni Palmstrom
Johan Dolmseth
Michael Hongyu Peng
Haakon Bergsholm
Eline Eide Bye
Arild Megard
André Berlin
Martin Vilhemson
Johanne Thoresen Mofoss
Ingrid Sondov
Teachers:
Siem Jan
Gilberg Arnstein
Bjørn Otto Braaten

University of Liechtenstein

Natalie Marinelli
Denise Pfleger
Nick Ulrich
Zoran Miletic
Pascal Büchel
Andreas Negele
Daniela Huber
Teachers:
Carmen Rist-Stadelmann
Urs Meister

Amsterdam Academy
of Architecture

Art Kallen
Jesse Stortelder
Anouk van Deuzen
Sander Gijsen
Milo Greuter
Maro Lange
Loretta So
Susanne Vruwink
Noury Salmi
Susanna Scholten
Charlotte Mulder
Matilde Bazzolo
Teachers:
Machiel Spaan
Jochem Heijmans
Niels Groeneveld
Jan Loerakker
Serge Schoenmakers
Yukiko Nezu

Vaduz
14–24.03.2019

NTNU Trondheim

Júlia Ros Bofarull
Gilles Gasser
Luis Martín Cea
Mar Campos
Alina Koger
Esteban Borteele
Alex Escursell
Anna Molina
Arthur Rundstadler
Pia Weber
Ben Quinn
Arno Léon Oreste
Alfred Wust
Berenice Aubriot
Bejan Misaghi
Silvia Riubrugent
Anna Prüller
Bertille Bourgarel
Agathe Cheynet
Iñigo Gutiérrez
Teachers:
Arnstein Gilberg
Bjørn Otto Braaten

University of Liechtenstein

Sandra Oeler
Shefket Shala
Maik Goop
Gebhard Natter
Bunjamin Sulejmani
Rikke Jensen
Christian Meier
Attila Truffer
Edwin Frei
Teachers:
Carmen Rist-Stadelmann
Urs Meister
Christoph Frommelt

Amsterdam Academy
of Architecture

Danny Kok
Anne Roos Demilt
Charlotte Mulder
Ayla Azizova
Anna Tores
Evie Lentjes
German Gomes Rueda
Noury Salmi
Adan Carnak
Teachers:
Machiel Spaan
Nina Knaack
Marcel van der Lubbe

Amsterdam
19–21.08.2020

NTNU Trondheim

Andreas Nielsen
Christina Schieferle
Clément Molinier
Gianmarco Pistoia
Giovanni Dello Loio
Johanna Kieft
Jostein Wigenstad
Julia Kapinos
Julie Bovier
Kotryna Navickaite
Laura Bergelt
Laura Villaverde
Melanie Vercauteren
Sjaak Velthoven
Sofie Gustafsson
Sofie Luise Fetting
Xavier Granados Esteve
Teacher:
Arnstein Gilberg

University of Liechtenstein

Chun Yin Kelvin Au
Shona Beatje
Morten Bjørn Jørgensen
Finn Buchanan
Carlos Vazquez
Roberto Villaseñor
Gregorio Candelieri
Elias Said
Libat Eden
Marie Mikulová
Herolind Elezi
Zaal Siprashvili
Lars Gassner
Nick Conrad Ulrich
Gabriela Ponechalová
Lucia Schachtner
Tata Zakaraia
Giorgi Evsia
Teachers:
Carmen Rist-Stadelmann
Urs Meister
Christoph Frommelt

Amsterdam Academy
of Architecture

Laurien Zwaans
Tom Vermeer
Anne-Roos Demilt
Daria Dobrodeeva
Richard Doensen
German Alfonso
Charlotte Mulder
Evie Lentjes
Sung-Ching Lo
Anouk van Deuzen
Teachers:
Machiel Spaan
Niels Groeneveld
Marcel van der Lubbe
Gerald Lindner

Arnstein Gilberg
is an architect and Associate Professor at Faculty of Architecture and Fine art, NTNU Trondheim, Norway. He teaches tectonics and working with full-scale constructions. Course manager for master course 'Timber structure' and a part of the Erasmus+ project 'Wood: Structure and Expression'.

Haakon Haanes
is co-founded Nøysom arkitekter just after graduating from NTNU in Trondheim in2015. Before studying architecture, Haakon studied philosophy and psychology for two years in Oslo, which sparked an interest for working with the broader questions concerning our built environment, such as sustainability and ecology. Together with Cathrine, Haakon has written several articles about architecture, ecology and alternative housing strategies. He has also held lectures, talks and arranged workshops with the other partners in Nøysom arkitekter. Haakon has also worked for several years with city planning and placemaking at The City Planning Office in Trondheim and The Agency of Planning and Building Services in Oslo. In addition to being partner in Nøysom arkitekter, Haakon is currently employed as an urban planner in Asplan Viak in Oslo.

Annemariken Hilberink
studied Architecture at the Technical University Eindhoven from 1983–1990. Received the 2nd price in the Archiprix 1990, the best Dutch graduation projects, with a design for a mountain station in Austria. Worked at several smaller architectural firms. Received a starter stipend of the Fonds BKVB on which she started her own architectural firm. In 1996, together with Geert Bosch, she formed the office Hilberinkbosch architecten. She has been involved in teaching at several Academies of Architecture, most recent as a member of examiners in Arnhem. Also worked as a member of Architectural advisory services in Etten-Leur and Venlo.

Tibor Joanelly
is an architect, publicist and teacher. He received his degree in architecture at the Federal Institute of Technology in Zurich (ETHZ) and worked in numerous well-known Swiss architectural offices. Next to his practice, he led atelier discourses with Swiss architects such as Christian Kerez, Valerio Olgiati and Livio Vacchini. He published essays and articles in architectural magazines. Tibor Joanelly was teaching at the Budapest University of Technology, at the ETHZ and at the University Liechtenstein. He currently lectures on Architectural Critique at the University for Applied Sciences in Winterthur and he is an editor of the Swiss architectural magazine werk, bauen + wohnen. He is engaged in several book projects as well as in architectural practice.

Cathrine Johansen Haanes
was born in the arctic city of Tromsø in Northern Norway. She studied architecture at The Norwegian University of Science and Technology (NTNU) and graduated in 2014 with a diploma project called 'The Way to Satori', a space for contemplation of nature on the mountain of Fløya in Tromsø. In 2015 she co-founded Nøysom arkitekter with Trygve Ohren and Haakon Haanes. The trio is most known for their urban ecological pilot project, 'Experimental Housing at Svartlamon', a self-build scheme were five families have been able to build their own low cost row-houses made largely from reused materials. The project has sparked a broad national and international interest in the young office, which was nominated to The European Union Prize for Contemporary Architecture—Mies van der Rohe Award 2019 and introduced as emerging architects in Architectural Review in May 2019. In addition to working as an architect, Cathrine writes and lectures, together with Haakon, about architecture, ecology and alternative housing strategies.

Urs Meister
is graduated in architecture from the ETH Zurich. He is a professor of design and construction at the Institute of Architecture and Planning at the University of Liechtenstein and partner of the architecture office Käferstein & Meister Architekten AG in Zurich. Coordinating Erasmus Intensive and Erasmus+ programmes since 2003, he was responsible together with Carmen Rist-Stadelmann for the programme 'Wood: Structure and Expression'.

Mario Rinke
is Professor at the Faculty of Design Sciences at the University of Antwerp. Trained as a structural engineer and working in the field of architecture for some years, he is teaching and researching construction in the realm of architecture. Genuinely interested in transformation processes between areas of knowledge, materials and institutions as well as structural thinking, he is specialised in hybrid material concepts, early reinforced concrete and early industrial timber (glulam). After working as a design engineer for major offices in London and Zurich, he ran his own practice in Zurich for several years. Mario Rinke holds a Diploma degree in civil engineering from the Bauhaus University Weimar and a PhD from ETH Zurich. He was senior researcher and lecturer at the architecture department at ETH Zurich and the senior lecturer at the Lucerne University of Applied Sciences and Arts. Currently, he serves as a member of scientific committees, as a reviewer for journals and is a founding member of the International Association of Structures and Architecture (IASA) and currently secretary the management board.

Carmen Rist-Stadelmann
graduated in Architecture from the Technical University Vienna, Austria and received her doctoral degree the same university. She has practiced professionally in Austria and Malaysia and is currently Master academic director at the Institute of Architecture and Planning at the University of Liechtenstein. She runs design studios at undergraduate and graduate level and her current research project 'Hands-on: An added value for teaching in architecture' focuses on building on a scale of 1:1 with students and professionals as part of their architectural education. She is the coordinator of 'Wood: Structure and Expression', funded by the European Commission, which focuses on the tectonic method for connecting wooden joints to a structure on a scale 1:1.

August Schmidt
established his private practice, Studio Sjellsand, in Trondheim in 2005. After finishing engineering studies in Austria, he pursued architecture studies in Graz, Stuttgart and Trondheim. He has worked in various architect firms in Austria, Germany, Canada and Norway, where he graduated and settled down in 1996. His early training in masonry and carpentry is evident in the craftsmanship and detailing in his projects. The link between form, construction and materials is the basis of his teaching at NTNU, and in his internationally published projects. August specializes in small self-built housing which strives towards quality in every inch.

Machiel Spaan
is an architect, co-founder of the Amsterdam firm M3H Architecten and has taught at various architecture programmes in the Netherlands and beyond for over twenty years. Recently he published *The Wandering Maker*. Spurred by his own observations, *The Wandering Maker* discovers the value of street, building, house and detail. He unravels constructions, cleans up, repairs and transforms; searches for a conscious way of dealing with the available material as a sustainable alternative for the fast conceptual and object-oriented approach. Machiel Spaan is involved in the Erasmus program since 2008.

Harm Tilman
is editor-in-chief of the Architect, an independent and opinion-forming professional journal and platform in the field of architecture, urban design and interior design. Website, magazine and events inform and inspire spatial designers and place their work in a broader social and cultural context. Before he has been coordinator at the Rotterdam Academy of Architecture. Tilman graduated from Delft University of Technology in 1984, after his studies worked as an urban designer and researcher, gave lectures and supervised projects at various educational institutions in the Netherlands and abroad. He is also the author of numerous publications in the field of modern architecture and spatial planning.

Werkstatt
is an Eindhoven based architecture practice founded by Raoul Vleugels (1985) and Niels Groeneveld (1985). They focus on sustainable building in wood, for which they have drawn considerable attention. In 2021 they were rewarded the Jonge Maaskantprijs for their contribution to a sustainably built environment. Their projects have developed from a radical ecological approach to a distinctive architecture in which sustainability is clearly expressed.

Klaus Zwerger
studied at the University of Applied Arts in Vienna. Alongside and afterwards he worked as carpenter, joiner and artist. In 1991 he became assistant at the University of Technology in Vienna. Since then he extensively travelled in most European countries, in East and Southeast Asia in order to study and investigate historic wood architecture. In 2012 he habilitated at the Vienna University of Technology. In 2015 he held a guest professorship in Tokyo. He gave numerous presentations and lecture series predominantly in China. He widely published in German, English, Chinese and Japanese language. Recently he expanded his research focus to Northern Laos and Vietnam.

Credits

Editors: Carmen Rist-Stadelmann, Machiel Spaan, Urs Meister
Contributions by Carmen Rist-Stadelmann, Urs Meister, Machiel Spaan, Niels Groeneveld (Werkstatt), Bjorn Otto Braaten, Jan Siem, Arnstein Gilberg, Annemariken Hilberink (HilberinkBosch Architects), Mario Rinke, August Schmidt, Klaus Zwerger, Tibor Joanelly, Cathrine Johansen Haanes, Haakon Haanes (Nøysom arkitekter).
Translation: Billy Nolan, David Koralek
Final editing: Billy Nolan
Design: SJG / Joost Grootens, Dimitri Jeannottat
Lithography: Marc Gijzen
Printing: Wilco Art Books

ISBN 978-3-03860-235-4

Park Books
Niederdorfstrasse 54
8001 Zurich
Switzerland
www.park-books.com

Printed in the Netherlands

Picture credits:
Bruno Klomfar (p. 11), Jonathan Drew (p. 27, 151–152, 154), Thomas Lenden (p. 30–33), Niels Groeneveld (p. 38–39), Miro Kuzmanovic (p. 42–46), Rene de Wit (p. 54–55), Jürg Zimmermann (p. 57–59), Pasi Alto (p. 61–63), Klaus Zwerger (p. 65–69), Musée d'art et d'histoire Fribourg (p. 71), Marco Bakker (p. 72, figure 2), Mélanie Rouiller (p. 72, figure 3), Museum zu Allerheiligen, Schaffhausen (p. 126, figure 2), Carpenter Wiedenkeller, A. Wiedenkeller, St. Gallen (p. 127, figure 3), Liechtensteinisches Landesarchiv, Vaduz (p. 127, figure 4), Seiher+Seiher (p. 128, figure 5), Darko Todorovic (p. 128, figure 6), Zhongguo gujianshu, in: Lothar Ledderose, *Module und Massenproduktion im chinesischen Holzbau* (p. 129, figure 7), Darko Todorovic (p. 143–148), Miro Kuzmanovic (p. 149). All other pictures by students and teachers.

Special thanks to:
Clarissa Frommelt and Stefan Sohler, Agentur für Internationale Bildungsangelegenheiten, Vaduz
Frommelt Zimmerei Ing. Holzbau AG, Vaduz
Bouwbedrijf van Engen, Kockengen
Slot Schaesberg en Slotlab, Landgraaf
IBA Parkstad, Heerlen
Gemeinde Schaan, Liechtenstein

Park Books is being supported by the Federal Office of Culture with a general subsidy for the years 2021–2024.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

AIBA Agentur für Internationale Bildungsangelegenheiten
Universität Liechtenstein
Bouwbedrijf van Engen
NTNU Norwegian University of Science and Technology
Frommelt intelligenter Holzbau
Erasmus+
Academy of Architecture Amsterdam University of the Arts