

Contemporary Architecture between Research and Practice

Experimentations in Digital Wood

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This paper is a take on contemporary works in wood designed with parametric softwares and seen from an academic and professional point of view. The knowledge about digital wood developed through Digital Fabrication Laboratories has proved to be effective but with certain limitations when used for real constructions. In fact, translating the freedom of building temporary architectures -which is usually one of the "learn by doing" activities of design studio or workshops- into wood architecture that respect all the constraints of real construction is a challenge. This paper shows several experiences where innovative ideas developed through research have been applied to temporary pavilions and real constructions in Japan, Italy and France.

Keywords: *Parametric design and fabrication strategies, Pedagogy and Practice, CNC and Woodworking Technology, Wood complex surface*

INTRODUCTION

Computational software and digital fabrication technologies are contributing to the transformation of the construction sector which, until the 20th century, was rather static and closed.

Currently, architects, designers and engineers have to face increasingly complex design requirements which leads to the question: how do practices acquire the ability to do so? There are at least two ways: either by developing applied research on their own or by including students trained in complex design. These are the two most viable methods to integrate research into work and to prepare for the changing form of practice in architecture. However, once this conceptual framework has been integrated into practice there are some issues left open such as

budget limitations, building code regulations, technical constraints, durability, expertise and machines used by the construction companies.

This paper considers contemporary works in wood seen from two different points of view: academic and professional. It builds upon several years of academic research experience at the Kengo Kuma Lab of the University of Tokyo, at the National Research Center (CNRS) in Paris and at the faculty of architecture La Cambre Horta, Université Libre de Bruxelles. The author is one of the founders of LAPS Architecture, an office based in Paris characterized by an applied research approach to architecture. In the past years, LAPS Architecture has developed a specific language through the integrated use of parametric design and the employment of different mate-

rials for private and public projects of different scales. Through the study of different case studies, the goal of this paper is to show the limits of the integration of research into practice.

BETWEEN PEDAGOGY AND PROFESSION, RESEARCH AND PRACTICE

Efforts in establishing research in the use of digital wood in architecture commenced in 2009 with the first courses at the University of Tokyo introduced by Kengo Kuma and related seminar courses that focused on a parametric approach to different materials including wood. Full-scale constructions constitute an essential element of research by design in these studio courses. Besides design studios, the study of architecture, materials and structure is often reinforced thanks to targeted activities such as summer schools and hands-on workshops.

Research by design as a mode of inquiry has its own particular modalities and one of the most effective strategies is to design and build a small pavilion. Building a pavilion presents several positive aspects because it can be done at reasonable costs, it is ideal to test new materials and it can be built by the students themselves. Learning outcomes are very positive because, thanks to these activities, students get a first concrete experience in the physicality of construction and test all the aspects of translating ideas into real projects.

Research at work

Among small-sized architectural offices, it is not common to do research because it is time consuming and not immediately economically sustainable. According to Hensel (2016), practices interested in research develop a knowledge that “involves specific ways of integrating architectural education and research, in particular research by design, to support the development of related knowledge, concepts, methods and frequently also the production of reliable empirical data, engaging real-life design problems and seeking interaction with practice”. LAPS Architecture has invested in research activities to create a compre-

hensive approach to architecture and has focused on the combined use of digital tools and materials, such as wood and raw earth, integrated in the construction of private and public buildings.

For the author, the knowledge about digital wood developed in academy has proved to be effective but within certain limitations when used for real constructions. In fact, translating the freedom of building temporary architectures -which usually is one of the prerogatives of architecture built at university- into wood architecture that respects all the constraints of building codes is a real challenge. The research at LAPS Architecture relies on a team of usually one to three people according to the size of the mission. The work is organized around two different types of projects: 1) basic research based on form finding and material testing, and 2) oriented research aimed at solving real projects. Basically, on one hand there is a research for aesthetic pleasure of searching for new geometry, shapes, materials, assembly logic and structures. On the other hand there is a research oriented at solving concrete constructive problems.

The results of research based practice

The paper describes how knowledge developed through academic research is increasingly integrated into a small sized architectural practice on different projects sizes ranging from small to large. The article is organized diachronically which is significant in that it addresses different projects and resourcing requirements that are enabled by specific project sizes. Scale determines the type, scope and modes of research of each project. With the aim of experimenting the use of wood in contemporary architecture, the projects covered include: a tea house, a shelter for archeologists, a partition and shelving system and the facade for a public building.

RESEARCH: BUILDING SMALL PAVILIONS AS A STRATEGY

A small pavillon does not require significant economic investment (often a private sponsor or a research fund cover the expenses) but it is an inval-

able tool to advance applied research, in testing new forms, materials, performances or assembly techniques. There is a rising demand in students wanting to participate in hands-on experience where they are involved in the translation of concepts into reality.

This paragraph describes two pavilions, which were the output of two workshops held respectively at the University of Tokyo in 2011 and at the Unesco Heritage site of Agrigento in 2013. The workshops were organized with the following structure: two universities invited, a topic linked to culture, a pre-defined budget, a two-phase period including design and construction, wood chosen as main material and use of parametric software and digital fabrication.

Approach and Practicability of Parametric Design and Digital Fabrication

The two workshops provided a point of reflection within the academic setting to consider the consequences of computational design when applied to the physical reality of making, rather than stressing too heavily on the form-finding aspects of computational design. Engagement in a continuous process leads to a constant feedback loop between the software, material characteristics, and contextual considerations. The parametric tool allows for the input of an almost infinite amount of information, producing mathematically logical, countless variations during the process, but it obviously cannot determine any hierarchical design decisions. Matsukawa (2007) dissects the differences between conventional design process versus the generative model, where diagrammatic process models between environment, architect, building, user, and other basic criteria such as building codes, operate differently and it is illustrated in examples including linear model or partial feedback loop model. One of the most complicated process diagrams -where series of algorithms are employed- leaves the architect with the "question" without a definite answer.

Each of the pavilion's physical presence and their feasibility on multiple levels were evaluated and re-

considered throughout. The process also assessed the technology employed and the highly sophisticated elements that can be produced, whilst relieving participants, who were inexperienced in construction, of some issues including protection from weather, foundations, and structural stability over an extended period of time, thanks to the temporariness of pavilions. It also encouraged material experimentation, intuitive predictions for structural elements, and a trial and error approach in detailing and assembly. The shift in focus from satisfying the public at large to an increasingly personal scale gave an ideal opportunity to test these digital tools. The small scale of the tea house and its function, both of which are deeply rooted in culture and its sensibilities, may not produce monumental visions single-handedly. The potential for individual insights to be optimized by the use of parametric tools and processes pointed to a direction where the framework of culture can serve as a starting point for selective optimization. Design has evolved alongside technology in a mutually beneficial relationship.

DIGITAL TEA HOUSE WORKSHOP

Held at the University of Tokyo, together with Columbia University GSAPP, Digital Tea House was a joint workshop with the aim to design and build three pavilions for hosting tea ceremonies. Issues addressed in the three-week workshop ranged from applications of computational design, interpretations of tradition and culture, structural stability, to practical solutions for quick physical materialization within limited time and budget. The workshop was divided into two sections. The first part introduced computational logic and concepts, which led to the second part where explorations relating to the Japanese tea ceremony culture served as a pretext for further exploring digital design and fabrication. Three teams, each comprised of 6 to 8 members, ultimately produced three full-scale tea houses to test out their concepts, methodologies and materials. Several elements served to make comparisons and analysis during the process and later in two distinct out-

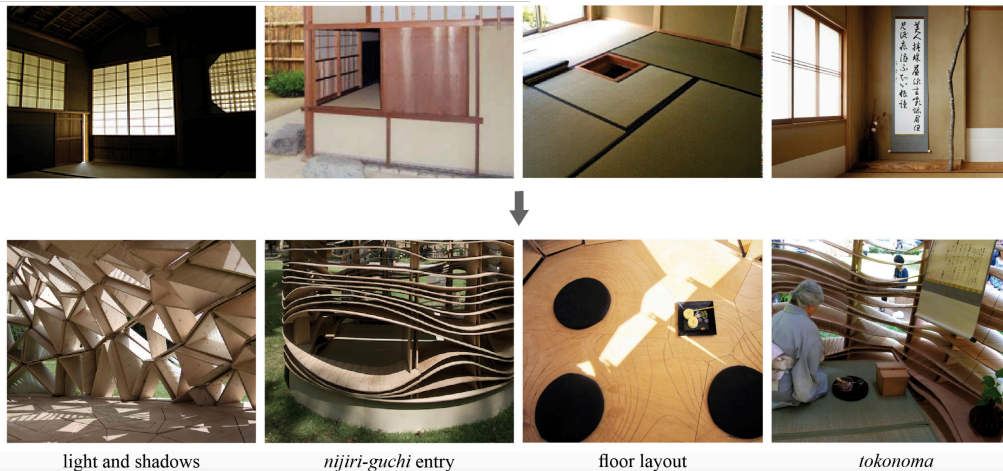


Figure 1
Traditional
elements, above,
were used as
inspiration to create
contemporary
interpretations

comes: baseline for common software (Rhino and Grasshopper), principal material (50 sheets of 9mm and 12 mm thick 3x6 plywood), fabrication method (CNC routing), and budget (of approximately 1,500 €, per team, excluding plywood and CNC fabrication costs). The output of the workshop clarified that, firstly, parametric processes are not contradictory to traditional cultural principles; and second, how traditional elements of the tea house can be decoded and formally reinterpreted through parametric design.

Tea house as a cultural backdrop

In the 16th century, the Japanese people gave life to a new culture which consisted of elements such as the tea house, *'Sukiya Style Architecture'* and the *'Wabi-Sabi'* aesthetic of transience [3]. At the time, the 'Tea House' thus represented an avant-garde type of architecture. Stemming from the use of the body as a point of reference, the tea house evolved into a microcosmic situation where host and guest(s) meet and, at the same time, an intellectual device through which one is made aware of the natural phenomena occurring outside. Moussavi (2006) writes: "architecture needs mechanisms that allow it to become

connected to culture. It achieves this by continually capturing the forces that shape society as material to work with it. Architecture's materiality is therefore a composite one, made up of visible as well invisible forces." The traditional tea house is composed of a variety of elements, including shoji screens or bamboo slats that serve as light filters that underscore gradations of light, a small wooden sliding door at nijiri-guchi entryway, tatami mats that signify where one may sit, and a recessed alcove tokonoma for hanging scrolls and flowers (Fig.1).

From Context-Neutral to Context-Aware Design

How can we build a bridge between the digital environment to the physical environment in which we live? First, we addressed the consequences of the designs - how every part should be considered for its strength, weight, its assembly sequence, and surface treatment. There are also questions regarding appropriateness and scale of design, which often cannot be resolved in the isolated modelling phase. How to reconcile disparities is one of the biggest challenges in the design process; this workshop used the cultural function of the Japanese tea house as a starting point

to address the gap. The often scale-less nature of design through scripting is applied via a traditional set of rules, such as the prototypical 4.5 tatami-mat scale of a tea house, to be physically implemented.

The process of computational design and fabrication can amplify complexity as desired, but perhaps more intriguing are considerations on what new values can be extracted from the combinations of culture, tools, and materials, and what sets of cultural values are left behind in the process of translation, or decoding. The development process from context-neutral idea to context-aware architecture calls for multidimensional views, and the deviations apparent in the outcomes each show different approaches and emphasise the problem of the rationalization of traditional aesthetic sensibilities.

Figure 2
Pavilion
Nami-no-Ma

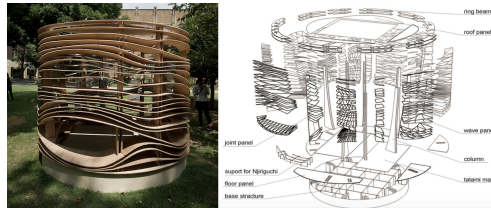


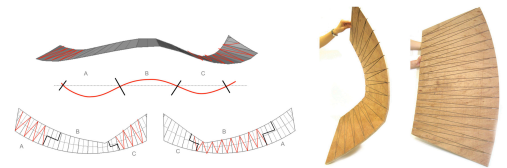
Figure 3
Detail of the joint
for solving the
double curvature
and the zig zag
grooves

Pavilion “Nami-no-Ma (Space of Waves)”

Guided by strong aesthetic characteristics from the tea ceremony, the expression of the beauty and imperfection of nature inspired by the tea bowl is translated to plywood, which surrounds the basic 2-tatami traditional layout of the interior space (Fig.2). The initial concept was drawn from the slightly irregular traces left from the process of throwing the tea bowl on the potter’s wheel. The bowl used in Japanese tea ceremony favored controlled imperfection in the aesthetic of *yuragi* and *yugami*. *Yuragi* is the slightest warping often from the uneven pressure of the kiln, which later developed into a more as deliberate and artistically restrained distortion of *yugami*. Pavilion Nami-no-Ma boldly translates the phenomenon of *yugami* in the same calculated manner as the ceramists of the past, with every layer of plywood by taking advantage of the CNC router. Efforts to create a

natural and flowing form from the 3-axis CNC routing, which is a flat surface fabrication, pushed for experimentations with half-depth grooves in specifically calculated patterns on the 9mm plywood. The key challenge was in achieving the desired bend in a continuous curve following a circular geometry of the plan. Enabled by close communications with CNC router operators, tests initially began with grooves of different depths and stitch patterns of varying lengths. The triangulated grooves eventually proved to be the ideal solution for 3-directional curves to be fixated on site, whereas perpendicular grooves only enabled 2-directional bending per panel.

Tea houses typically offer a limited level of openness to the outside. In this interpretation, the varying thickness of the wall becomes the boundary between the tea ceremony taking place inside and the surrounding nature, while the views are controlled by the density and bending angle of each layer. The undulating waves also facilitate the functions of *tokonoma* and *nijiri-guchi*, where the largest opening in the pavilion is structurally reinforced beneath the lower curvature to support body weight.



A PAVILLON FOR ARCHEOLOGISTS IN AGRIGENTO, ITALY, 2013

“Architecture X Archaeology” is a co-joint workshop held in 2013. Students from the University of Tokyo, Politecnico di Milano and Università di Palermo explored the design and construction of lightweight, temporary structures to shelter excavation works otherwise exposed to the weather.

The workshop was divided into two parts: a preliminary part, 45 days duration, took place at each university. The second phase, 7 days long, took place on site. The workshop focused on the complexity of

designing within archaeological sites such as anchoring to uneven ground, run-off and collection of rain water, transportability but also applications of computational design, structural stability, and practical solutions for quick physical materialization of ideas within limited time and budget.

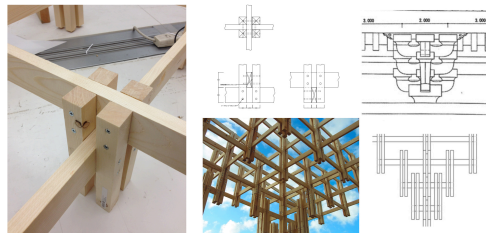


Molecular Shelter: a temporary shelter for archeologists

While respecting the local context, the Molecular Shelter design reinterprets a concept borrowed from Japanese traditional culture. It takes inspiration from the To-Kyou bracket system found in traditional wood Japanese temples, where the roof plays a prominent role. It is a stacking structure composed of wood materials and it enabled architects to design flexible plans. The shelter meets the requests to have a shelter with a roof as large as possible, designed to carry the rain as far away as possible from the excavations, movable from site to site, and with the possibility to be set up again in different locations and with minimum surface area at the column base. The used bracketing system presents an intrinsic elasticity, which lessens the impact of lateral forces by acting as a shock absorber. The position of the columns can be changed thanks to a grid ceiling-structure (Fig.10). The shape of the inclination of the roof - to evacuate rainwater - is borrowed from Tempio della Concordia, so to have a direct reference to existing forms in the landscape. The shelter is light, easy to fabricate and assemble in a reasonably short time (it takes one day and four people), movable, adaptable to the site, and modular. The structure is designed to allow the archaeologists to move the shelter without any help and to hang their working tools.

The shelter is composed by a joint system of 4 small struts, with constant section, bound along both X and Y direction beams with M6 screws. The screws add resistance against rotational movements. If requested by particular site conditions, columns can be positioned at different points of the grid and have different heights. The structure weighs around 100 Kg, and can be easily moved by four people. The shelter is made of local pine trees, cut and assembled with 1500, 6mm size screws. It took five days to cut and prepare the pieces and one day to assemble them. The final cost of the pavilion amounted to 1,200 €.

Programming was developed through Rhino, Grasshopper and Python. This made it possible to organize the exchange of information and optimize the calculation which enables parametric changes. In particular, the use of parametric software proved to be essential for testing different size and arrays of the grid structure, structure thickness and weight, materials length and number of elements used. As for the fabrication, a hand-made easy fabrication system was preferred, which demands only simple holes by drilling and screwing instead of sophisticated machinery. Due to limited vehicular access to the archaeological areas, it has proved strategic to use transportable lightweight tools.



PRACTICE

Increasingly complex design requirements demand practices to acquire the ability to cope with them. LAPS Architecture has been developing applied research as a tool for experimenting on its own by conducting applied research and by including students trained in complex design in its team. As written

Figure 4
The Molecular
Shelter near the
Tempio della
Concordia

Figure 5
Joint detail and
mock up

above these are the two most viable methods to integrate more research into real work and prepare for the changing form of practice in architecture (Samuel 2017). Experimenting has some costs, however, in the case of LAPS Architecture, the investment in research is a calculated risk that is bearing good results in terms of integration of research into practice and it defines the identity of the office. Issues such as budget limitations, building code regulations, technical constraints, durability, expertise and machines used by the construction companies involved in the projects are decisive for building an architecture with an advanced level of complexity.

This paragraph focus on how the use of advanced digital modelling solutions have been translated into solutions that respect all the constraints of building code and different parameters such as structural soundness, fire risk prevention, standard assembly logic, certified materials, budget and time constraints.

Architecture practices experience a paradox: to work they need to build projects, to build projects they need to have already some built references, to have references they need to build. But for a young architect there are not many possibilities to build since the practice does not have references. One solution is to design and build temporary installations which is a good strategy to test ideas, materials, etc. But once a practice gets a project, usually, there is no time to experiment new solutions, because the different phases of a project are very strictly regulated by public rules regarding the due date for delivery i.e. for a project such as the recreational center for children discussed later in this paper (a 1.000 sq. m. project), the schematic design was limited to four weeks, the design development to four weeks, construction documents to eight weeks. This means that there is a very limited amount of time to experiment, test and analyse new ideas: basically, quite often, an architect usually prefers to rely on concepts, materials, technologies he/she already knows which are possibly certified and normed. All delays are subject to economic penalties that an architecture office

does not wish to pay just for the sake of doing an experimental design. Basically, to avoid risk is to use standard protocols, forms and materials and one of the possibilities for small size architecture practices is to use ongoing, personal research and try to integrate the knowledge developed when a real possibility arises. It does not mean that research previously developed is adjusted randomly to a project but the sole fact of having a research mindset helps to develop potential solutions faster. For LAPS Architecture office investing in applied research represented a way to diversify its business and to define its identity and style. Architectural constructions are often quick in terms of drawing phases and slow in construction, impeding an immediate feedback between ideas and reality. On the contrary, small projects or installations offer architects the possibility to test ideas more immediately. The strategy used by the office is clear: instead of investing only in medium or large size architectural projects, the partners of the office decided to stimulate potential economic gain from interior and product design. There are some legal protocols such as the so called "ATEX" or "Appreciation of Technical Experimentation" that transfer the research risks onto the contractor and make it easier for architects to promote innovation and changes in regulations. In French Building Code regulation there are several classes of public building that demand different types of wood according to different safety and risk factors such as the number of people allowed in a building or the number of floors. These factors define the class of the wood for structural loads and fire prevention. For structures and facades there are different classes of wood allowed. In the past years there has been an increasing interest in wood construction and accordingly new rules and limitations have been updated to current demands for safety and risk preventions. For those architecture offices integrating research into practice is even more challenging because they have to manoeuvre within this framework in constant evolution.

X.ME SYSTEM

The X.me project is an investigation on structure, assembly and fabrication process in order to produce a customisable modular system for interior design. Developed firstly as an academic research, the X.me system evolved into a product thanks to several prototypes built in real contexts such as the Norman Castle of Favara, the Hotel de Gallifet in Paris and Sasebo in Japan. Resulting in a redefinition of the classic chain designer-maker-distribution-client, the X.me system is modular and flexible and easy to configure (Liotta 2016). The X.me system is reduced to its bare essentials which allows everyone to assemble it without using nails, bolts or glue. The system is self standing and presents a solid structure, it is easy to assemble and disassemble resulting in a reversible system. The intersecting elements of a grid pattern has been extruded to create customized elements for different interior design needs such as partitions, bookshelves, sitting spaces, benches and tables. Interestingly, the orthogonal rigidity of the grid patterns permits a great degree of diversification on the Z axis. The system is composed of customised panels made of different materials such as wood, MDF or PVC. Horizontally or diagonally cut, the panels are then combined and assembled manually. Customized elements cut by a 4 axis CNC machine are assembled by using extruded aluminium joints of different size. An online configurator allows for real time customisation, shopping and delivery. The system offers a different approach to design and gives the possibility to the customers to design and order online a customised solution of different products directly from the maker thus reducing the cost of production, stockage, promotion and transport.

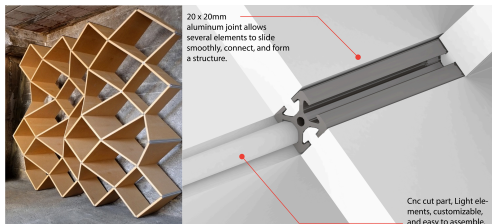


Figure 6
A configuration of the X.me and the aluminum joint detail

X.Me Design and development

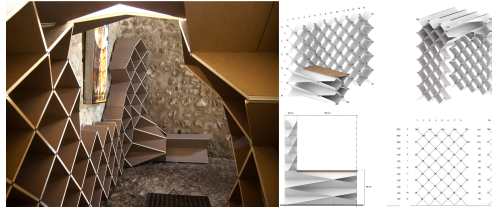
The development of the X.me system is here shown through the analysis of two installations -at the Norman Castle of Favara and at the Italian Cultural Institute in Paris. Besides showing different formal solutions, flexibility and adaptability, at the same time the two installations underline some limits of the system. While it has proved to be very intuitive to design and simple to assemble when composed of a limited number of elements, it still needs improvements for medium and large scale projects due to the difficulty to put in place the upper part of the system. The difficulty is due to the fact that even slightly uneven floors affect the assembly by deforming the grid through its weight. Because of the weight, the geometry of the grid varies infinitesimally but enough to impede a smooth assembly of the system. To solve this issue, the elements were cut thinner than the aluminum joint size, however some elements needed to be hammered to slide into the joints. This proves to be a major problem for commercialization, because only specialized workers can assemble the system. Another solution is to send the furniture already assembled, but this will increase the shipment costs because it will occupy more space than when it is sent disassembled.

In the project for the info point center of the Norman Castle of Favara, after testing different materials such as wood, plywood and MDF, the last was chosen. Because of the unpredictability of the direction of its fibres, wood proved to be the least performative material. MDF -being a composite wood material- presents an homogeneous fibre direction which is indispensable for the elements to easily slide in and out from the aluminium connector. In this first project, the modular system integrated different programs such as tables, benches, partitions and shelves.

In conclusion, several installations served to test as many issues as possible regarding functions, program, assembly, materials. The knowledge collected helped to finalise an online configurator by which the X.me system can be designed directly by potential customers. Customers get an immediate price and

delivery time. Once the order is finalized, the drawings are processed through Rhinos and Grasshopper and then exported and arranged on panels and ready to cut by CNC milling machines.

Figure 7
Installation of the
X.me at the Norman
Castle of Favara and
fabrication
drawings



RECREATIONAL CENTRE FOR YOUTH IN CANTELEU, NORMANDY, FRANCE, 2016

Figure 8
The facade with flat
and curved lamellas



The project for the recreational centre for children and young people in Canteleu is located in a depressed area of Rouen suburbs. The rate of unemployment of this area is around 25% (two times the national rate) with a presence of nearly 60% of social housing built in concrete. The mayor required that the recreational centre for children and young people 1) included a certain attention to aesthetics as a positive message for the youth of the city, and 2) that the building had to be in wood for it is a sustainable material, and thus bring a positive message in opposition to the existent concrete landscape of the town. The project includes in its architecture these two elements: a building which is recognisable thanks to a wood facade shaped in form of a wave which represents the energy and dynamism of the youth of Can-

teleu. The wooden wave is one of the possible results of a research on how to generate an iconic architecture by mixing standard and non-standard elements (respectively flat and curved lamellas) to reduce the costs of the project.

Recreational Center Design

Whilst the structure of the building is made in cross laminated timber, the facade is made in pre-coated pine wood. The facade was partially pre-cut at factory and assembled on site by carpenters.

The design includes 40 mm wide lamelles of wood which alternate two flats one and a curved one. The distance between the lamellas is 10 mm, which is the maximum distance allowed by the so called DTU-Dossier Technique Unifié (Unified Technical Regulation). The original project presented a distance between lamellas of 40 mm with 40 mm wide lamellas. The idea behind the design was to minimize the use of wood by having a certain distance between lamellas. The fact that new regulation for public building was changed between the competition phase and the construction phase demanded the design to be updated to comply with the new rules.

The design of the wave on the facade was defined by some spline lines that change direction according to the facade openings. For the construction, initially only the flat lamellas were positioned and fixed on a horizontal substructure composed of 4 battens distanced 1 meter from one another. Subsequently, the curved lamellas were nailed to the substructure. Originally the curved lamellas were supposed to be more than 150 mm deep in the highest point, but there are no standard nails long enough to fix such a deep element on the supporting substructure. Therefore, the thickness of the lamellas had to be adjusted to 50 mm. This affected the initial design making it more flat. In the DTU there were no indications concerning the depth of wood in facade, however the design changed for technical constructive reasons.

Concerning computational aspects, programming was developed with Rhino and Grasshopper.

This did not help the exchange of information and optimization with the construction company, since they only used Cad software. The use of parametric software proved to be good for testing different size and arrays of wave design, materials length, thickness and number of elements used. As for the fabrication, a mix of CNC mill cut elements and hand-made fabrication was used. The overall result is acceptable but it respects the original design only partially. In fact the curved lamellas were resized and since they were hand cut on site do not exactly correspond to the design.

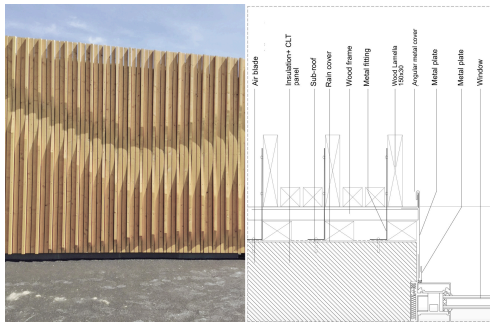


Figure 9
A detail of the
facade and a
technical drawing

CONCLUSIONS

Translating the freedom of building temporary architectures -which usually is one of the prerogatives of architectural design at university- into wood architecture that respects all the constraints of real construction proves to be difficult because of several parameters that must be taken into consideration.

The use of parametric design can, at times, promote a tendency where its users can easily produce forms too complex to control with little regard to issues not only of structure and feasibility but also economy, society or culture, in part due to a fascination with new forms. The chapter makes clear that constraints including structure, material, budget, time, assembly, site, and function help avoid the risk of designs that are impossible to be realized. When parametric design is integrated into a process

within a framework of real-life constraints, its advantages are beyond mere stylistic choices or visual effects. Often, as we are limited to the constraints of borrowed code, the majority of architects are forced to limit their imagination within the prefabricated pattern of existing protocols. In a way this situation has started to improve with the introduction of custom scripting where architects can tweak the limitations of their tools.

This paper clarifies that 1) the democratisation of combined use of digital and fabrication tools have made it possible to conceive and realize complex design with limited budgets whilst respecting the building code, 2) the design of the projects here discussed has evolved alongside technology, within a mutually beneficial relationship 3) integrating research into practice is a way to try to make better buildings, that are appropriate to their users, clients, context and time.

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