Zukunft Bau

STRUKTUR / GLIEDERUNG KURZBERICHT

Titel

Long Title:
Solid Timber Construction for energy-efficient and sustainable buildings responding to fabrication and thermodynamic challenges through its form and connection.

Anlass/ Ausgangslage

Short description of the problem and solution proposal

Wide availability, high structural capacity and easy workability make wood an ideal building material for innovative construction techniques. The goal of this research project is the development of a solid timber construction system through which digital machining processes are applied to generate form and joint details capable of meeting structural and thermodynamic requirements of energy efficient and recyclable building standards. Through a partnership between the *University of Stuttgart*, the *Jade Hochschul*e, and the *International Building Exhibition (IBA) Thüringen*, a prototypical demonstrator is being constructed to test the system.

Gegenstand des Forschungsvorhabens

Description of the research methods and solution strategies

Construction System
Solid timber displays not only ecologically beneficial properties, but is also one of the most economically inexpensive construction materials. Compared to other material capable of load-bearing applications, wood's insulation values typically outperform those of other common materials. The capillary makeup of wood's molecular structure allows it to be applied in both structural and insulation applications. The basic principle of an insulating, solid-timber, construction system was originally developed in a preliminary research project at the *Münster School of Architecture*, under the leadership of Hans Drexler. Cutting slits in to the material served not only to improve insulation values, but also to release internal stresses in the material. These relieving cuts prevent tangential splitting in the wood, while the accumulation of air chambers increases insulation. The development of the construction system in connection to digital design and fabrication prioritized two different goals. The first focused on the increase in physical performance of the system while facilitating a more efficient construction process. The second aim was to broaden the architectonic design space through precise computer-controlled(CNC) machining. By completely digitizing the design, planning, and fabrication system, it becomes possible to define each individual construction element in relation to each other. Thus, a material system with extremely flexible geometry, through form and joinery, can fulfill or surpass the static and thermodynamic requirements of energy efficient and sustainable buildings. Often, strategies to achieve high performance buildings utilize expensive and highly developed products; in contrast, the basis for this project is to use the most inexpensive material available. Similar to a contemporary log cabin, the primary construction only uses wood as a raw material. In contrast to a log cabin, however, the fiber orientation in this construction elements runs parallel to the principal stresses.

During the project, the number and arrangement of slits had to be optimized and compared to other construction materials and methods through simulation software. The evaluation of built prototypes by the *Materialforschungs- und Prüfanstalt der Bauhaus-Universität Weimar* resulted in a thermal transmission coefficient of U= 0.20 W/(m²K), while this value was shown to be heavily dependent on the airtightness of the construction.

The development of construction details is made possible through the close interrelation of digital design tools that generate all necessary details and data from the design. Not only would the geometry of the final building be represented in the model, but also the entire digital workflow, including all relevant building metrics, construction details, and machine control code. Above all, the joints at corners and between beams play an important role. The type of joint was developed mostly based on the criteria of airtightness, structural rigidity and constructability. For this development, it was necessary to work in close contact with industry partners in order to continuously evaluate the constructability of the system. Several small prototypes were fabricated and assembled in the ICD robot lab, however contemporary state of the art CNC machining processes use different processes and protocols, and therefore the mass production of the demonstrator building had to be realized in close collaboration with an industrial carpentry firm.

The planning and construction of the demonstrator building represents a significant step in the development of design and fabrication technologies in the practical realm covered by this research project. In August 2017, the final global design and construction details were chosen in order to begin the production of the demonstrator. From an architectural viewpoint, it is clear that even in full building-scale, the construction elements, due to their geometric complexity, would undergo particularly intensive work processes. It can clearly be established that simple construction-grade timber is not meant for the stringent requirements of high tolerance machining and precise assembly. This meant that the subtractive fabrication processes took considerably longer and removed more material than initially anticipated. In less than eight weeks, however, 464 individual beams were milled by a five-axis CNC machine and assembled into six building modules. In one day, these modules were loaded onto two low-bed trailers and transported to the construction site, and within two days, the modules were brought together into a complete structure.

Architectonic Concept
The *IBA Thüringen*, working as a project partner, found a new location in Apolda in an historic building by the architect Egon Eiermann. Behind the building is a larger terrain with wild, undeveloped characteristics. The prototype will perch lightly in the open space as an architectural insertion in the landscape. This insertion reflects the task of the *IBA Thüringen* to address the Urban-Rural dichotomy. The contrast between the small dispersed settlements and the landscape in which they are stamped represents the contextual conflict of Architecture’s placement in a landscape.

Fazit

Description of the planned goals and results

As one of the first fully parametrized and digitally produced, solid-timber buildings, this project represents an important step for contemporary architectural research. Through a practice based evaluation of the design and construction methods, a number of important realizations were made. First and foremost, mono-material- construction can be efficiently realized through an intelligent design and fabrication process, while also broadening the possible design opportunities. The demonstrator ultimately required a high degree of precision and more fabrication investment than anticipated. This discrepancy could be reduced through a general evaluation and reworking of the production process and equipment. This research project could be looked at as the first step in the development of a new standardized building system.

Eckdaten

Short Title: Highly insulated and recyclable solid timber construction method

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Hoffmann GmbH
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Gesamtkosten: 186.428,98 € €

Anteil Bundeszuschuss: 103.970,24 €

Projektlaufzeit: 18 Monate

BILDER/ ABBILDUNGEN:

5 - 7 Druckbare Bilddaten als **eigene Datei** (*.tif, *.bmp, ...) mit der Auflösung von mind. 300 dpi in der Abbildungsgröße (z.B. Breite 10 - 20cm). Bilder frei von Rechten Dritter.

Bild 1: ZB-MASSIV_01.jpg
Explosion diagram of the construction system
Bild 2: ZB-MASSIV_02.jpg
Construction system details for the connection between beams and corners.
Bild 3: ZB-MASSIV_03.jpg
Diagrammatic visualisation of the digital design tool's steps from design to fabrication.
Bild 4: ZB-MASSIV_04.jpg
The design space of the digital design tool is shown through a variety of possible designs.
Bild 5: ZB-MASSIV_05.jpg
Processed timber beams. Each beam has an individual geometry was fabricated just-in-sequence.
Bild 6: ZB-MASSIV_06.jpg
Each of the six building segments was assembled in a horizontal manner.
Bild 7: ZB-MASSIV_07.jpg
All pre-fabricated building elements ready to be assembled on site.