# Material Performance of Solid Wood:

## *Paresite, The Environmental Summer Pavilion*

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*The Paresite - The Environmental Summer Pavilion designed for reSITE festival, is a möbius shaped structure, built from torsed pine wood planks in triangular grid with half cm thin pine wood triangular sheets that provide shadow and evaporate moisture in dry weather. The sheets, cut in a tangential section, interact with humidity by warping themselves, allowing air circulation for the evaporation in arid conditions.The design was accomplished in Grasshopper for Rhino in combination with Rhino and afterwards digitally fabricated.This interdisciplinary project involved students from the Architectural Institute in Prague (ARCHIP) and the students of the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague (FLD CZU). The goal was to design and build a pavilion from a solid pine wood in order to analyse its material properties and reactions to the environment and to accommodate functions for reSITE festival. The design was prepared within half term studio course and completed in June 2013 on Karlovo Square in Prague where it hosted 1600 visitors during festival weekend.*

**Keywords:** *Material Performance, Solid Wood, Wood - Humidity Interaction*

### RESEARCH QUESTIONS

In this work, we are reporting on the research behind the Paresite pavilion (produced for the reSITE festival 2013 in Prague, figure 1):

- The main area of our occupation lies in the material performance of solid wood: Wood - Humidity - Temperature Interaction (section 'Material Performance').
- A second topic is the question of how to create parametric model of the design and produce CNC fabrication data, leading up to the question: Can parametric design cover all the design tasks? Section 'Design Process in Grasshopper for Rhino 5'.
- To finish, we ask ourselves over the structural possibilities of CNC fabricated design (see section 'Structural Design').

Figure 1
pareSITE
(photo courtesy of
Wágnerová, 2013)

## MATERIAL PERFORMANCE

The tradition of building wooden summer pavilions has been established in many architectural schools. The most striking examples have been created at the AA School of Architecture in London and at the Institute for Computational Design - University of Stuttgart. Usually, they are built from ply-wood. On the contrary, the project is aimed at experimenting with the material performance of solid wood. The strength in the torsion of the planks and the humidity - wood interaction has been explored.

The form of pavilion does not allow subdivision into planar surfaces, but anisotropic properties of the material support torsion. Several prototypes of the triangles with different plank thicknesses and moisture content were sampled. The angles of cuts hold the boards' torsion together in the joint. Because of its ability to bend, it was agreed to use green wood for the structure.

The Environmental Summer Pavilion is based on the concept of wooden oriental screens so called 'mashrabīyas' (figure 2). Mashrabīyas absorb moisture during the night when the relative humidity of air is very high and release moisture whilst providing shadow during the arid conditions of sunny summer days. The performance of 'mashrabīyas' has been explored by Michael Hensel. Hensel writes:

'Mashrabīyas are multi-functional elements that control light penetration, airflow, privacy and views, while operating on a synergetic relation between ornamental pattern and material distribution' (Hensel 2011).

Figure 2
Mausoleum of Sultan Oljeitu, Sultaniyeh in Iran (photo courtesy of the WADE Photo Archive [2])

Wood - humidity interaction systems have their origin in traditional Norwegian panelling and further on they were explored by Asif Amir Khan at the AA School of Architecture with a veneer based screen. The research on performative wood is held by Michael Hensel at the Oslo School of Architecture and Design and by Steffen Reichert and Achim Menges at ICD University of Stuttgart. Most of the contemporary research has been done on laminated veneers to reach the highest performance of the material. Such structures have the best performance, but since the pavilion served for a festival in public space, they would have been too fragile.

In case of this pavilion, the air circulation was supported by warped triangles cut in tangential section (figure 3). Warping in tangential section generates so called "cup" across the fiber (Knight, 1961). It has been observed that most warping occurs on the plates in rhombus shape. Considering material waste, this figure in the project was replaced by two triangles.

## DESIGN PROCESS IN GRASSHOPPER FOR RHINO 5

The studio course Environmental Summer Pavilion was focused on generative concepts and algorithmic mechanisms for creating performance-based and interactive design systems. It was open to architects, designers and anyone interested in learning generative and algorithmic design techniques based on graphical algorithm editor - Grasshopper.

The students learned from the basics to advanced coding and implemented several Grasshopper plug-ins to the design process. LunchBox plug-in from the author Nathan Miller was used to design Environmental Summer Pavilion. The plug-in contained algorithmic geometry, panelling tools, structure and powerful utilities. It became the main tool to finish and create better workflow for the final definition.

For the initial surface it was decided to use a möbius surface with its logic of closed and vertiginous continuity. After the best spatial concept and the area solution was found, the final surface of two layers was developed. The first layer contained static structure presented by triangular tilling creating torsional hexagon loops over the surface. The second layer was again a triangular tilling that was cracking each triangle of the first layer of the initial surface. The after effect of cracking was used to obtain a star

Figure 3
Torsed Structure with Responsive Skin
(photo courtesy of Zapletal, 2013)

Figure 4
pareSITE
(photo courtesy of Zapletal, 2013)

perforation generating under diverse angle positions different views through the Pavilion (figure 4).

Due to the geometry of möbius stripe, the structure was not easy to generate. The initial surface was generated in Lung Box than edited in Rhino 5 afterwards offset in Grasshopper. The ends of the surfaces had to be connected in Rhino 5 manually and the structure was loft between those two offset surfaces, through the panelling tools from Lunch Box (figure 5).

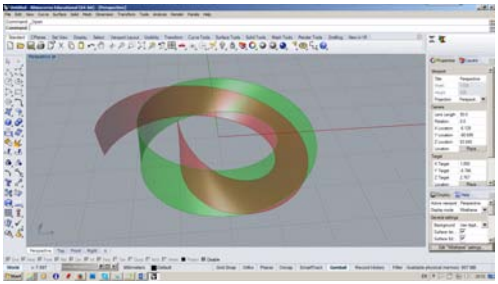

Figure 5
Offset of Möbius Stripe
(photo courtesy of Davidová, 2014)

Afterwards the main problem was, that the planks in the structure were torsed. That time Grasshopper couldn't unroll into plains. The planks were unrolled and constructed back into objects manually in Rhino 5 while the component, written by Tudor Cosmatu for unrolling in planes was found on Grasshopper3d forum.

For the reason, that the structure could not be generated other way than offset (möbius geometry) the model of the pavilion was imprecise, not respecting the width dimensions of the planks. But it worked well for the generation of the fabrication data that were adjusted in Rhino 5 manually.

## STRUCTURAL DESIGN

Triangular grid was chosen for the construction of möbius shape because of its ability to mimic curvatures and stability features. Grid was offset inward thus defining shapes of planks which are generally perpendicular to the surface of möbius stripe.

The shapes of planks were not planar, and they could not be generated as such while keeping general perpendicularity to the surface. Hypothetically, to achieve planarity, all of the joints axes would have to intersect in one point. In case of möbius stripe, parts where joint axes would be parallel with the surface would occur, making planks parallel too, and therefore weakening rigidness of whole structure.

The experiment had therefore to deal with twisted planks which introduced new set of forces into the structure. Due to rather unpredictable and complex nature of these forces, decision was made to encapsulate these into triangular particles (figure 6), preventing unwanted accumulation and interactions. Planks were cut by Hundegger Speed-Cut 3 cnc saw, and put together to form triangular particles. Each particle consisting of three twisted pine 20mmX150mm planks was connected by 0,6 mm metal sheet overlay on whole length of connecting edge tightened by screws. These particles were afterwards connected with each other by 4 m8 bolts and large washers, hiding the metal overlay.

System presented good manufacturing options as particles or differently sized clusters could be prefabricated indoors and easily assembled on site later (figure 7). However, certain level of imprecision due to twisted geometry of planks was to be expected. Bolt connections allowed for a later distribution of imprecision throughout surrounding structure, making it less disturbing. Each plank and joint (accept rim parts) was doubled, providing additional strength necessary for the use of green solid wood. Structure, once assembled, was covered by smaller 5 mm thick pine wood triangles creating moisture-reactive skin. These triangles were made using HOMAG Venture 06S 3-axis milling machine. washers, hiding the metal overlay.

Figure 6
Production of Triangles with Torsed Planks
(photo courtesy of Davidová, 2013)

Figure 7
Ribs
(photo courtesy of Davidová, 2013)

## CONCLUSION

Thanks to the material performance of untreated solid wood, the pavilion generated pleasant environment for its visitors in hot days of the festival. The skin reacted to the humidity changes as was observed on the samples. During the night the sheets were bent inwards while warped outwards in the day time. The relative humidity along the pavilion was higher compared to the other places covered with asphalt.

This effect in its full performance takes time till the initial stresses from the tree trunk disappears. Therefore the structure has to be ready at least one month before the expected performance.

Torque forces locked in triangles preloaded them and added rigidity, proving advantages of solid wood. Underlying structure proved to be rigid enough to sustain 200 kg weight on the highest not directly supported point (figure 8). Such load bearing capability was necessary for the public exposure of the pavilion (vandalism, children climbing, etc. ...). However we experienced some problems in very shallow joints after the winter season. This also could be for the reason of using green wood at initial stage. (Dinwoodie 2000)

Figure 8
Structural Stability Test
(photo courtesy of Novák 2013)

The structure itself was dynamic and it found its stable state which a bit differs from the digital model. Furthermore, the project itself is disturbing the concept of digital fabrication by the impossibility of generating precise Grasshopper model. This fact leads to the conclusion that the parametric modelling still have limits for designing experimental structures.

The combination of physical, parametric and digital modelling tools might be necessary in the design and fabrication drawings process.

The use of solid untreated wood allowed for significant budget savings, making the price of all material, CNC cutting/milling and transport less than 5000 euros, and for creating structure with no built in chemical agents.

The pavilion serves as a prototype for further development of industrial solutions for performative screens.

## ACKNOWLEDGEMENT

The project was accomplished with the kind support of Skanska, Eurodach, Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague, Lesy České republiky, reSITE, ARCHIP, Collaborative Collective and Oximoron. We also like to thank all the students who took place in this, namely: Yuliya Pozynich, Jason Nam, Alena Repina, Daria Chertkova, Yana Vaselinko, Mikkel Wennesland, Dan Merta, Daniela Kleiman, Liv Storla, David Lukas, Christopher Hansen, William Glass, Jiří Šmejkal, Milan Podlena, Josef Svoboda, Tomáš Pavelka, Miroslav Runštuk, Ladislav Rubáš, Radim Sýkora, Anna Srpová, Ivana Kubicová, Gabriela Smolíková, Karel Ptáček, Jan Matiáš, Tomáš Mišoň, Lukáš Růžička, Jan Hyk, Marian Loubal, Jan Dostál, František Juhász and Jakub Vykoukal

## REFERENCES

Dinwoodie, JM (eds) 2000, *Timber, Its Nature and Behaviour*, E and FN Spon, London

Hensel, M 2011, 'Performance-oriented Architecture and the Spatial and Material Organisation Complex', *FORMakademisk*, 4(1), pp. 3-23

Knight, E 1961, *The Causes of Warp in Lumber Seasoning*, Western Pine Association, Oregon

[1] http://www.grasshopper3d.com/forum/topics/unroll

[2] http://patterninislamicart.com