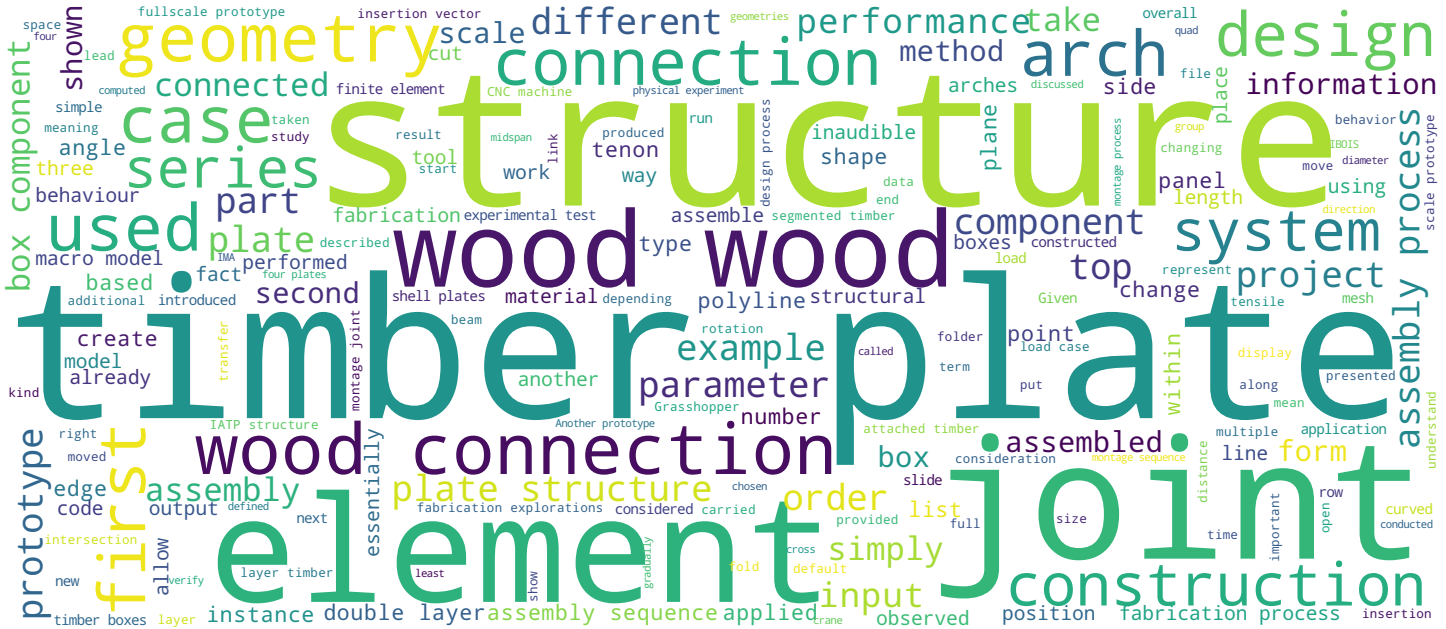
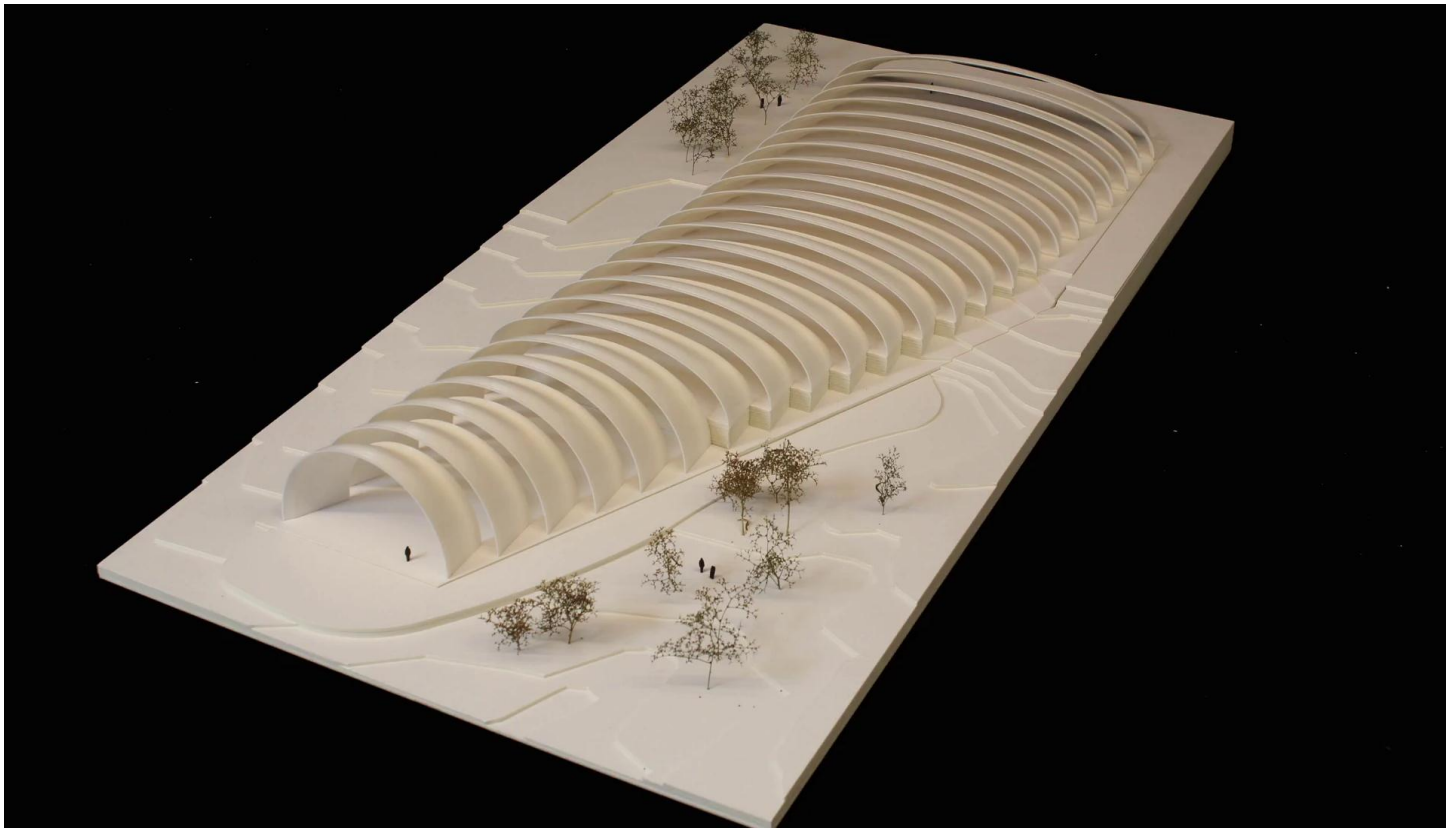


Search MOOC

Video

EPFL



As a next step, we introduced a double layer of freeform timber plate structure. After reviewing and demonstrating the different case studies in this chapter the most complex IATP structure, designed by Valentiny architects and myself, was subject to a major technology transfer at IBIOS EPFL and it will be presented. The project is called Anan as our headquarters, and it's the most recent structure pushes the boundaries of construction further.

Notes

Summary

0m 04s

Inspired from ...

Prof. Dr. Yves Weinand

- Port Warehouse, Montevideo, Eladio Dieste, 1977-1979

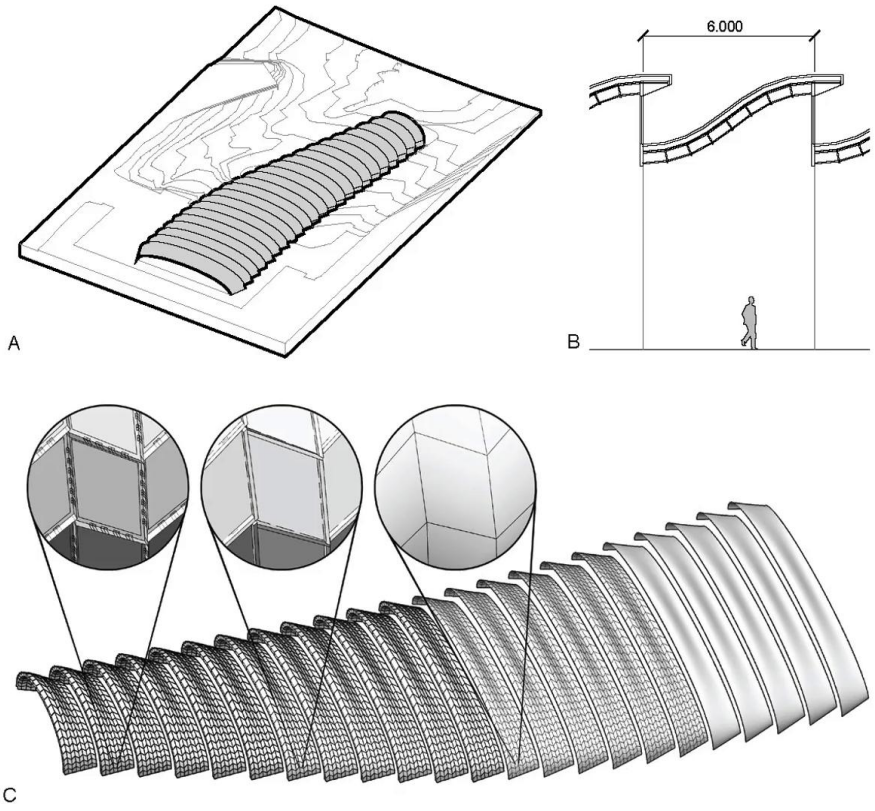
The design of the arches is inspired by Gaussian walls of the Uruguayan architect and engineer, Eladio Dieste such as the TM factory in Montevideo, Uruguay in the '60s and the Ceasa Produce Market in Porto Alegre, Brazil.

Notes

Summary

0m 35s

Prof. Dr. Yves Weinand

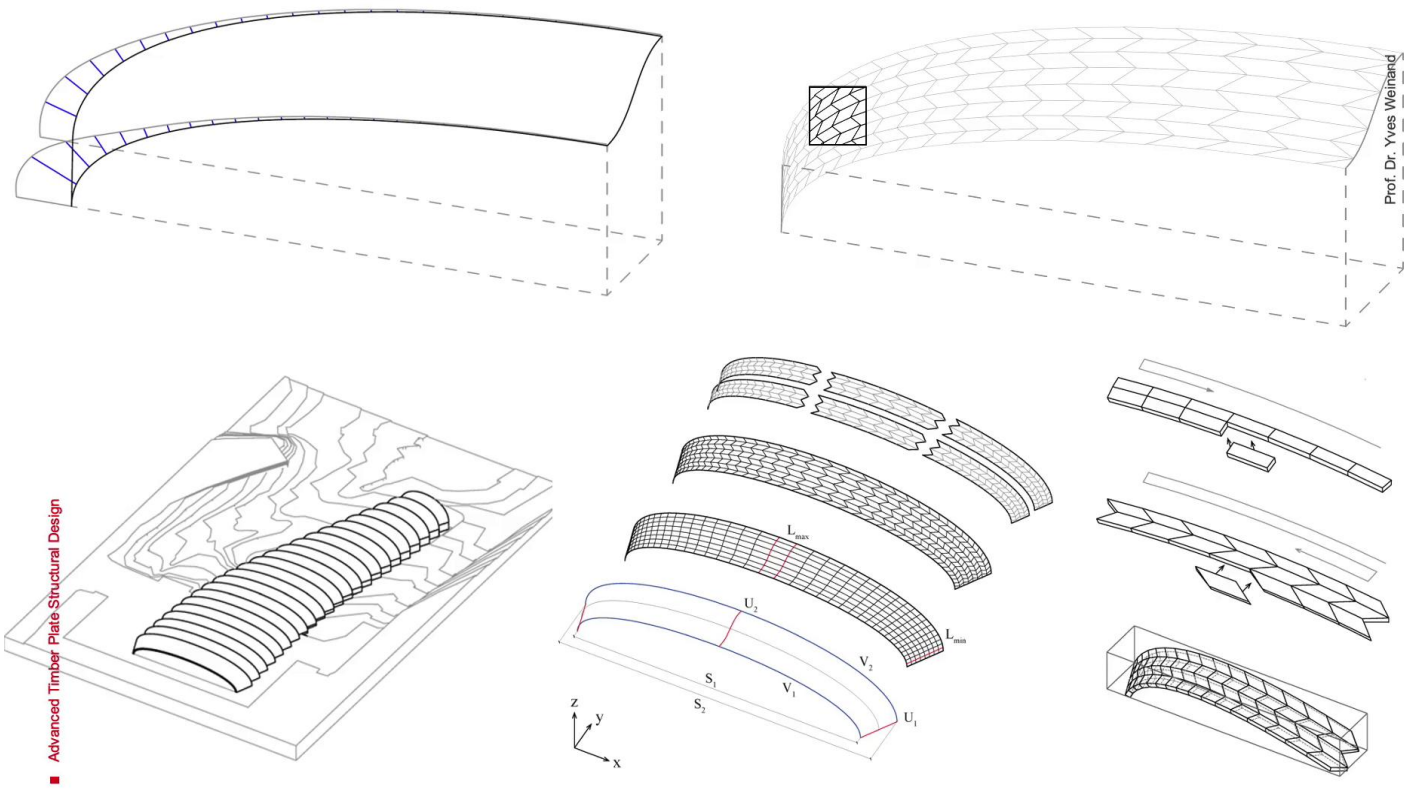


The construction method is based on timber plate component boxes, each composed of four plates. The geometry requires multiscale modeling techniques, including knobs, subdivision into mesh, fabrication and structural cultural calculation data shown for architectural representations.

Notes

Summary

0m 50s



CNC cutting analyzes of the structures and validation of the assembly sequence. The unique interpretation of Eladio Dieste is based on segmented timber plate elements interconnected using wood-wood connections to form a continuous shell structure. Each arch has its own exclusive freeform geometry designed using custom-developed CD plugins. Since the geometry of this project corresponds to a freeform shape, the project represents the most complex form of inter re-attached timber plate structures. The two layer structure of 40 centimeter thickness timber plates is constructed from quad mesh. The plate geometry follows both graph structure of the annealing mesh and its geometric properties, such as a mesh face normals, edgeline, vertices, a list of parameters are changing the rotation of plates, plate thickness, offset between layers, as well as special cases, for boundary elements. There are no plates for the Romanian vertical faces of a quad because those plates are shared with the neighboring elements, while each point represented as a pairwise connecting joining two elements, the sidewall employs a tree valence joint that groups the two pairwise connections.

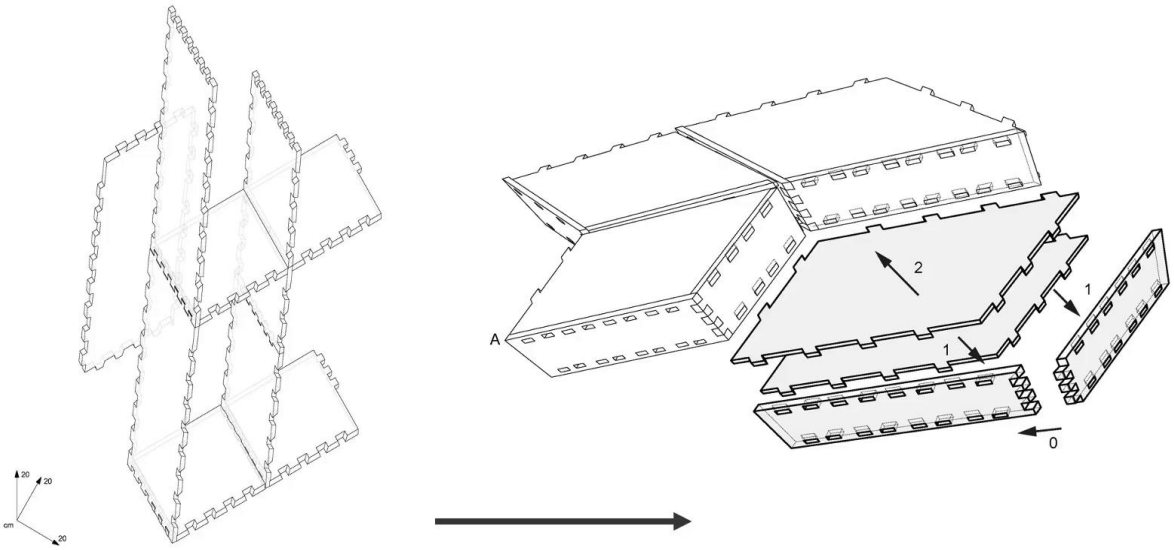
Notes

Summary

1m 10s

Double-layer free-form shell

Prof. Dr. Yves Weinand



Primary Design

Final Design

This method allows reducing material of one-third compared to the case when all four edges is treated as a timber plate instead of two. The Tenon and Mortise joint design must consider the three valence connection by enlarging the distance between Tenons. The intersection area of the three plates is divided into alternating segments, creating slots that receive the lapse of the shell plates. This allows for direct contact between the shell plates for the transfer of compresses forces between those slots. And on the top and bottom phase of all tabs, the vertical plate holds the shell plates. The joinery process together with the intersection, all of box component, is shown here. The design of freeform double layer timber plate structures started with an initial physical prototype, which was essential to understand the assembly patterns. As a secondary objective, the design of timber plates aimed to avoid doubling up old surfaces within a box beam structure.

Notes

Summary

2m 35s

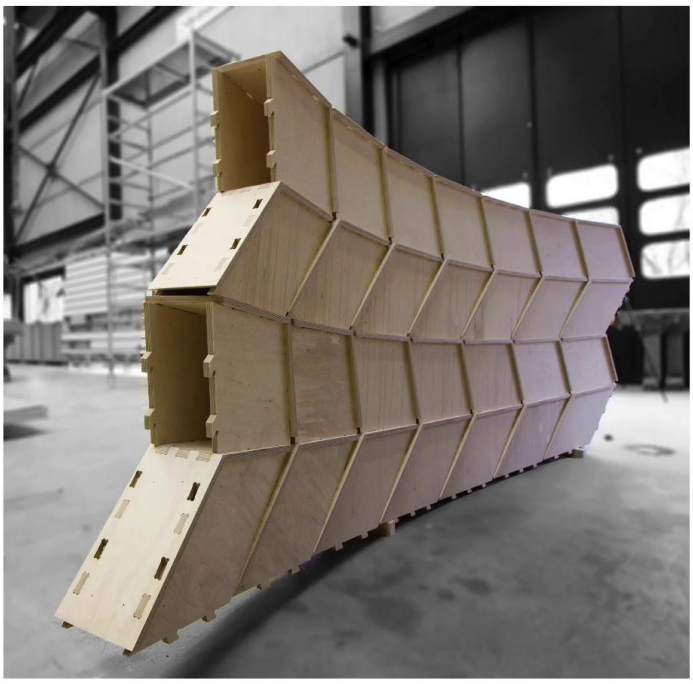
Within the geometry exploration stage, two alternative principles were taken into account. The structure consists of several closed boxes, where each box includes six timber plates connected by means of wood-wood connections. In this case, each box exists independently and it is produced as a discrete element. And second, at least one side of each box is left open to enable the sequential assembly of multiple boxes without additional connectors. In this context, only after the assembly process the boxes are closed. This prototype examines that the second solution, showing a straightforward solution to connect all boxes with surfaces left open at first and closing during the assembly sequence. As a consequence, fabrication concerns directly determine the geometrical and use metallic quality of the wood-wood connections.

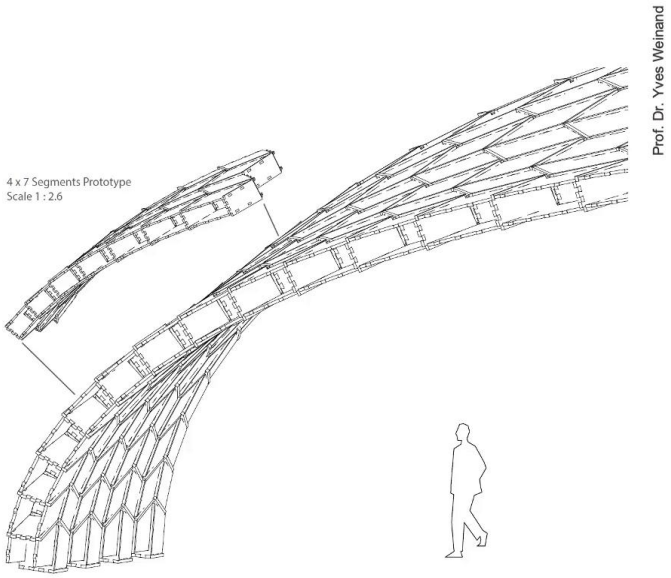
Notes

Summary

3m 40s

Double-layer free-form shell



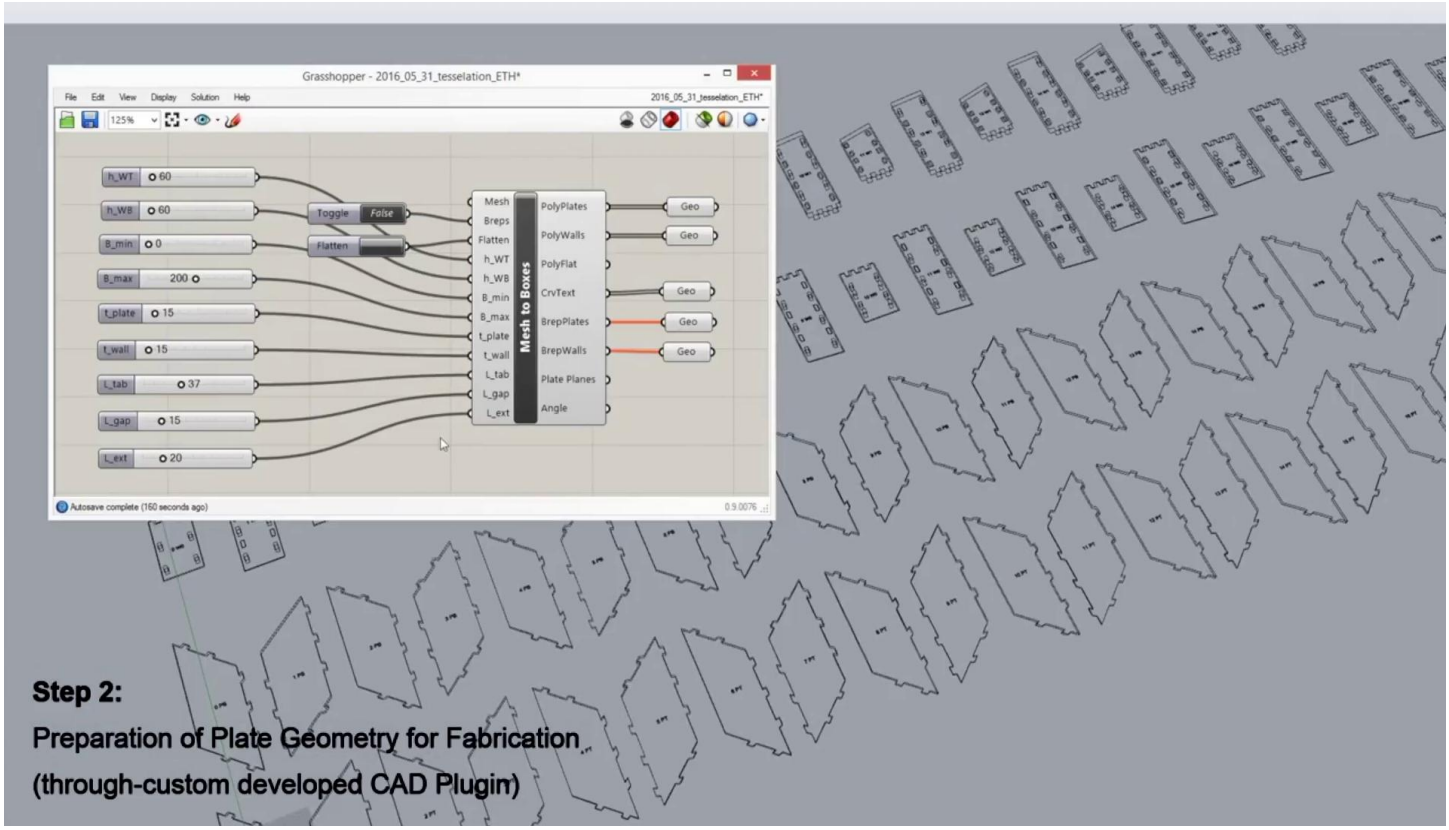


Another prototype related to the same project was used for assembly and fabrication explorations at component level. To gain insights into the fabrication process of wood-wood connections. The prototype shown was investigated design mythology, was applied at a one-to-one scale using 40 millimetre-thick LVL panels made from beach hardwood. The hardness of the material itself and the diameter of the cutting tool have direct consequences of the assembly process and determining the geometry of tenons, associated net surface, and local geometrical singularities. Furthermore, the prototype serve to verify the complexity involved in assembly at the scale of conventional buildings.

Notes

Summary

4m 39s

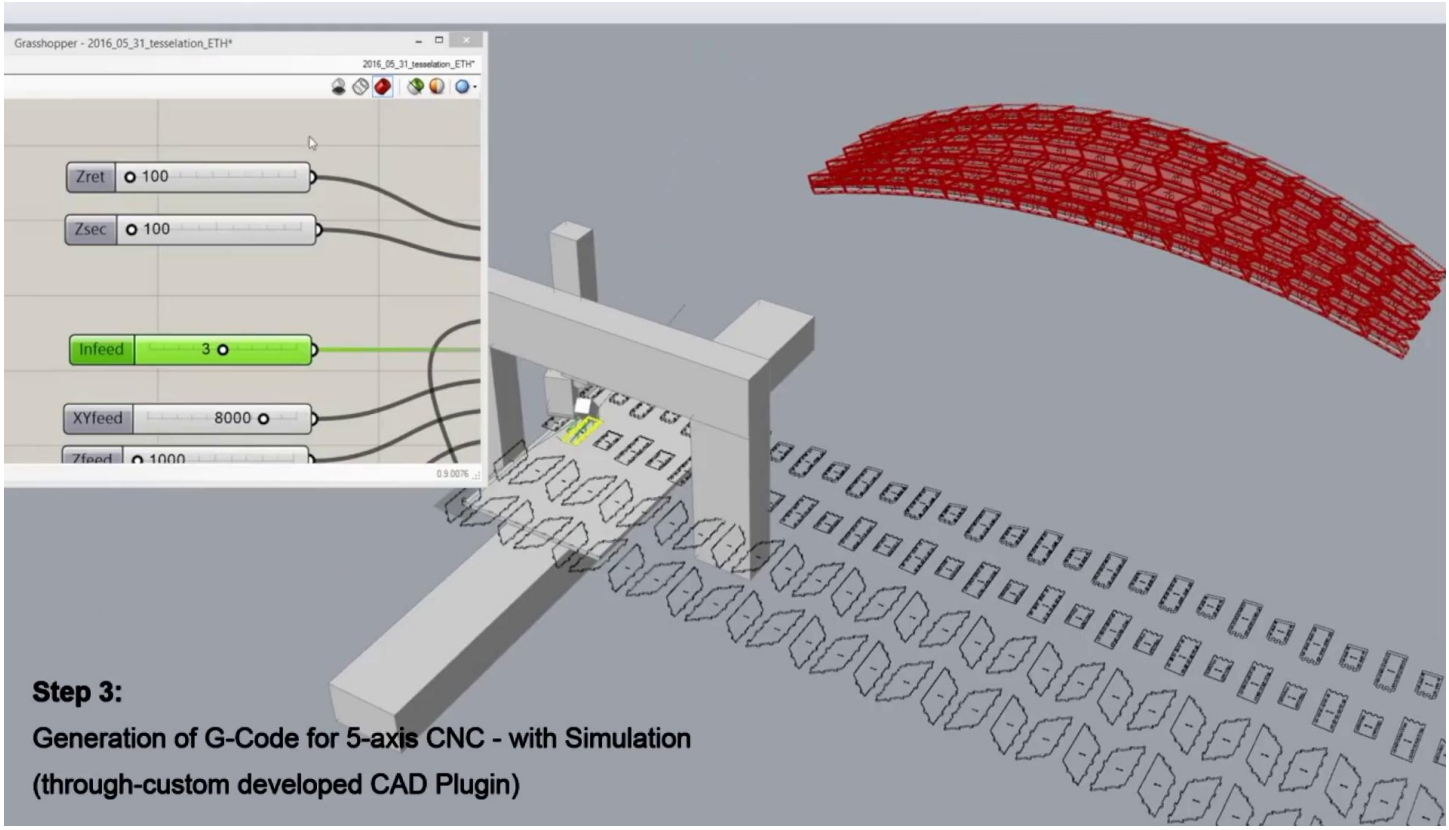


Within the fabrication and assembly process, it was observed that even geometrical imperfections do not lead to considerable errors. The transfer from digital workflow towards the physical realization gives the credibility of the system and allows to go further the path of innovation.

Notes

Summary

5m 26s

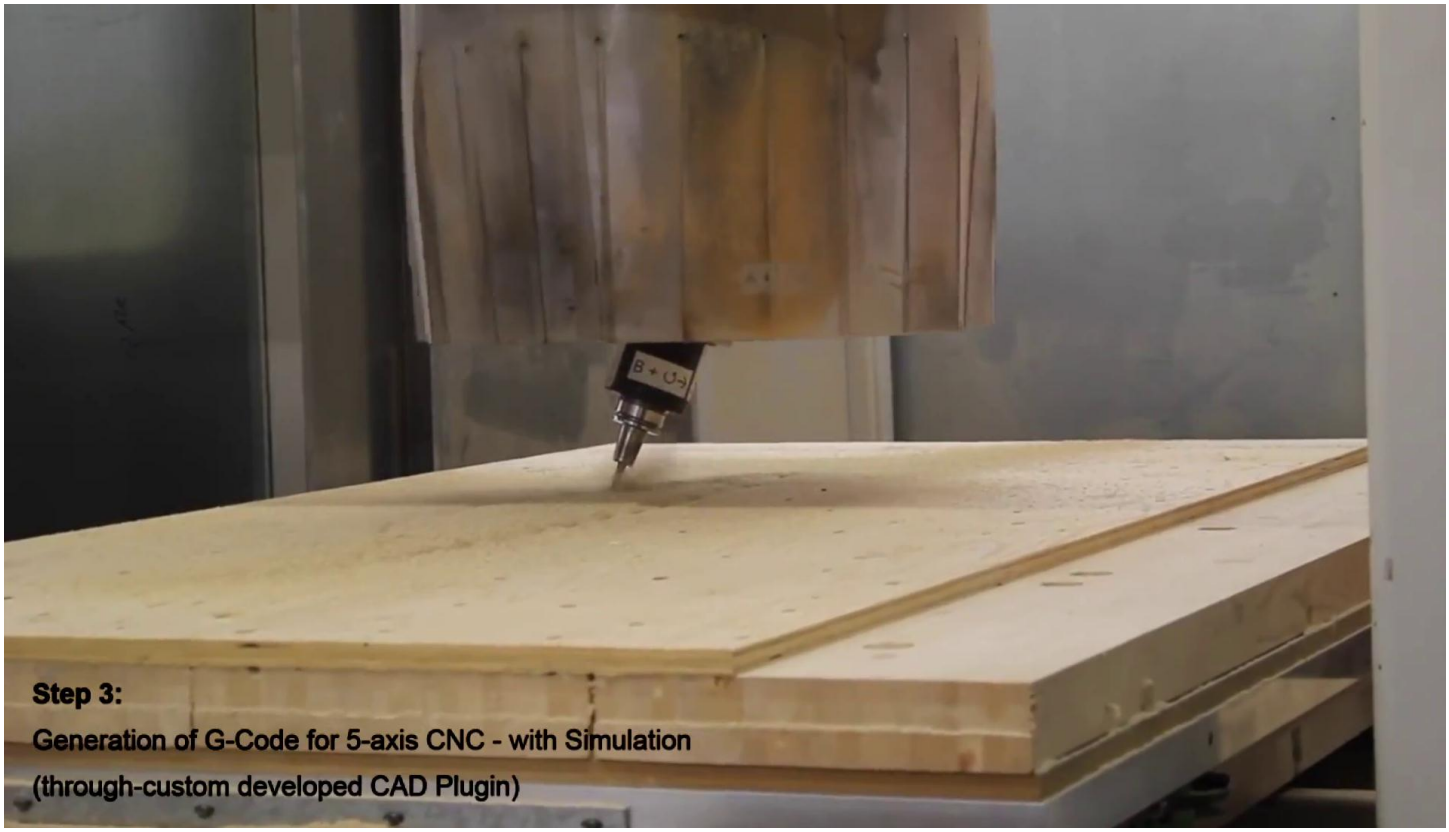


The assembly of the segments follows the numbering.

Notes

Summary

5m 45s

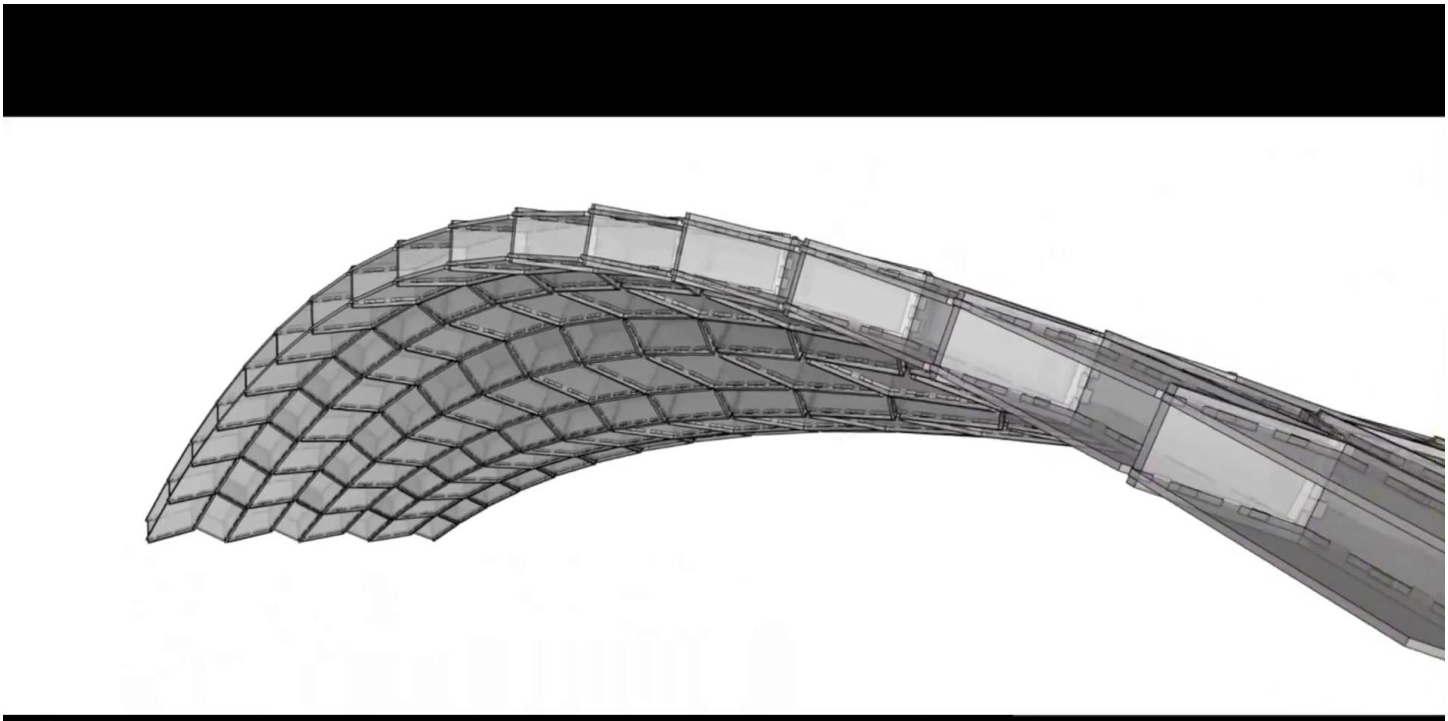


First, a box component is assembled by connecting side walls by [inaudible 00:05:54] joints and then inserting the top and bottom plates. Second, the box component are connected one by one in a linear manner, following the indexing of each row.

Notes

Summary

5m 49s



Step 4:
Assembly Sequence Simulation
Shell Assembly through 6 prefabricated Segments

The shells are assembled lying on the longer side, inserting the box with a hammer. The components are connected using 210 joints using one insertion vector pair box. The individual shells are connected with shear plates joint with metal fastened on side. The whole shell is assembled lying on the long edge.

Notes

Summary

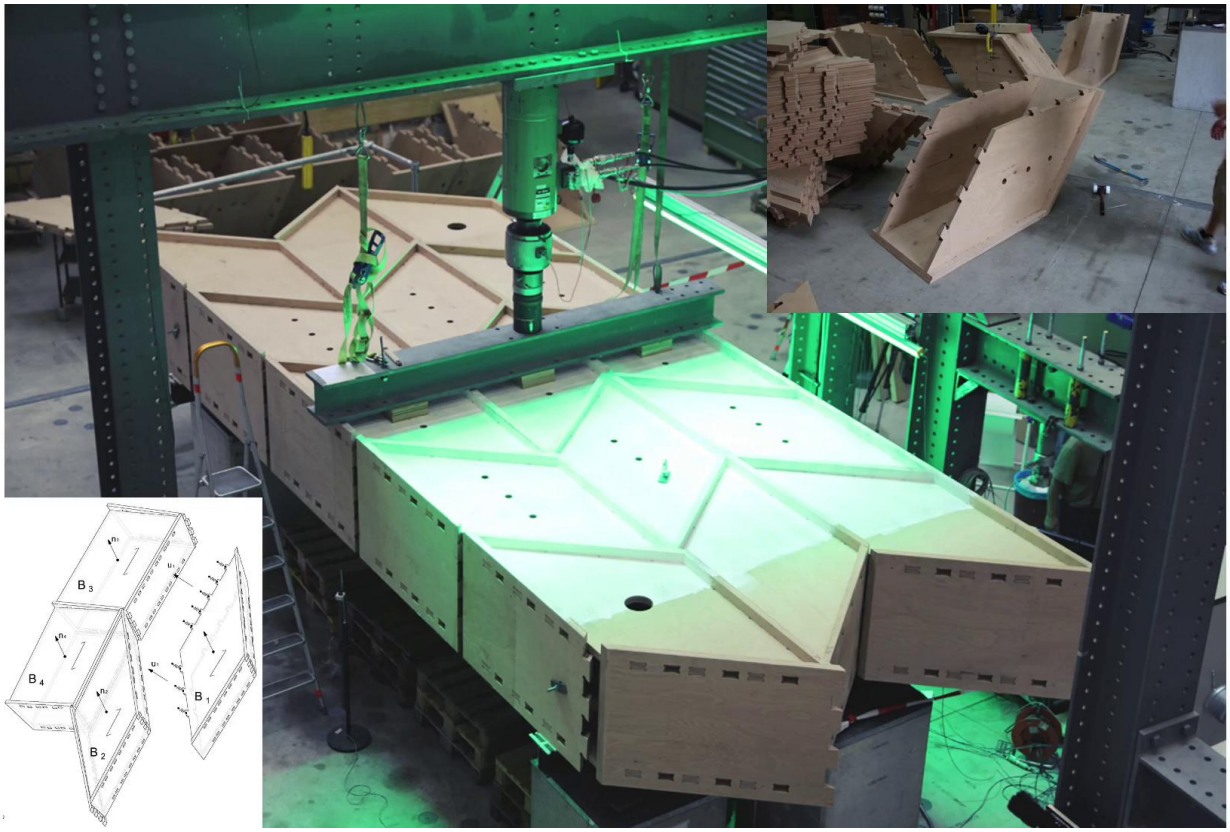
6m 04s

When the structure is assembled, it is lifted up in place by a crane. Assembly in fabrication explorations at structure level with scale 1:3.3. The exhibition at the Advanced Architectural Geometry Conference, in 2016 at ETH Zurich, allows us to collaborate on a small scale prototype for the first time, and the contractor. The prototype with a 7.1 meter span and 2 meter height, was essentially fabricated and assembled at EPFL. 15 millimeter thick spruce plywood panels were used as the construction material and similar assembly logic as described was employed. The montage sequence was verified using timber panels with a scale of 1:2.7. This offered a fast, precise and simple assembly, allowing for constructing a series of differently shaped shells without a costly mode of support. Instead, inclined joints cut with the 5 Axis CNC Milling machine embedded the correct location and angle between plates into the shape of the parts. This constraints the relative motions between joint parts to one assembly path.

Notes

Summary

6m 25s



Prof. Dr. Yves Weinand

To take advantage of the benefits of such connectors, the constrained assembly paths must be considered in the fundamental design of the system, allowing for the insertion of each plate. The fabrication and assembly process engaged in the prototype also provided an overview and estimate of the construction time necessary to mount the rear structure. The design and construction of the prototype helped to gain confidence in the coding and digital production process. Another prototype, in addition, a load for structural explorations at structure level with scale 1:1. To verify the design methodology and gain insight into the performance of integrated touch timber plate structures. A mediumscale prototype was designed, fabricated and assembled. Accordingly, experimental tests are carried out. The cutting process was optimized and all connections were more precisely executed.

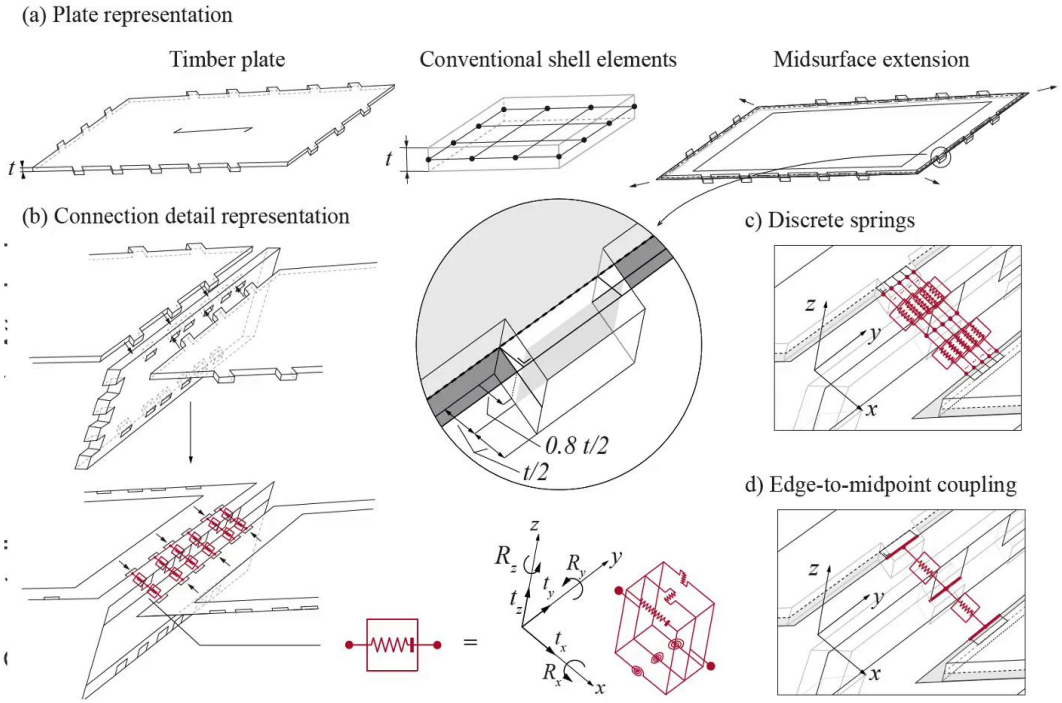
Notes

Summary

7m 36s

Double-layer free-form shell

Prof. Dr. Yves Weinand



The fabrication process could choose be validated by producing this prototype. In addition, mechanical research was performed on this prototype. The prototype was realized after the initial prototypes made for assembly and fabrication explorations. Seeing that for such complex spatial structures, fabrication, and geometrical observation must first be established before moving on to the mechanical investigation.

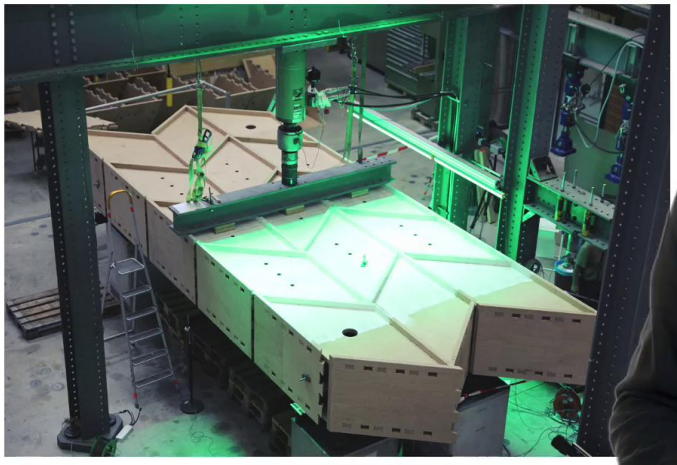
Notes

Summary

8m 38s

Double-layer free-form shell

Prof. Dr. Yves Weinand



Advanced Timber Plate Structural Design

The performance of a medium scale prototype was first investigated through a physical experiment, extracting the geometry from a largescale prototype with a 24-meter span and the scale of 1:1. The prototype consists of 15 boxes arranged in the format of 53 boxes, each with the length, width, and static height of 1.70 meter, 0.85 meter, 0.6 meter, respectively. The arrangement of boxes forms a slab type structure with a length of 6.85 meter and a width of 2.59 meter. Within this configuration, each box is connected to at least two other boxes. Consequently the global gem, it leads to a minimum side effect caused by the boundary support. Given that each box consists of four plates, the prototype had 60 timber plates, each with 12 wood-wood connections located around its perimeter. The wood-wood connections have the same geometrical dimension used in the smallscale experimental tests. The geometry associated with the prototype is shown here. In order to study the replicate to replicate viability, three specimens of the prototype were fabricated assembled, at École Polytechnique Fédérale de Lausanne in Switzerland.

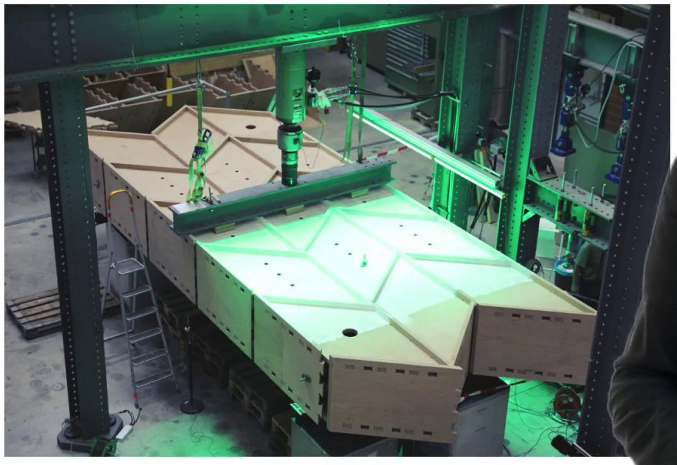
Notes

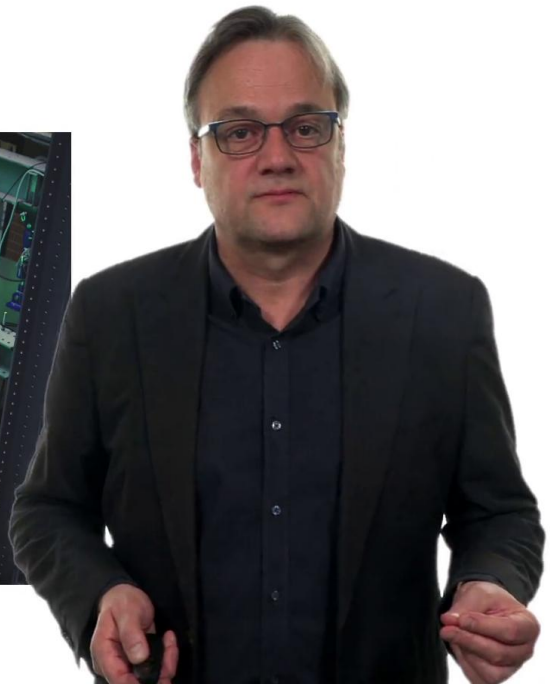
Summary

9m 05s

Double-layer free-form shell

Prof. Dr. Yves Weinand





Advanced Timber Plate Structural Design

Two linear viable differential transducers were installed on the north and south side of the physical specimen to measure the vertical deformation. A fourth transducer was attached to the low actuator an hydraulic jack. The low dispersion in the fourth deformation response indicates that the test set up was optimally designed. During the test procedure, it was observed that the timber boxes deform like rigid blocks. This in particular indicates that wood-wood connections play a more important role than the timber plates. Moreover, the incrementors installed on the support of the prototype showed that the structure had almost a 1.3 degree rotation on its two ends. This observation also supports affected timber boxes deform like rigid box.

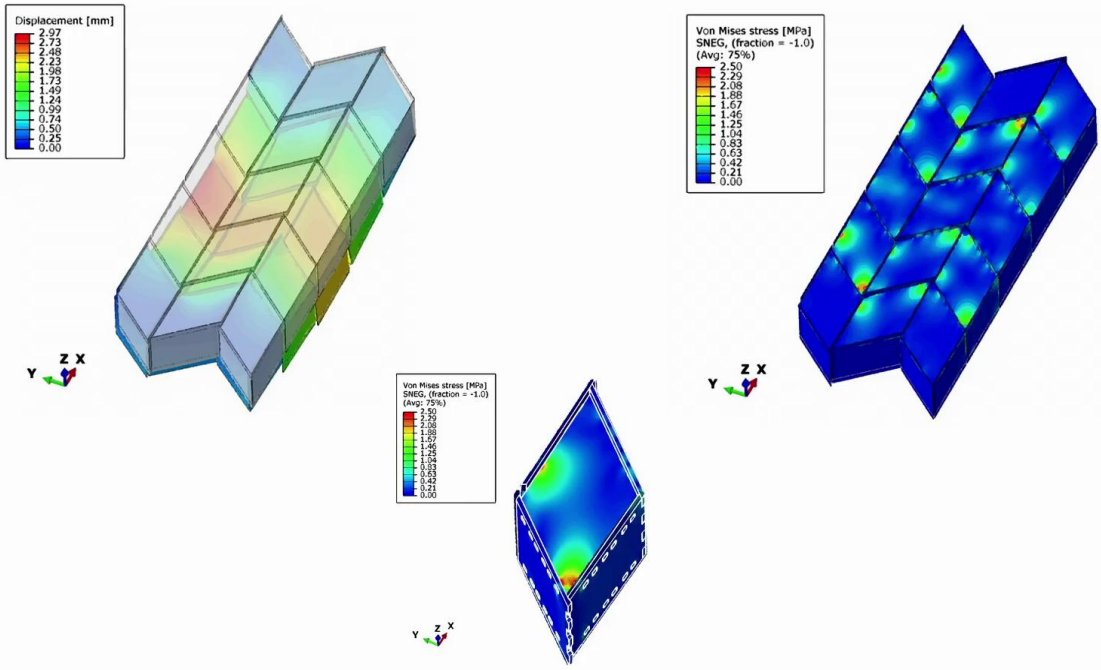
Notes

Summary

10m 25s

Double-layer free-form shell

Prof. Dr. Yves Weinand



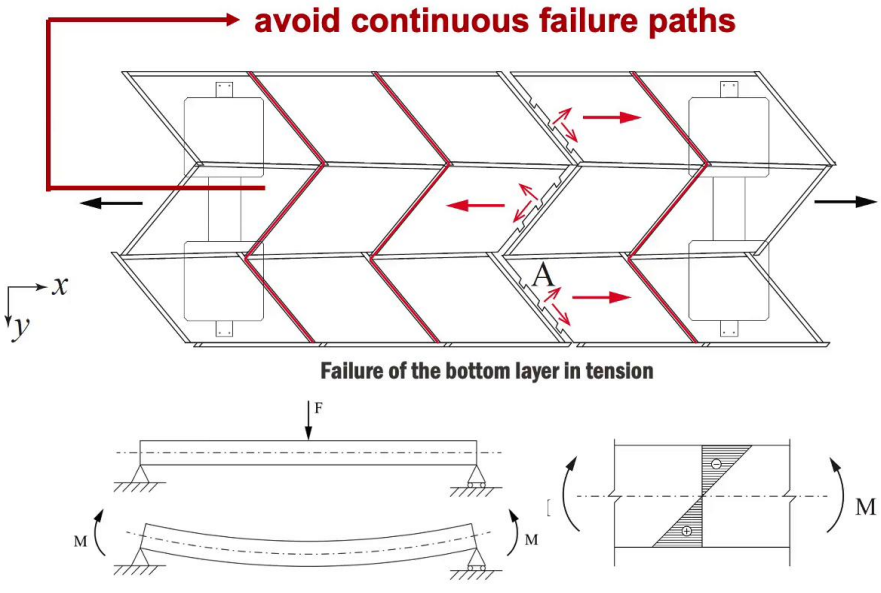
Given that the performance of the structure was mainly governed by the wood-wood connections, the failure of the structure was mainly attributed to the failure of the connections, particularly the connections located at midspan of the structure and the bottom timber plates were under the maximum amount of tensile load. Besides that, because of the pattern of timber plates, the structure was evenly in plan. Accordingly, in-plane forces were also applied to each connection. The in-plane forces were translated to edgewise sheer forces. Given those considerations, a combination of tensile and edgewise filler of the connections is observed at the collapse damage state. The tensile and edgwise filler evidence that occurred in the connection had the same indications observed in the smallscale tests. Furthermore, since multiple connections failed another load case, they formed a continuous failure line. As noted earlier, the failure pattern depends directly on the herringbone pattern used in the design of the structure. This pattern caused a continuous failure path and separation between the boxes.

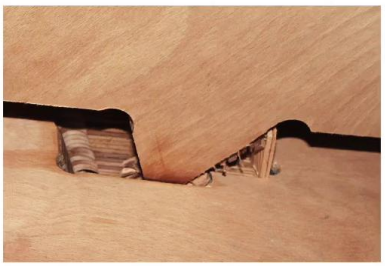
Notes

Summary

11m 15s

Optimized design pattern and force flow





Prof. Dr. Yves Weinand

Advanced Timber Plate Structural Design

It will be shown later that by changing the design patterns, the failure mode can be controlled and an optimized system can be used in the design process.

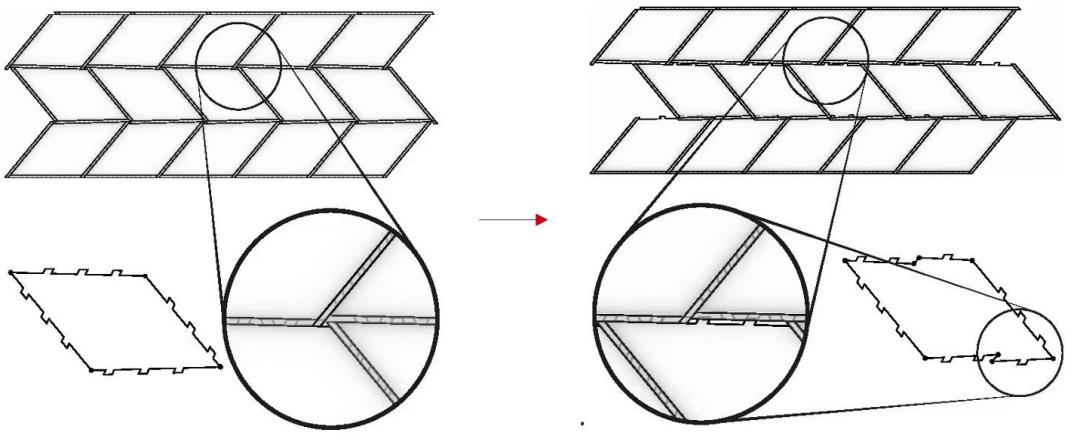
Notes

Summary

12m 34s

Optimized design pattern and force flow

Prof. Dr. Yves Weinand



Regular IATP structure

Optimized IATP structure

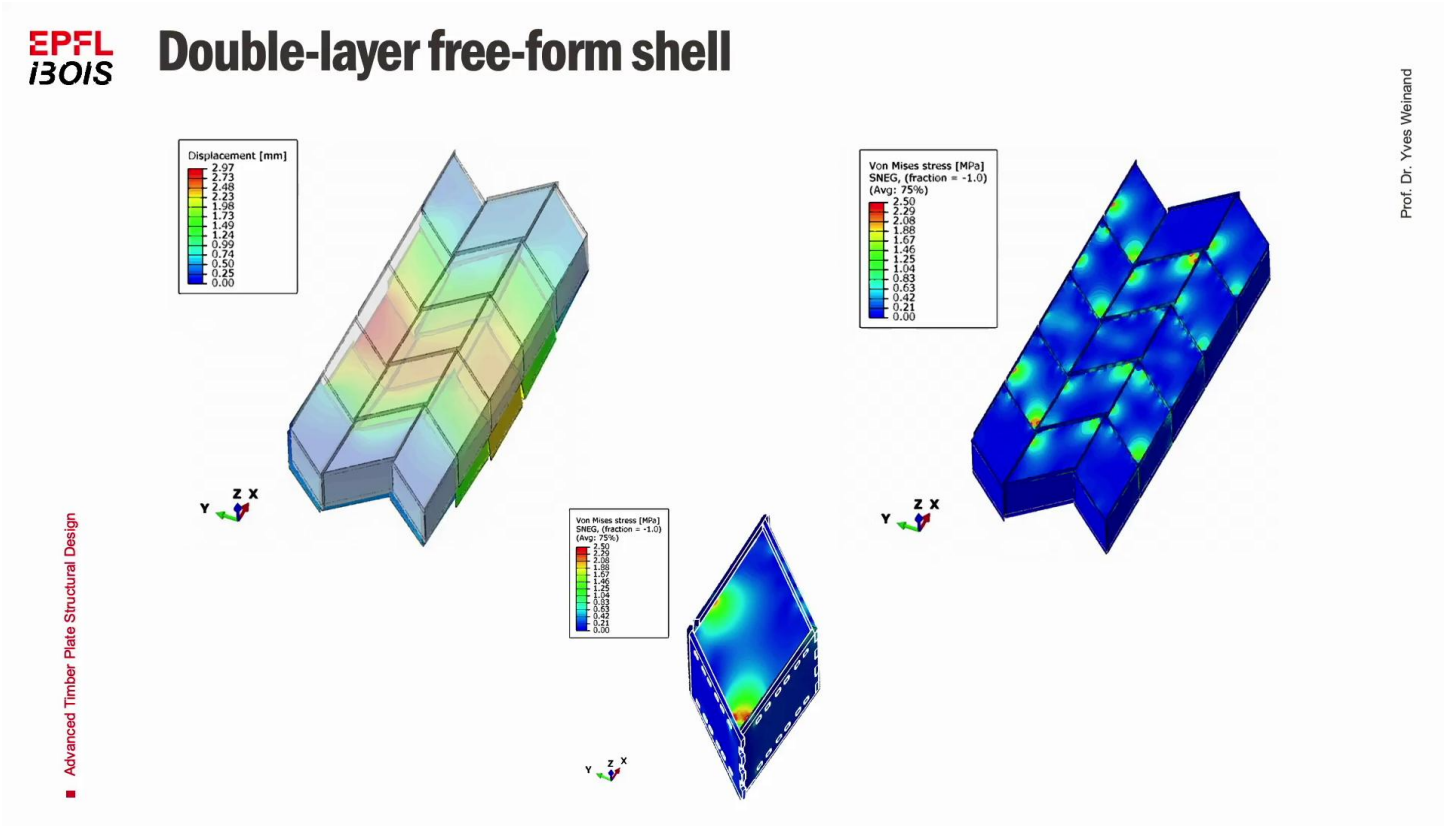
The developed spring model shows promising results for its application to a full double layer timber plate channel.

Notes

Summary

12m 46s

Double-layer free-form shell



However, the spring model is stiffer than the linear regression of the two tested specimen.

Notes

Summary

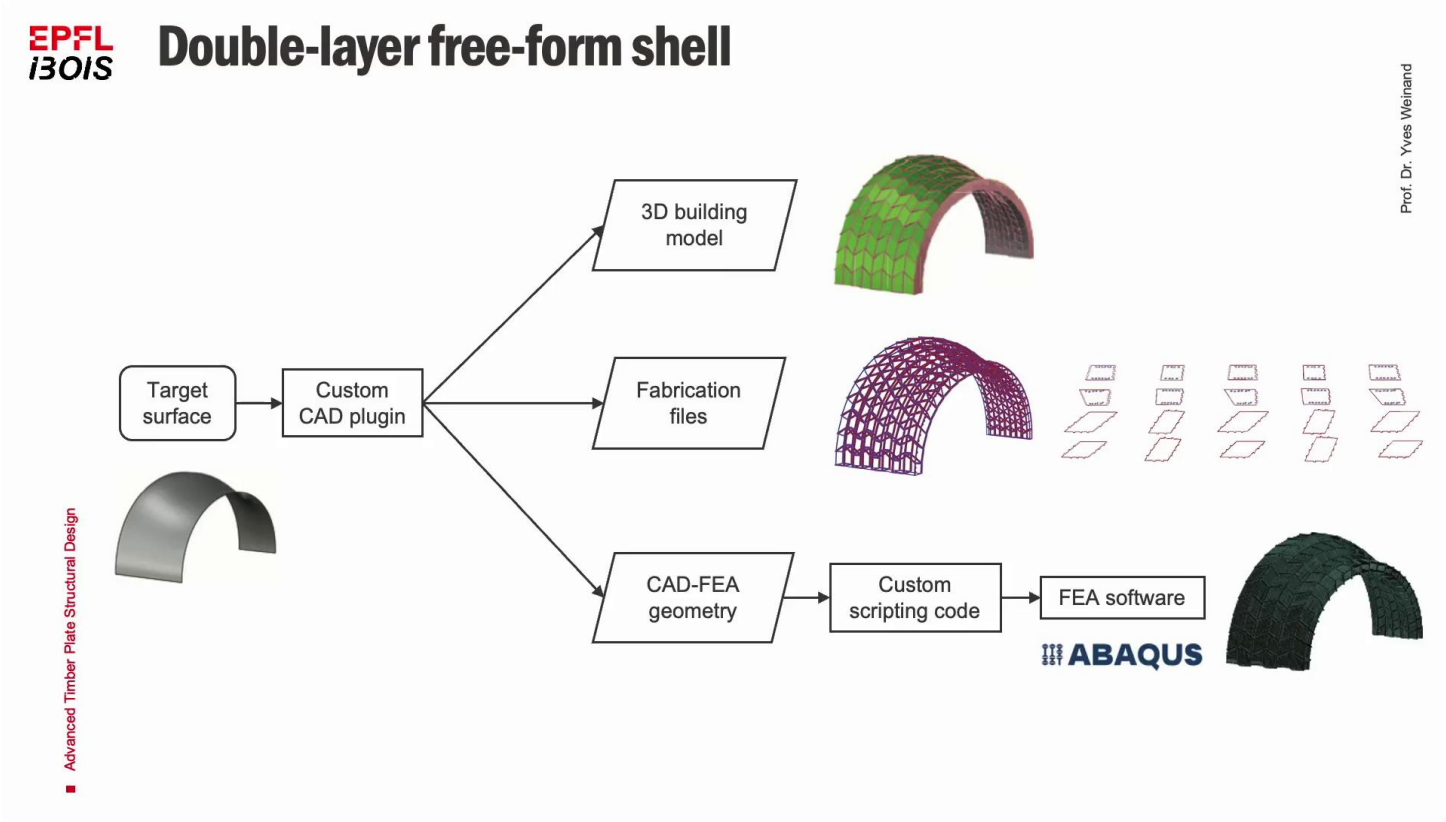
12m 54s

Then we moved on to a fullscale prototype, which, in fact was a largescale prototype, one and half scale. We called it Anan Max One. The scale of all planets is chosen as the final scale, with 40 millimeter thick panels. But the scale of the arch is chosen at one arch. The company intended essentially here to test the montage process, the montage of the assembly, but also the montage of each arch is investigated in this module.

Notes

Summary

13m 02s



Working on this perspective, it became clear that we had to mount each range of the arch one by one and horizontally. Given the fact that final boxes had a large span arches can have a length of up to 2.4 meter, it becomes difficult or even impossible, to move them up and then insert them into the system. Using the same load combination, the engineering analysis was cut out in ABAQUS [inaudible 00:13:57] environment, and the behavior of the structure was explored. The results indicate that the performance of the structure satisfies the objectives dedicated by design standards. Furthermore, the force that appeared in the wood-wood connection satisfy the design target of Uruguayan standards as well. And they remain in their safest limit state. You can see the workflow where we use the target surface. And we can from there via plugin, have a 3D building model, a fabrication file for finite element analysis, and AN ABAQUS file.

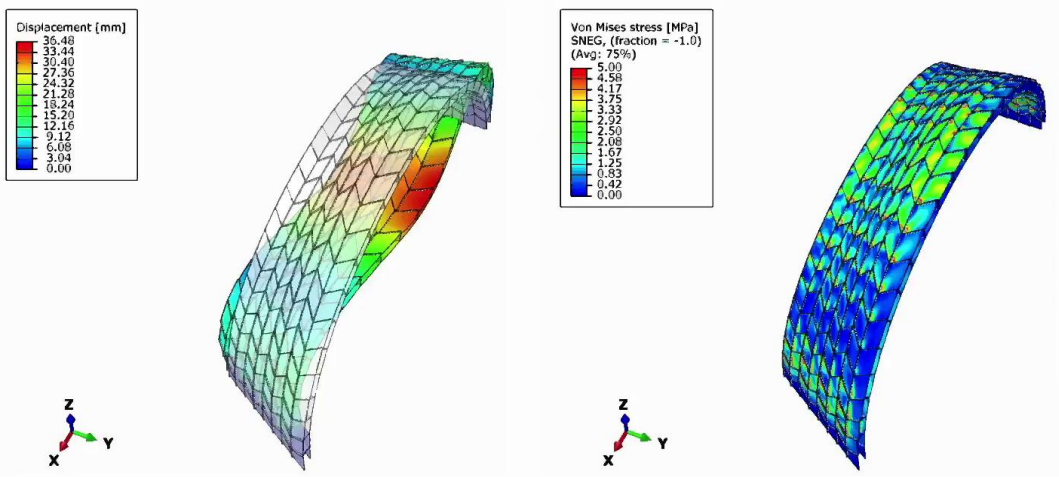
Notes

Summary

13m 31s

Double-layer free-form shell

Prof. Dr. Yves Weinand



Here you see some of the works which has been performed.

Notes

Summary

14m 35s

Double-layer free-form shell

Prof. Dr. Yves Weinand

Finally, we moved on to a fullscale prototype called Annen Max Two. It was the first fullscale prototype of the project. The construction of this project allowed for a D-Type check of all production and construction constraints. We had to check CNC commanded automatic label in storage and assembly. The montage of those two arches, as already shown required a proper and specific montage sequence. But the remaining question is to see how this montage we can see has been realized manually and in what specific geometric position each arch needs to be assembled by single manpower. My office, [inaudible 00:15:21], located in Liège, spent several working sessions to discuss montage joints and the sequences on the assembly process with the contractor. Even though the predominant assembly sequence had been discussed and experimented over the construct of several prototypes, the erection process of such a large tracker had not been addressed. In this regard, the planning and construction team had to deal with different challenges. Specifically, they have to identify the position where arches assembled. Also the maximum wide of each box should be determined.

Notes

Summary

14m 38s

Double-layer free-form shell

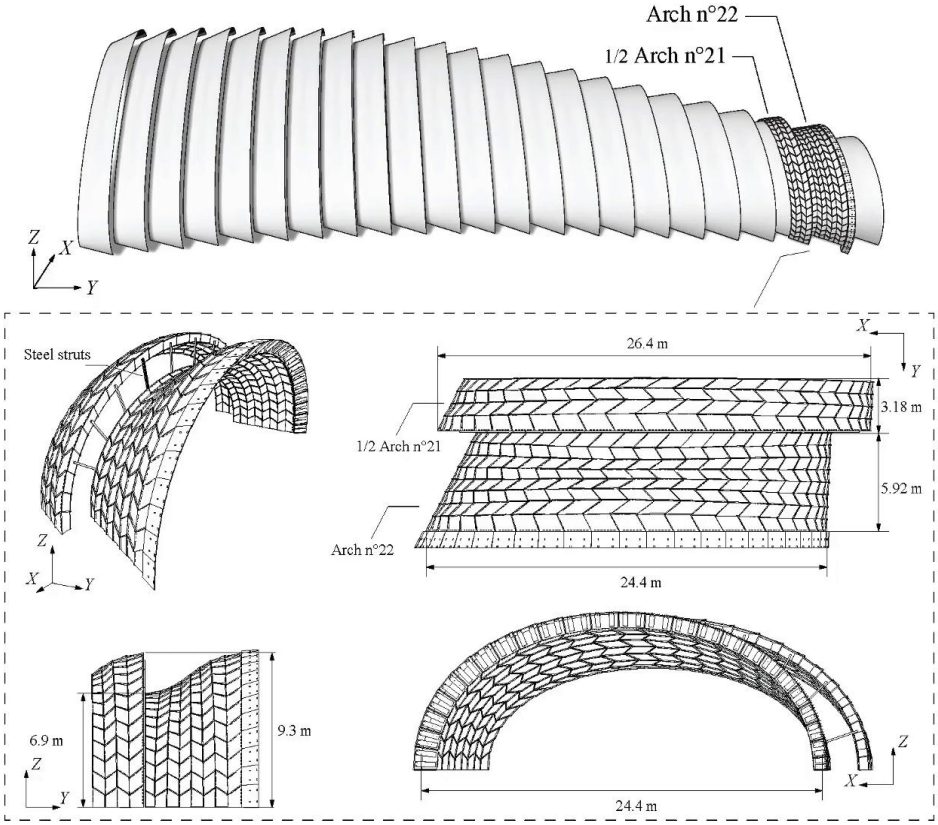
Prof. Dr. Yves Weinand

Furthermore, the construction team should decide whether or not sub assembles are included in the montage process, and if so, which size can be tolerated for them. Moreover, a possible montage joint between those sub assembles should be clarified. Finally, identifying the cinematic needed to link the wooden structure with the prepared concrete foundation system is another key challenge. A large scale, nondestructive experimenter test is conducted on a fullscale arch constructed by an [inaudible 00:16:35]. In the current investigation, two experimental tests are conducted. In the first fullscale test, the performance of arch 22 is individually studied. This arch consists of 792 planar timber plates, each with multiple tenons of slots located around its parameter. Those timber plates form 204 side timber boxes. In the second test, the behavior of arch 22 and half of 21 is researched.

Notes

Summary

15m 58s



A row of timber cups is attached to each arch, enabling the connection to the neighboring arches with multiple steel struts. The entire timber plates used to construct arch 22 and one-half arch are 1,188 elements in total, which were fabricated and brought to the site. For this purpose, again, a 5 Axix CNC machine using tool with a diameter of 25 millimeter employed for the digital fabrication process. The G code required for the fabrication process, general to a loft-like 3D offset of each timber plate contour polygon. Inserting the tightfitting timber plates one by one.

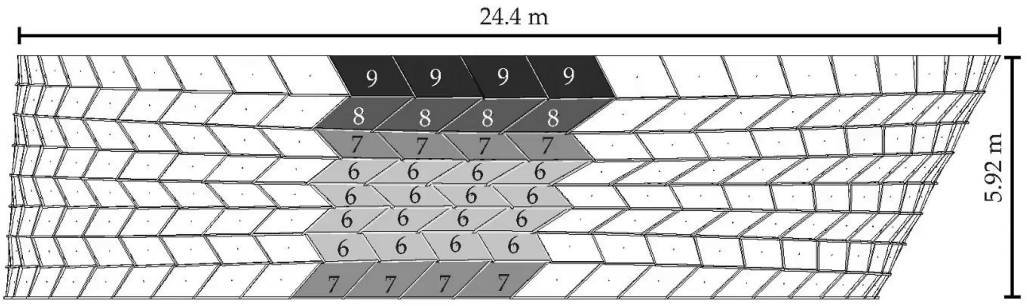
Notes

Summary

17m 07s

Double-layer free-form shell

Prof. Dr. Yves Weinand

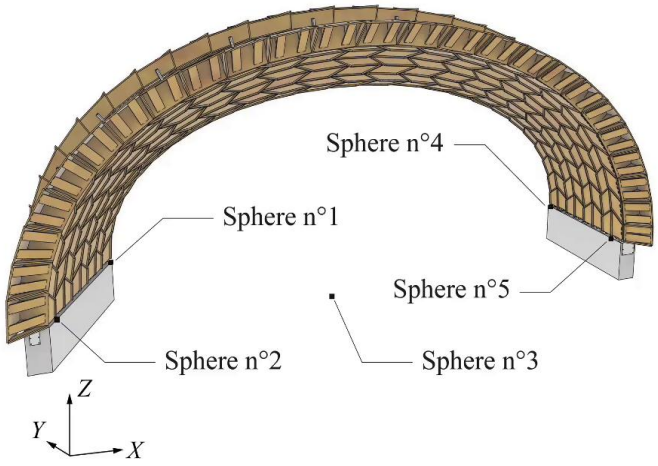


According to the assembly plan, the foursided boxes are first manually assembled on the ground. The assembly of boxes then follows the assembly process. Once the entire arch is constructed, a crane is used to lift it up at once and positioned in its determined location. Reiterating the assumption made earlier, two types of experiments are carried out for the largescale structure. The structure was loaded using 25 kilo cement bags distributed over the top surface. Computing the worstcase scenario regarding the vertical displacements at its midspan, the arch is partially loaded. This amount of load is used to ensure that the structure stays at its linear elastic face. The cement backs located on each top plate of a box component were distributed in a way that provided a uniform, distributed load and avoid any load concentration. A crane was used to put each cement back one by one on top of the structure without imposing a dynamic effect.

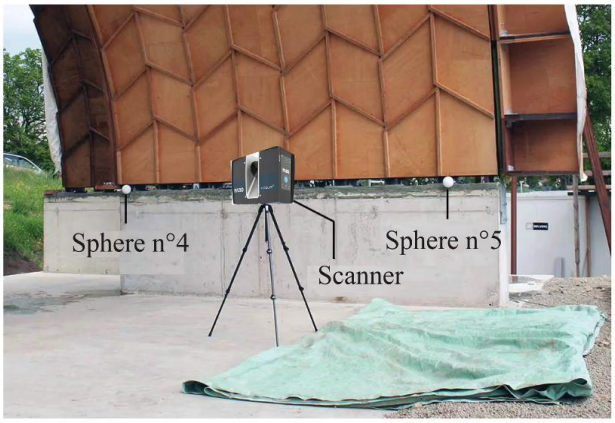
Notes

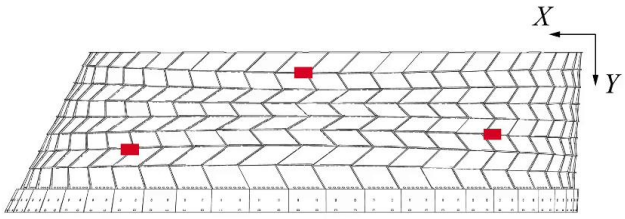
Summary

17m 53s

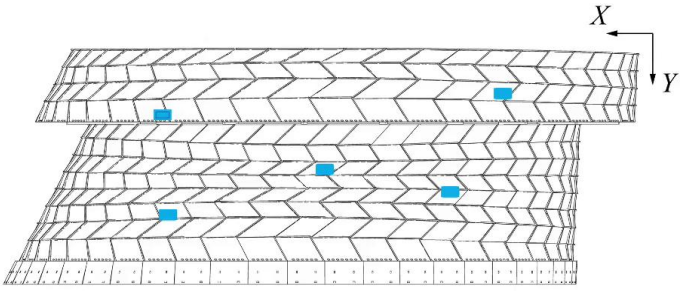


(a)





(b)



(c)

Different intensify measures can be adopted to evaluate the performance of largescale surface structures. However, the condition of the construction side, the complex geometry of the structure, complicated interaction between the timber plates and wood-wood connections, do not allow to record force stress and strain field.

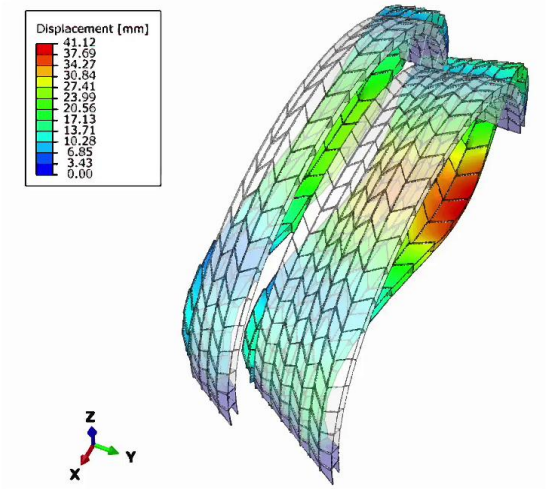
Notes

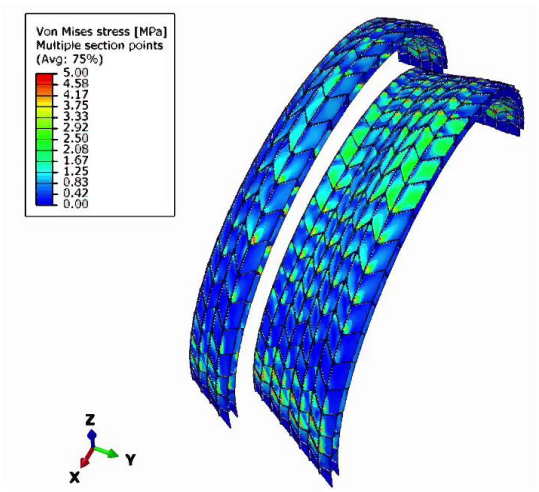
Summary

18m 59s

Double-layer free-form shell

Prof. Dr. Yves Weinand





Two structural displacement is considered as the primary performance measure on the current physical experiment. In fact, measuring displacements in largescale physical tests is deemed a reasonable way to understand the structure of interest performance. The stiffness of the structured system can be readily computed by having the corresponding displacements in the structure. On the other hand, measuring local stress contact forces and strain of element seems more complicated than measuring displacements because of the complexity involved in the instrumentation with respect to the size of the structure, calibration of associated device and robustness of the outputs.

Notes

Summary

19m 20s

References

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Notes

Summary

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