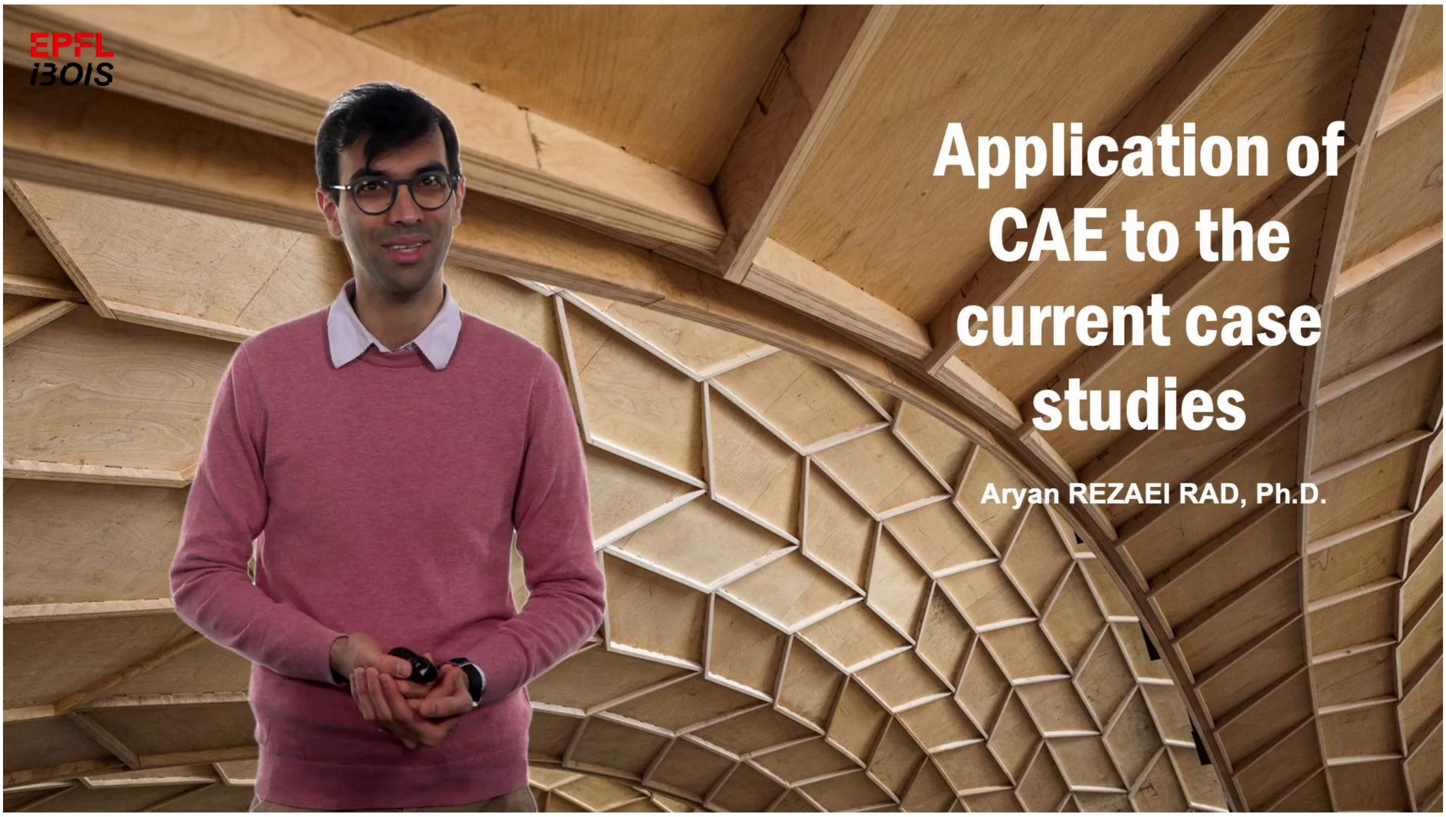

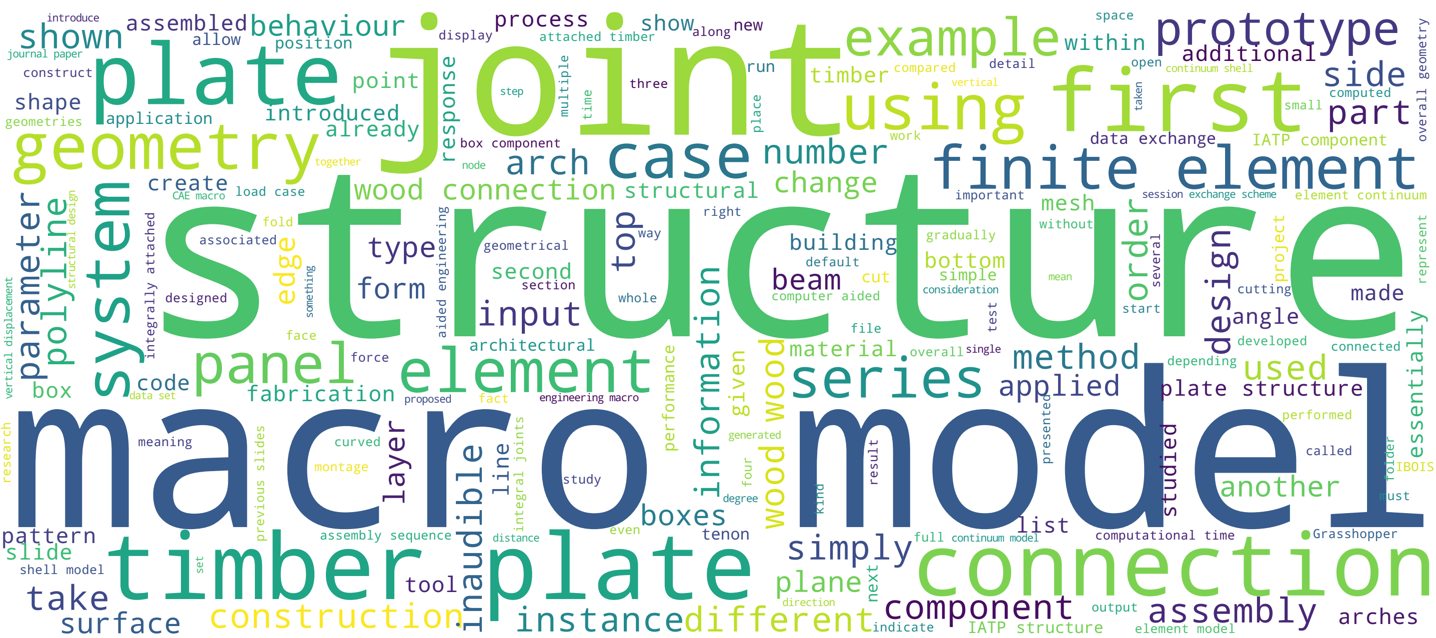

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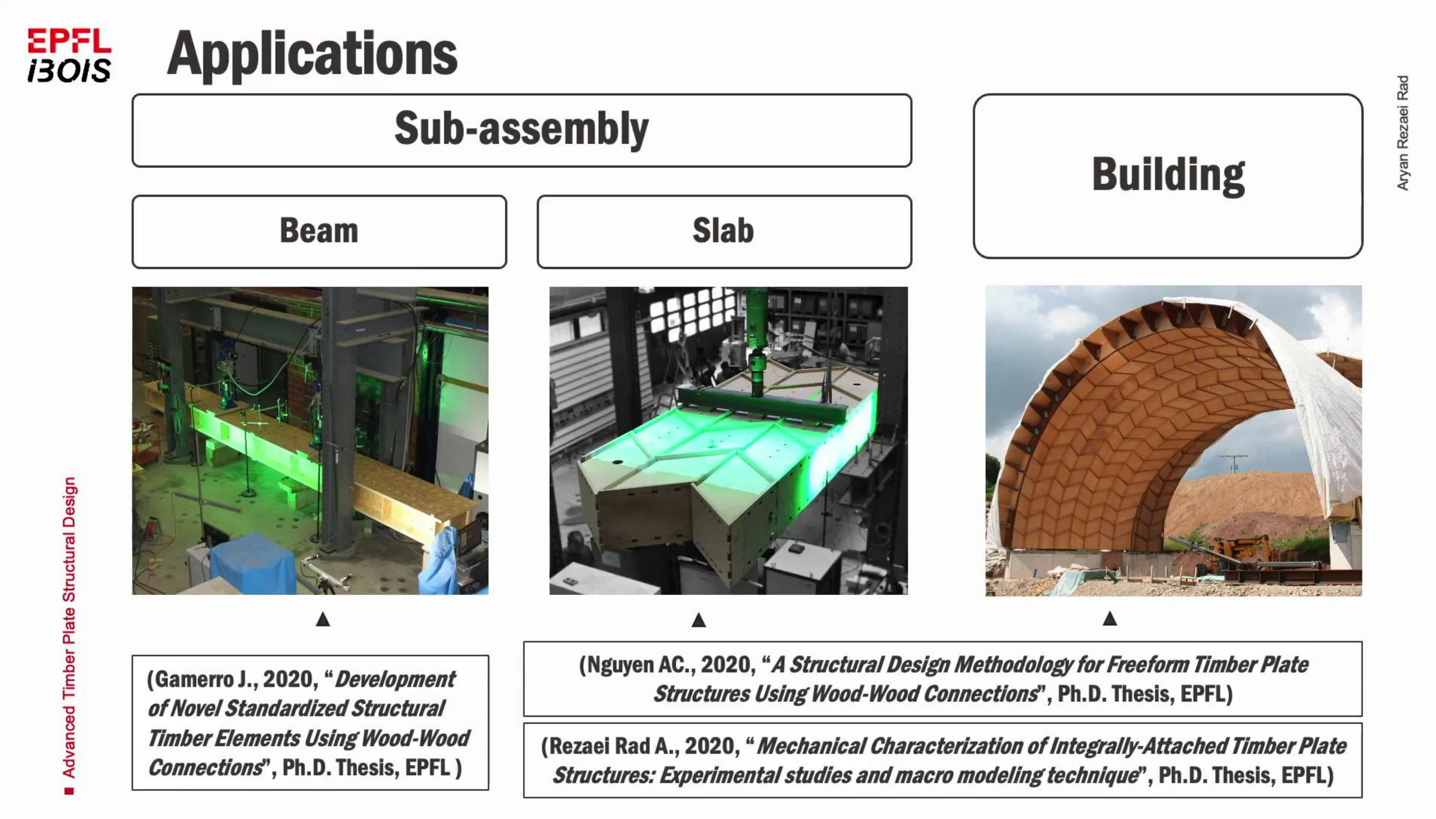

Now that we have gained insight into the different modelling approaches, it is time to tackle the building scale. In this section, an algorithmic modular framework is introduced to receive the 3D geometry of a custom defined IATP structure, compute the mechanical properties and non-geometry information of the associated macro model and finally construct the CAE model. Given the macro model and the data transformation framework that I introduced in the previous slides, different case of studies are presented here. The algorithm is used to construct the computer aided engineering macro model and analyze prefabricated IATP structures with beam and slab geometry and a larger scale free-form structure. Those are the applications to the recent project conducted at IBOIS EPFL. For more information, you can find the associated details in this slide.

Notes

Summary

0m 04s

Beam sub-assembly

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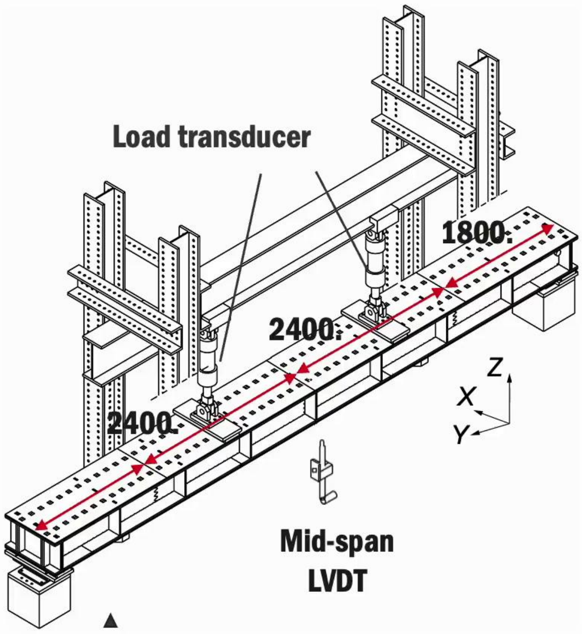
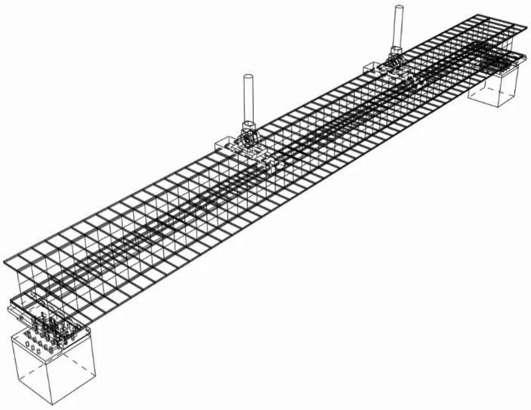




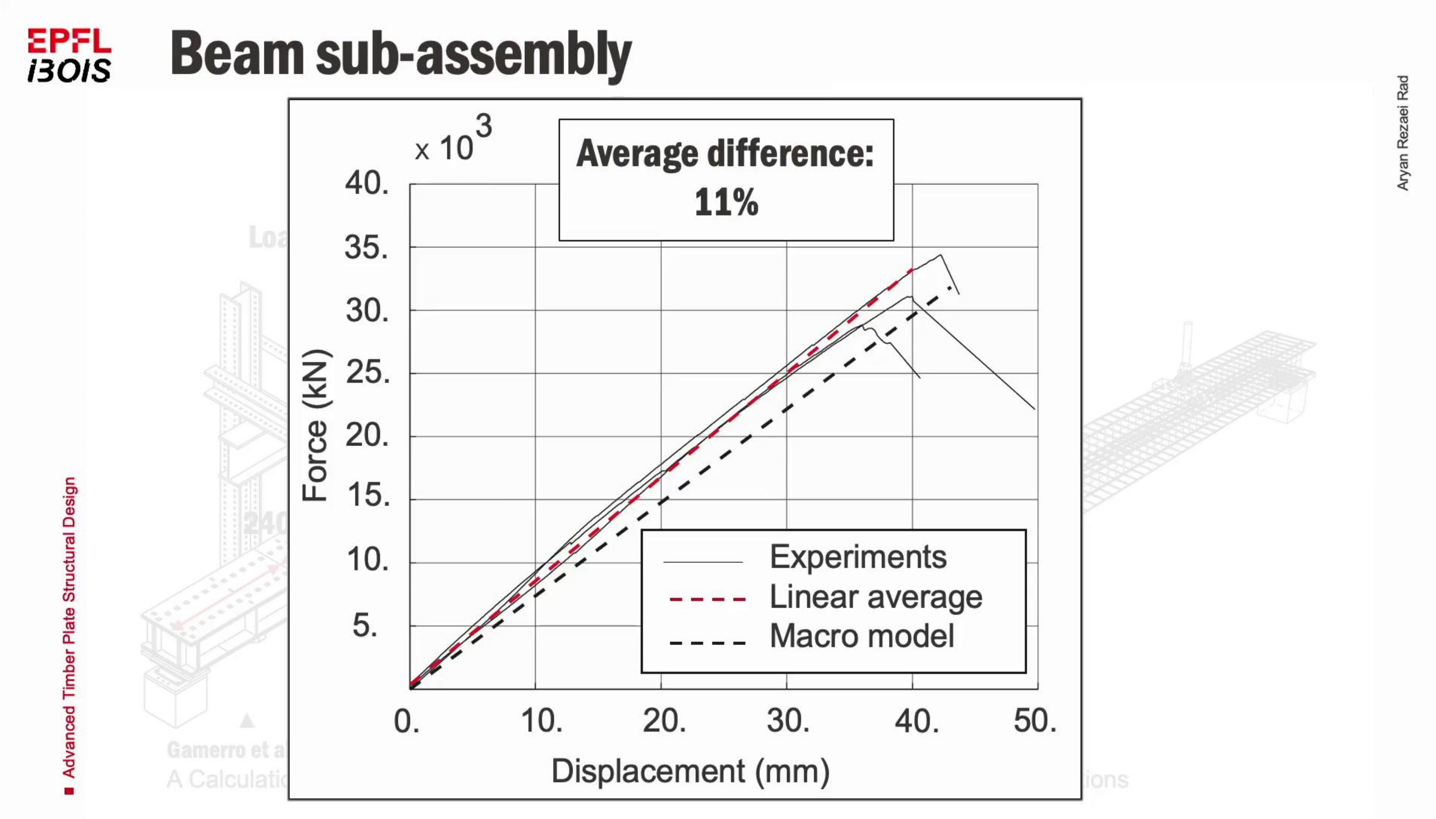
Gamerro et al. (2020), Buildings 10(3), 61
A Calculation Method for Interconnected Timber Elements Using Wood-Wood Connections

For the beam sub-assembly, the structure consists of segmented planed timber plates and it is assembled to form a beam element with hollow cross section. This system is detailed in the open source journal paper address in this slide. Using the data exchange scheme that I explained in the previous slides, the corresponding CAE macro model is generated.

Notes

Summary

1m 10s



And by applying the same loading protocol, the load–deformation curve obtained from the macro model shows a good agreement with the physical model with approximately 11% error. The adequate performance of the macro model is mainly attributed to the symmetry of the assembly.

Notes

Summary

1m 37s

EPFL IBOIS

Slab sub-assembly

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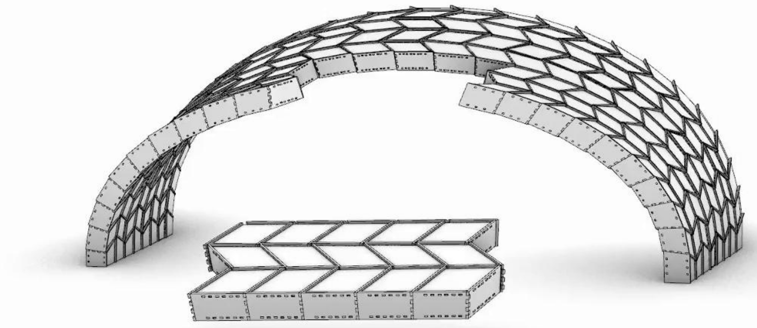
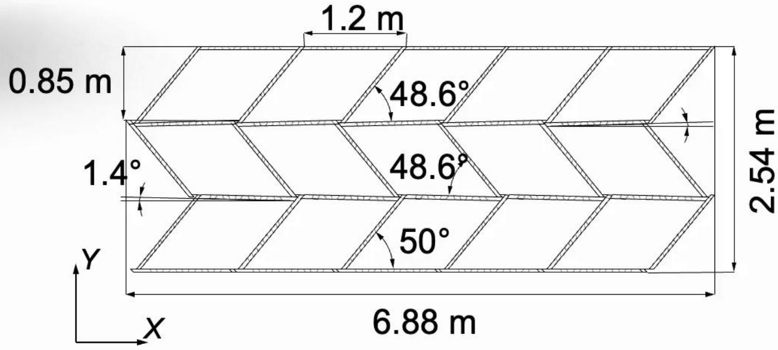




▲ Nguyen et al. (2019), Automation in construction
Design framework for the structural analysis of free-form timber plate structures using wood-wood connections

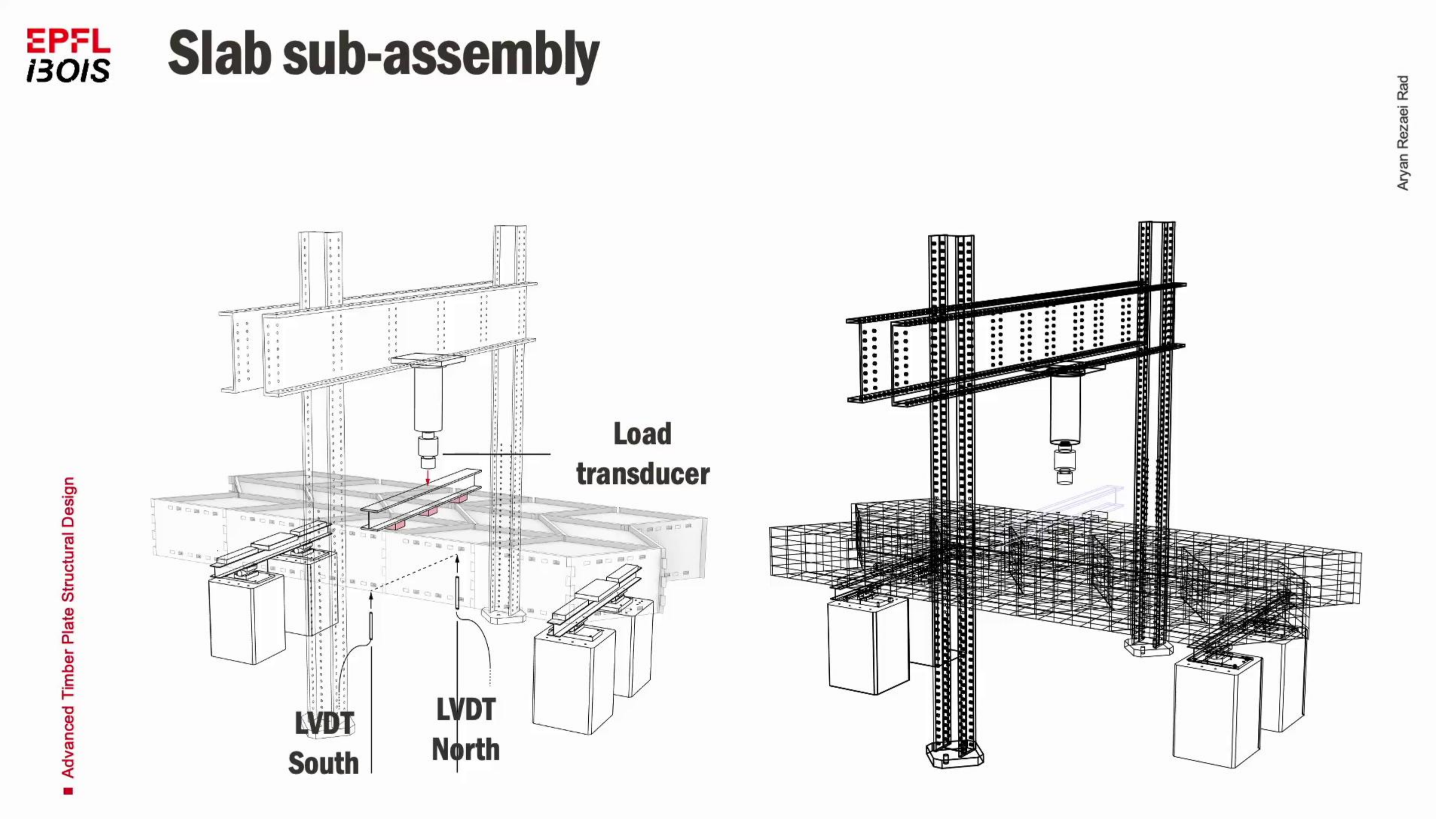
The open access journal paper by Nguyen et al provides the overall geometry of the slab sub-assembly system. As you see the top view of the structure, the system consists of 15 boxes which was extracted for the 24 metre span arch.

Notes

Summary

1m 59s

Slab sub-assembly



The overall geometry and the location of the LVDTs are shown. Three replicates of the prototype were tested under three-point bending test. And accordingly, the CAD to CAE data exchange that I already explained in the previous slides is applied to this prototype and the macro model is constructed.

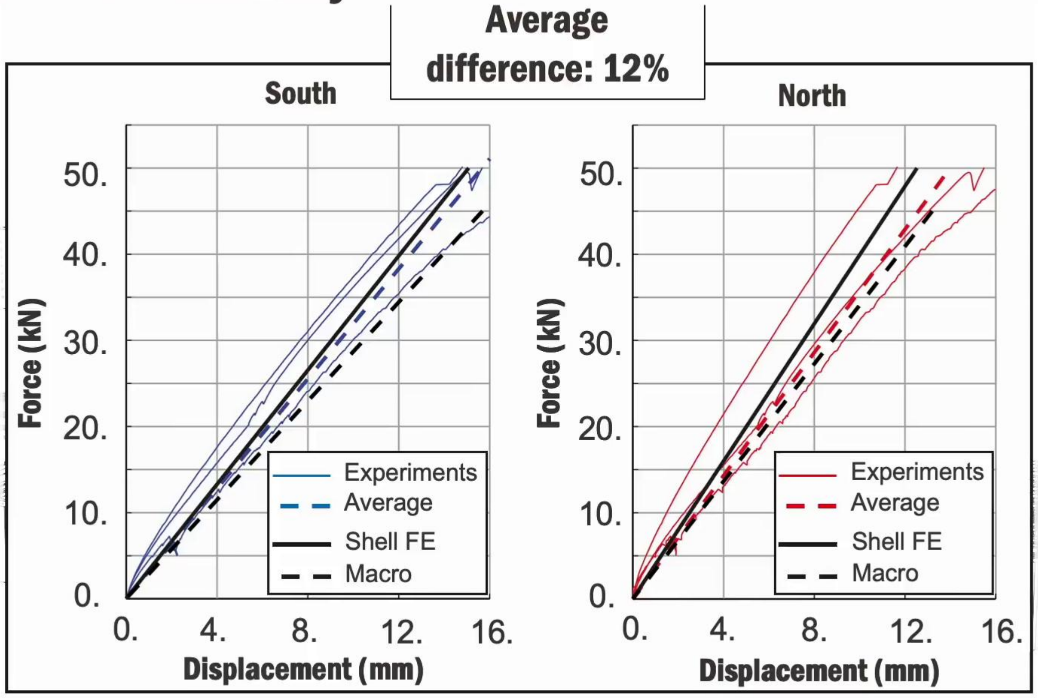
Notes

Summary

2m 21s

EPFL IBOIS

Slab sub-assembly



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Using the deflection based criteria, the response of the macro model and the finite element continuum shell models are assessed at a serviceability limited state, SLS with respect to the experimental tests. The results show that the response obtained from the macro model is close to the experimental load deflection behaviour and the finite element model with almost 12% error. This indicates that the main kinematics of the macro model are well identified and properly employed.

Notes

Summary

2m 42s

EPFL i3OIS

Full-scale assembly

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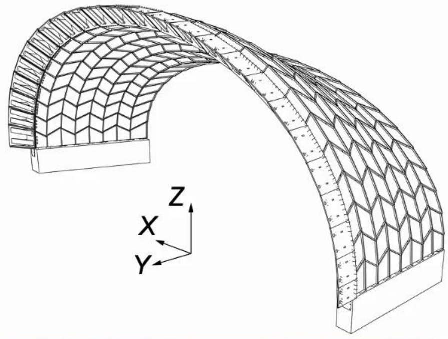
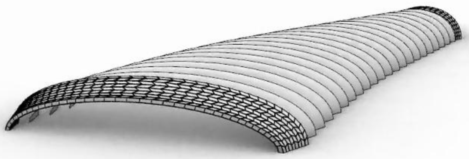




23 arches

- Spans: 23 to 54 m
- Width: 6 m
- Height: 6.8 to 9.2 m

▲

Nguyen and Weinand (2020), Sensors
Displacement Study of a Large-Scale Freeform Timber Plate Structure Using a Total Station and a Terrestrial Laser Scanner

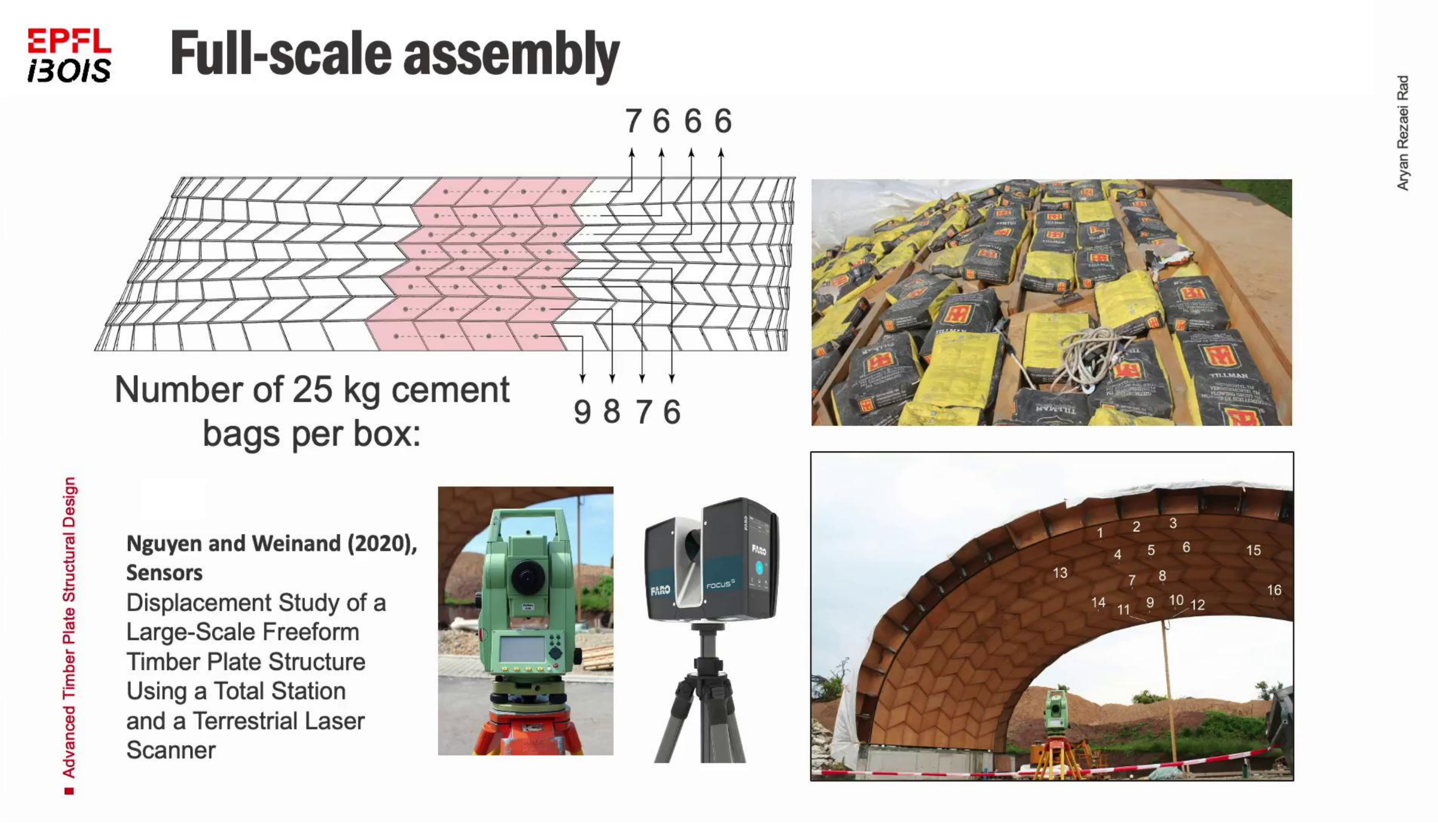
Advanced Timber Plate Structural Design

Another case of study is a roof structure of an industrial hull. The hull consists of 23 arches of beech LVL where the spam of the arch ranged from 23 metres to 54 metres. Nguyen and Weinand experimentally tested the performance of Arch 22 as you see here in this slide, and the research is published in an open access format as addressed herein.

Notes

Summary

3m 17s



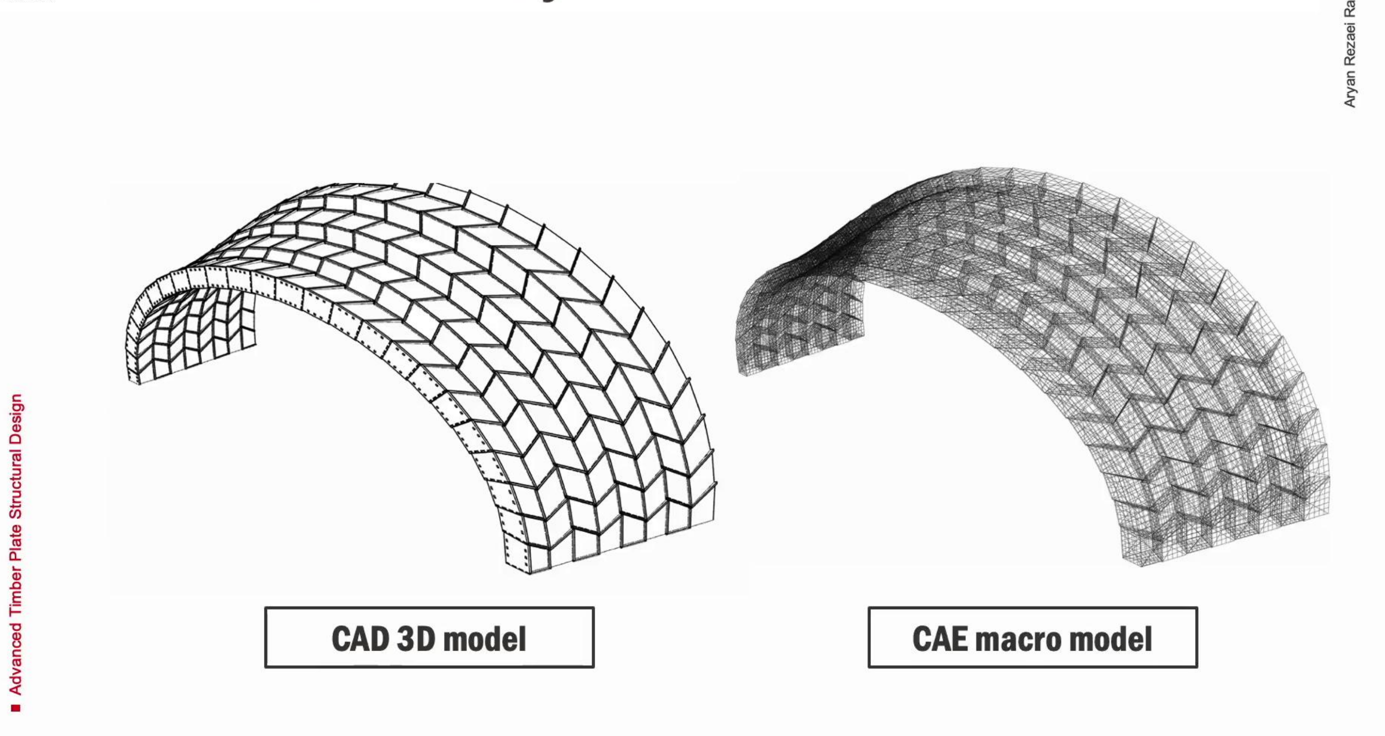
By applying cement bags on top, the structure was partially loaded at its mid span. The displacement of the structures was studied by using two measuring devices, total station, and laser scanning at 16 fixed targets of the bottom of the surface.

Notes

Summary

3m 44s

Full-scale assembly

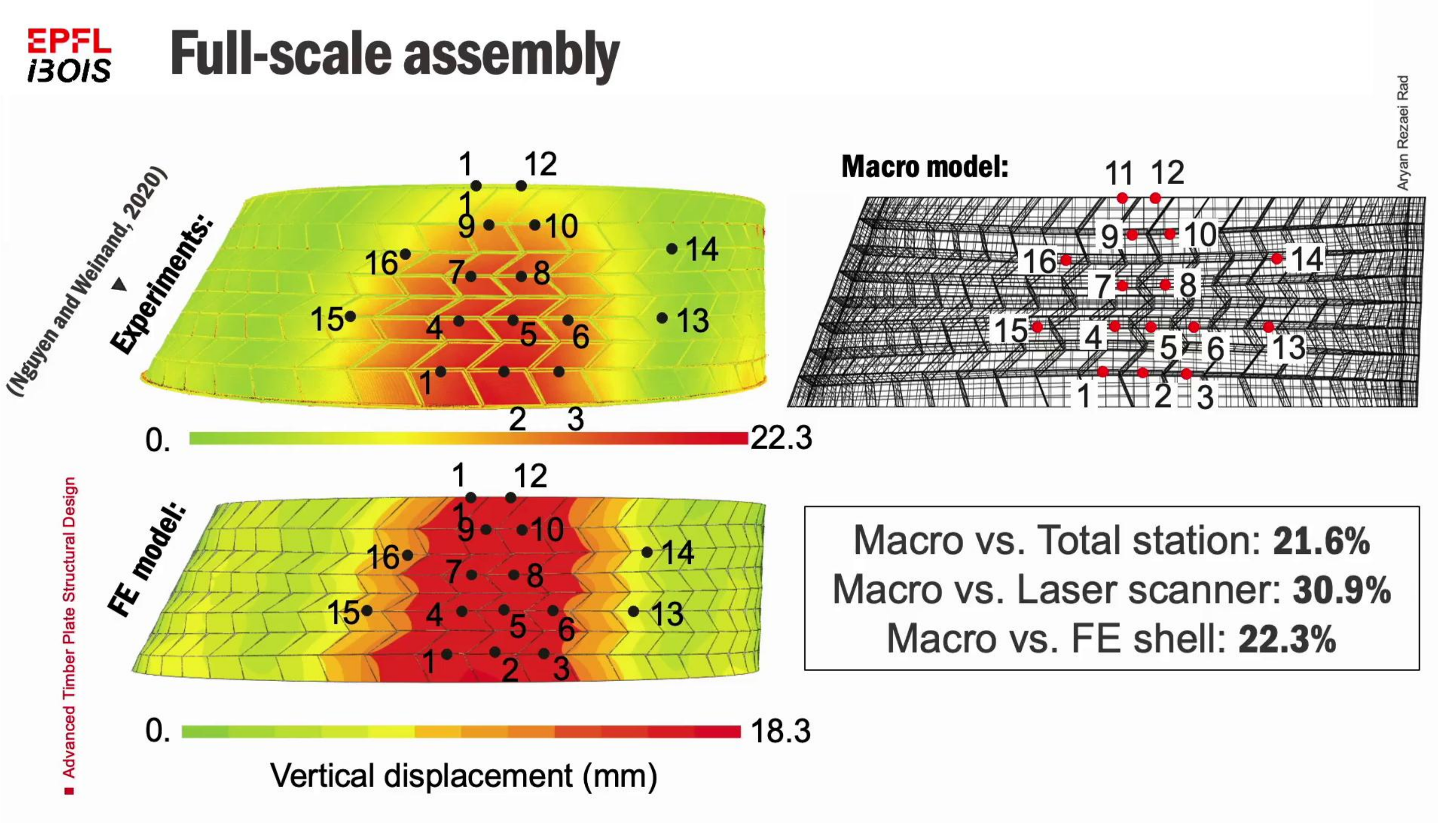


The 3D CAD geometry and the computer-aided engineering macro model, generated by the data exchange scheme that I talked about before are shown here.

Notes

Summary

4m 03s



The vertical displacement from the physical and finite element shell models are shown herein. Applying the same loading protocol, the vertical displacement of the macro model is studied in the 16 identified stations of the real prototype. The macro model is 22%, 31%, and 22% different when compared to the total station measurements, laser scanning measurements, and finite elements continuum models. Considering the scale of the structure and the differences in the response from the two types of physical experiments and the errors of the finite element continuum model, the accuracy of the macro model is deemed reasonable. It is also observed that the responses from the macro model are closer to that of the experimental results when compared to the finite element model.

Notes

Summary

4m 18s

Full-scale assembly

Aryan Rezaei Rad

Advanced Timber Plate Structural Design

Parameter	Arch #22
Model creation (sec.)	Macro: 0’ 1.9”
	FE: 103’ 15”
Analysis (sec.)	Macro: 11’ 27”
	FE: 68’ 15”
Data processing (sec.)	Macro: real-time
	FE: ≈1380’
Memory required (MB)	Macro: 14.1 MB
	FE: 1715 MB

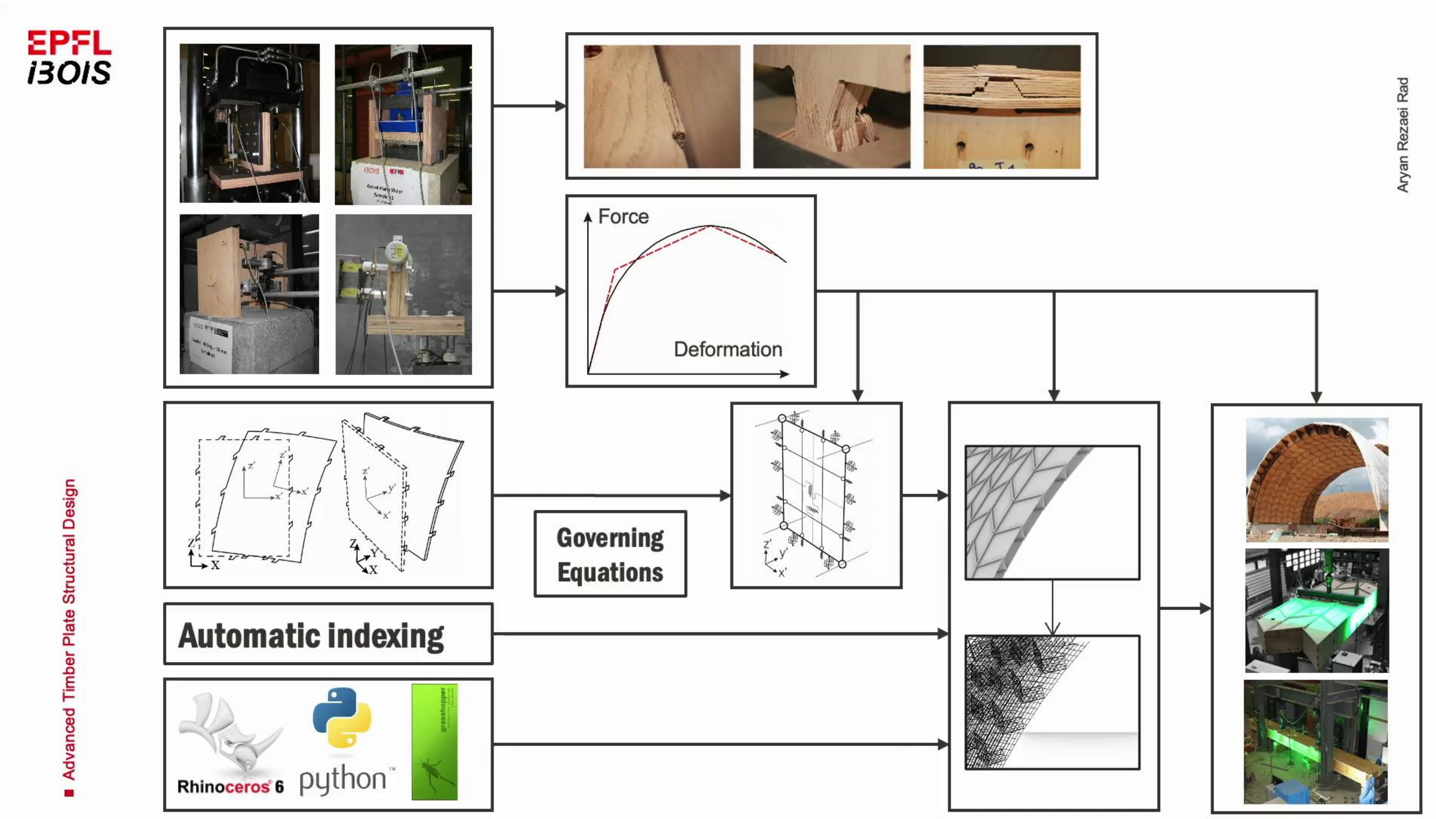
Machine configuration:
Intel® Core TM i7-4800MQ CPU @ 2.7GHz with 16 GB of RAM

One of the major benefits of using the macro modelling approach is the computational time which is considerably reduced. This effect is pronounced in every scale of the numerical simulation. For instance, the computational time including the model creation, analysis, data processing in the structural analysis of Arch 22 is almost one day for the finite element continuum shell model, while the computational time associated with the corresponding macro model is almost 11 minutes. This is attributed to the significant decrease in the number of nodes and elements in the macro model.

Notes

Summary

5m 22s



Let's summarise our session. As far as the structural design methodology of timber plates with integral joints is concerned. The behaviour of two tenon IMAs under four different load cases, namely tensile, edgewise, flatwise loads, and flexural moments was studied and explained. Specimens with minimum of five replicates were designed and the mechanical behaviour of the integral joints is evaluated in both qualitative and quantitative terms. Next, the kinematic and associated force flow mechanism of IATP components are studied, equilibrium equations are established, and the components stiffness metrics were formulated. The macro model associated with the IATP component is introduced, developing an automatic indexing using CAD environment and visual programming, a CAD to CAE macro model data conversion scheme is developed. And lastly, the developed framework and the macro model were applied to the recently constructed integrally attached timber plate prototypes and full-scale structures.

Notes

Summary

6m 10s