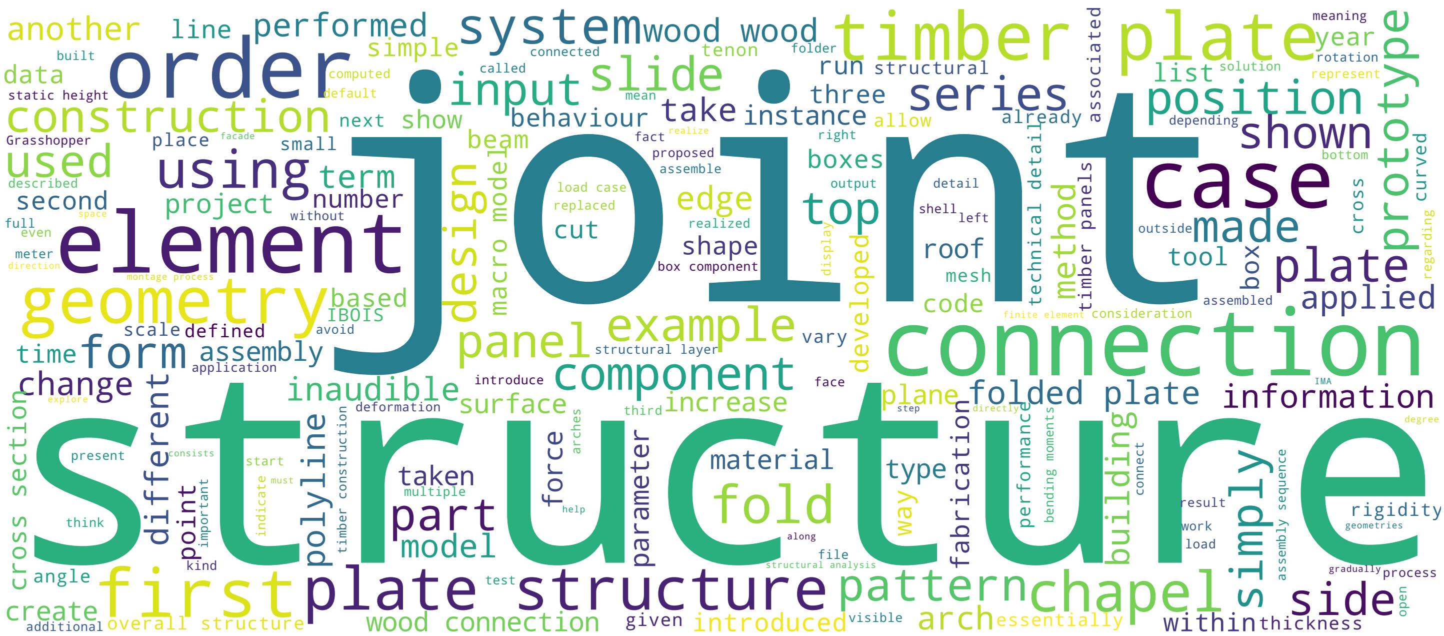


Search MOOC

Video

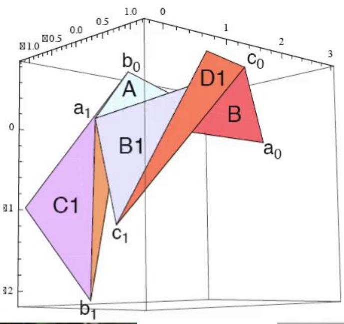
EPFL IBOIS

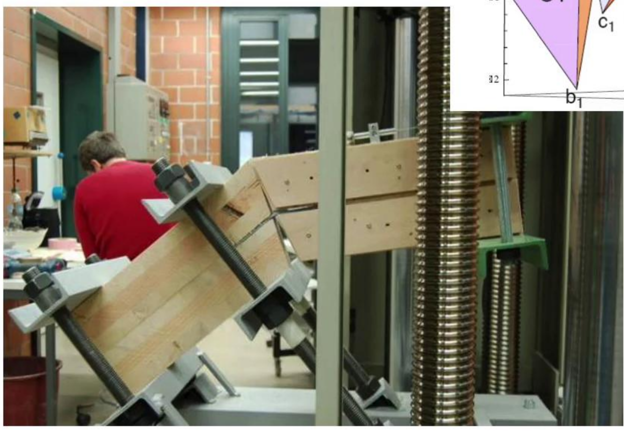
Origami – Timber Plate Structures

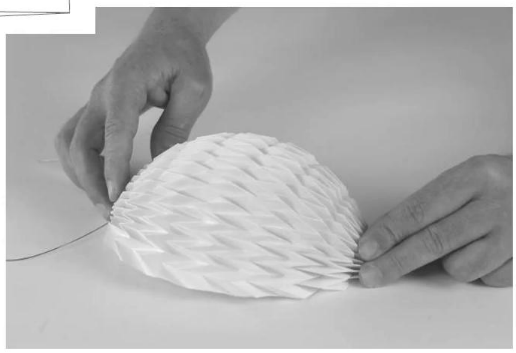
Interdisciplinary research: architects, engineers, mathematicians.

Prof. Dr. Yves Weinand

Advanced Timber Plate Structural Design







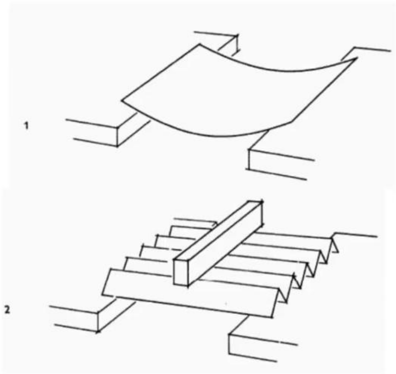
Today, I would like to present the first technology transfer from our early research at IBOIS towards a real building scale, the construction of the Chapelle St. Loup in Pompaples, Switzerland. The project was based of Hani Buri's investigations, where we would combine different ingredients as origami-folded paper structures, analytical mathematical models, and mechanical testing of connections of timber plate structures. The laboratory for timber construction combined architect structure engineers, but also mathematicians, in order to develop new methods of construction of timber plate structures.

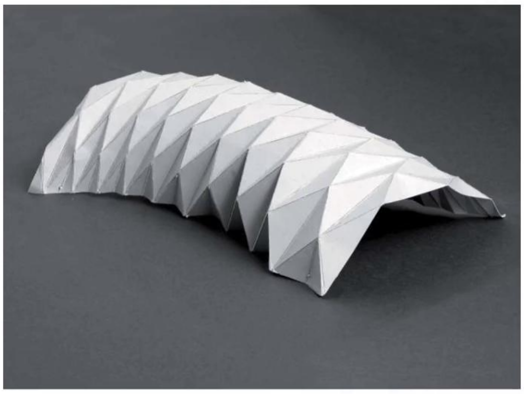
Notes

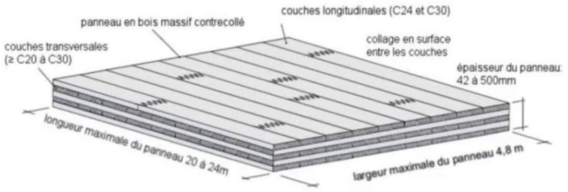
Summary

0m 04s

Motivations







Hani Buri would specifically look at folded plate structures and on different patterns which can be developed by folded plate structures or folded origami paper. The idea here, the underlying idea is first, that we would like to take advantage of the rigidity of the fold. We would like to use at that time, newly-produced timber derived panels. And we would like to use also automated CNC cutting methodology. What perhaps differs from the traditional Japanese origami techniques is that we would not fold a given figure or pattern into its final figurative representation of a bird or blueberry, but we would keep the geometry within an intermediate state, where the fold would reach a certain depth, which would correspond to the static height of that folded plate structure, if it would be built out of timber plates.

Notes

Summary

0m 55s

Three Types of Folds

Prof. Dr. Yves Weinand

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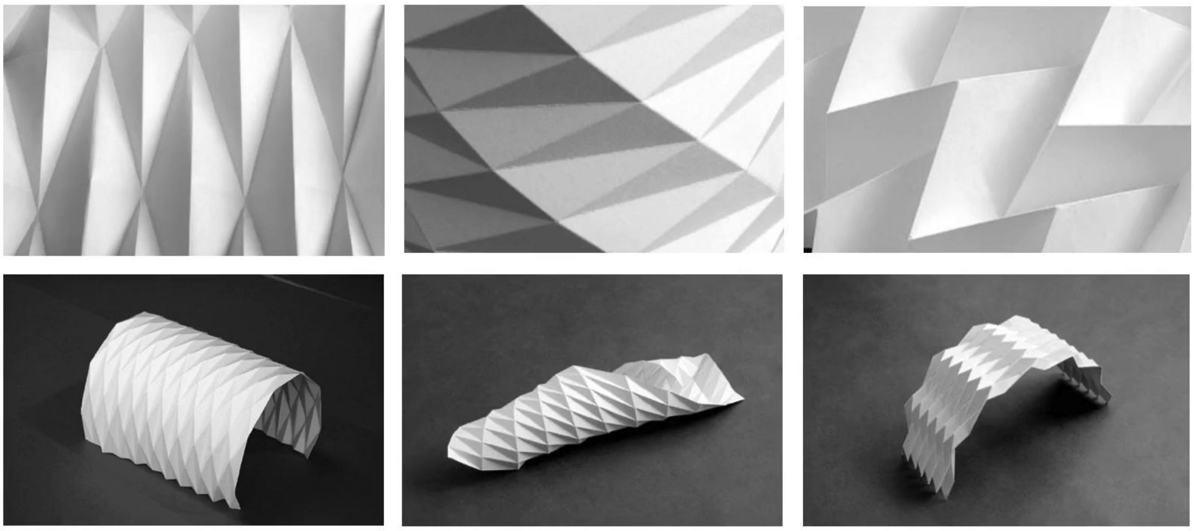


Here you see different developments proposed. And the underlying logic is that it is reined by the same rules, meaning that we cannot cut into this paper, that the paper itself should be left as it is. And from there, different patterns are developed.

Notes

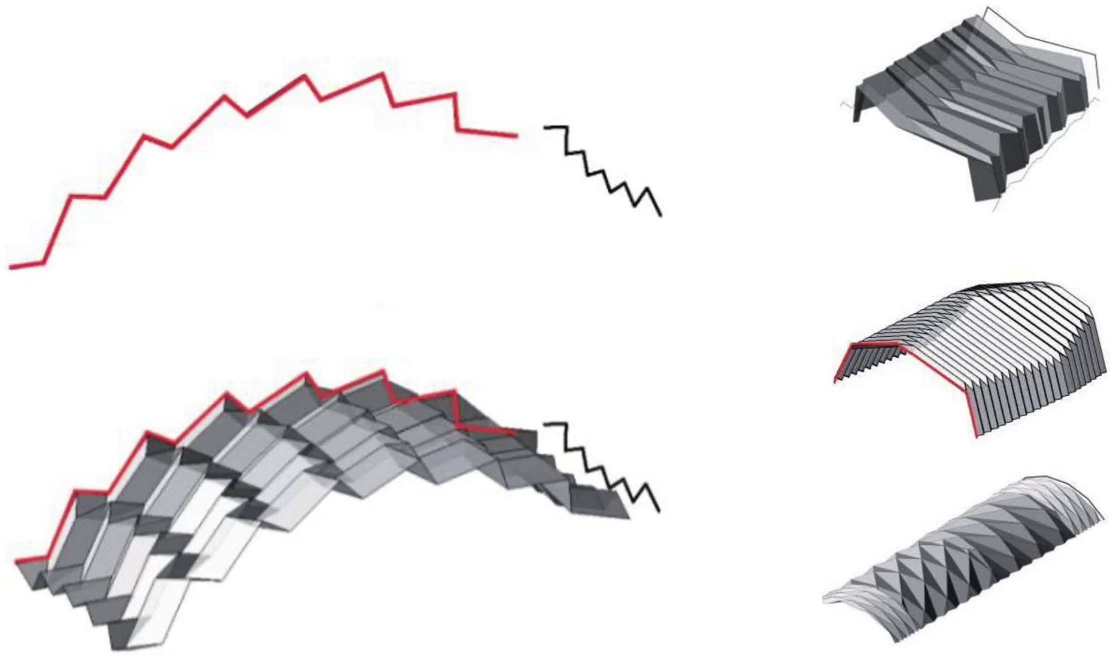
Summary

2m 11s

Building and Loading a Prototype

Prof. Dr. Yves Weinand

Advanced Timber Plate Structural Design



As we would not do those folded operations by hand, a cross section and a longitudinal section generative would be defined, as a custom design tool would be proposed, where we had a longitudinal and a cross section to be as operated in order to generate different types of folds over a surface.

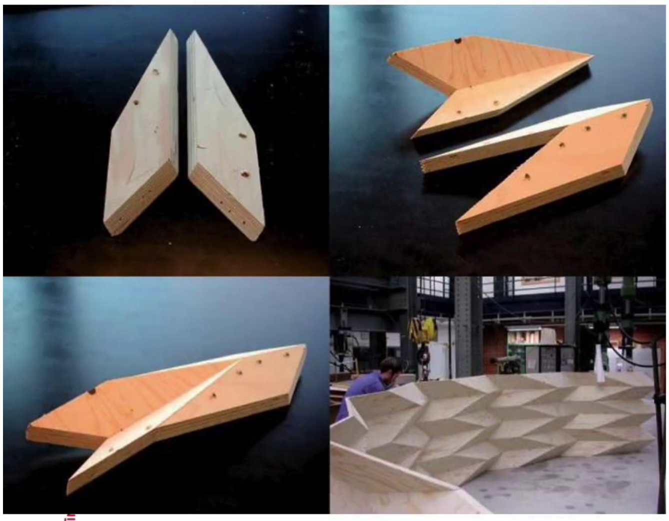
Notes

Summary

2m 38s

Building and Loading a Prototype

Dr. Yves Weinand



From there we moved on and we defined basic elements within those patterns, which could then be indeed cut out of panels, but which would be not of a large number of different elements, but were small, in this case, just two. On the right side, on this slide, you see our first fully plate structure made out of 2.1 millimeter panels, which was tested at IBOIS in 2006.

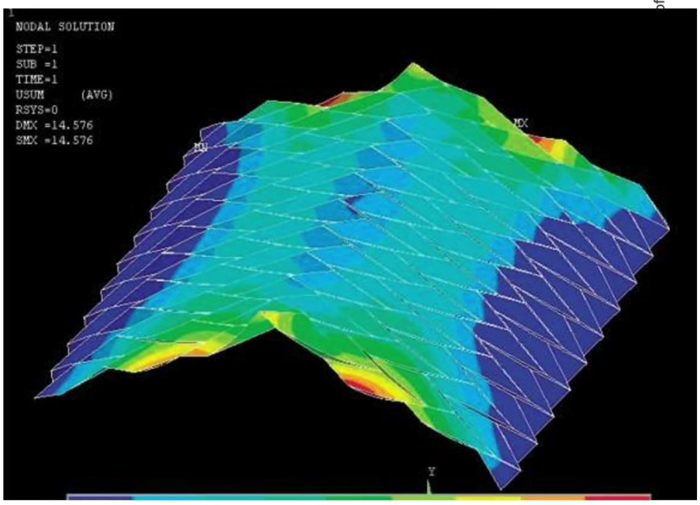
Notes

Summary

3m 09s

Joint Testing and Stability Modeling

f. Dr. Yves Weinand



Advanced Ti

At the same time, mechanical investigations would be performed on those prototypes, and we would also look very closely how we could connect those panels with each other. Interesting on the left you can see that a folded steel plate has been integrated into two wooden panels, and is completely protected by those timber panels in case of fire. Meaning that this is not only a technical advantage for that specific load case, but it is also an advantage in terms of aesthetics, because the connection itself disappear.

Notes

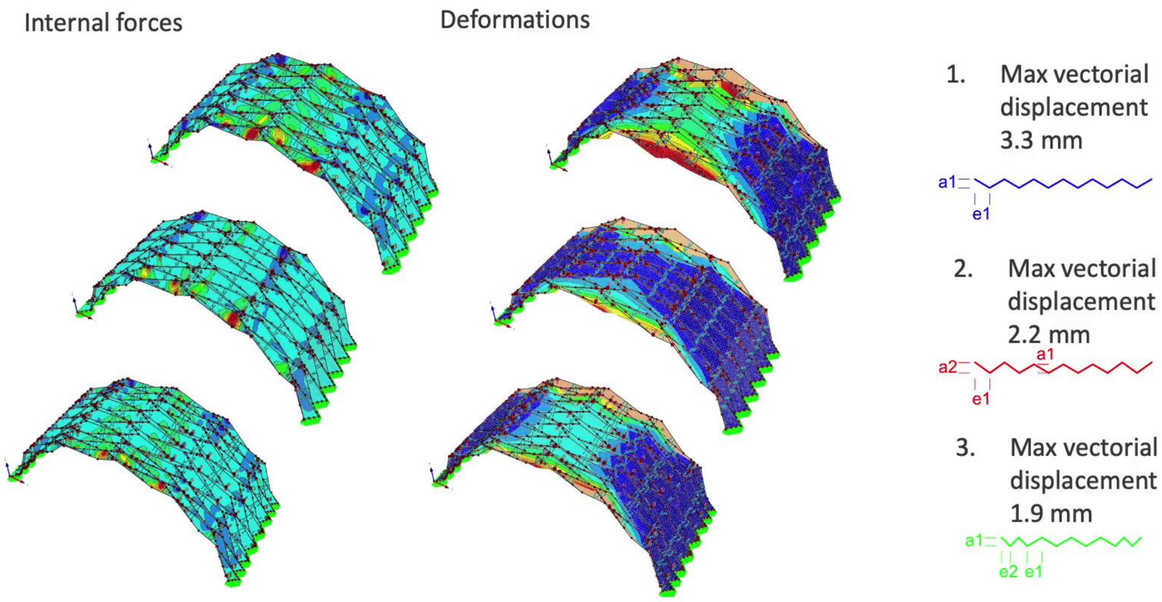
Summary

3m 46s

Parametric Study, Variation of the Amplitude and the Extension of the Folds

Prof. Dr. Yves Weinand

Advanced Timber Plate Structural Design



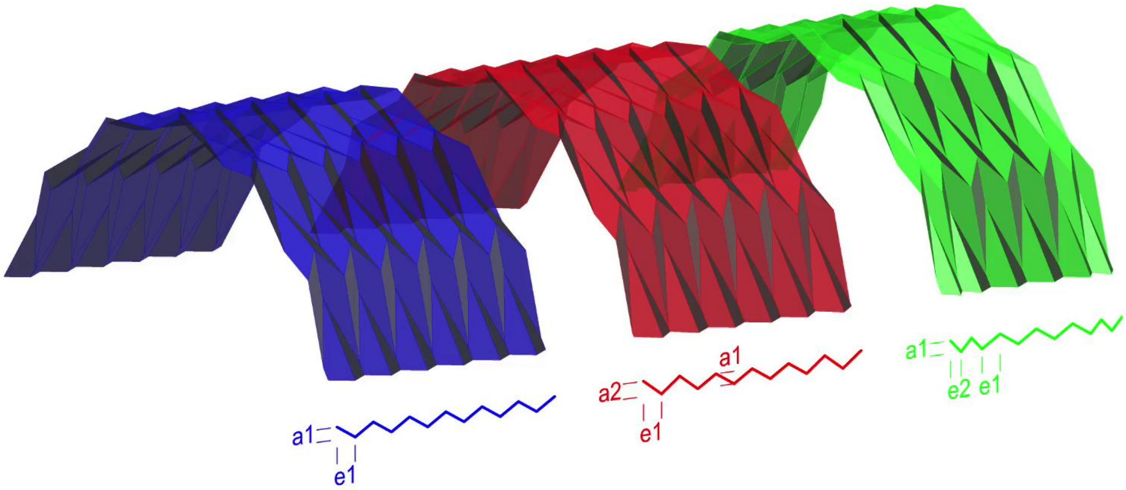
We realized that we could perform parametric studies, where we vary the amplitude and the extension of the folds, meaning that if we vary the amplitude, we would increase the static height of the overall structure. Or if we change the pattern or the extension, we would rigidify the borders of a given fold structure. On this slide, you see that the performance can be reached by simple geometrical manipulations and not an increase of materials.

Notes

Summary

4m 29s

Parametric Study, Variation of the Amplitude and the Extension of the Folds



1. amplitude a1 constant extension e1 constant
2. amplitude a2>a1 extension e1constant
3. amplitude a1 constant extension e2<e1

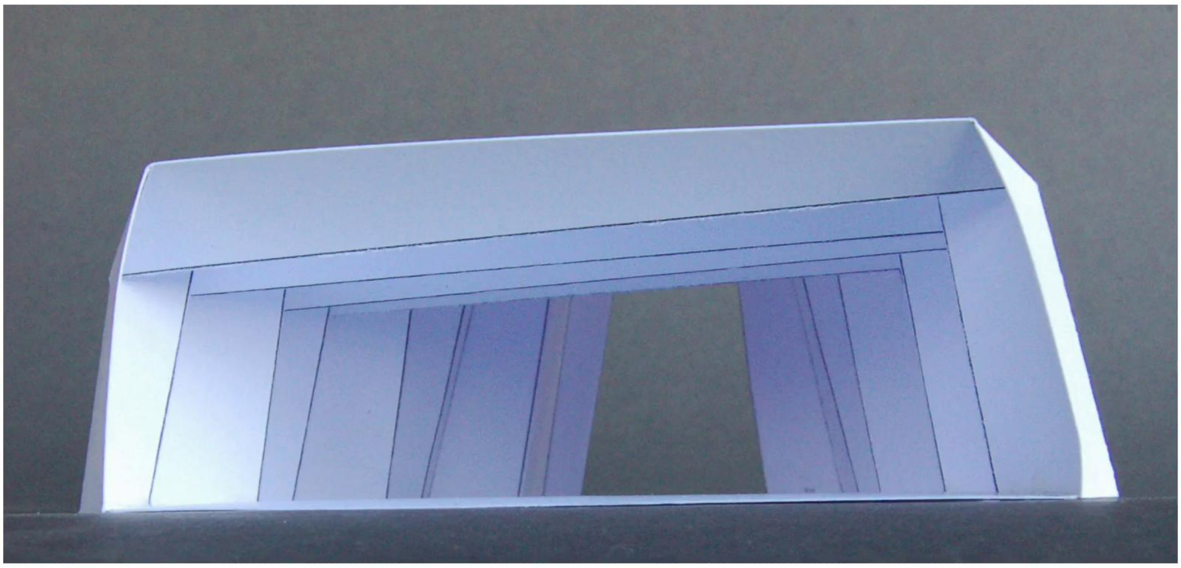
This is also the case on this slide, where we have, with a given pattern, a variation and an increase of the rigidity.

Notes

Summary

5m 05s

Form Generation



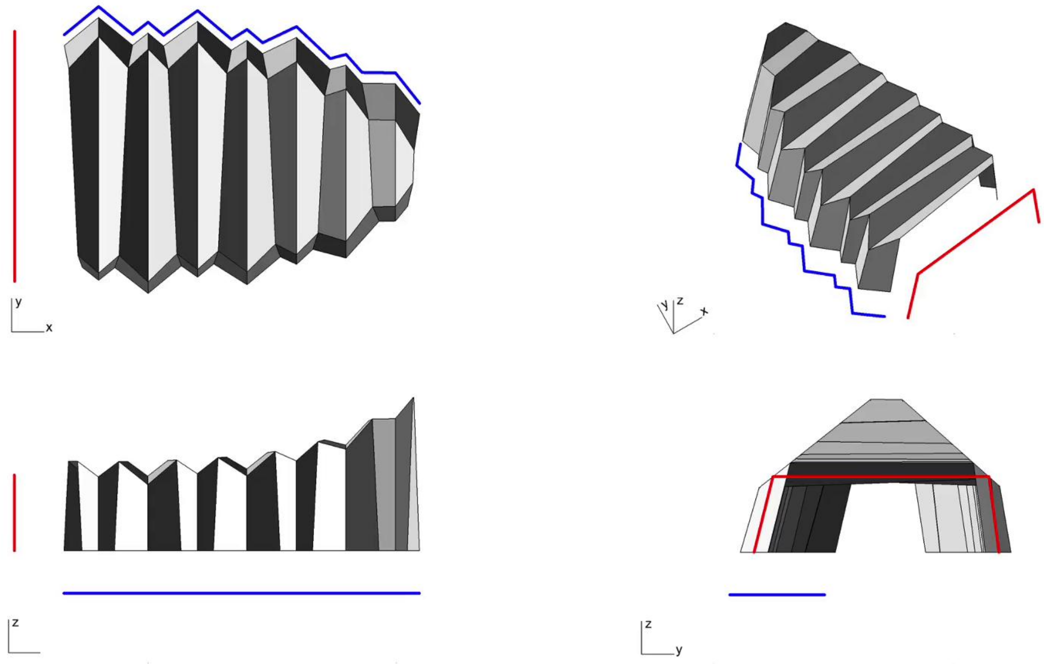
It happened that close to Lausanne, we were asked to build a chapel which would only be used for a given time of two years. And we developed several case studies where we would, instead of mounting the tent, proposing a light folded plate structure.

Notes

Summary

5m 16s

Form Generation



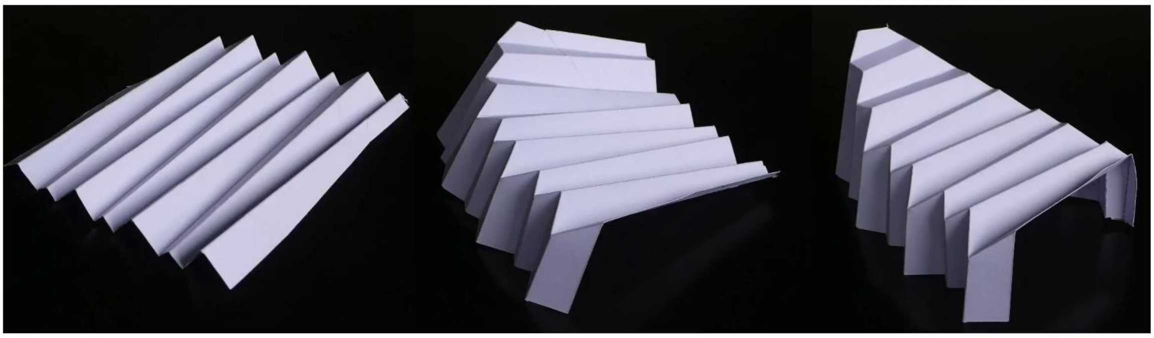
On this slide, you can still see some model making, where we tried to explore the general form. On the bottom left you see the form which has been retained, meaning that that form describes a spatial evolution, starting from a horizontal rectangle to a vertical rectangle while you cross or walk through the chapel. The [inaudible 00:06:09] tool would be applied to a target surface. And here you see the longitudinal section and the cross section in red. And by manipulating it, folds would be introduced, which would be first, a regular pattern, and then we would introduce slopes in order to let rainwater flow down from the roof towards the earth. So very simple geometrical manipulations would give directly the final architectural form of the building. And the reasons why those manipulations occur were for spatial reasons. First, an evolution of space towards a vertical rectangle. Second, a folding plate structure in terms of having a rigidity, which could help us to realize that building, using very thin timber panels. And third, an asymmetrical slope condition must be introduced in order to avoid any horizontal line on the roof and give it a slope for executing and helping rainwater to run down.

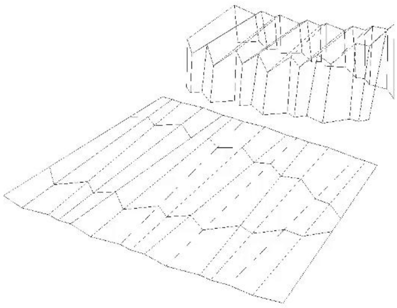
Notes

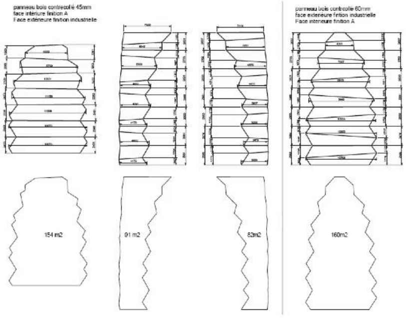
Summary

5m 38s

Form Generation







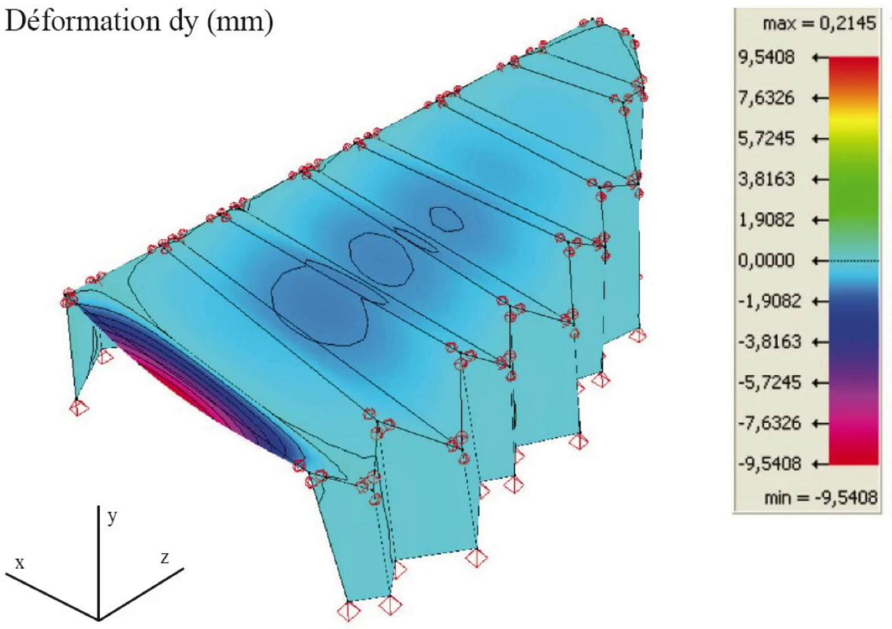
From there, a tool path of [inaudible 00:07:36] where each panel coming out of the overall geometry would be described in its dimension [inaudible 00:07:45].

Notes

Summary

7m 33s

Structural Analysis, Deformation dy



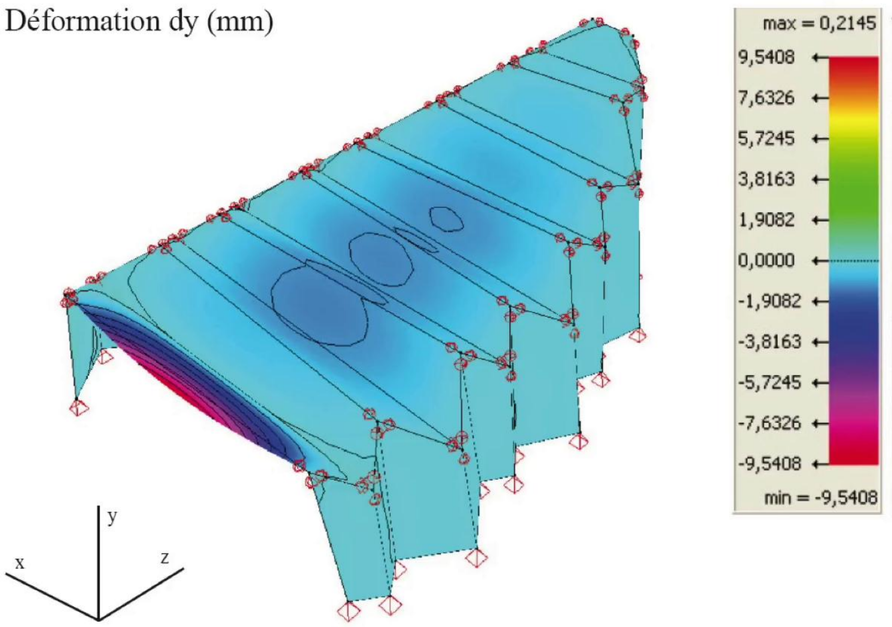
A structural analysis would be performed where we would consider all edges fully articulated. Meaning that this structure is already stable by only considering the full possible rotation of all connections. Indeed, the rigidity comes from the form itself and from the fold itself. And the frame rigidity comes from a spatial fold, which goes into the depth. So that means, as from structure engineering point of view, you are able to avoid expensive connections or connections who would be able to take bending moments. So as rotations can be left free, this gives a very free opportunity for bidding and for proposals by contractors; how those connections can be executed since we only need to block the translations along the edges of the overall structure. You see that when we performed the structural analysis, we could exteriorize membrane forces, very logically you have maximum stress here in the middle of the roof appearing. But the weakest point in terms of deformation of the overall structure is the border facade condition at the entrance of the chapel. This is also easily understandable because this is the single point or situation where a fold is left open.

Notes

Summary

7m 48s

Structural Analysis, Deformation dy



So here an additional technical detail had to be taken into account in order to avoid the increased deformation, which actually would have been visible while you would enter the chapel, by adding a connection between the structural layer panels and the facade or cladding layers of panels, which have been positioned on the top of this layer, which is shown here.

Notes

Summary

9m 35s

Fabrication Layout, 2D Nesting

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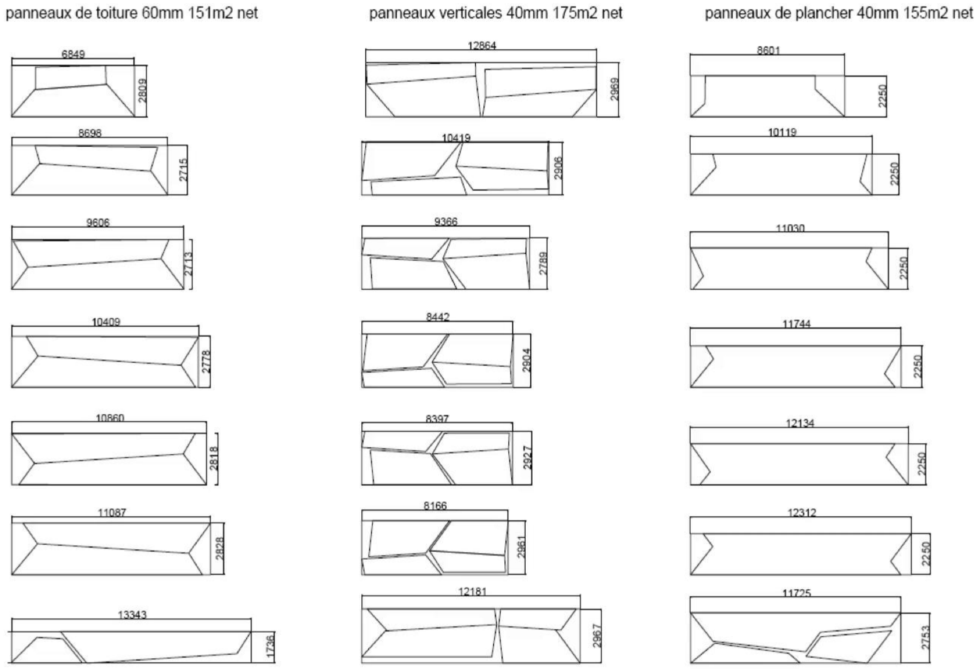
Advanced Timber Plate Structural Design



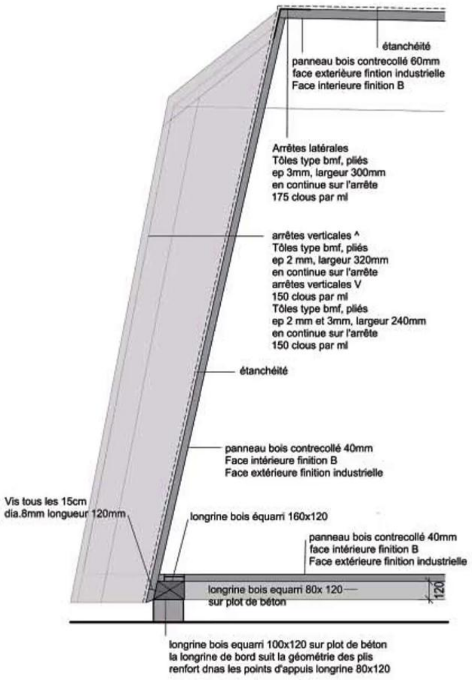
Here you see the fabrication layout and the nesting of old panels.

Notes

Summary

10m 03s

Construction Principle, Transversal Section



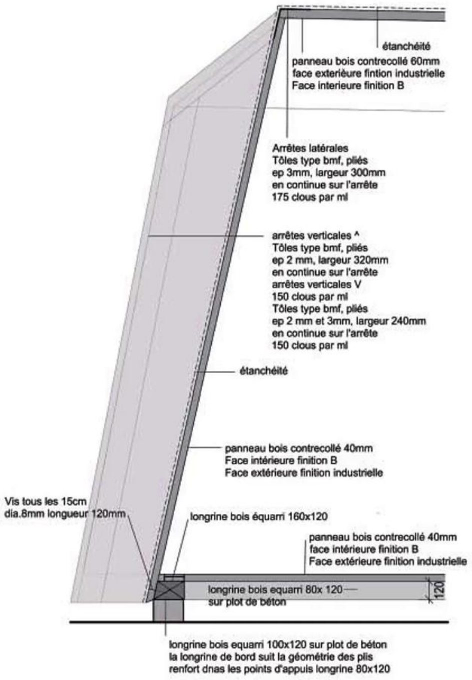
And some technical details and construction principles, where you can see that vertical panels are only made out of three layers, with a total thickness of 40 millimeters. Horizontal panels covering the roof are also made out of three-layer panels, but with a thickness of 60 millimeters, spanning over 9.5 meters. You'll see that the floor itself holds the structure together.

Notes

Summary

10m 08s

Construction Principle, Transversal Section



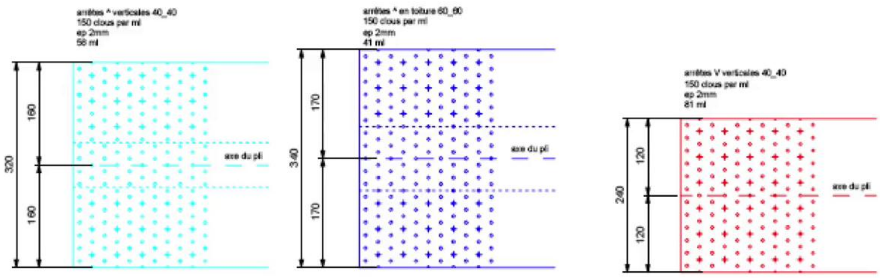
And that we have recurred to a very simple foundation principle, because we just fixed the chapel on four cylindrical concrete blocks of one meter height and 80 centimeter in diameter, which would help the chapel to stay in position, because the maximum loading case was actually in helicopter point next to the chapel, because the whole infrastructure is part of an hospital.

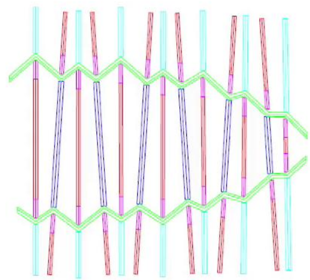
Notes

Summary

10m 40s

The Different Types of Assembly Plates and Their Positioning





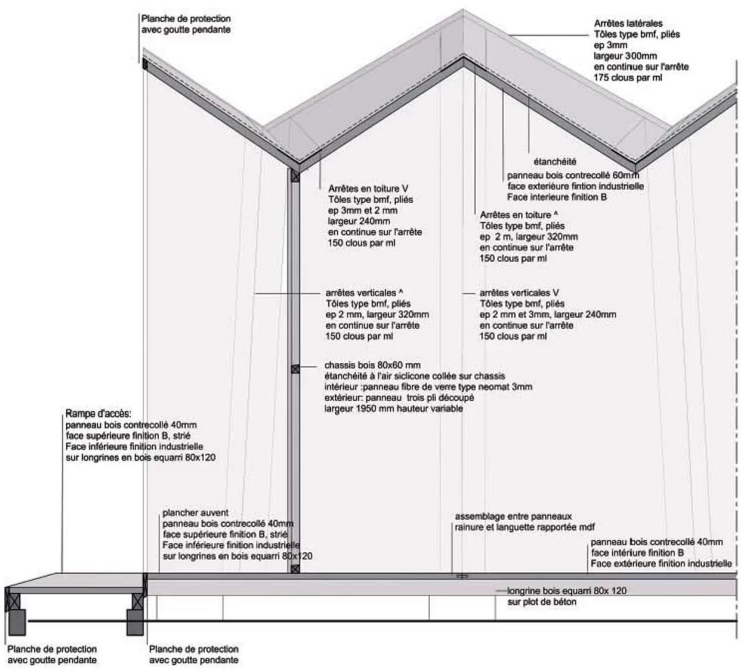
You can also see on this slide that we used single plates, folded plates, only two millimeter thick, which are pre-perforated, and which would be nailed from the outside on two panels in order to connect them. We had five types of technical details, or structural details where regarding the appearance of forces you can see on the bottom right, you would have to position a certain number of nails, which would vary from detail one to detail five. So the technical concept and realization stays very simple. And the carpenter itself would have that material in order to position and to assemble the plates on site.

Notes

Summary

11m 14s

Construction Principle, Longitudinal Section



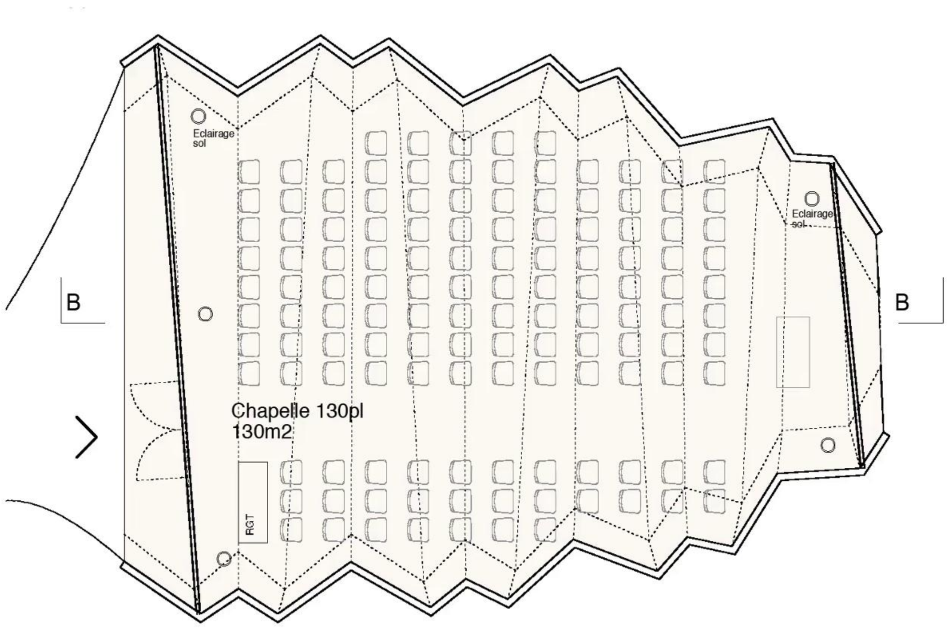
Here you can see how it's realized, and that those plates would introduce some bending rigidity for two connected plates, but not very high. We believe that we have a solution where translations are fully blocked, but some bending moments could also been taken partially by this type of connection.

Notes

Summary

12m 03s

Project Drawings



The ground floor plan shows how floor panels connect both facades, left and right, with each other.

Notes

Summary

12m 33s

Foundations

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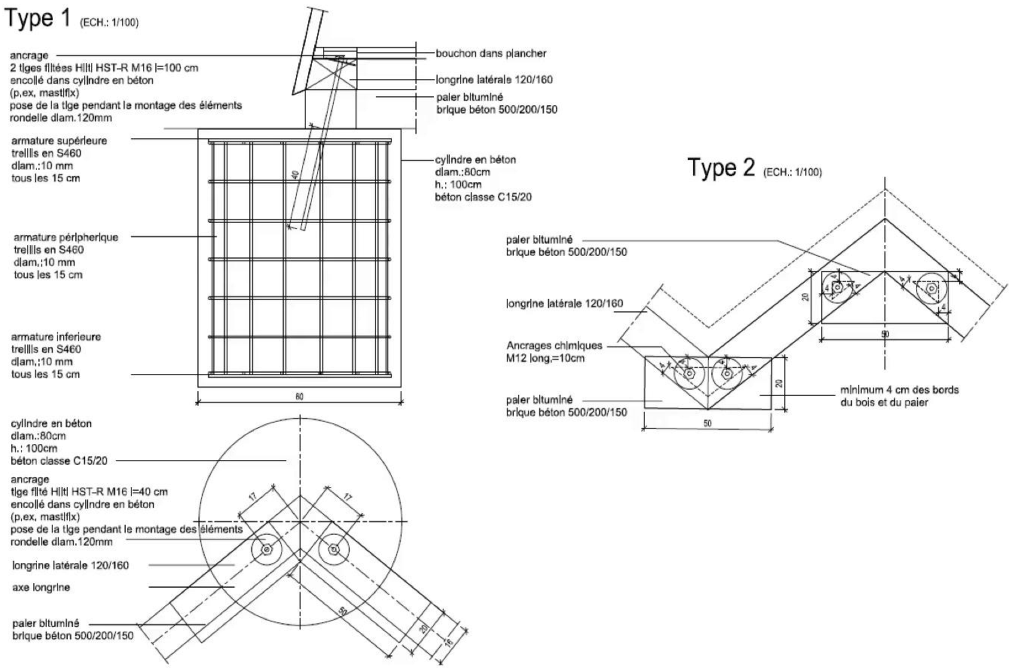

Here you can see the foundation drawing, just a cylinder, armed cylinder, which can be taken out once the chapel should be disassembled and used somewhere else.

Notes

Summary

12m 44s

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Assembly

The montage process has been performed in sections where frames, fold by fold, have been taken into position. On this picture you see the first frame in position, and the second frame is on its way to be mounted. First, two side plates on both sides, and then two roof plates are mounted. And each frame already has in itself stability during montage.

Notes

Summary

12m 56s

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The whole montage process took roughly four weeks. From there, a simple waterproof layer would be applied at the outside of the structural layer; additional smaller timber elements which we applied in order to create a void and a ventilation zone. And then the facade cladding. It's also three-layered, plywood panel of 13 millimeter thickness, which constitutes the facade and finishing of the building. Here you can see that those planets are not treated. They are exposed to rain and snow, and with the time, they become grey and even proper. It is a very nice, let's say, agreeable color.

Notes

Summary

13m 28s

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And we know that that facade need to be replaced after 15 years. So we think that we can fully build timber buildings. The structural layers are made out of timber panels, which are protected and which can stay, let's say, forever. But the outside layer needs to be replaced. We indicate that we prefer not to treat any panel, and we prefer directly to speak about a maintainance contract, taking into consideration the replacement of the wood cladding system after a given time period. Here you see the entry of the chapel as it is finished, and has been taking into service. The bearing structure stays fully visible at the inside of the chapel. And we realize that after, now it's 14 years, the project still stays very well. Panels stay in place. There is no movement or opening of the different joints. And the structure works at satisfaction of its users.

Notes

Summary

14m 19s