Wisdome – Technisches Museum Stockholm

27. Internationales Holzbau-Forum 2023 - Innsbruck

Stefan Rick – vertreten durch Philipp Schmon

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Der Wettbewerb

TEKNISKA MUSEET

storaenso

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Der Wettbewerb

Bauherr: Tekniska Museet, Stockholm, Schweden

Architekt: Elding Oscarson Architects, Stockholm, Schweden

Design Tragstruktur & Bauingenieur: Florian Kosche AS, Oslo, Norwegen

Materialsponsor & Hauptpartner: Stora Enso, Schweden

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Das Siegerprojekt

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Das Team

Hermann Blumer

David Riggenbach

Martin Antemann

Fabian Scheurer

Stefan Rick

Evy Slabbinck

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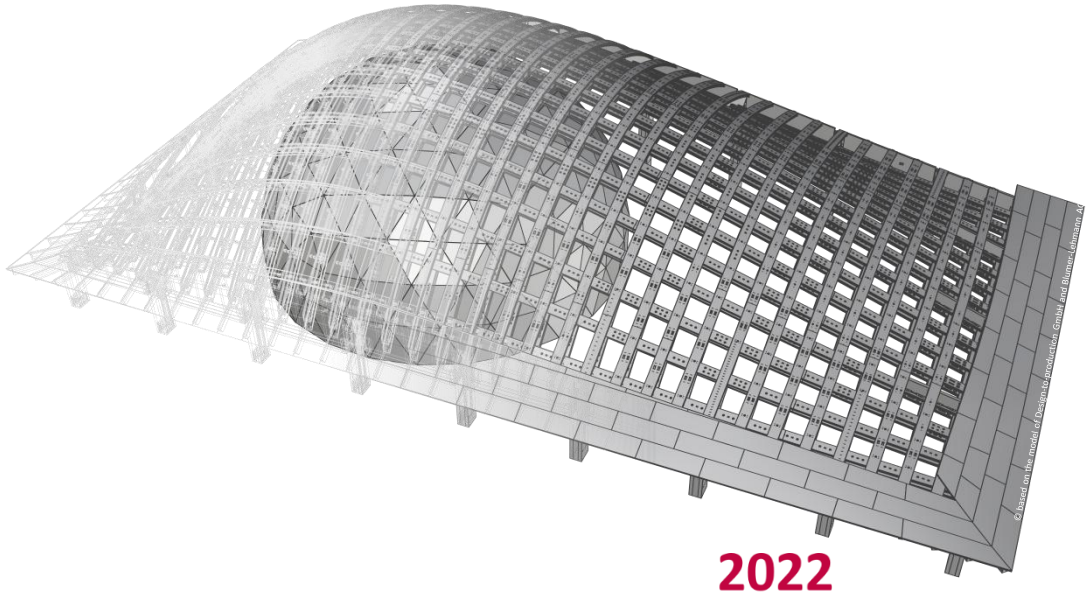
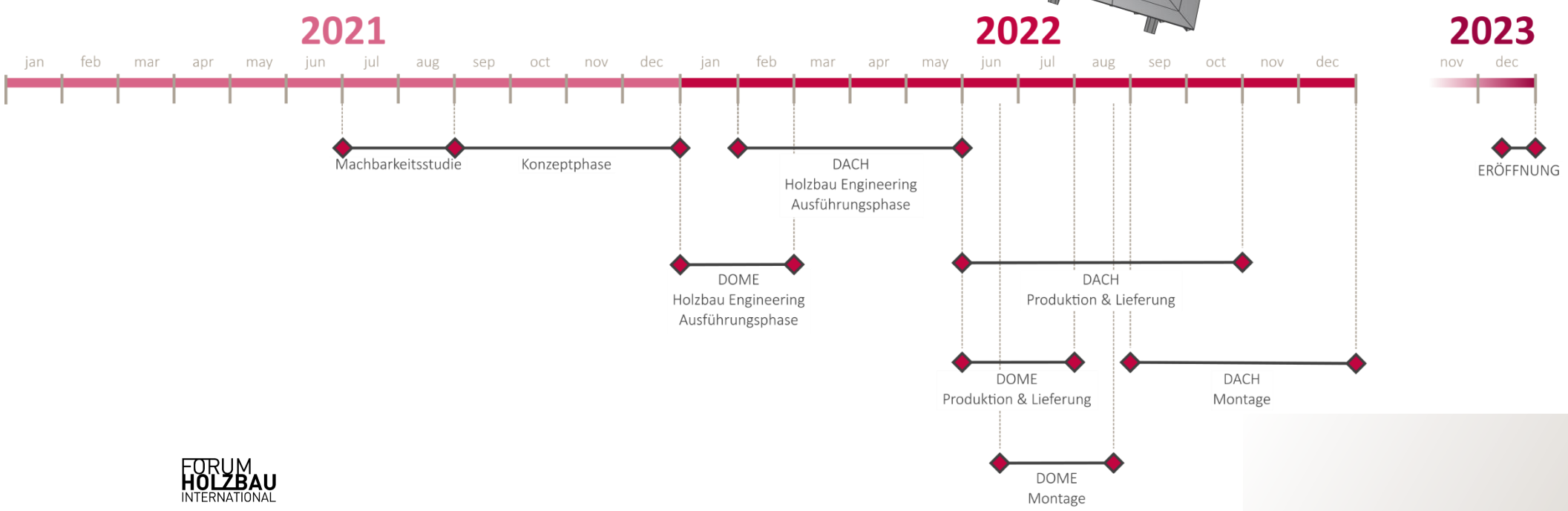
Das Projekt





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Die Randbedingung…

→ Brettsperrholz (BSP)

→ Furnierschichtholz (FSH)

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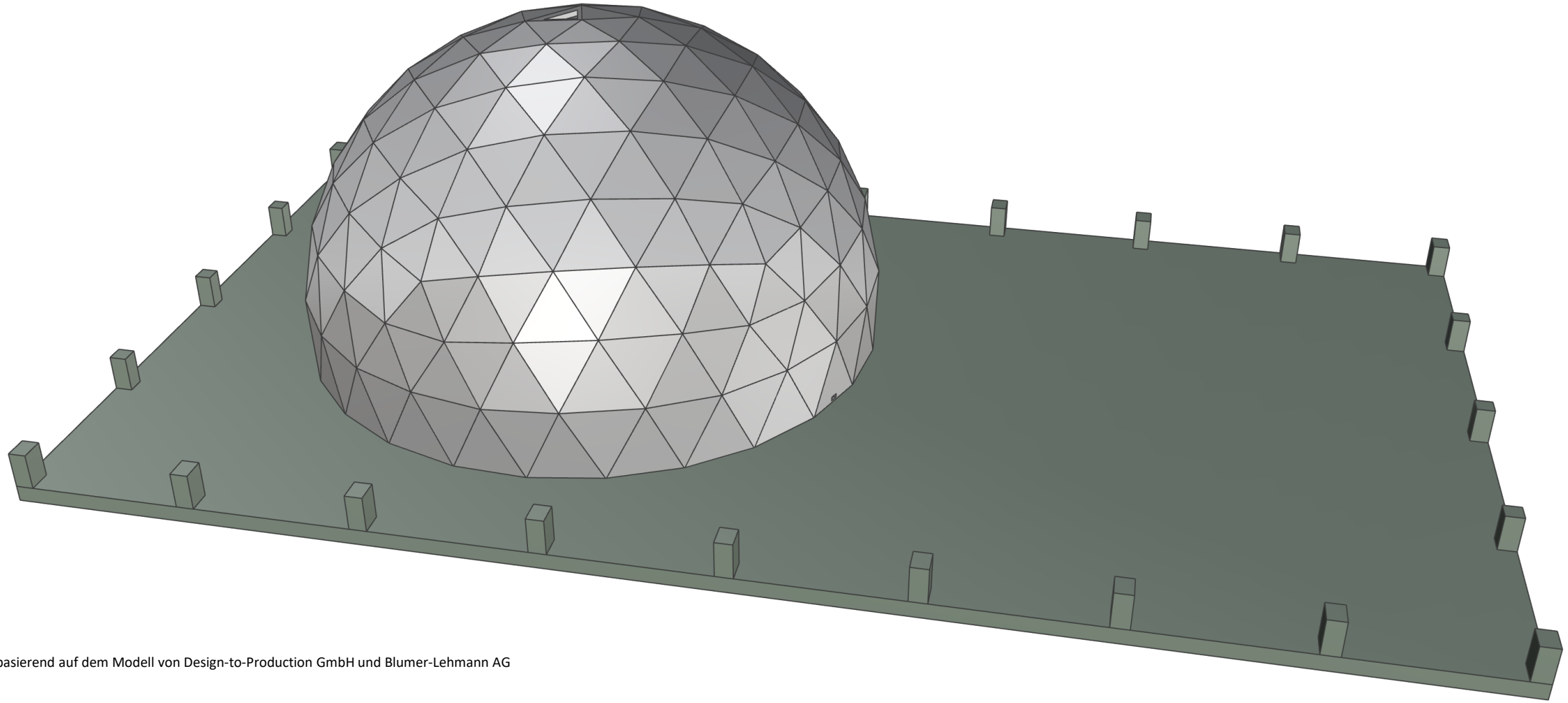
Der Dome…



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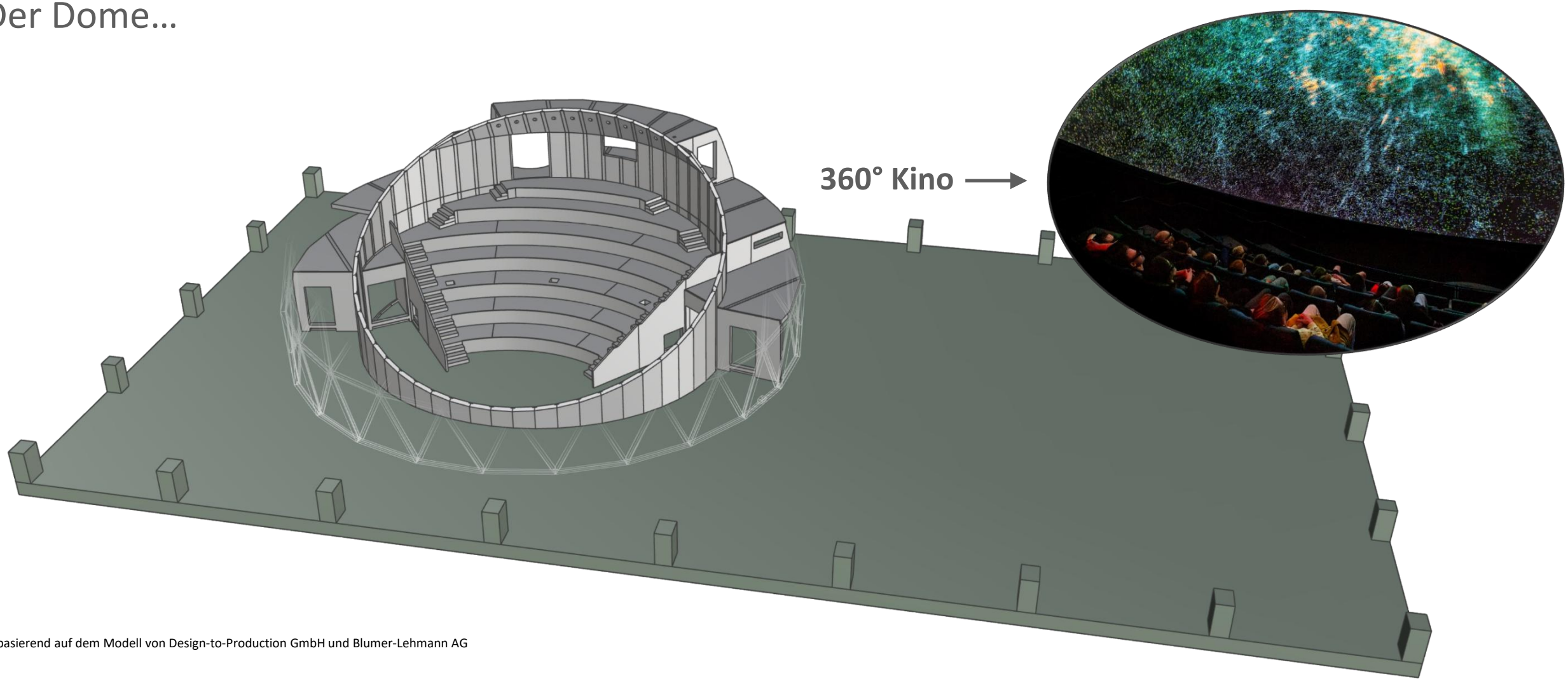
Der Dome…



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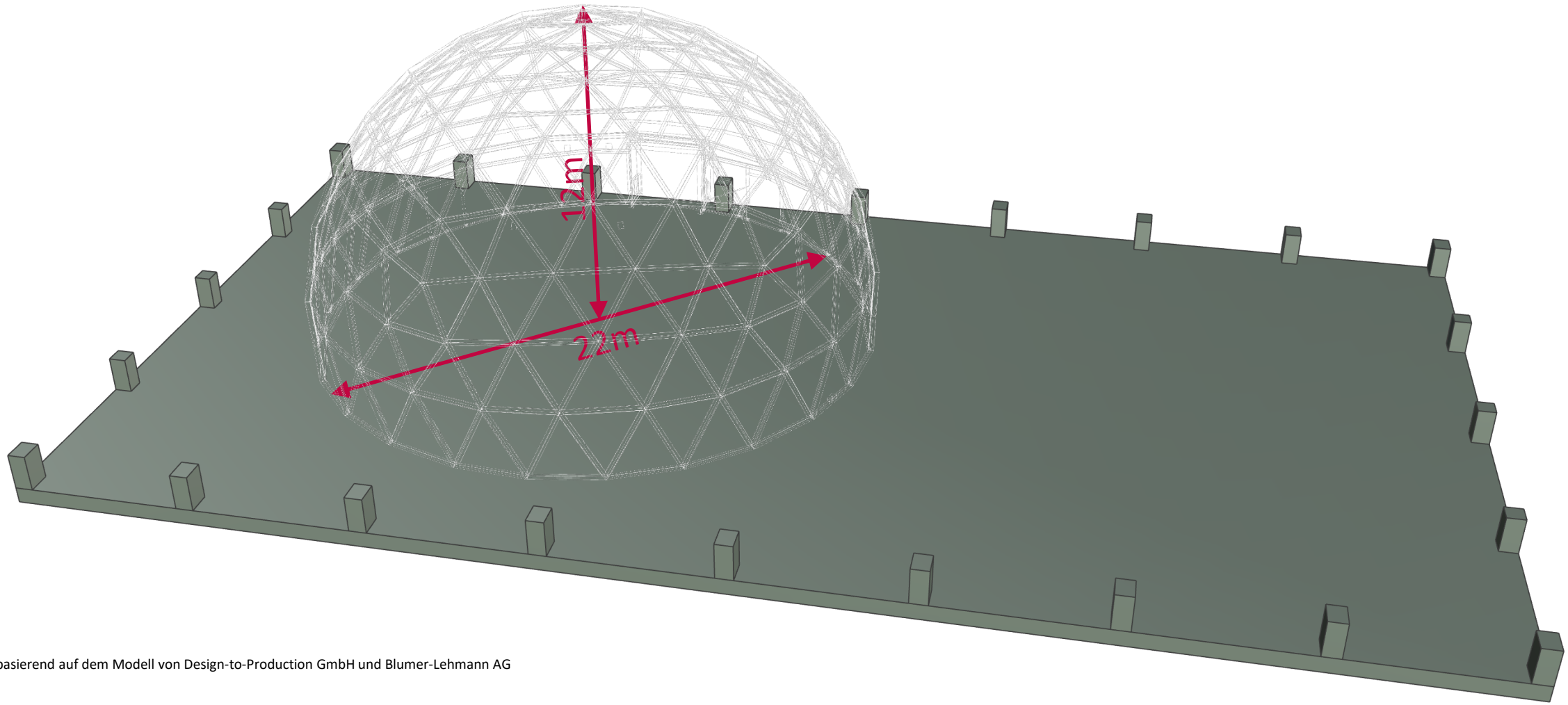
Der Dome…



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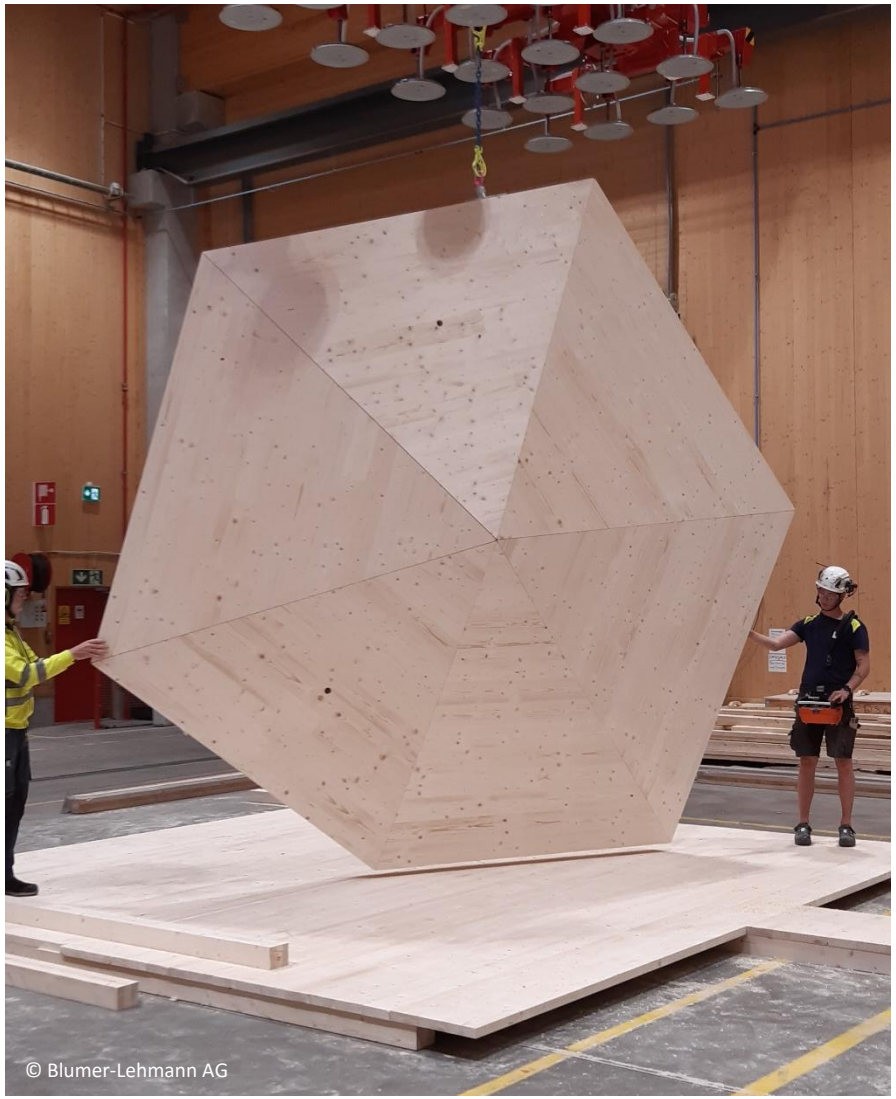
Der Dome…



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Das Dach…

+

→ **Wie geht das?**

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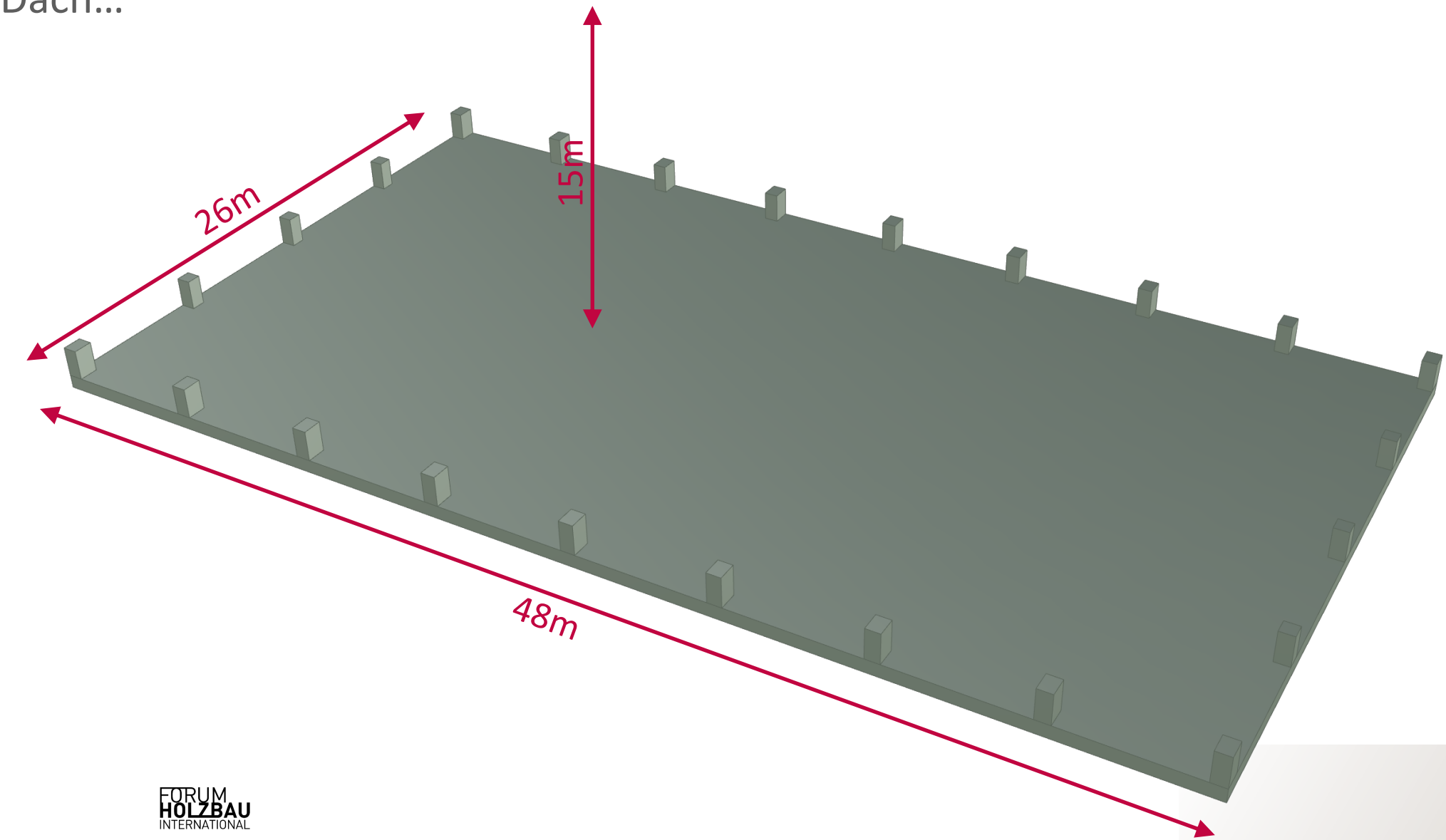
Das Dach…



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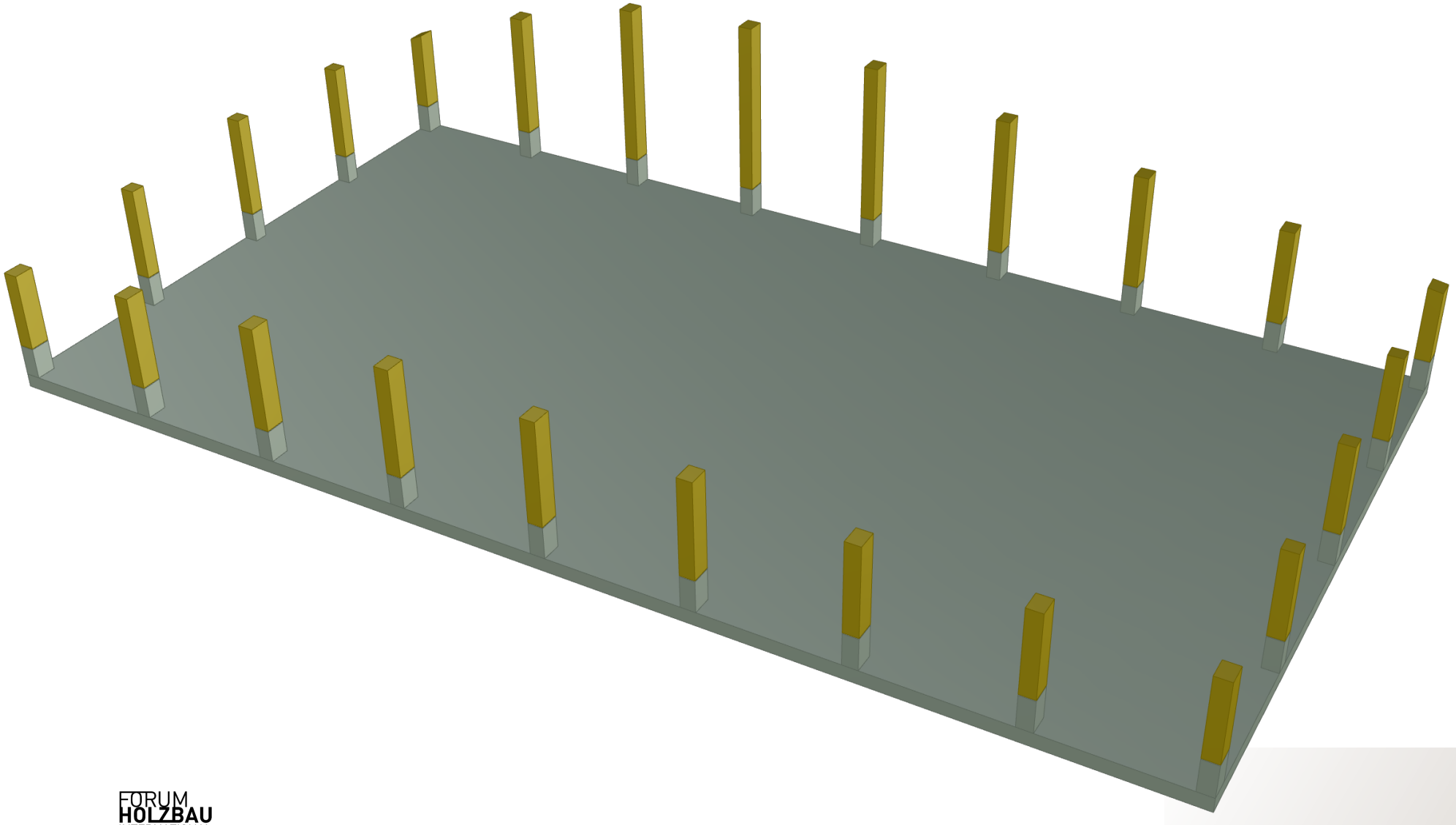
Das Dach…



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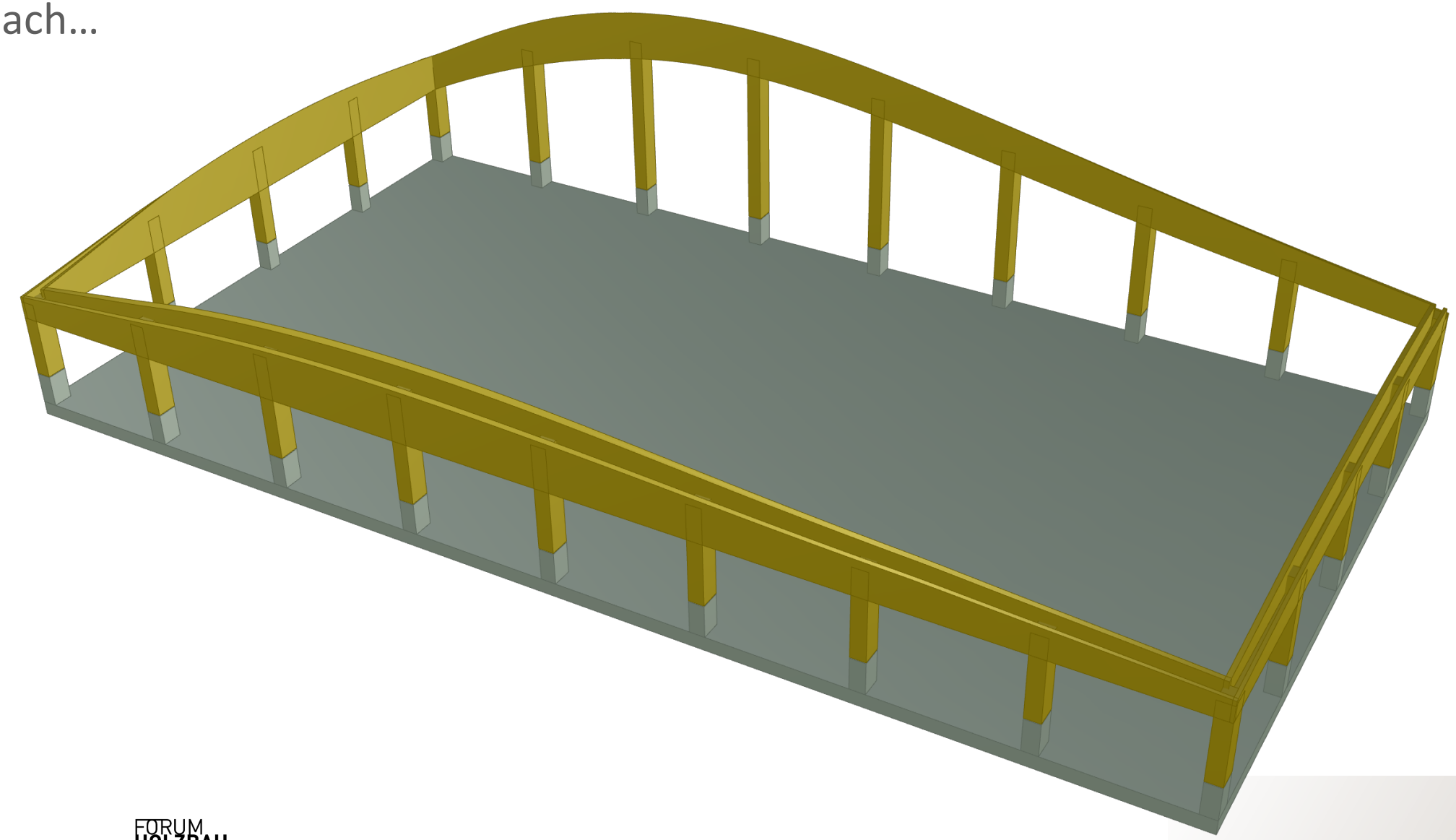
Das Dach…



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Das Dach…

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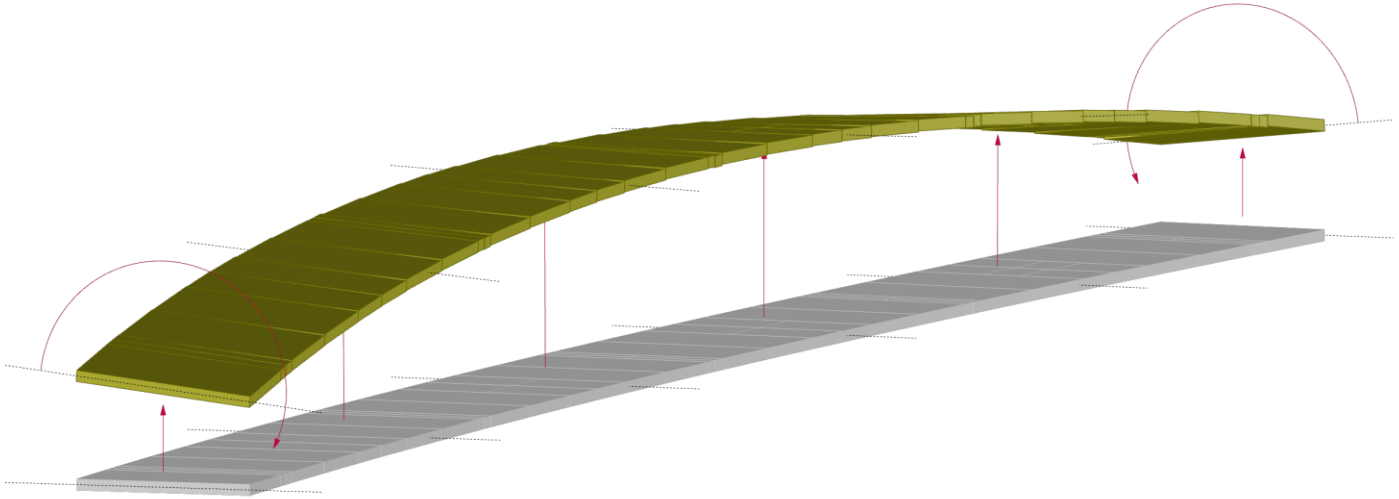
Das Konzept – Wir machen folgendes Prinzip…

FSH Lamellen…

In Form biegen und tordieren…



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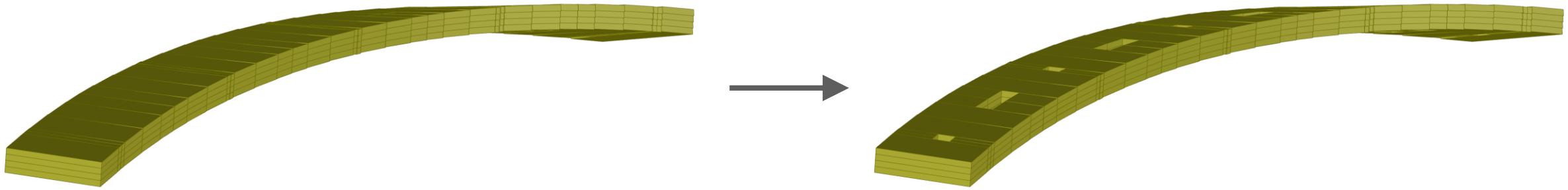
Das Konzept – Wir machen folgendes Prinzip…

Lamellen aufeinander stapeln…

In die CNC-Fräse und Ausschnitte fräsen…



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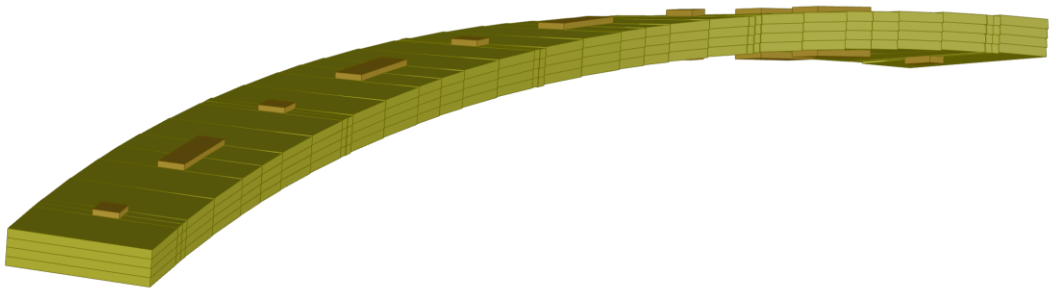
Das Konzept – Wir machen folgendes Prinzip…

Dübel einstecken…



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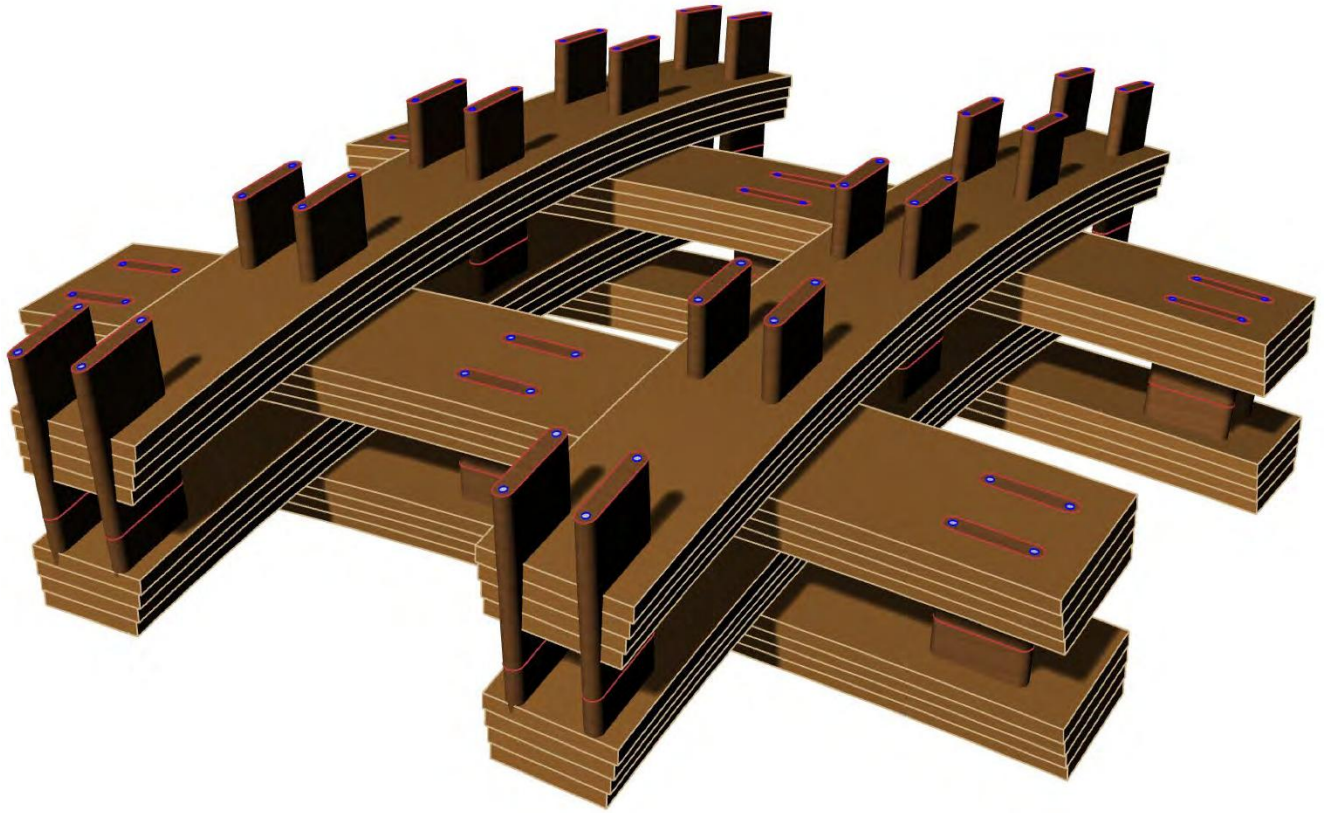
Das Konzept – Wir machen folgendes Prinzip…



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Die ersten zwei (drei) Mock-ups…

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Die ersten zwei (drei) Mock-ups…

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Die ersten zwei (drei) Mock-ups…

Was haben wir gelernt?

- Die Rückstellung ist zu gross, dadurch wird eine exakte Geometrie schwierig
- Wir hätten gerne dünnere Lamellen
- Zu viel Schlupf in den Verbindungen → **Konzept!**
- Abgestufte Lamellen sind gut
- Prinzip Dübel ist gut, aber noch nicht ganz ausgereift
- …

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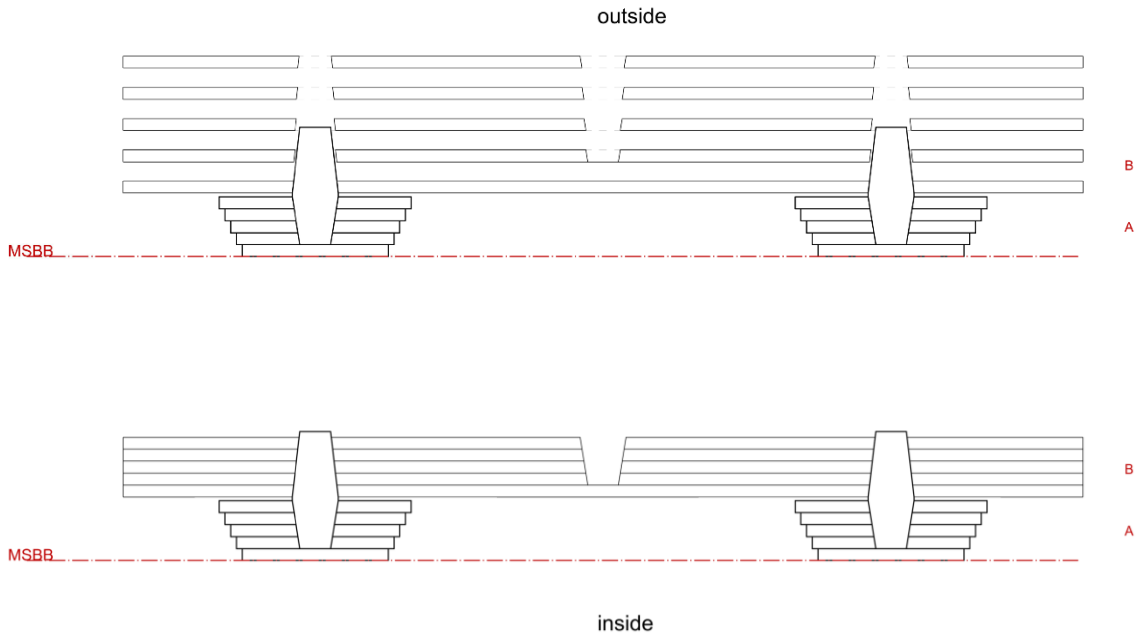
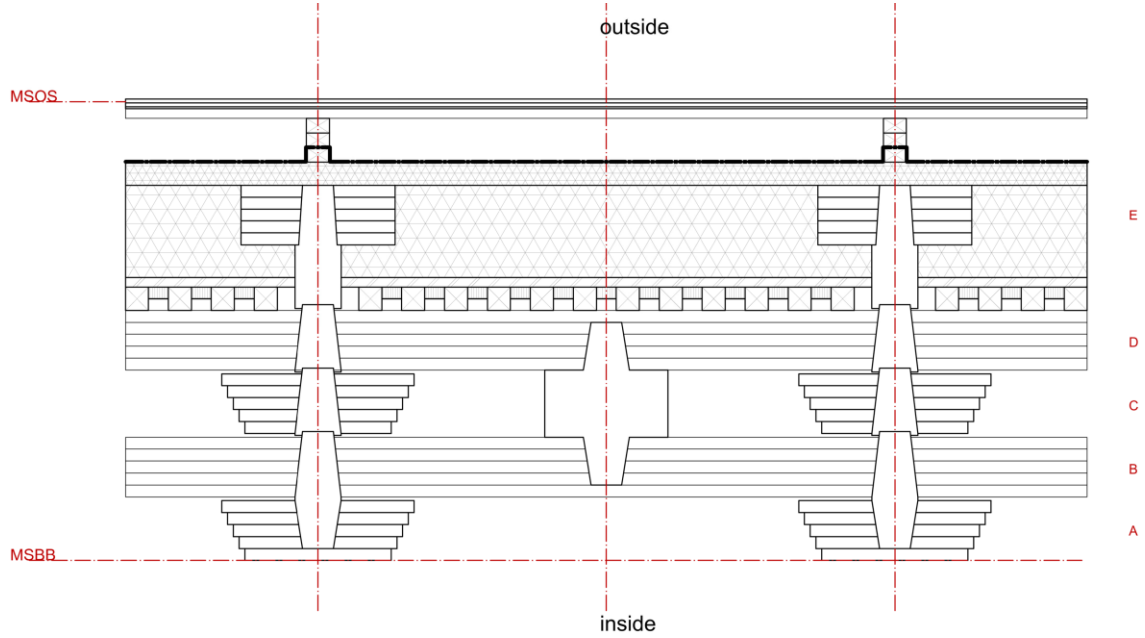
Das Konzept





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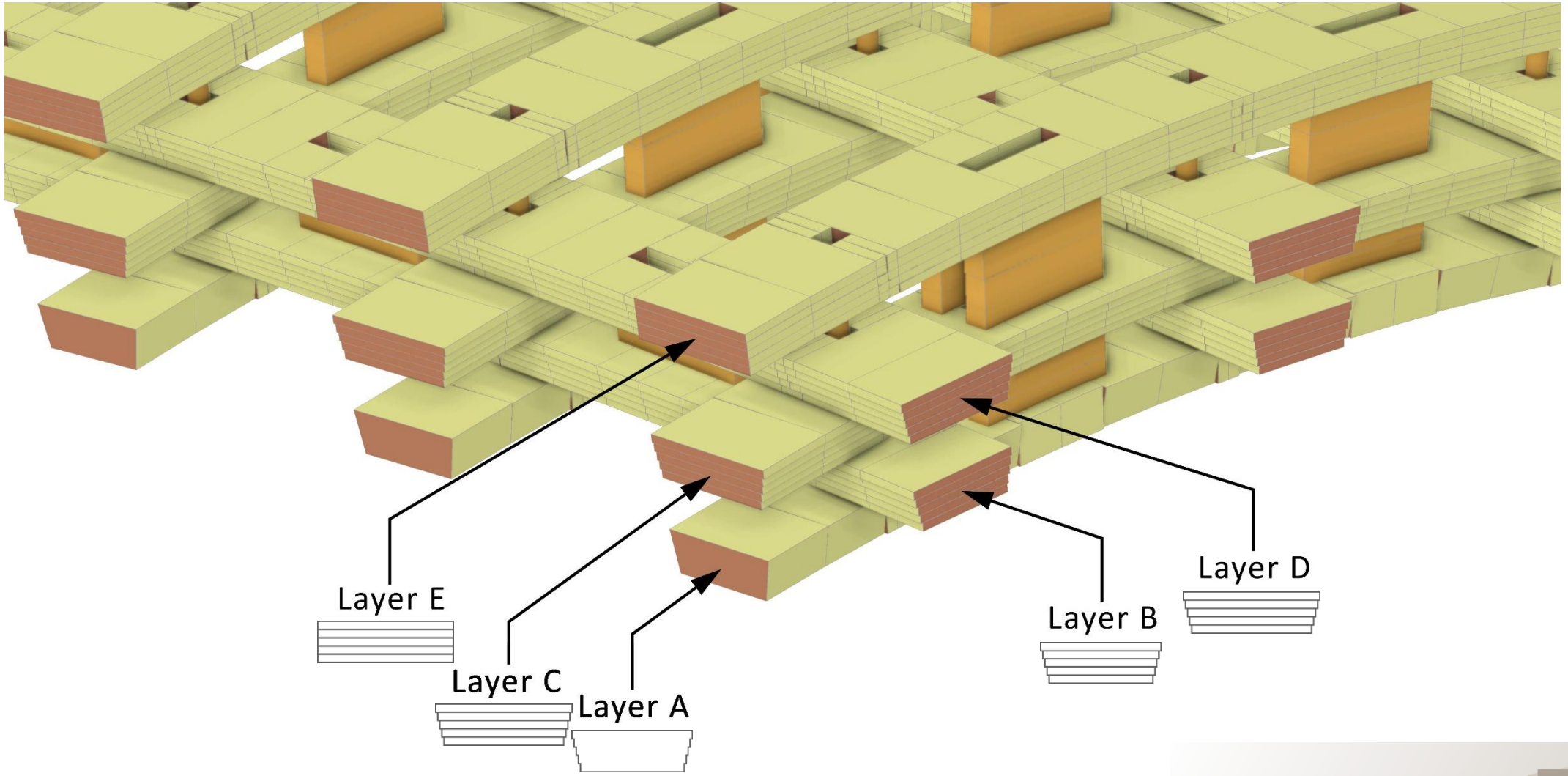
Das Konzept



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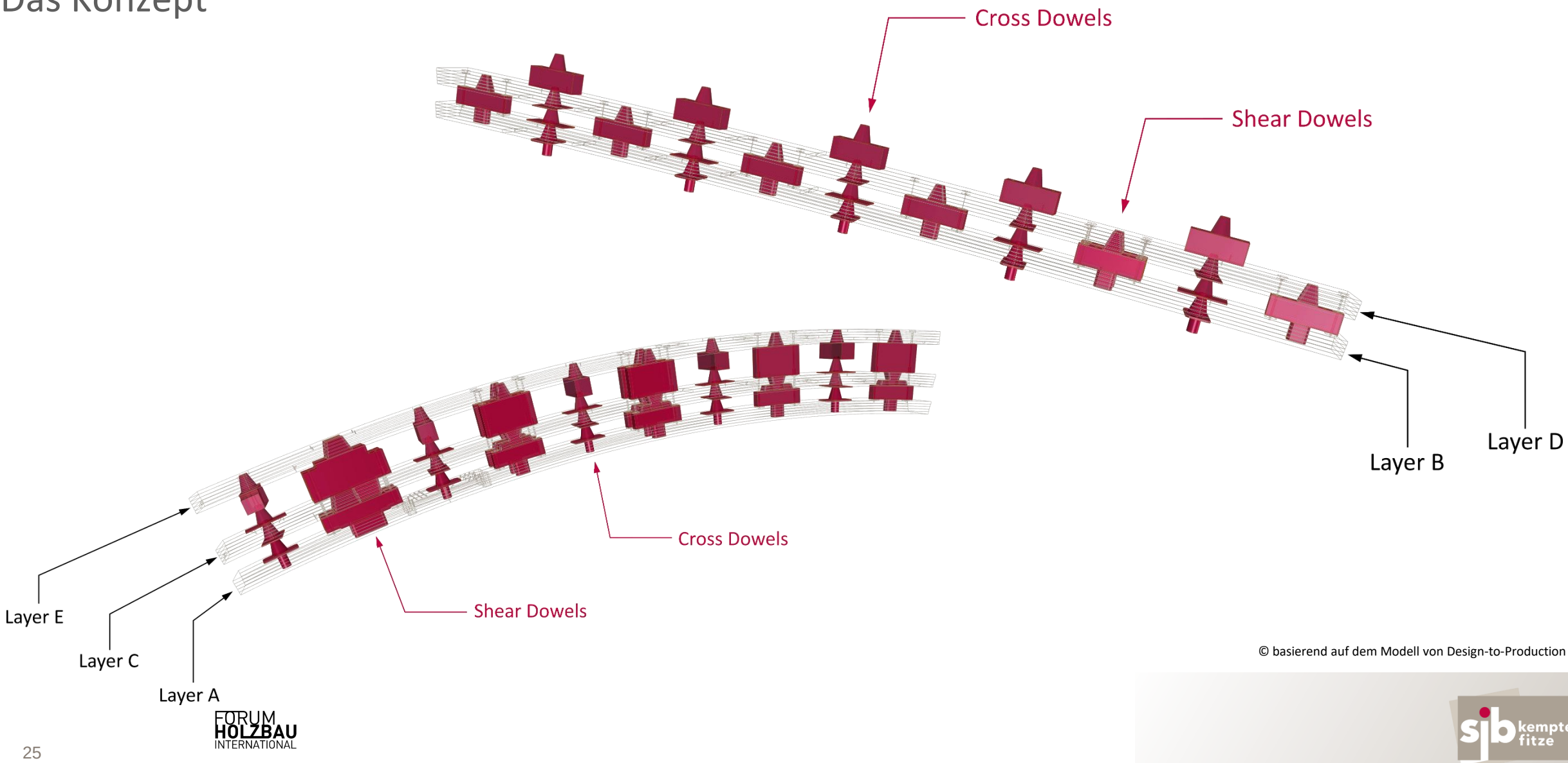
Das Konzept



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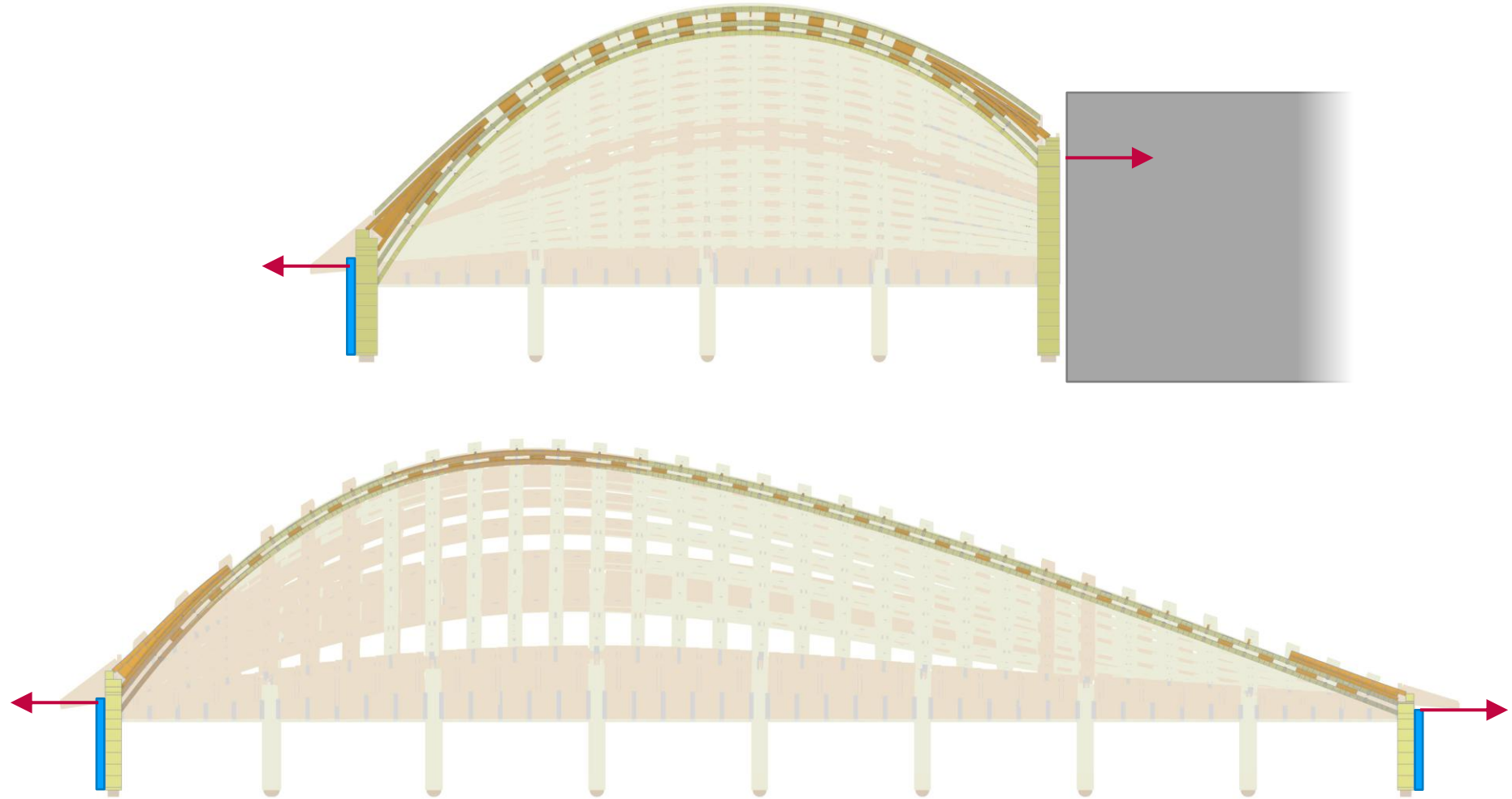
Die Dachgeometrie



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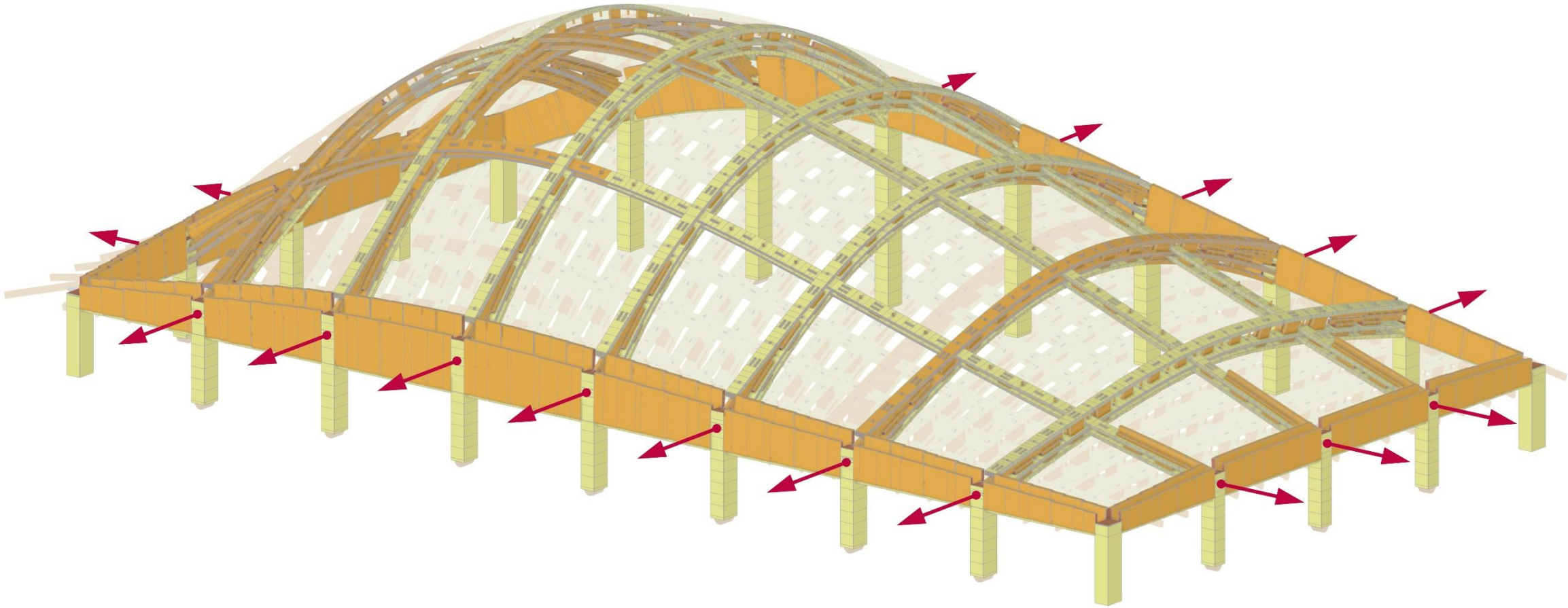
Die Dachgeometrie



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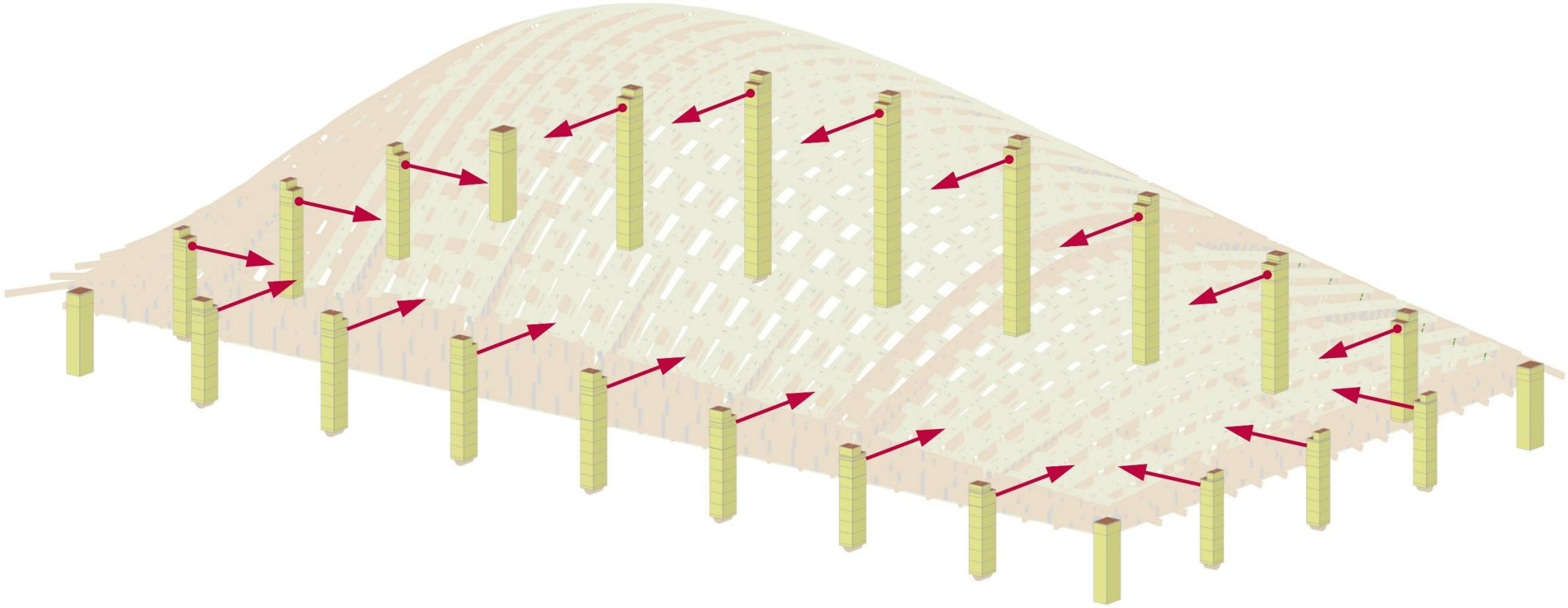
Die Dachgeometrie



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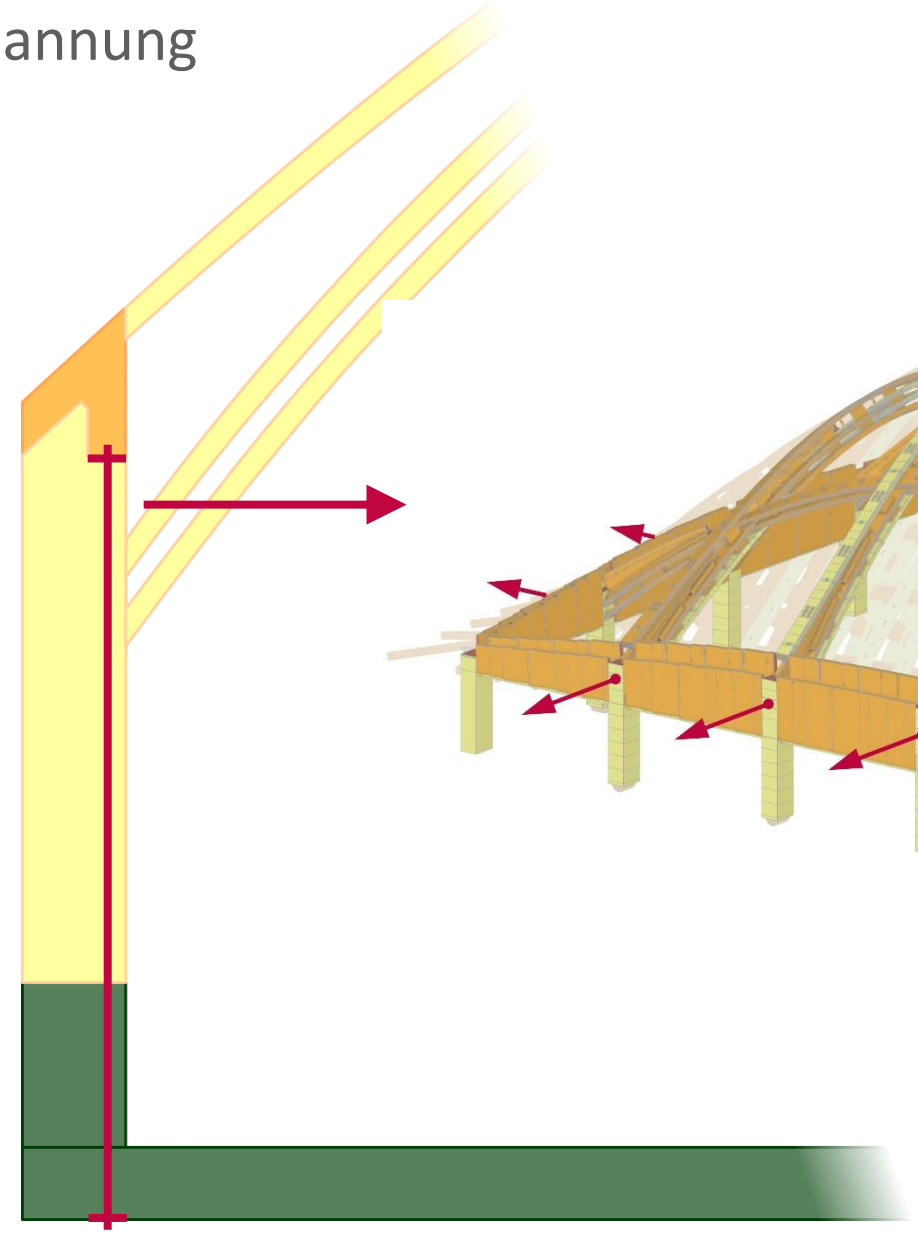
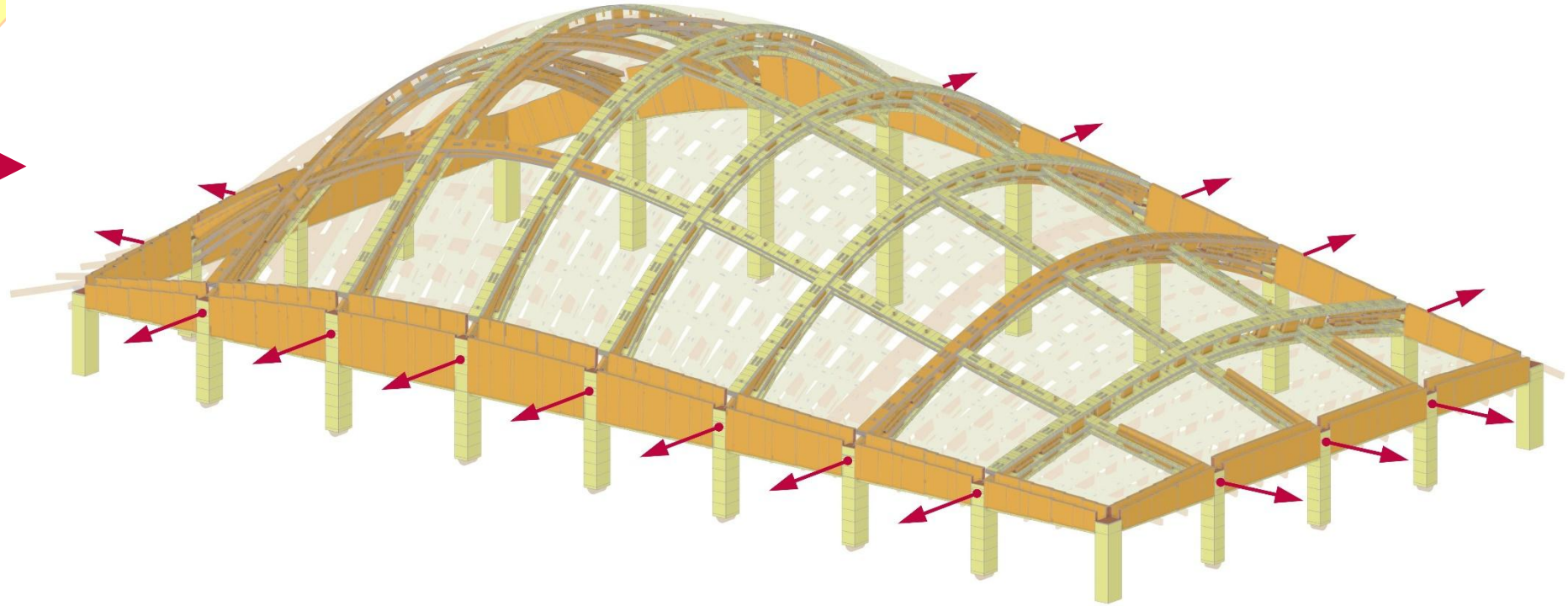
Die Vorspannung





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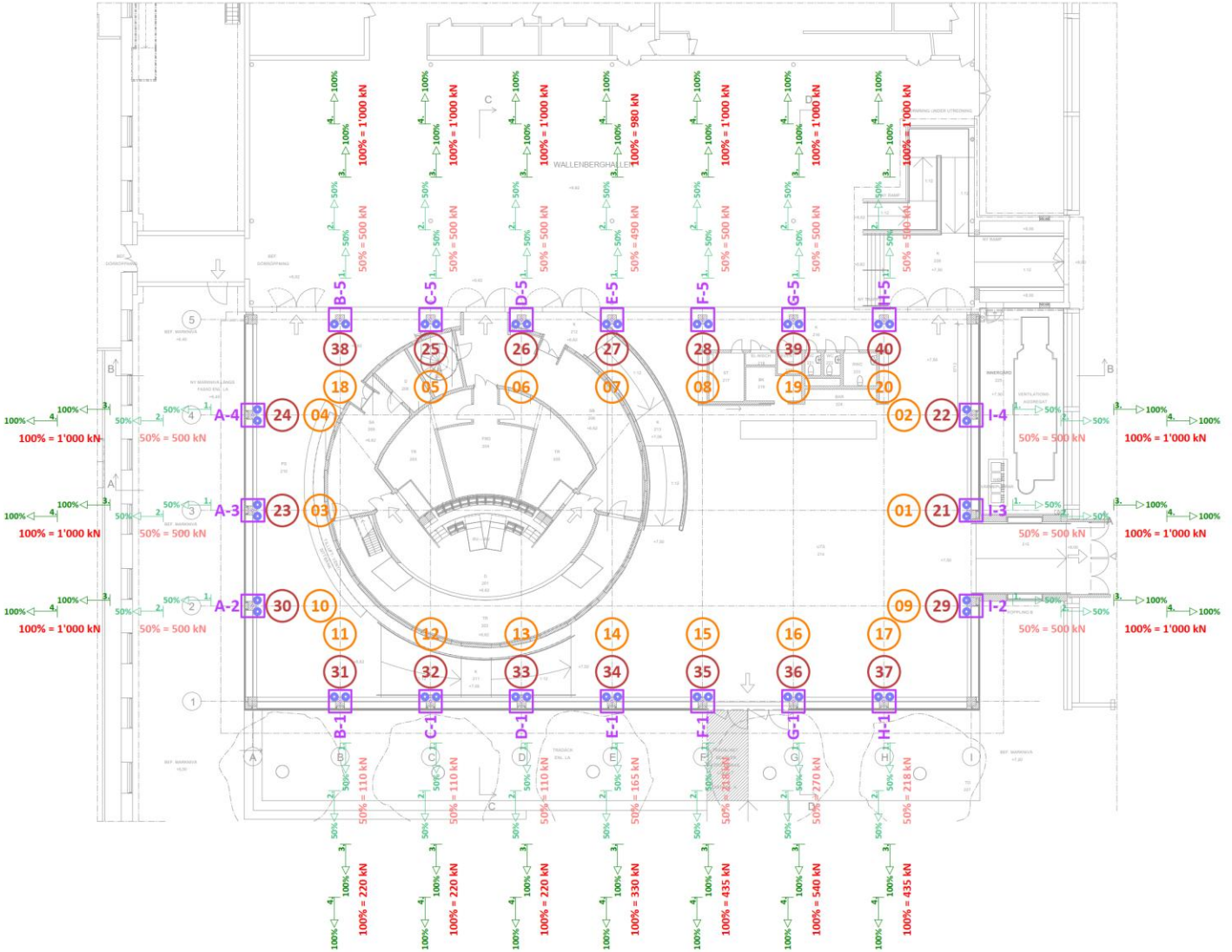
Die Vorspannung



01	pre-tension sequence ROUND 1
21	pre-tension sequence ROUND 2
I-4	No. column
1. 50%	pre-tension stages ROUND 1
3. 100%	pre-tension stages ROUND 2
50% = 500 kN	pre-tension force per rod ROUND 1
100% = 1'000 kN	pre-tension force per rod ROUND 2
	pre-tension rods

No. column	final pre-tension force per rod
A-5	- (per rod)
B-5	1'000 kN (per rod)
C-5	1'000 kN (per rod)
D-5	1'000 kN (per rod)
E-5	980 kN (per rod)
F-5	1'000 kN (per rod)
G-5	1'000 kN (per rod)
H-5	1'000 kN (per rod)
I-5	- (per rod)
I-4	1'000 kN (per rod)
I-3	1'000 kN (per rod)
I-2	1'000 kN (per rod)
I-1	- (per rod)
H-1	435 kN (per rod)
G-1	540 kN (per rod)
F-1	435 kN (per rod)
E-1	330 kN (per rod)
D-1	220 kN (per rod)
C-1	220 kN (per rod)
B-1	220 kN (per rod)
A-1	- (per rod)
A-2	1'000 kN (per rod)
A-3	1'000 kN (per rod)
A-4	1'000 kN (per rod)

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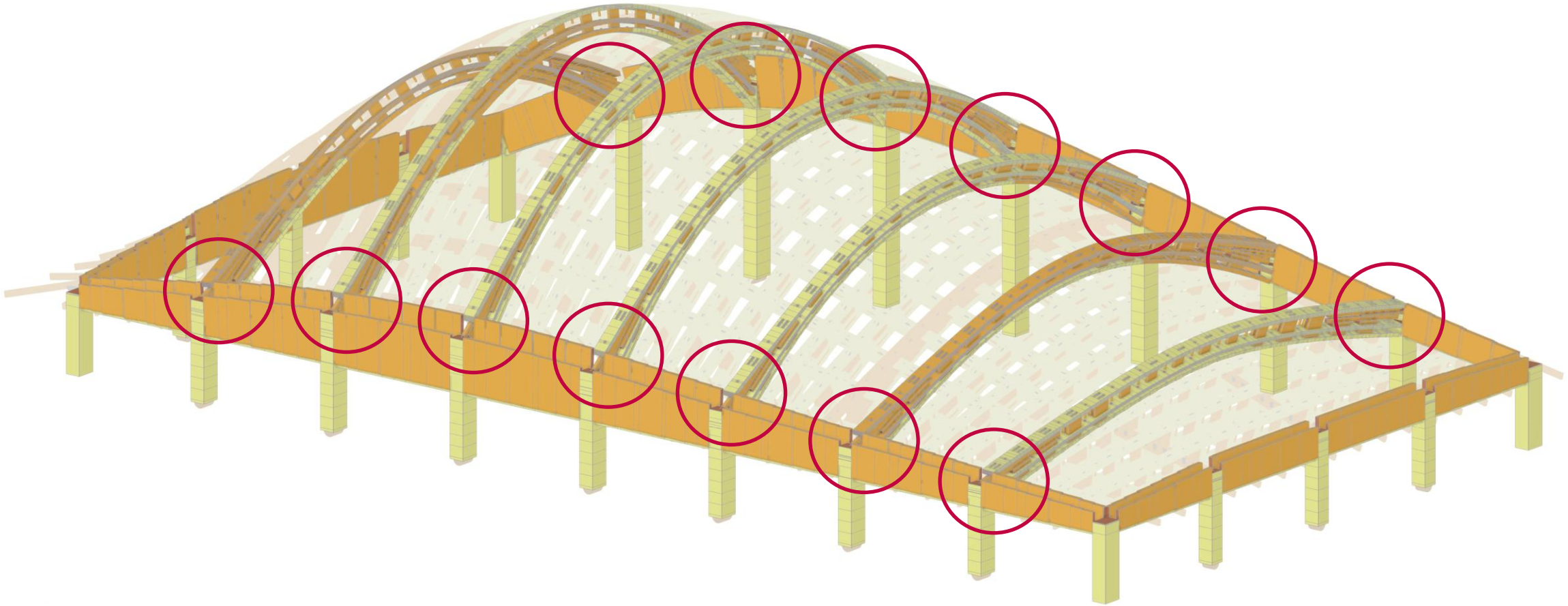
Die Rahmenecke



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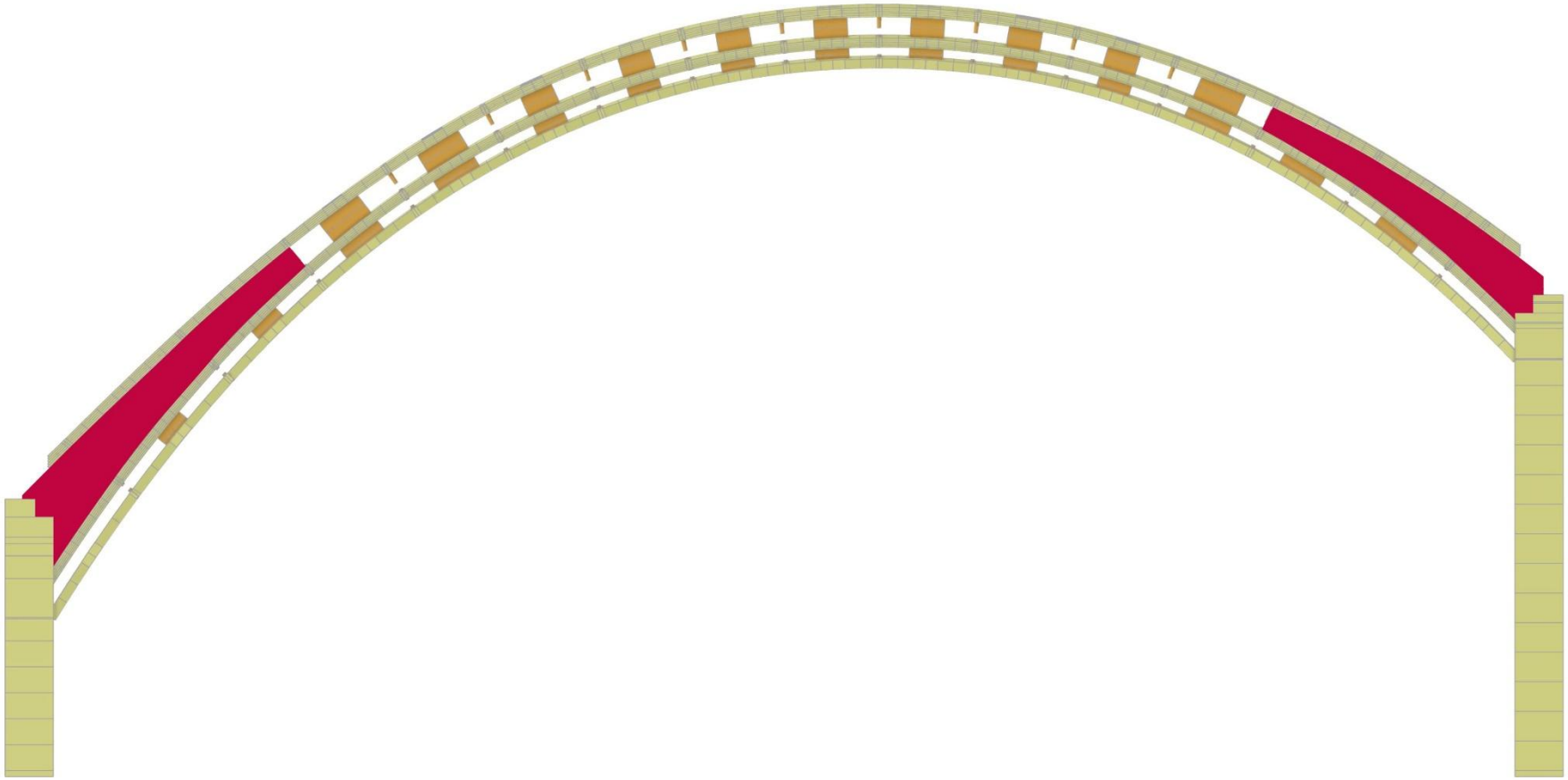
Die Rahmenecke



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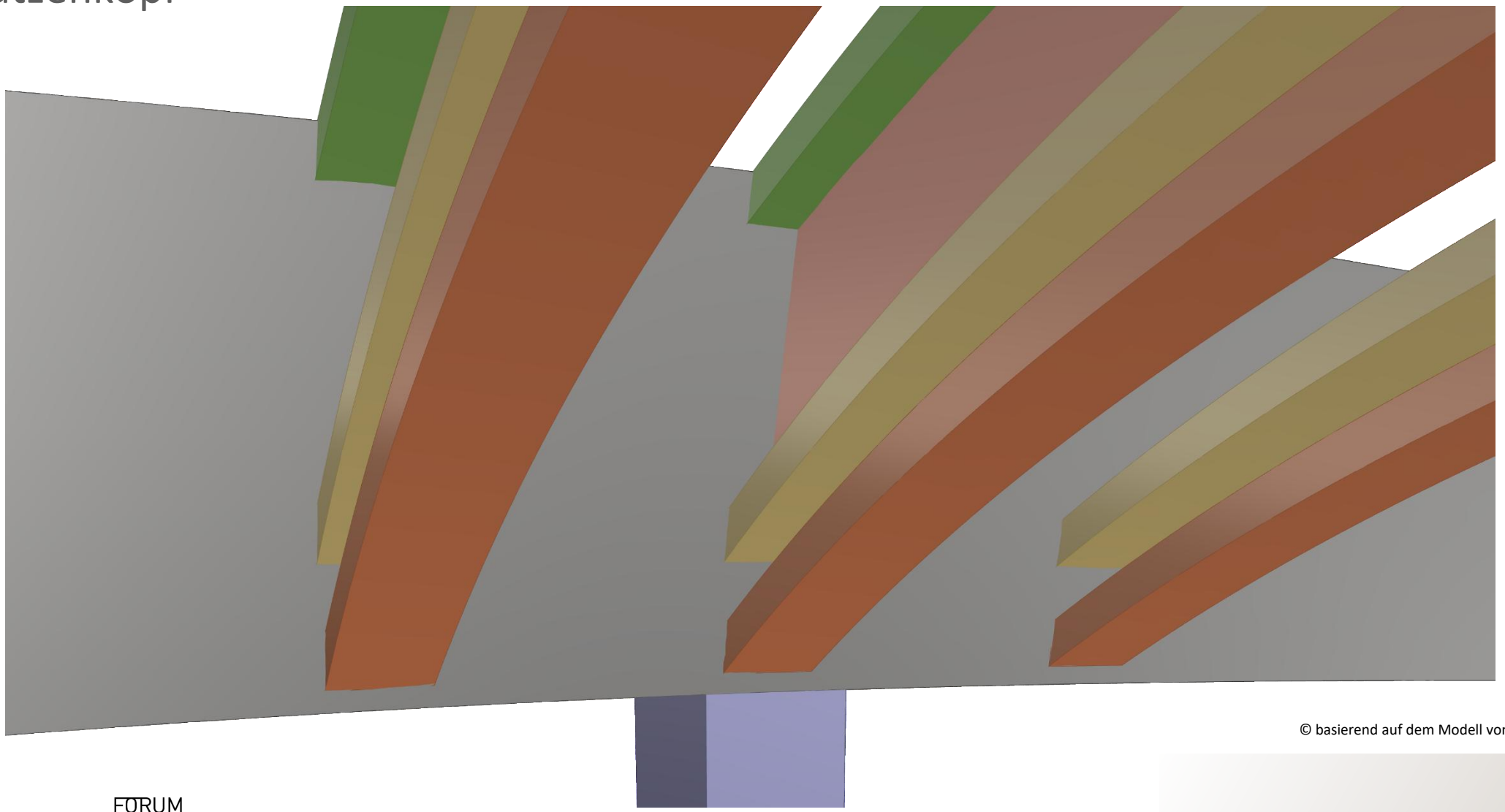
Der Stützenkopf



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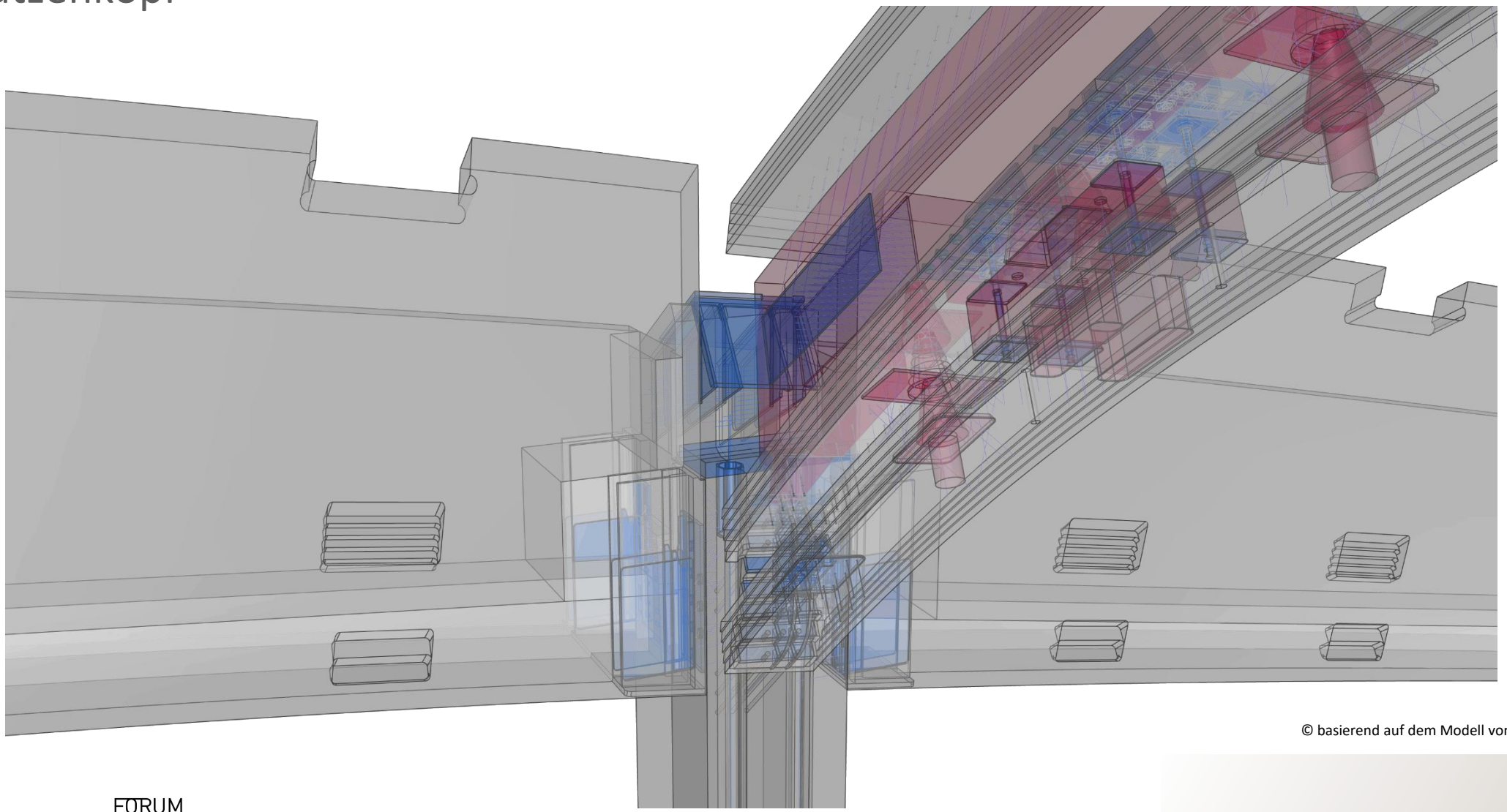
Der Stützenkopf



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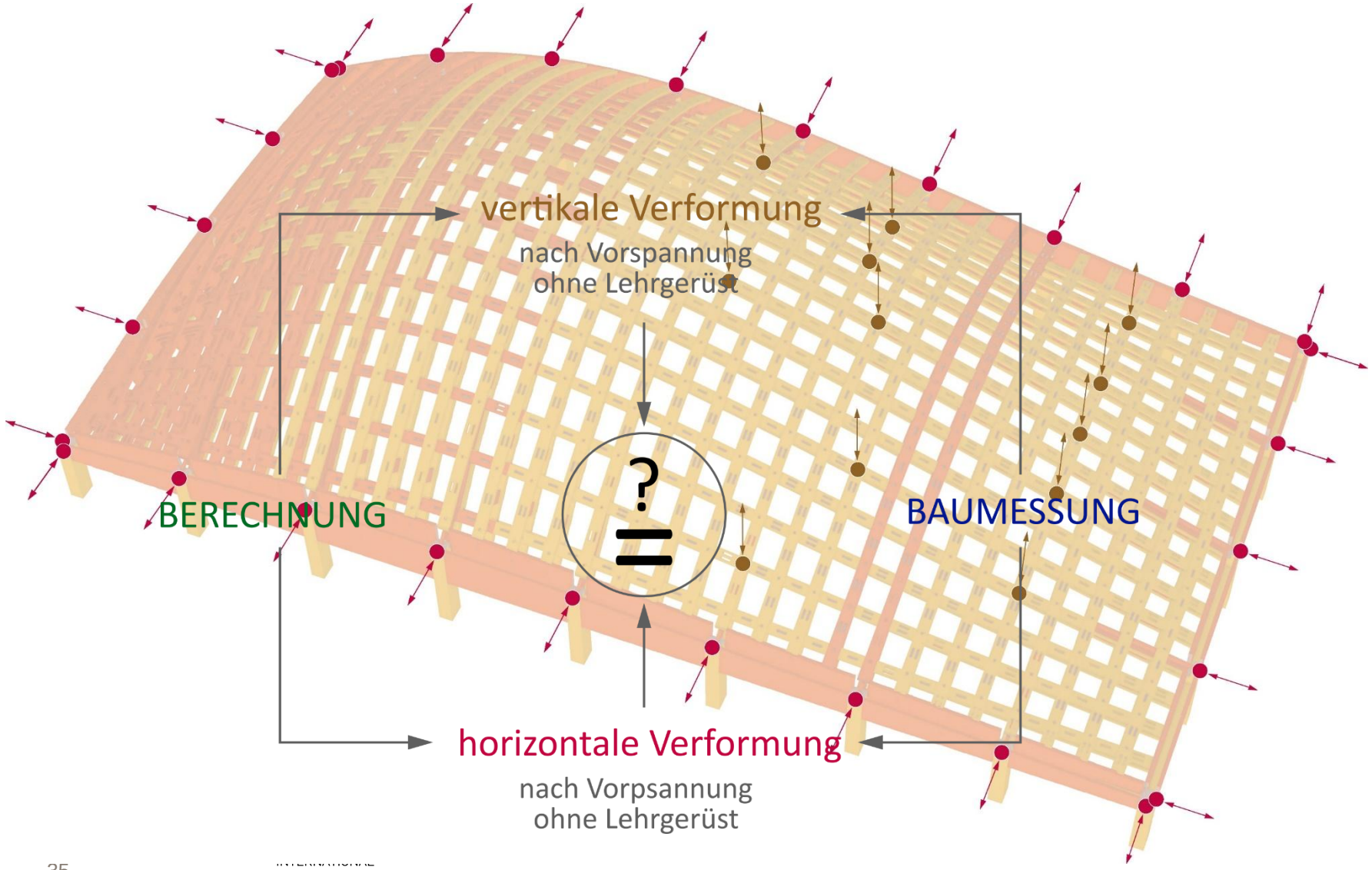
Das statische Modell



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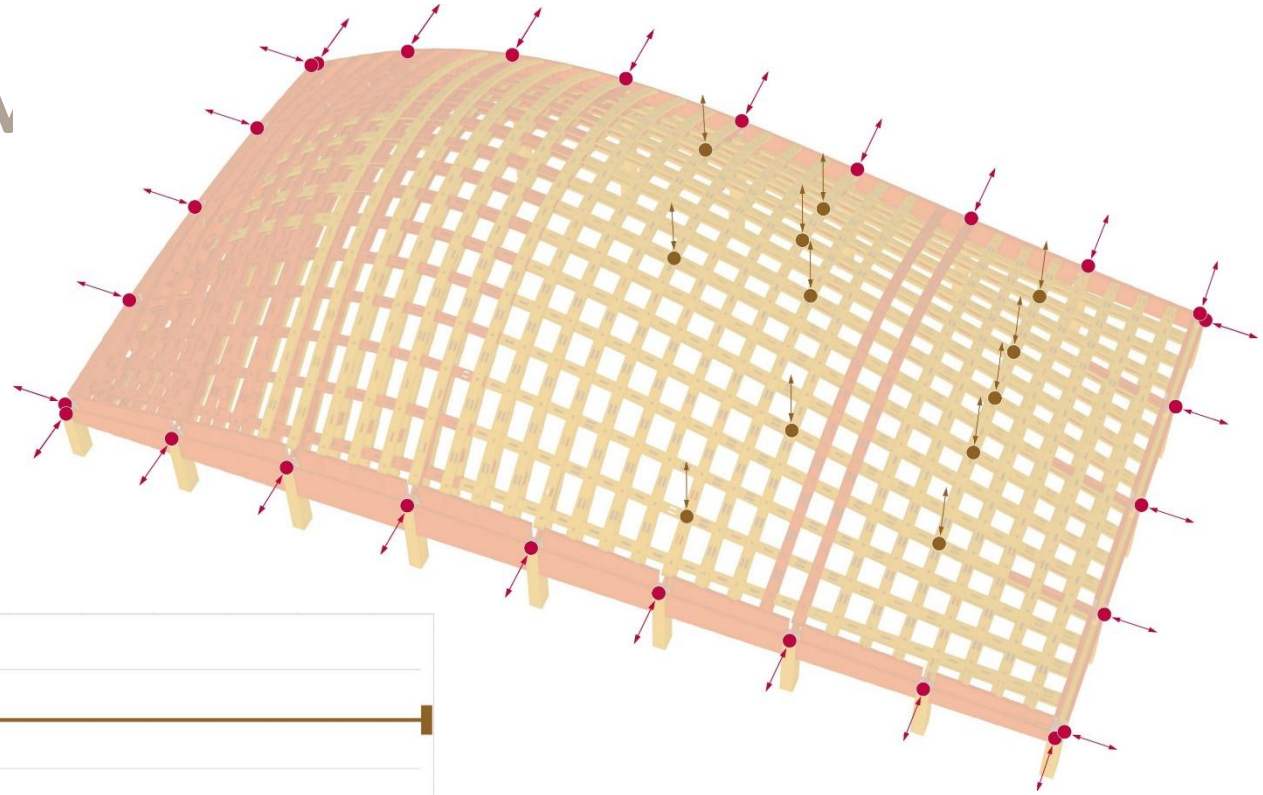
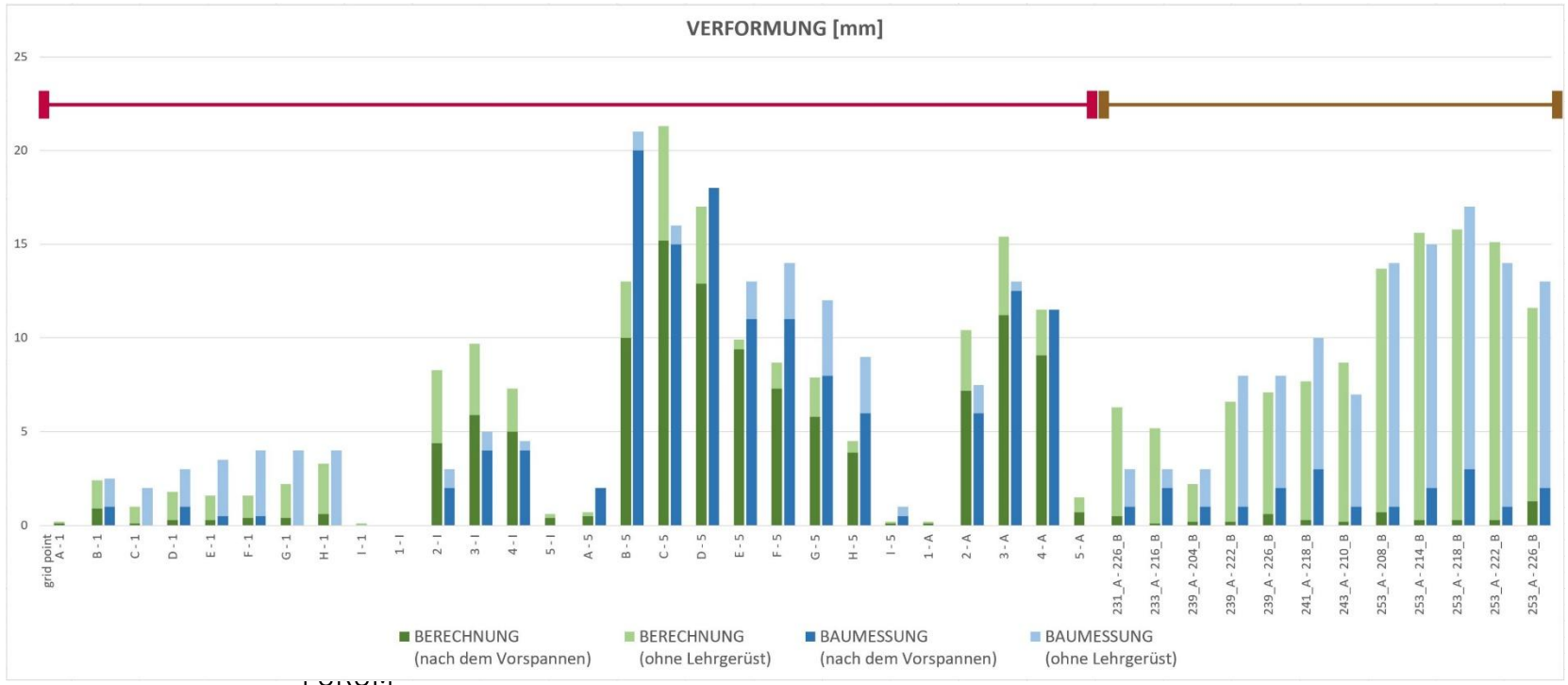
Das statische Modell





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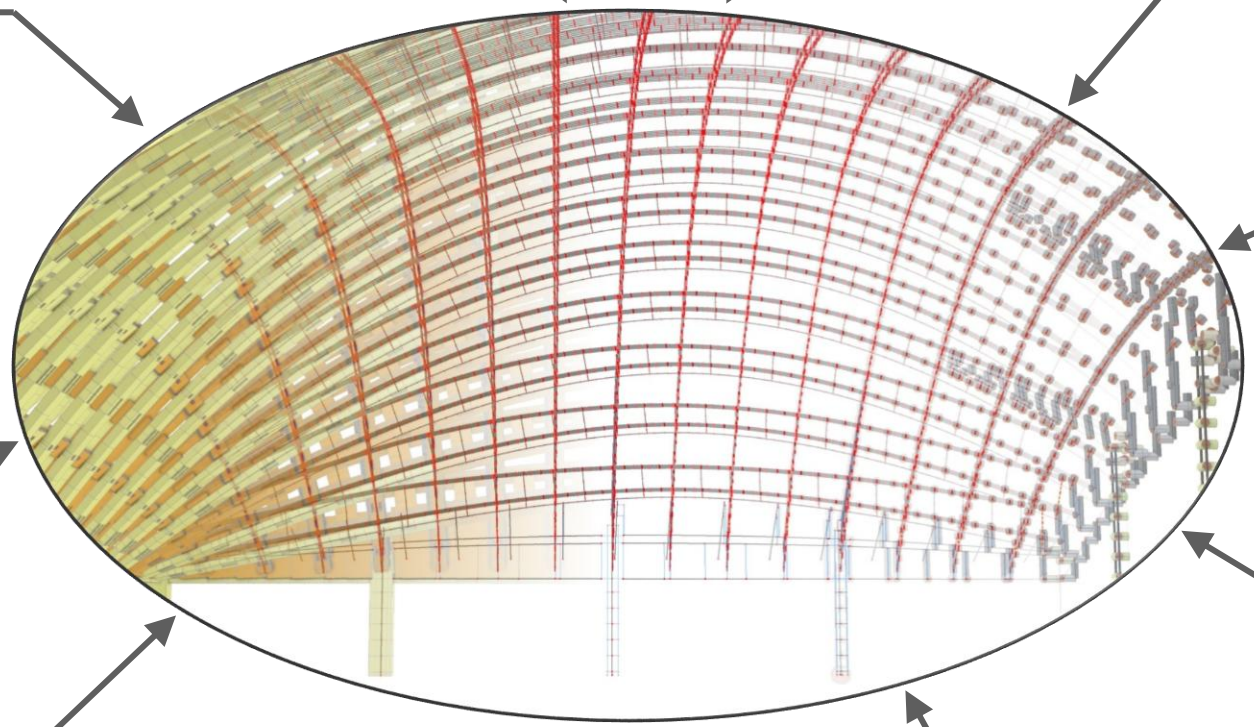

EIGENSPANNUNGEN

VORSPANNUNG

MATERIALIEN

STEIFIGKEITEN

QUERSCHNITTE

AUFLAGERDEFINITIONEN

LASTEN

GEOMETRIE

FASERANSCHNITTSWINKEL

AUSSCHNITTE / DURCHBRÜCHE

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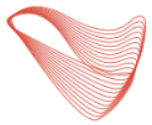
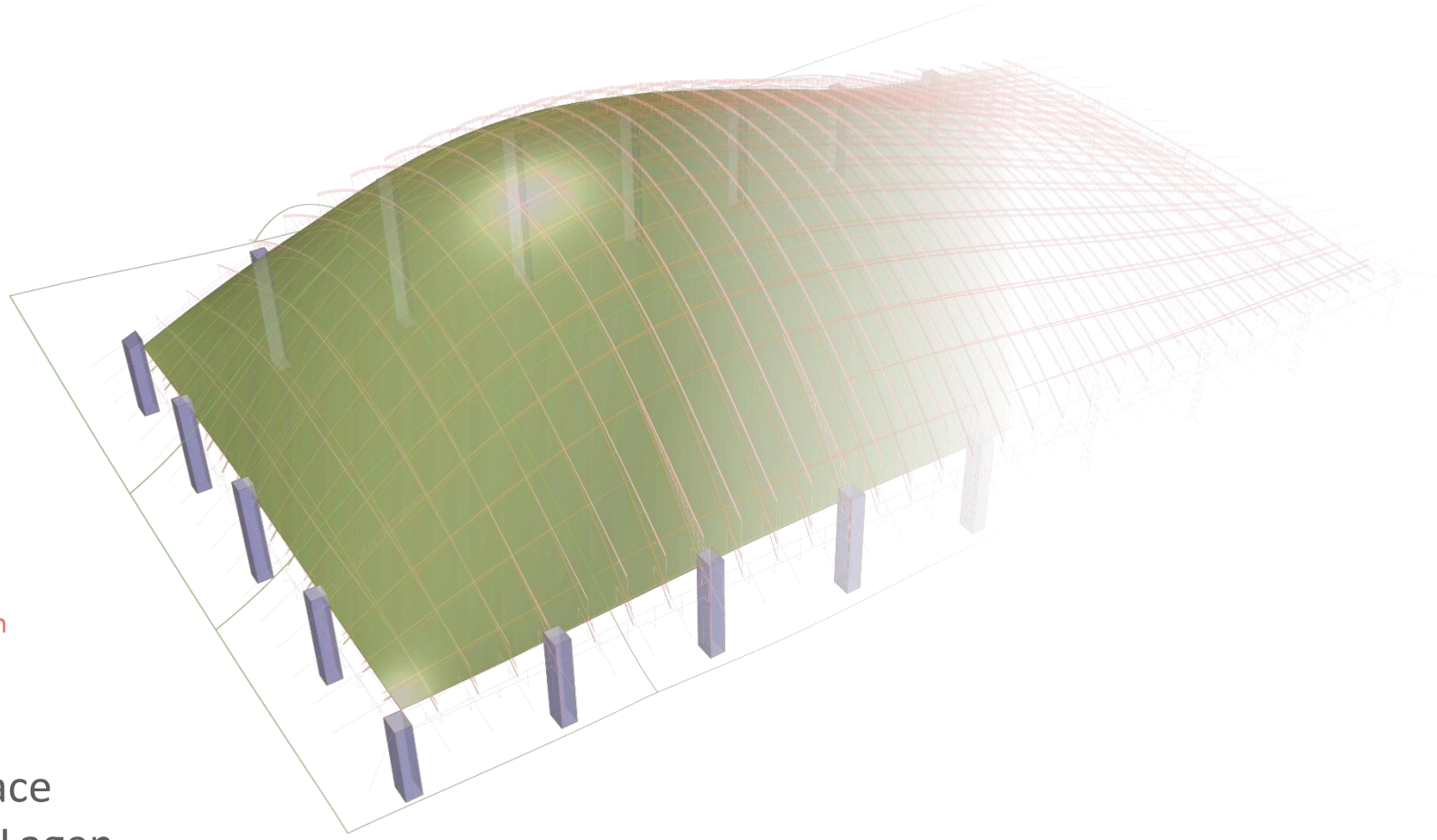
Das statische Modell

INPUT



design
to
production

- Stützen
- Mastersurface
- Achsen der Lagen



OUTPUT

- alle Stäbe
- Querschnitte
- Materialien
- Stabdrehungen
- Kopplungsstäbe
- …

- 118‘557 Knoten
- 153‘746 Stäbe
- 941 Querschnitte

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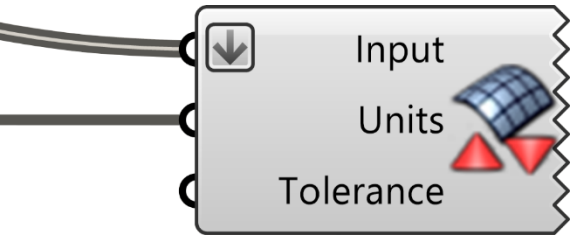

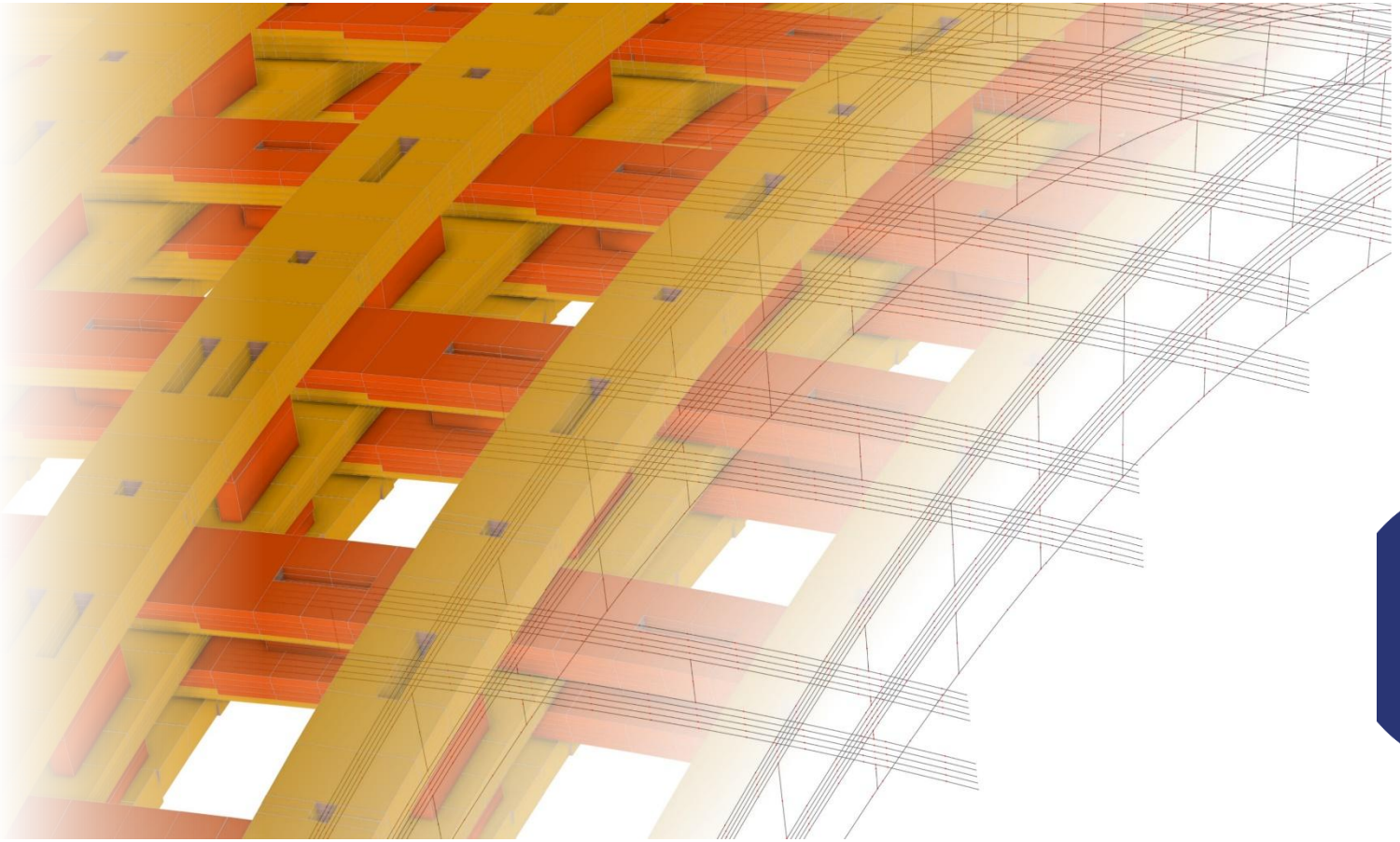

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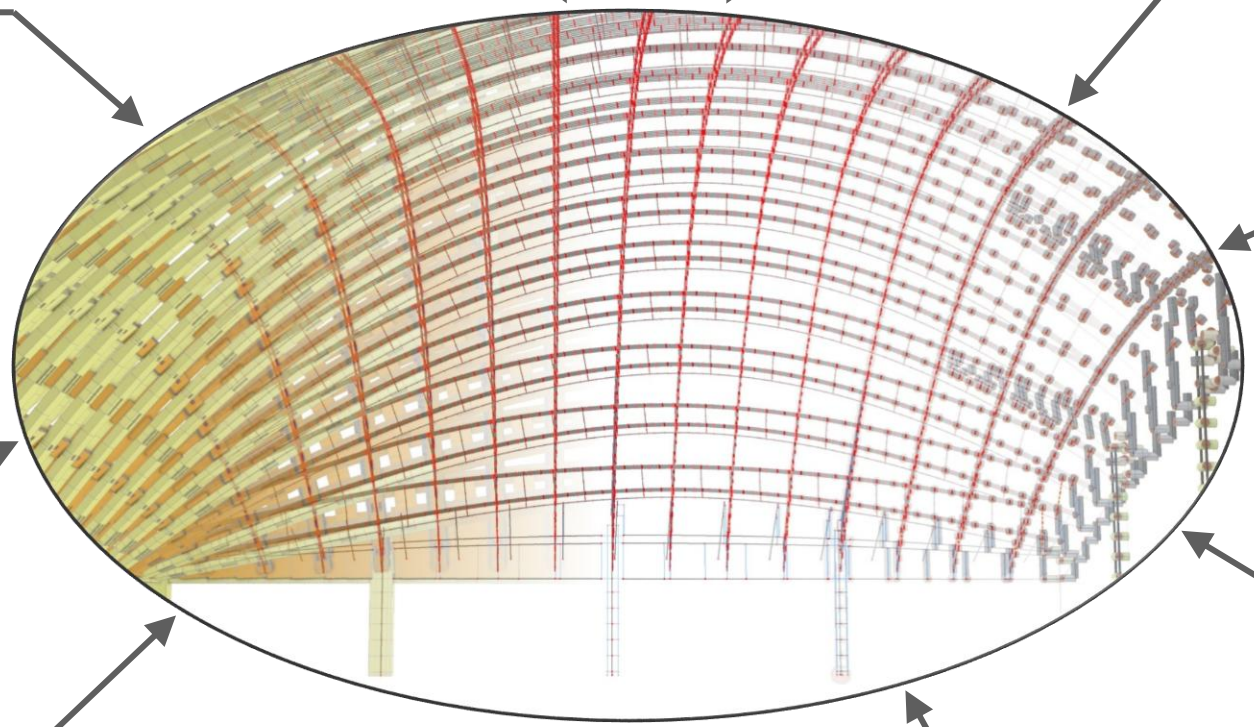

EIGENSPANNUNGEN

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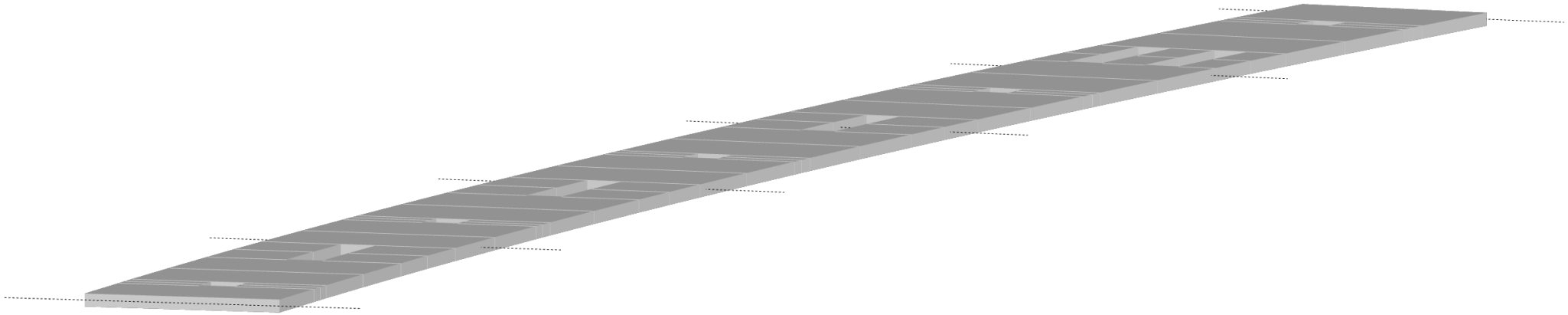
Die Eigenspannungen



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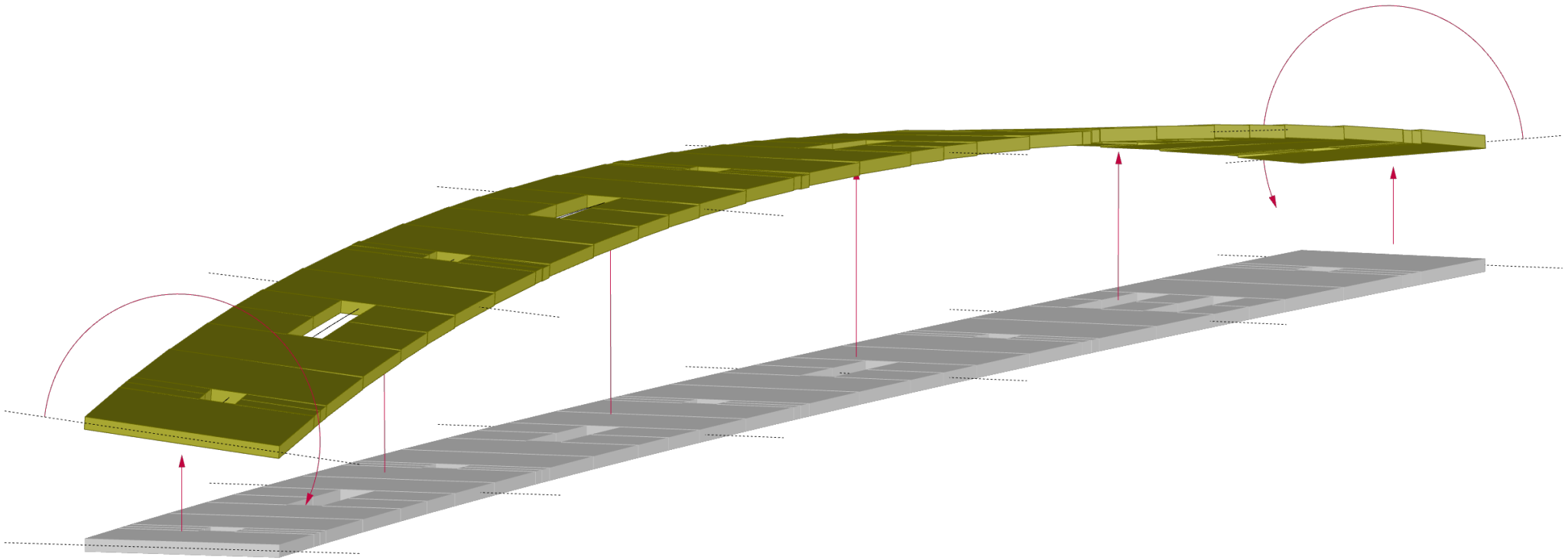

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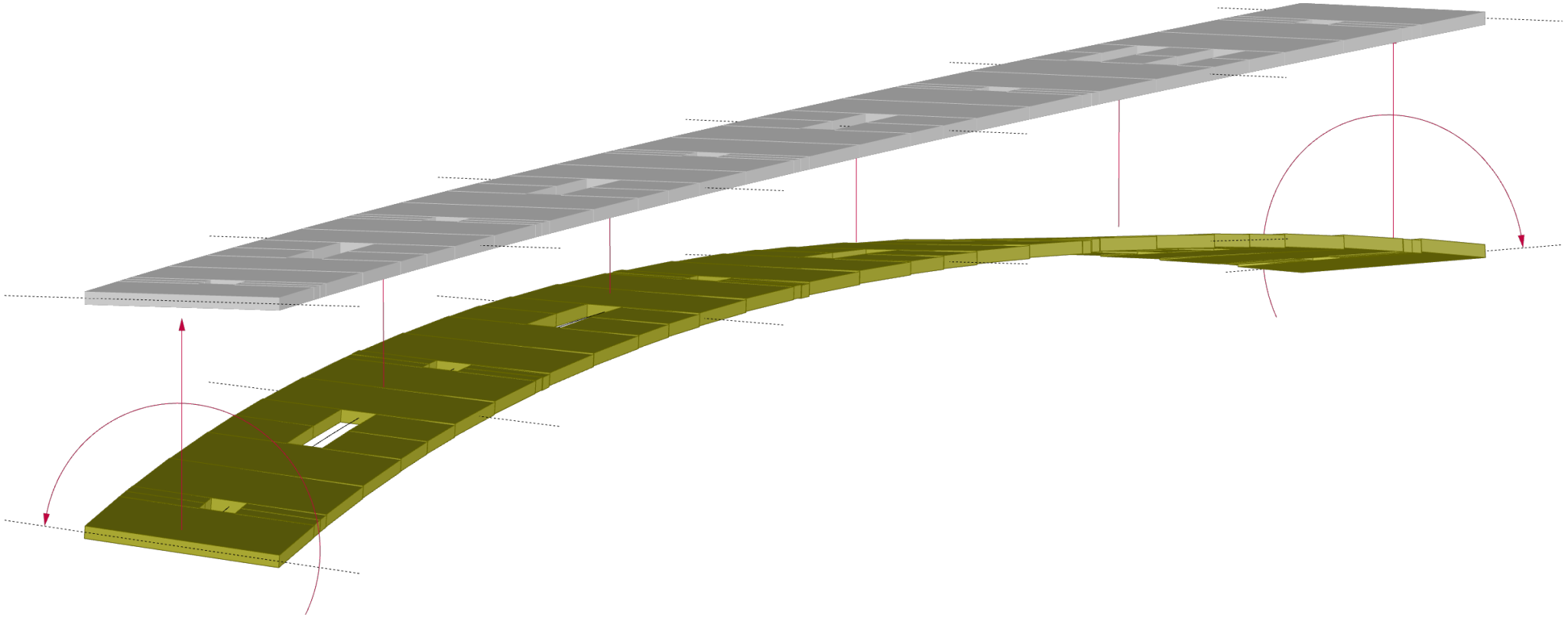

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Die Redundanz

Wisdome Stockholm, Sweden

9 Sensitivity Analysis

9.1 General

Sensitivity Analysis: **General:**	- Because of the dependence of the structure to the stiffness distribut done to evaluate the influences of stiffness variations to the structure - Worst case scenarios are also modelled to determine the impacts or at: failure of a high stressed shear dowel, failure of a high stresses ten - One exemplary load case is picked for the sensitivity analysis to eval

9.2 Scenarios

Sensitivity Analysis: **Scenarios:**	**Scenario:**	**Structural Adjustments:**
	00	base line, structural model without adjustm
	01	decrease of all E-Modules and member hing
	02	increase of all E-Modules and member hing
	03	decrease of all E-Modules of the timber stru
	04	decrease of all member hinges of the timbe
	05	decrease of the Shear Dowel member hinge
	06	slippage of the Shear Dowels of +/- 0.50mm
	07	failure of a high stressed Shear Dowel
	08	decrease of pre-tension force to 90%
	09	failure of a pair of high stressed pre-tension rods

Project No.: 821.062
Project: Wisdome, Stockholm
Title: sensitivity analysis (preliminary design)
Date: 13.10.2021
Author: sr

		Limits specified in the Basic Document			
		L/150 25000/150 167 mm	L/150 25000/150 167 mm	H/75 7000/75 93 mm	H/75 3800/75 51 mm
	STRUCTURAL SET-UP	**RESULTS**			
		STRESS RESULTANTS		**DEFORMATION**	
No.	connection column to base plate / connection roof to edge beam / connection roof to columns / columns dimension / columns material / additional columns / dowel / dowel connection / layer A / layer E / shear plate in frame corner / pre-tension of colmns	dowel max. shear force lengthwise (force per dowel pair)	max. bending moment at bottom of column	max. deformation vertical high pitched area (grid line C)	max. deformation vertical low pitched area (grid line G)	max. deformation horizontal on top of edge beam Wallenberghallen (grid line E)	max. deformation horizontal on top of edge beam long facade (grid line G)
		ULS (design-values)		SLS (LC: 1.00*(g+a)+1.00*p+1.00*s+0.70*q+0.60*w) incl. Creeping			
1	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / lengthwise / no / no / no	607 kN 100 %	1900 kNm 100 %	91 mm 100 %	240 mm 100 %	210 mm 100 %	49 mm 100 %
2	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 1.00 mm slippage / transferring only shear and normal forces through dowel connection / lengthwise / no / no / no	536 kN 88 %	2100 kNm 111 %	103 mm 113 %	275 mm 115 %	236 mm 112 %	57 mm 116 %
3	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / no / no / no	592 kN 98 %	1800 kNm 95 %	101 mm 111 %	237 mm 99 %	213 mm 101 %	46 mm 94 %
4	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / no / no	435 kN 72 %	1350 kNm 71 %	80 mm 88 %	152 mm 63 %	141 mm 67 %	28 mm 57 %
5	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring all possible forces through dowel connection / crosswise / yes 5 x 30 mm LVL / no / no	397 kN 65 %	1280 kNm 67 %	76 mm 84 %	143 mm 60 %	132 mm 63 %	26 mm 53 %
6	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / no / no	380 kN 63 %	1780 kNm 94 %	65 mm 71 %	122 mm 51 %	101 mm 48 %	27 mm 55 %
7	fixed connection / only transferring vertical loads / fixed connection / 600/600mm / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	425 kN 70 %	1300 kNm 68 %	78 mm 86 %	149 mm 62 %	133 mm 63 %	28 mm 57 %
11	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	371 kN 61 %	1710 kNm 90 %	63 mm 69 %	119 mm 50 %	96 mm 46 %	27 mm 55 %
12	fixed connection / only transferring vertical loads / fixed connection / 600/1000mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	337 kN 56 %	2130 kNm 112 %	54 mm 59 %	104 mm 43 %	75 mm 36 %	25 mm 51 %
13	fixed connection / only transferring vertical loads / fixed connection / 600/1200mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	310 kN 51 %	2550 kNm 134 %	46 mm 51 %	92 mm 38 %	59 mm 28 %	24 mm 49 %
14	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / yes 2 additional columns next to door to Wallenberghallen Stora Enso LVL (grid line C + D) / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	361 kN 59 %	1860 kNm 98 %	55 mm 60 %	119 mm 50 %	86 mm 41 %	27 mm 55 %
15	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / yes 2 additional columns next to door to Wallenberghallen Stora Enso LVL (grid line C + D) / pair of dowels 60/300mm 0.00 mm slippage / transferring all possible forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	330 kN 54 %	1780 kNm 94 %	51 mm 56 %	110 mm 46 %	82 mm 39 %	25 mm 51 %
16	fixed connection / only transferring vertical loads / fixed connection / 600/1000mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / yes 2 additional columns next to door to Wallenberghallen Stora Enso LVL (grid line C + D) / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	327 kN 54 %	2400 kNm 126 %	45 mm 49 %	104 mm 43 %	66 mm 31 %	25 mm 51 %
17	fixed connection / only transferring vertical loads / fixed connection / 600/1200mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / yes 2 additional columns next to door to Wallenberghallen Stora Enso LVL (grid line C + D) / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / yes / no	300 kN 49 %	2810 kNm 148 %	38 mm 42 %	92 mm 38 %	54 mm 26 %	24 mm 49 %
21	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Stora Enso LVL (E-Module 13800 N/mm²) / yes 2 additional columns next to door to Wallenberghallen Pollmeier Baubuche (grid line C + D) / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel connection / crosswise / yes 5 x 30 mm LVL / no / no	370 kN 61 %	1980 kNm 104 %	56 mm 62 %	122 mm 51 %	92 mm 44 %	27 mm 55 %
22	fixed connection / only transferring vertical loads / fixed connection / 600/800mm (along long walls) / Pollmeier Baubuche (E-Module 16800 N/mm²) / no / pair of dowels 60/300mm 0.00 mm slippage / transferring only shear and normal forces through dowel / crosswise / yes 5 x 30 mm LVL / no / no	362 kN 60 %	1900 kNm 100 %	57 mm 63 %	112 mm 47 %	90 mm 43 %	25 mm 51 %

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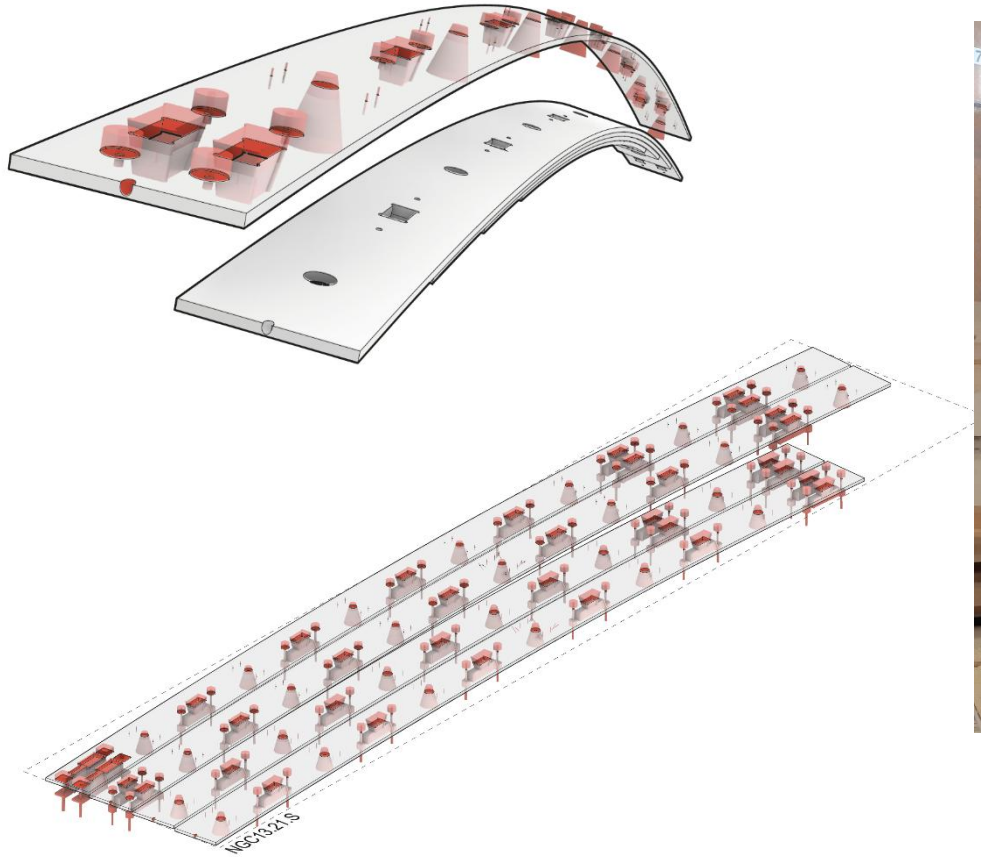
Produktion



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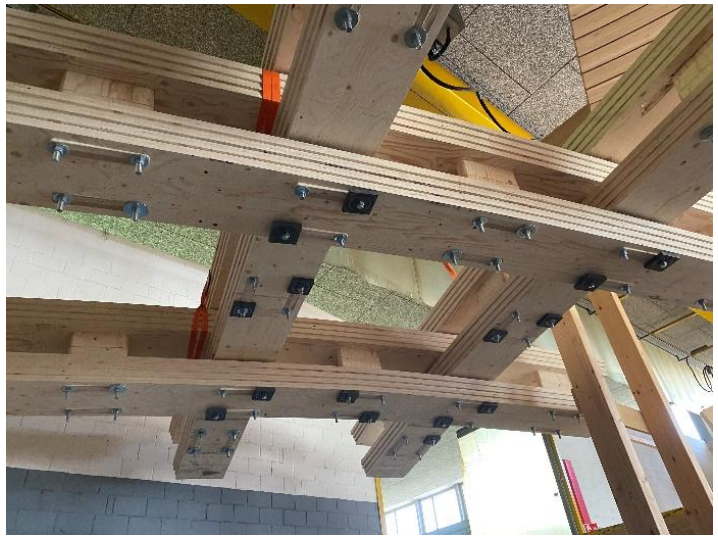
Mockup



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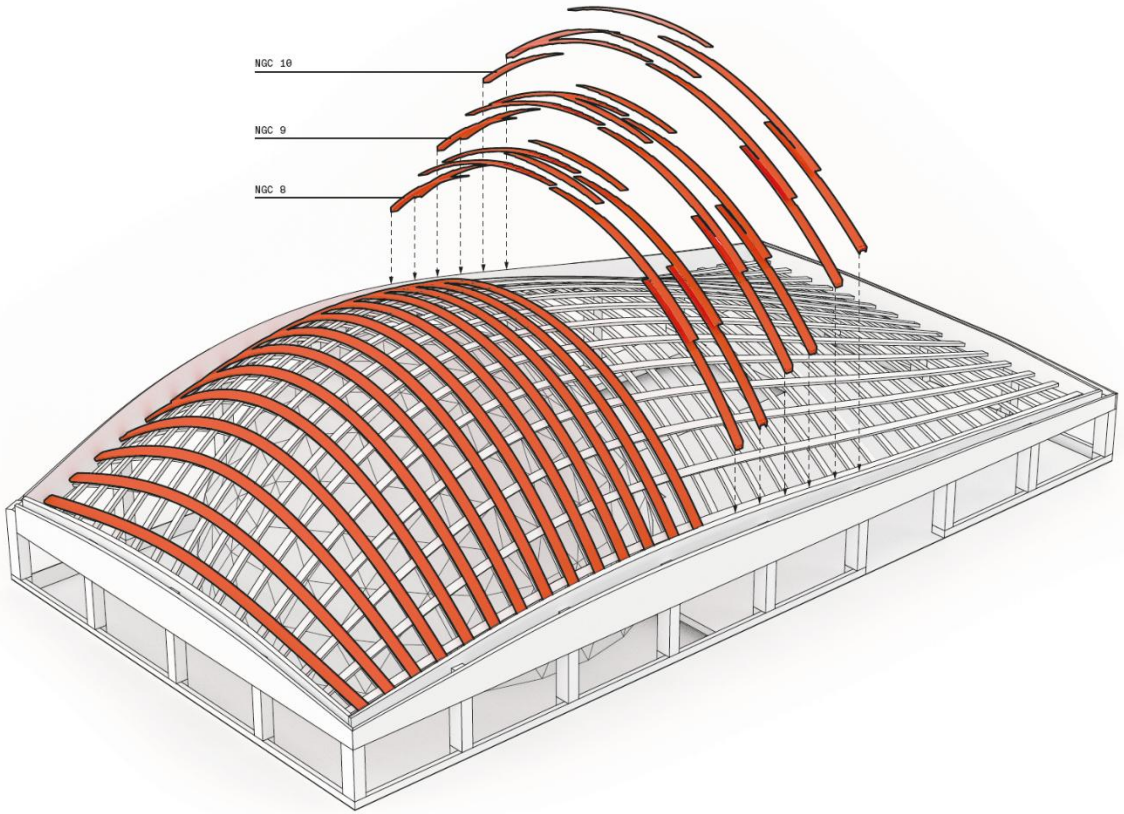
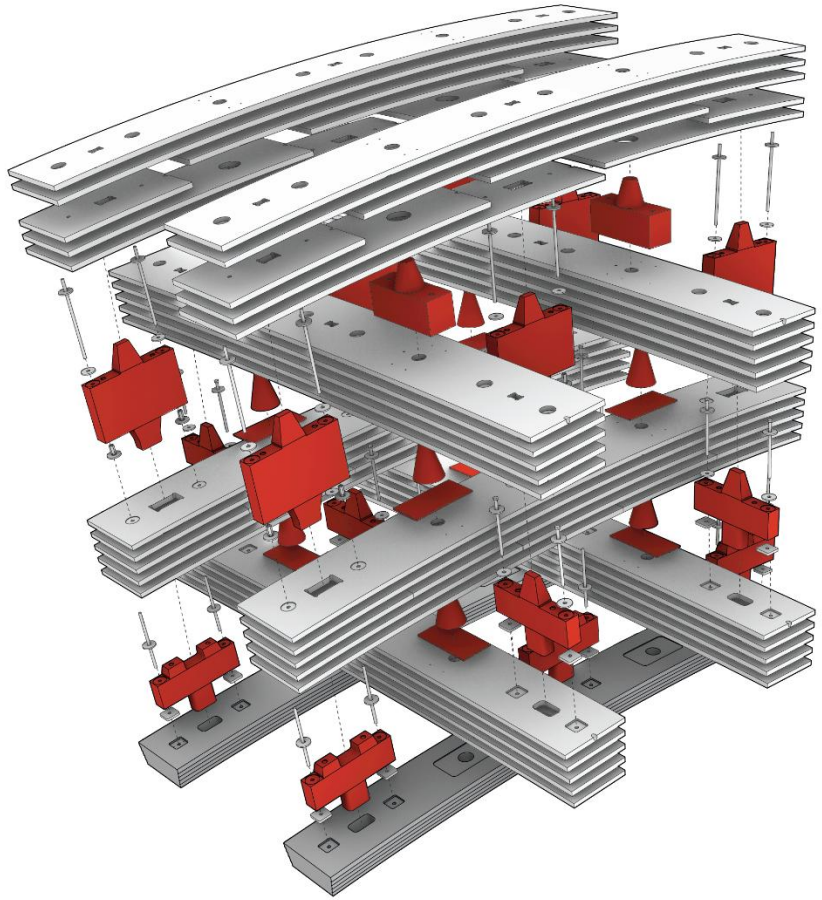
Montage





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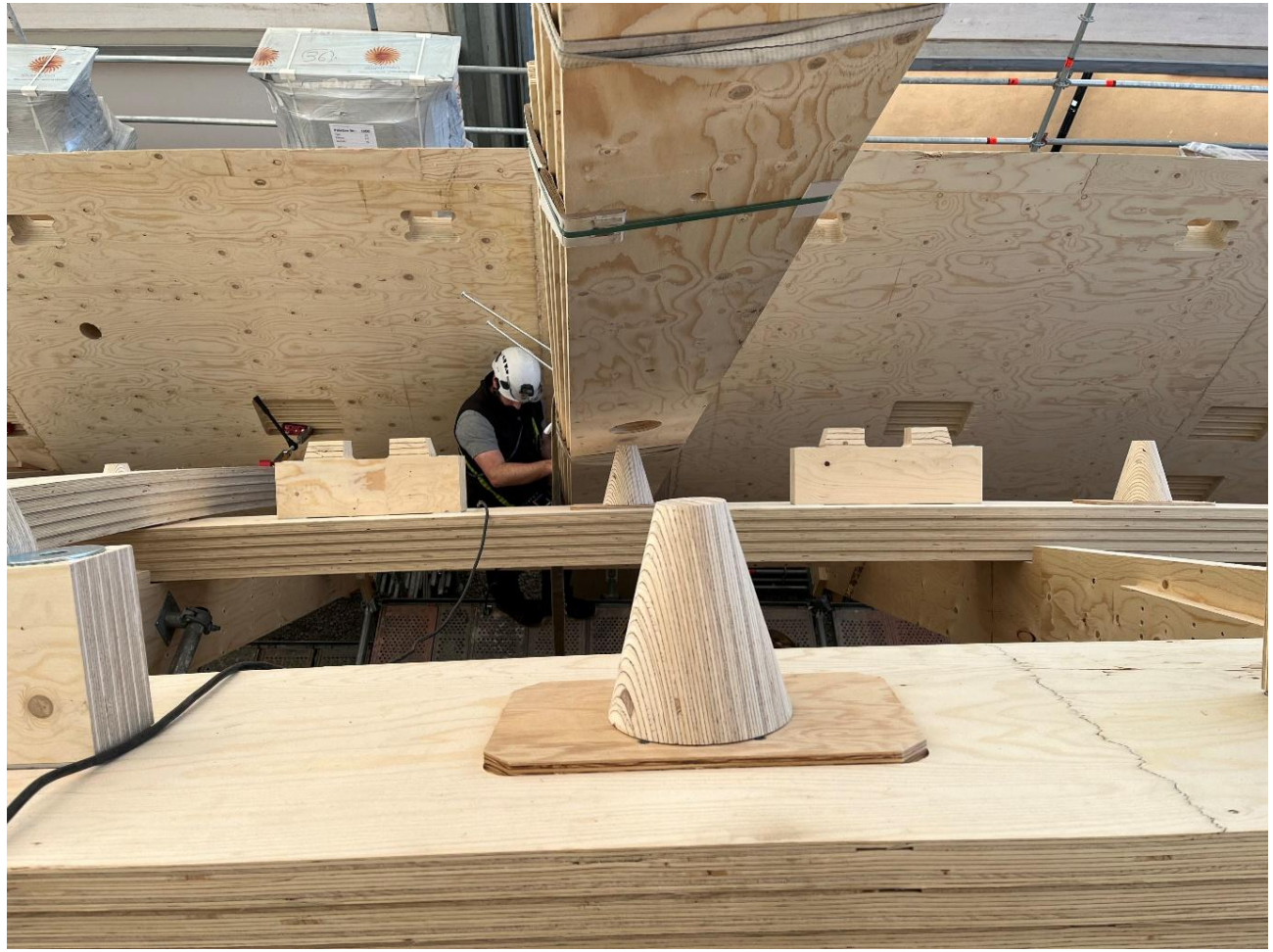
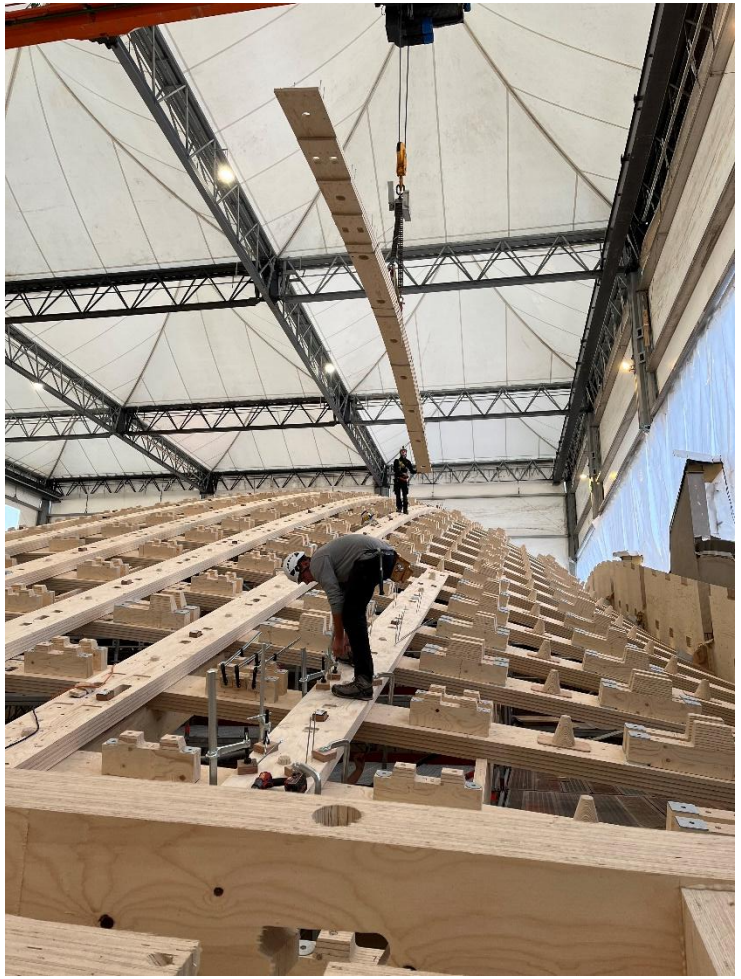
Montage





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Stefan Rick
vertreten durch Philipp Schmon