PREFAB SHELL STRUCTURES

METHOD FOR CHECKING CONNECTIONS

P5 Guido van der Straten - 4159039 - 02/07/2018

STRUCTURE

GENERAL INFORMATION
- What are shell structures
- Problem statement
- Solution

CASE STUDY

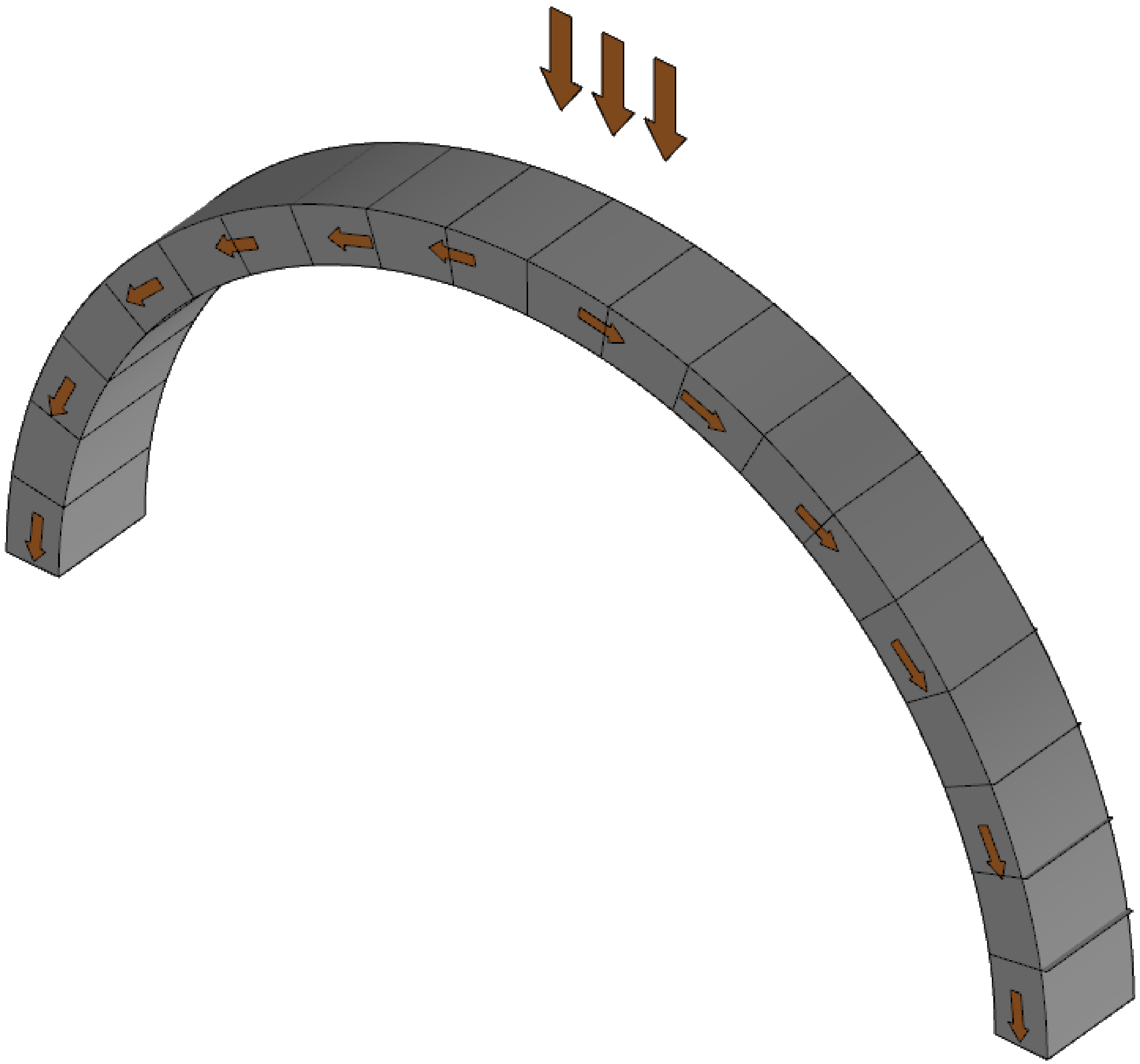
METHOD
- Connections
- Design
- Prototype construction
- Testing

ANALYSIS
- Prove method
- Extend method

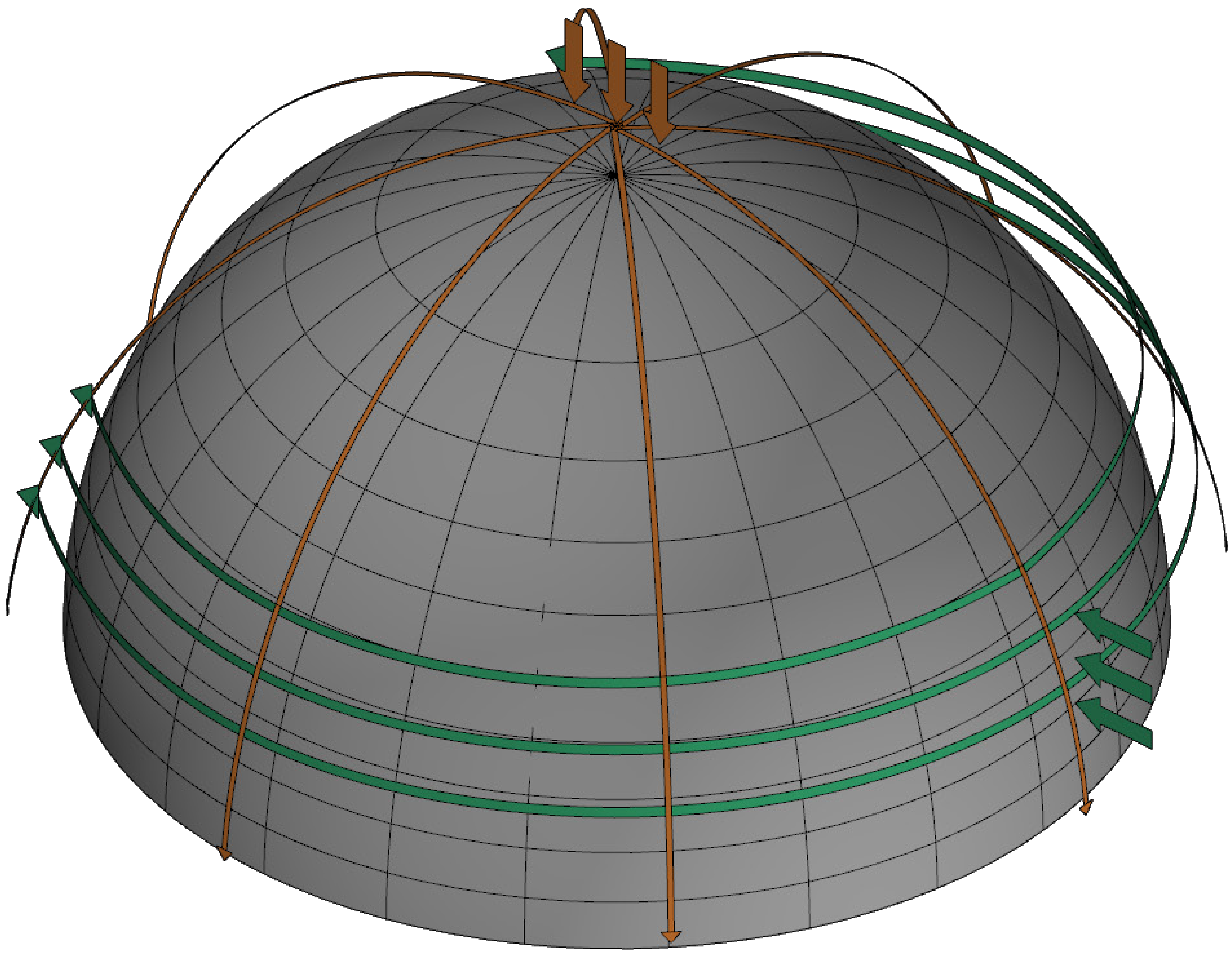
CONCLUSION

REFLECTION

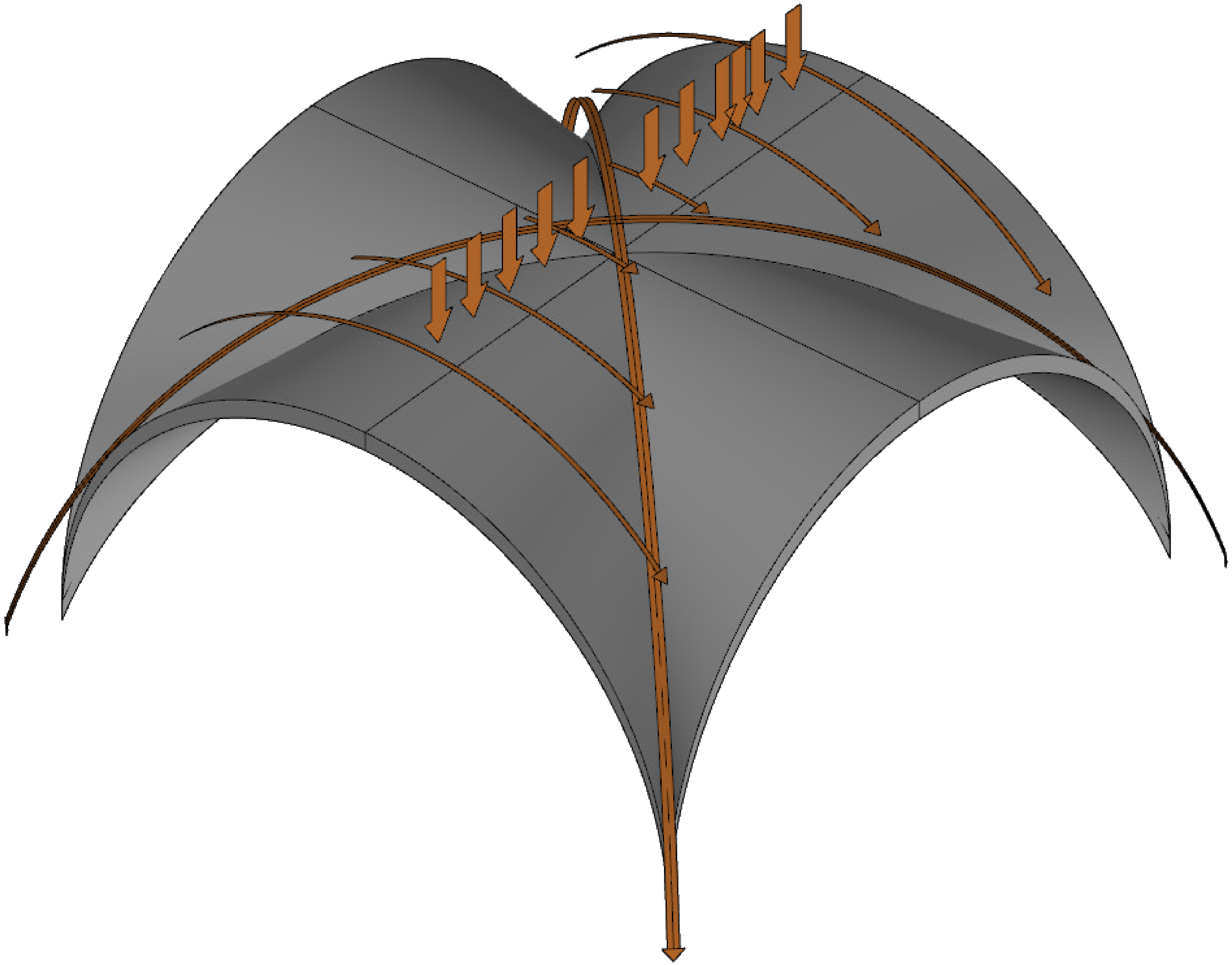
SHELL STRUCTURES



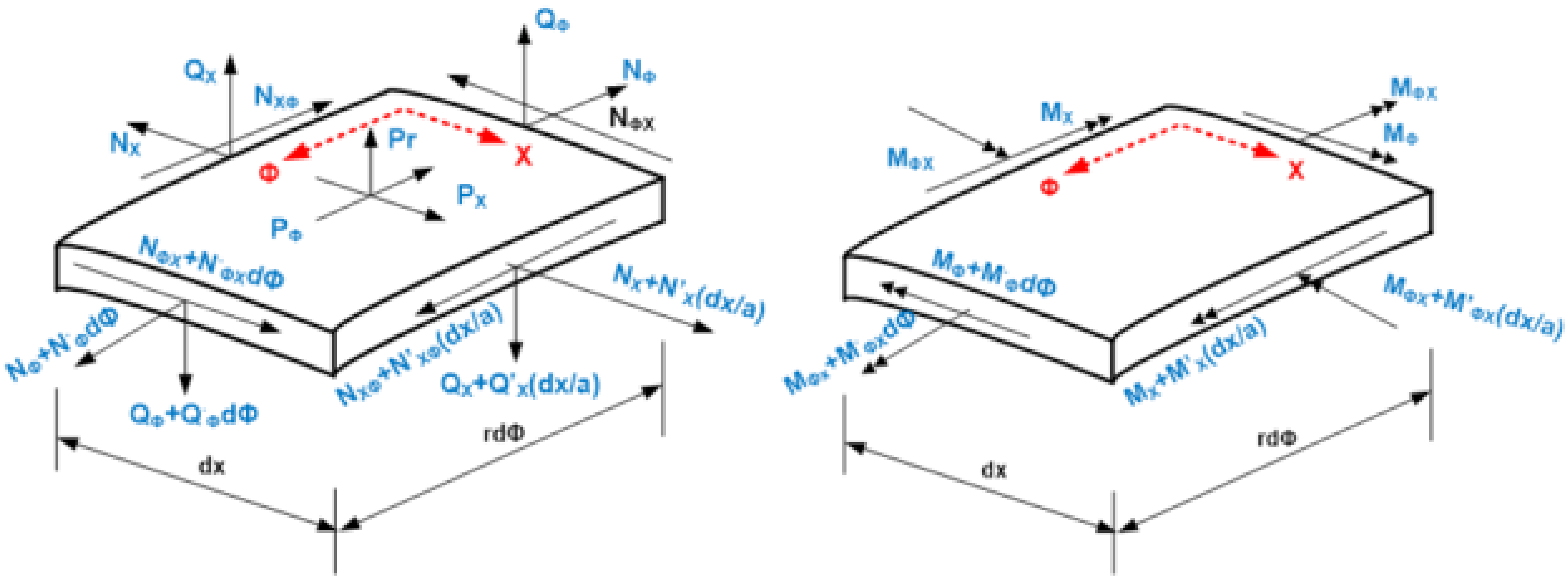
SHELL STRUCTURES



SHELL STRUCTURES



SHELL STRUCTURES

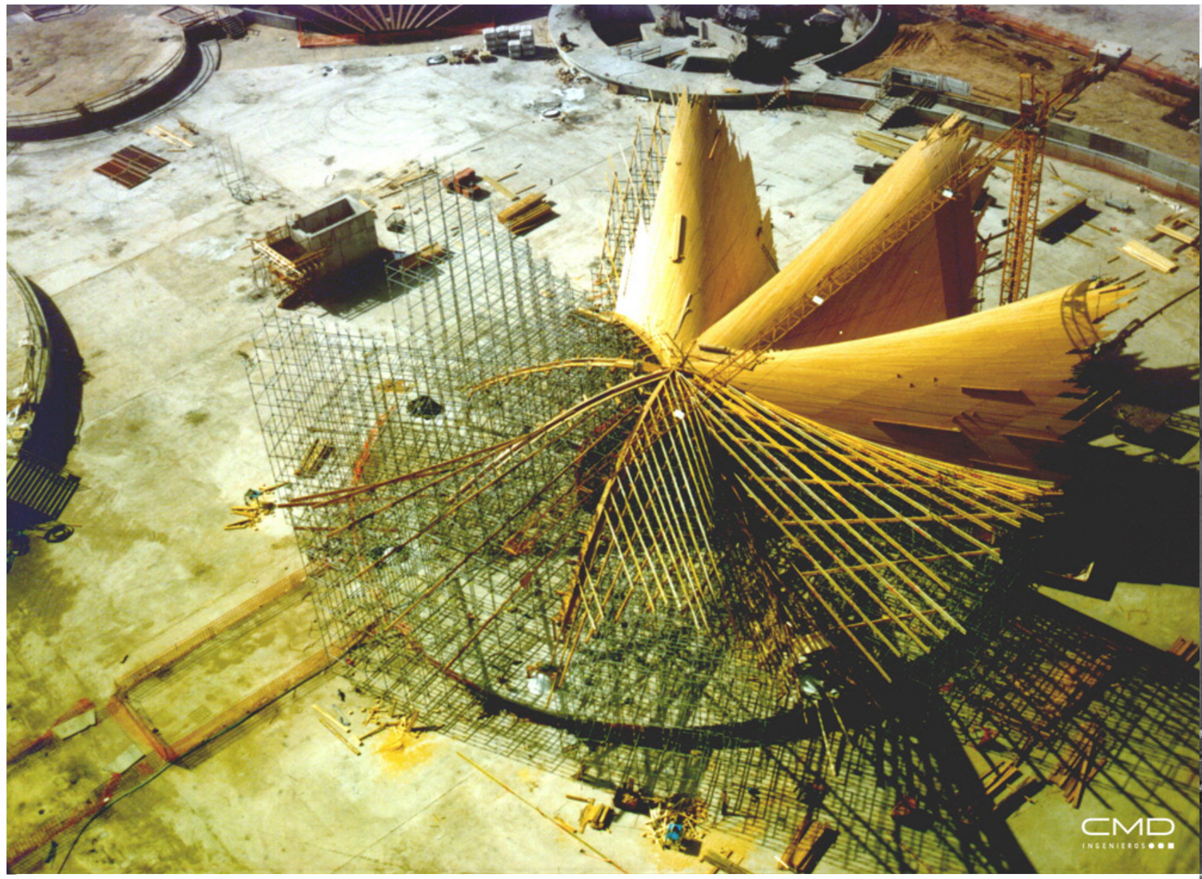


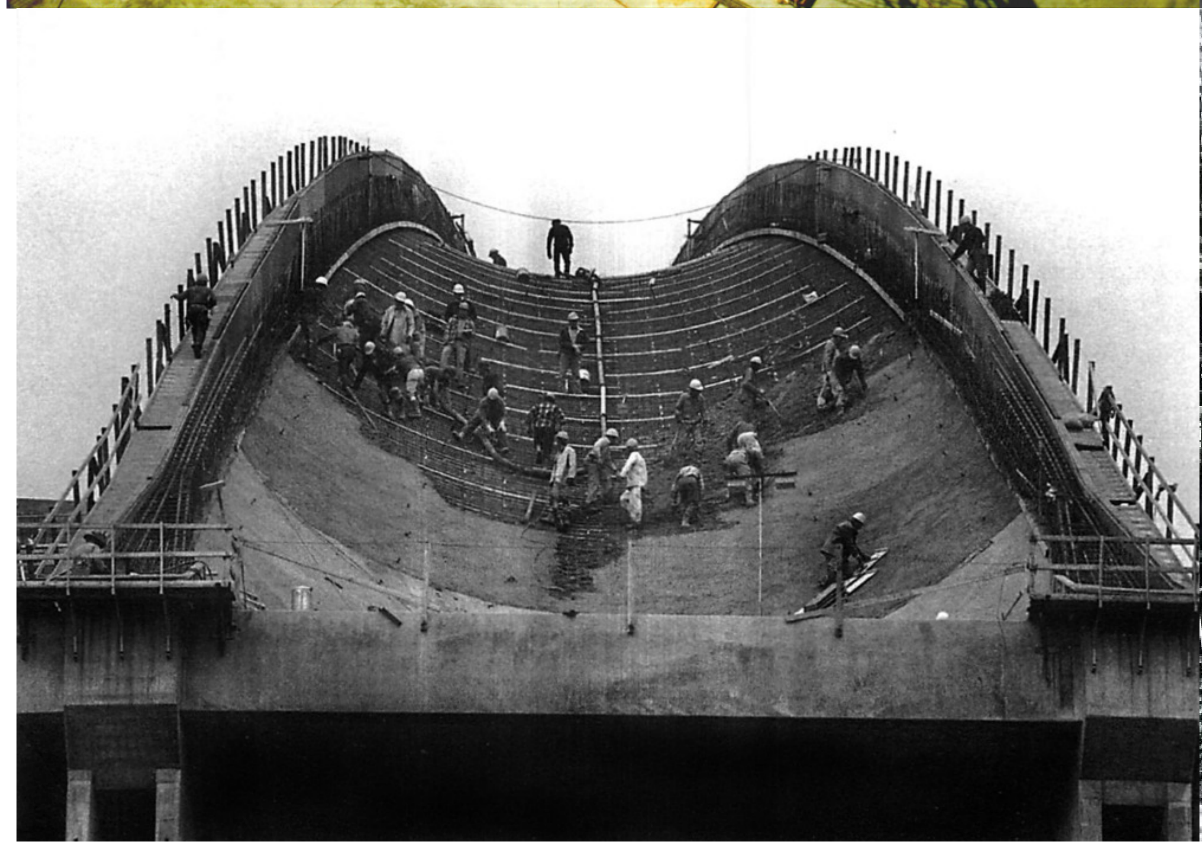
EXAMPLES

Deitingen Service Station
- Heinz Isler
- 26 m x 31 m
- 3 supports

Sagrada Familia
- Antoni Gaudi
- 40 m dome
- 135 m towers

PROBLEM STATEMENT

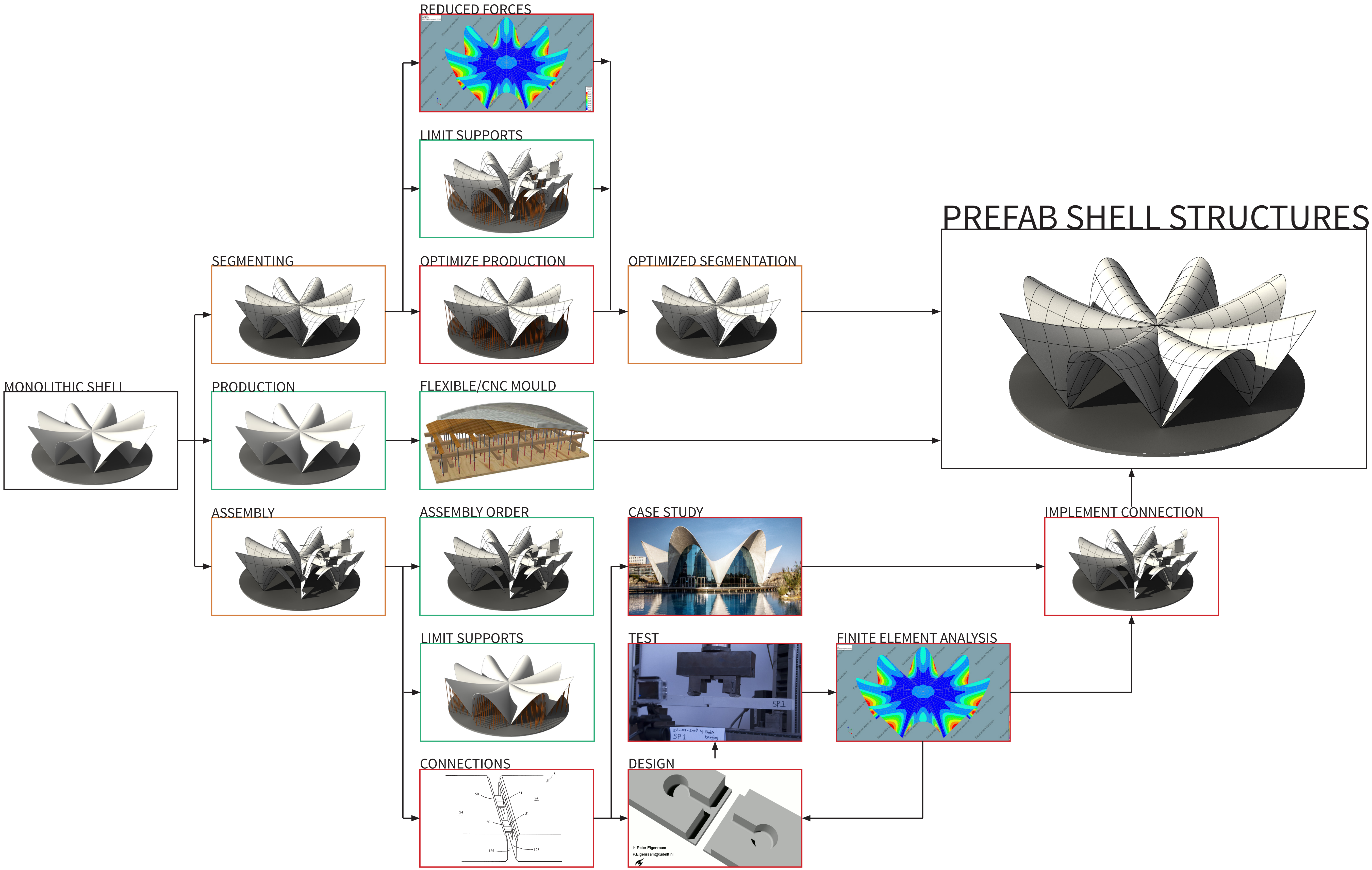




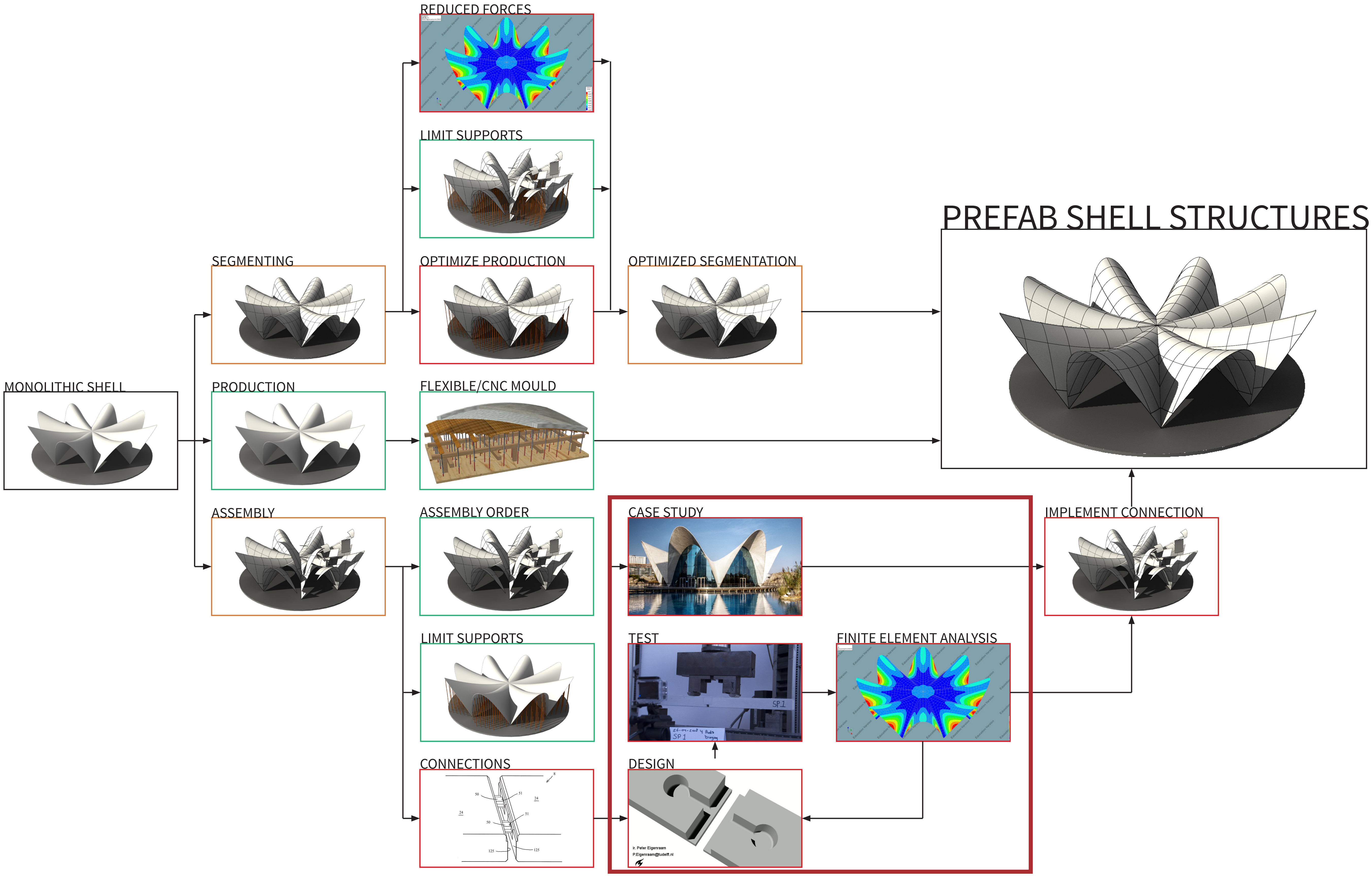
SOLUTION

PREFABRICATING SHELL

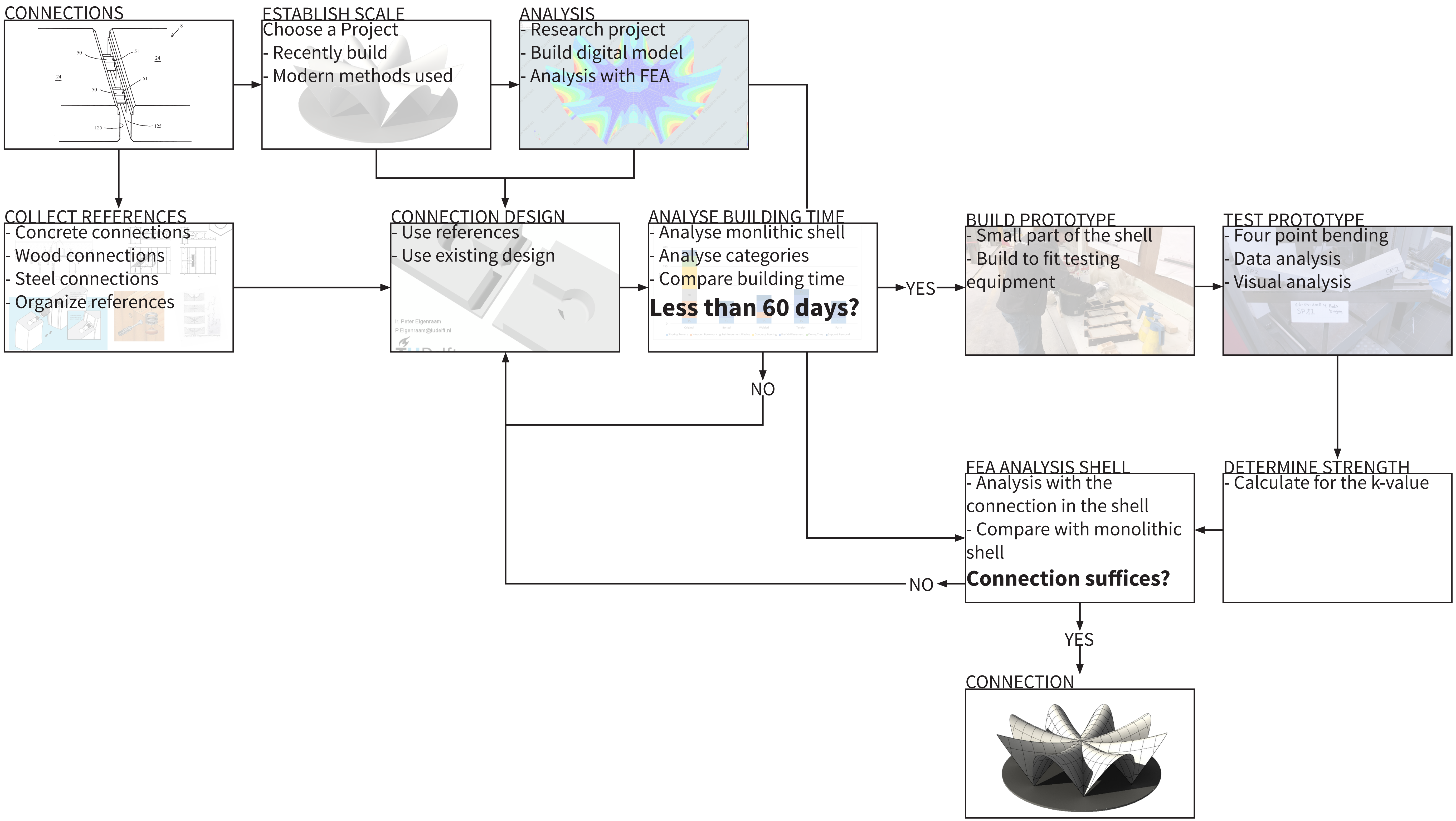
TOPIC SELECTION



TOPIC SELECTION



CONNECTION DESIGN



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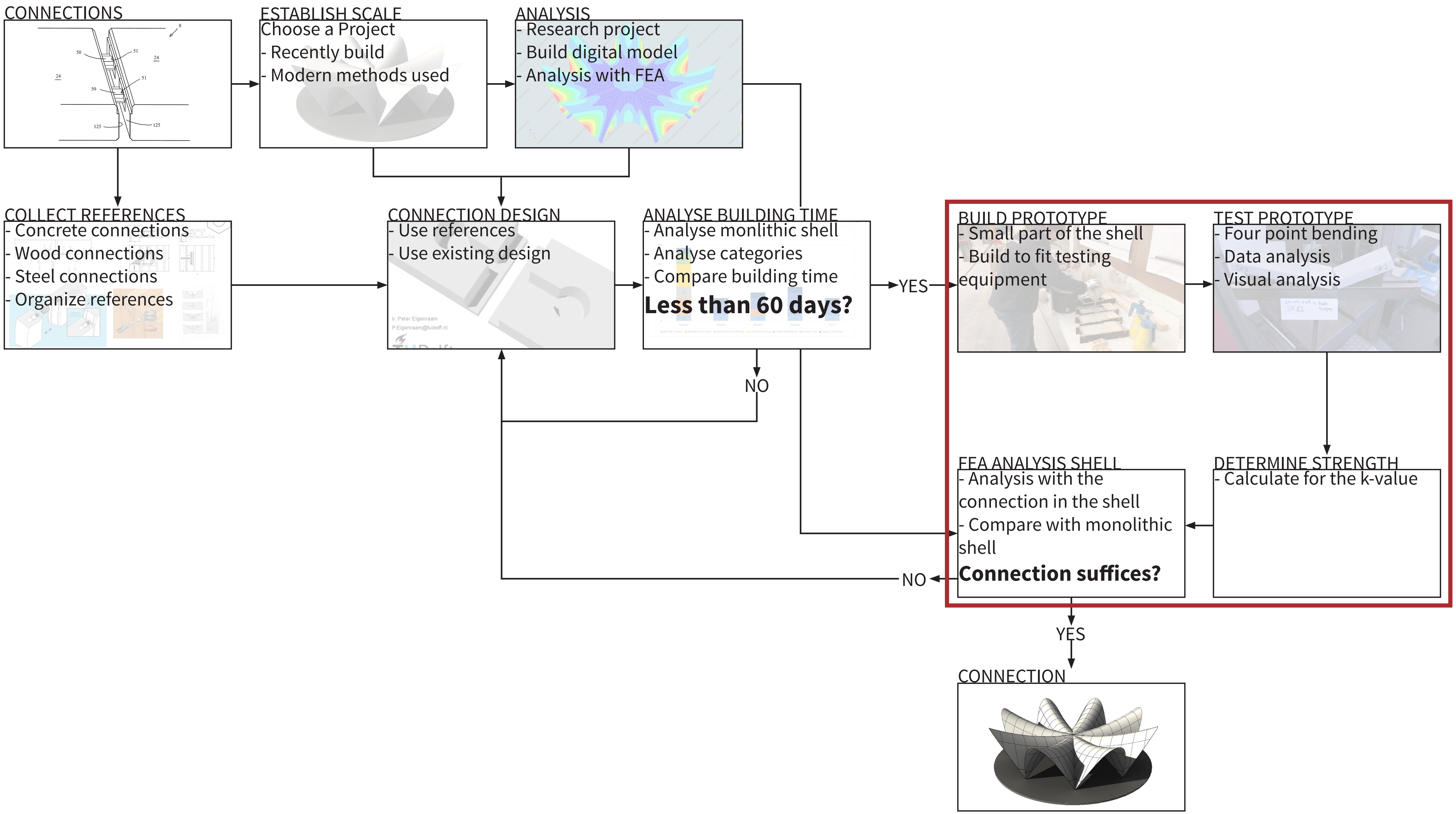

RESEARCH QUESTION

How can we prove that a connection is suitable for use in a segmented prefabricated shell structure?

- Which demands are made for a connections in a segmented prefabricated shell structure?
- How can we test the strength of a connection?
- How can we implement a connection in a digital model?

OCEANOGRAPHIC VALENCIA

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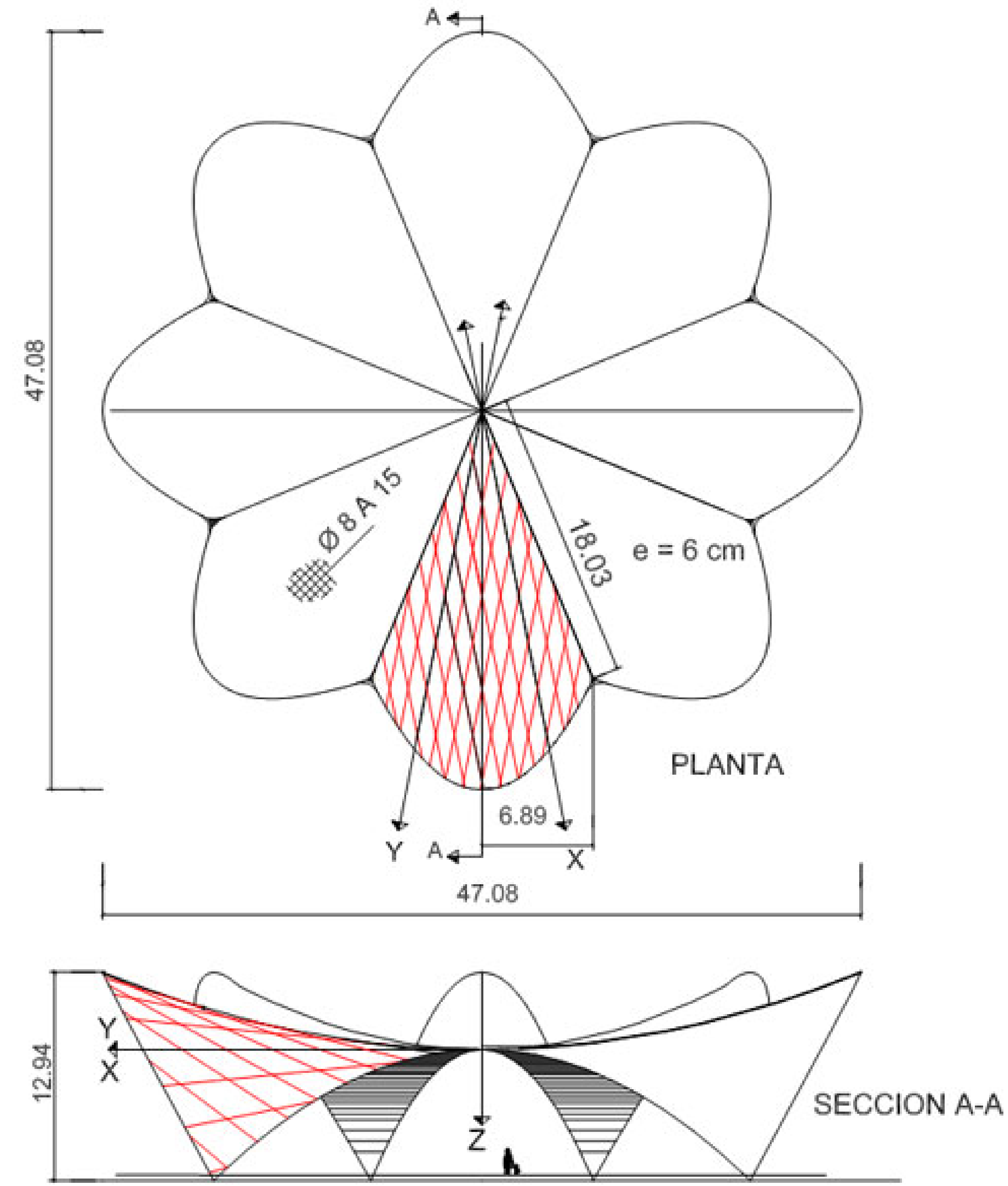
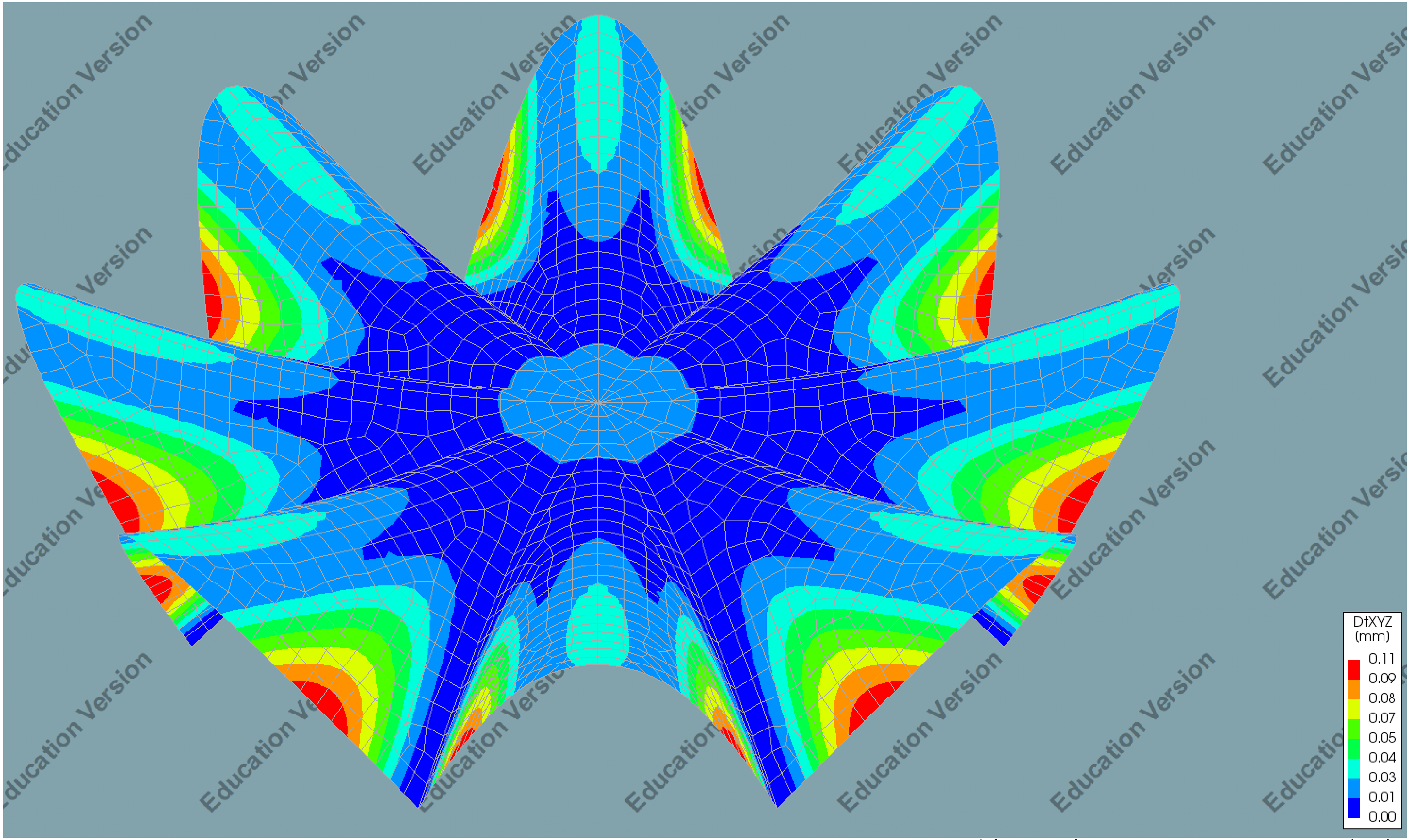
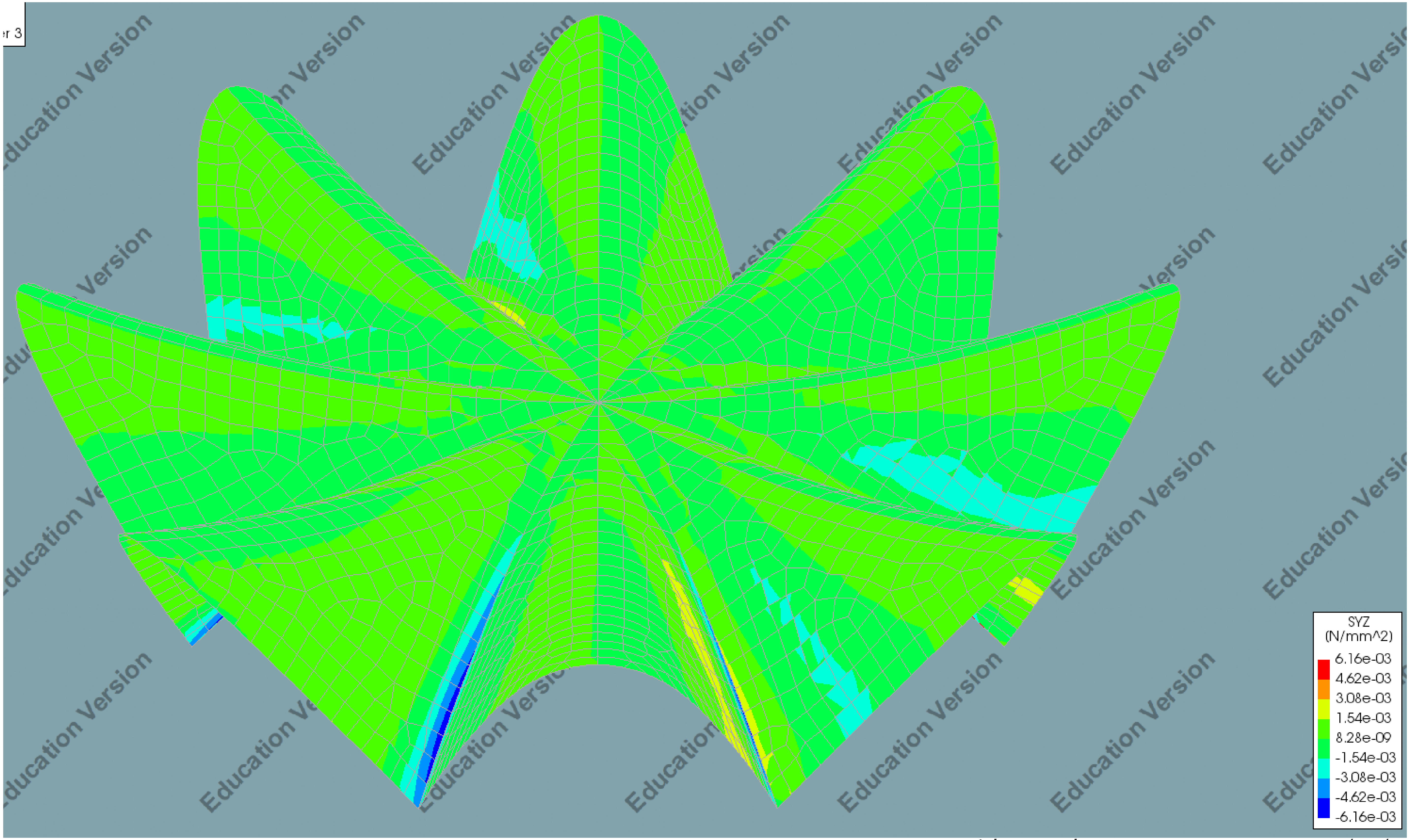


- Valencia
- Restaurant
- 47 x 47 m
- 60mm thickness

DISPLACEMENT

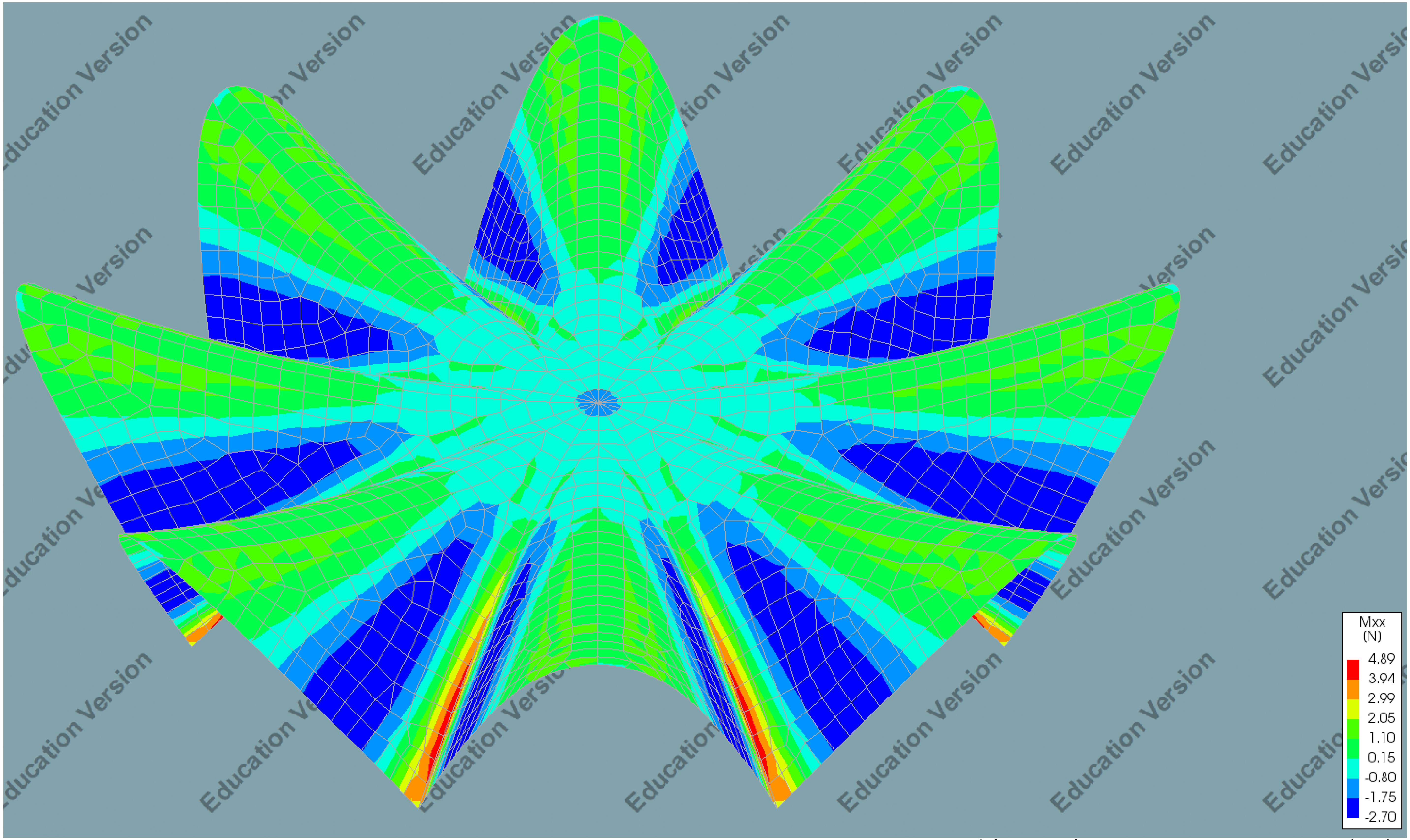


STRESSES

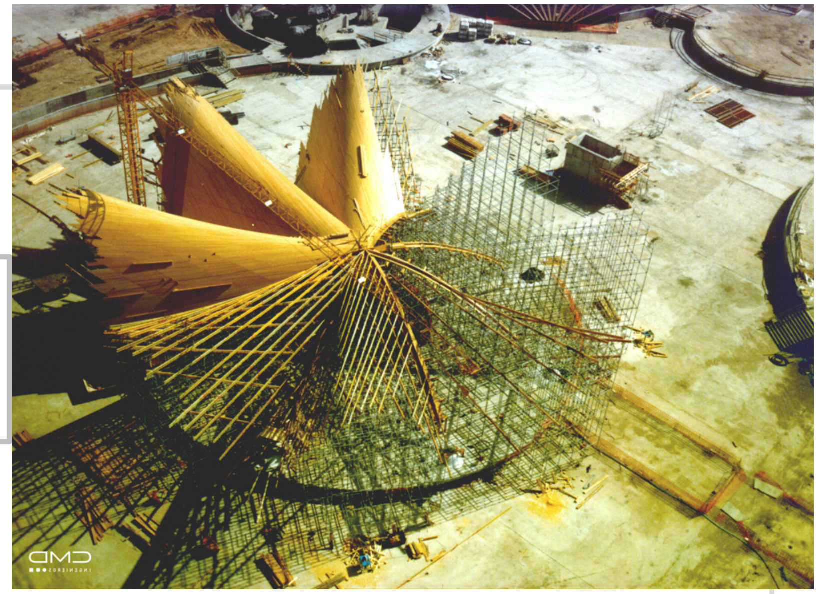


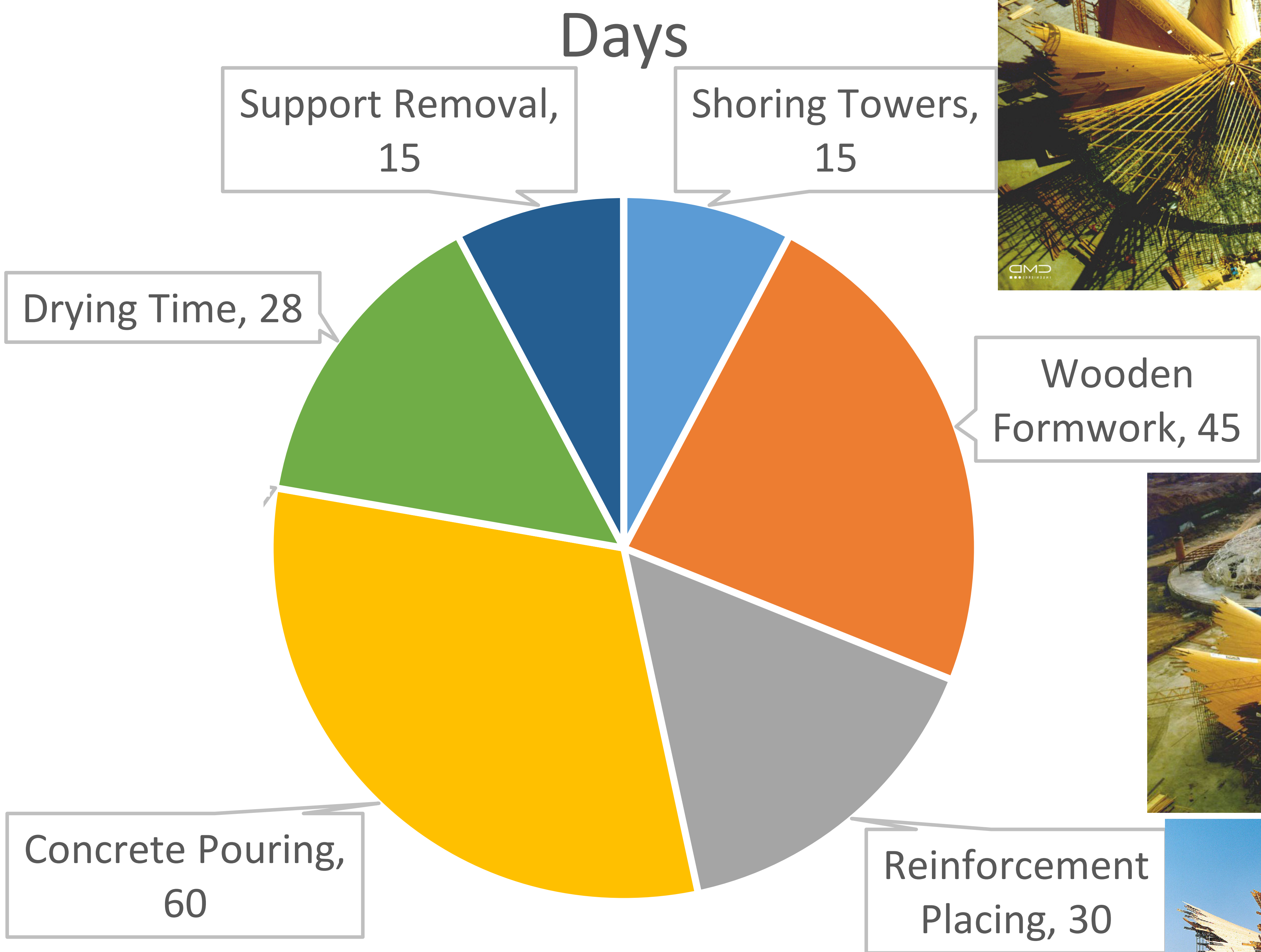
SYZ
(N/mm^2)
6.16e-03
4.62e-03
3.08e-03
1.54e-03
8.28e-09
-1.54e-03
-3.08e-03
-4.62e-03
-6.16e-03

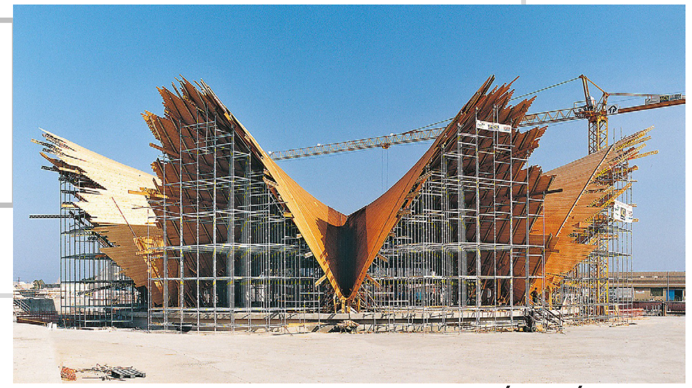
DISTRIBUTED MOMENT



CONSTRUCTION TIME

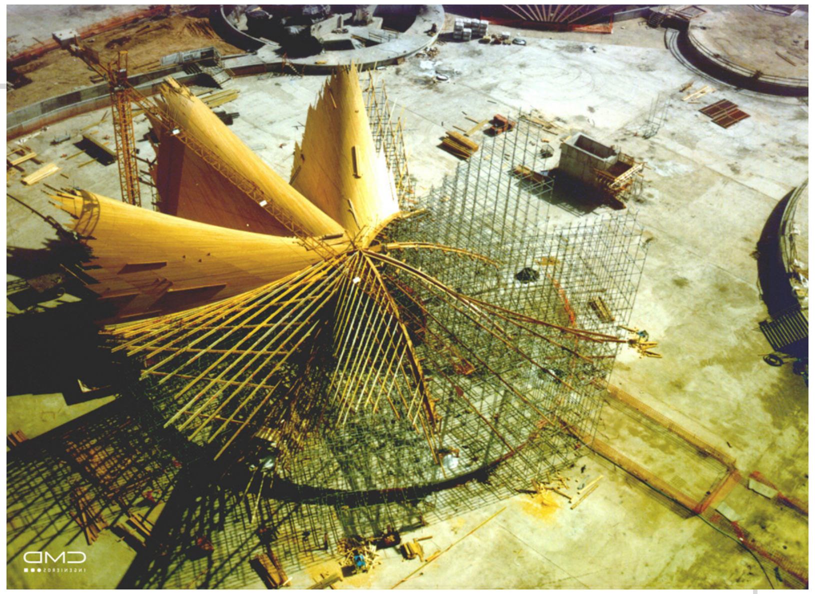


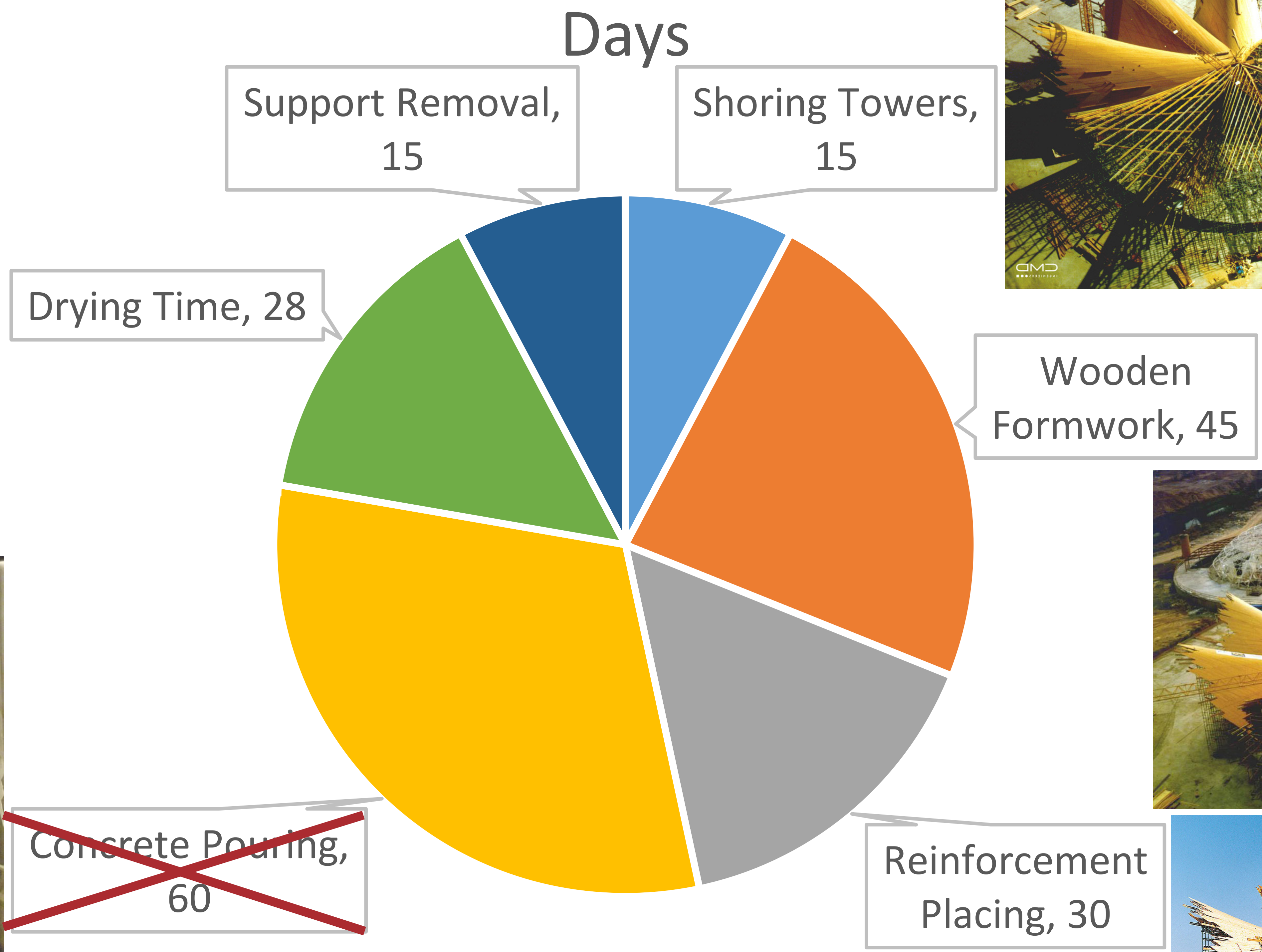




Total: 200 days

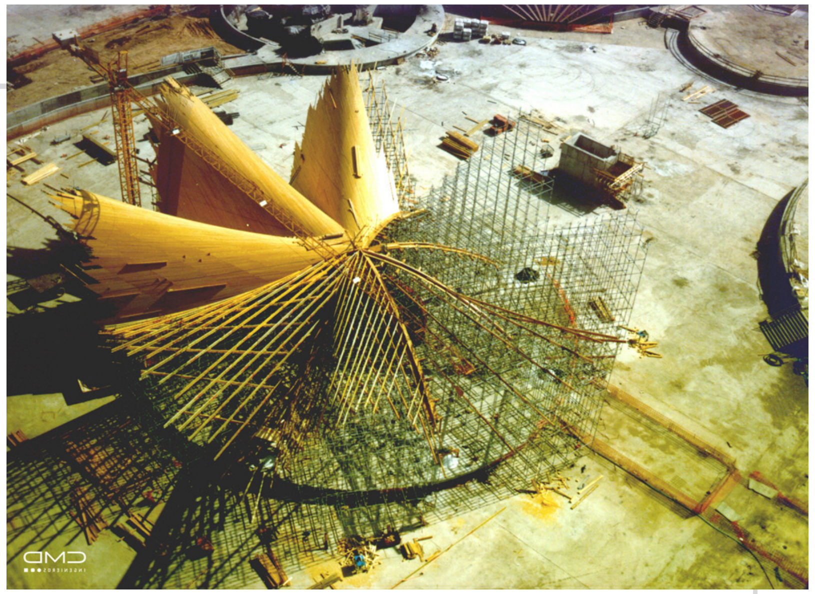
CONSTRUCTION TIME

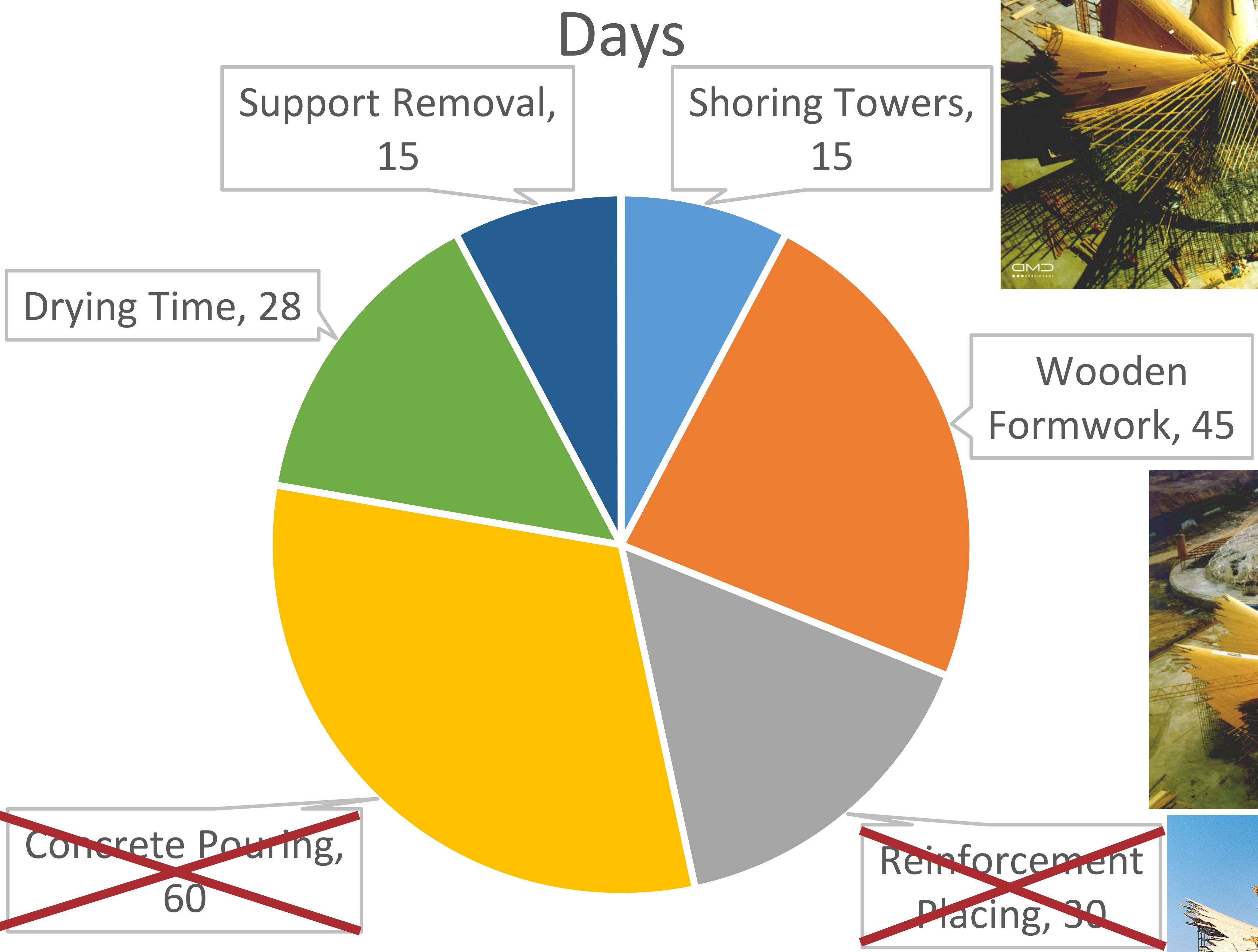


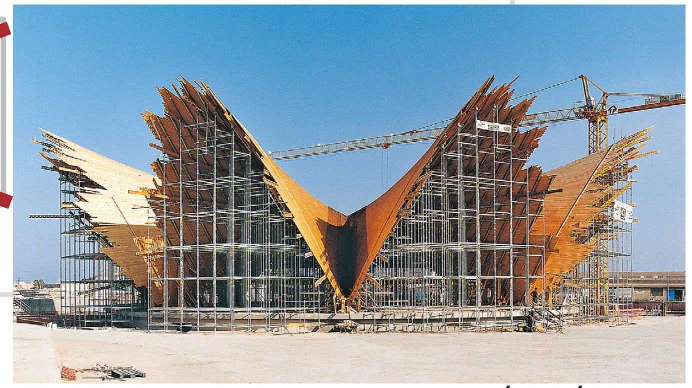


Total: 140 days

CONSTRUCTION TIME

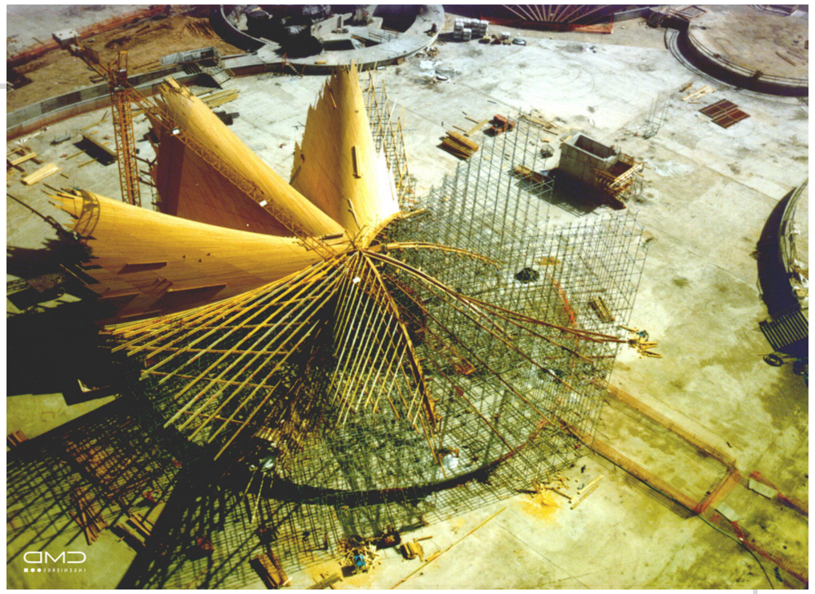


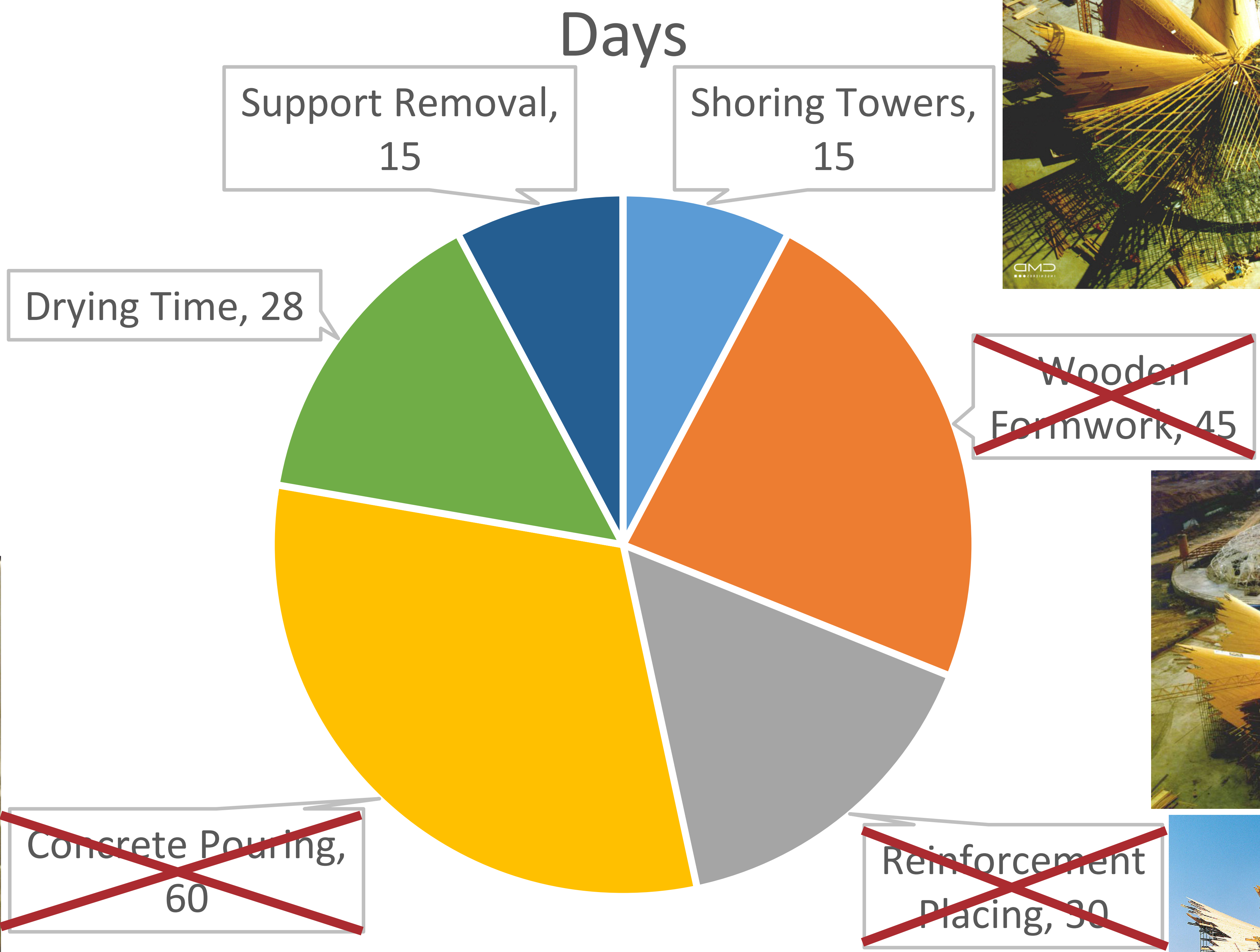


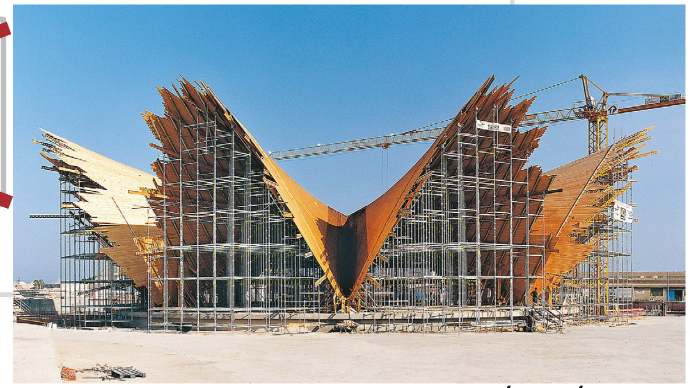


Total: 110 days

CONSTRUCTION TIME

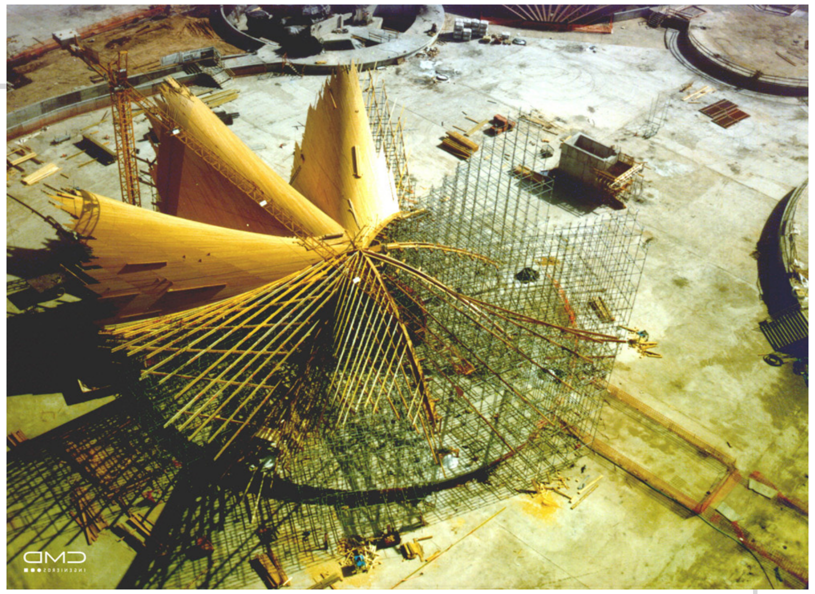


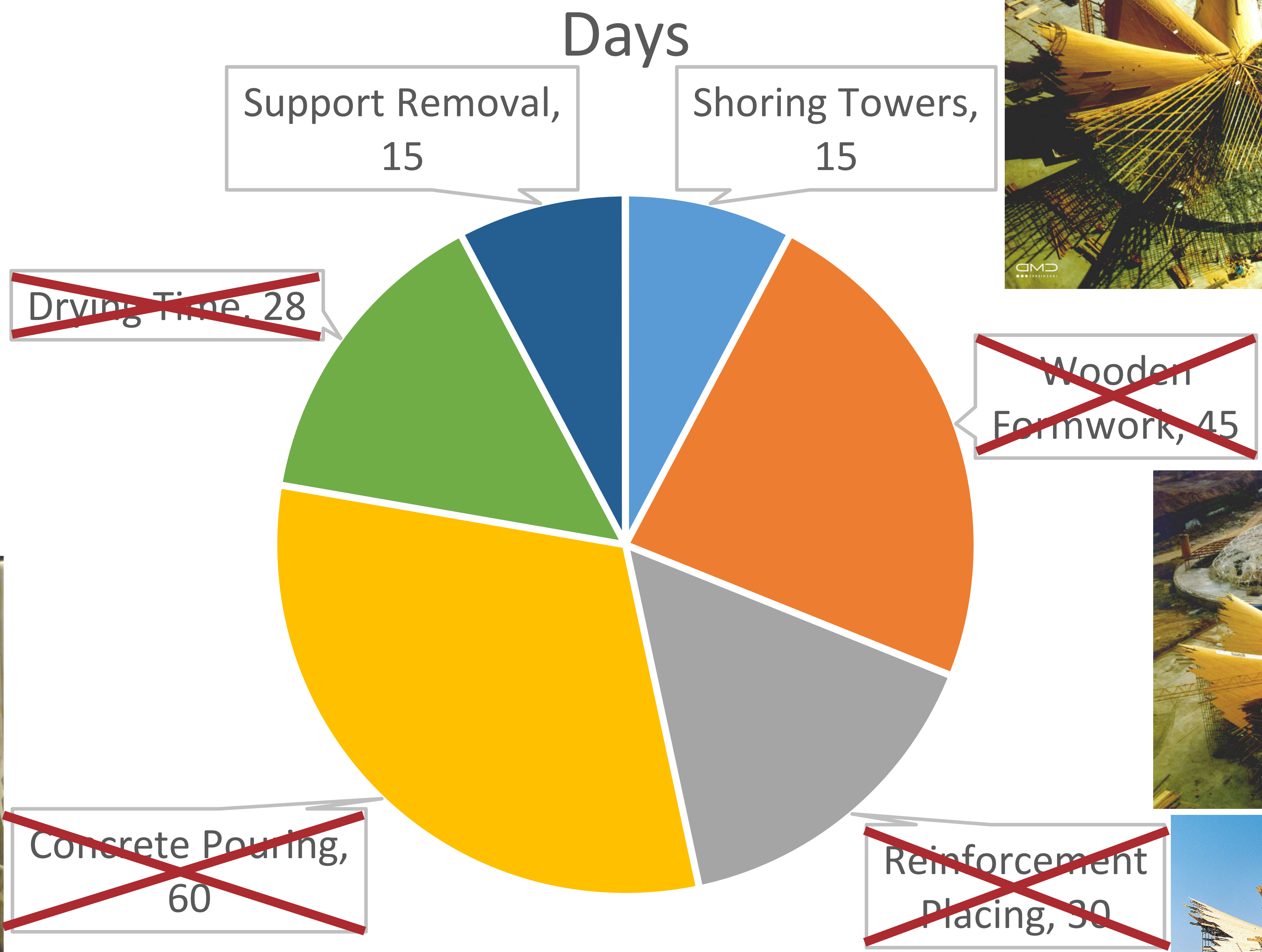


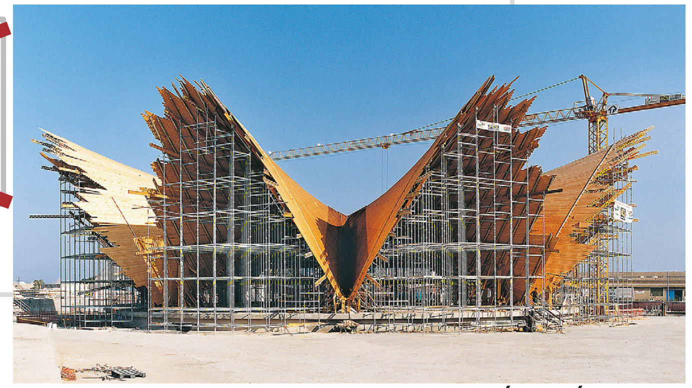


Total: 65 days

CONSTRUCTION TIME

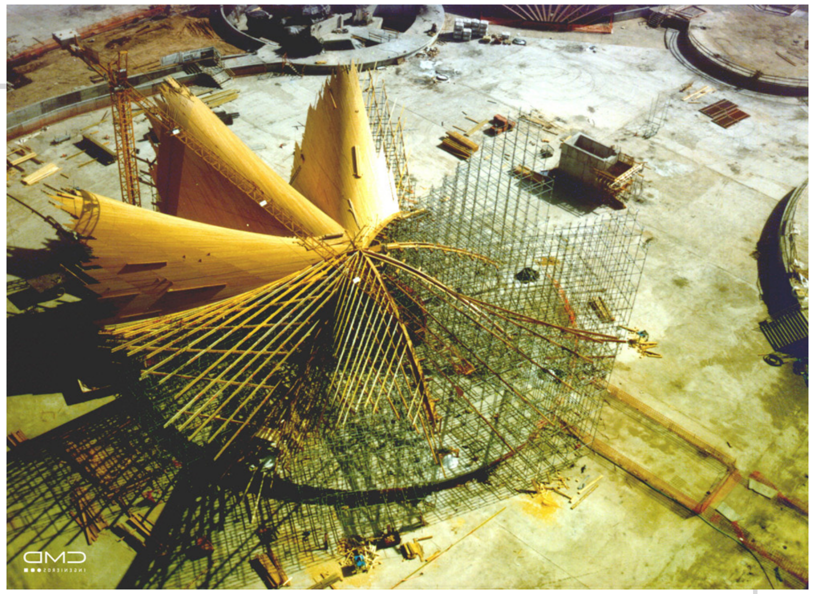


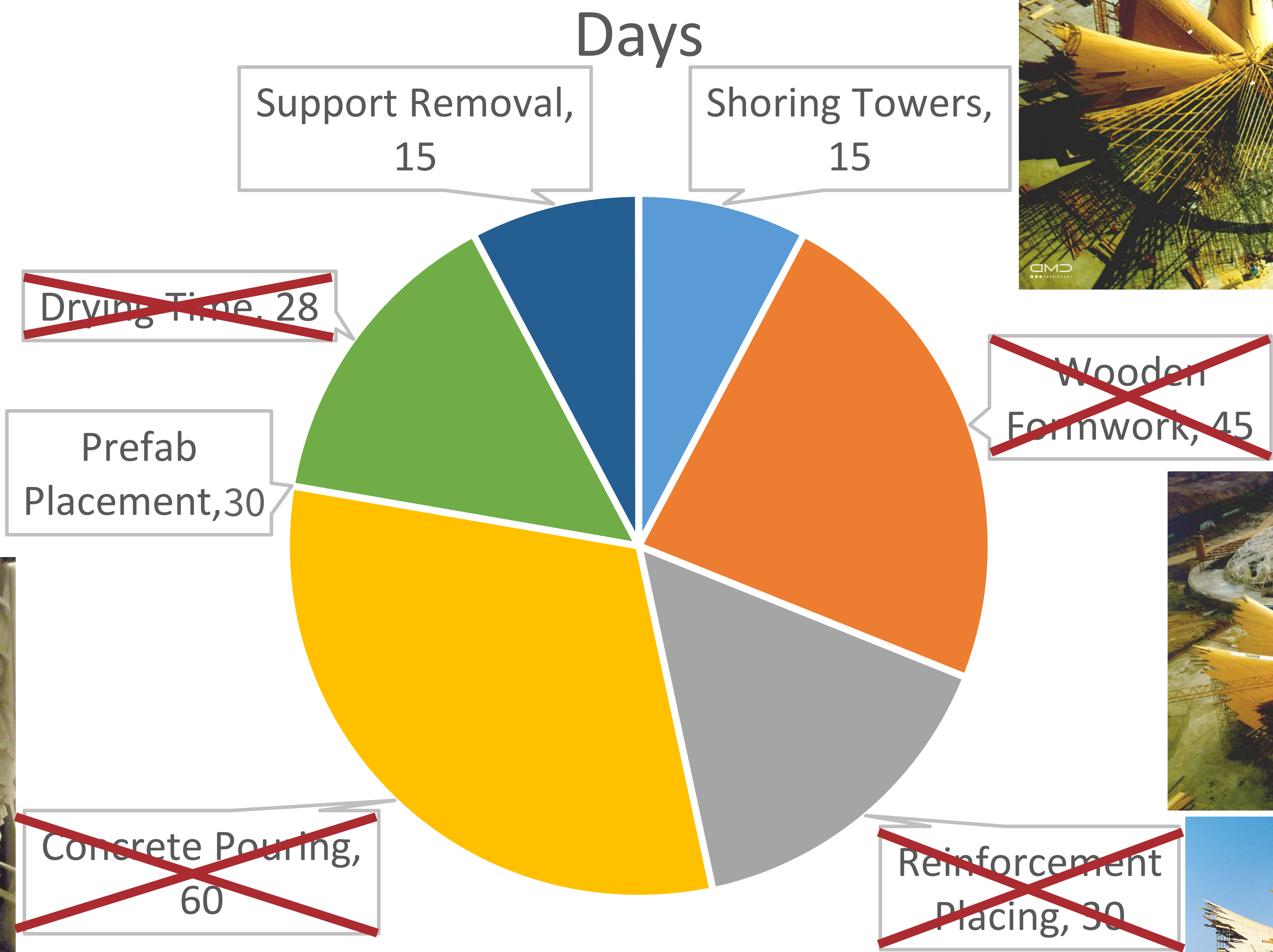


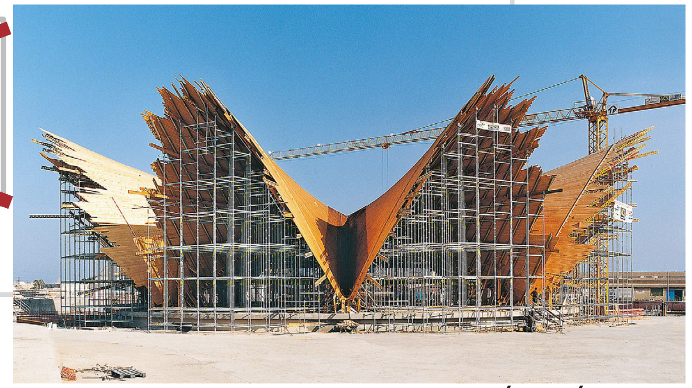


Total: 30 days

CONSTRUCTION TIME

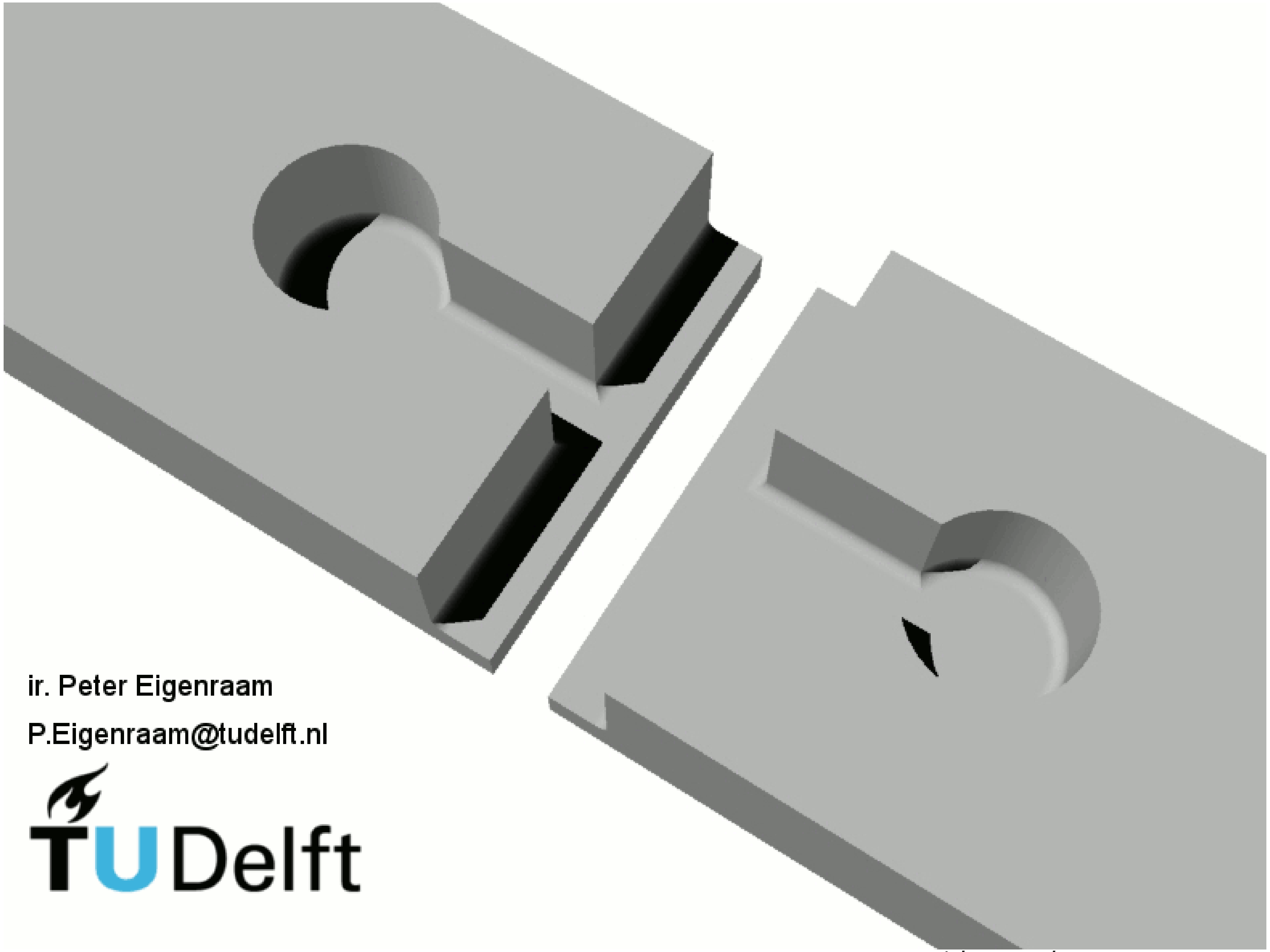






Total: 60 days

CONNECTION



ir. Peter Eigenraam

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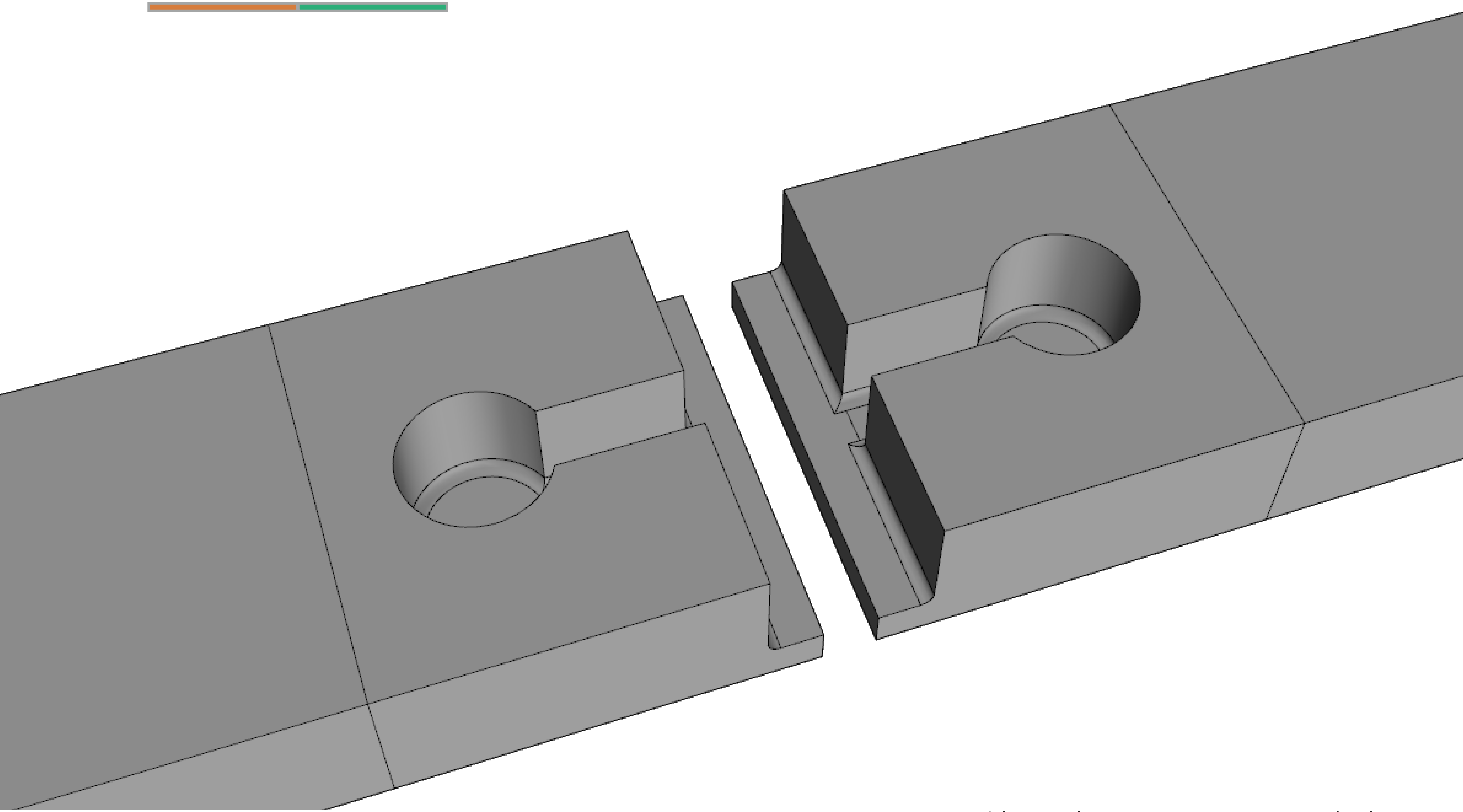
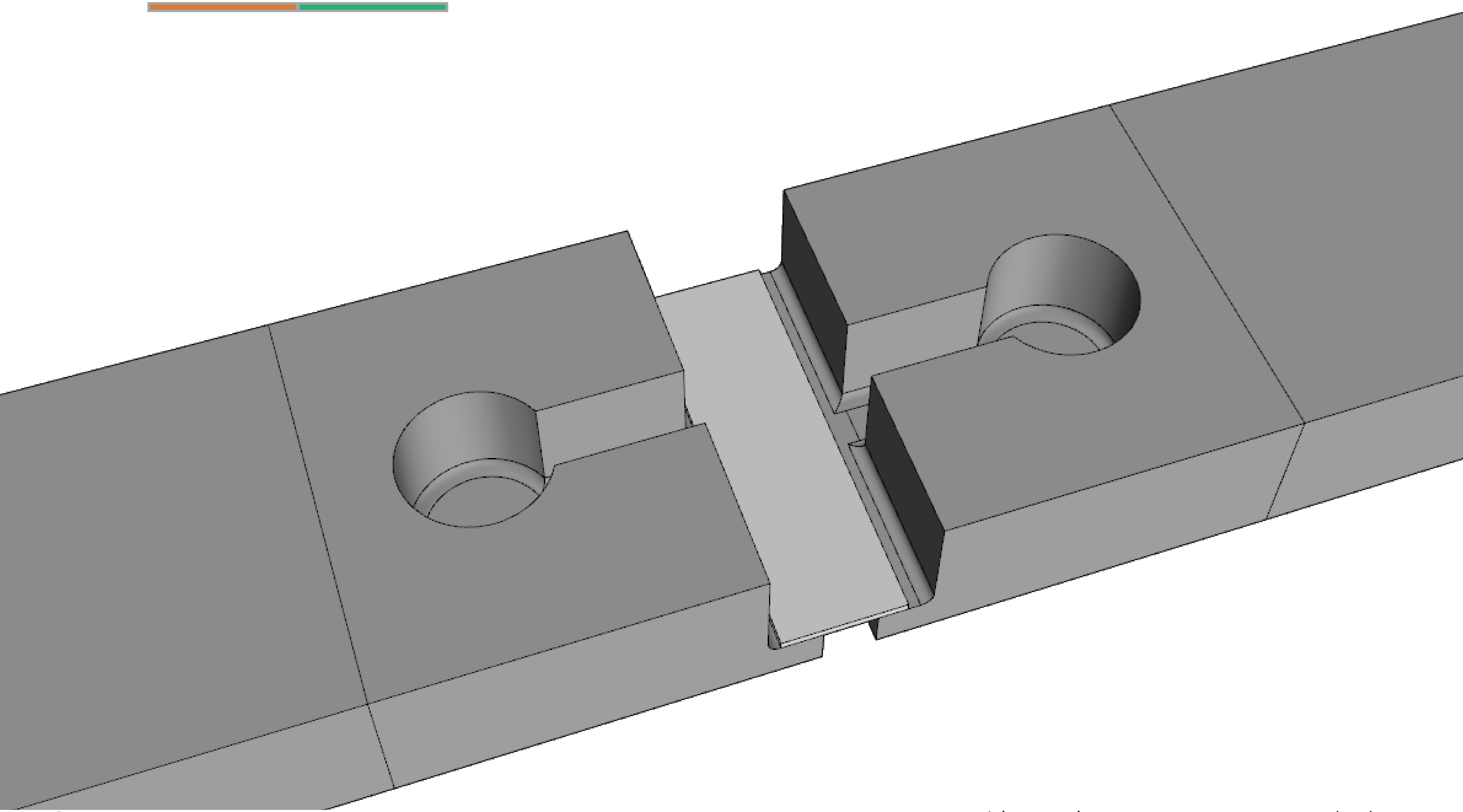
TU Delft

COUNTERTOP CONNECTOR



COUNTERTOP CONNECTOR



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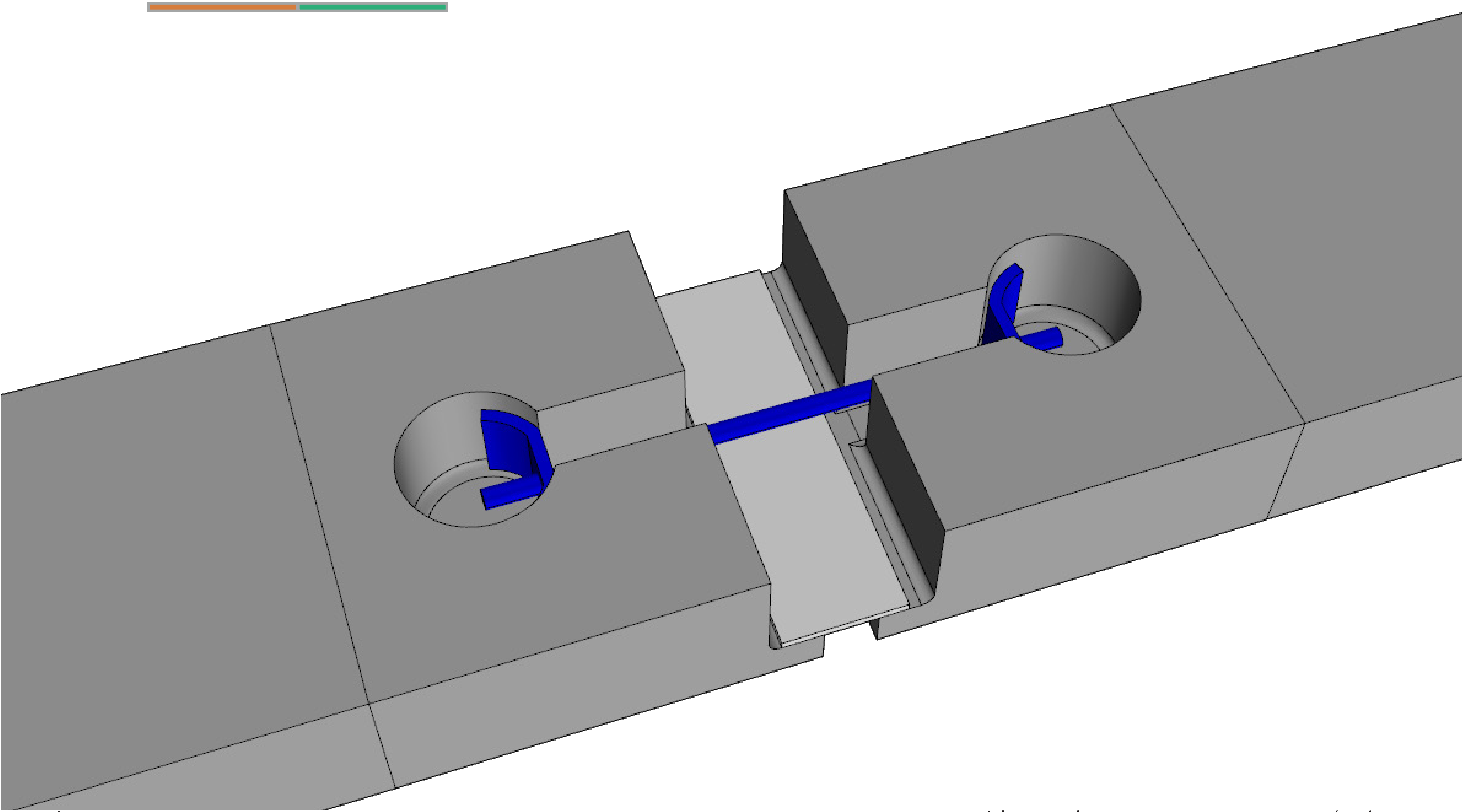

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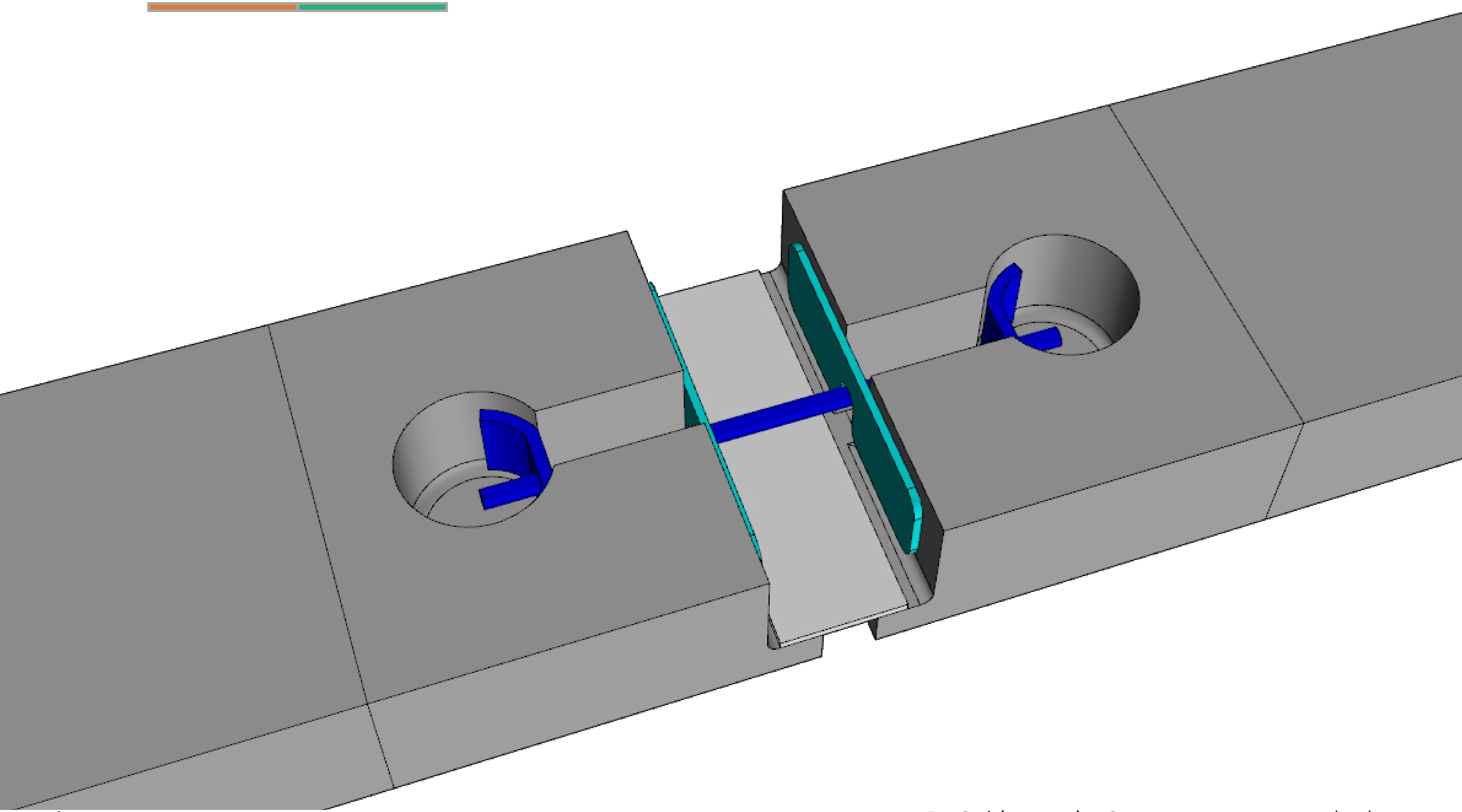

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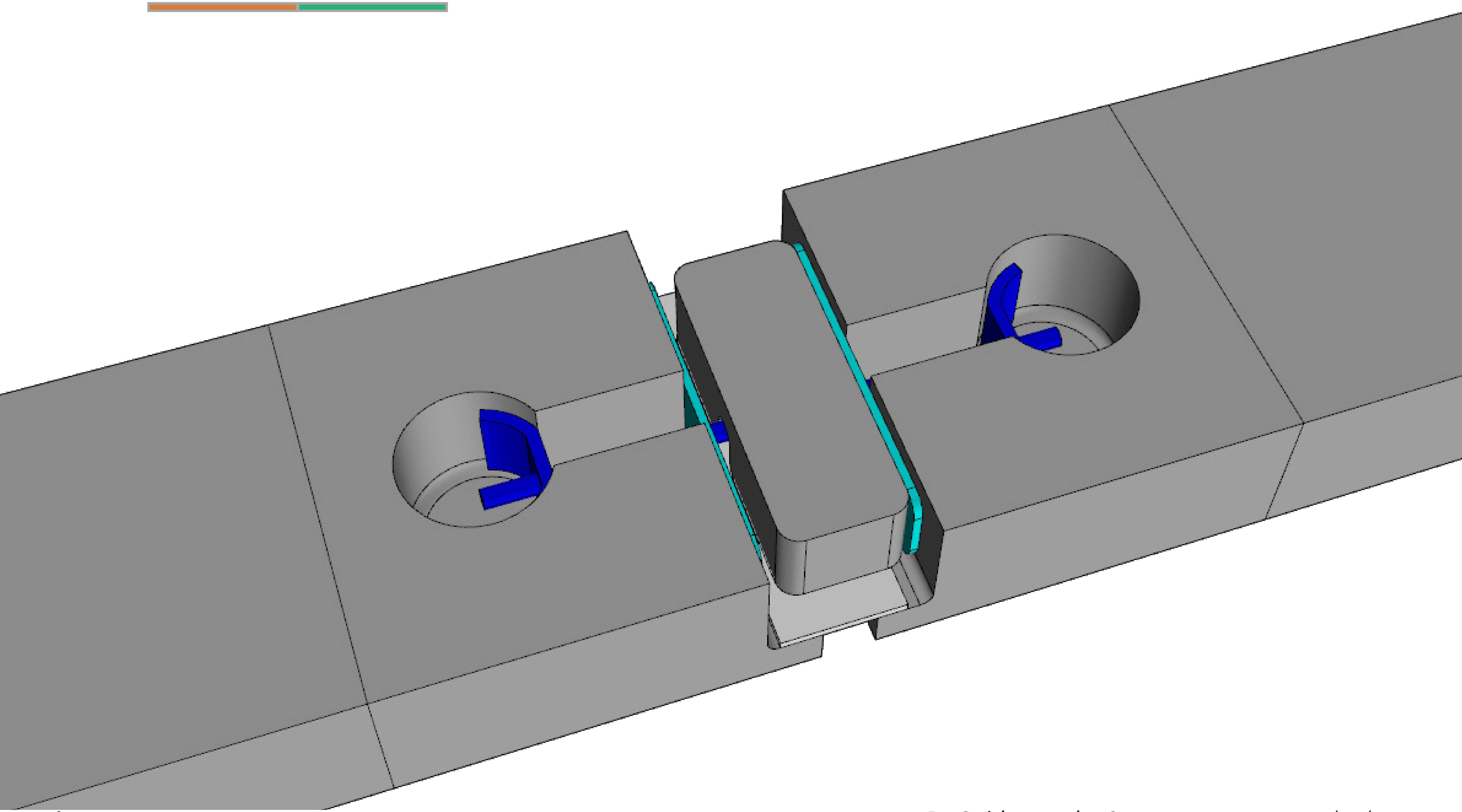

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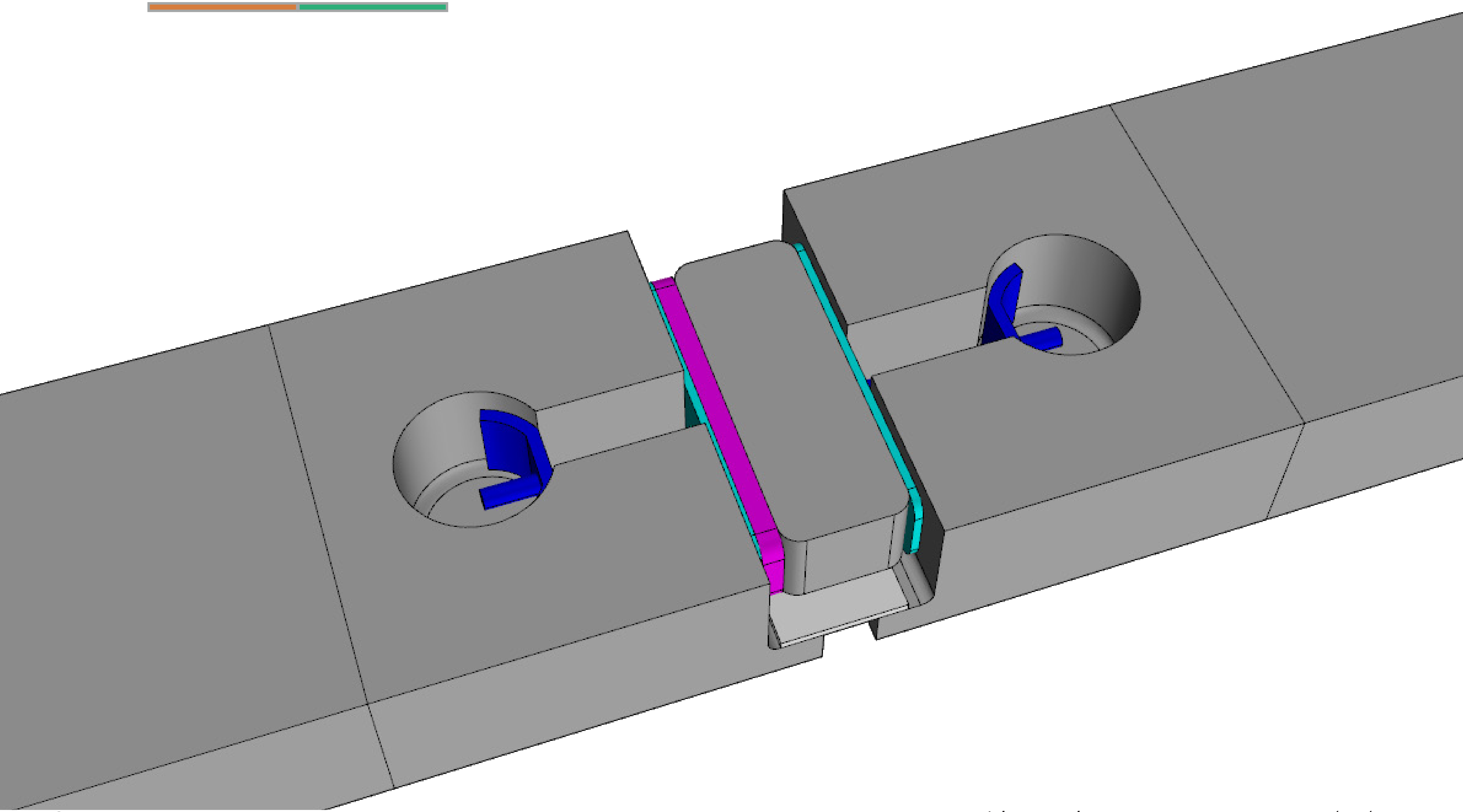

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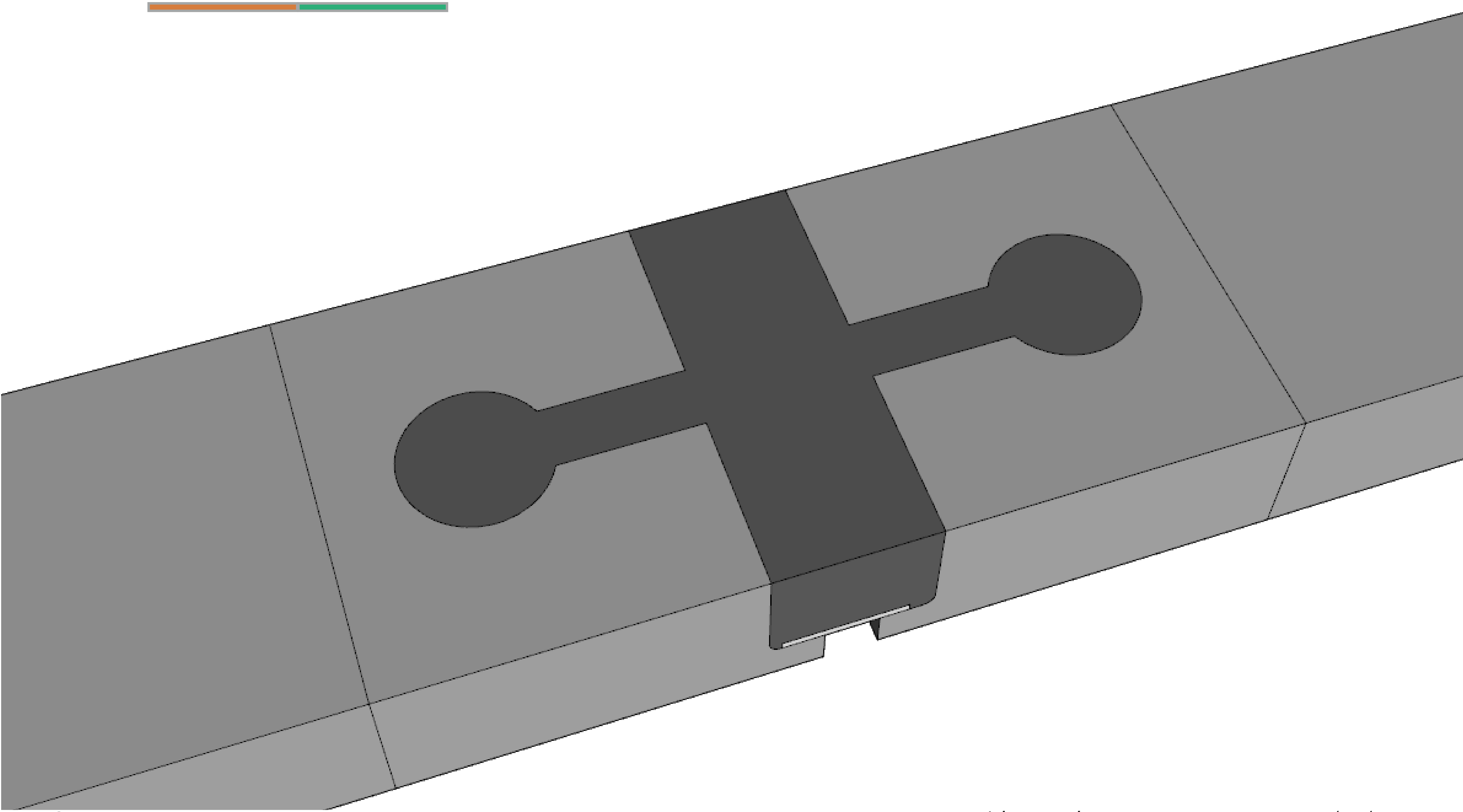
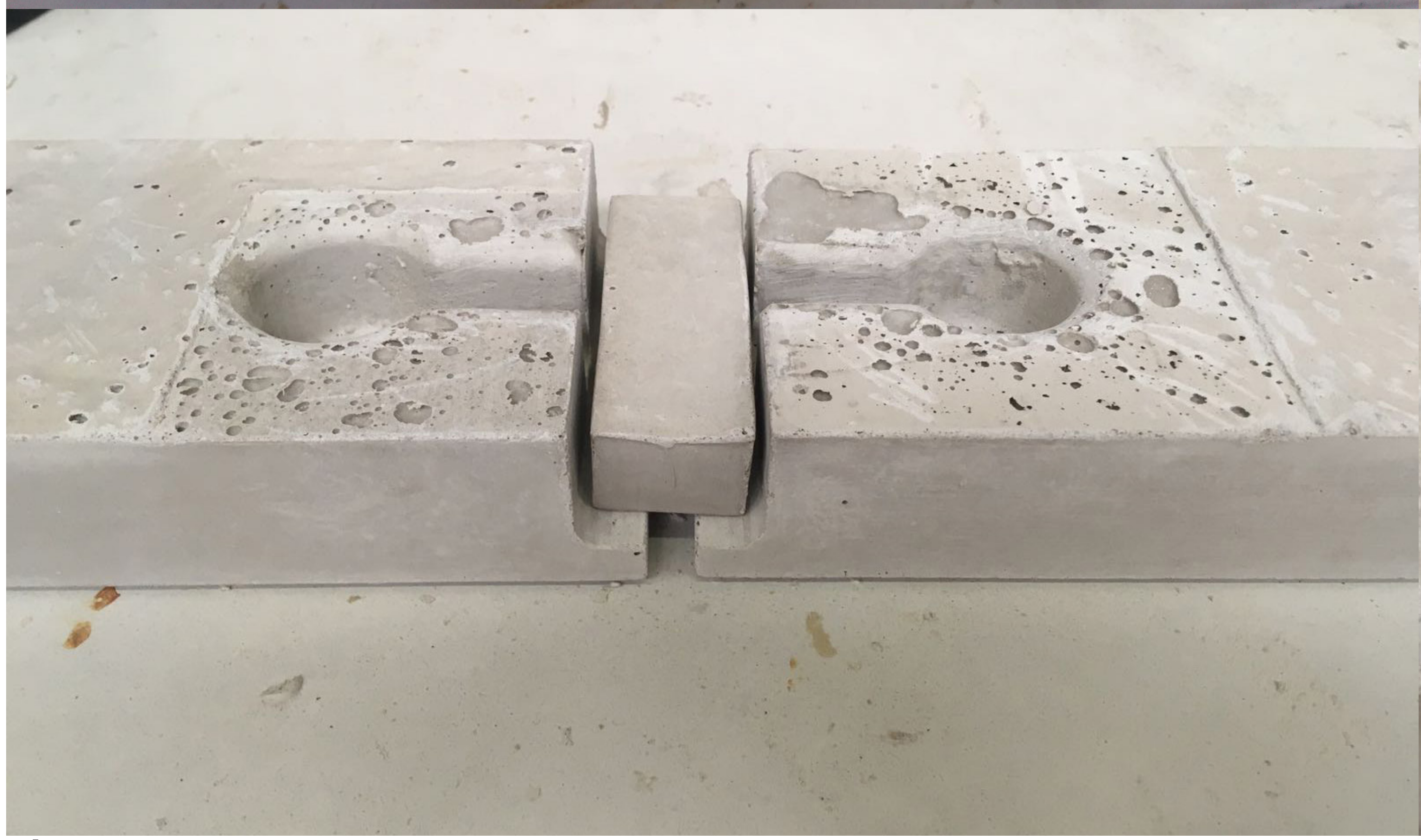
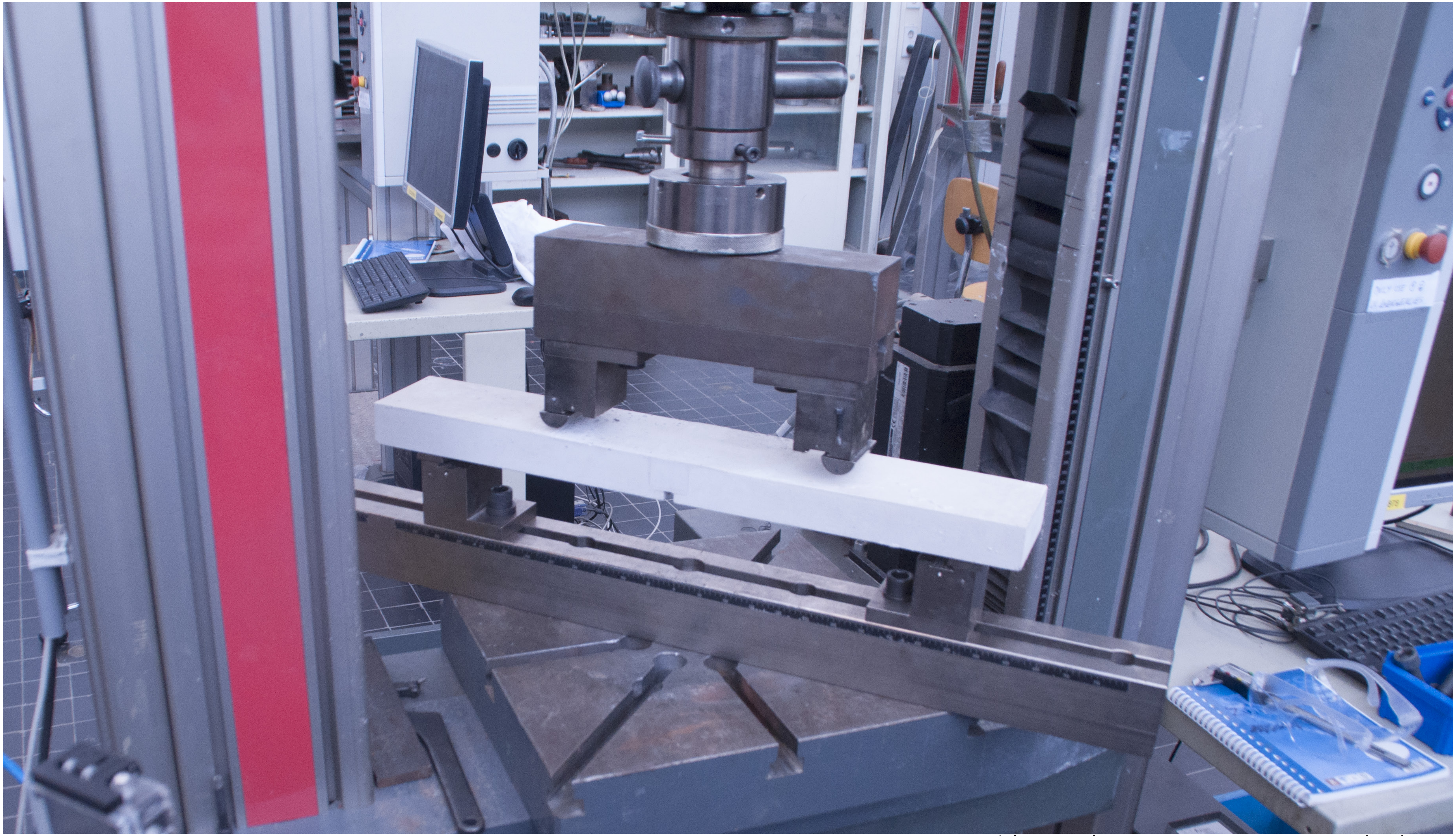


PROTOTYPE PRODUCTION

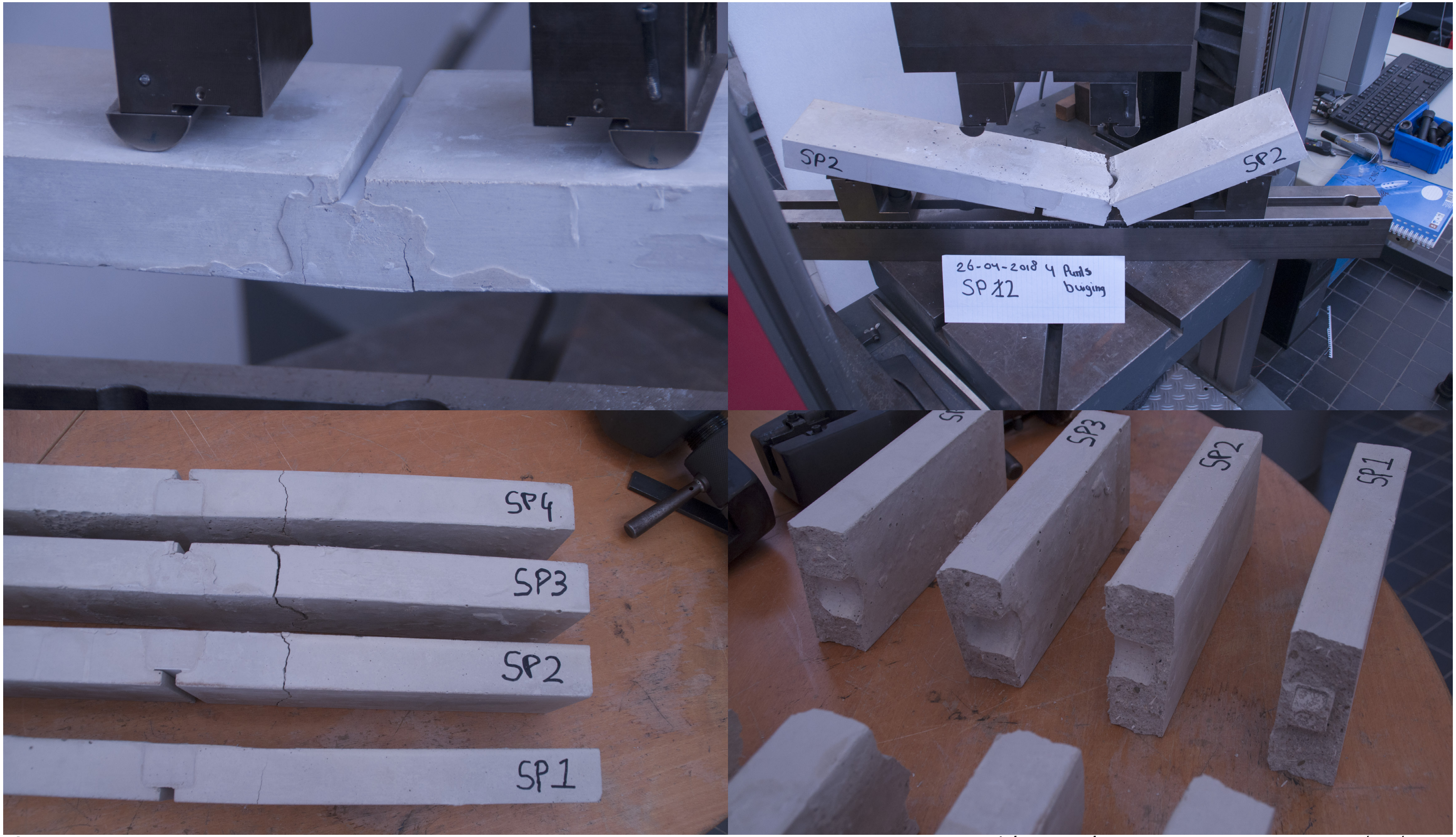


PROTOTYPE PRODUCTION

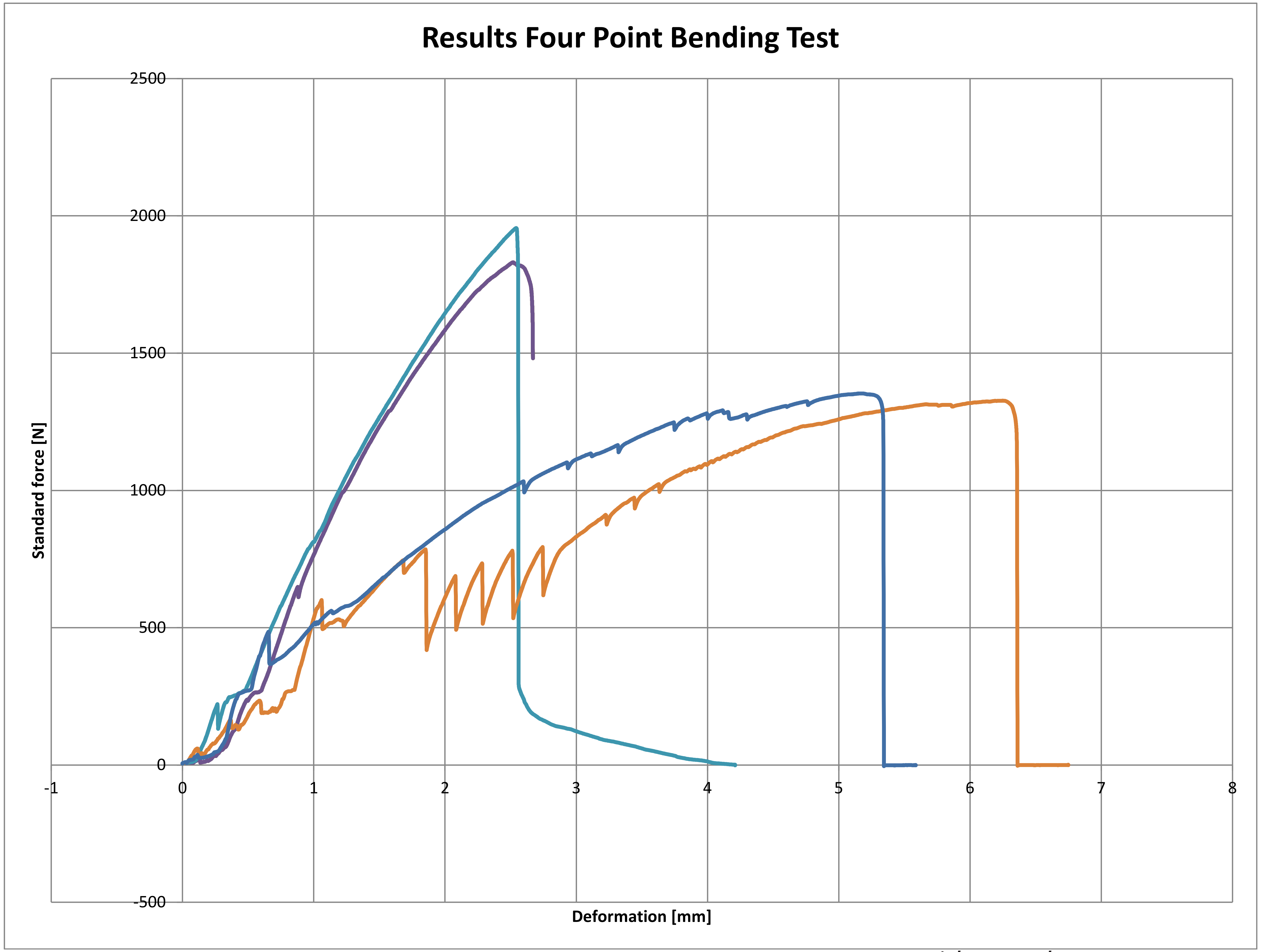
TESTING



RESULTS

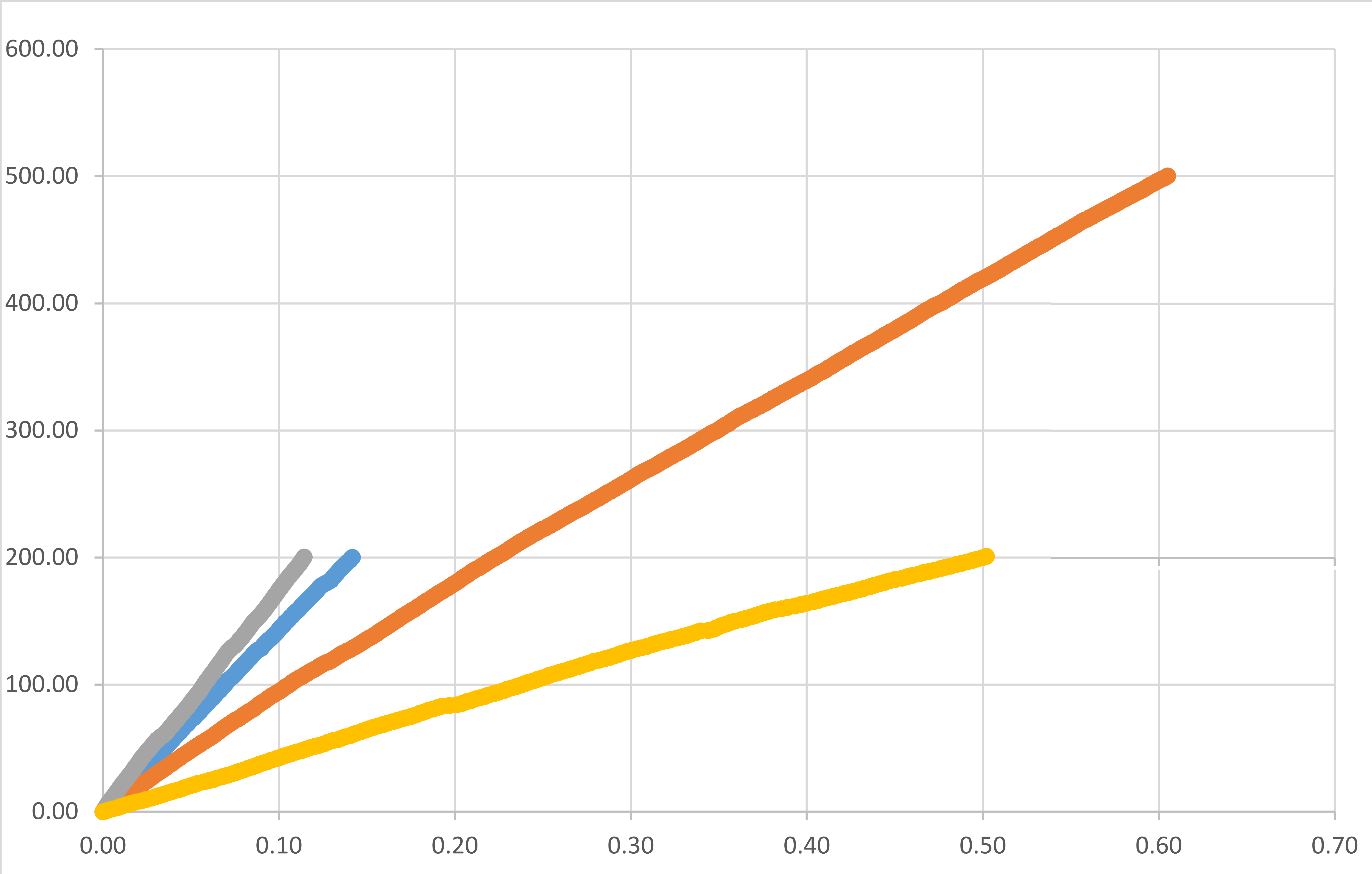


RESULTS



Results Four Point Bending Test
Standard force [N]
2500
2000
1500
1000
500
0
-500
-1
0
1
2
3
4
5
6
7
8
Deformation [mm]

RESULTS COMPARISON



K-CONSTANT CALCULATION

$$\theta_B^{AB} + \theta_B^{BC} + \Delta\theta_B = 0$$

$$\theta_B^{AB} = \frac{M_B * l}{3EI} - \theta$$

$$\theta_B^{BC} = \frac{M_B * l}{3EI} - \theta$$

$$\Delta\theta_B = \frac{M_B}{k}$$

Subsitueeren geeft:

$$\left(\frac{M_B * l}{3EI} - \theta\right) + \left(\frac{M_B * l}{3EI} - \theta\right) + \left(\frac{M_B}{k}\right) = 0$$

$M_B = R_A * x - F(x-a)$ (Zie afbeelding 1)

$$\theta = 2\frac{\omega_B}{l}$$

Subsitueeren geeft:

$$\frac{\big(R_A * x - F(x-a)\big) * l}{3EI} - 2\frac{\omega_B}{l} + \frac{\big(R_A * x - F(x-a)\big) * l}{3EI} - 2\frac{\omega_B}{l} + \frac{\big(R_A * x - F(x-a)\big)}{k} = 0$$

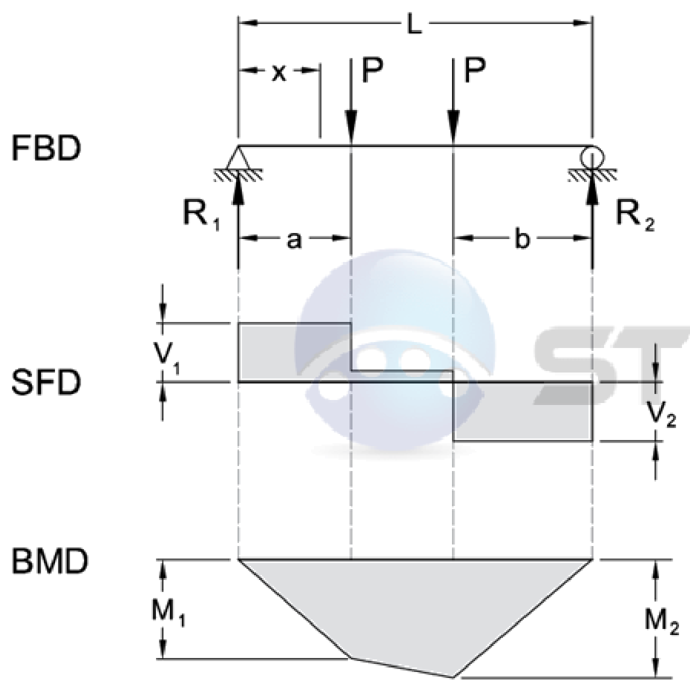
Veerconstante naar een kant halen geeft:

$$2\left(\frac{\big(R_A * x - F(x-a)\big) * l}{3EI} - \frac{2 * \omega_B}{l}\right) = -\frac{\big(R_A * x - F(x-a)\big)}{k}$$

$$k = -\frac{\big(R_A * x - F(x-a)\big)}{2\left(\frac{\big(R_A * x - F(x-a)\big) * l}{3EI} - 2\frac{\omega_B}{l}\right)}$$

$$R_A = \frac{F}{l}(l - a + b)$$

$$k = -\frac{\left(\frac{F}{l}(l-a+b) * x - F(x-a)\right)}{2\left(\frac{\left(\frac{F}{l}(l-a+b) * x - F(x-a)\right) * l}{3EI} - 2\frac{\omega_B}{l}\right)}$$



$R_1 = V_1$ (max when $a < b$) . . . . $= \frac{P}{L}(L - a + b)$

$R_2 = V_2$ (max when $a < b$) . . . . $= \frac{P}{L}(L - b + a)$

$V_x\ (a < x < (L - b))$ . . . . $= \frac{P}{L}(b - a)$

M_1 (max. when $a > b$) . . . . $= R_1 a$

M_2 (max. when $a < b$) . . . . $= R_2 b$

M_x (max. when $x < a$) . . . . $= R_1 x$

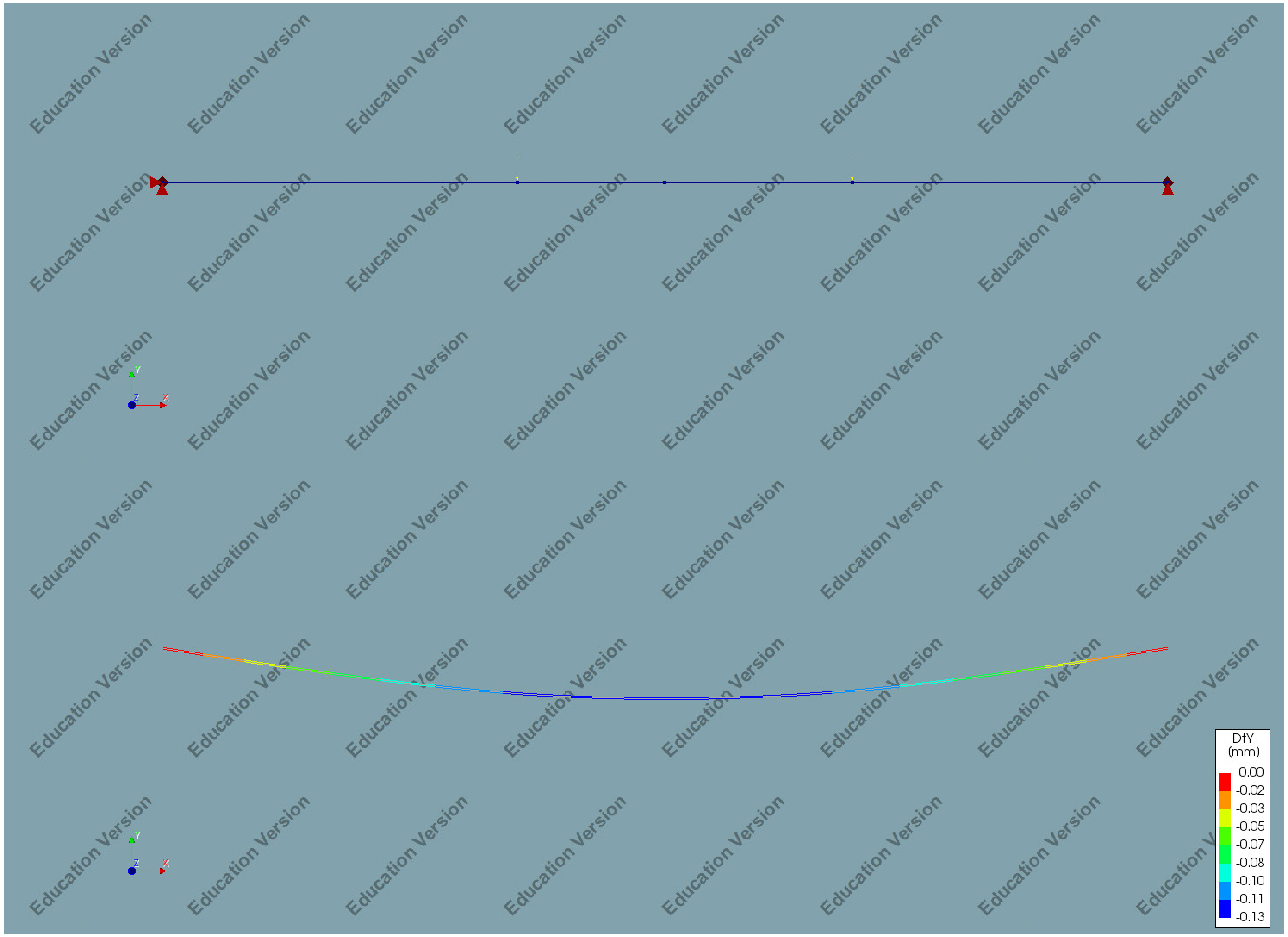
M_x (max. when $a < x < (L - b)$) . . . . $= R_1 x - P(x - a)$

K-Constant (spring stiffness)

=

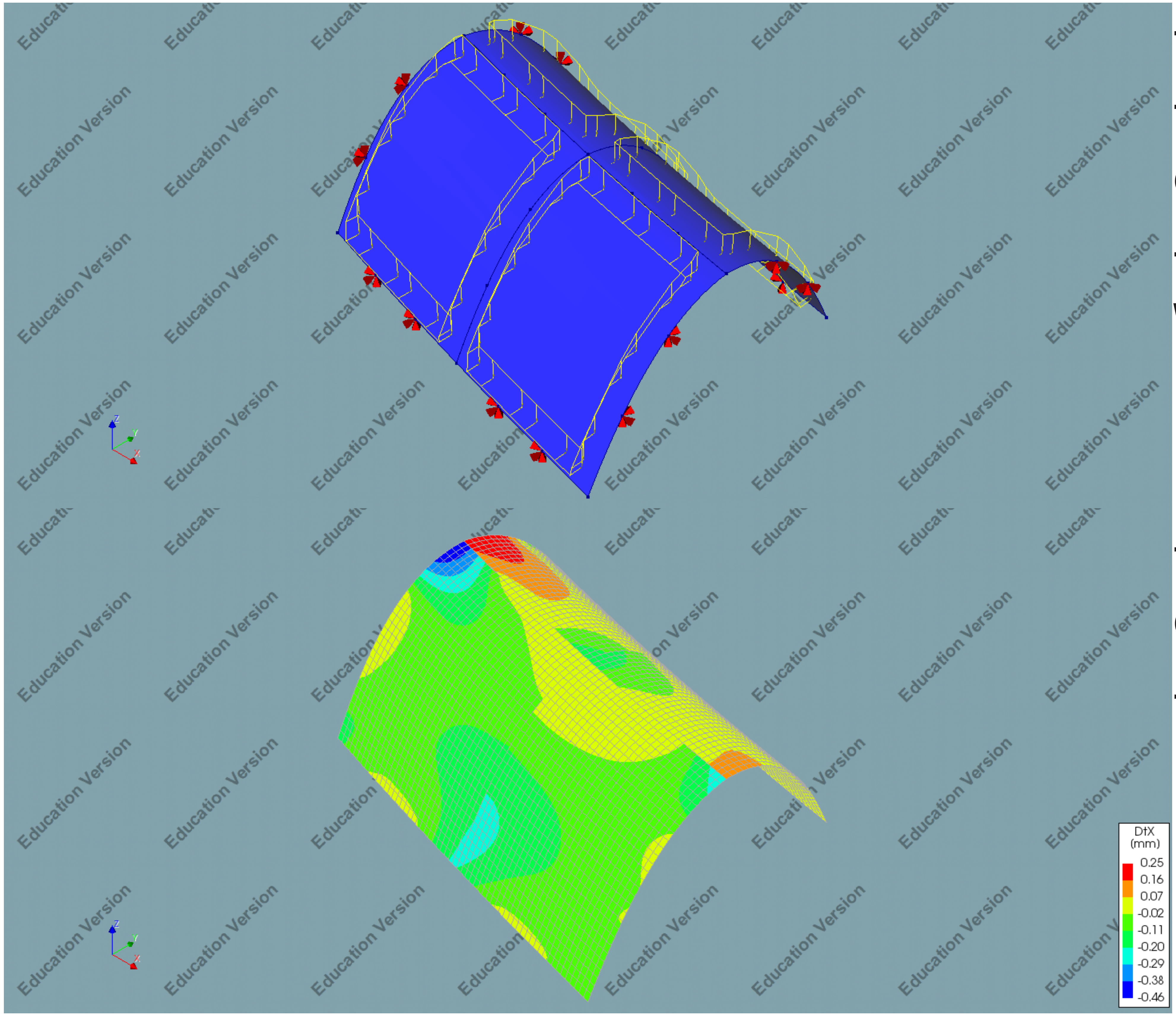
10702026.94 N/mm

VERIFYING RESULTS



	Test 1	Test 2	DIANA
Applied Force	200.7787	200.092	200.347
Deformation	0.143249	0.192506	0.13104

VERIFYING RESULTS



- 4 Segments
- 2 Connections per edge
- Own weight and Windload

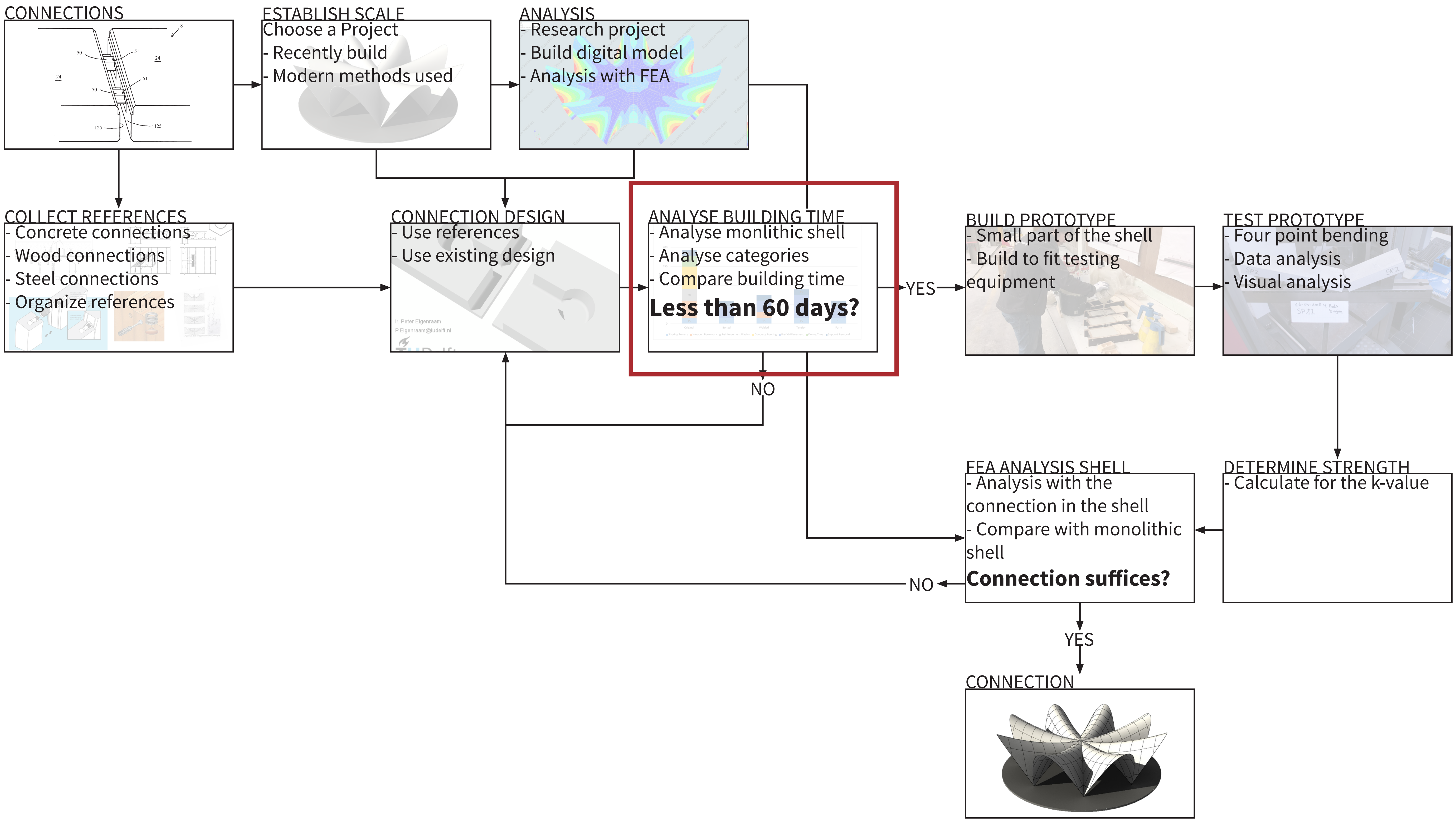
- Deformation at the corners
- Max 0.46 mm

CONCLUSION

How can we prove that a connection is suitable for use in a segmented prefabricated shell structure?

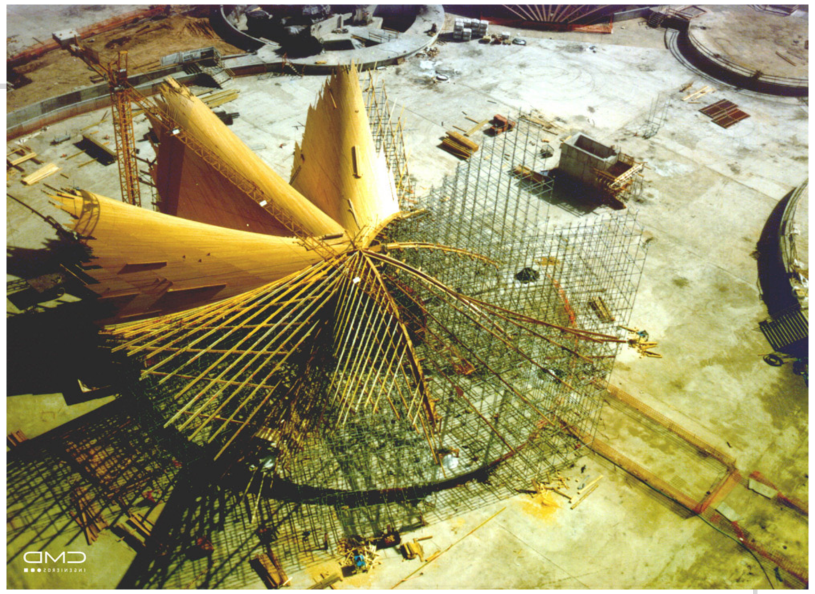
- Which demands are made for a connections in a segmented prefabricated shell structure?
- How can we test the strength of a connection?
- How can we implement a connection in a digital model?

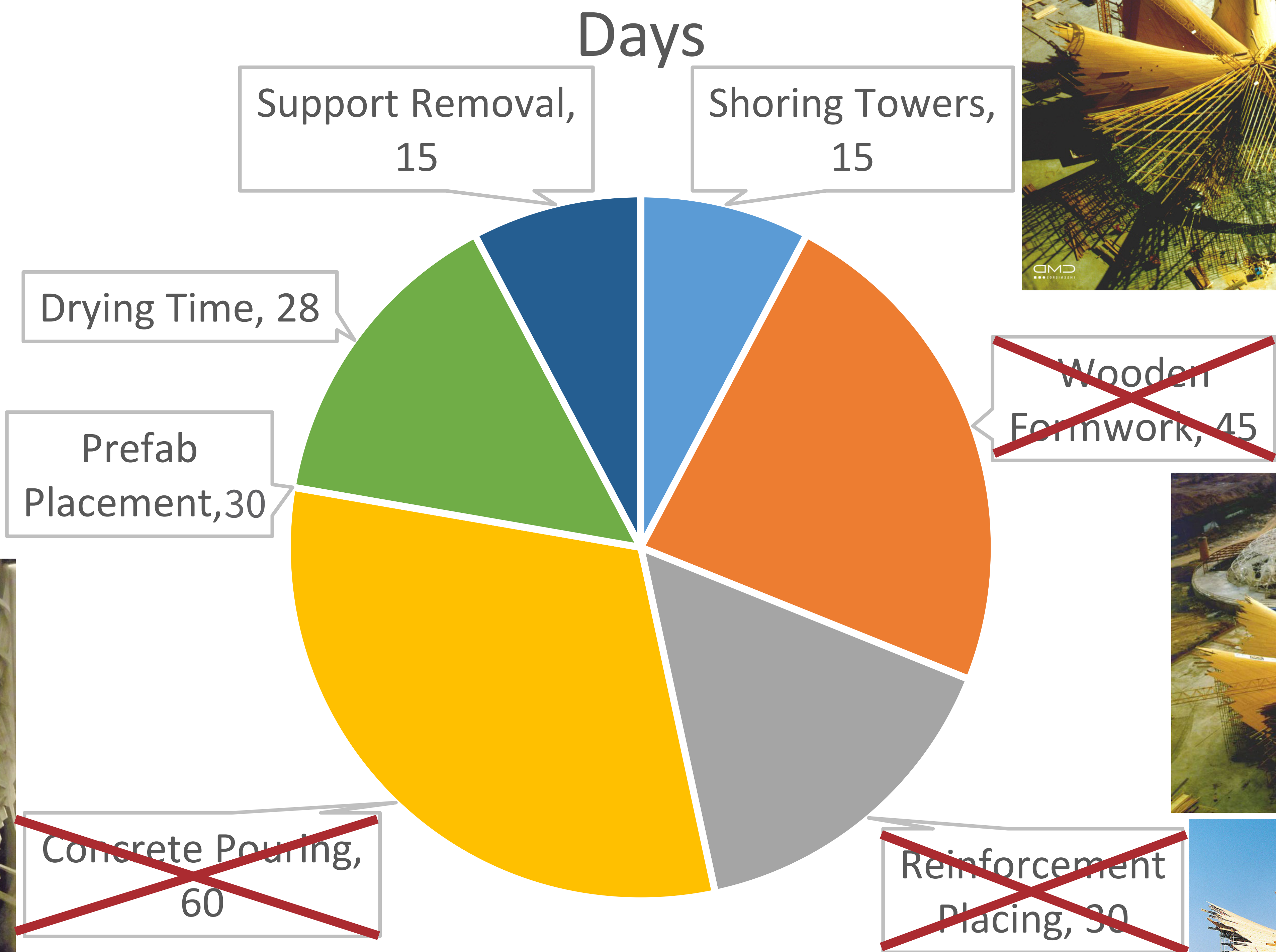
CONCLUSION



CONNECTIONS
ESTABLISH SCALE
Choose a Project
- Recently build
- Modern methods used
ANALYSIS
- Research project
- Build digital model
- Analysis with FEA
COLLECT REFERENCES
- Concrete connections
- Wood connections
- Steel connections
- Organize references
CONNECTION DESIGN
- Use references
- Use existing design
ANALYSE BUILDING TIME
- Analyse monlithic shell
- Analyse categories
- Compare building time
Less than 60 days?
NO
YES
BUILD PROTOTYPE
- Small part of the shell
- Build to fit testing equipment
TEST PROTOTYPE
- Four point bending
- Data analysis
- Visual analysis
FEA ANALYSIS SHELL
- Analysis with the connection in the shell
- Compare with monolithic shell
Connection suffices?
NO
YES
DETERMINE STRENGTH
- Calculate for the k-value
CONNECTION

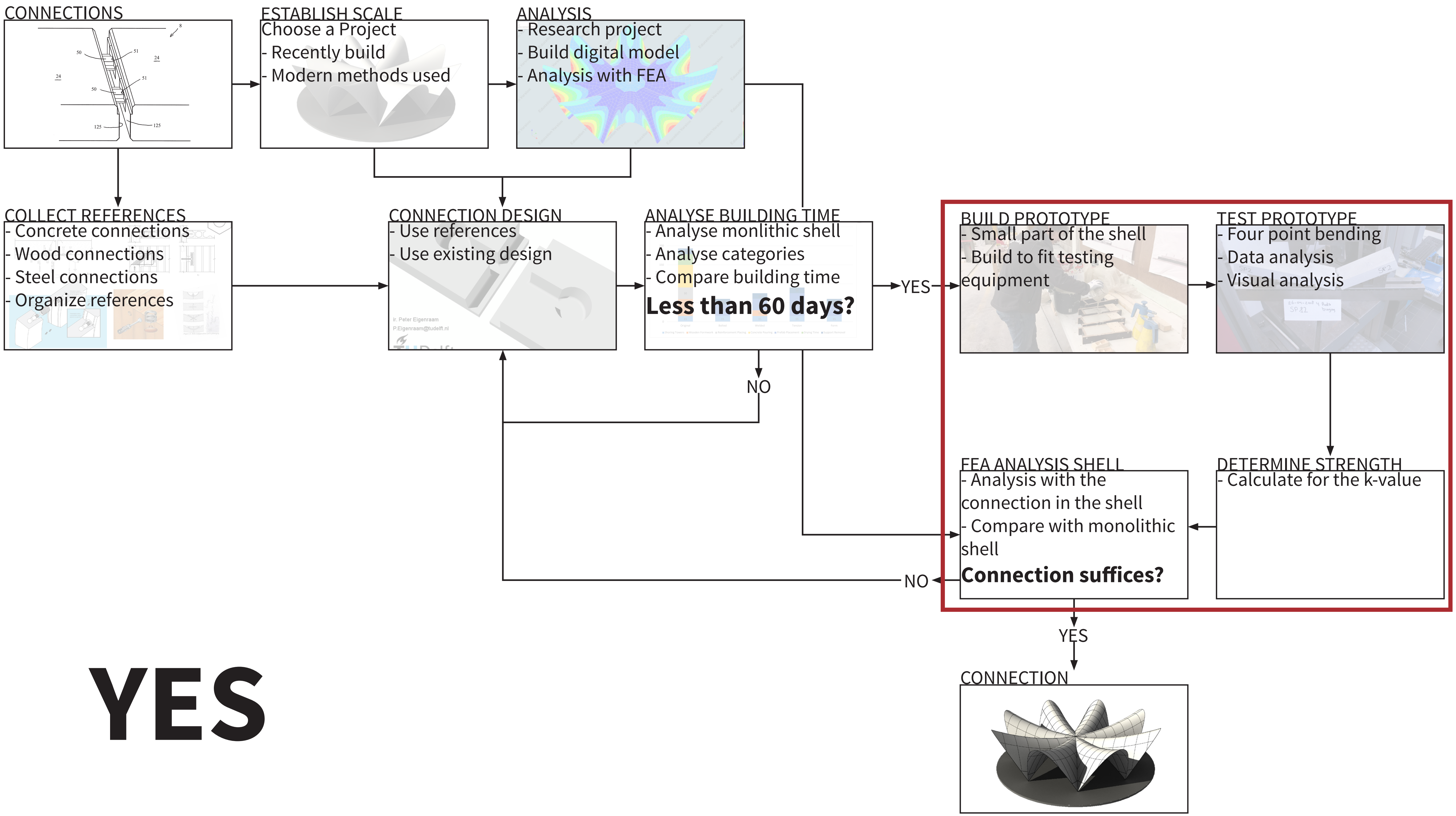
CONSTRUCTION TIME





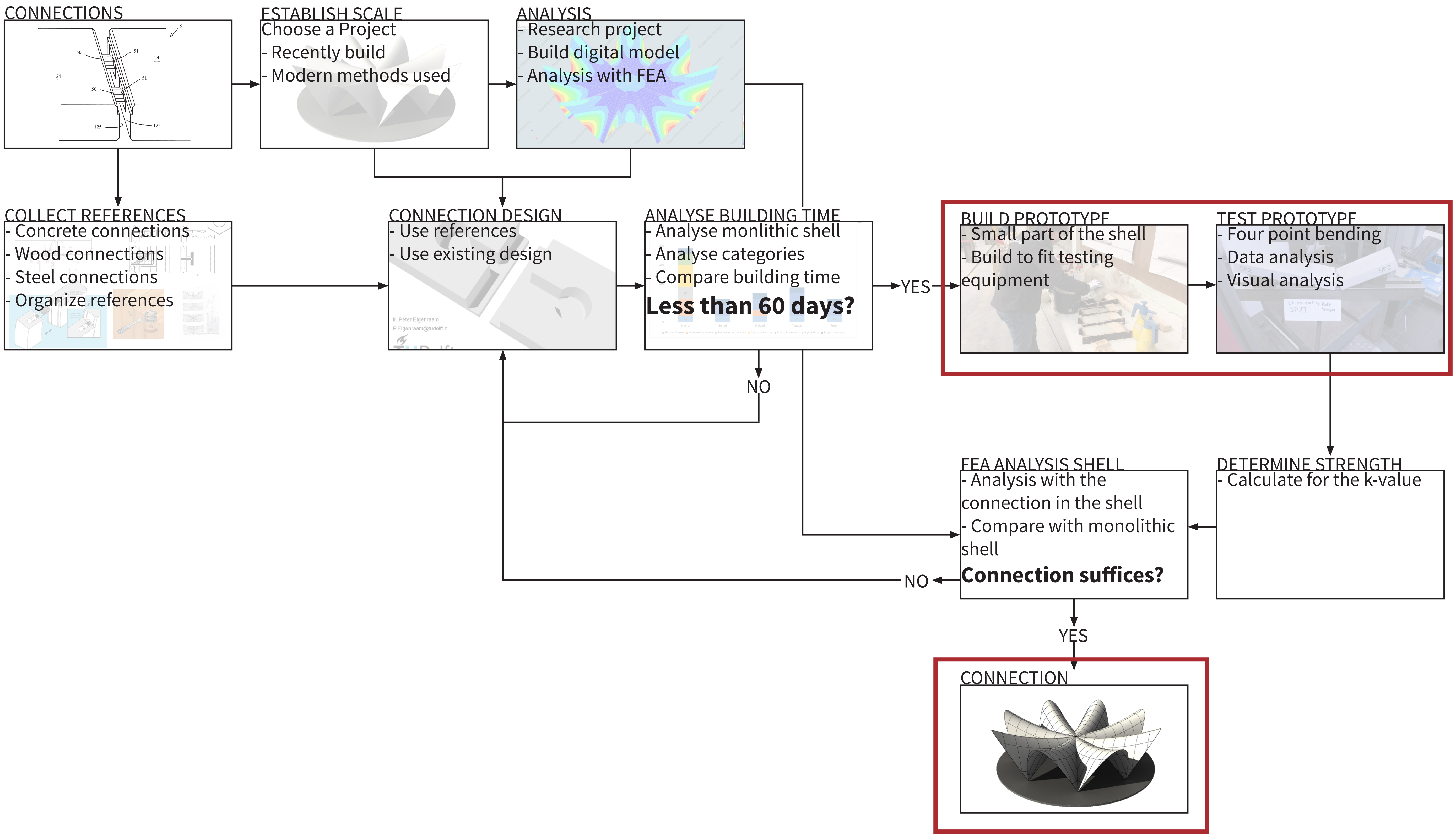
Total: 88 days

CONCLUSION



YES

REFLECTION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- Calculate for the k-value
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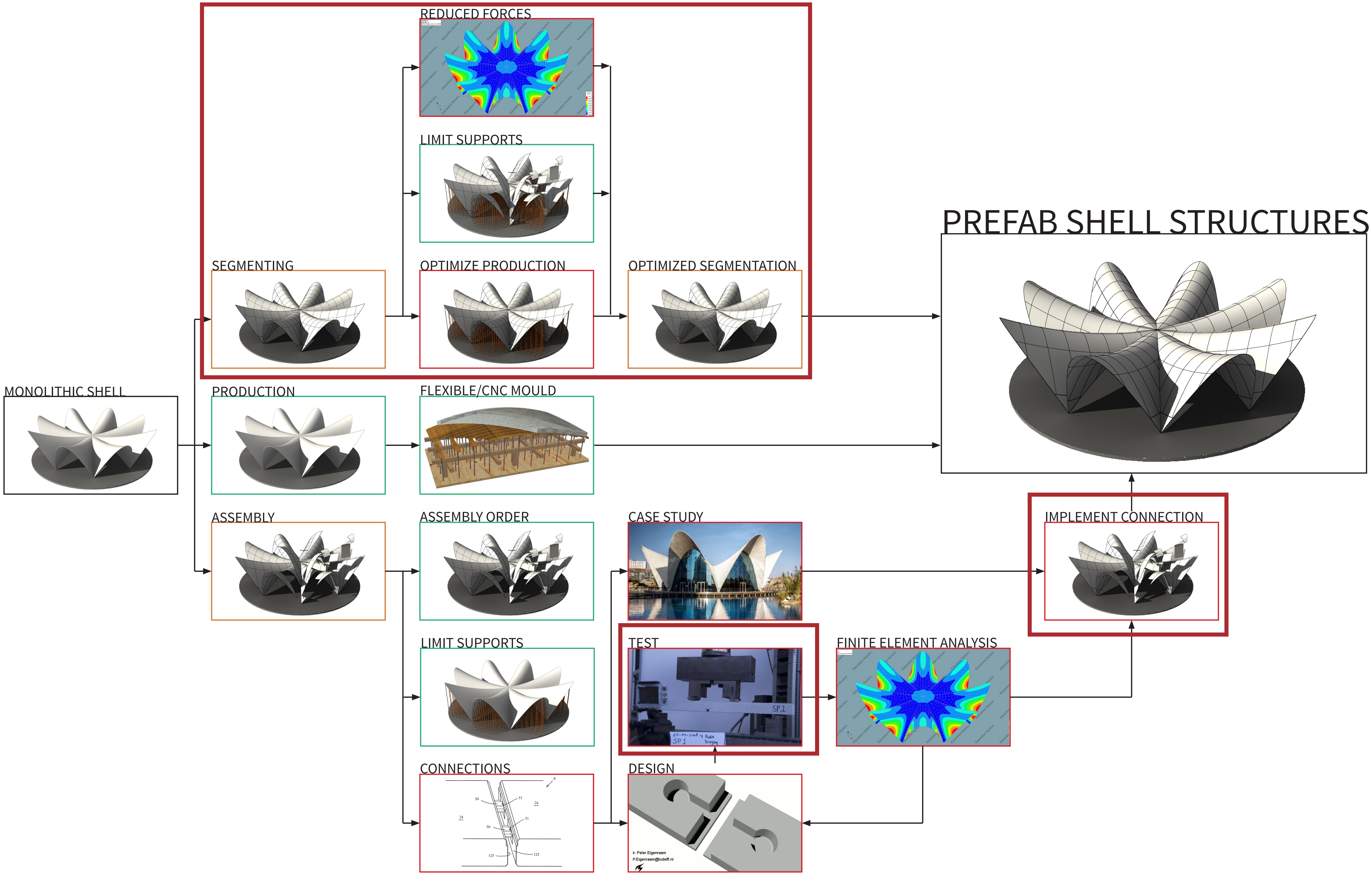
CONNECTION

REFLECTION



REDUCED FORCES
LIMIT SUPPORTS
SEGMENTING
OPTIMIZE PRODUCTION
OPTIMIZED SEGMENTATION
PREFAB SHELL STRUCTURES
MONOLITHIC SHELL
PRODUCTION
FLEXIBLE/CNC MOULD
ASSEMBLY
ASSEMBLY ORDER
CASE STUDY
IMPLEMENT CONNECTION
LIMIT SUPPORTS
TEST
FINITE ELEMENT ANALYSIS
CONNECTIONS
DESIGN

QUESTIONS