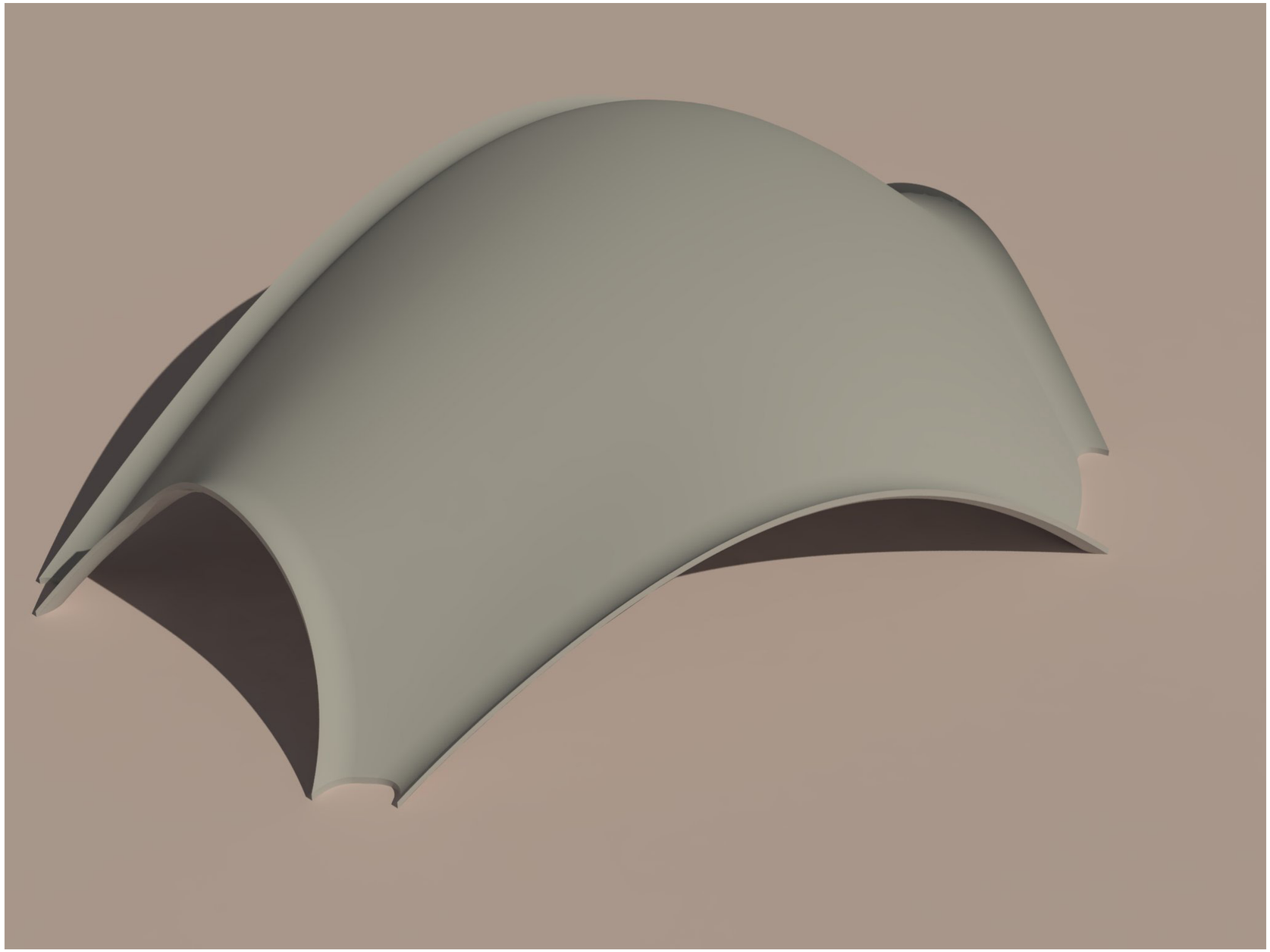
PREFAB SHELL STRUCTURES

CONNECTIONS



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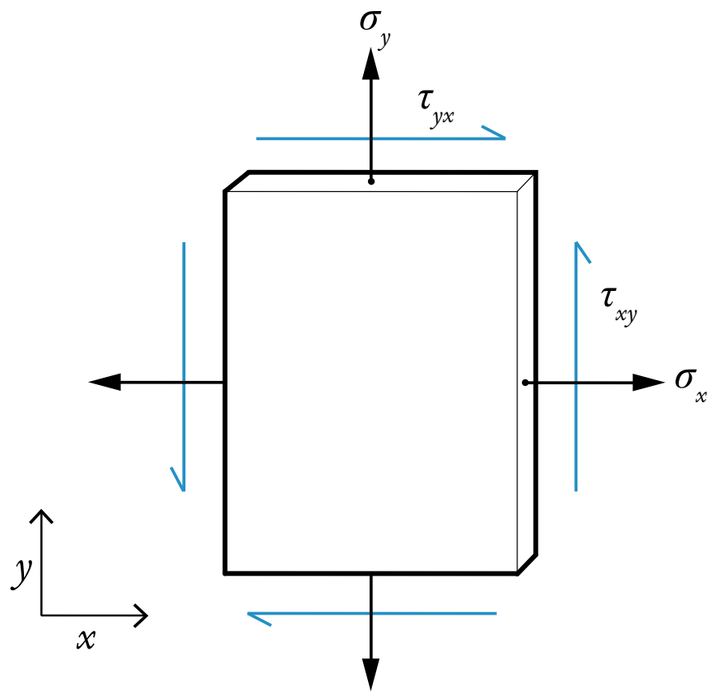
SHELL STRUCTURES

Shell structures are constructed systems described by three-dimensional curved surfaces, in which one dimension is significantly smaller compared to the other two. They are form-passive and resist external loads predominantly through membrane stresses.

(Adriaenssens, Block, Veenendaal, and Williams, 2014)



SAGRADA FAMILIA

DESIGN

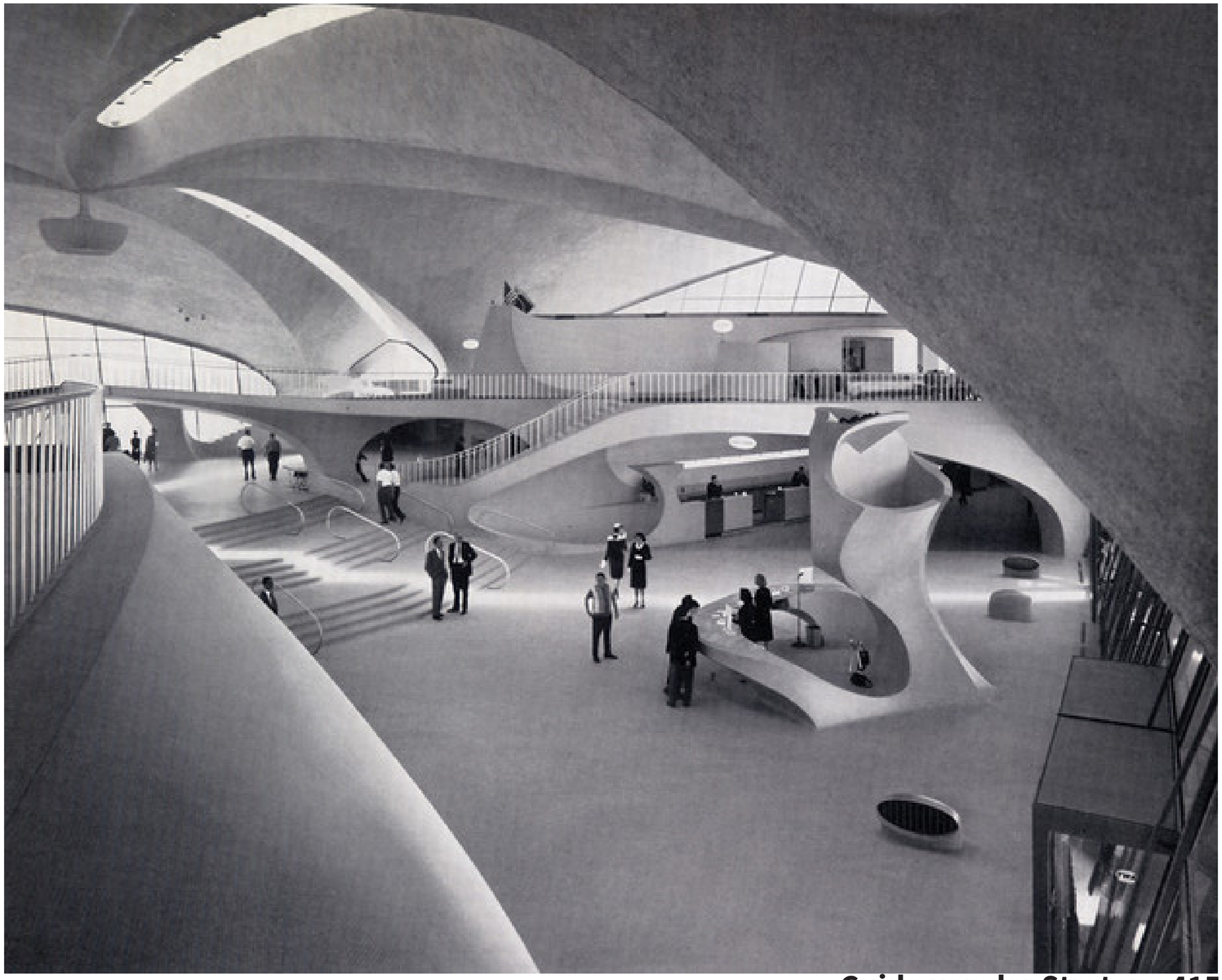
- Antoni Gaudi
- Inspiration from Nature
- Still not finished

SHELLS

- Dome 40m
- 4 Towers of 135m
- 1 Tower of 172,5m
- Construction started 1880

TWA FLIGHT CENTER

INTERIOR



CONSTRUCTION

- Eero Saarinen
- Thickest 100 cm
- 24 meter cantilever
- 4 Columns
- Covers 71.000 m^2

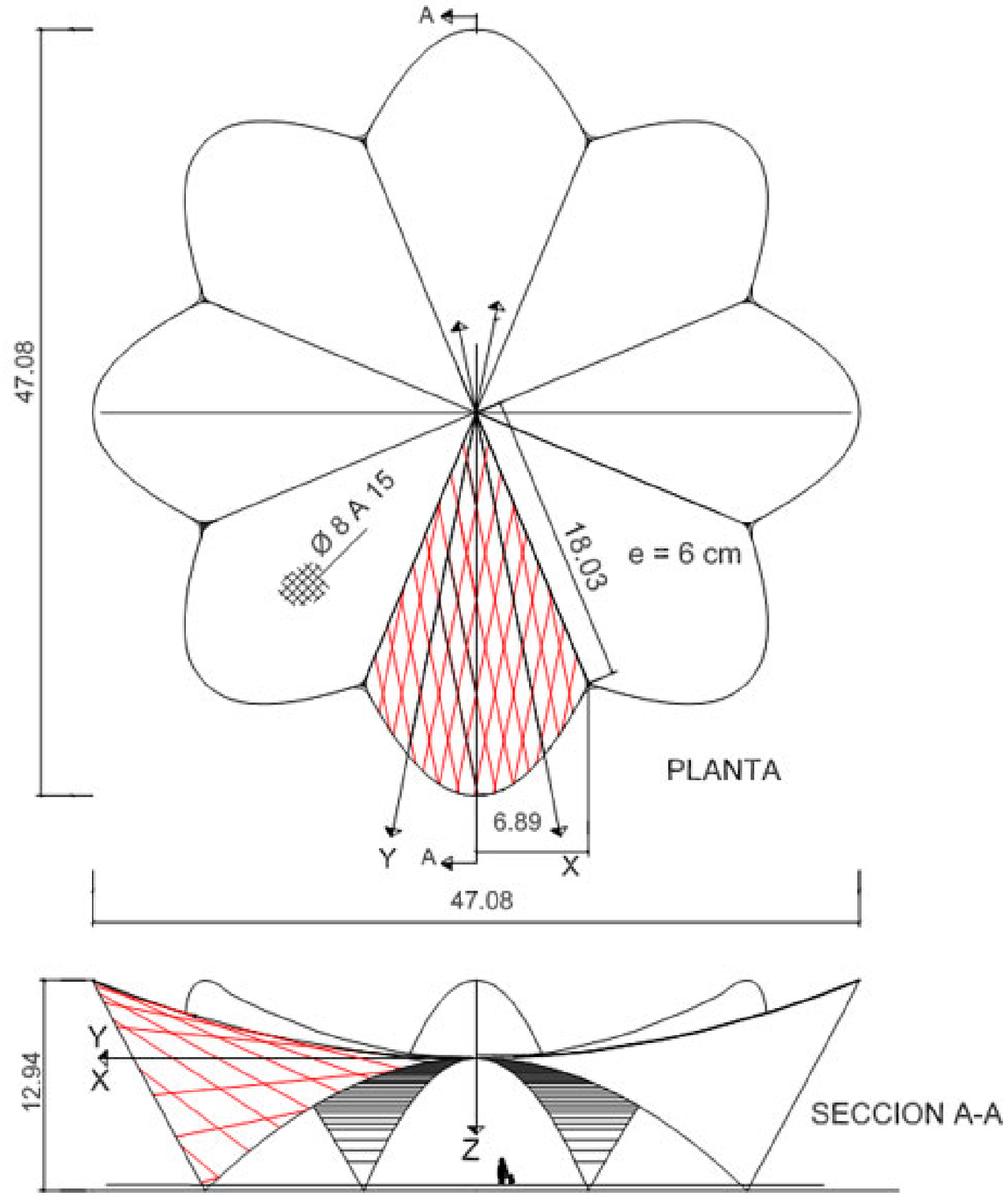
DEITINGEN SERVICE STATION

DEITINGEN SERVICE STATION

- Heinz Isler
- 26 m x 31 m
- 3 supports
- Center few centimeters thick

OCEANOGRAFIC

DESIGN



- Felix Candela
- Span 35.5 m
- Dimensions: 47 x 47 m
- Thickness 6 cm

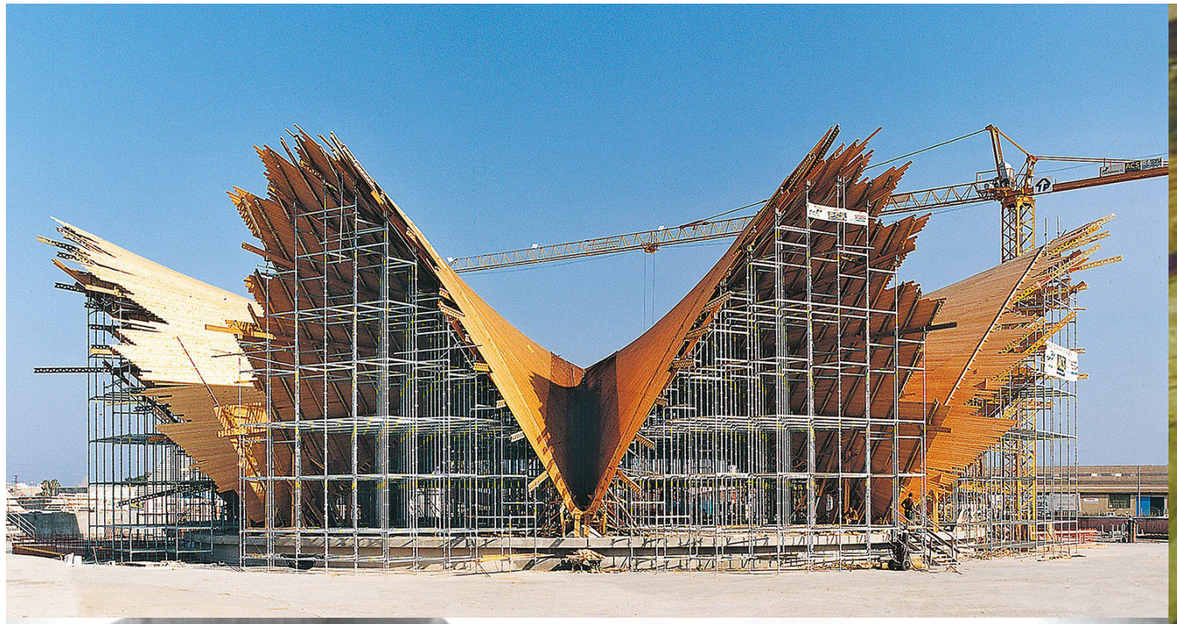
CONSTRUCTION

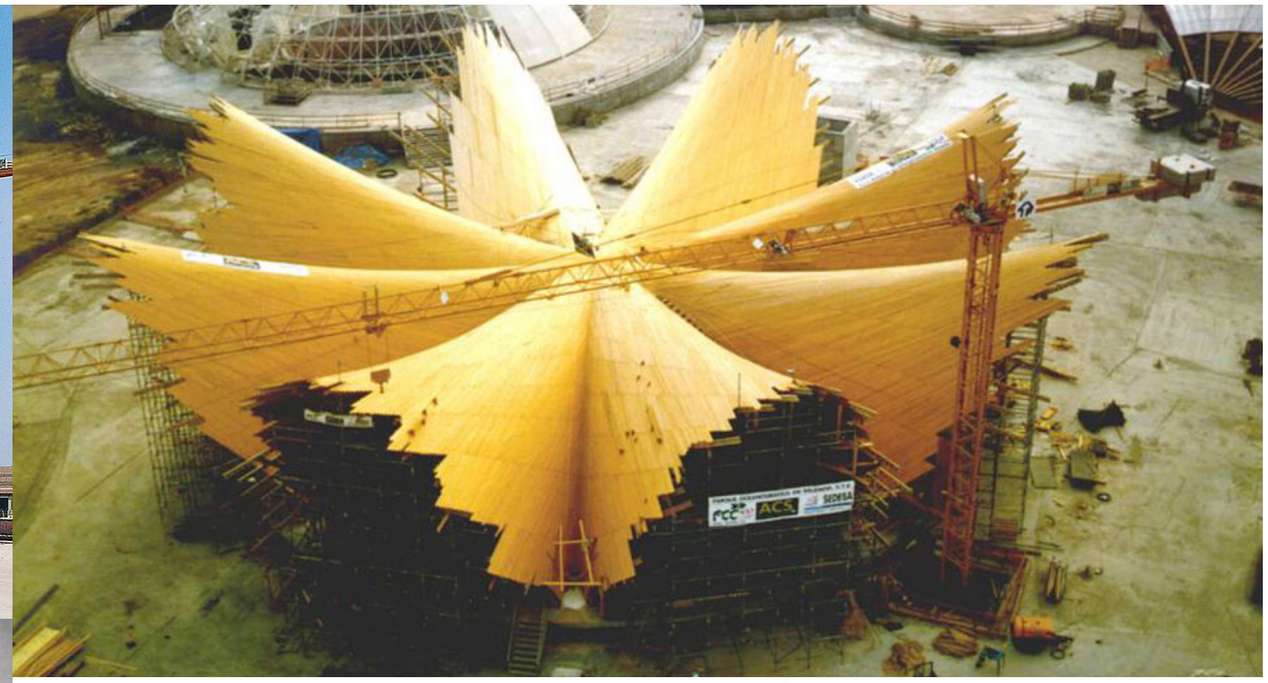
- Exstensive Scaffolding
- Manual Formwork
- 01-12-2001 till 01-12-2003

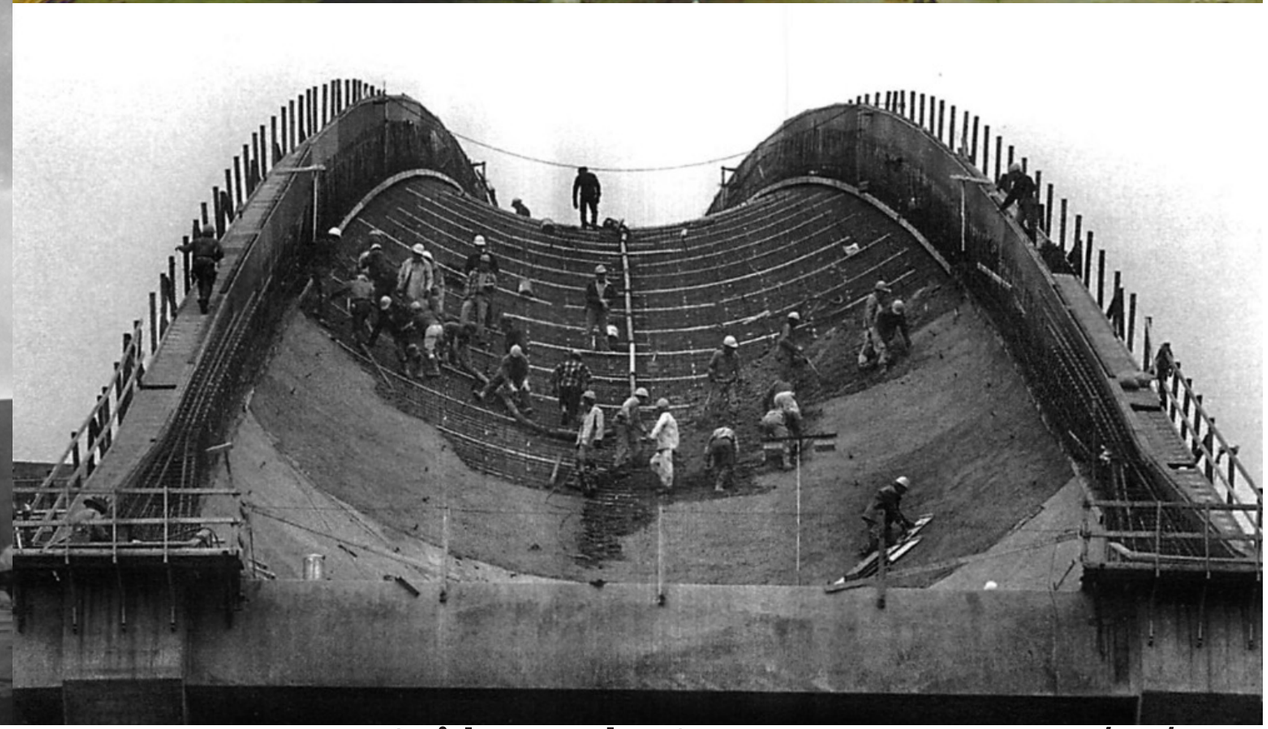
DISADVANTAGES

SHELLS

DISADVANTAGES







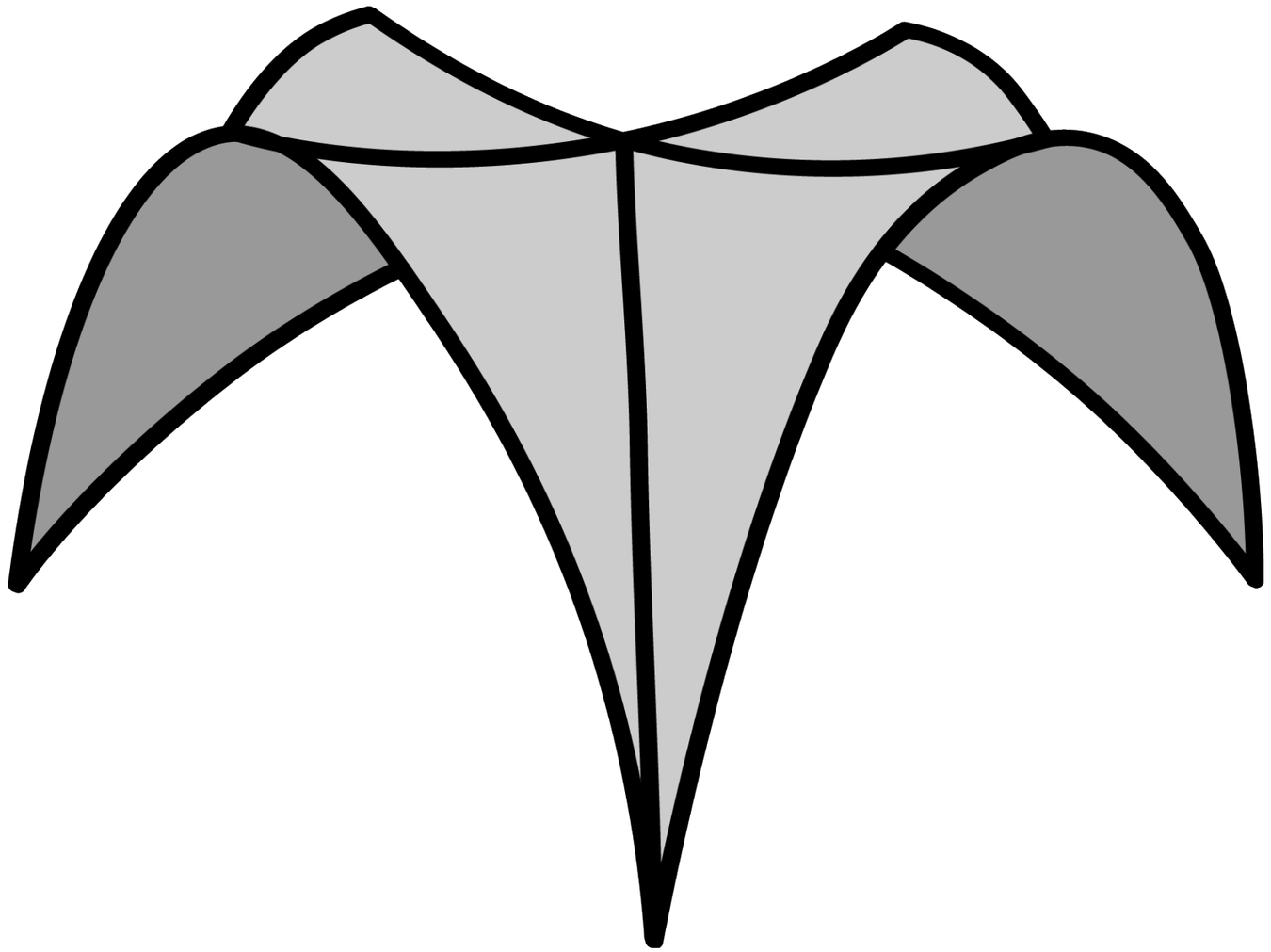
PROBLEM STATEMENT

Shell structures are rarely used because they are labour intensive and therefore very expensive to make.

- Scaffolding is time consumming
- On-site pouring of concrete leads to long drying period
- Handbuilding the formwork is very time-consumming

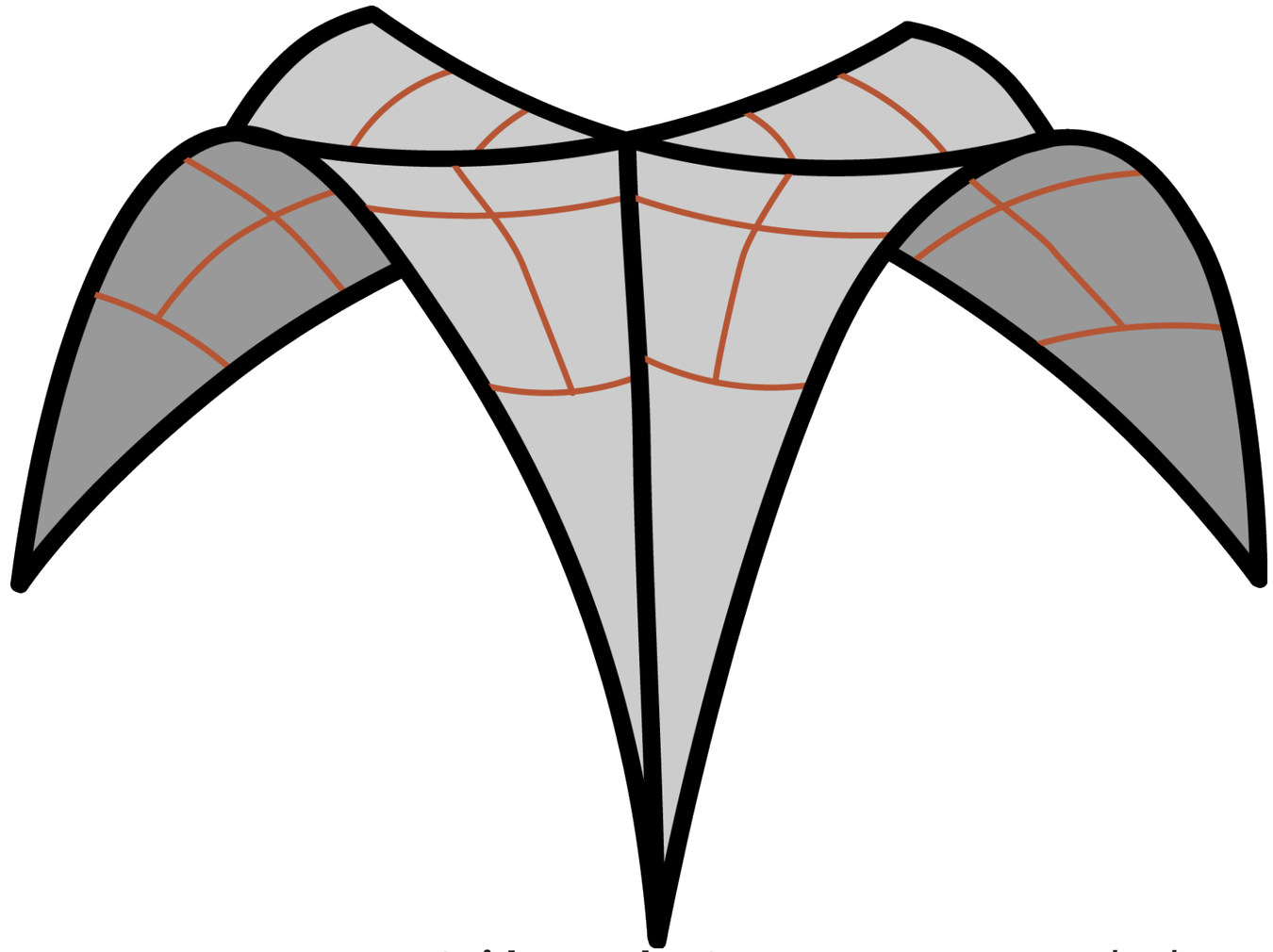
SOLUTION

PREFAB SHELL STRUCTURES



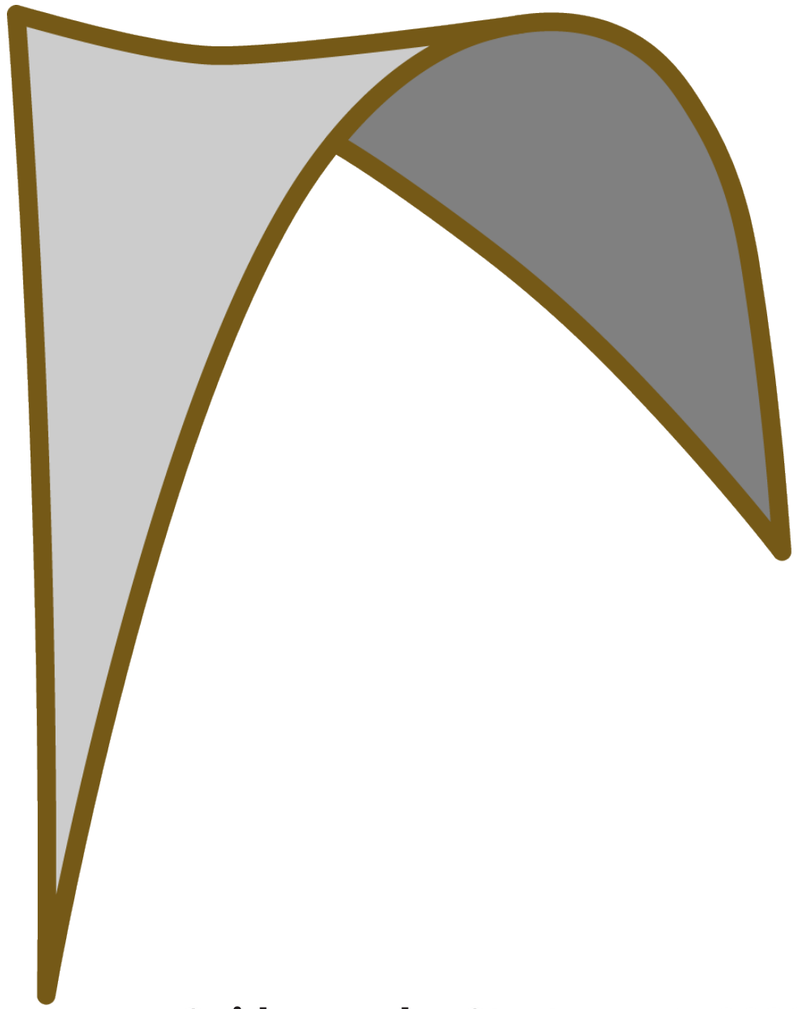
SEGMENTING

- Force optimizing
- Construction optimizing



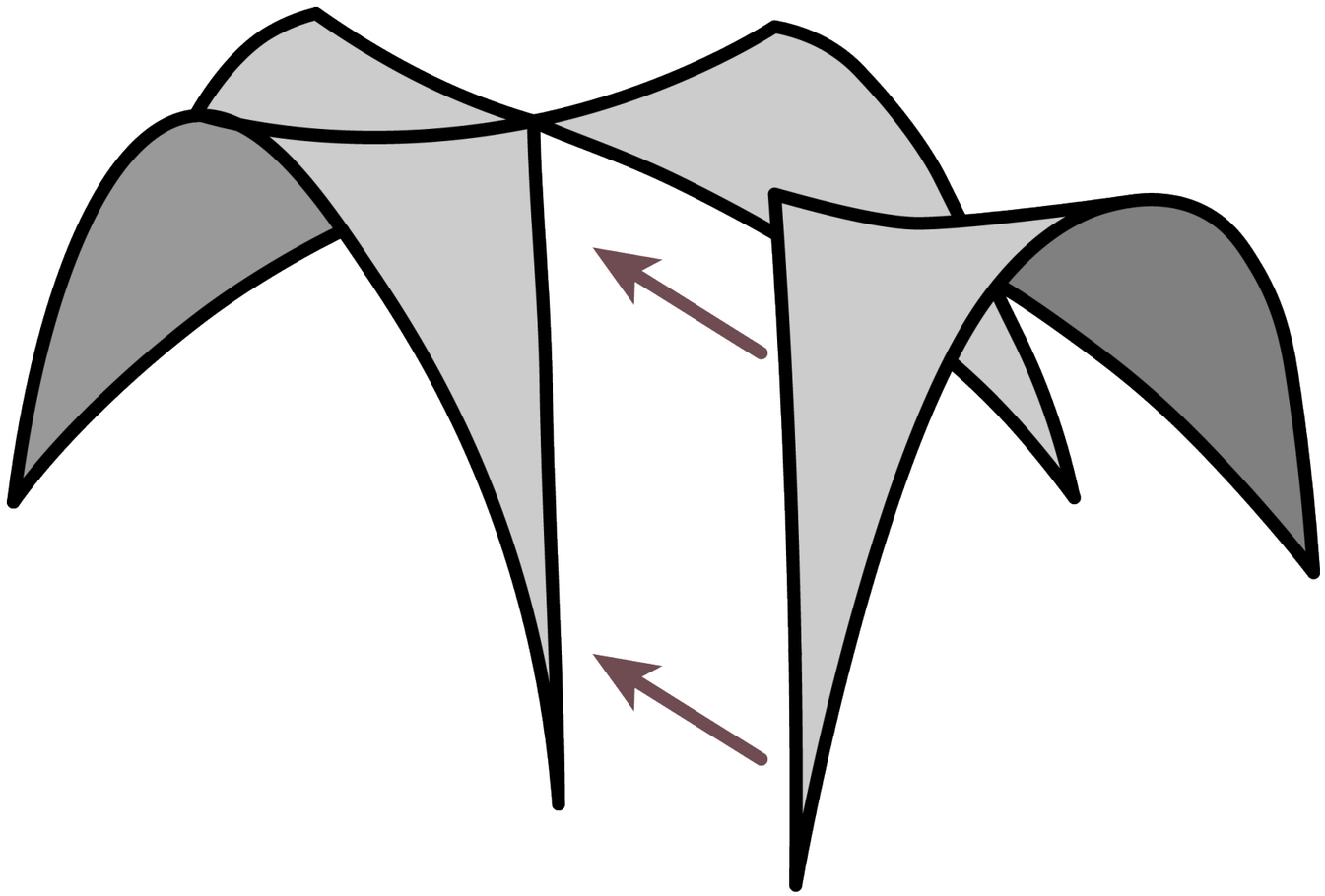
PRODUCTION

- Manual formwork
- Adaptable formwork



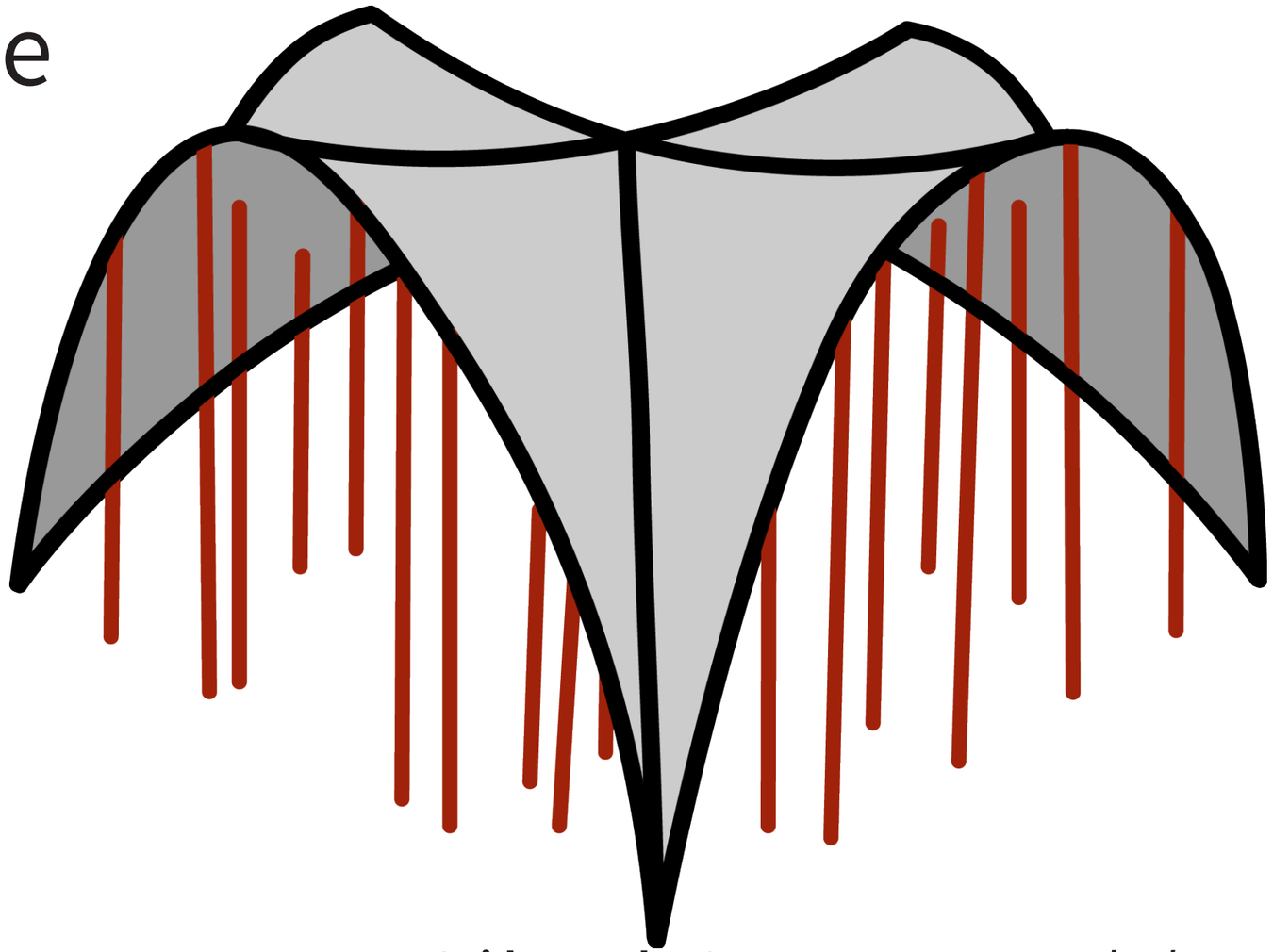
CONNECTION

- Direct stiffness, strength and stability
- Simple building



CONSTRUCTION

- No/little scaffolding
- Direct stiffness, strength and stability
- Fast building sequence



WHY CONNECTION?

- Segmenting > Computational
- Production already possible/researched
- Construction and Connection are intertwined

RESEARCH QUESTION

What is the influence of making a monolithic shell structure into a prefabricated segmented shell structure with a dry/wet connection?

- How does the connections influence strength?
- How does the connections influence stiffness?
- How does the change in strength and stiffness influence the stability?

METHODOLOGY

- Case Study (Oceanografic Valencia)
- Divide the Shell
- Design knot
- Test/Analys knot
- Improve design

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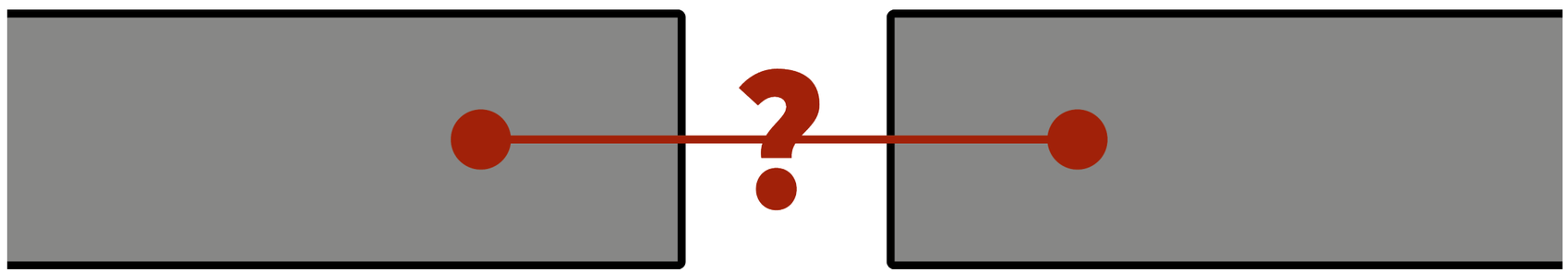
DESIGN BRIEF

Connection:

- Direct stiffness, strength and stability
- Fast placement/construction
- Deal with tolerance of concrete
- Decrease building time
  - No concrete pouring on site
  - As little scaffolding as possible
- Has the same deflection compared to monolithic shell

DESIGN

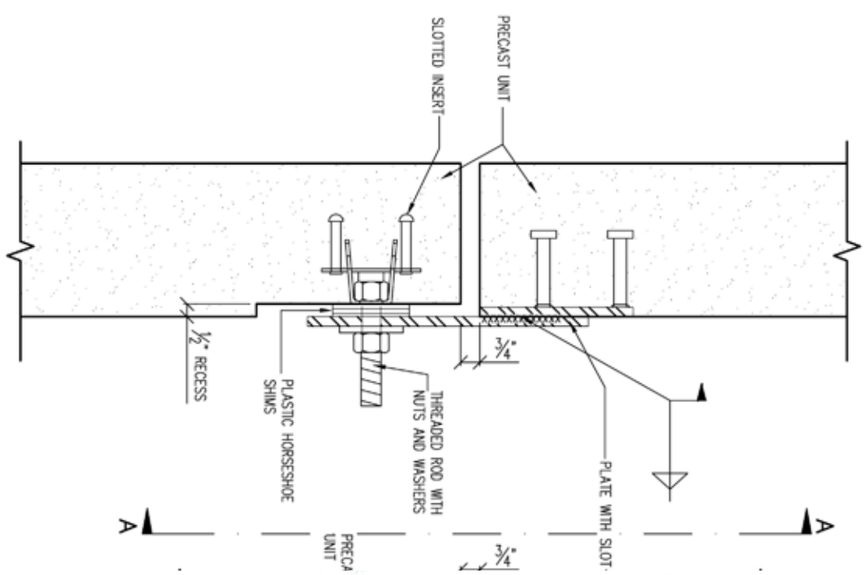
- Design knot
- Drawings
- Digital model
- Knot Peter Eigenraam

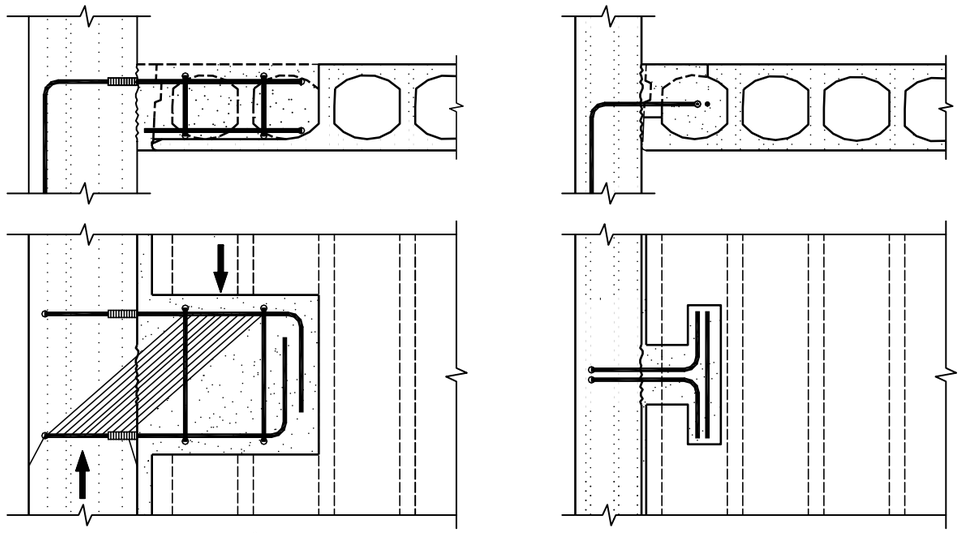


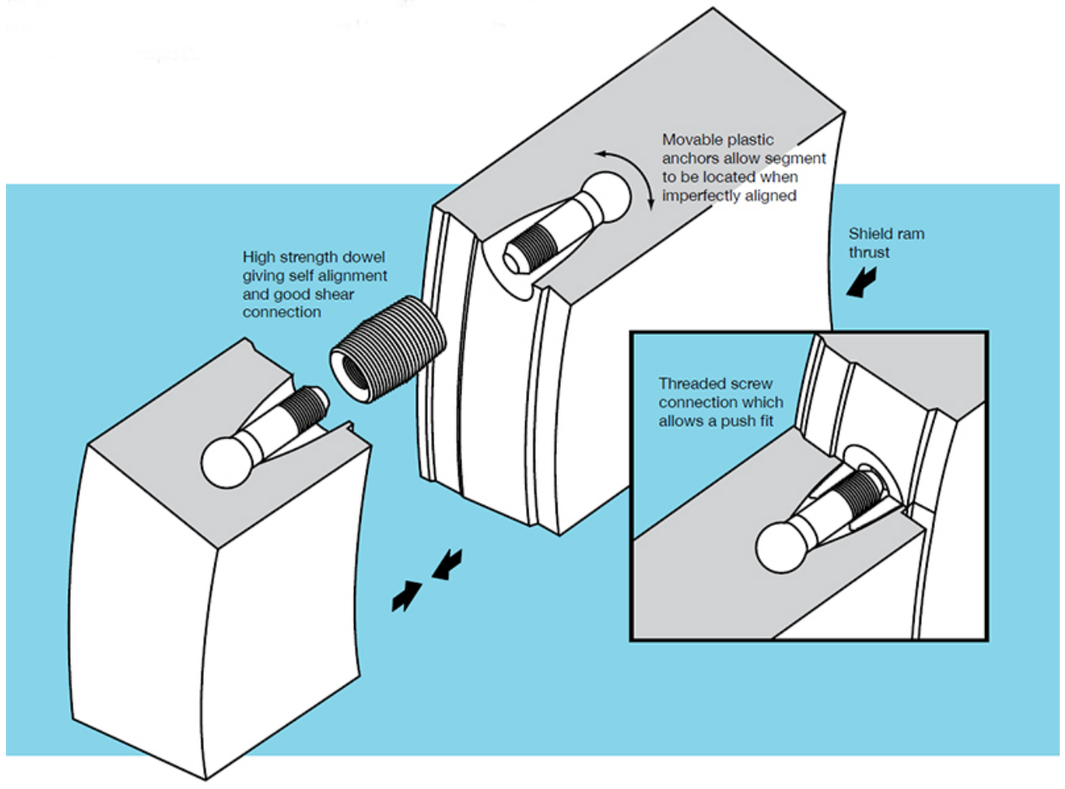
DESIGN CHOICES

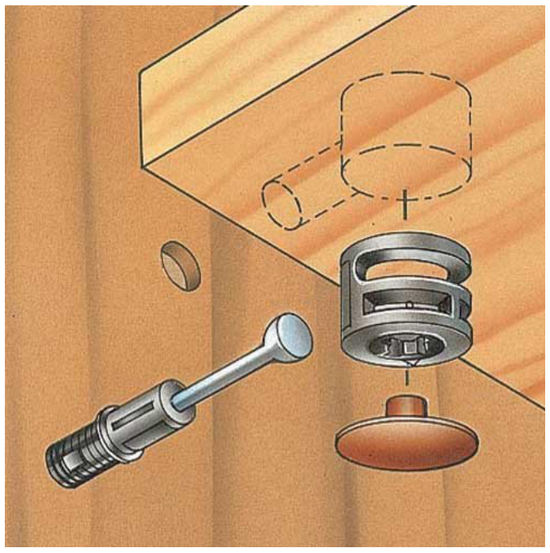
- Bolted
- Welded
- Tension
- Cast
- Form

BOLTED









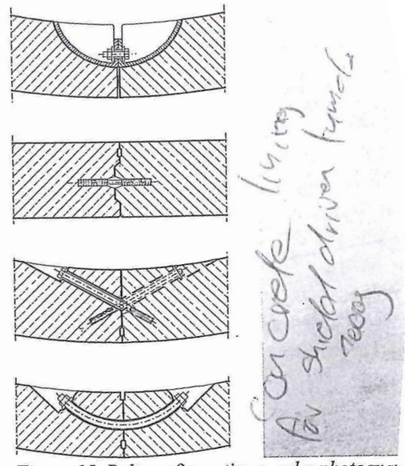
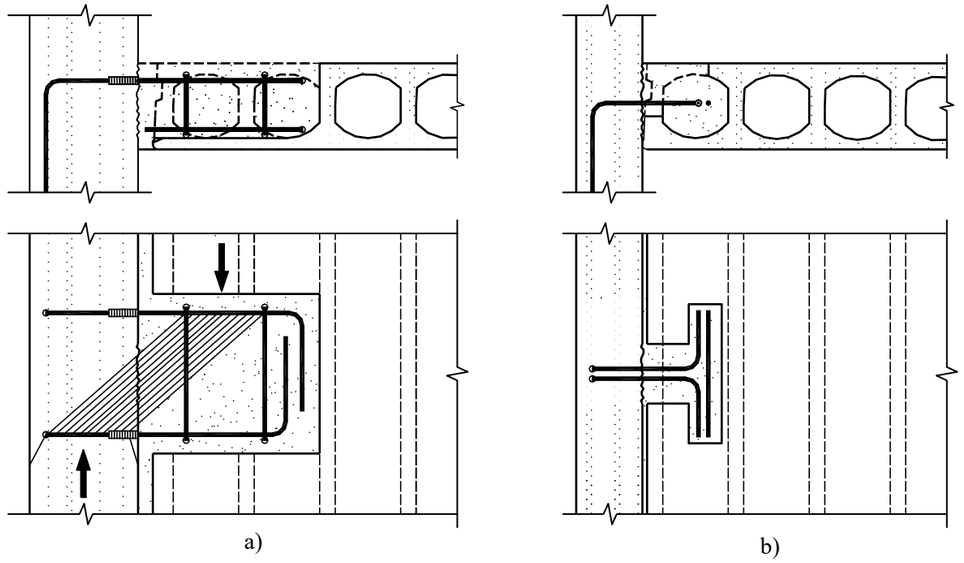


Figure 15. Bolt configurations and a photograj

WELDED



a) b)

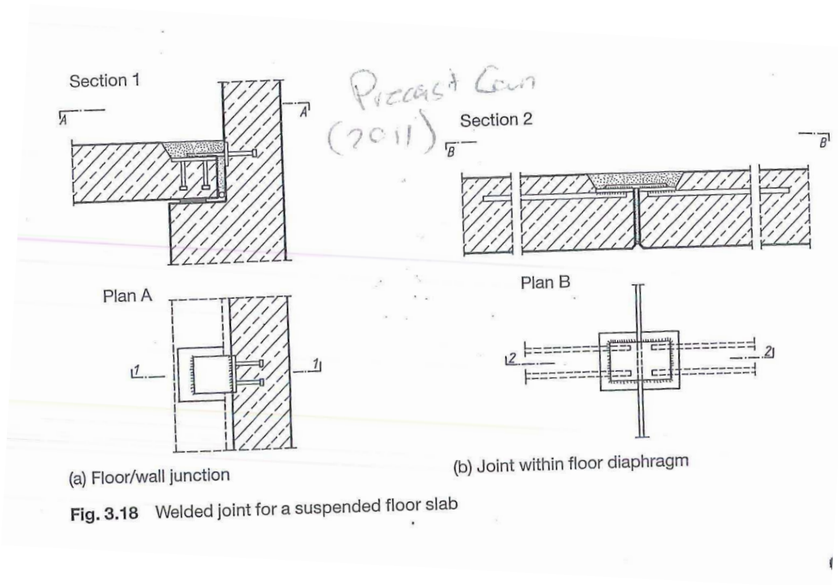
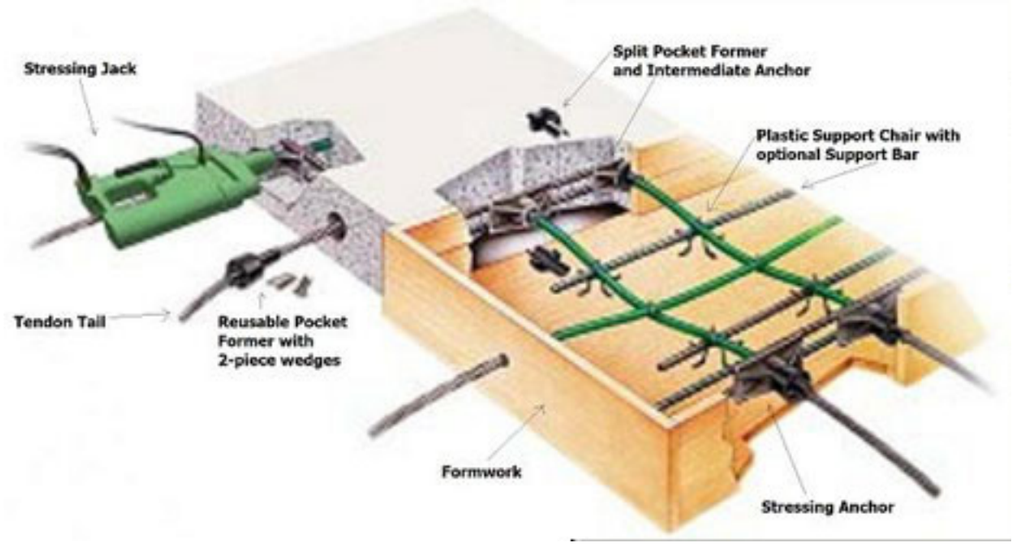
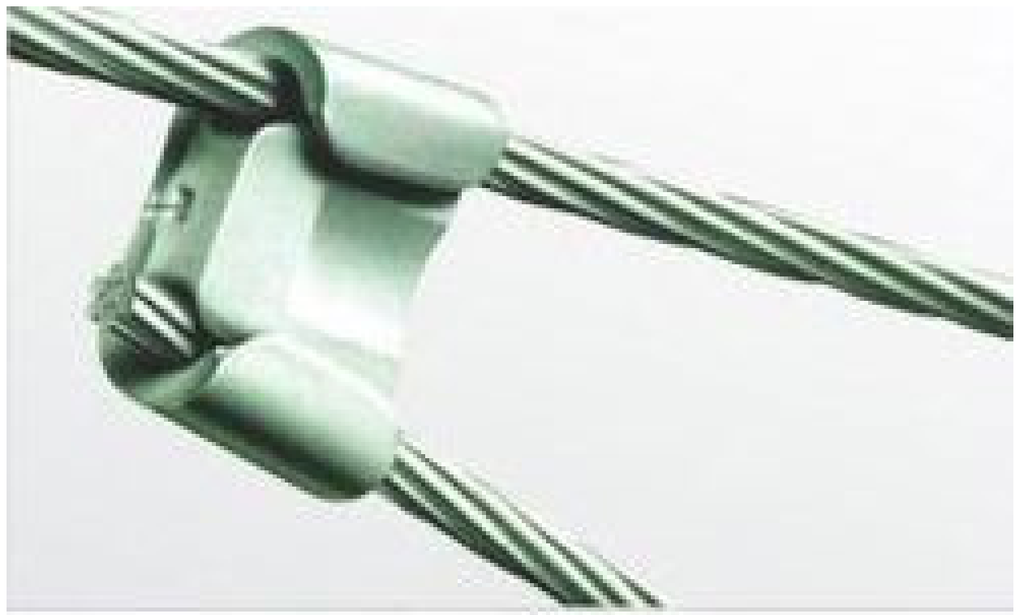
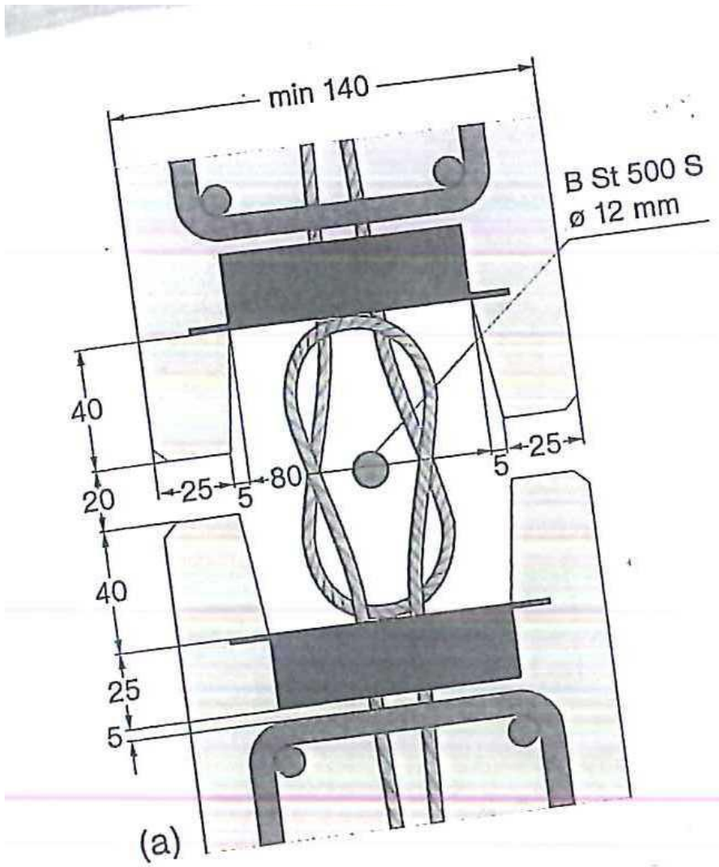


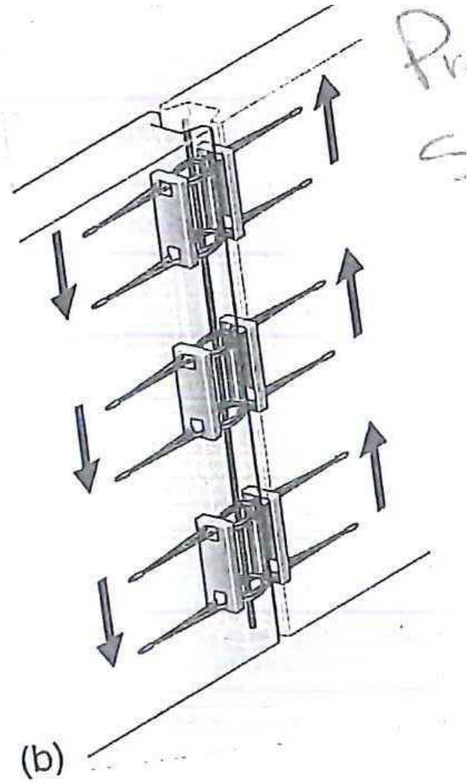
Fig. 3.18 Welded joint for a suspended floor slab

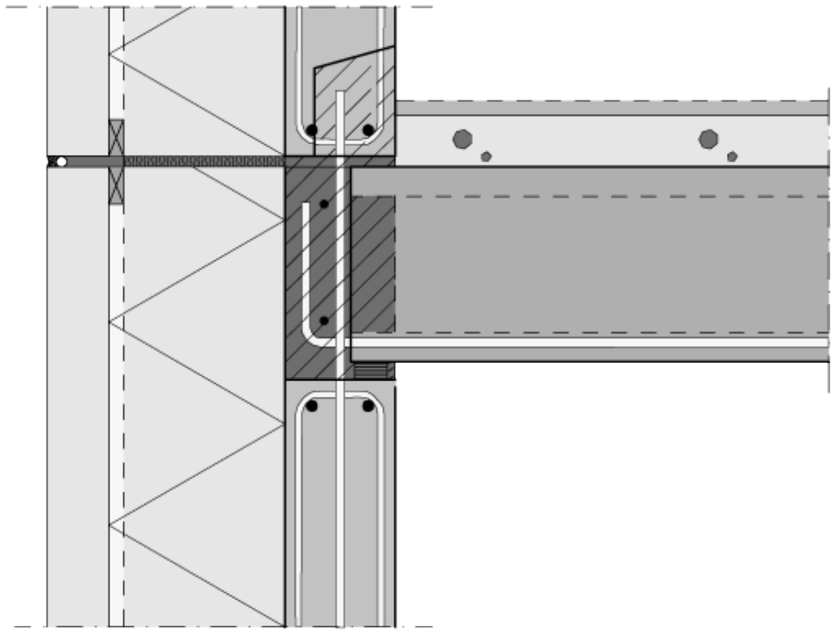
TENSION


Stressing Jack
Split Pocket Former
and Intermediate Anchor
Plastic Support Chair with
optional Support Bar
Tendon Tail
Reusable Pocket
Former with
2-piece wedges
Formwork
Stressing Anchor




min 140
B St 500 S
ø 12 mm
40
20
25
5
80
5
25
40
25
5
(a)


(b)



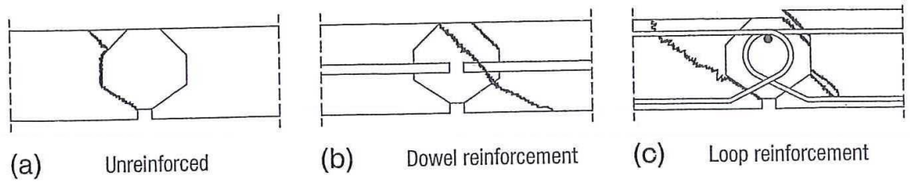


Fig. 3.39 Failure mechanisms for unreinforced, dowel-reinforced and loop-reinforced joints (according to [244] and [245])

Precast Concrete Structures (2011)

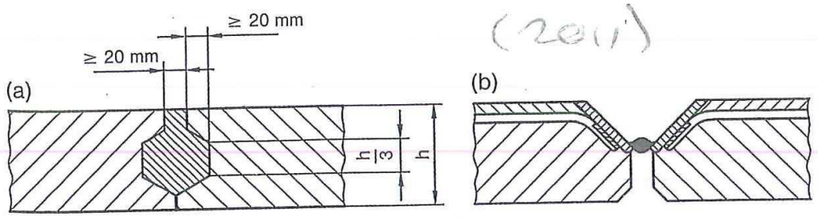
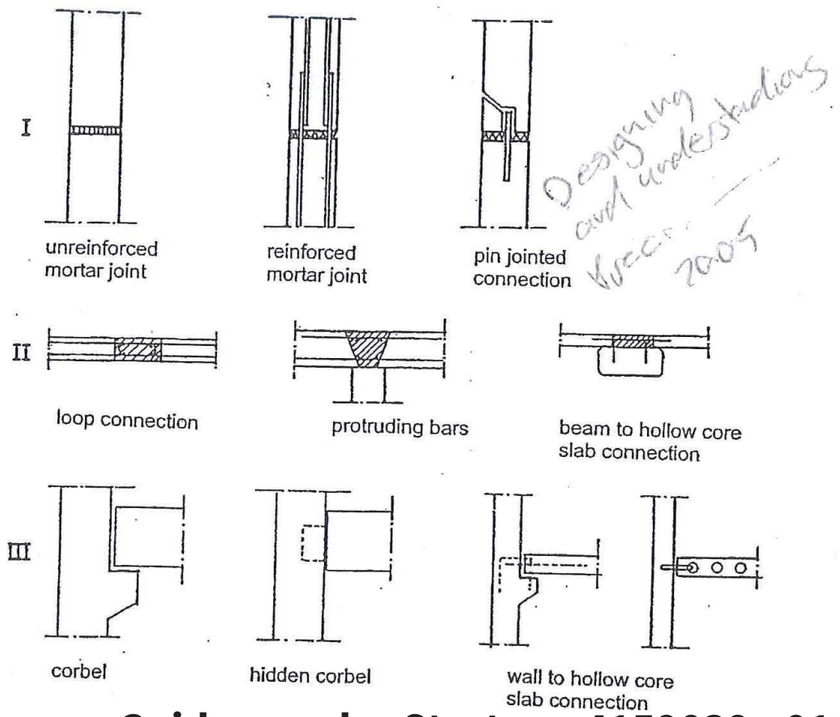
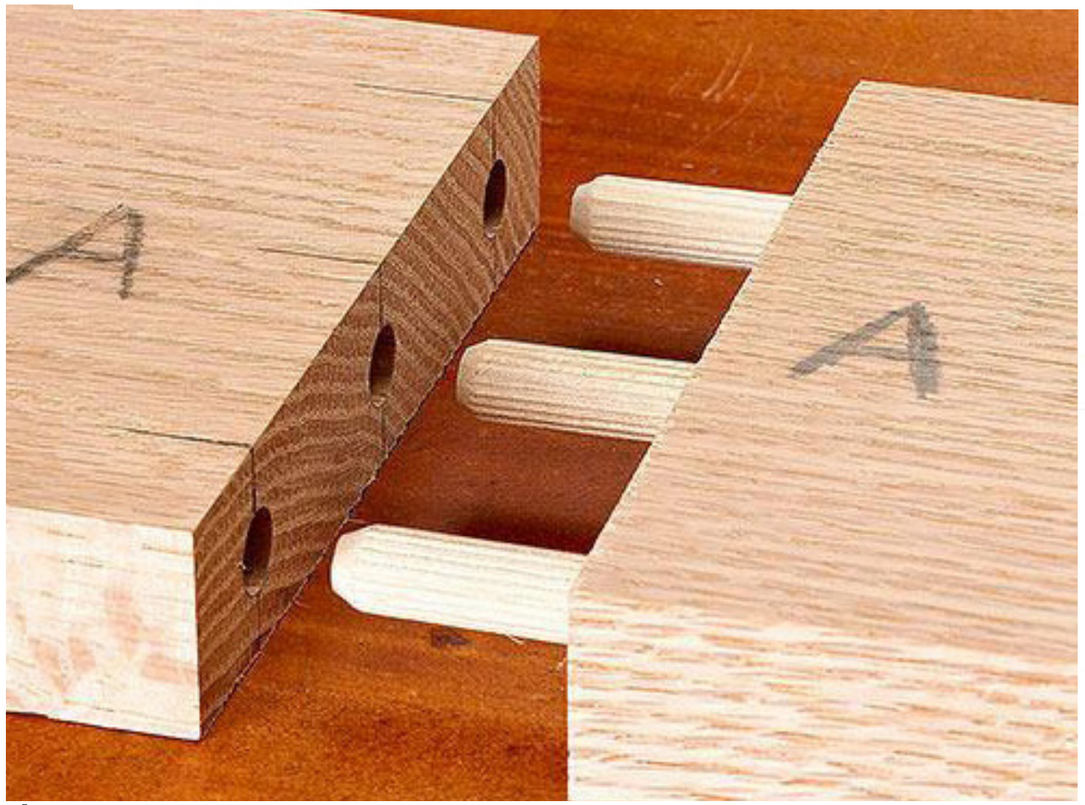


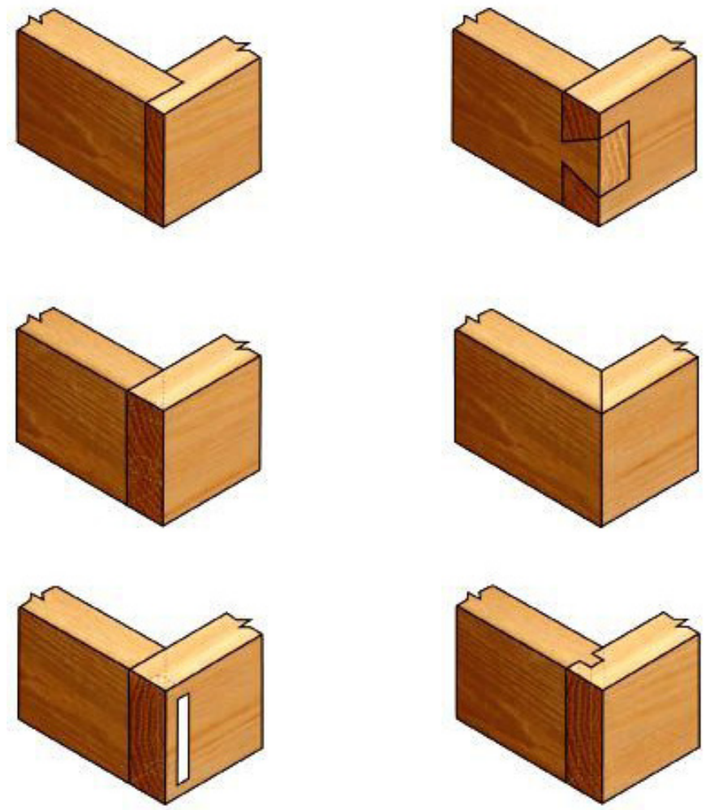
Fig. 3.40 Examples of joints between precast concrete elements to DIN 1045-1 (dims. in mm)

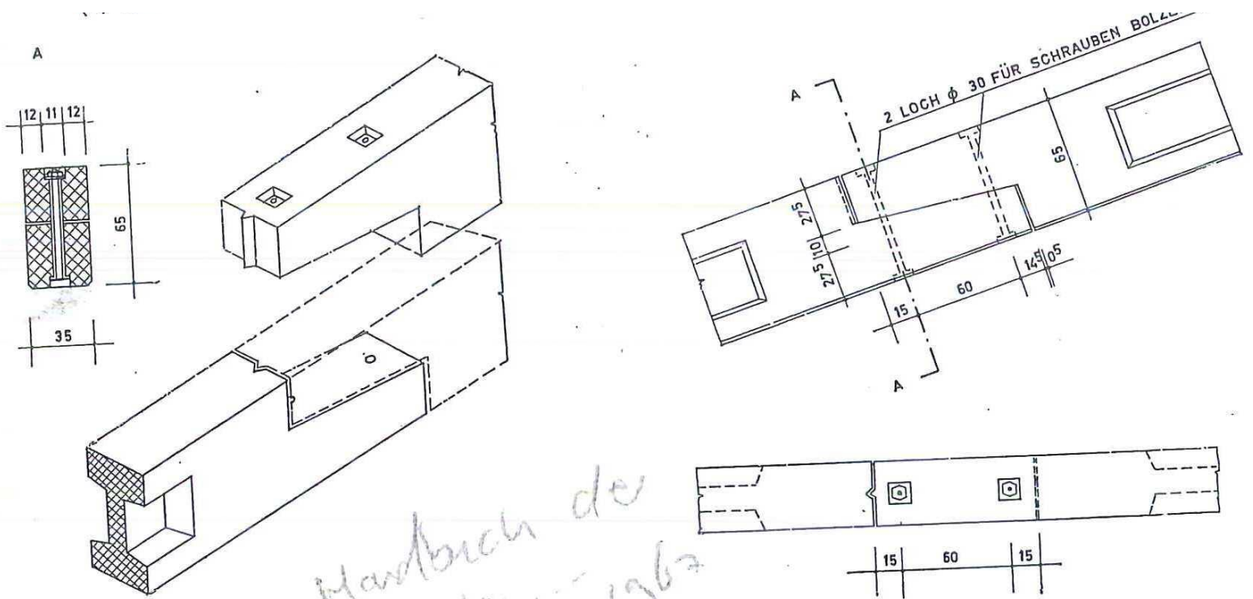


Designing and understanding ... 2005

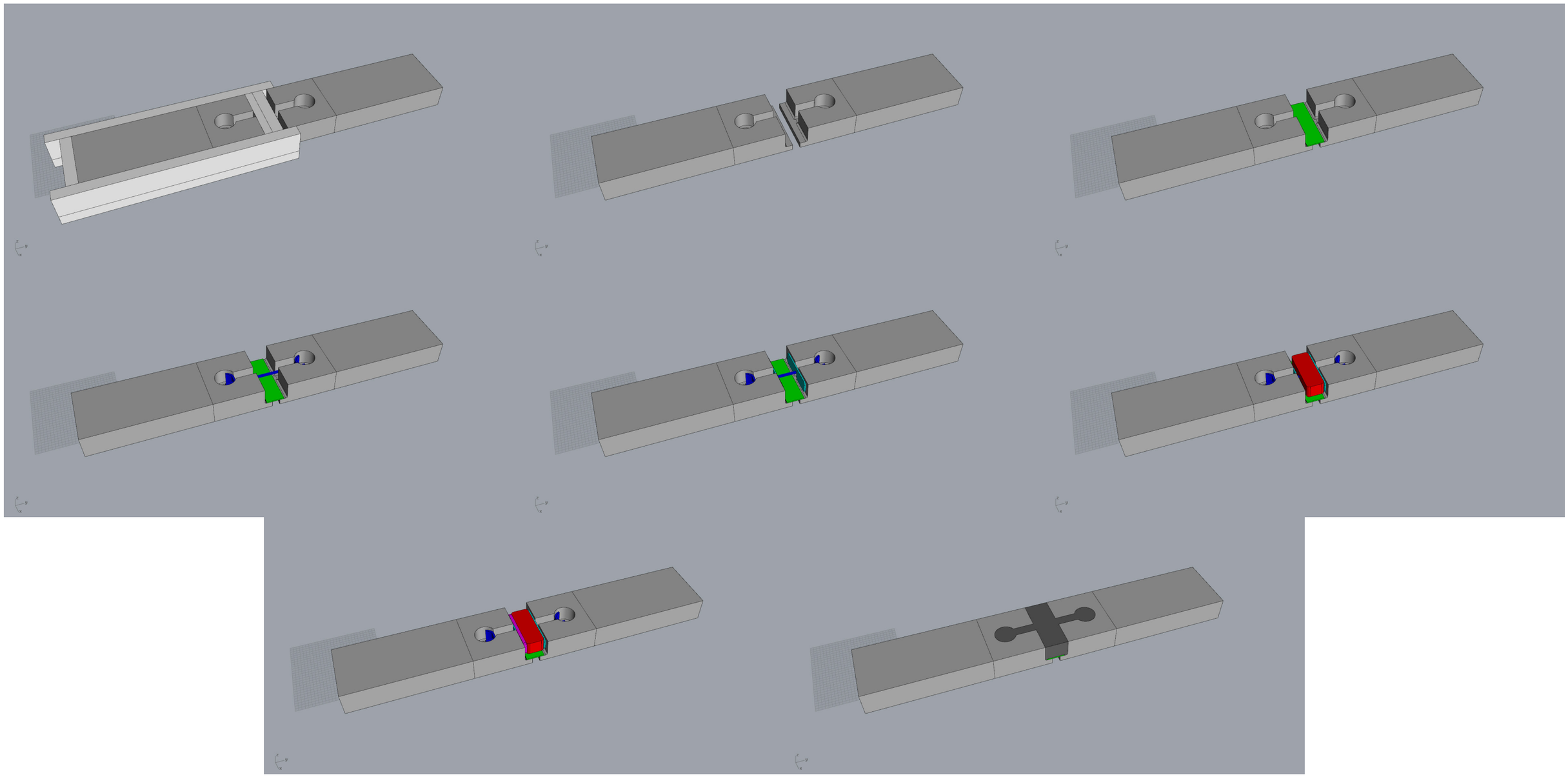
FORM


A
A




A
12 11 12
65
35
2 LOCH ϕ 30 FÜR SCHRAUBEN BOLZ
A
65
27,5 110 27,5
15 60 14,5 0,5
15 60 15

PETER EIGENRAAM KNOT



CONSIDERATIONS

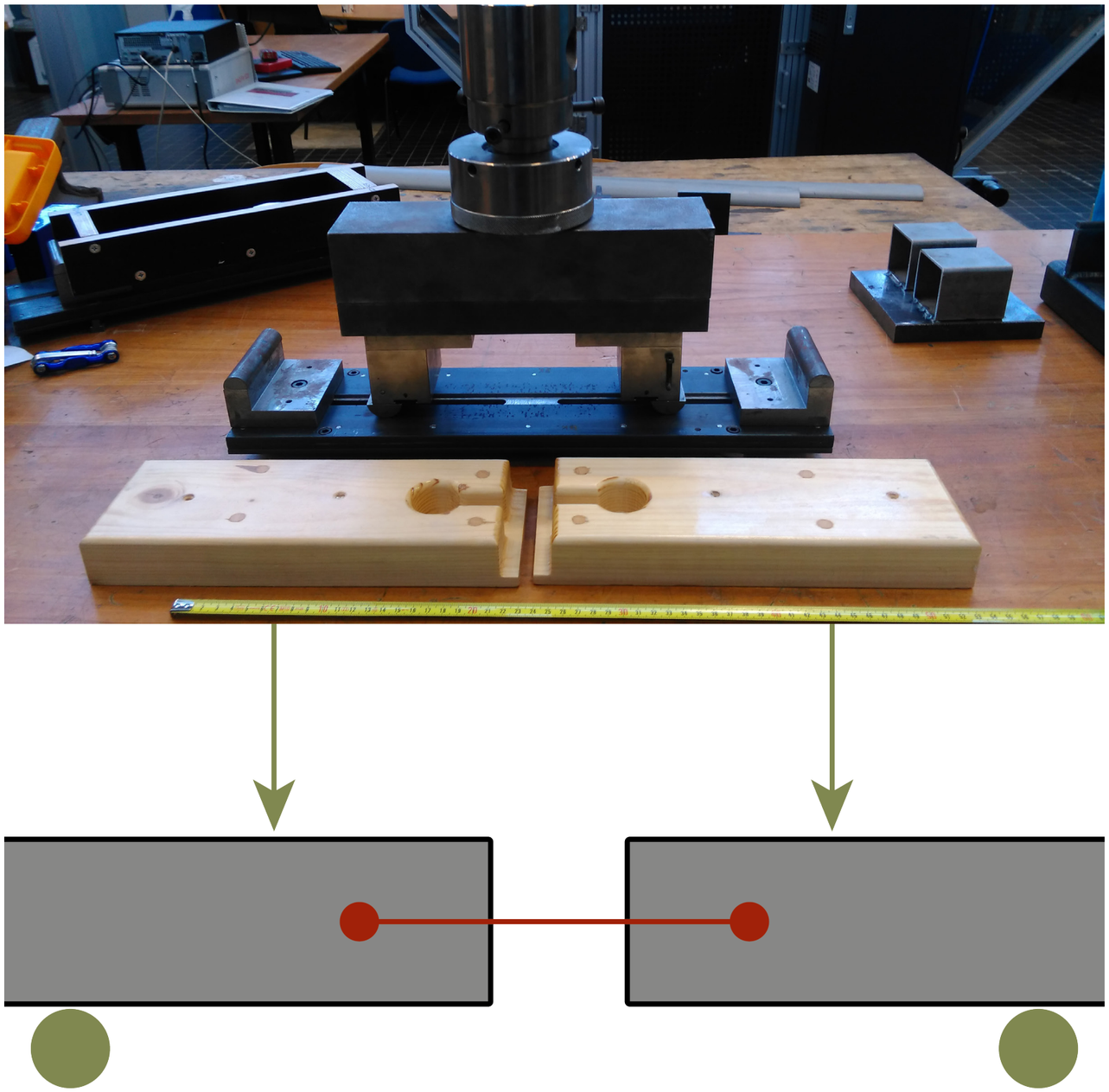
- Wet/Dry
- Demountable/Permanent
- No/Little scaffolding
- Extra Finishing layer?

PROTOTYPE

- If possible
- Build the knot (steel and concrete)
- Scale to fit testing machine
- Make a serie

TESTING

- If prototype
- Four point bending test
- Test force needed for certain deflection
- Parallel to Analysis



ANALYSIS

- Digital model for Finite Element Method Anlaysis
- Analyse force needed for certain deflection
- Parallel to Testing

COMPARING

- Ditermine the quality of the analysis
- Use analysis for further design
- Compare monolithic shell with segmented shell

IMPROVING

- Use results to improve the design
- Test the design with Analysis

RESULT

- A feasible knot
- Analysis
- Prefabricated shell structures feasible (yes/no)

PLANNING

Event	Date	
P1	**14/11/2017**	
	Defining the "Brief"	
	Literature Study	
P2	**18/01/2017**	
	Test knot of Peter Eigenraam	
	Design Dry Knot	
	Run calculations and Simulations on the design	
	Start with building the knot	
P3	**29/03/2017**	**06/04/2017**
	Build the knot	
	Test the kont	
	Incorporate the results in the design	
	Make final design	
P4	**24/05/2017**	**01/06/2017**
	Prepare presentation and finish report	
P5	**01/06/2017**	**30/06/2017**

QUESTIONS?