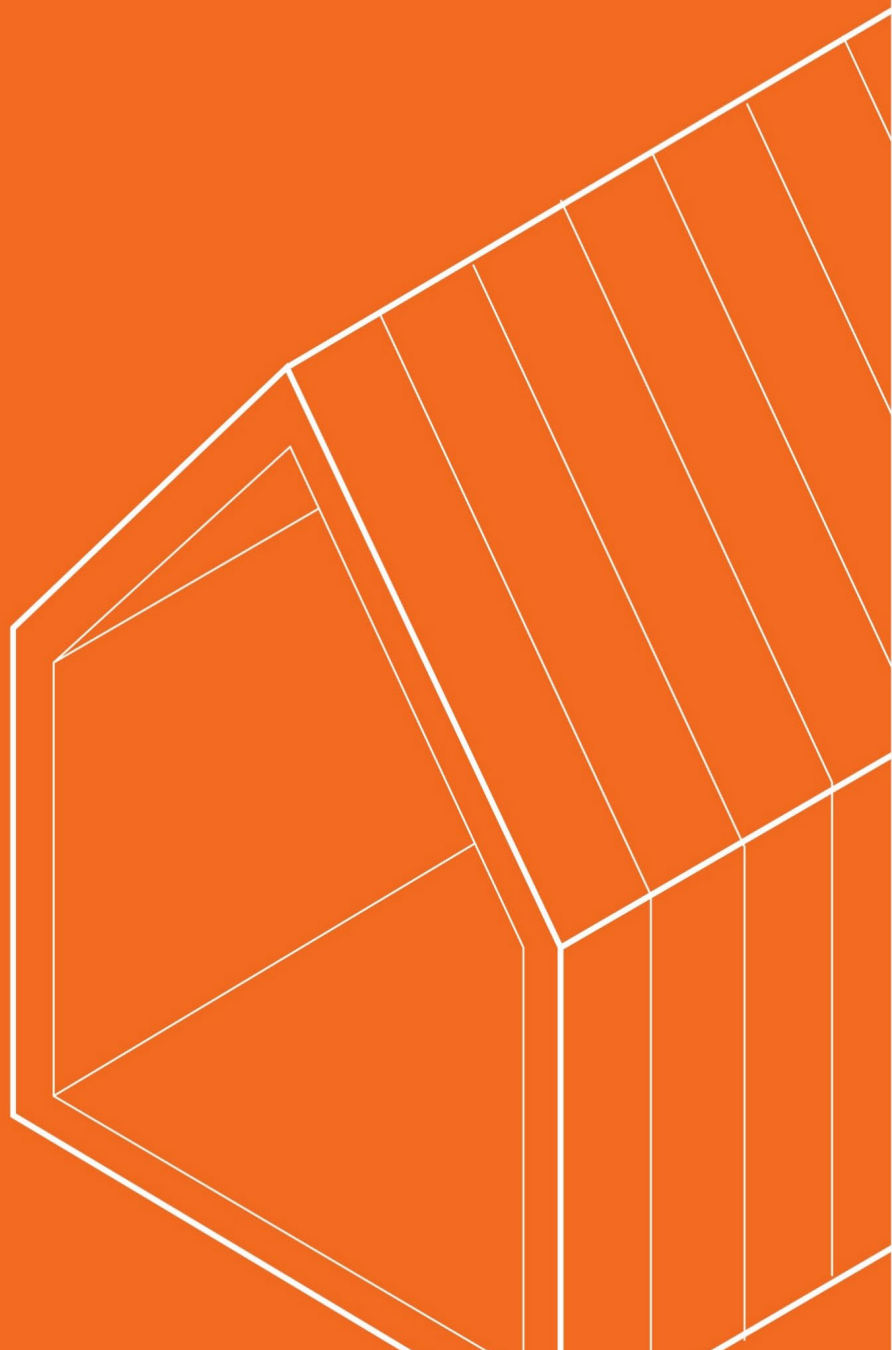
.fabfield

structural design and development for CNC-milled construction

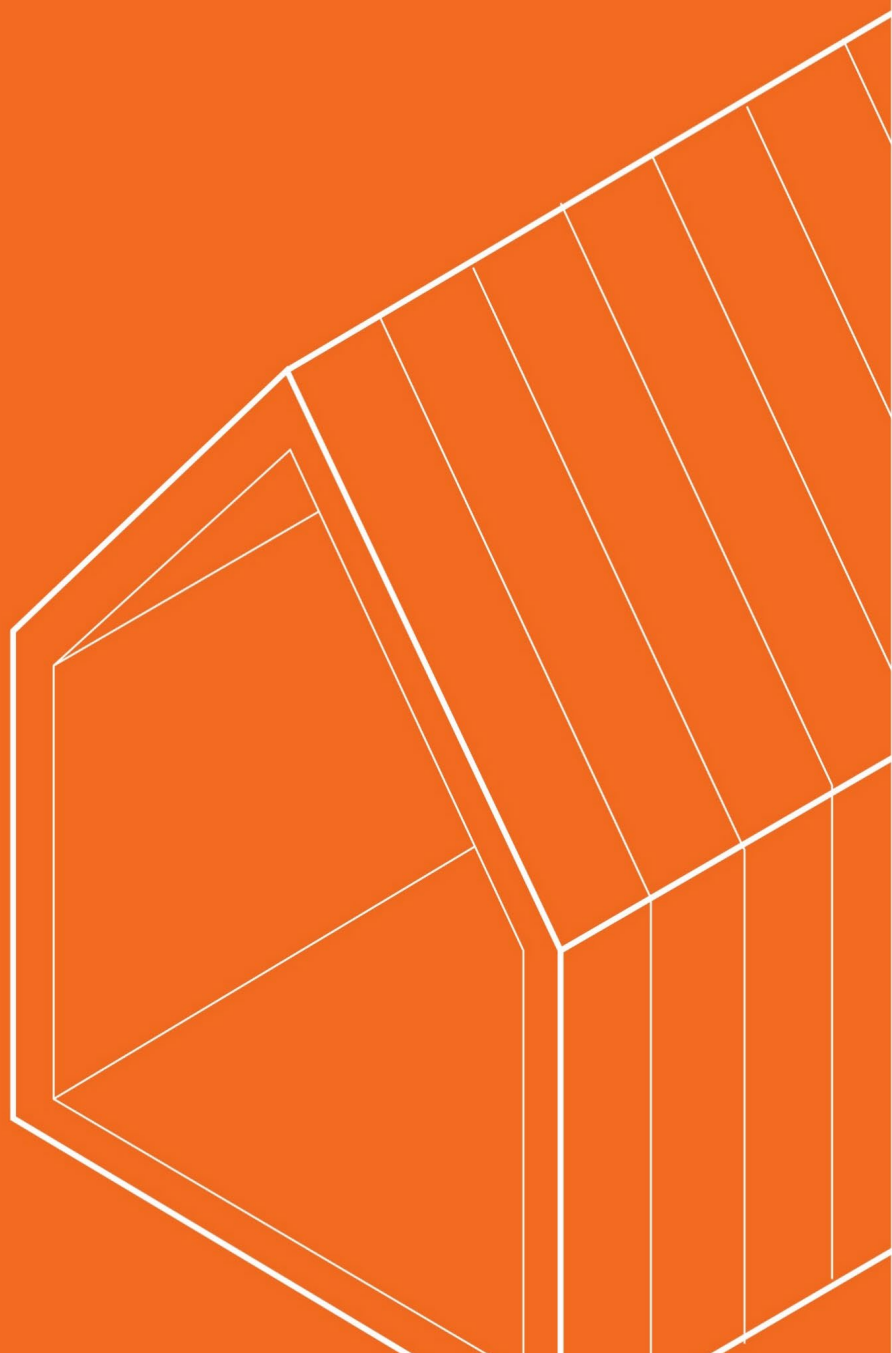


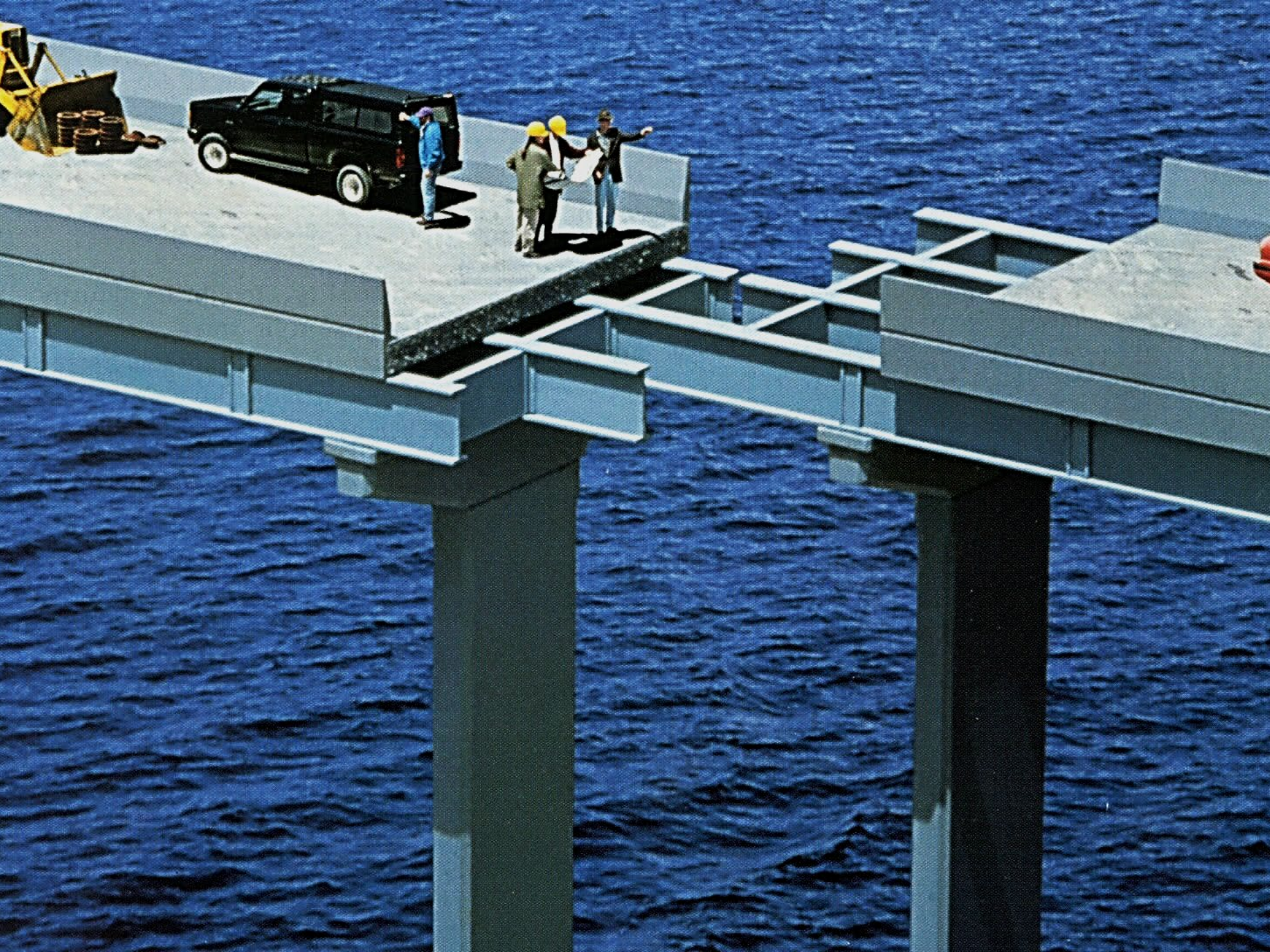
THE NEW MAKERS

TU Delft

LŪNING
Ingenieurs in houtconstructies

01
research



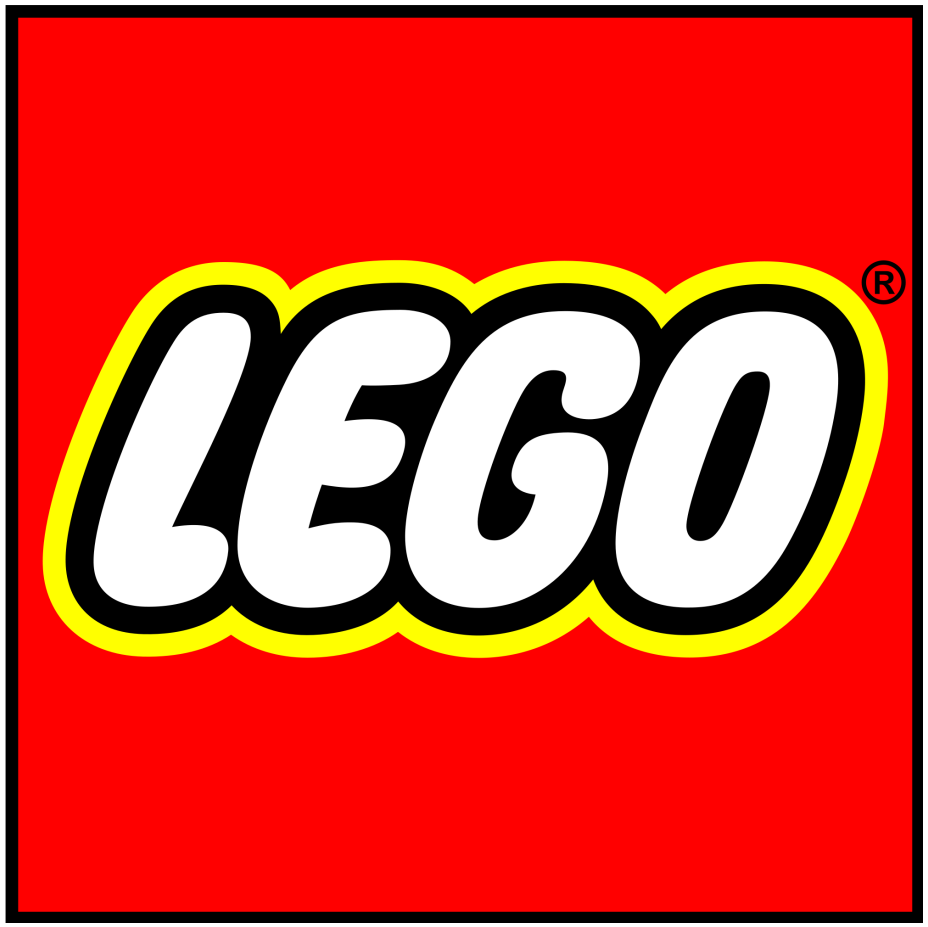


environmental

efficiency

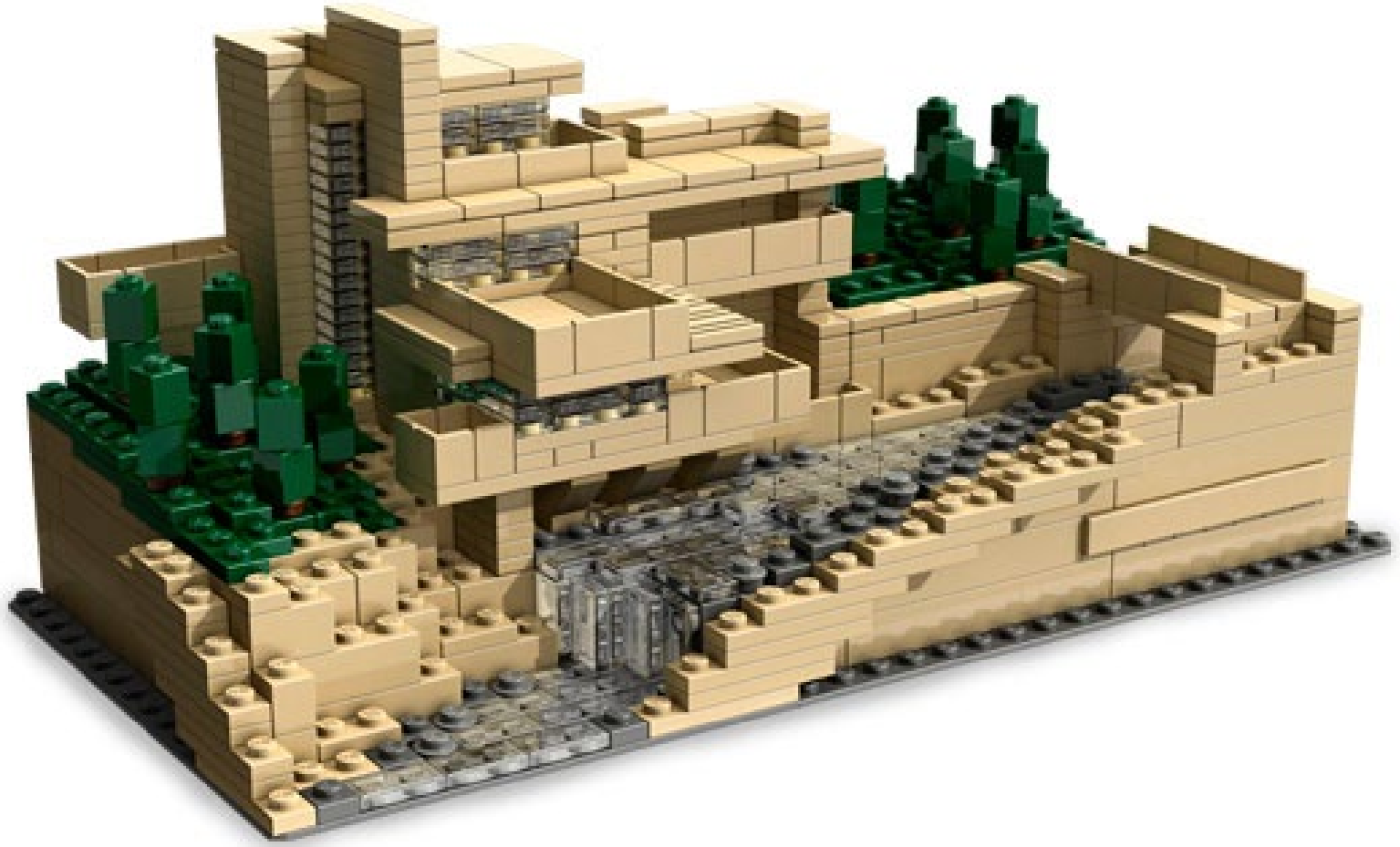
adaptability

IFD Buildings

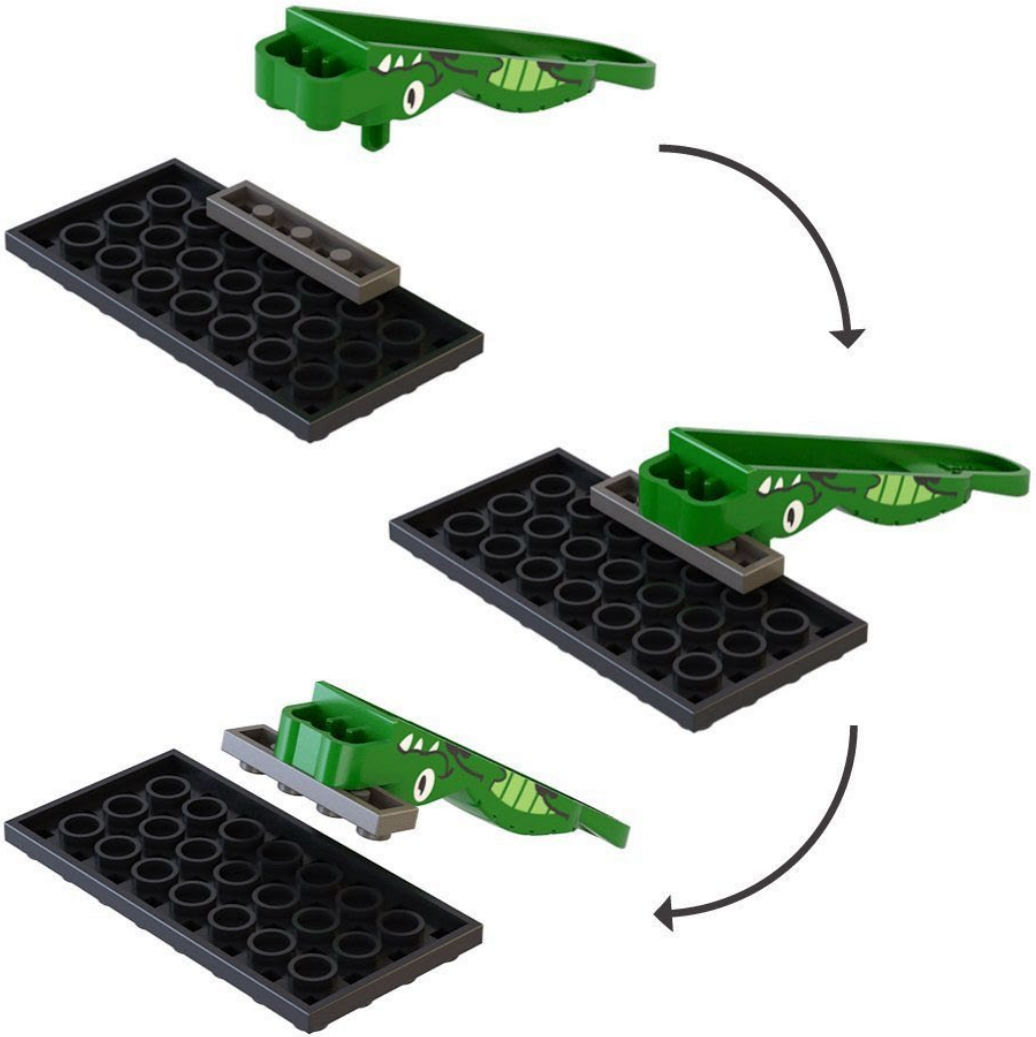

LEGO

INDUSTRIAL

FLEXIBLE

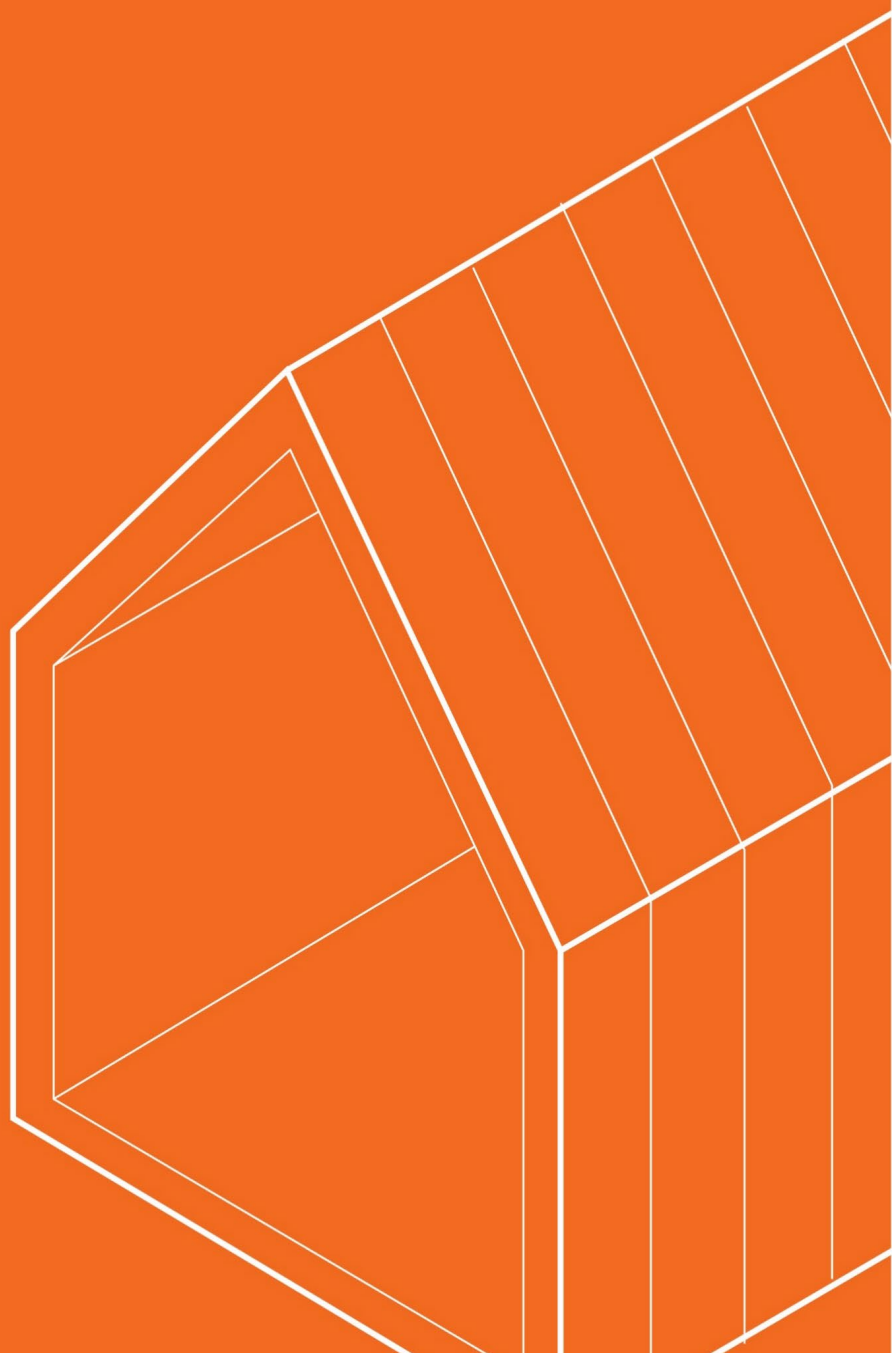


DEMOUNTABLE



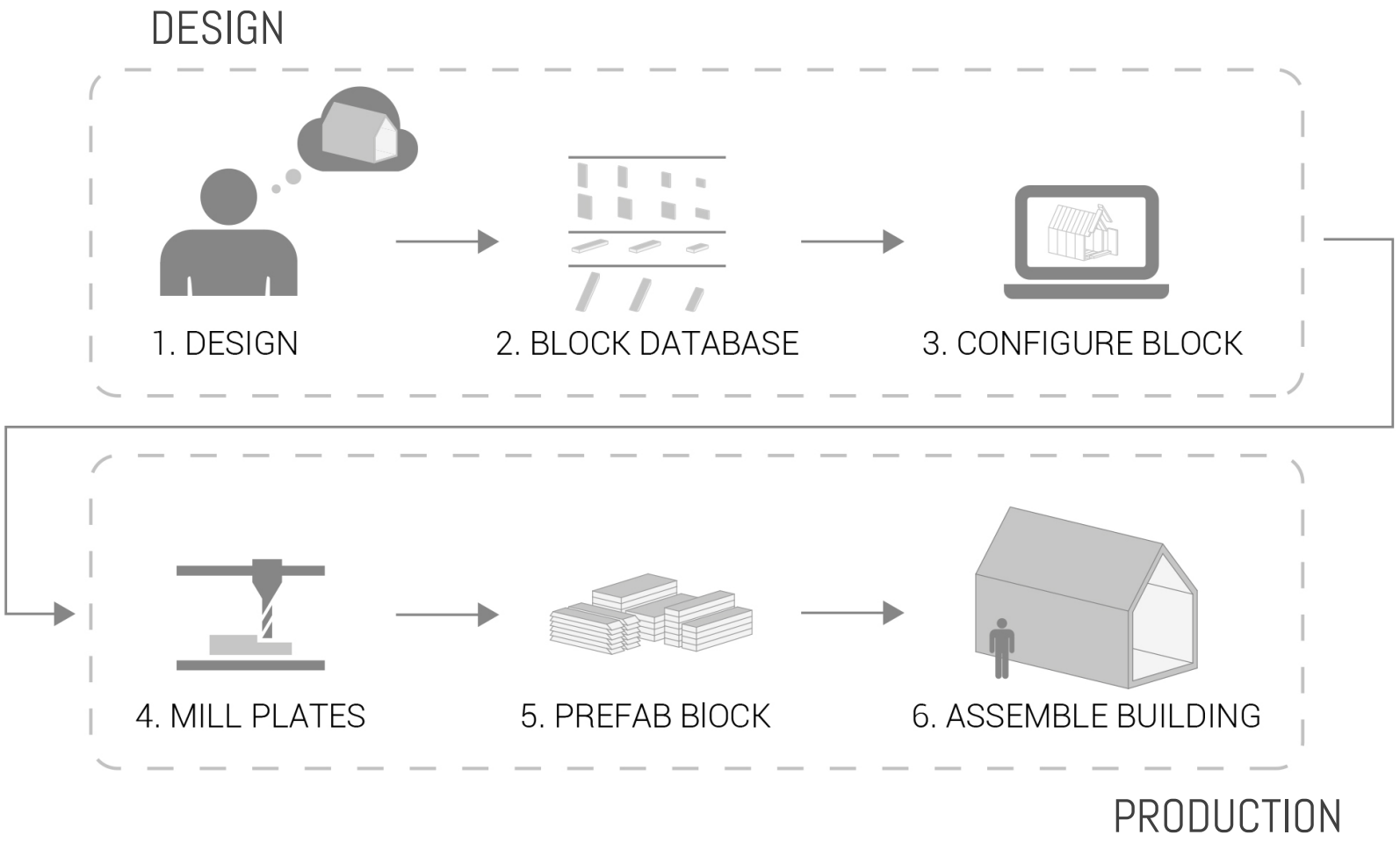
02

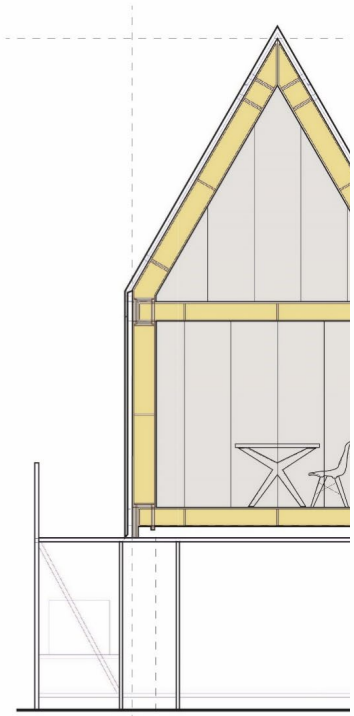
precedents study



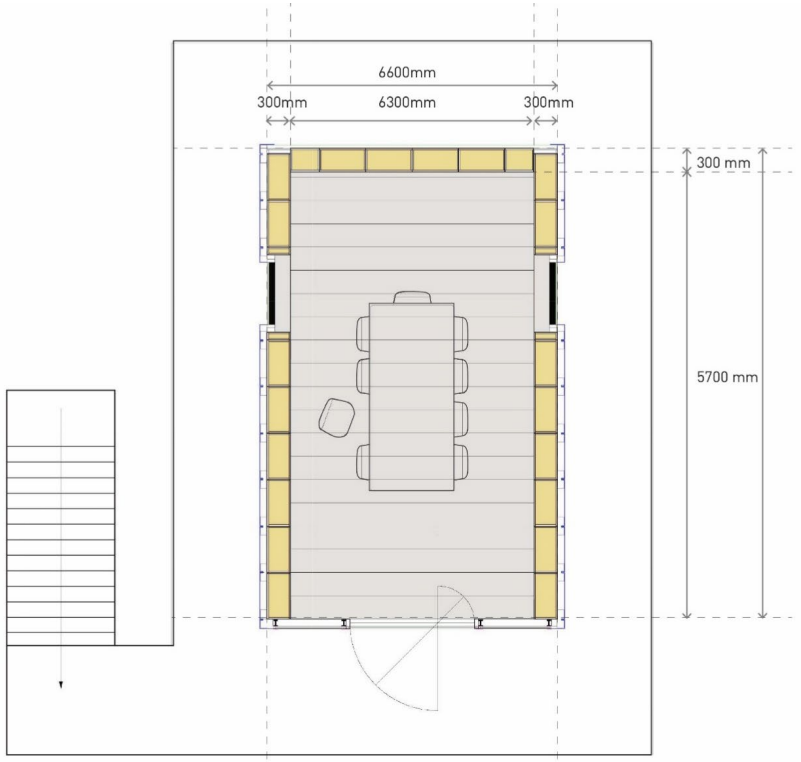
PD-LAB / FABFIELD

FabField: Structure


DESIGN
1. DESIGN
2. BLOCK DATABASE
3. CONFIGURE BLOCK
4. MILL PLATES
5. PREFAB BlOCK
6. ASSEMBLE BUILDING
PRODUCTION



Section



Plan

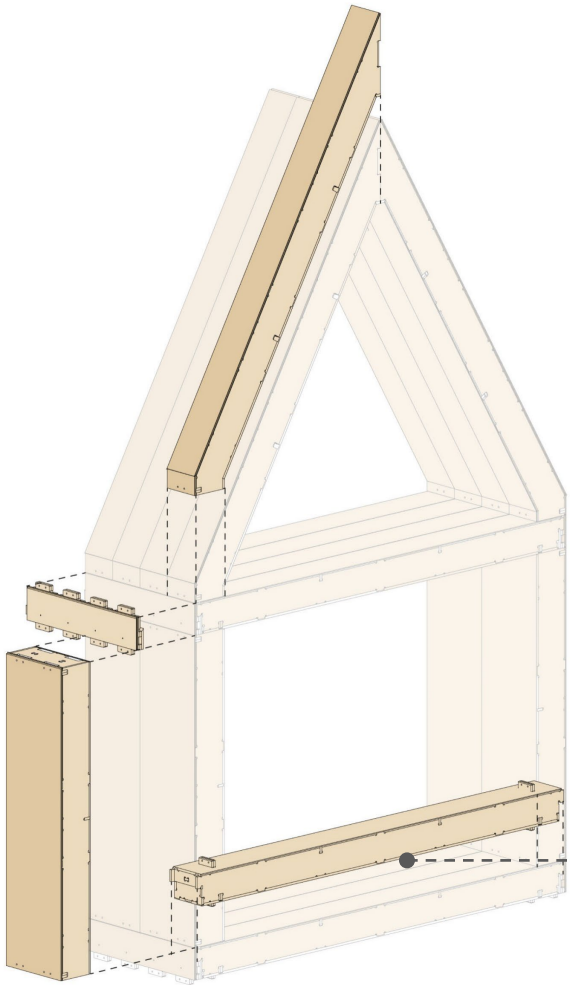

BOMMEER

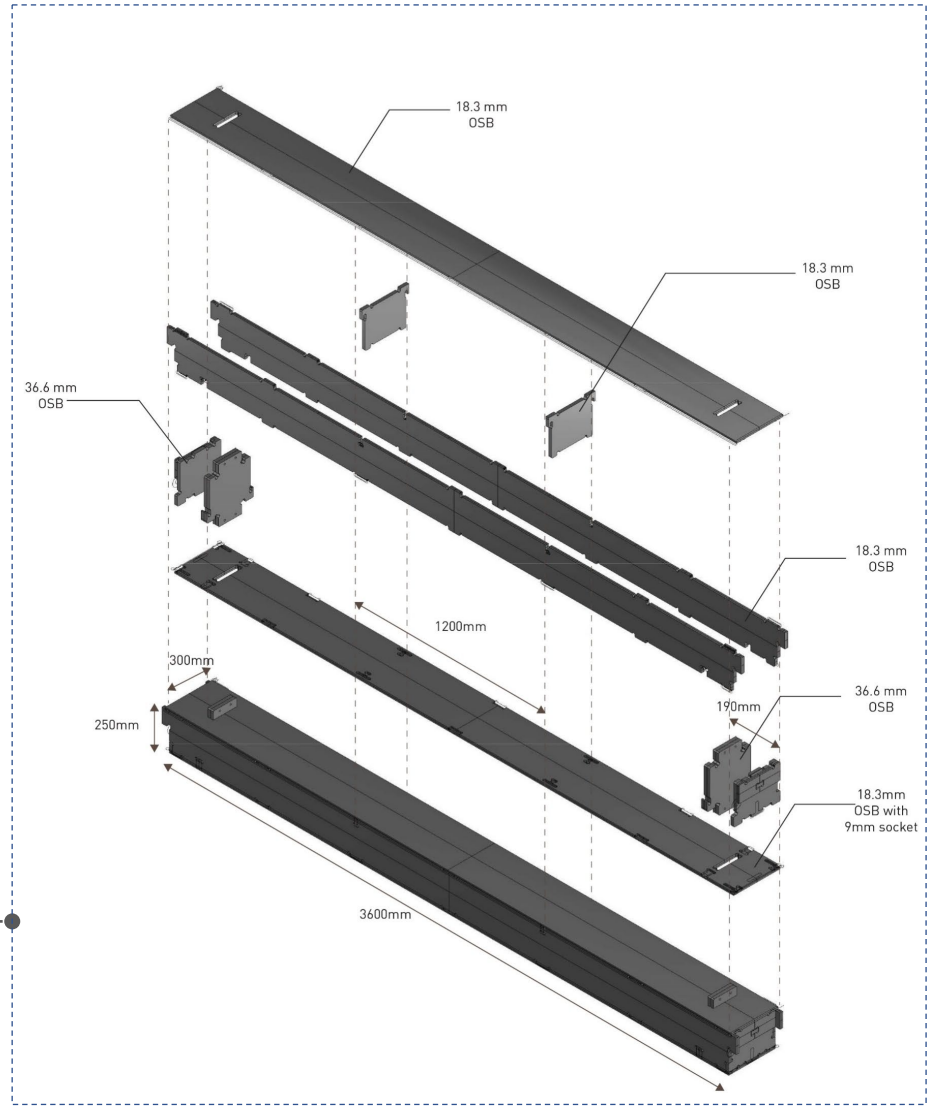

UNILIN

FabField: Structure

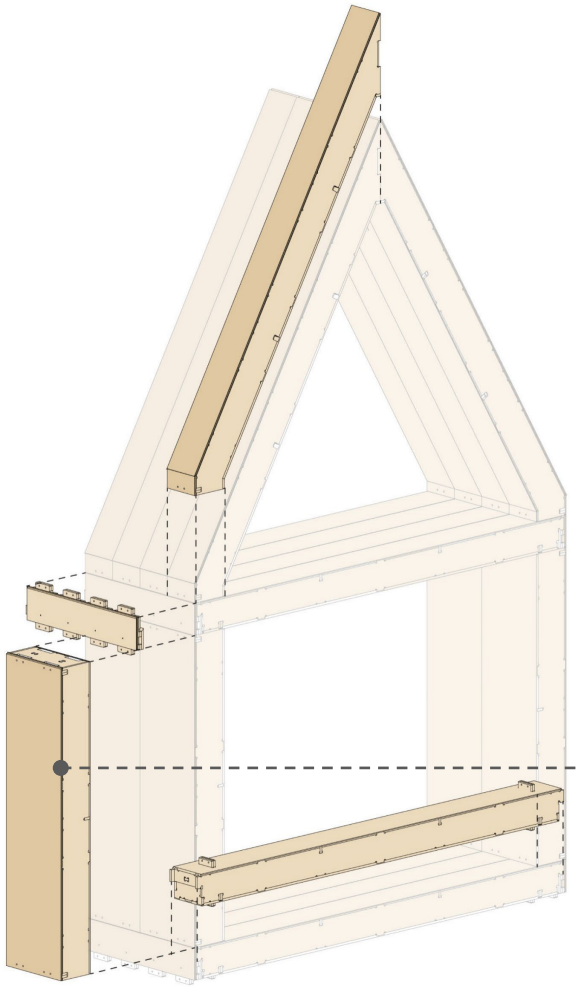
FabField: Structure

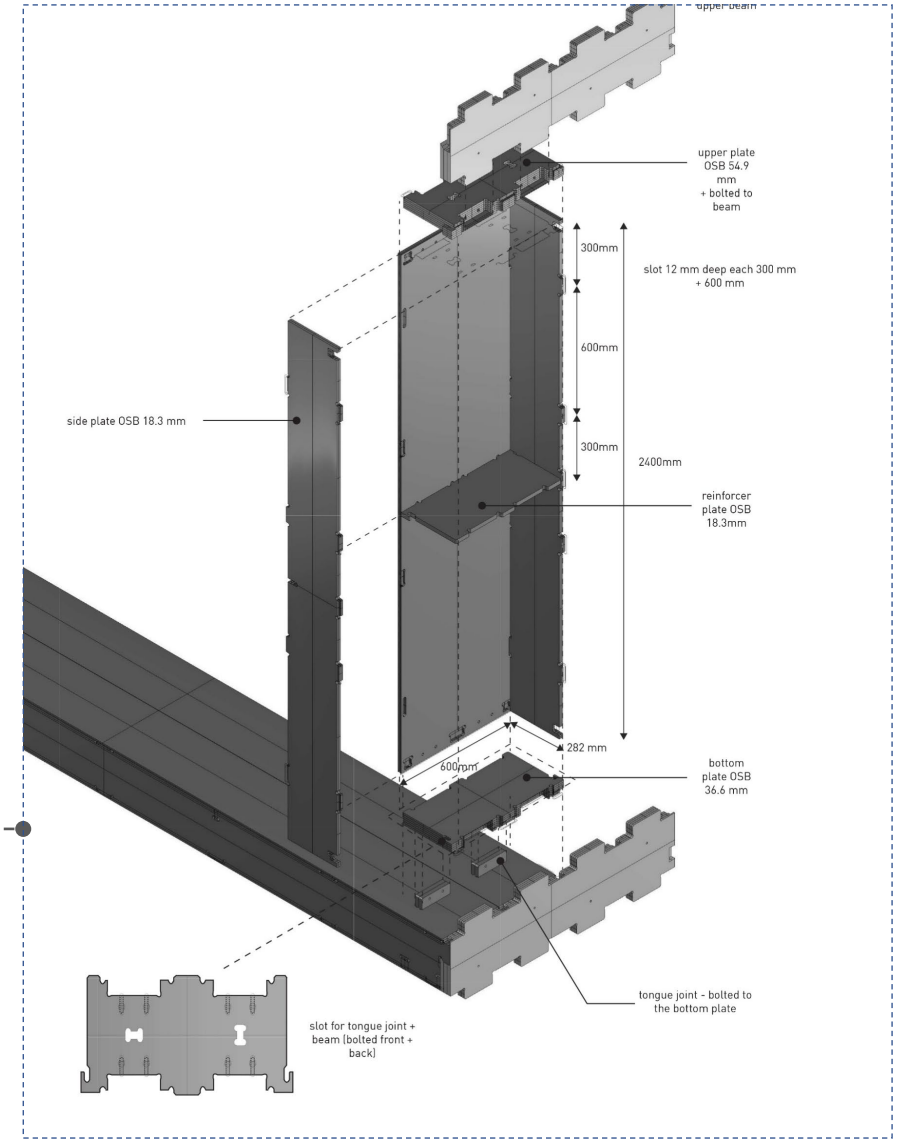
Floor block



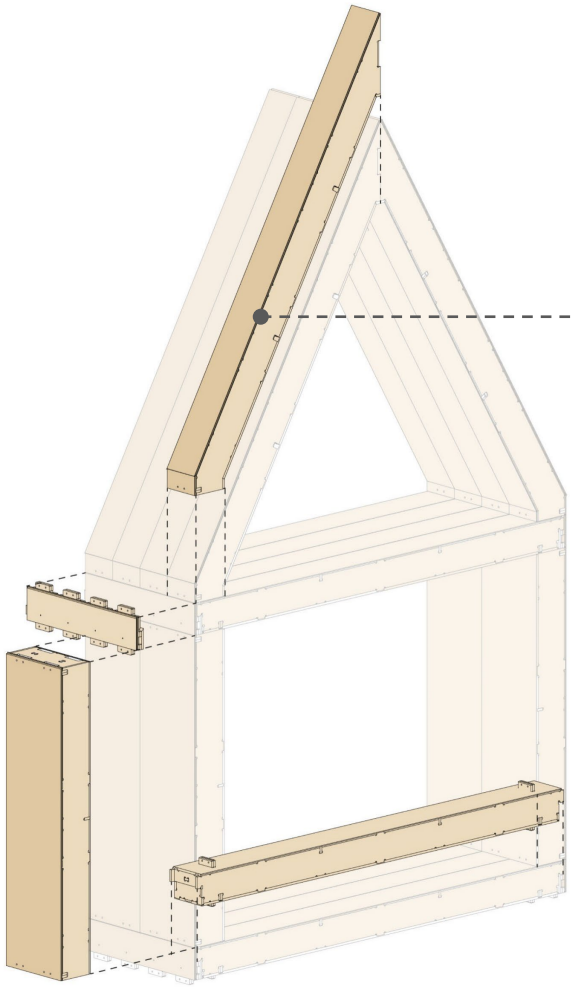

18.3 mm
OSB
18.3 mm
OSB
36.6 mm
OSB
18.3 mm
OSB
1200mm
300mm
190mm
36.6 mm
OSB
250mm
18.3mm
OSB with
9mm socket
3600mm

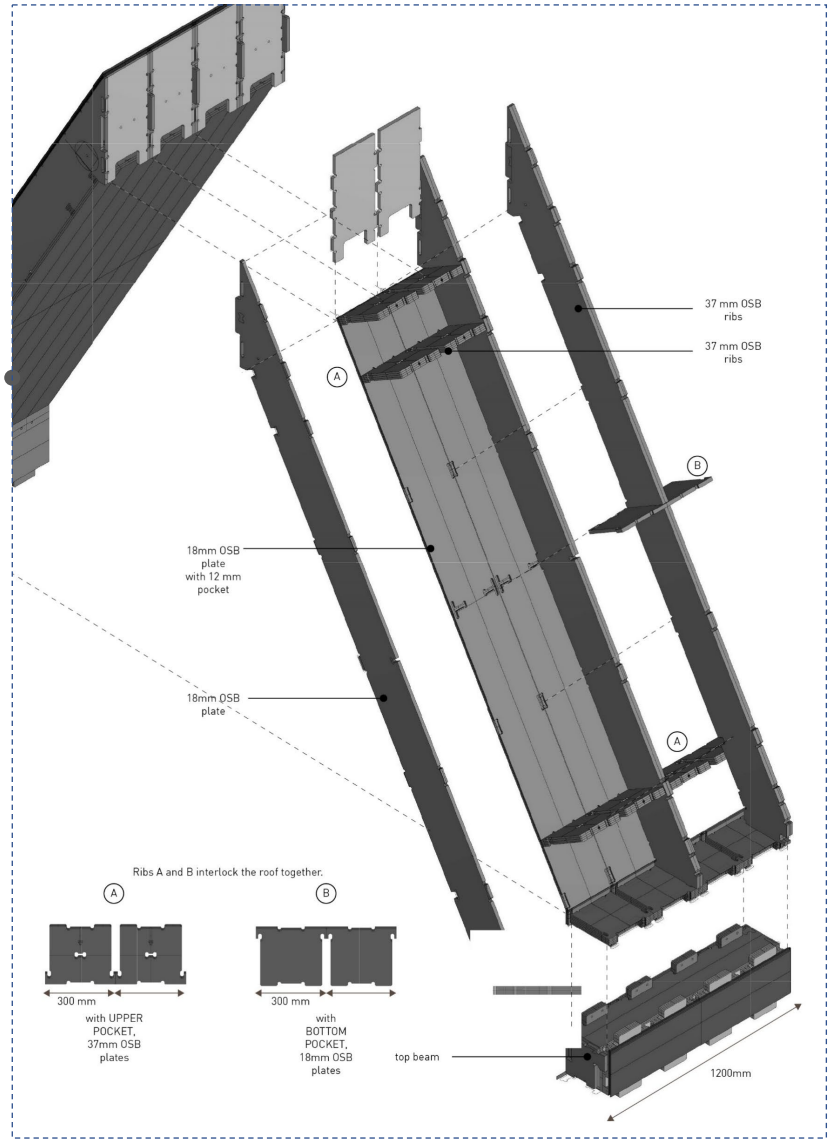
Wall block




upper plate
OSB 54.9
mm
+ bolted to
beam
300mm
slot 12 mm deep each 300 mm
+ 600 mm
600mm
side plate OSB 18.3 mm
300mm
2400mm
reinforcer
plate OSB
18.3mm
282 mm
600mm
bottom
plate OSB
36.6 mm
tongue joint - bolted to
the bottom plate
slot for tongue joint +
beam (bolted front +
back)

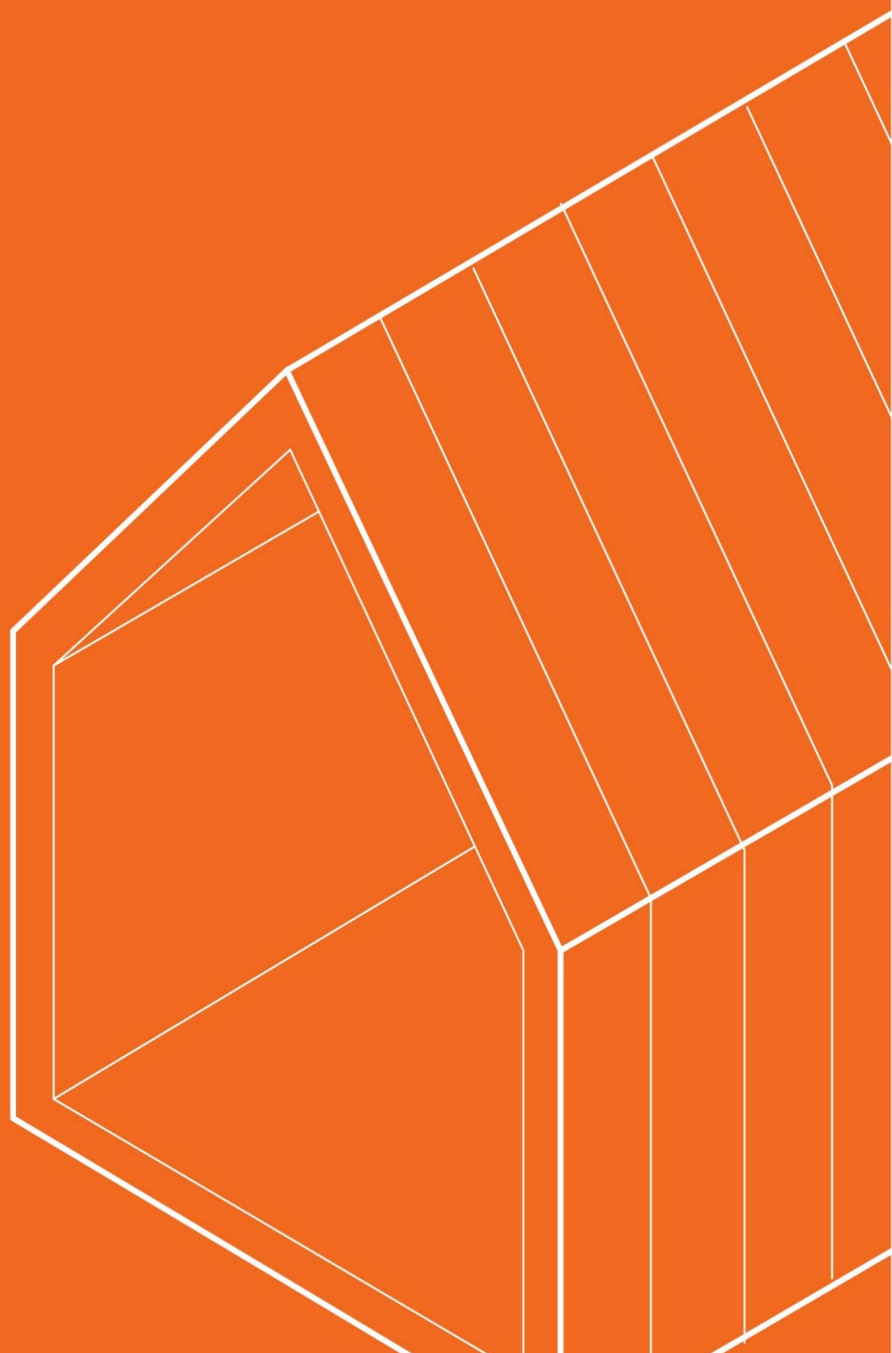
Roof block



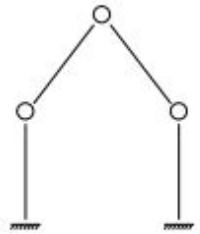

37 mm OSB ribs
37 mm OSB ribs
A
B
18mm OSB plate with 12 mm pocket
18mm OSB plate
A
Ribs A and B interlock the roof together.
A
B
300 mm
with UPPER POCKET, 37mm OSB plates
300 mm
with BOTTOM POCKET, 18mm OSB plates
top beam
1200mm

03

problem statement



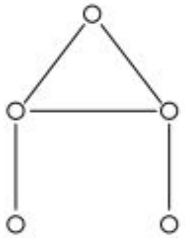
Original hypothesis



Bottom fixed

\+ Maximum freedom of design

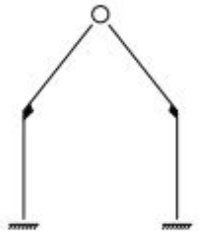
\- Concentrated force



All hinged

No complex connection

Less freedom of design

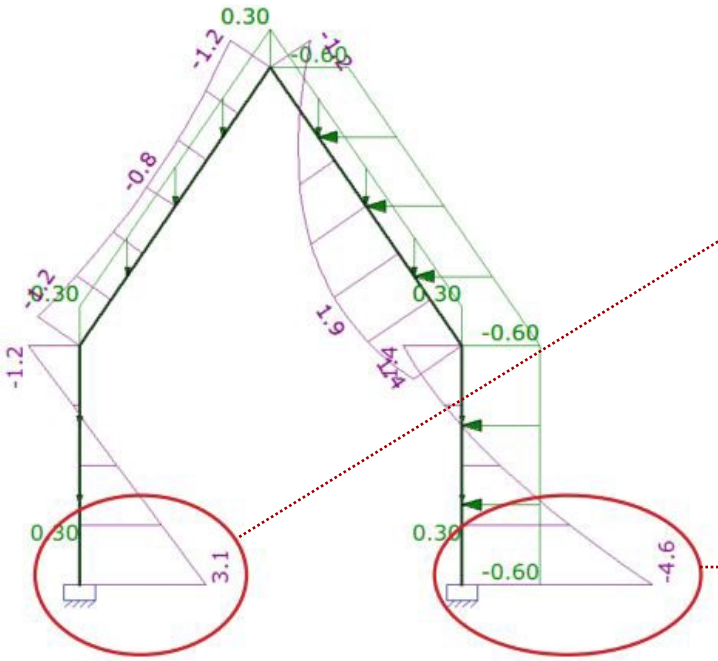


All fixed

Maximum freedom of design

Oversizing

Original hypothesis

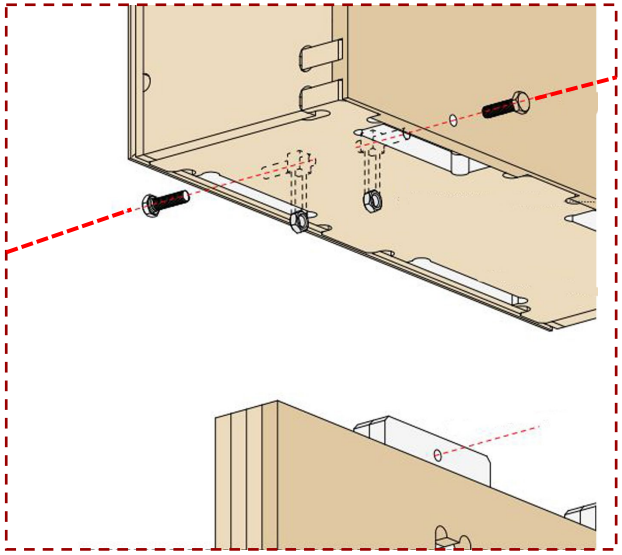


M=F(force) * a(distance)

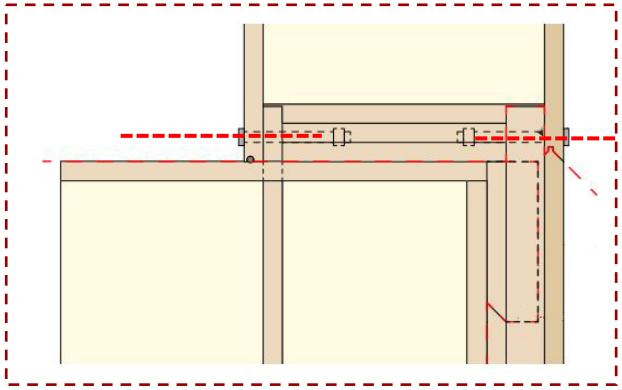
Tensile strength inside the connection
Mmax inside : 3.1 kNm
A : 300 mm (width of the block) = 0.3 m
F = M/a = 3.1/0.3 = 10.33 kN
Divided over 2 connections : 5.17 kN per joint

Tensile strength outside the connection
Mmax outside : 4.6 kNm
A : 300 mm = 0.3 m
F = M/a = 4.6 / 0.3 = 15.33 kN
Divided over 2 connections : 7.67 kN per joint

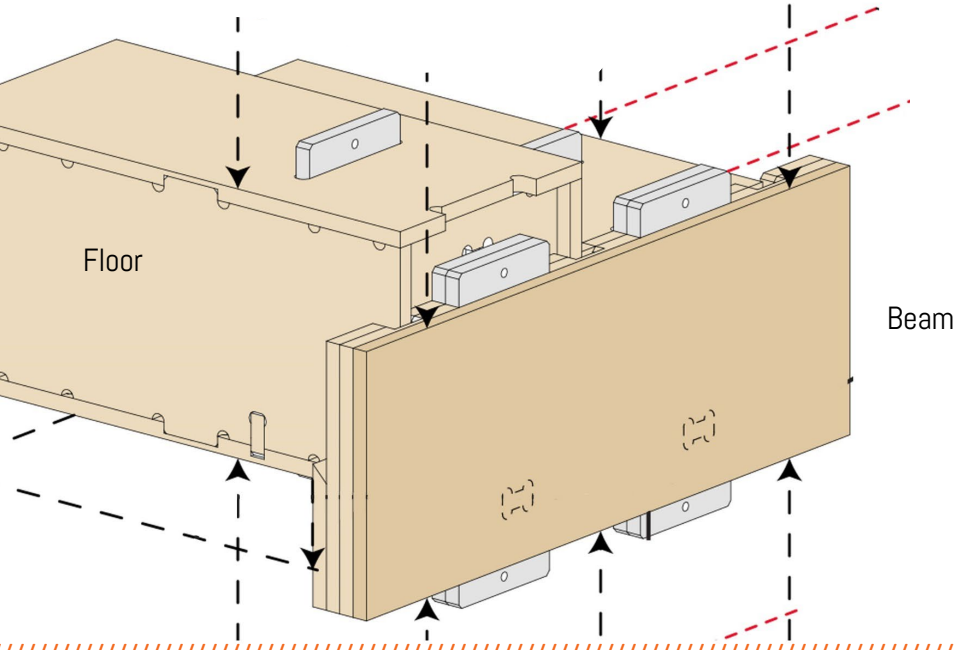
Connection



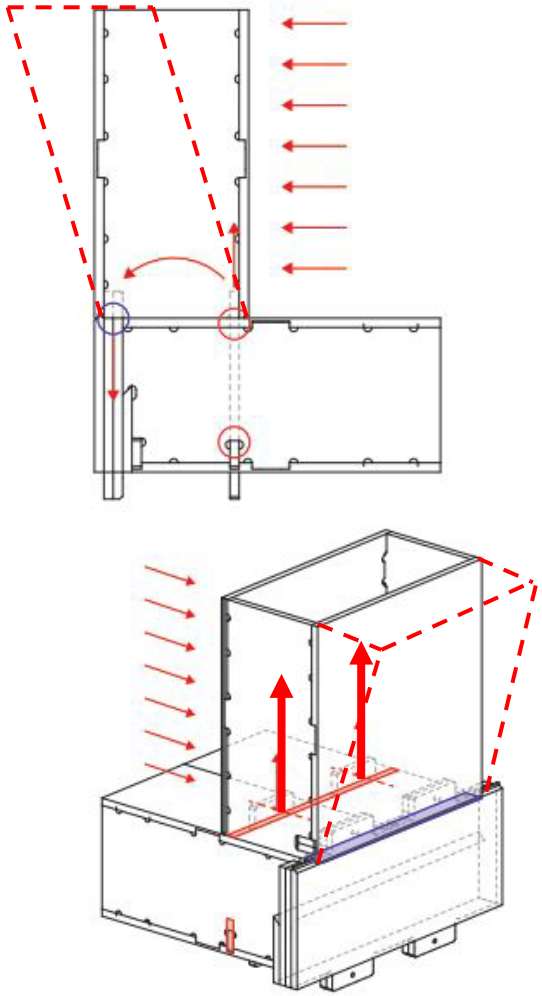
M10 bolt compression on OSB = area * max. stress
area = 628 mm2
628 * 3.5 = 2.2 kN
so 7.7/2.2 = 3.5 (4 connections needed)



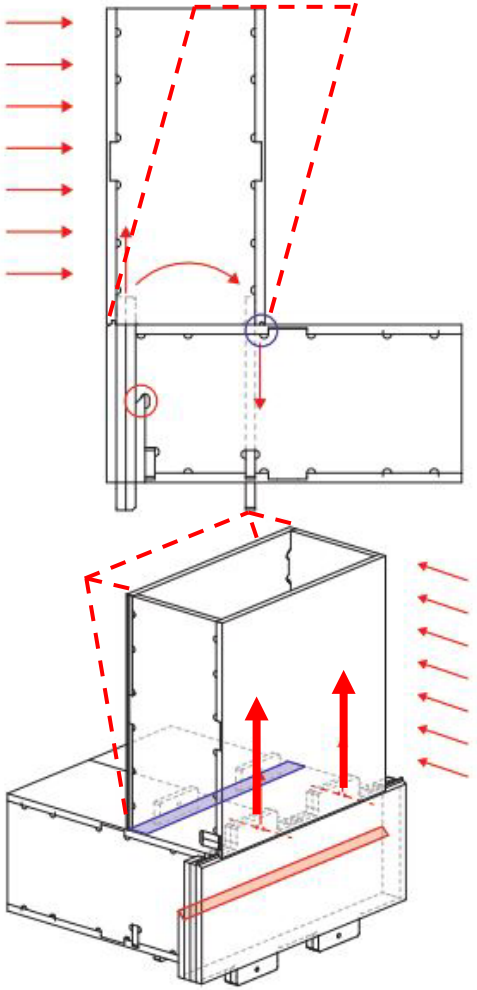
(Van der Knaap , 2016)



Original hypothesis

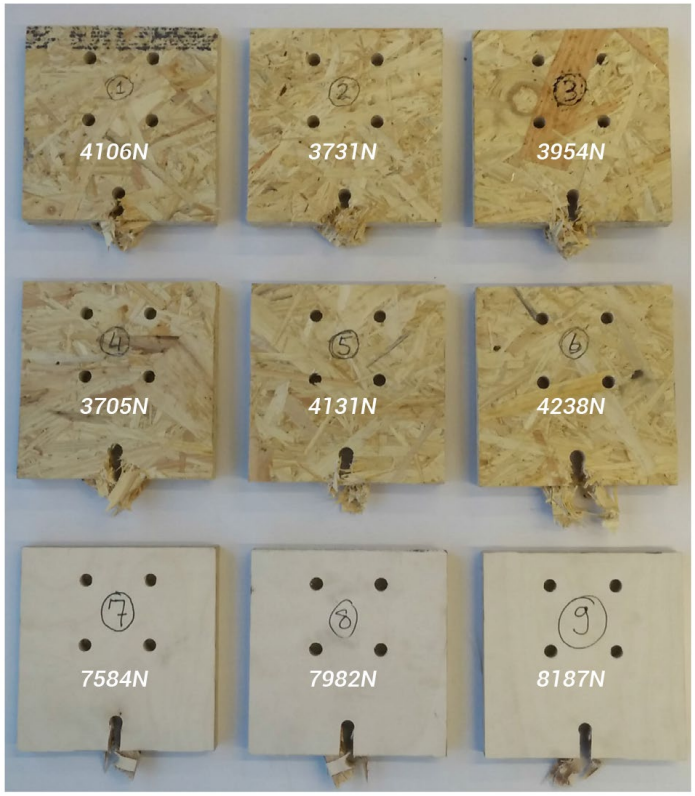


Tensile force of the bolt in the notch counteract the moment



(Van der Knaap , 2016)

Original hypothesis : Material test



M10 18mm OSB

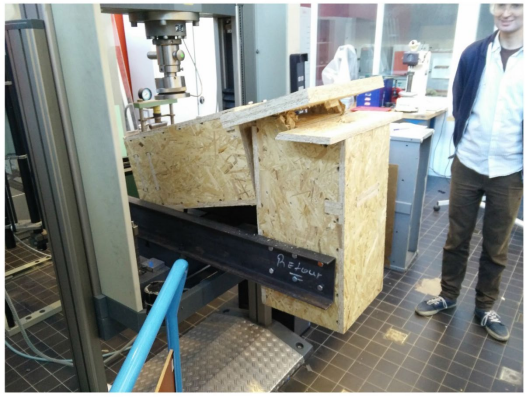
M12 18mm OSB

M10 18mm plywood

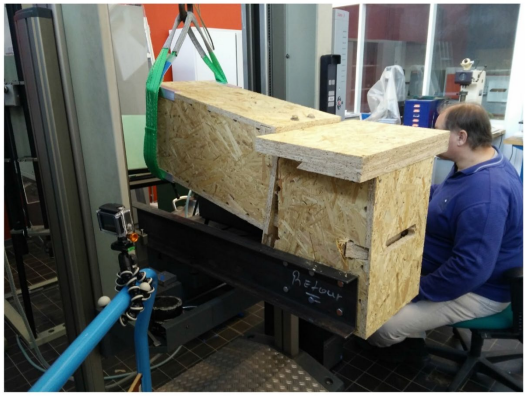
(Van der Knaap , 2016)

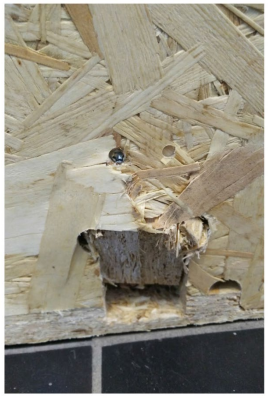
Original hypothesis : Connection test

Compression test

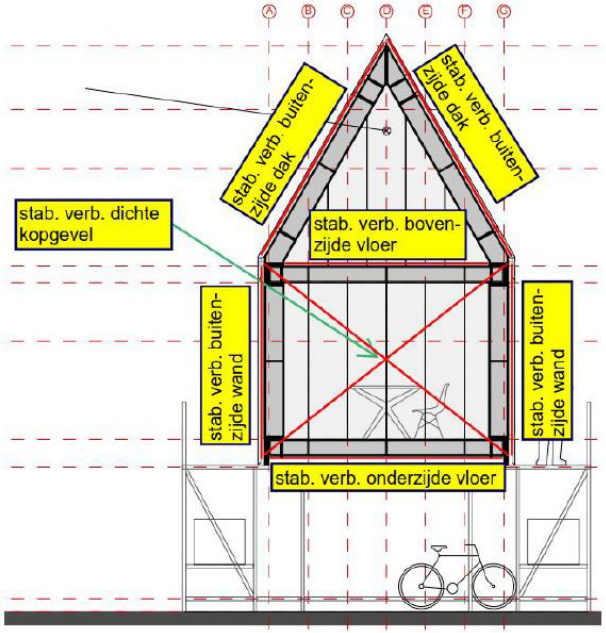


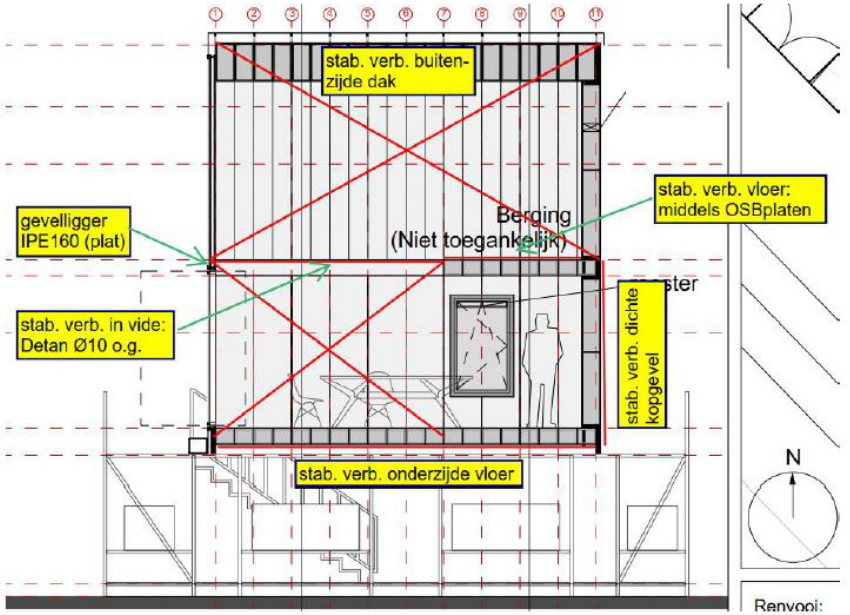
Tension test





Problem statement

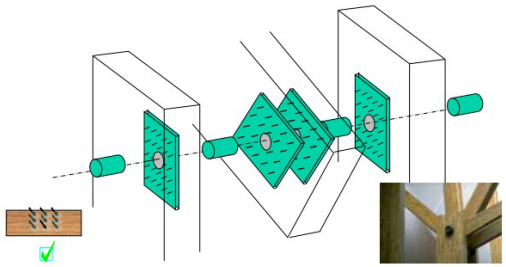




Luning BV, 2016

Problem statement

Examples of fixed wood joint



Re-calculation

Maximum moment : 4.6 kNm
a : 200 mm (in reality) = 0.2 m
F = M/a = 4.6 / 0.2 = 23 kN

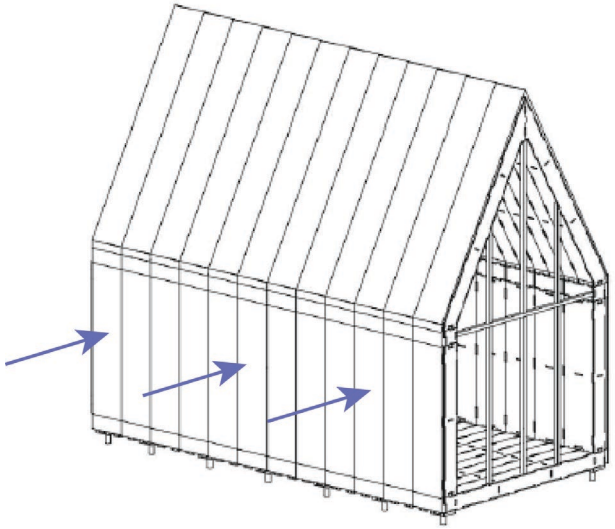
Divided into 2 connections :
11.5 kN

After safety factor of 0.4 (friction coefficient between steel and wood) = 16.1 kN / connection

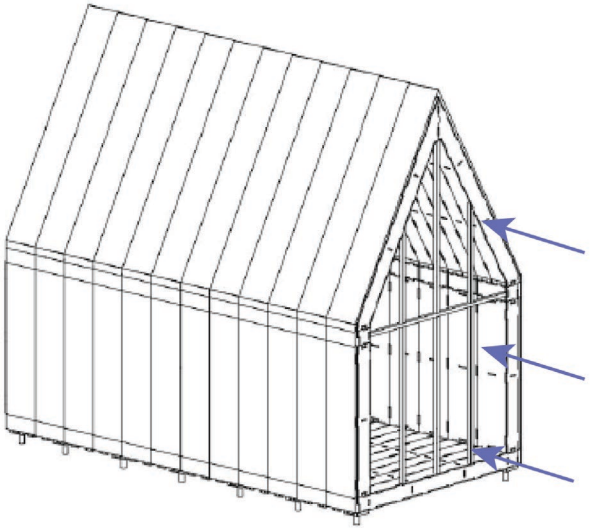
Max shear strength of 18 mm OSB against M10 bolt : 4 kN each.

CONCLUSION :
Far from sufficient to be a fixed joint!

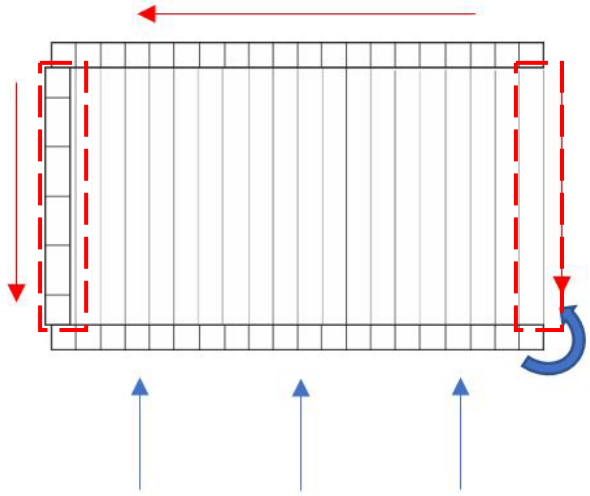
Lateral force reaction

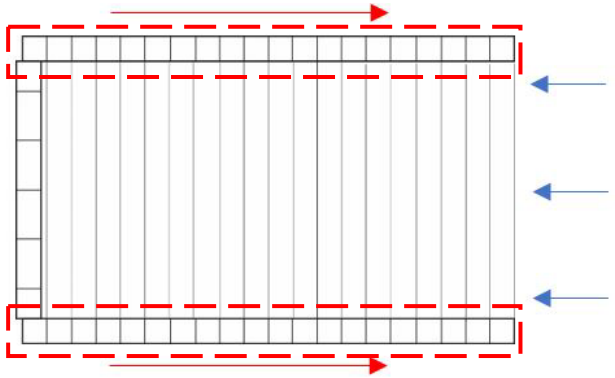


Y-axis

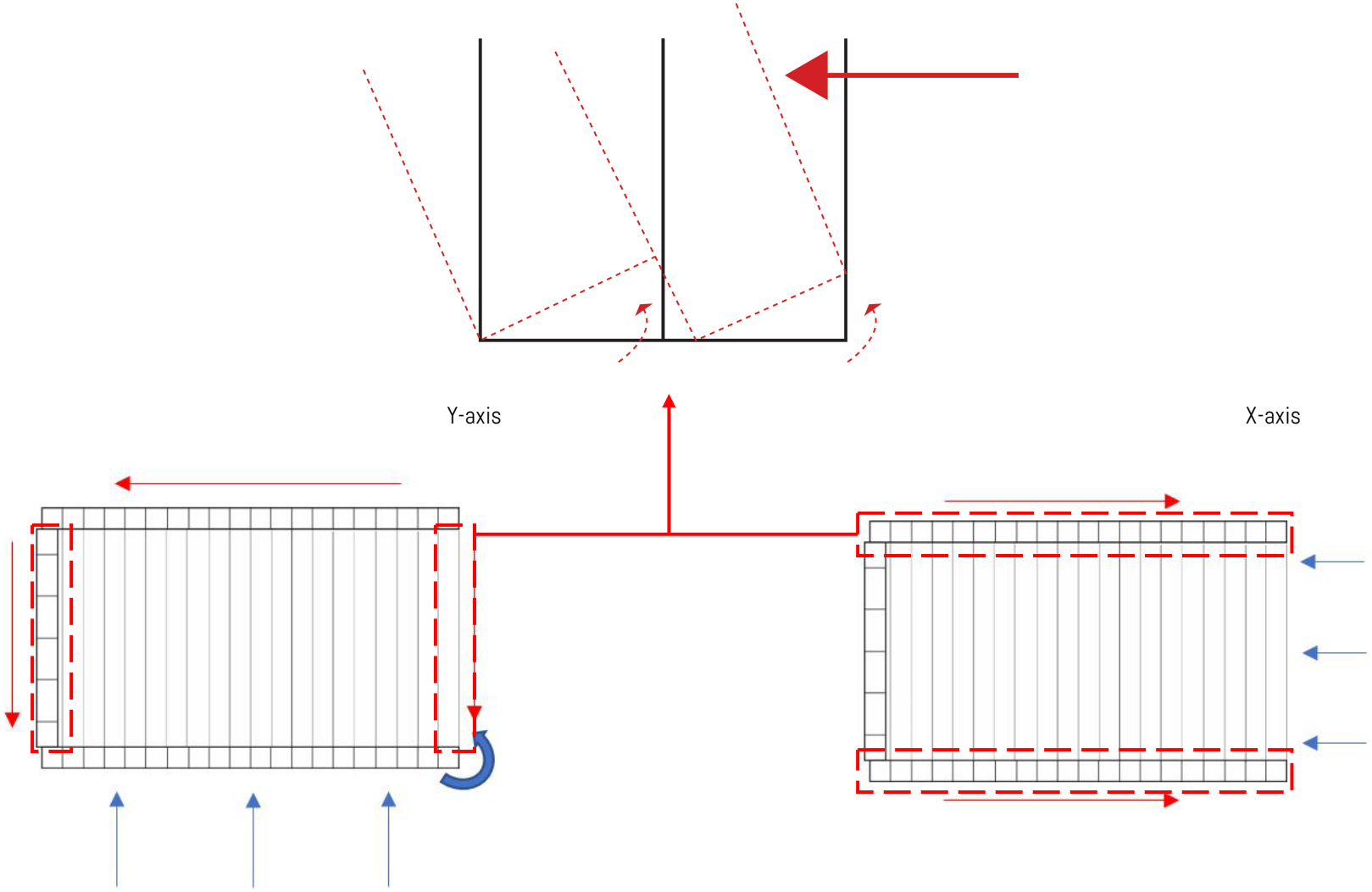


X-axis





Lateral force reaction



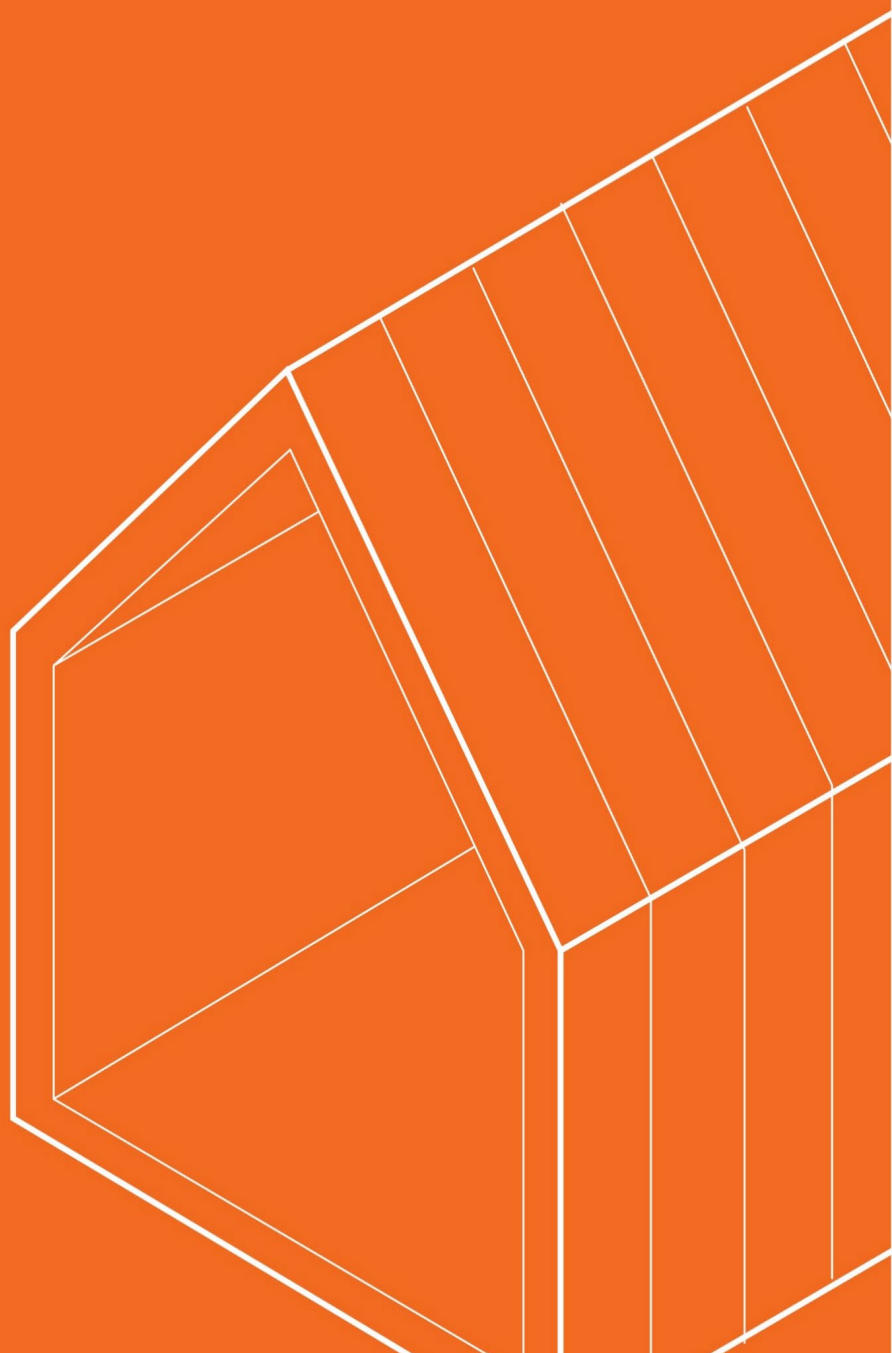
CONCLUSION

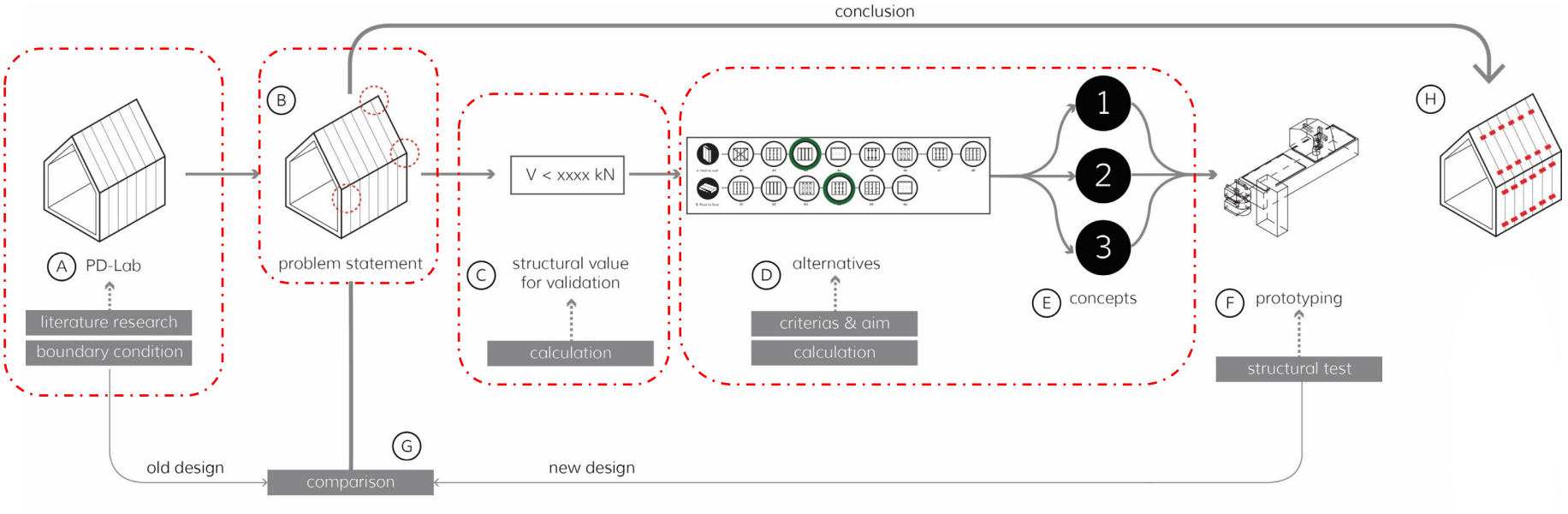
The connections act in hinged behaviour instead of fixed.

To reach stability, the wall and floor components needs to act together as shear wall and diaphragm floor.

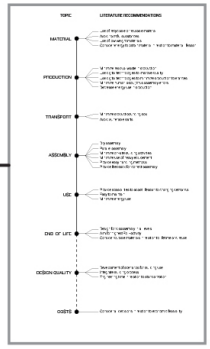
04

methodology




conclusion
A
PD-Lab
literature research
boundary condition
B
problem statement
V < xxxx kN
C
structural value
for validation
calculation
D
alternatives
criterias & aim
calculation
1
2
3
E
concepts
F
prototyping
structural test
H
G
old design
comparison
new design

RESEARCH



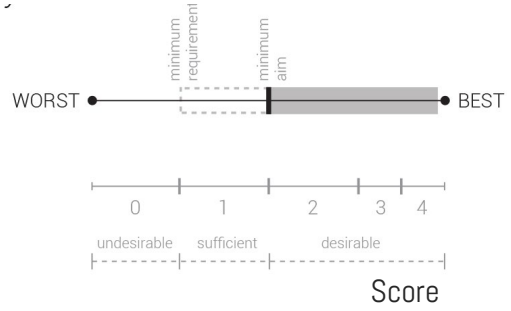
SUSTAINABLE
STRATEGIES

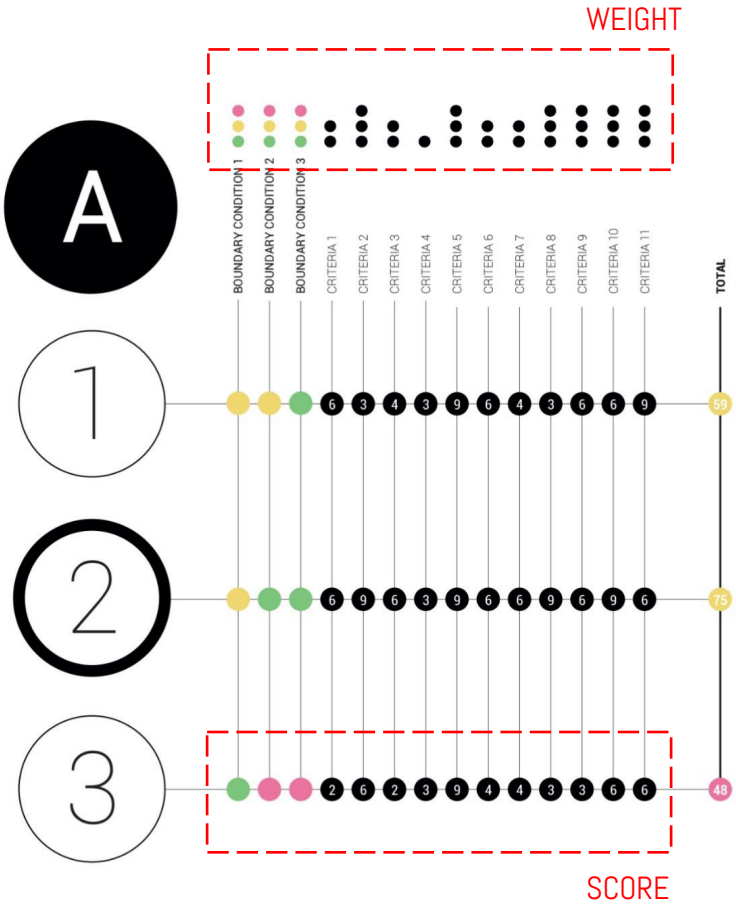
Strategies :

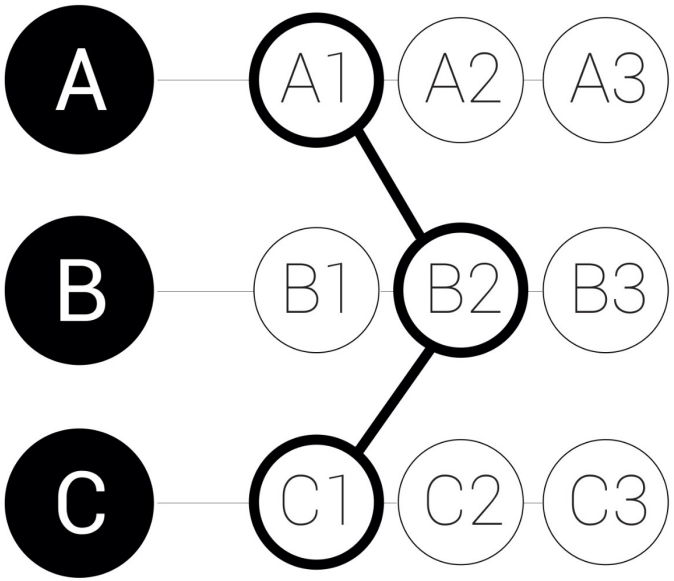
All the necessary goals related to the project, e.g. environmental aspect, end-of-life, production process,etc.

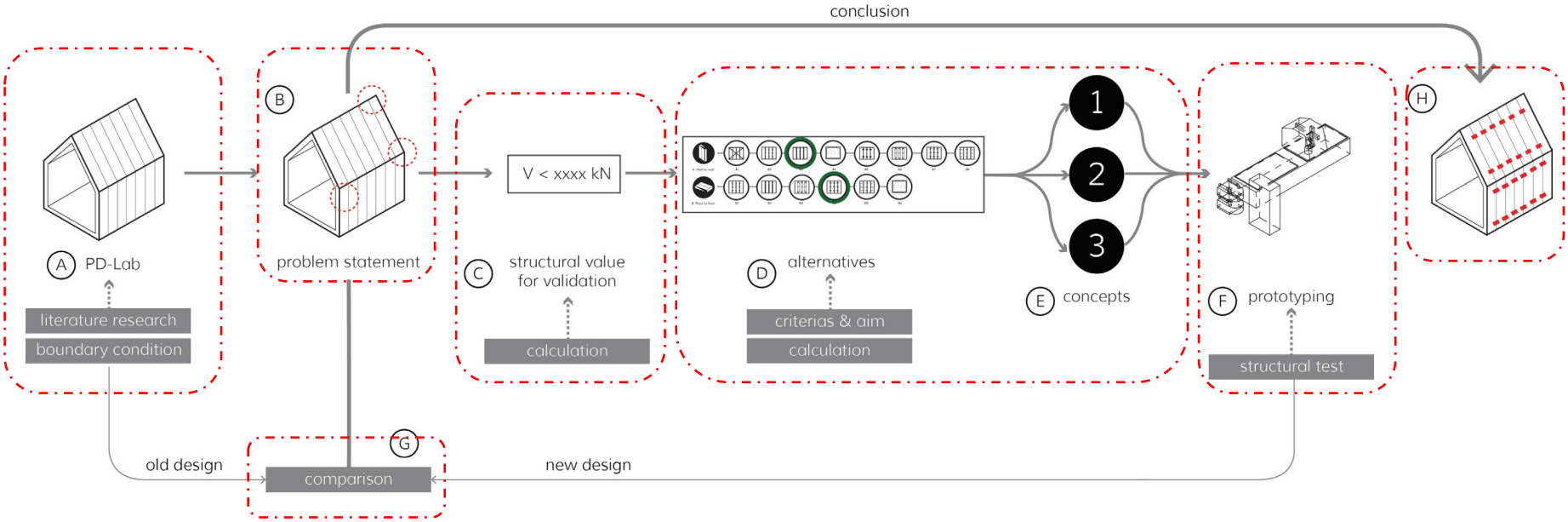
Requirement and ambitions :

By comparing all strategies individually, one can conclude from the most to the least important one. (weight)




WEIGHT
A
1
2
3
BOUNDARY CONDITION 1
BOUNDARY CONDITION 2
BOUNDARY CONDITION 3
CRITERIA 1
CRITERIA 2
CRITERIA 3
CRITERIA 4
CRITERIA 5
CRITERIA 6
CRITERIA 7
CRITERIA 8
CRITERIA 9
CRITERIA 10
CRITERIA 11
TOTAL
6 3 4 3 9 6 4 3 6 6 9 59
6 9 6 3 9 6 6 9 6 9 6 75
2 6 2 3 9 4 4 3 3 6 6 48
SCORE


A
B
C
A1
A2
A3
B1
B2
B3
C1
C2
C3


conclusion
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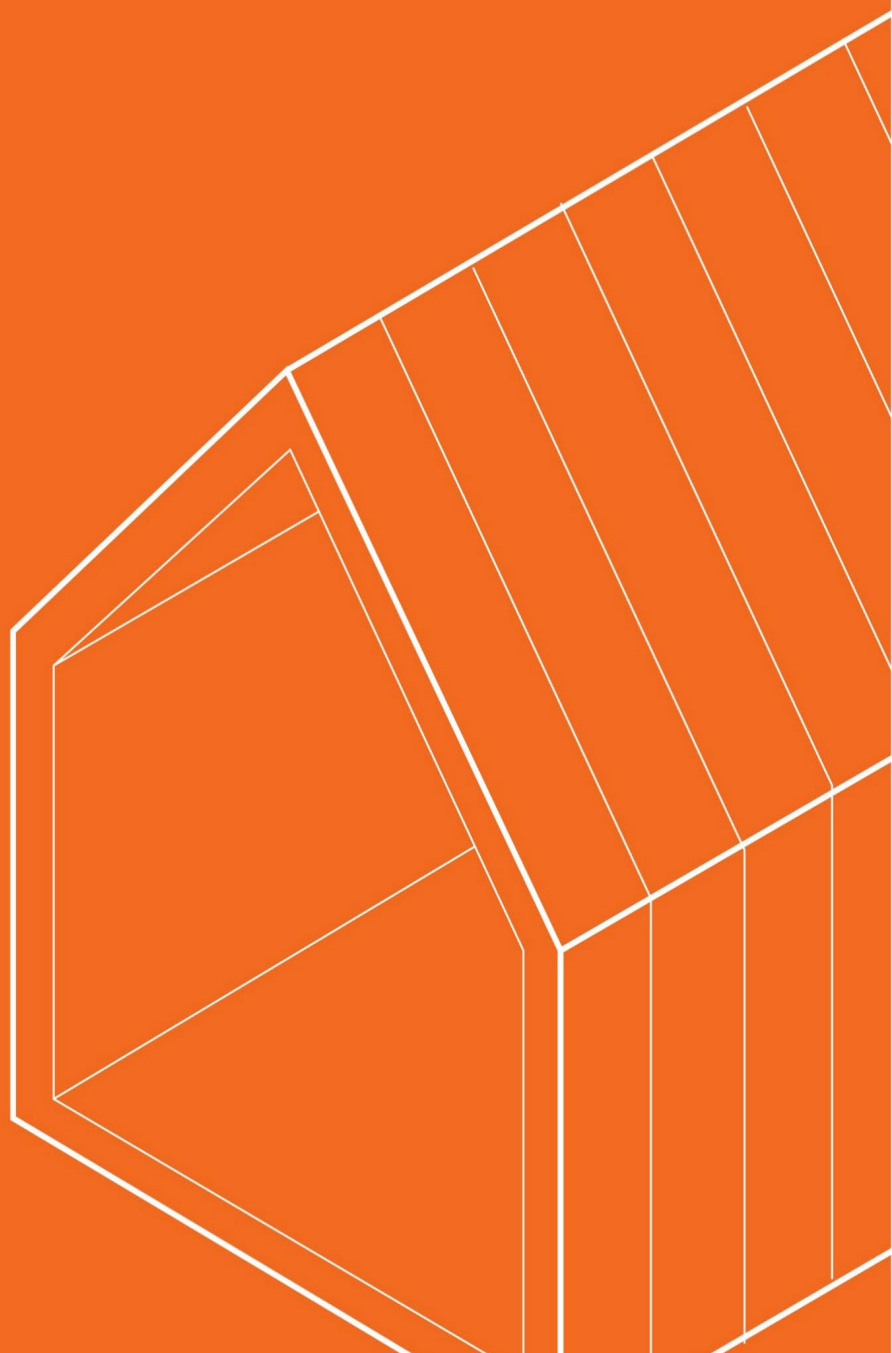
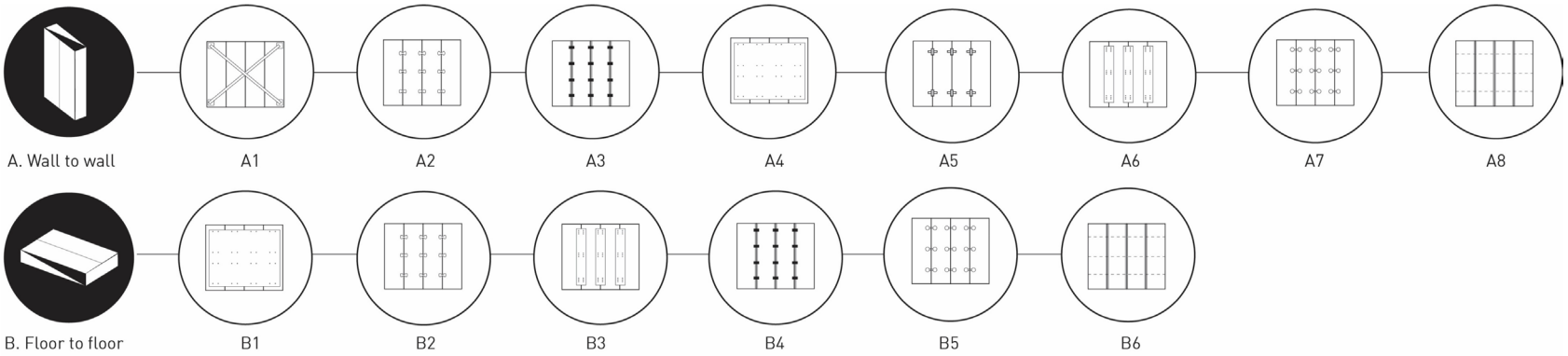
calculation
1
2
3
E
concepts
F
prototyping
structural test
H
G
comparison
old design
new design

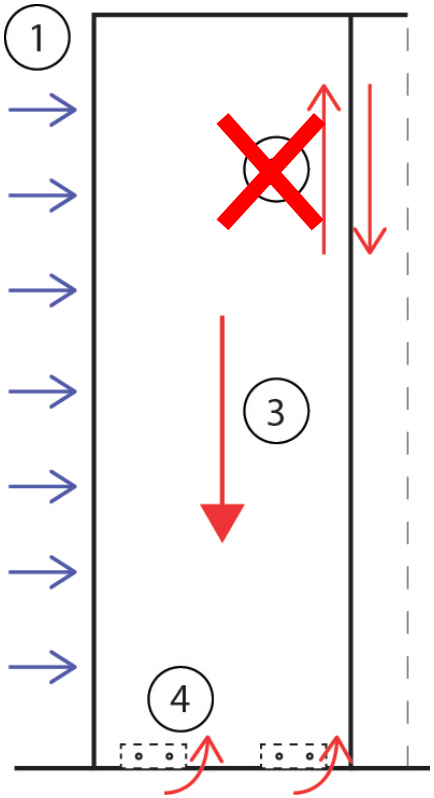
04

design development



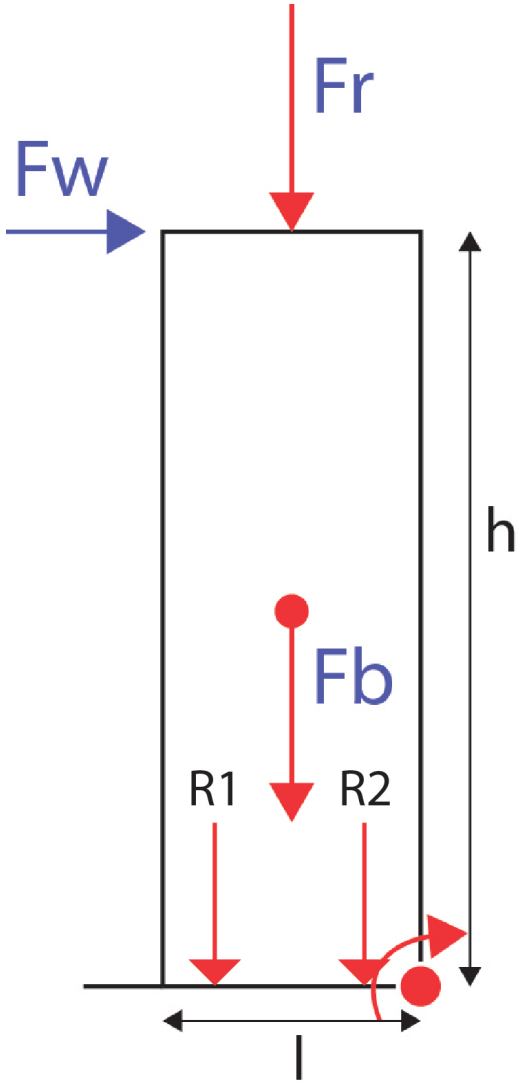

A. Wall to wall
A1
A2
A3
A4
A5
A6
A7
A8
B. Floor to floor
B1
B2
B3
B4
B5
B6

Structural Analysis
Wall to wall connection



1. Wind force
2. ~~Friction force~~
3. Self weight
4. Reaction force from bolts

Structural Analysis
Wall to wall connection



Fw : wind force (31.65 kN)
Fr : roof weight (0.5 kN)
Fb : wall weight (0.5 kN)
R1 : reaction force (2 kN)

H : height (2.7 m)
L : length (0.6 m)

Principle

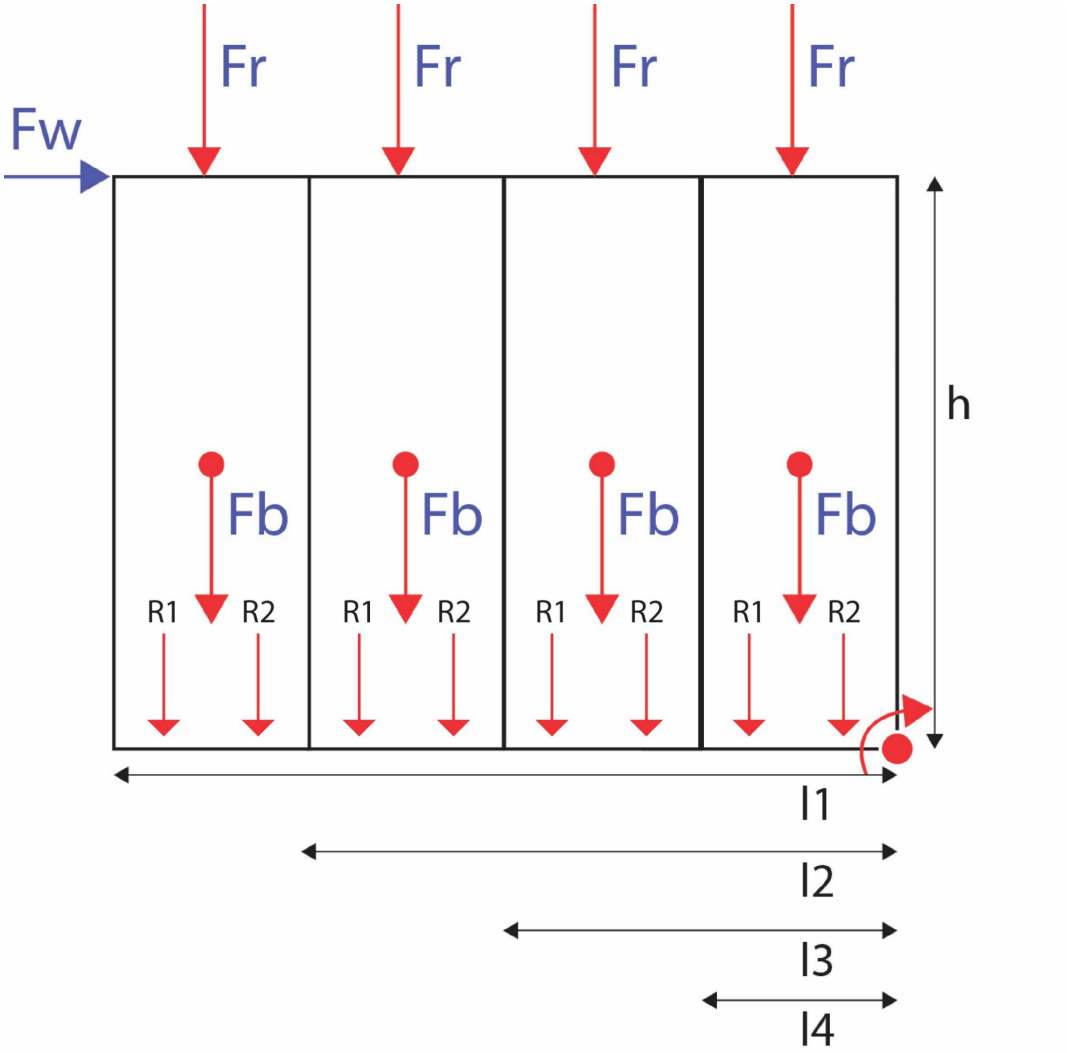
Moment caused by all the reaction & weight forces > Moment caused by the wind

Calculation

Wind force - self weight < 0

Fw*h - 1/2l(Fb+Fr) < 0
31.65*2.7 - 0.3(0.5+0.5+0.5) - 4< 0
80.75 knM < 0
29.9 kN < 0 (NOT CAPABLE TO WITHSTAND THE WIND)

Structural Analysis
Wall to wall connection



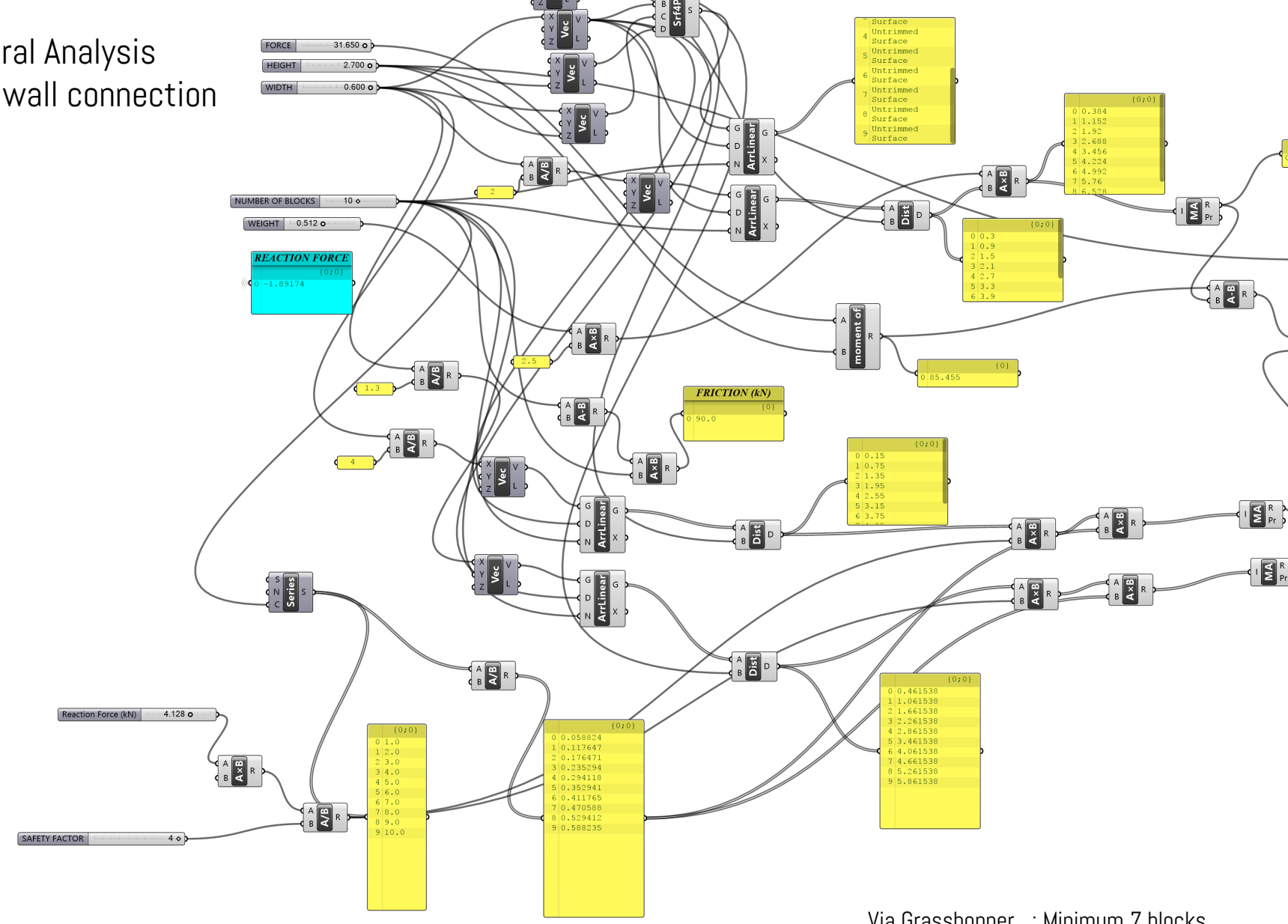
Fw*h - (Fr+Fb+Fb)(3.5l + 2.5l + 1.5l + 0.5l) - (4/4 * Fr * l1 + 3/4*Fr*l2 + 2/4*Fr*l3 + 1/4*Fr*L4) < 0

the reaction forces is gradually reduced based on the number of the blocks due to different magnitude. The closer it is to the point of rotation, less reaction force occurs.

31.65 * 2.7 - (0.5+0.5+0.5)(2.1+1.5+0.9+0.3) - (4*2.4 + 3/4*4*1.8 + 2/4*4*1.2 + 1/4*4*0.6)< 0

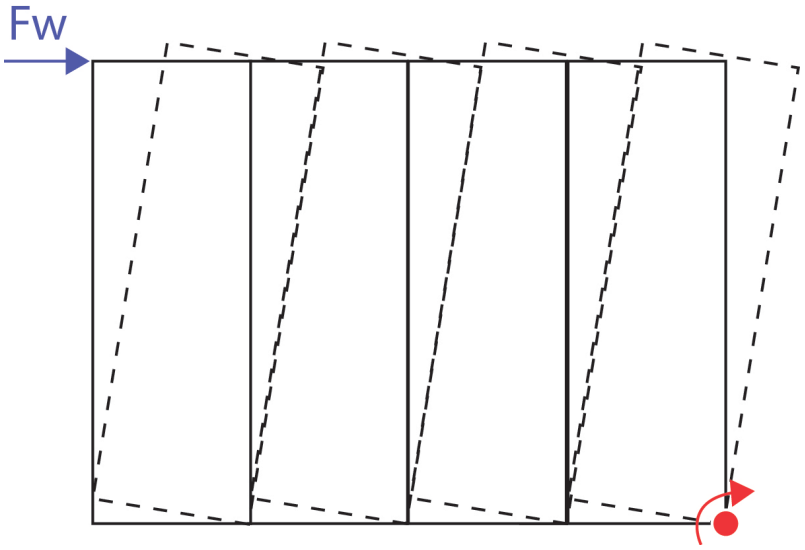
85.45 - 7.2 - 18 < 0
60.25 kNm < 0
22.3 kN < 0 (REDUCED)

Structural Analysis
Wall to wall connection



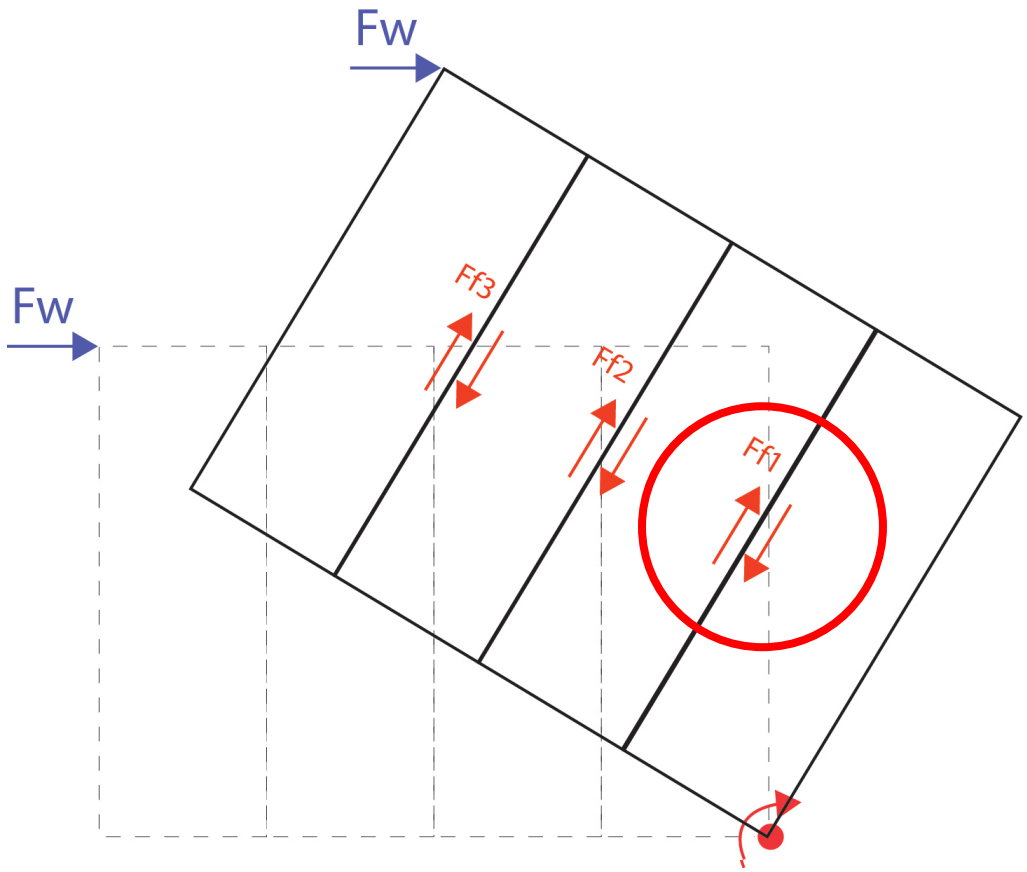
Via Grasshopper : Minimum 7 blocks.

Structural Analysis
Wall to wall connection



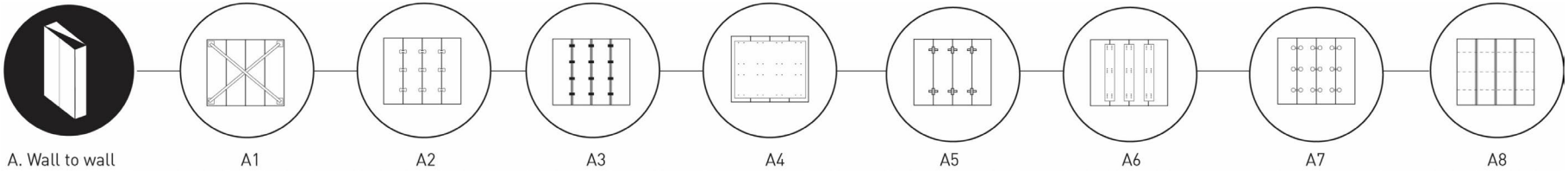
Existing deflection

Structural Analysis
Wall to wall connection

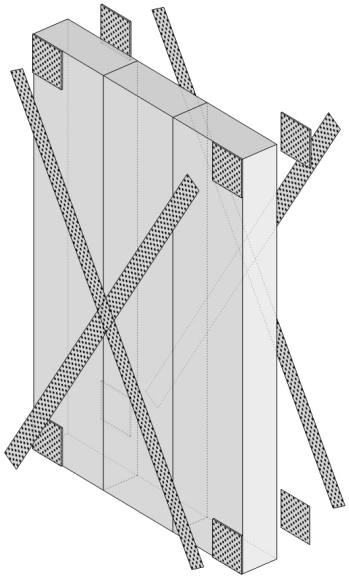


Expected deflection

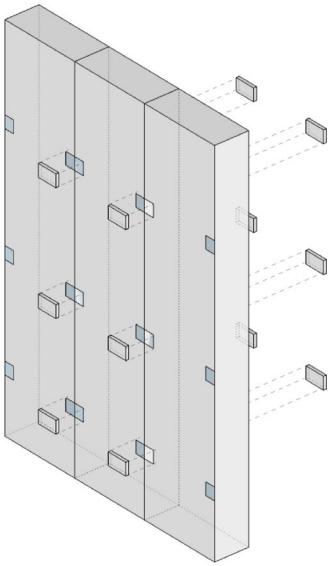
Wall to Wall Alternatives



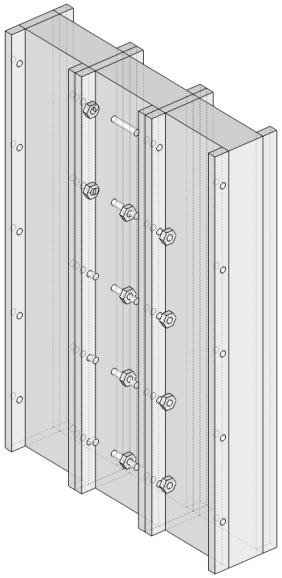
Wall to Wall Alternatives



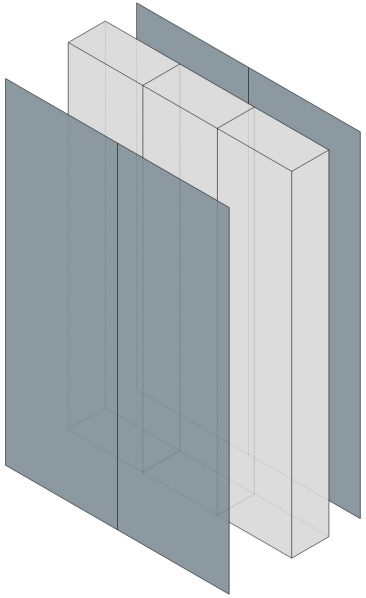
A.1. Steel Bracing



A2. Butterfly



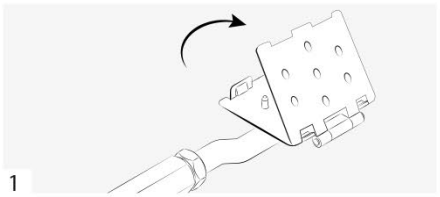
A3. Steel bolt



A.4. Wood Plate

Wall to Wall Alternatives

A1. Steel bracing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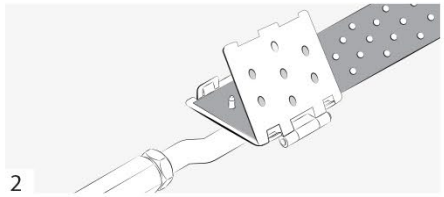
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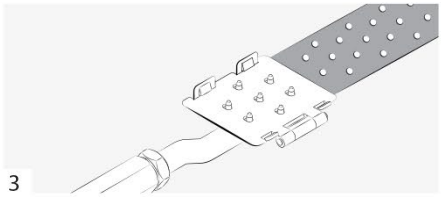
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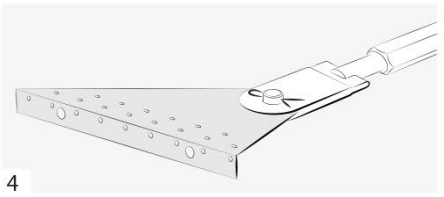
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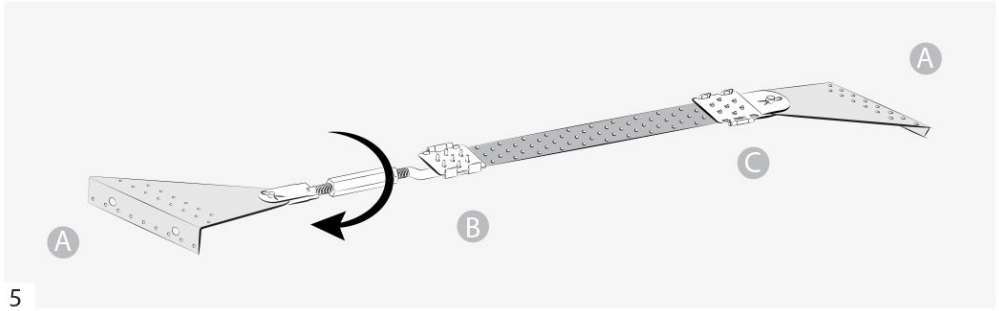
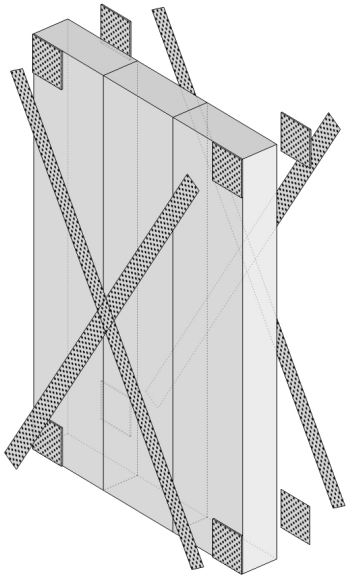
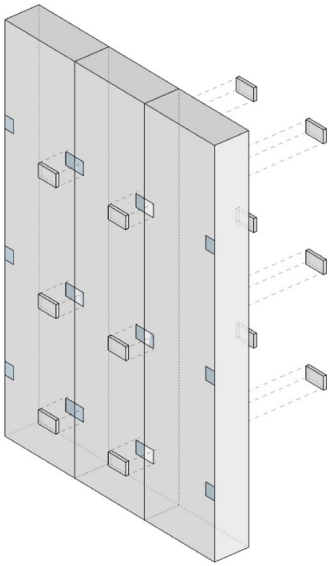


5

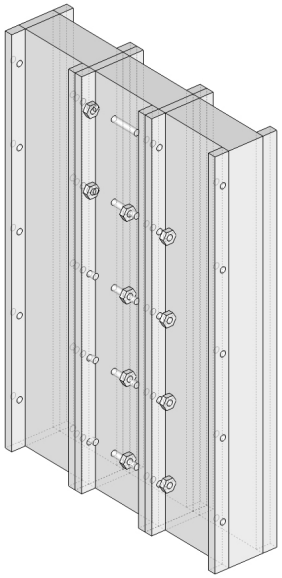
Wall to Wall Alternatives



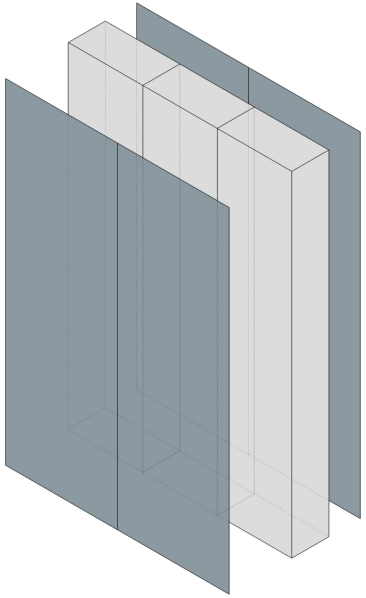
A.1. Steel Bracing



A2. Butterfly



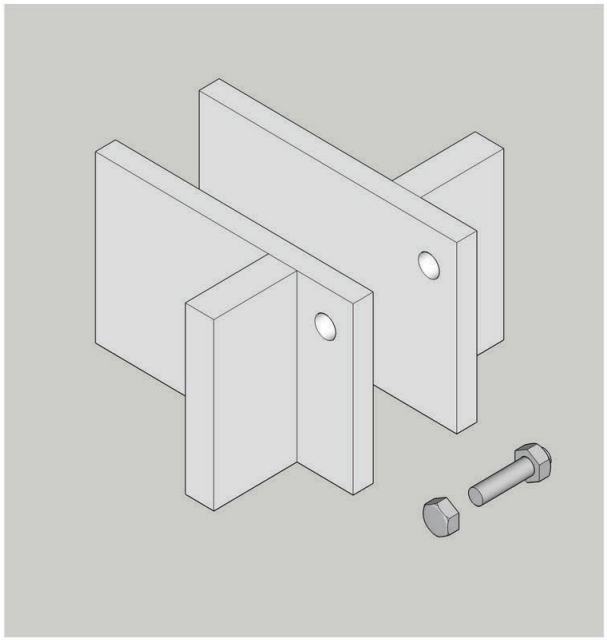
A3. Steel bolt

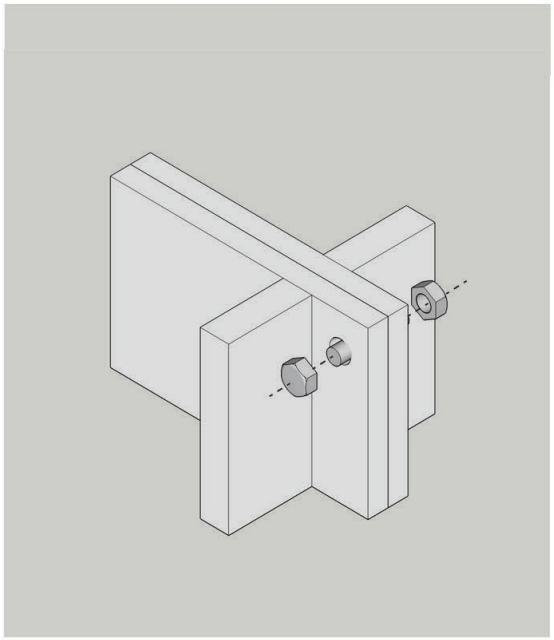


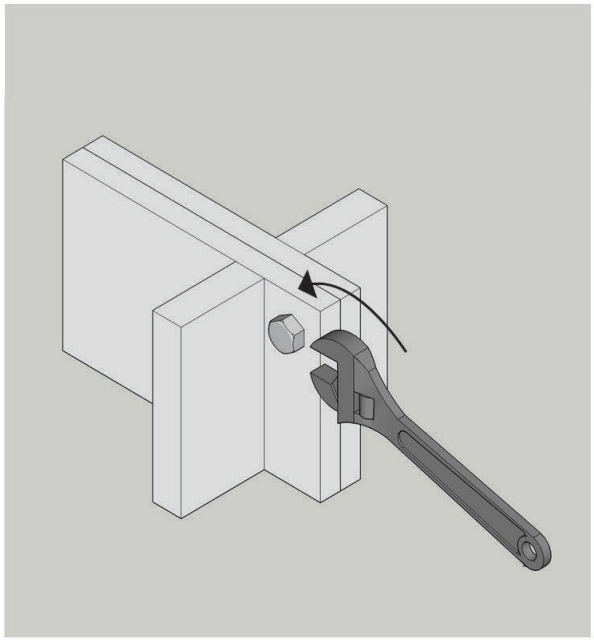
A.4. Wood Plate

Wall to Wall Alternatives

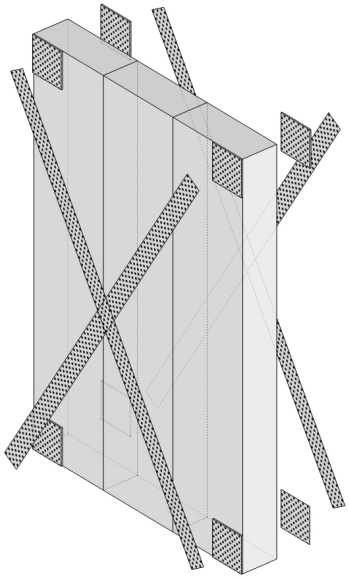
A3. Steel bolt



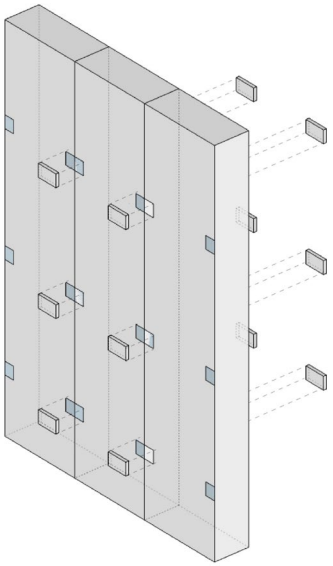




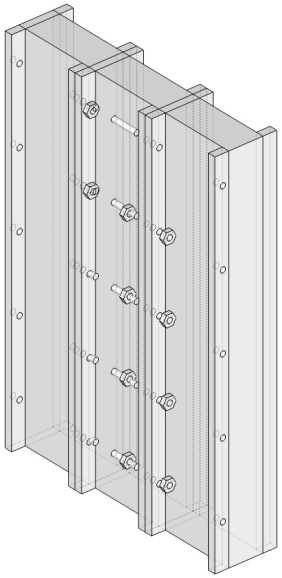
Wall to Wall Alternatives



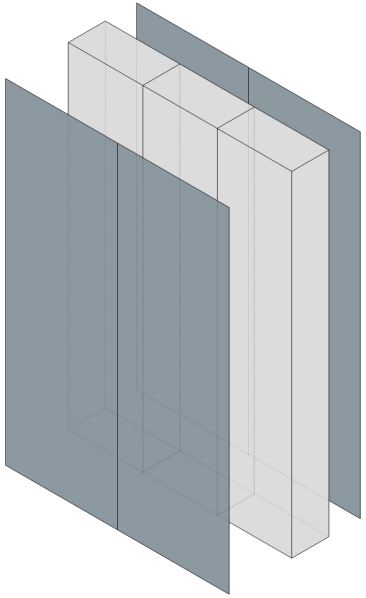
A.1. Steel Bracing



A2. Butterfly

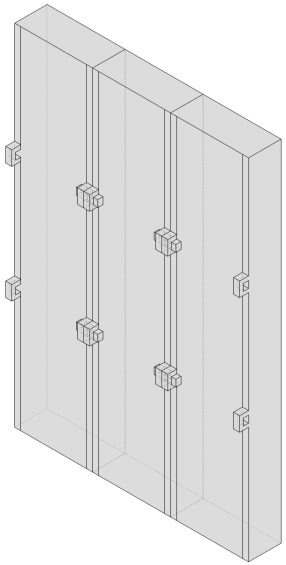


A3. Steel bolt

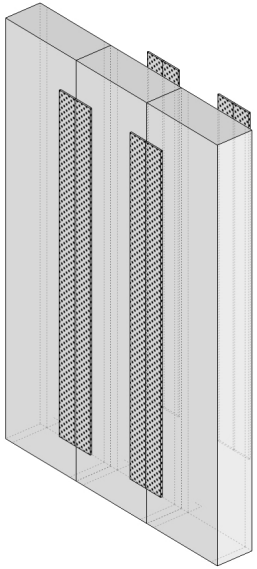


A.4. Wood Plate

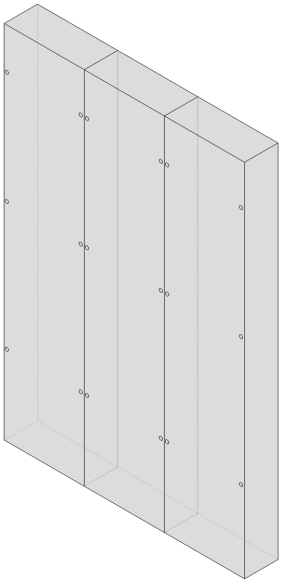
Wall to Wall Alternatives



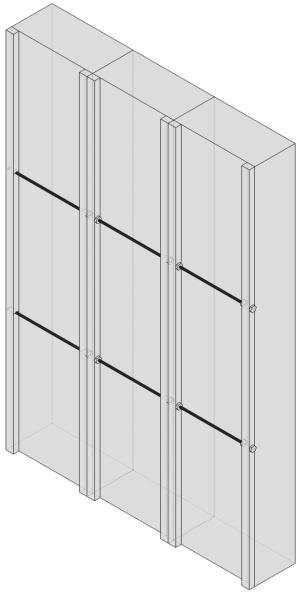
A.5. Wood wedges



A6. Steel plates



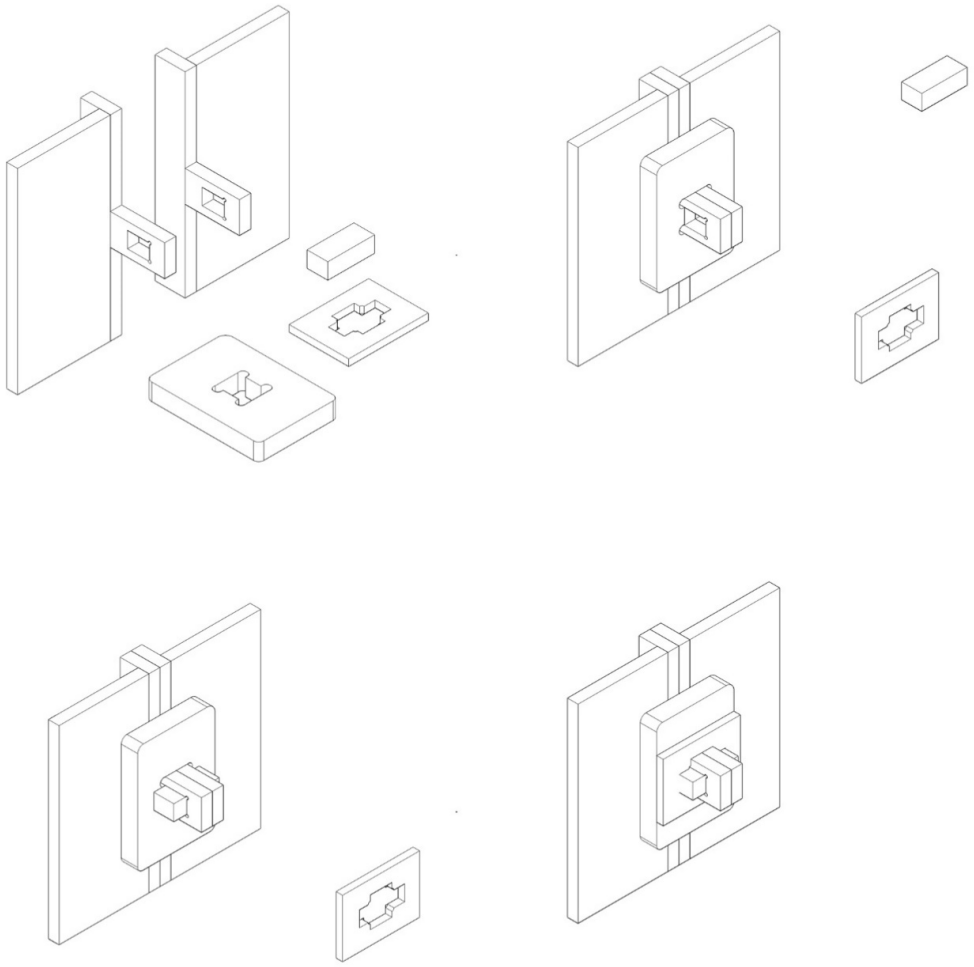
A7. Smart connection



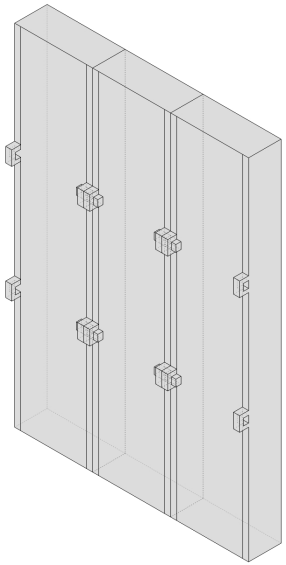
A8. Steel rod

Wall to Wall Alternatives

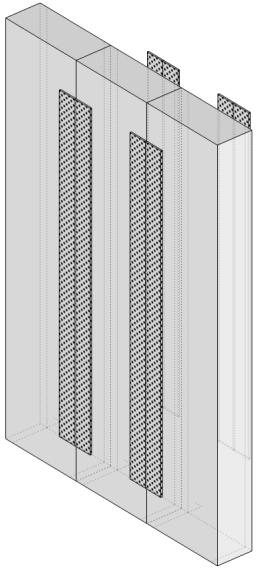
A5. Wood wedges



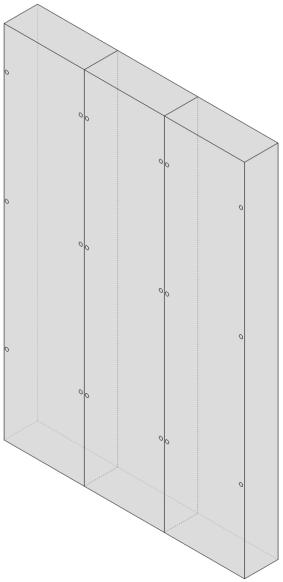
Wall to Wall Alternatives



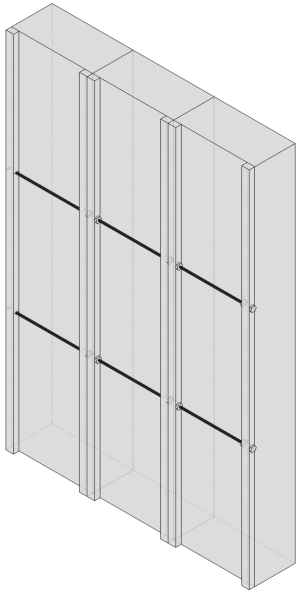
A.5. Wood wedges



A6. Steel plates



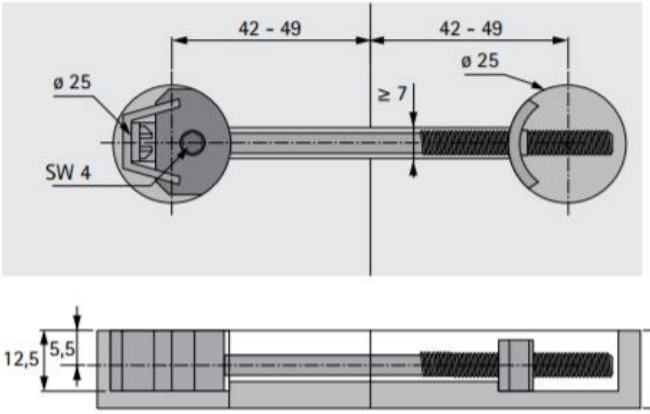
A7. Smart connection

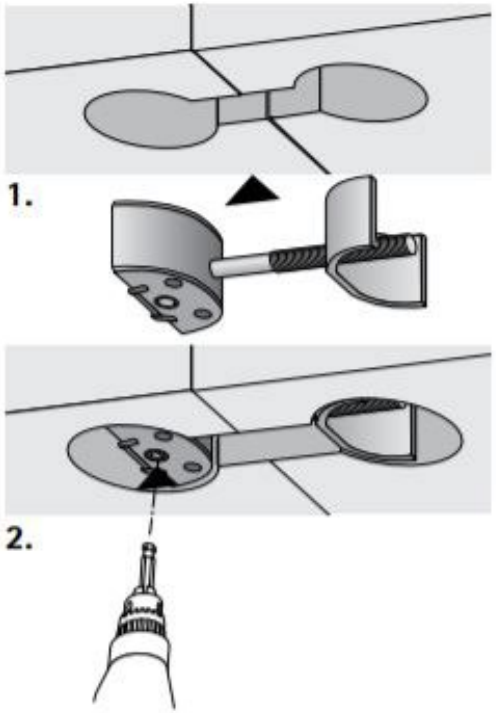


A8. Steel rod

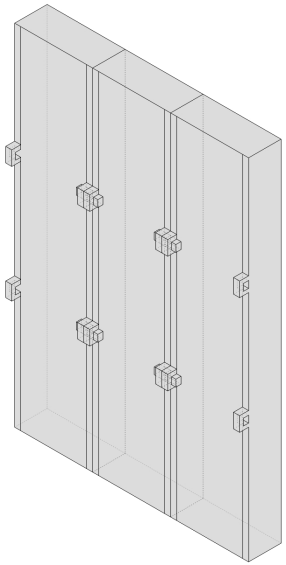
Wall to Wall Alternatives

A7. Smart connection

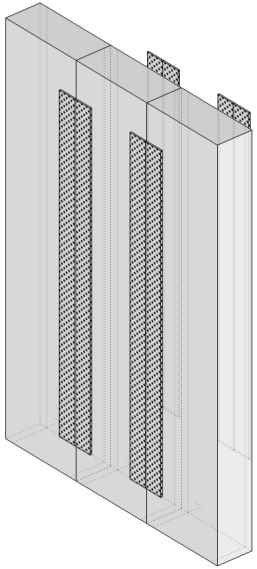




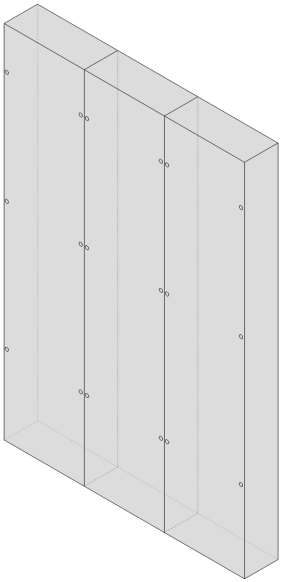
Wall to Wall Alternatives



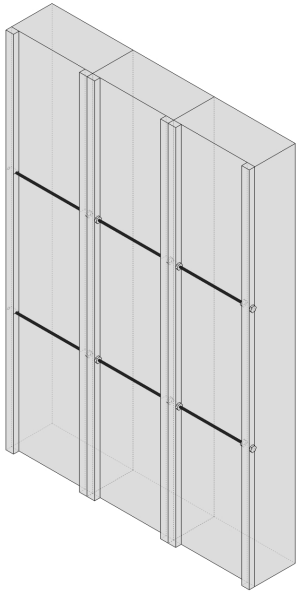
A.5. Wood wedges



A6. Steel plates

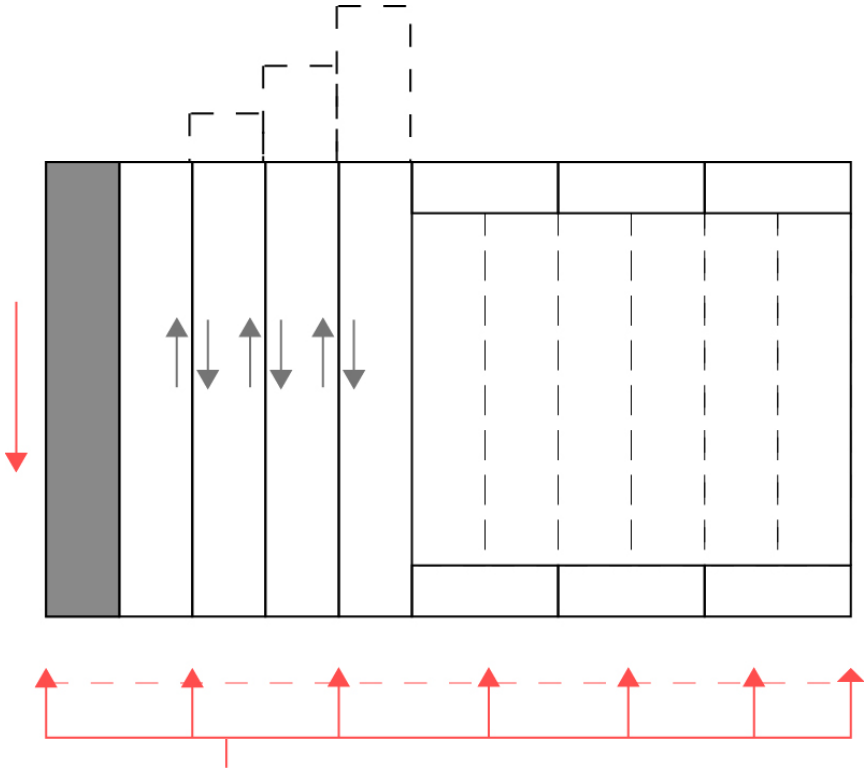


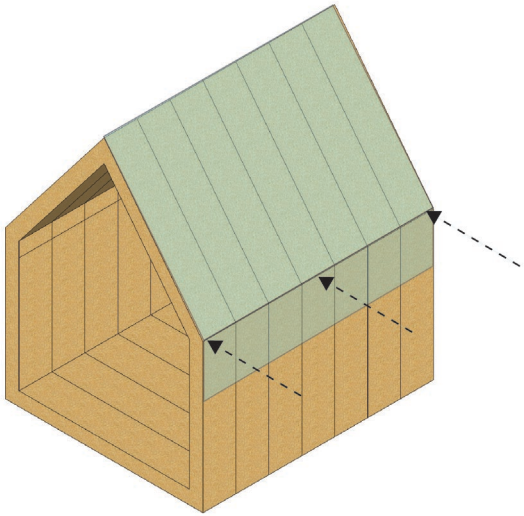
A7. Smart connection



A8. Steel rod

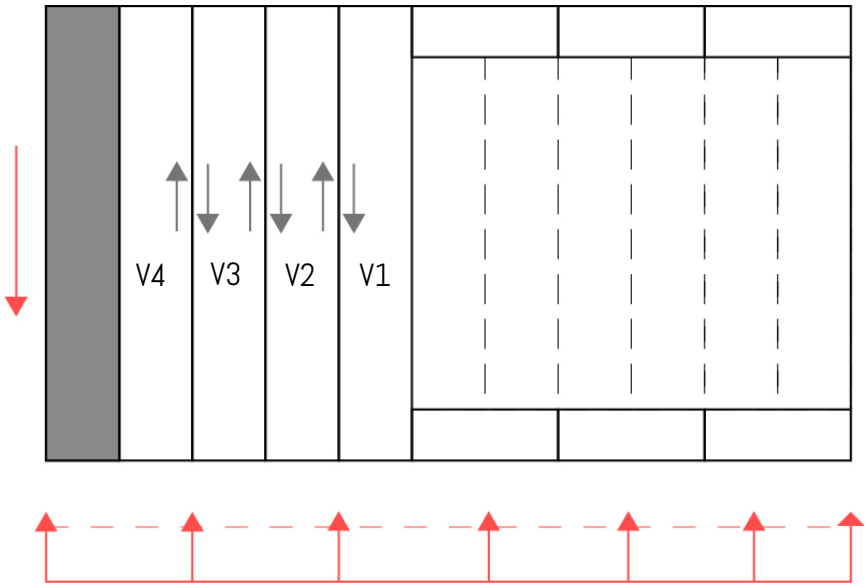
Structural Analysis
Floor to floor connection





Expected deflection

Structural Analysis
Floor to floor connection



Expected reaction

Calculation example

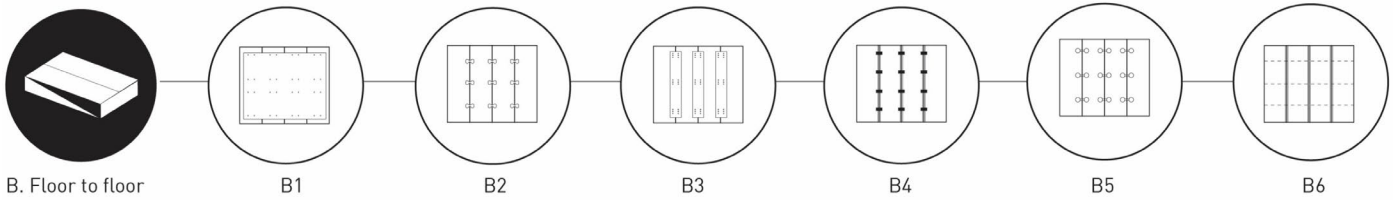
Wind force : 0.65 kN/m2

0.65*(3.4 (roof height) + 1.45 (half of the wall))
= 3.125 kN/m

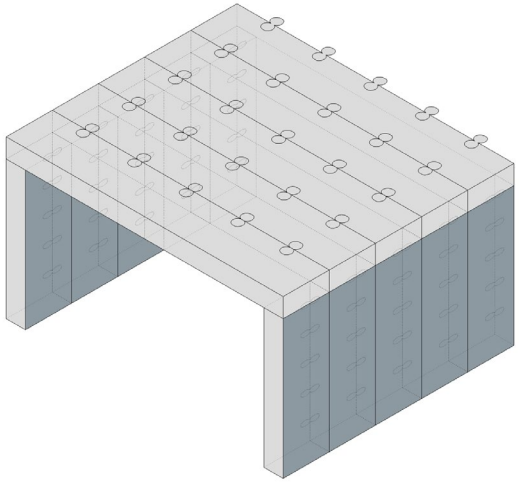
Width of 1 floor block : 0.3 m

V1 : 1 * 3.125 * 0.3 = 0.93 kN
V2 : 2 * 3.125 * 0.3 = 1.88 kN
V3 : 3 * 3.125 * 0.3 = 2.79 kN
V4 : 4 * 3.125 * 0.3 = 3.75 kN

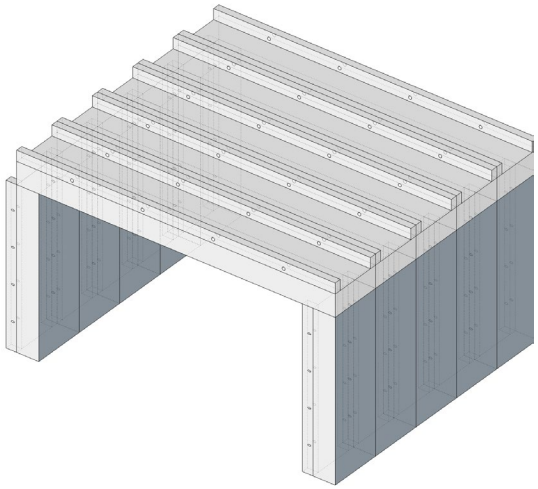
Floor to Floor Alternatives



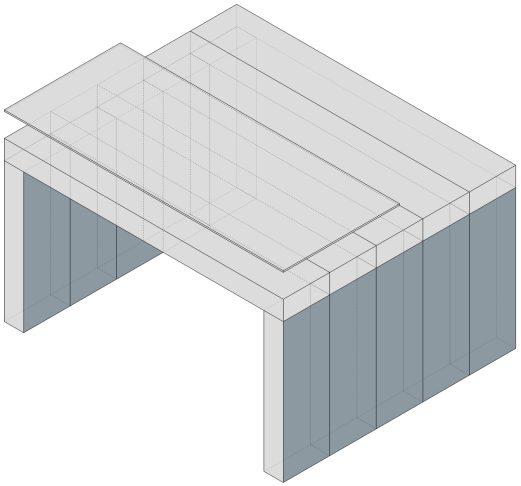
Floor to Floor Alternatives



B1. Butterfly

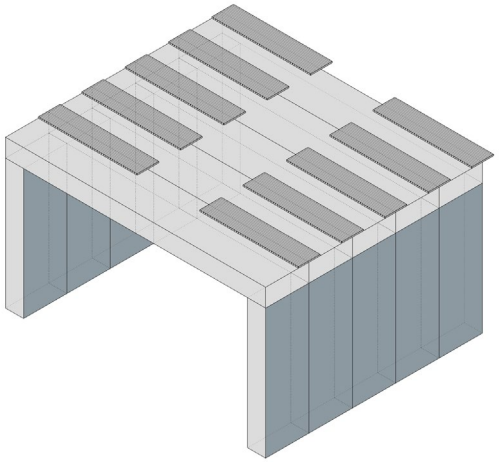


B2. Steel bolt

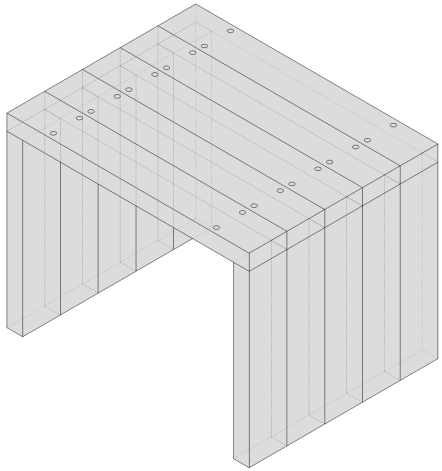


B3. Wood plate

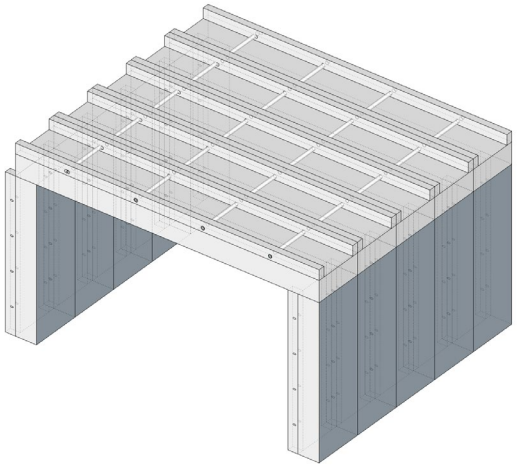
Floor to Floor Alternatives



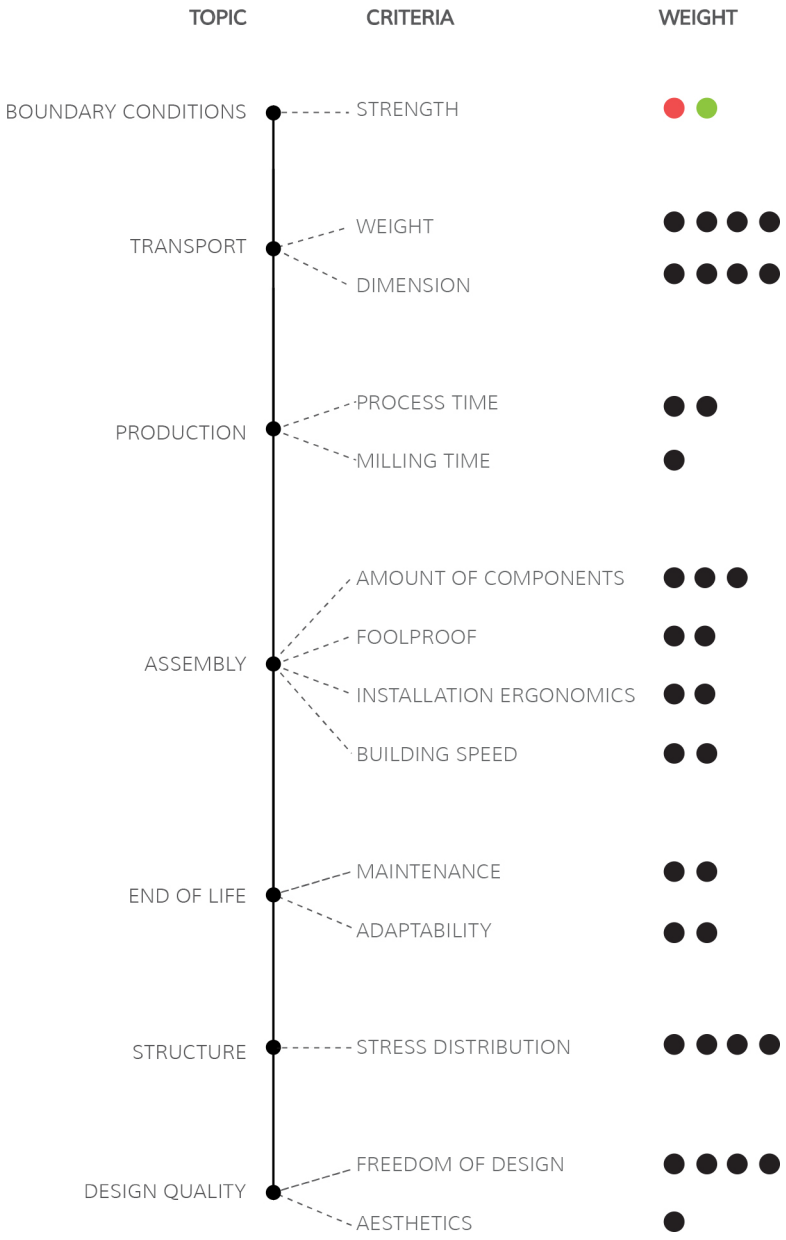
B4. Steel plate



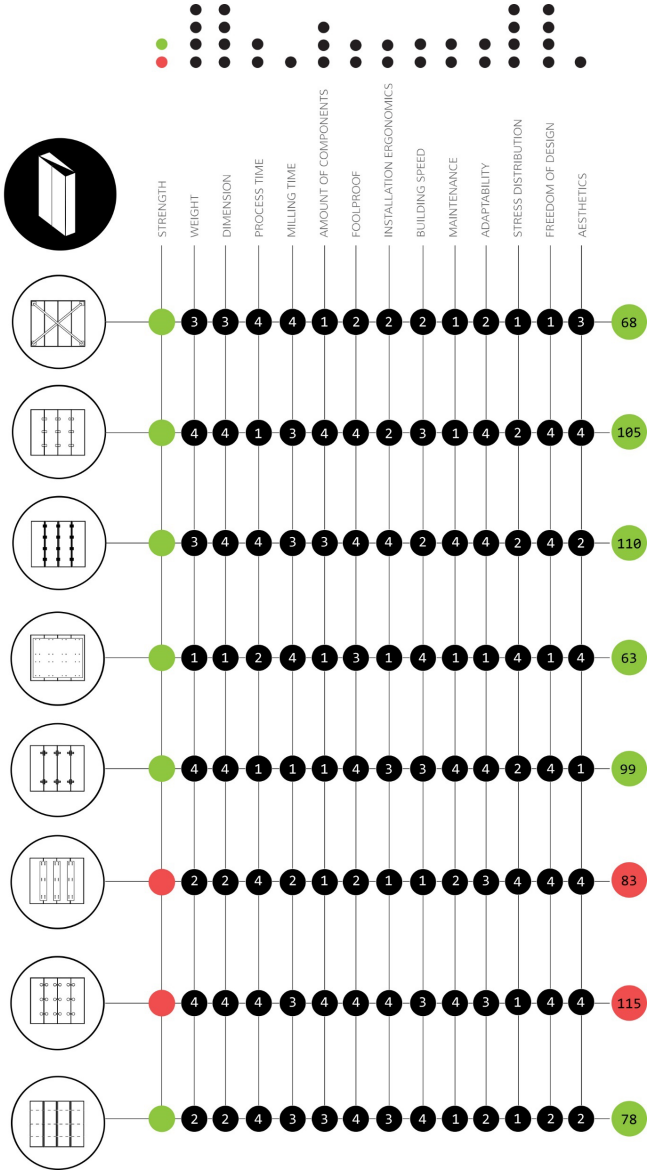
B5. Smart connection

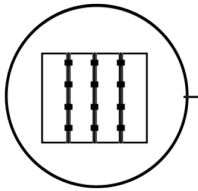


B6. Steel rod


TOPIC
CRITERIA
WEIGHT
BOUNDARY CONDITIONS
STRENGTH
TRANSPORT
WEIGHT
DIMENSION
PRODUCTION
PROCESS TIME
MILLING TIME
ASSEMBLY
AMOUNT OF COMPONENTS
FOOLPROOF
INSTALLATION ERGONOMICS
BUILDING SPEED
END OF LIFE
MAINTENANCE
ADAPTABILITY
STRUCTURE
STRESS DISTRIBUTION
DESIGN QUALITY
FREEDOM OF DESIGN
AESTHETICS

Wall to Wall Alternatives

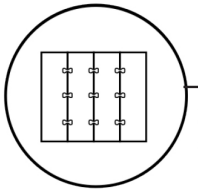




STEEL BOLT CONNECTION

110

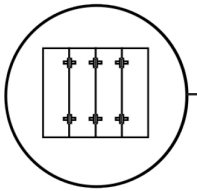
2 x M10 bolts for wall to wall
2 x M10 bolts for roof to roof



BUTTERFLY JOINT

105

2 x 200 mm width key for wall to wall
2 x 200 mm width key for roof to roof

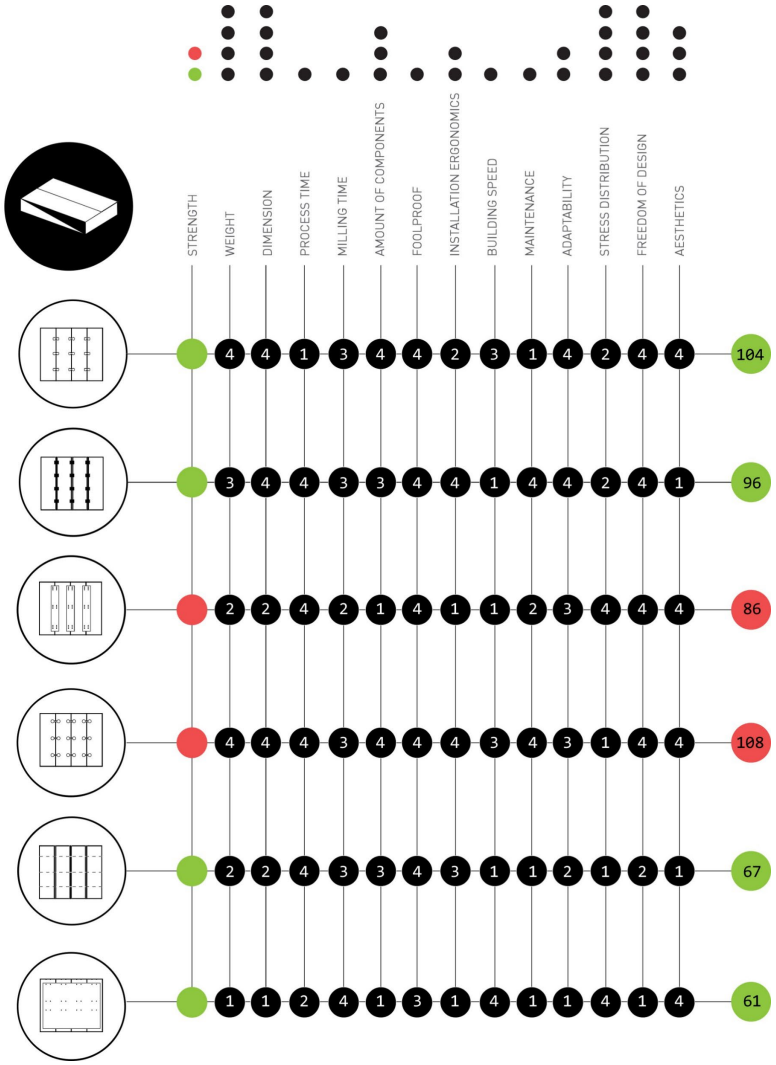


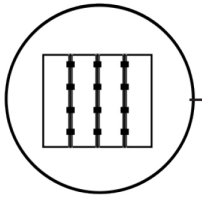
WOOD WEDGE

99

2 X 38 X 89 mm wedge for wall to wall
2 x 38 x 89 mm wedge for floor to floor

Floor to Floor Alternatives

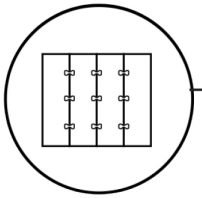




Butterfly Joint

2 x 200 mm width OSB key

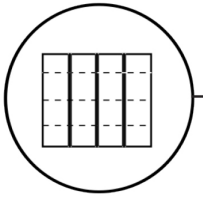
104



Steel Bolt Connection

2 x M10 bolt (possible on the bottom surface)

96

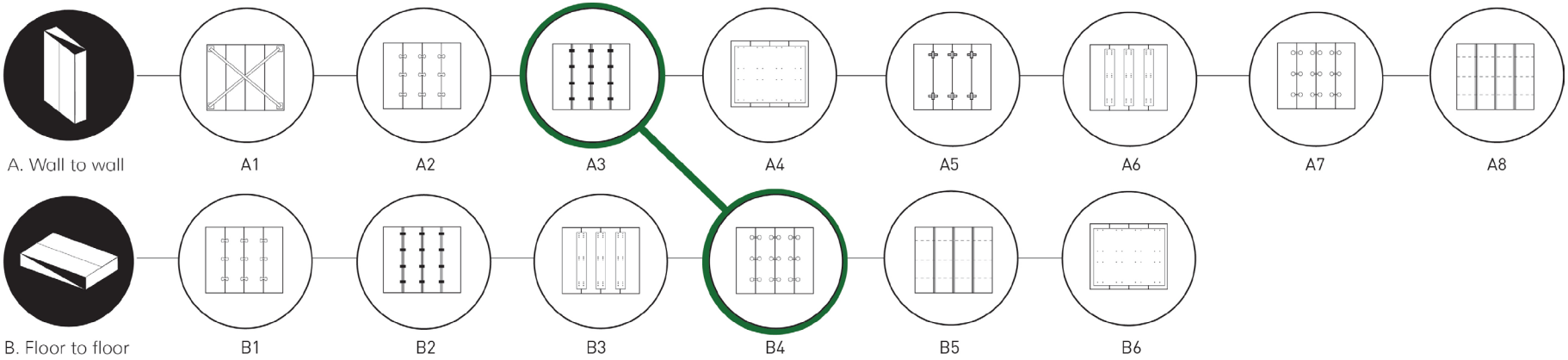


Steel Rod

2 x 10 mm steel rod (on the top surface)
Wooden plates for cover

67

Design Concept



NEXT : Prototype & Test

Thank you!