FLEXIBLE PREFABRICATED COMPONENTS

Flexible and modular housing components for the Circular economy

Inaka Sema | 5089557
AR3B025 Building Technology Graduation Studio
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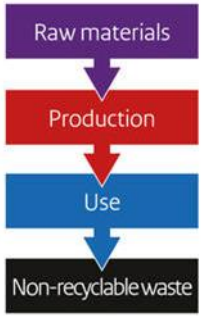
Examiner | Prof. G. Coumans

RESEARCH FRAMEWORK

Background | Context | Problem statement | Research question

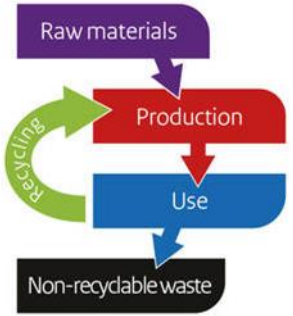
CIRCULAR ECONOMY

Linear



Raw materials are used to make a product, and after its use any waste is thrown away.

Reuse



Materials are **recycled** and **reused**. For example, waste glass is used to make new glass.

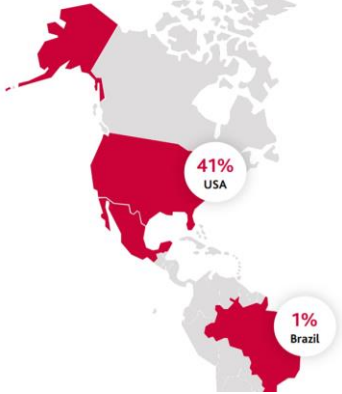
Circular

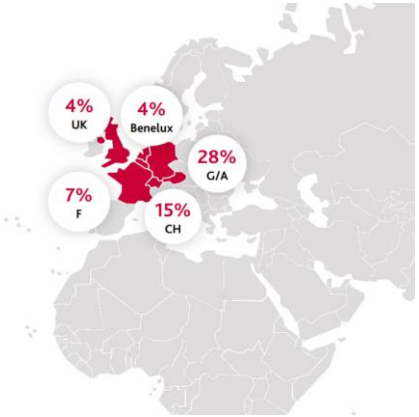
Preventing waste by making products and materials more **efficiently** and **reusing** them. New raw materials must be obtained **sustainably**.

KLOECKNER METALS ODS NEDERLAND

kloeckner metals
ODS Nederland

JANSEN
by ods





Jansen VISS

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kloeckner metals
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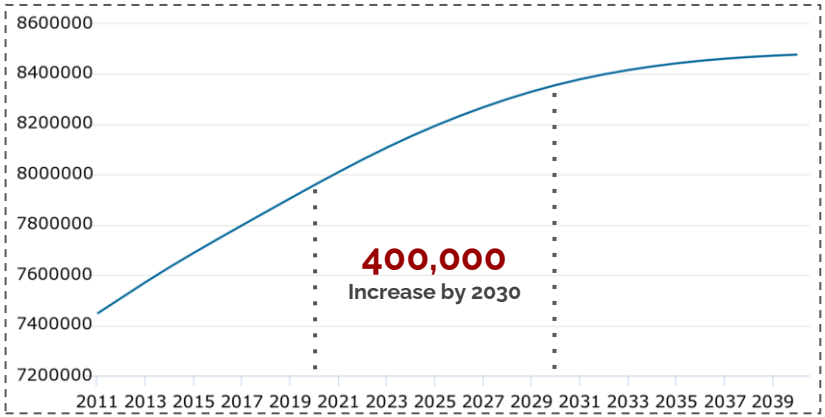
Rotterdam central station

GTB lab Circular module, 2019

HOUSING DEMAND IN NL



Forecasted number of households (Government of NL)

263,000
Housing shortage in 2019

845,000
Demand for new houses by 2030

95,000 - 115,000
Annual demand

PREFABRICATED MODULAR CONSTRUCTION

Reduction in construction time

More affordable

Reduction in waste

High quality

TOP-UP HOUSING UNITS

Build houses on top of **existing flat rooftops**, instead of building them on vacant plots in order to save land in and around cities.

Rotterdam has over **18 sq.km** flat roof areas
Municipality Rotterdam, 2019

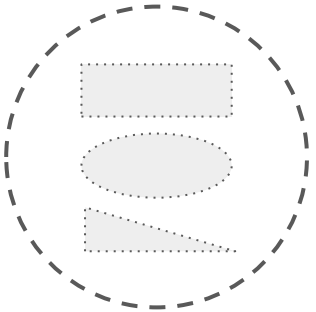
Design assumptions:
Lightweight construction with **Lightweight steel frame** (LSF) systems
Two storeyed houses with approx. 3m floor to ceiling height

FLEXIBILITY IN HOUSES

Change in lifestyle

Change in user

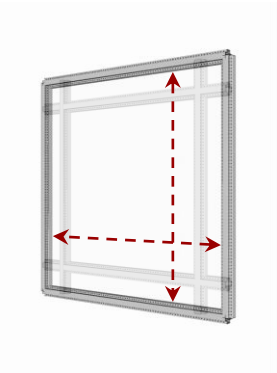
Change in technology



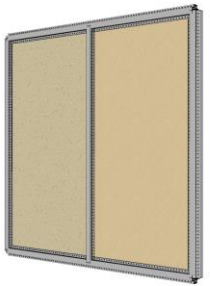
Different building rooftops shapes

FLEXIBILITY

"Flexible building components are building parts which have the capability to adapt functionally, aesthetically or structurally to constant change in user and strategy demands to address social, sustainable and economic issues".

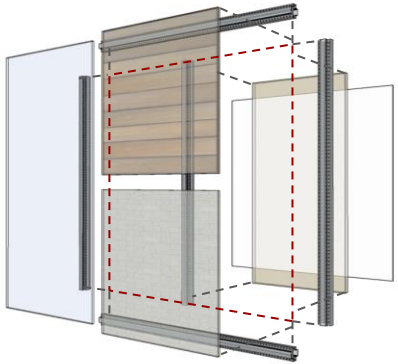


Dimensional & structural



Thermal & acoustics

Components & material



Demountable & Circular

MAIN RESEARCH QUESTION

*How can **flexibility** of **Lightweight steel framing** (LSF) construction in **Top-up dwellings** help improve its potential towards **Circularity** with added benefits (Thermal and Acoustics)?*

LITERATURE STUDY

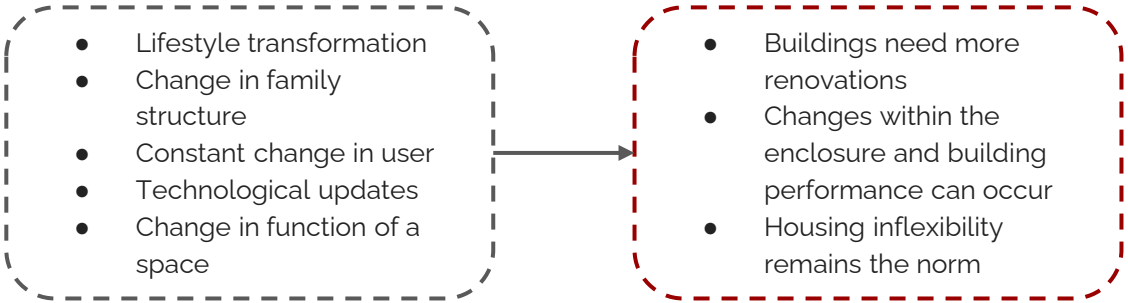
Flexibility problem | Circular building strategies | Prefabrication | Building physics

HOUSING FLEXIBILITY PROBLEM

- Lifestyle transformation
- Change in family structure
- Constant change in user
- Technological updates
- Change in function of a space

Factors for change

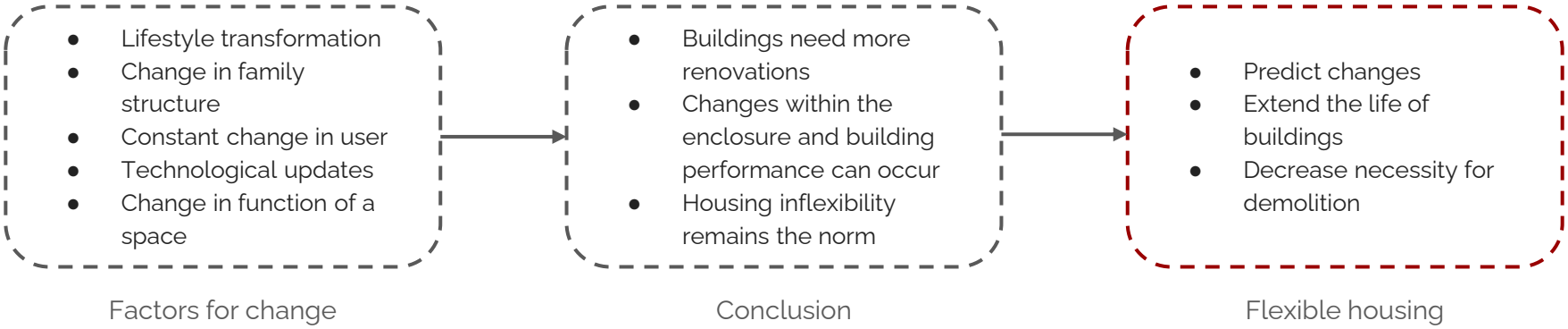
HOUSING FLEXIBILITY PROBLEM



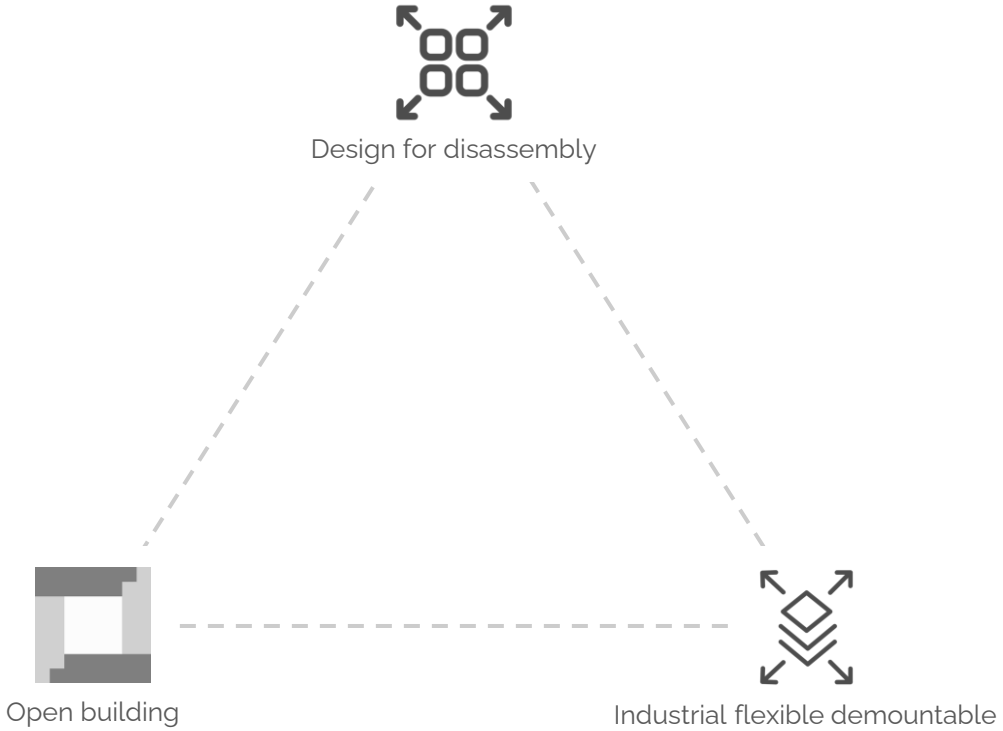
Factors for change

Conclusion

HOUSING FLEXIBILITY PROBLEM



CIRCULAR & FLEXIBLE BUILDING STRATEGIES



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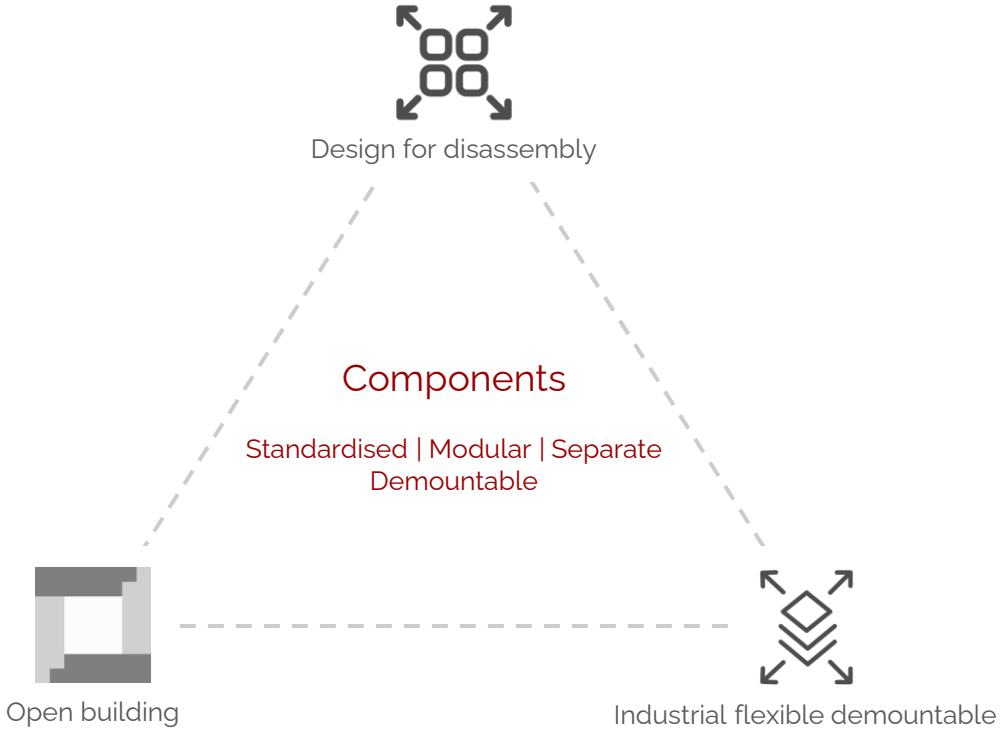

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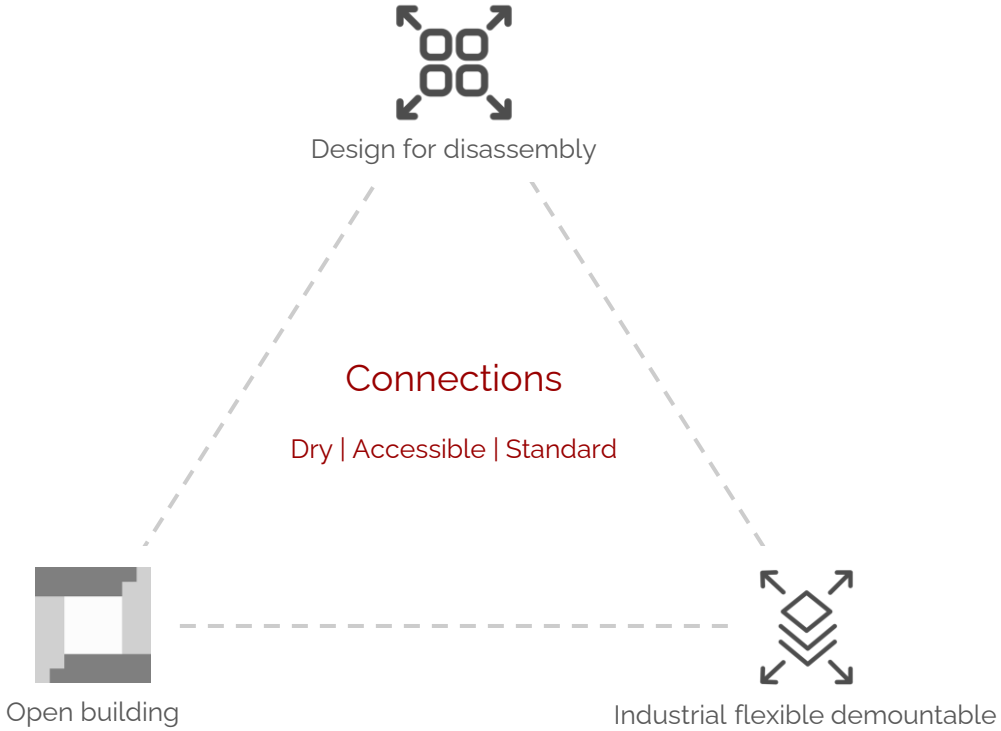

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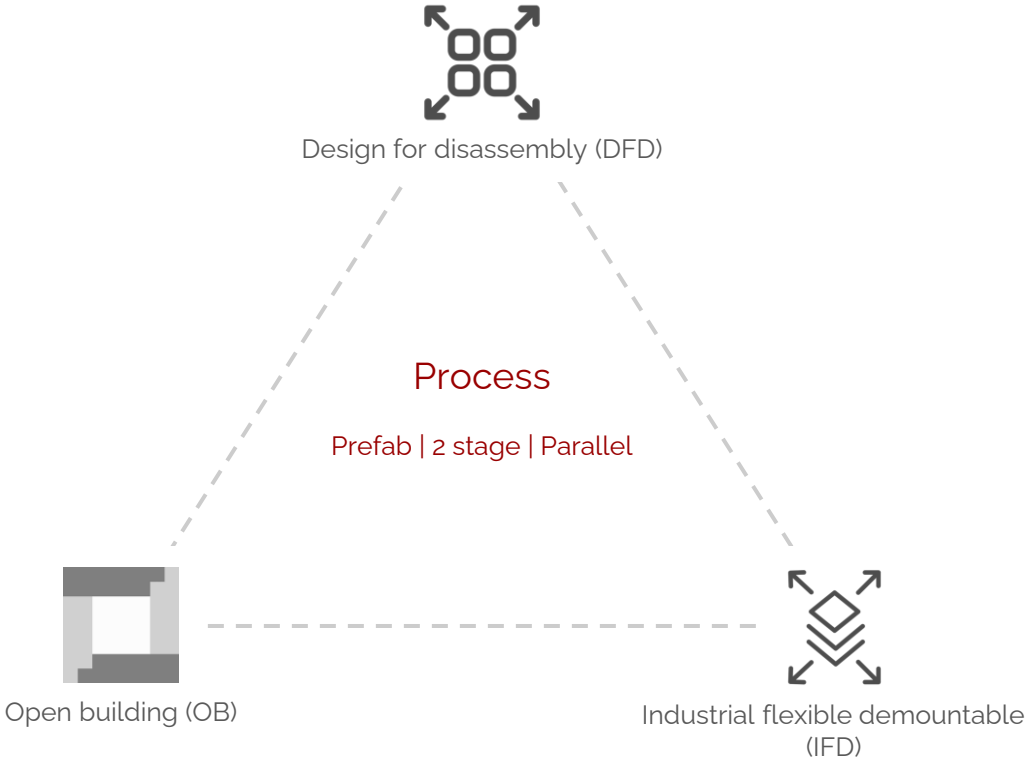
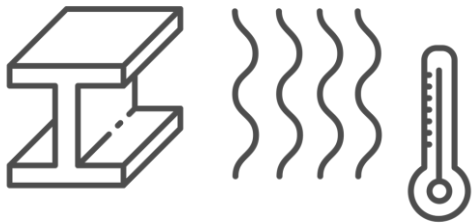


THERMAL PROPERTY OF STEEL



High thermal conductivity

Continuous external insulation

Slotted steel studs

Decrease contact area

Thermal breaks with
low conductivity materials

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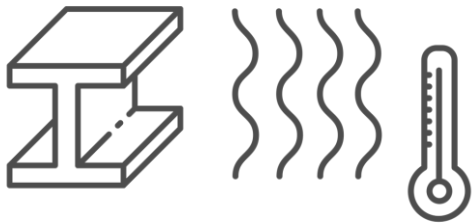

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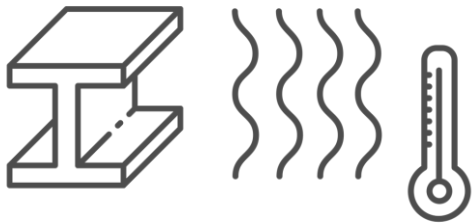

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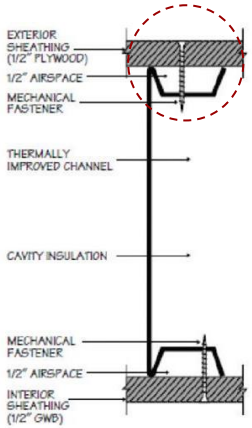

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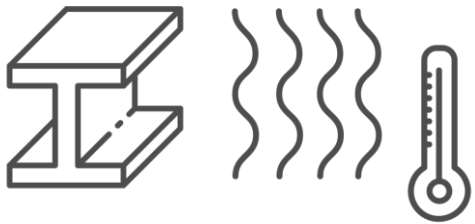

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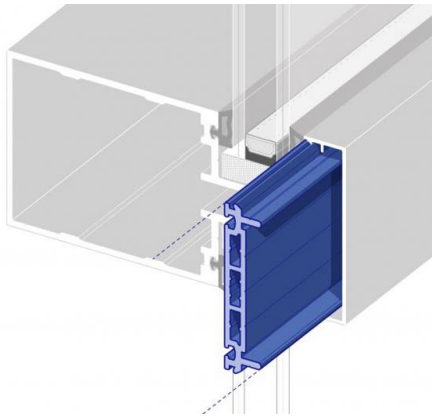
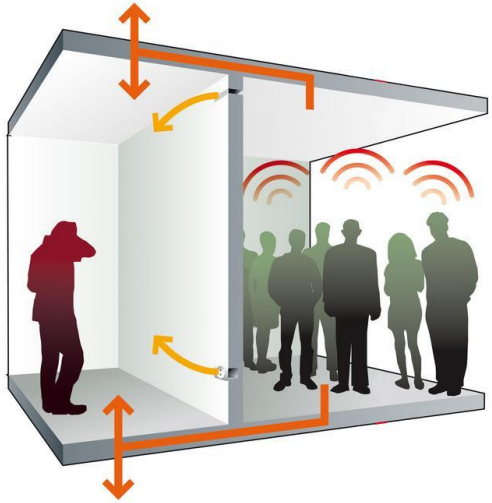


ACOUSTIC PROPERTY OF LIGHTWEIGHT STEEL FRAME CONSTRUCTION

- Lower mass
- **High flanking** sound transmission
- Sound insulation in nodes is important in lightweight construction



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Add insulation in cavities for sound absorption

Increase cavity width with insulation

Adding more mass

Introduce damping elements

Introduce more connections with damping elements to dissipate vibrations

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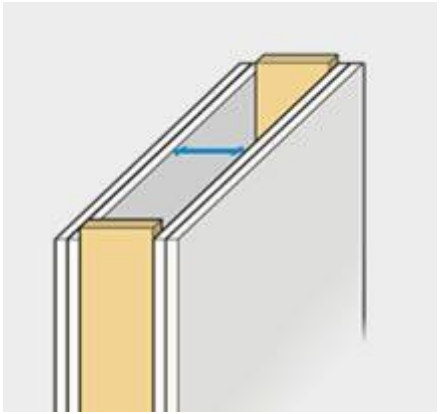

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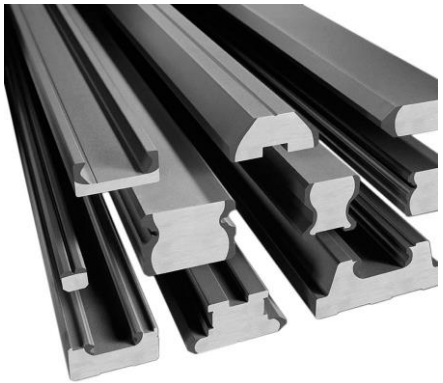

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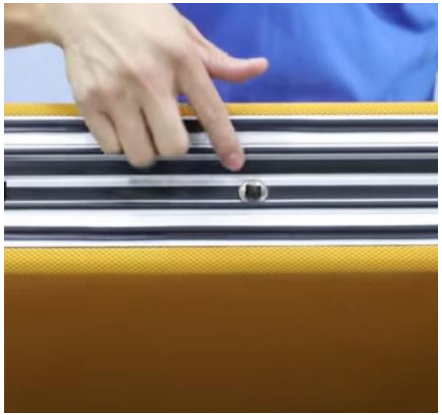

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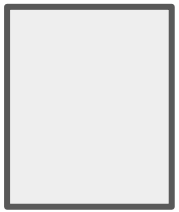
PREFABRICATION CATEGORIES

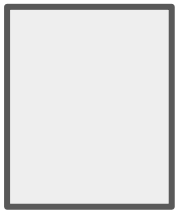


Panelised

Modular building

Whole buildings

PREFABRICATION CATEGORIES



Panelised

Modular building

Whole buildings

Flexible

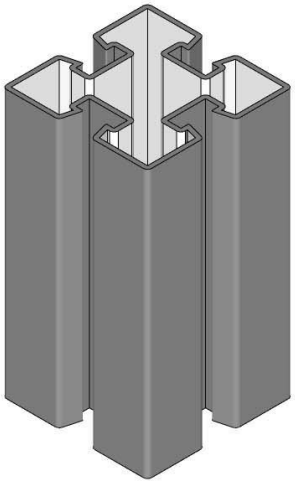
PREFABRICATION CATEGORIES

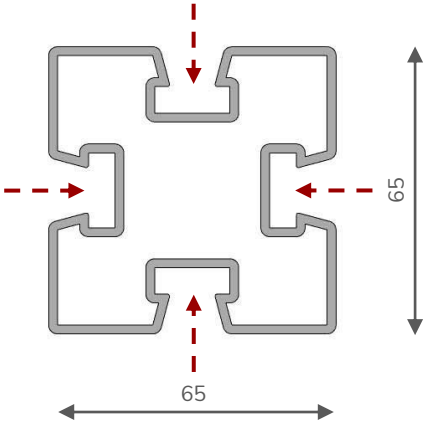
Hybrid of panels and modules

DESIGN PROPOSAL

Flexible prefabricated components

JANSEN VISS QUATTRO

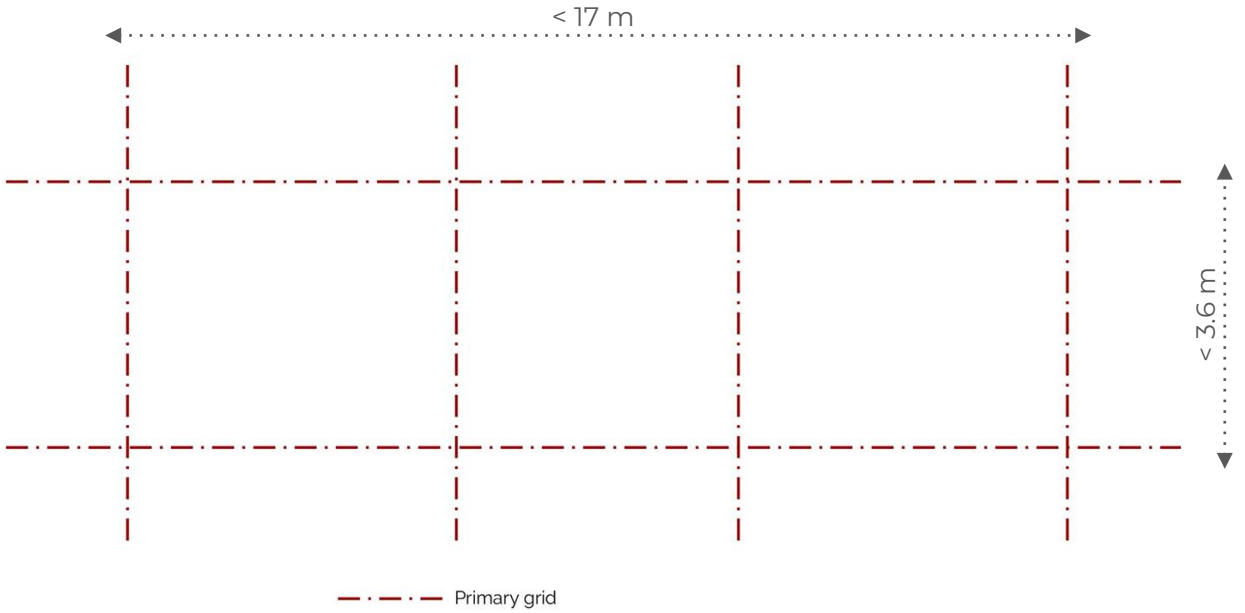




Features:

- 4 grooves
- Opens up possibilities to mount other functions
- Square shape allows for either vertical or horizontal orientation
- 2 mm thickness

DEFINING THE GRID



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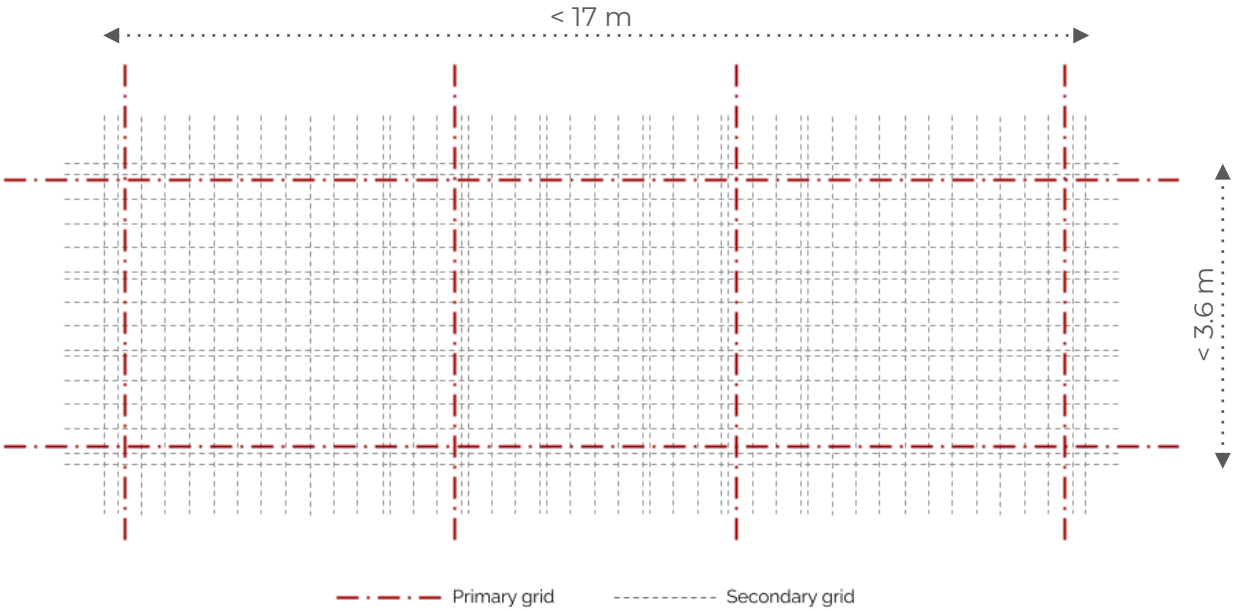
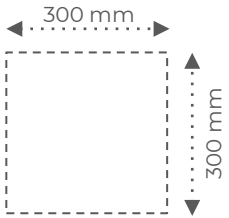
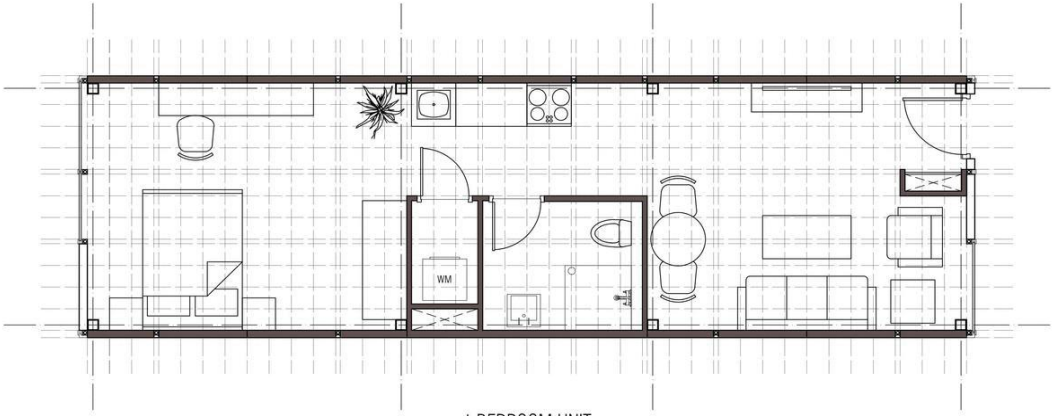


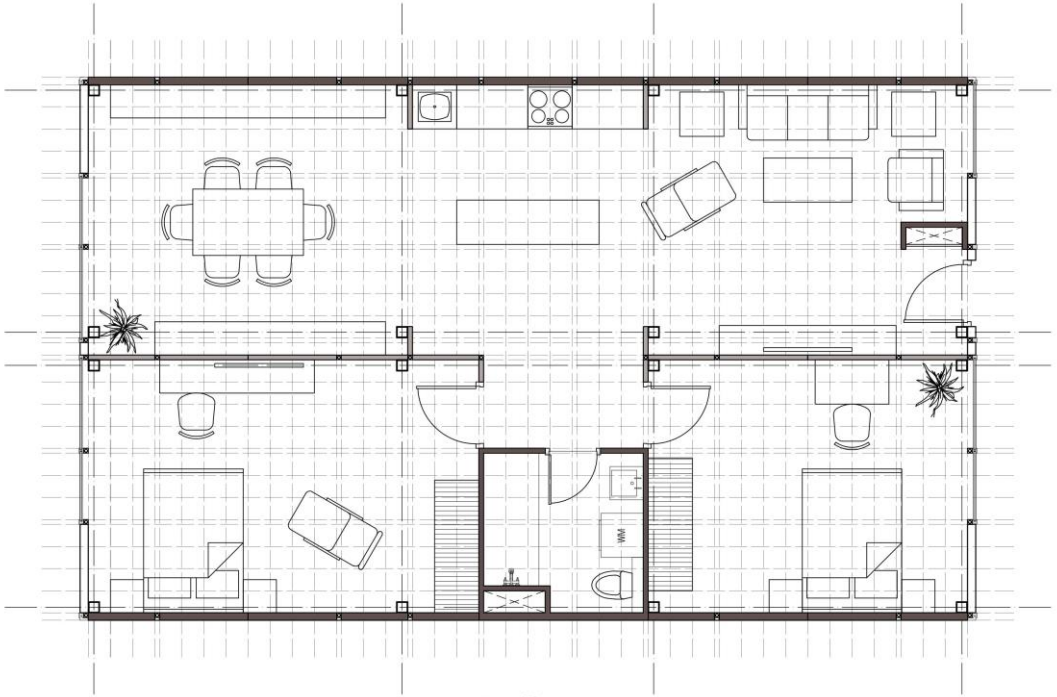


MODULAR LAYOUT CONFIGURATIONS



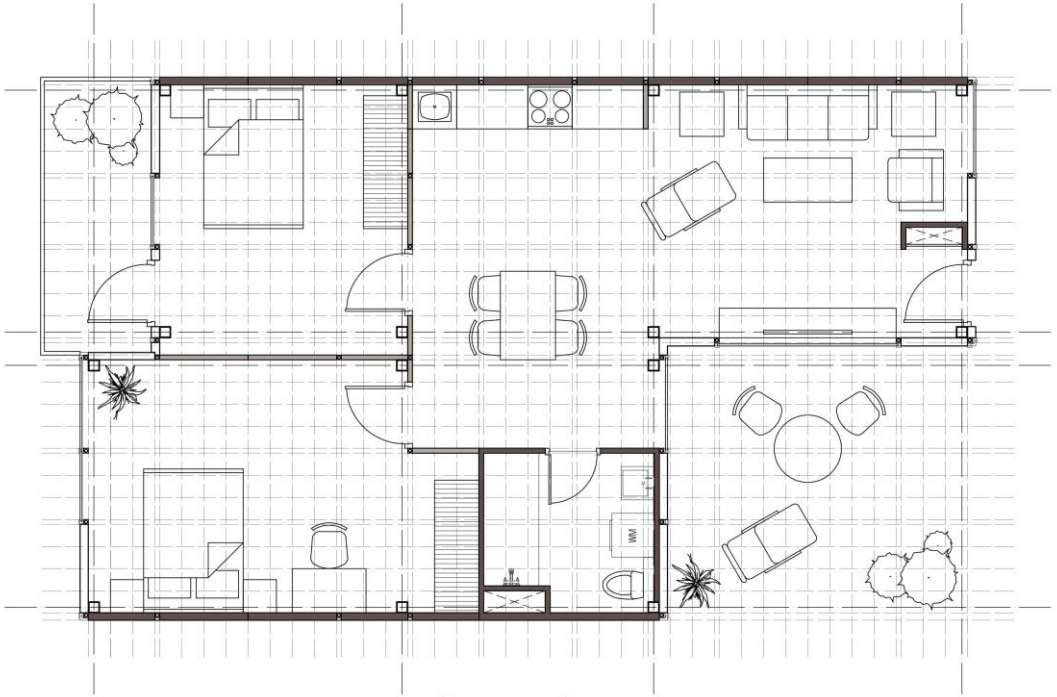
1 BEDROOM UNIT

MODULAR LAYOUT CONFIGURATIONS



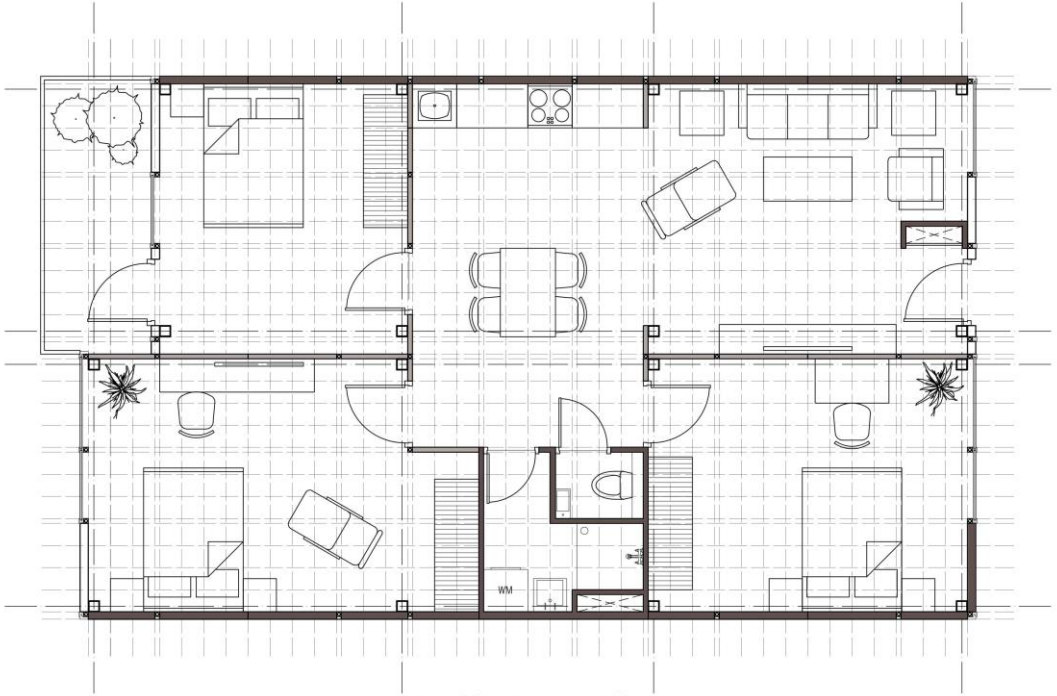
2 BEDROOM UNIT

MODULAR LAYOUT CONFIGURATIONS



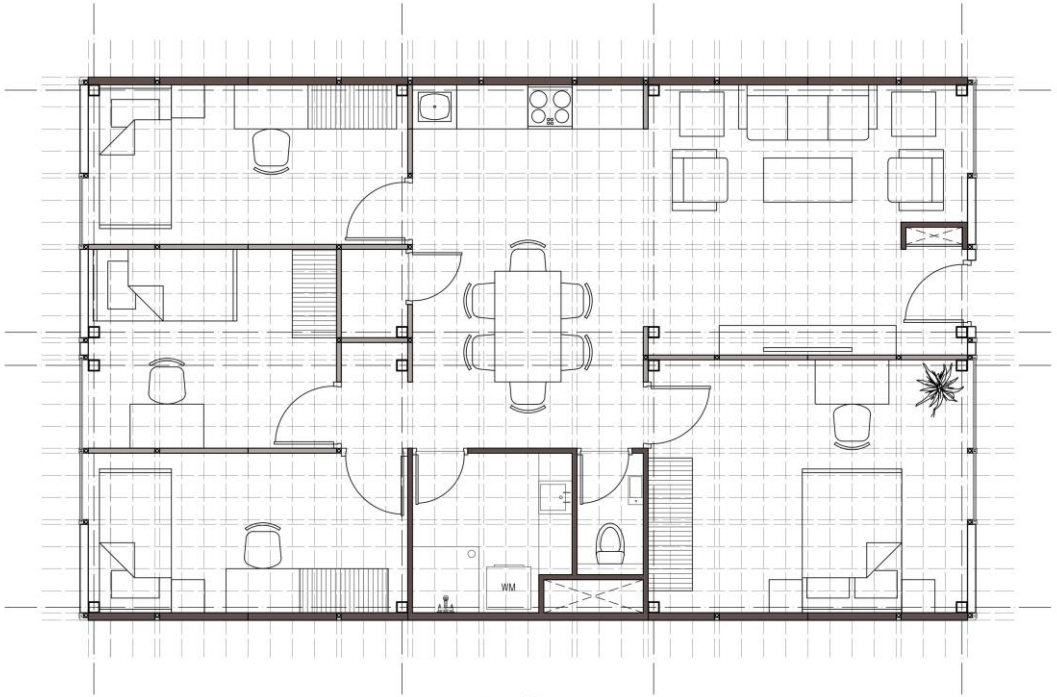
2 BEDROOM UNIT WITH OPEN TERRACE

MODULAR LAYOUT CONFIGURATIONS



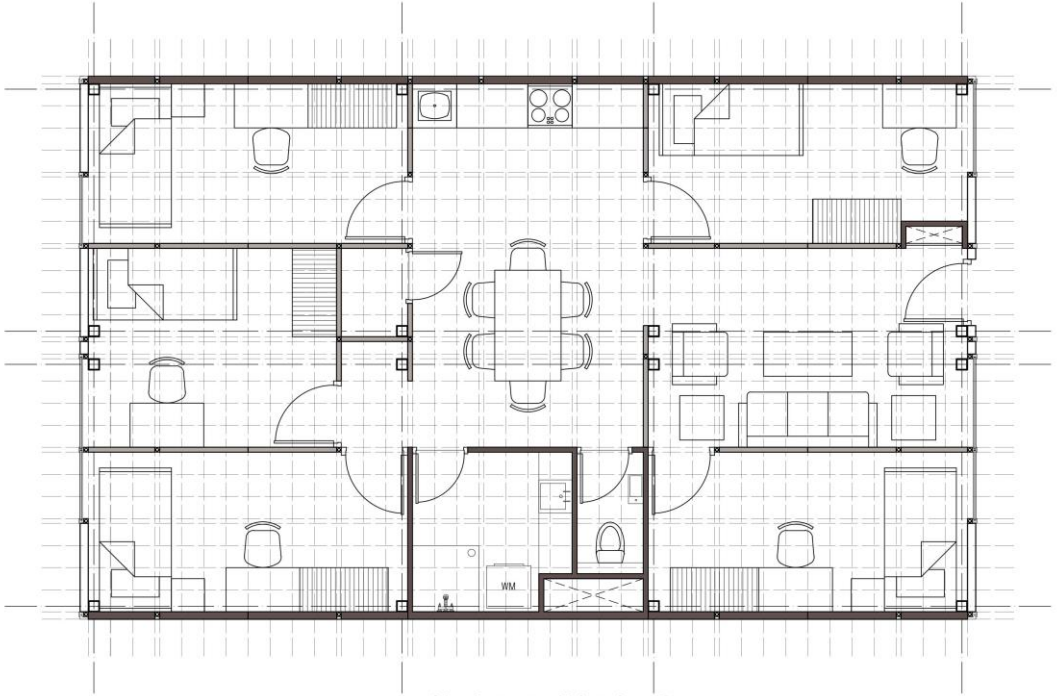
3 BEDROOM UNIT WITH BALCONY

MODULAR LAYOUT CONFIGURATIONS



4 BEDROOM UNIT

MODULAR LAYOUT CONFIGURATIONS

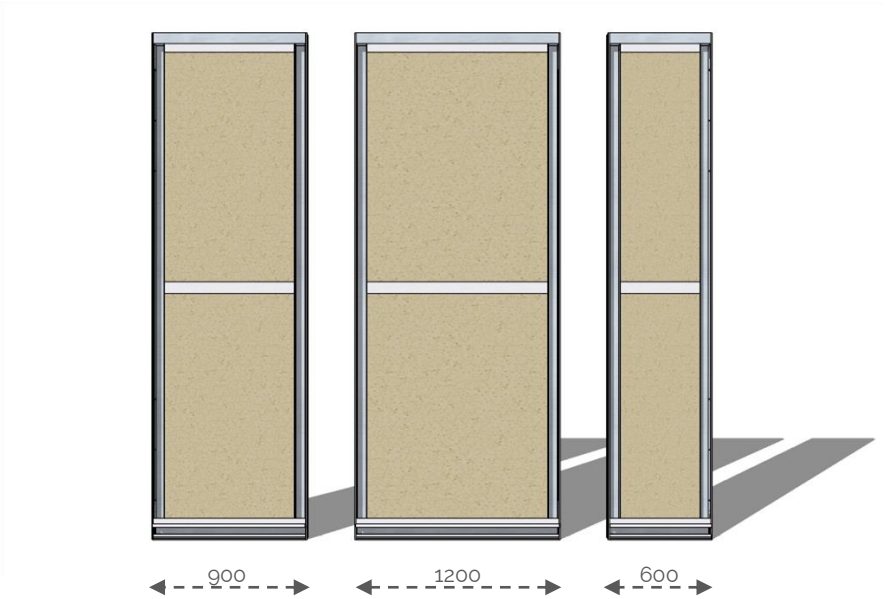


5 BEDROOM STUDENT ACCOMMODATION

FLEXIBLE PARTITION SYSTEM

Design proposal

FLEXIBLE PARTITION MODULES



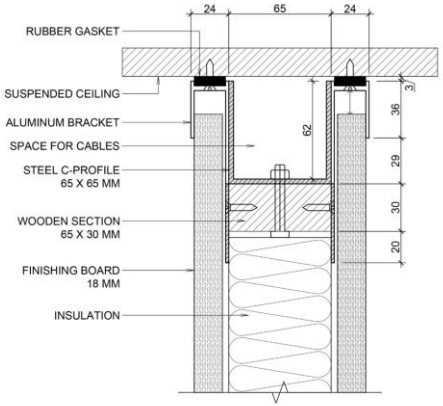
FLEXIBLE PARTITION - OPTION 1

Main components

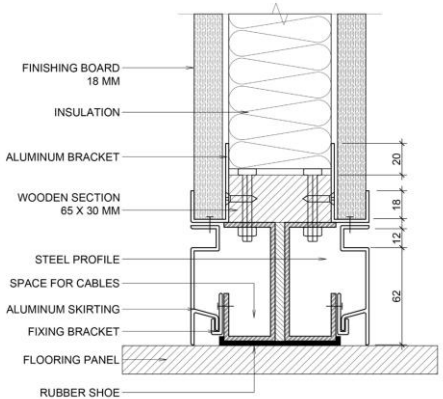
1. Steel C-section frame
2. 65 mm thick insulation panels
3. Aluminium top bracket with rubber gasket
4. Bottom steel profile with rubber shoe
5. Aluminium skirting
6. 10-18 mm thick finishing board

Acoustic strategies

1. Insulation panels are proposed in cavity
2. Acoustic seal is provided at the top, bottom and sides by damping elements
3. VISS Quattro vertical profiles are filled with sand to increase mass

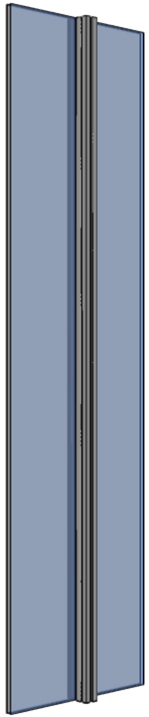


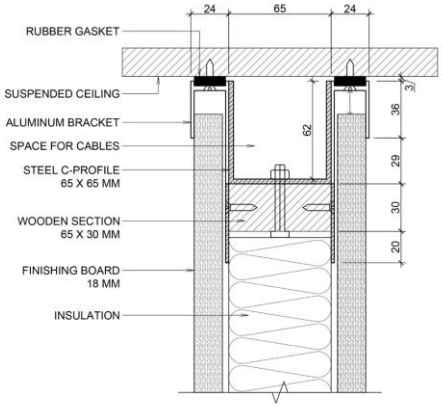
PARTITION - TOP DETAIL



PARTITION - BOTTOM DETAIL

ASSEMBLY PROCESS - OPTION 1





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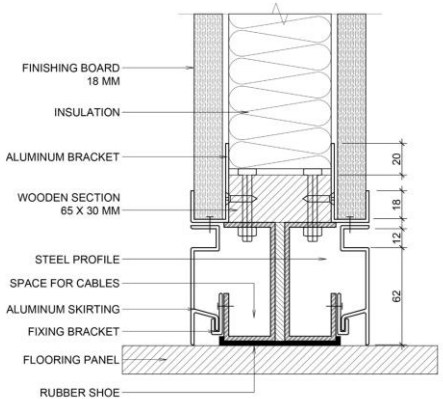

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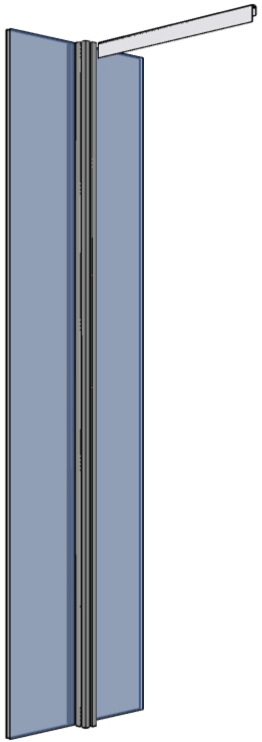

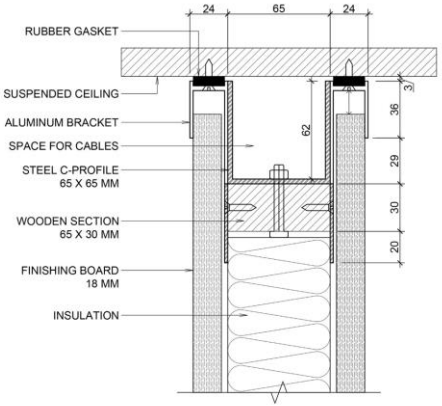

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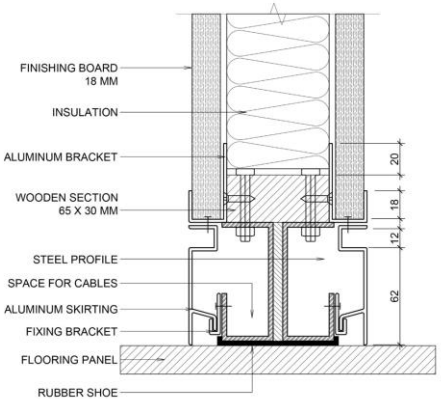
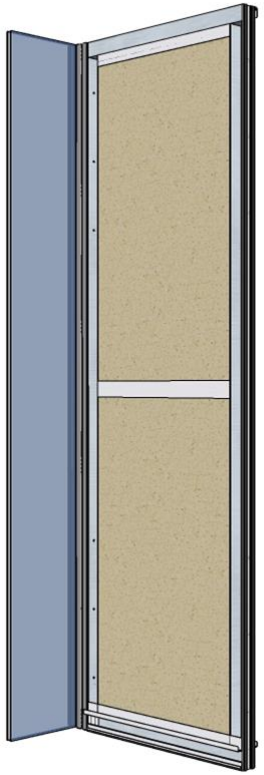
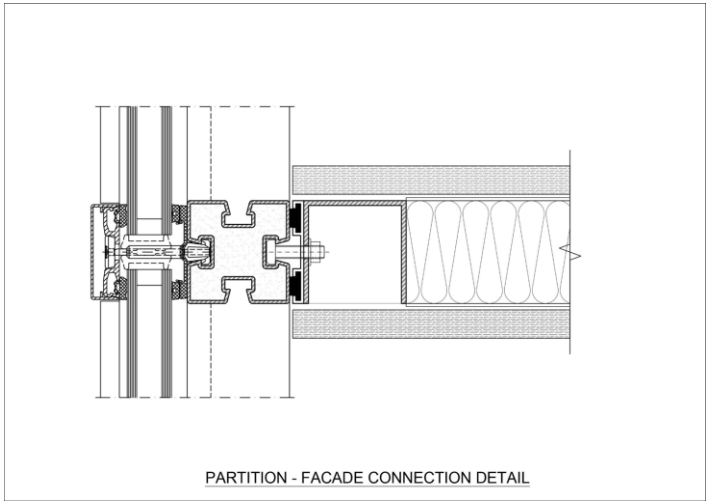


PARTITION - BOTTOM DETAIL

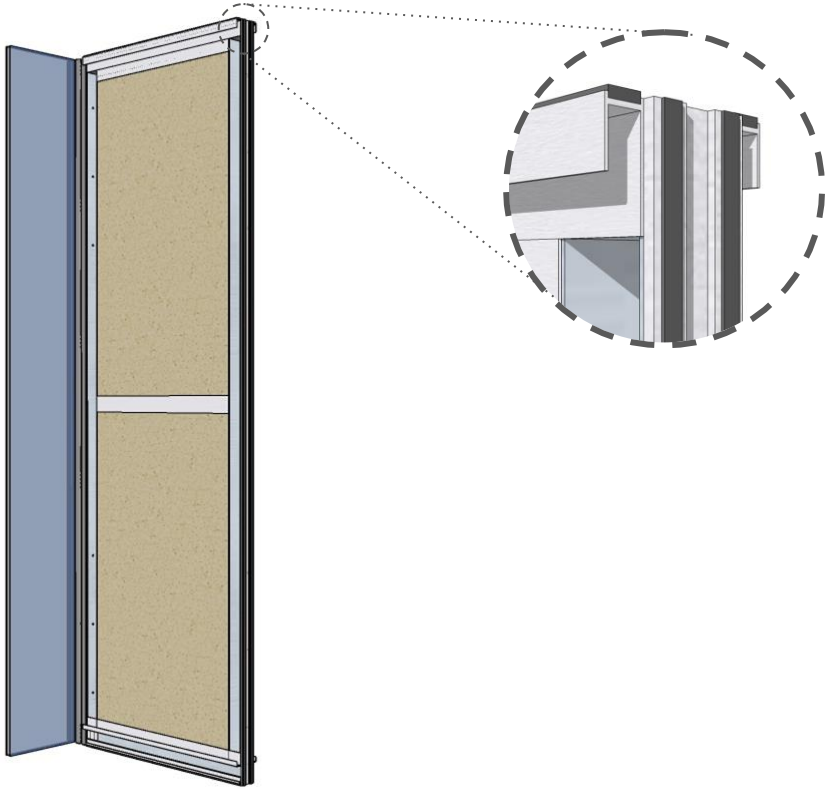
ASSEMBLY PROCESS - OPTION 1

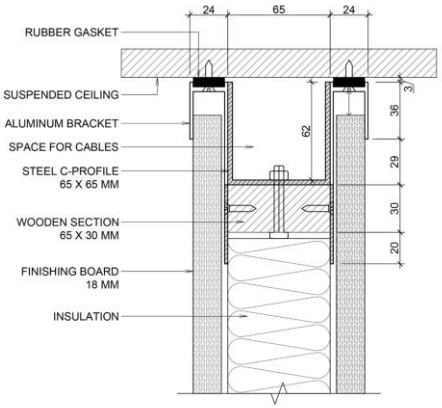




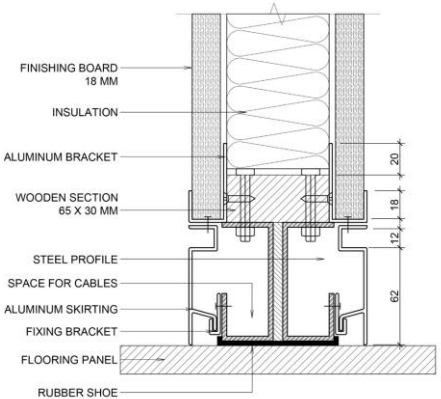
PARTITION - FACADE CONNECTION DETAIL

ASSEMBLY PROCESS - OPTION 1



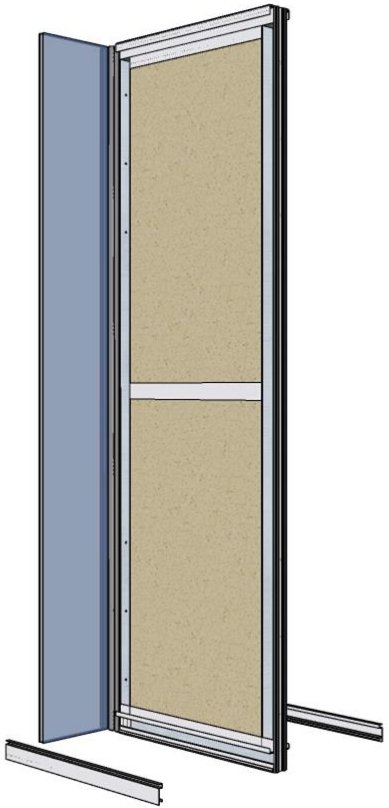


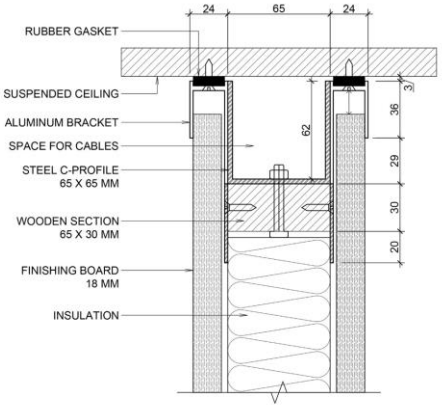
PARTITION - TOP DETAIL



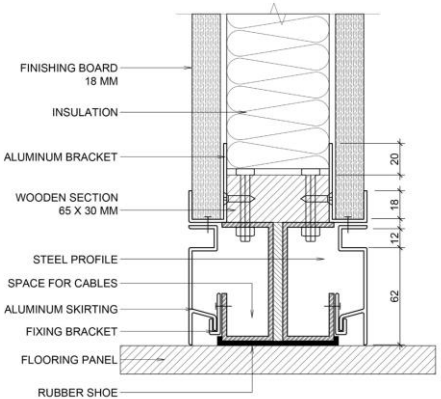
PARTITION - BOTTOM DETAIL

ASSEMBLY PROCESS - OPTION 1



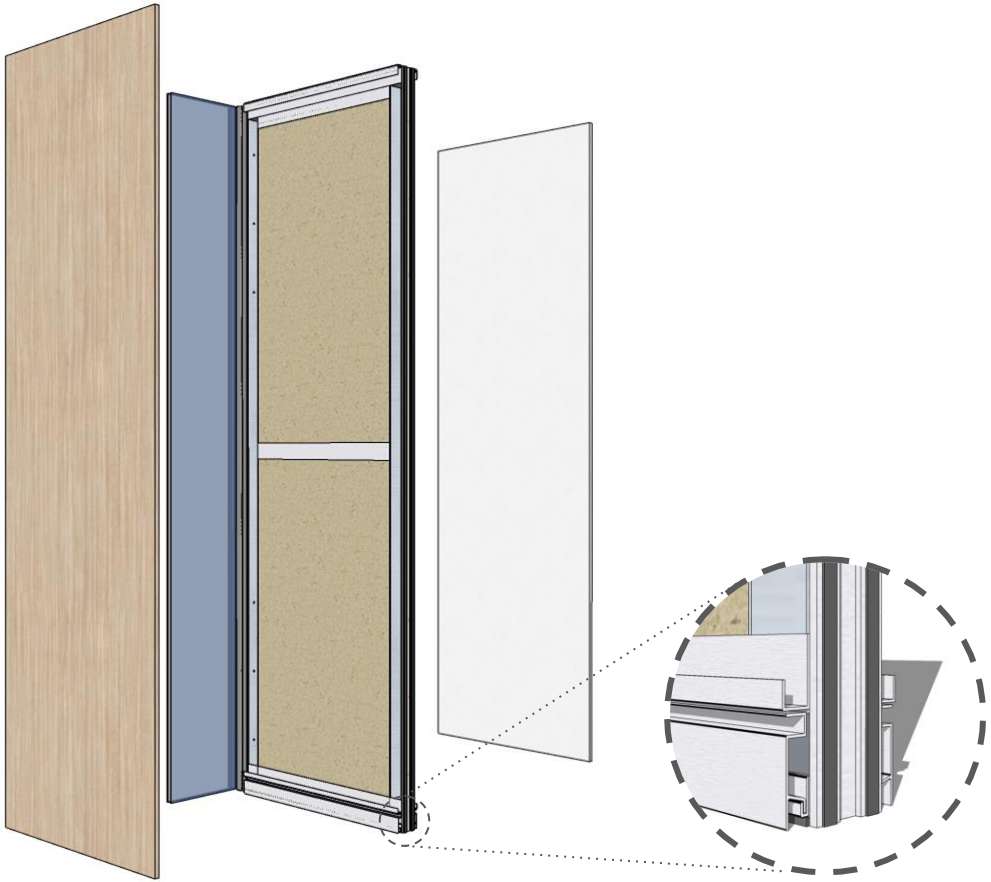


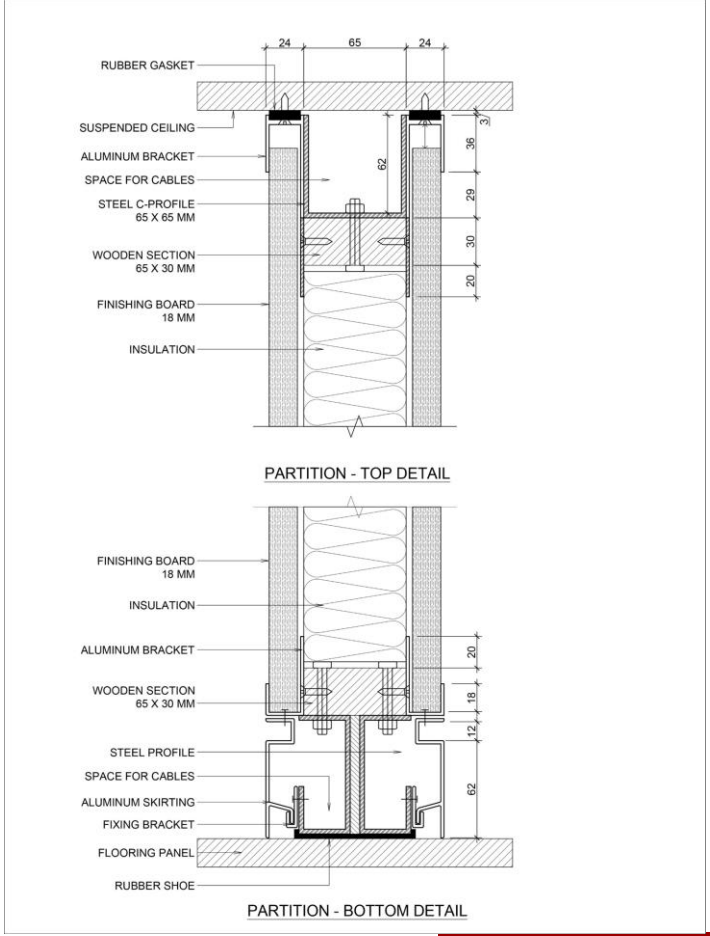
PARTITION - TOP DETAIL



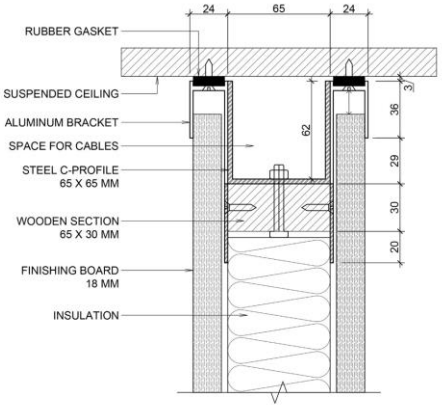
PARTITION - BOTTOM DETAIL

ASSEMBLY PROCESS - OPTION 1

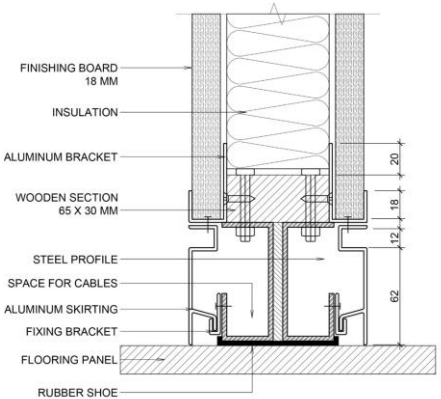




ASSEMBLY PROCESS - OPTION 1

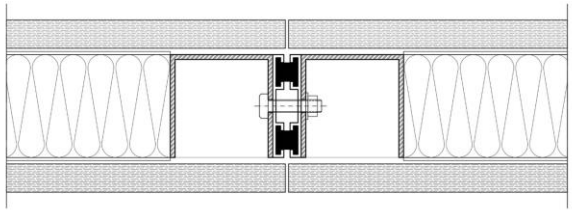


PARTITION - TOP DETAIL

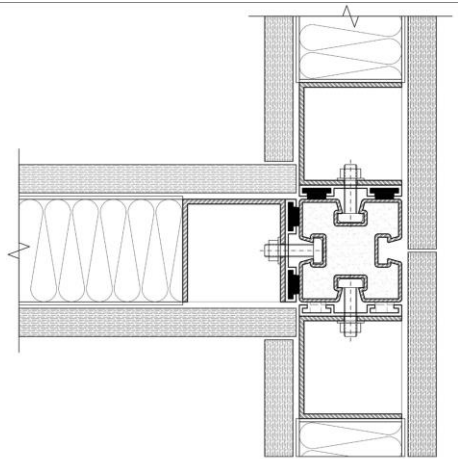


PARTITION - BOTTOM DETAIL

ASSEMBLY PROCESS - OPTION 1



PARTITION - PARTITION CONNECTION DETAIL

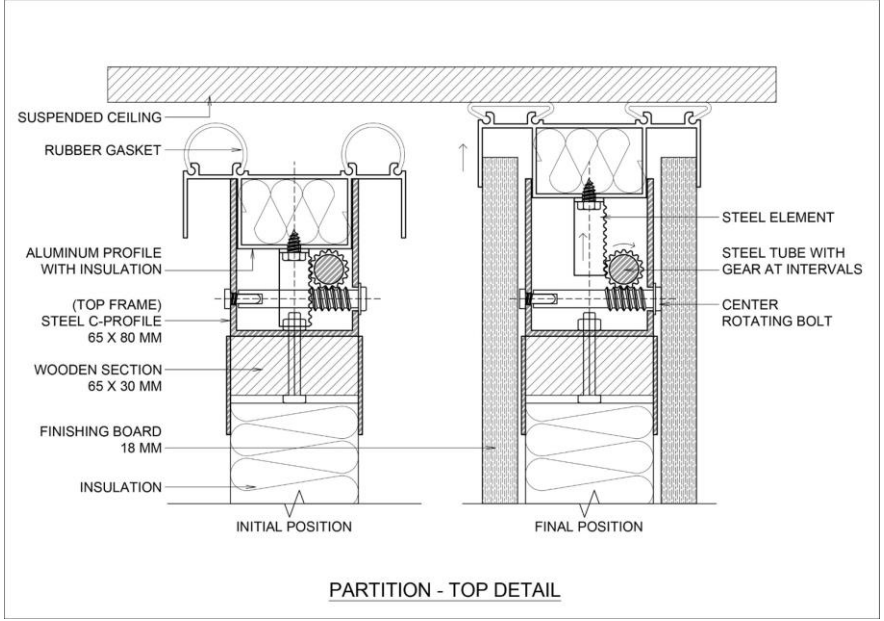


PARTITION - CORNER CONNECTION DETAIL

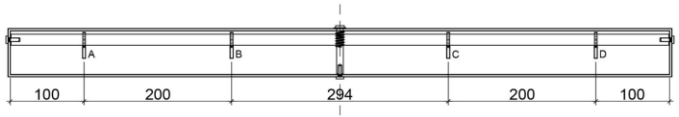
FLEXIBLE PARTITION - OPTION 2

Main components

1. Steel C-section top frame 65 x 80 mm
2. Movable aluminium top bracket with rubber gasket
3. Steel tube with gears at intervals
4. Rotating bolt



PARTITION - TOP DETAIL

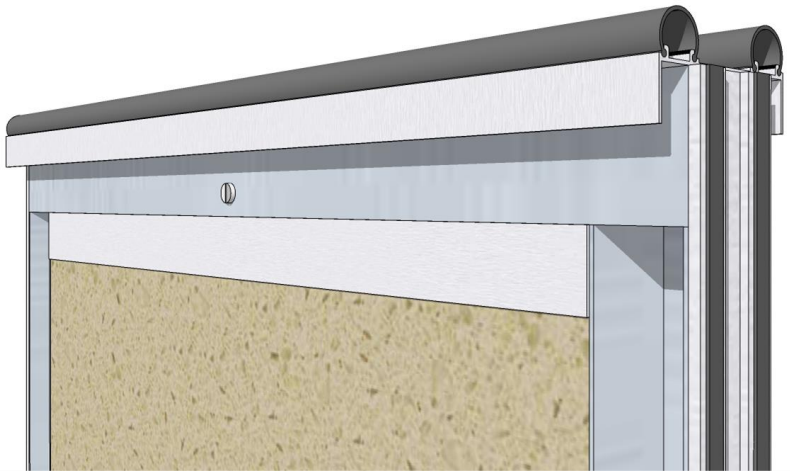


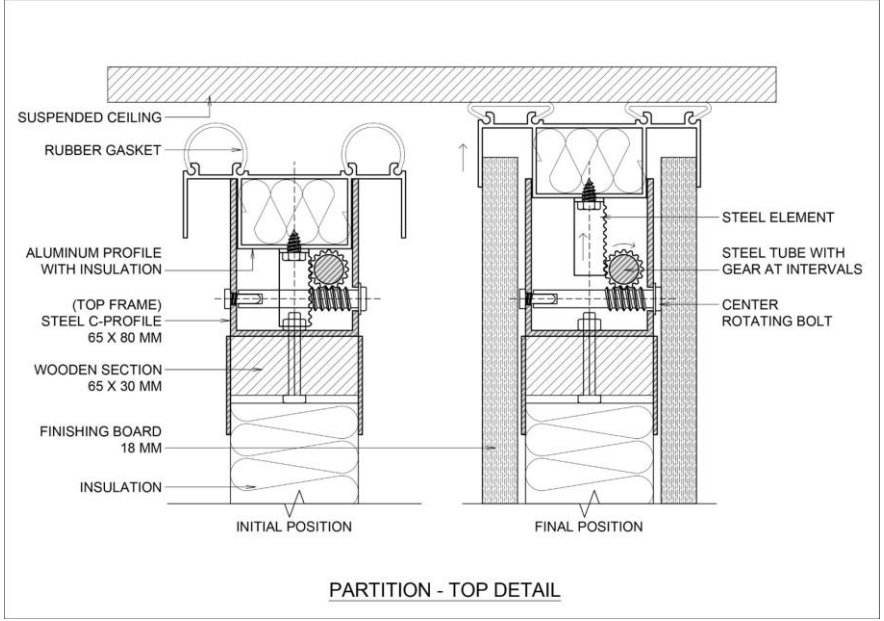
PLAN THROUGH THE TOP FRAME

ASSEMBLY PROCESS - OPTION 2

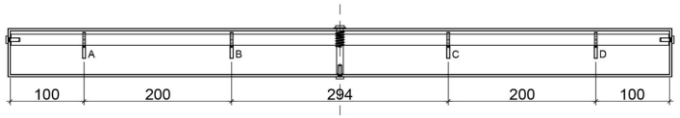
Assembly disassembly steps

1. Steel frame with insulation are positioned
2. Steel frame is connected to adjacent members
3. Center bolt is rotated that seals the top profile to the ceiling
4. Skirting is mounted to the steel frame
5. Finishing board is inserted to the top and bottom bracket





PARTITION - TOP DETAIL



PLAN THROUGH THE TOP FRAME

ASSEMBLY PROCESS - OPTION 2

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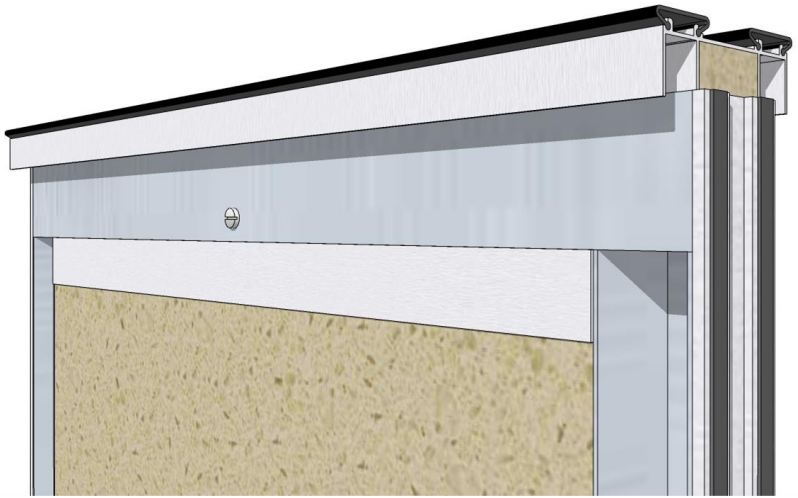
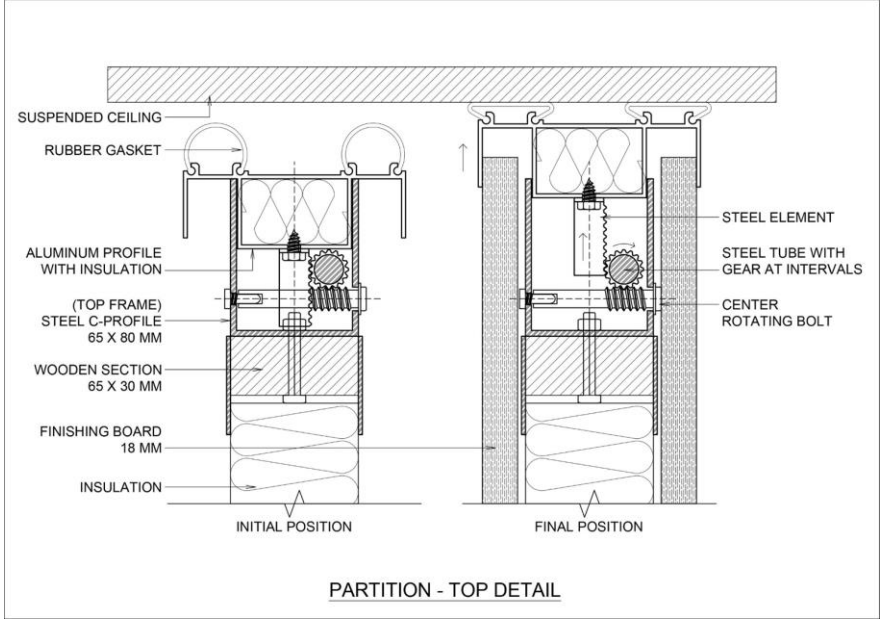
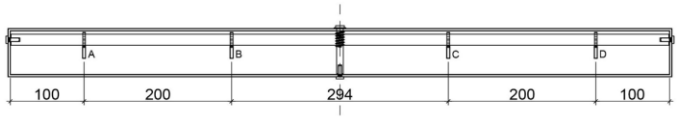




PARTITION - TOP DETAIL



PLAN THROUGH THE TOP FRAME

ASSEMBLY PROCESS - OPTION 2

Assembly disassembly steps

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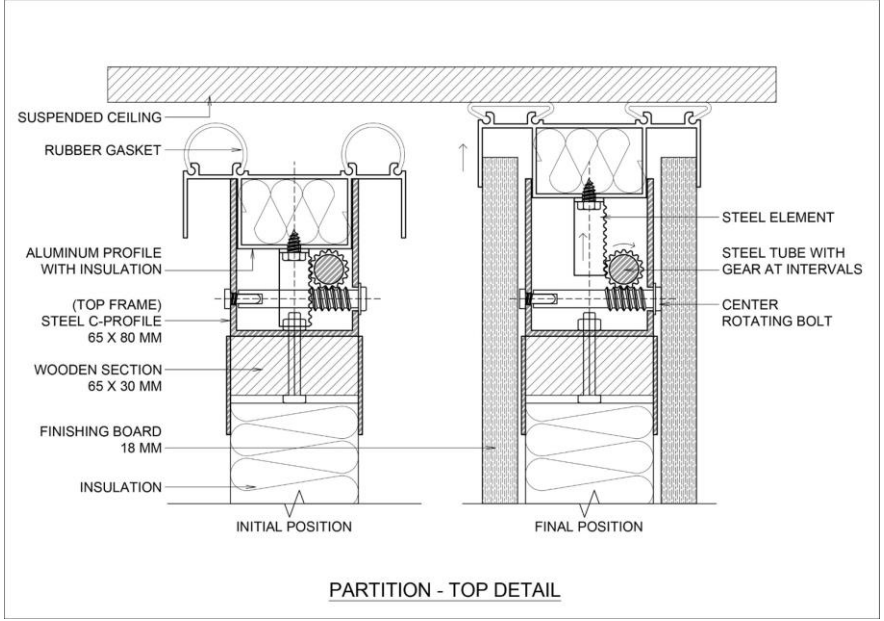
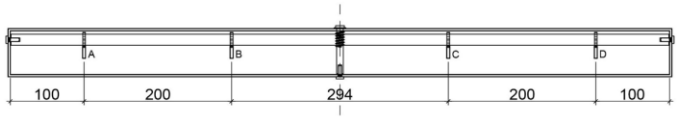
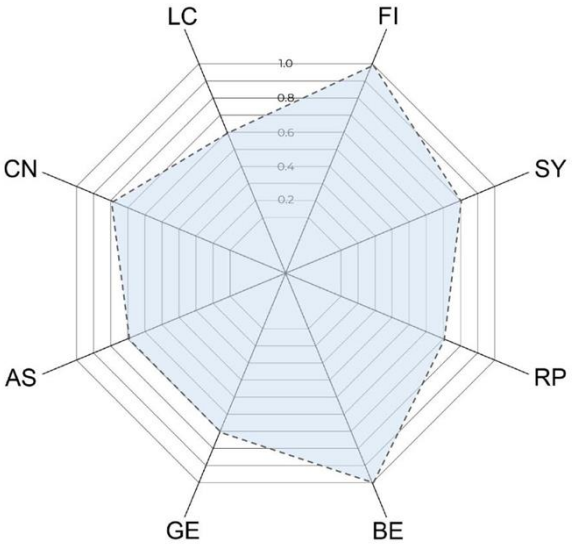


PARTITION - TOP DETAIL

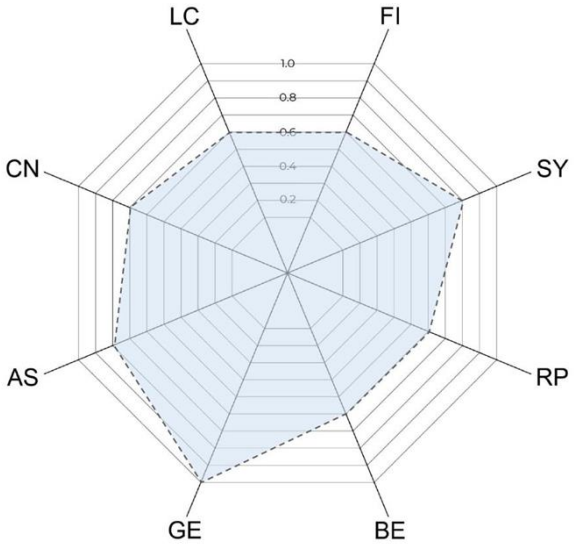


PLAN THROUGH THE TOP FRAME

DFD EVALUATION



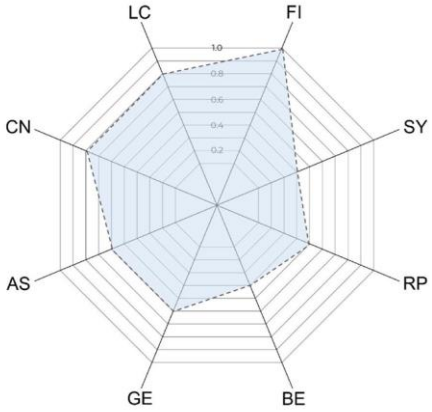
Option 1 DFD Score - 78.75%



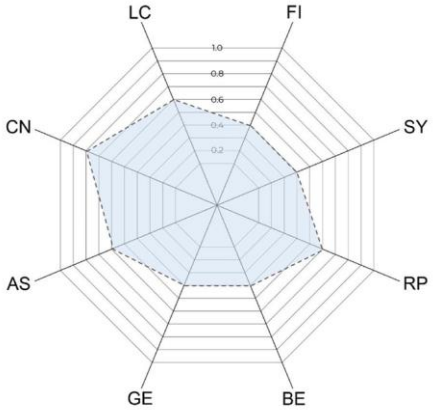
Option 2 DFD Score - 71.25%

DFD EVALUATION

JuuNoo
cleverly divide spaces

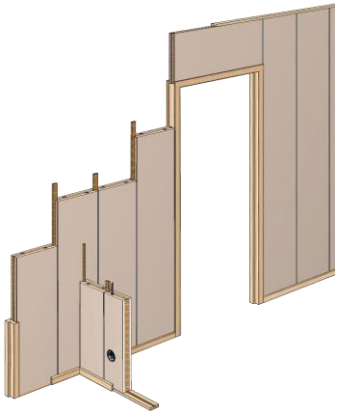


JuuNoo - 63.75%



Faay VP DFD Score - 52.5%

FAAY
WANDEN | PLAFONDS

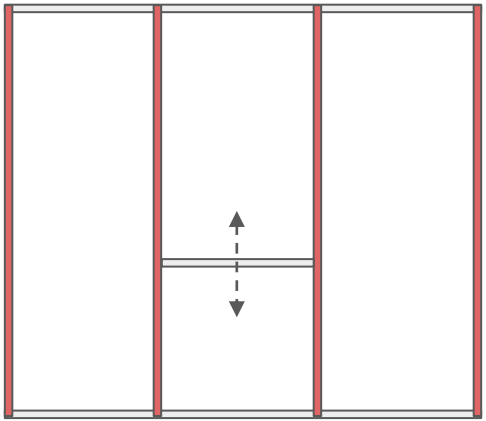


FLEXIBLE FACADE SYSTEM

Design proposal

FACADE FRAMING

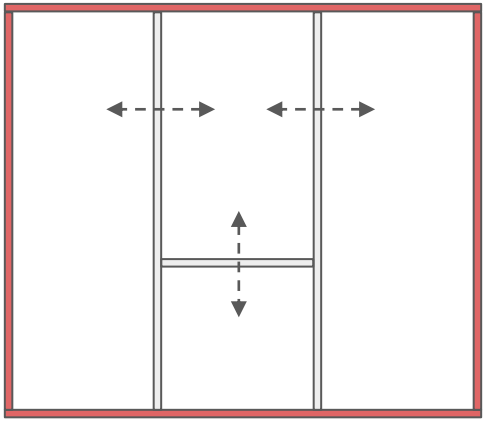
Stick system



Primary structural member

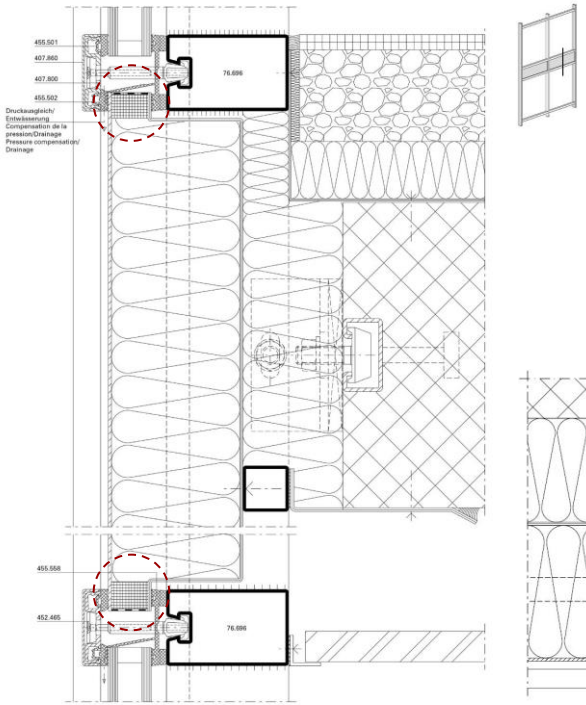
Secondary member

Flexible system

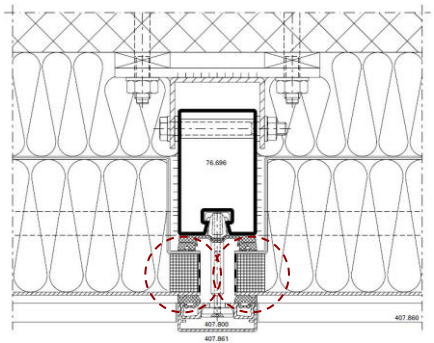


- Mullion as structural element limits future change
- Transom placement is flexible

- Portal framing as structural element as a flexible approach
- Transom and mullion placement is flexible



Section through floor & ceiling

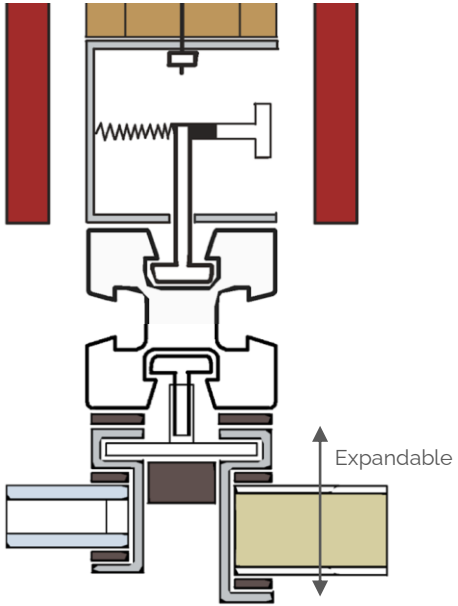


Plan

Drawbacks wrt. Flexibility and Disassembly

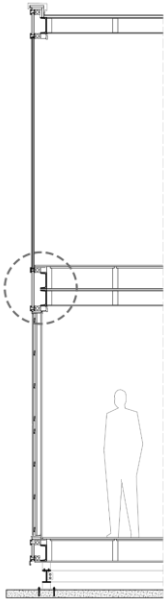
1. Interpenetrating geometry
2. Rebated panels have to be customised
3. Repurposing and reuse is difficult because of the geometry
4. Dependency is created with adjacent panels
5. Sequential disassembly process

FACADE CONCEPT

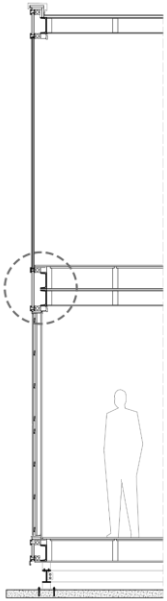


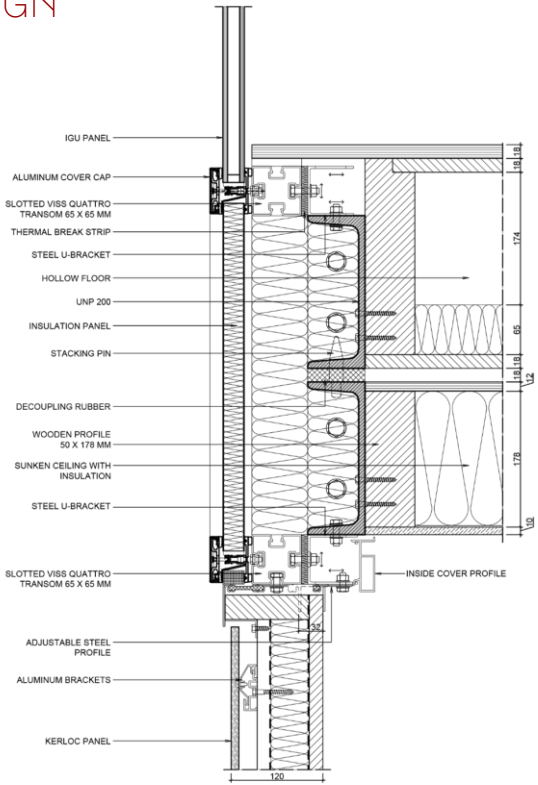
Plan

FACADE DESIGN



FACADE DESIGN





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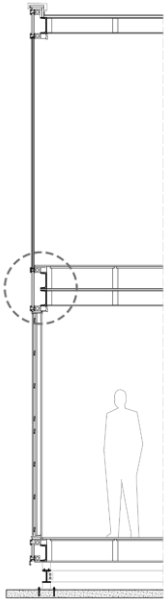

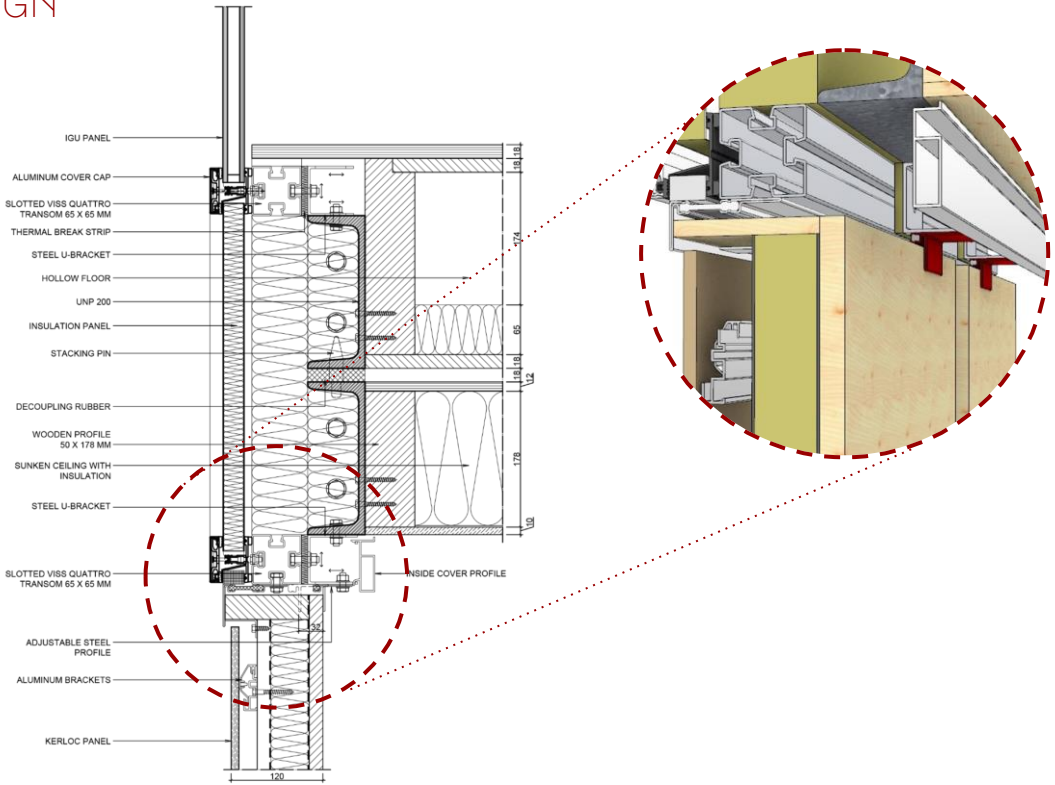

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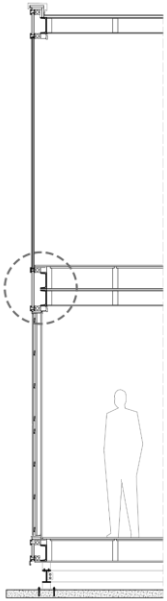
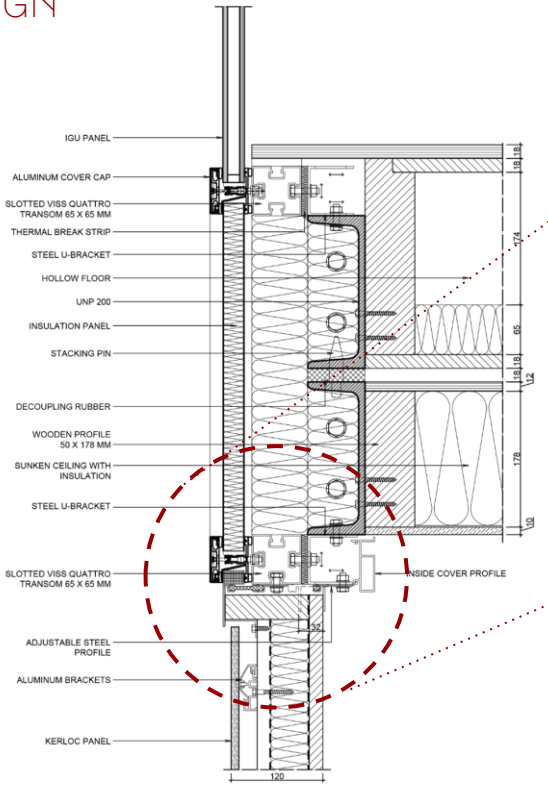
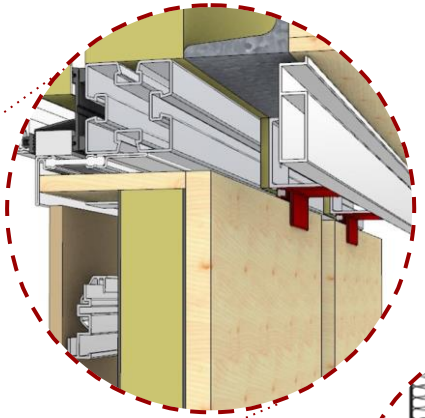
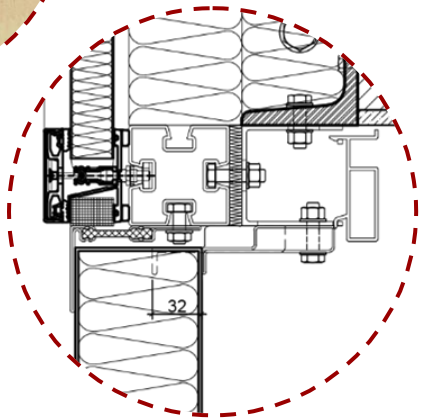
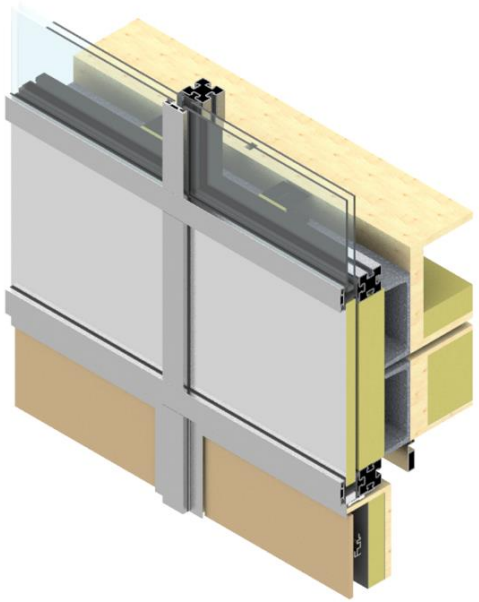








FACADE DESIGN



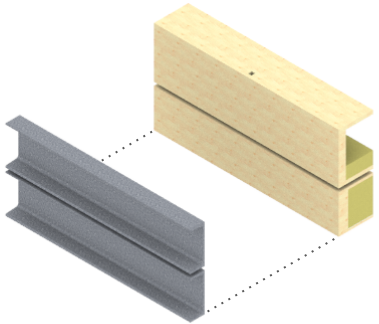
Design

1. Geometry of product edges are maintained
2. Interpenetrating geometry is eliminated
3. Connections are accessible
4. Wide range of facade panels with thicknesses ranging from 50 to 128 mm or more are possible
5. Allows parallel disassembly process

Thermal strategies

1. External thermal insulation
2. Slotted steel transoms
3. Thermal break strip between quattro profile and U-bracket
4. Damping elements between steel profiles

ASSEMBLY SEQUENCE



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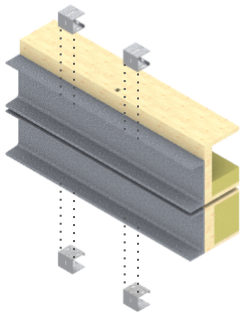

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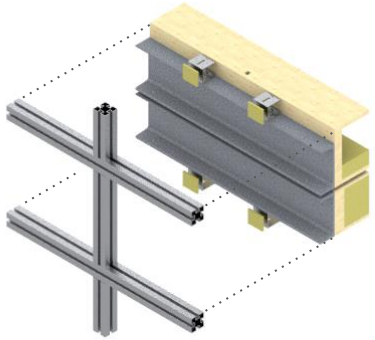

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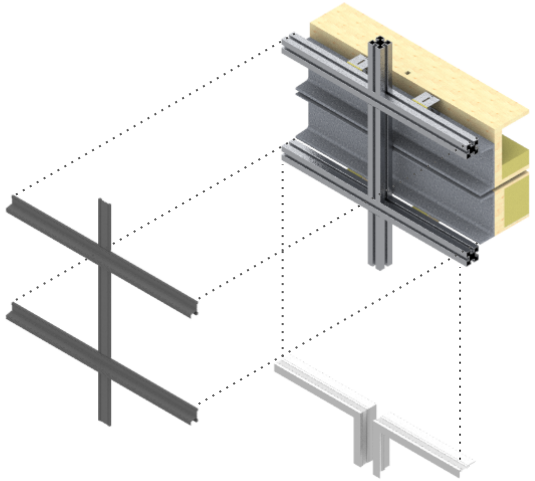

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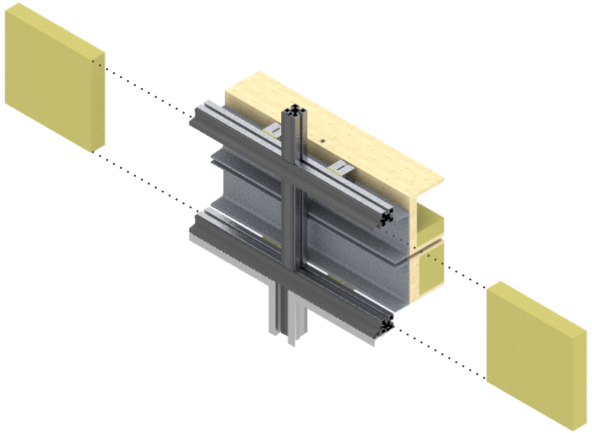

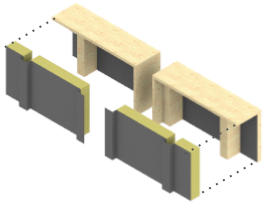

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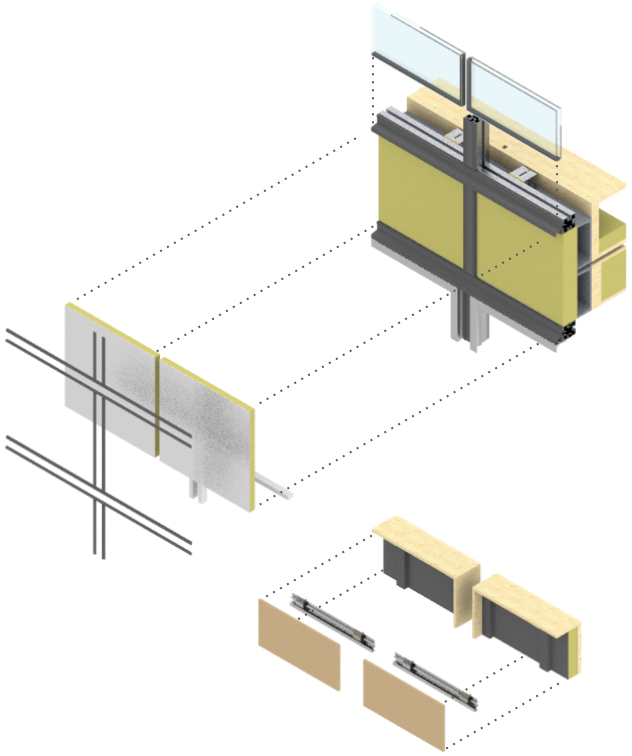

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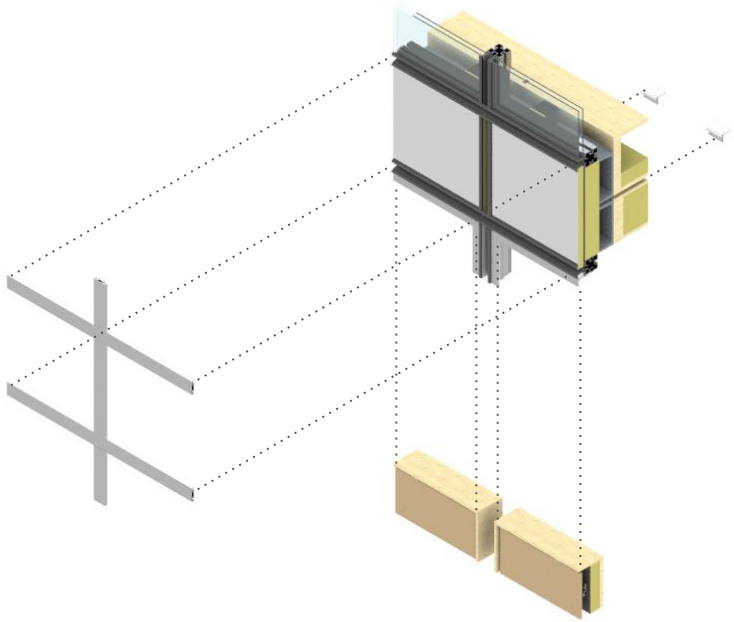

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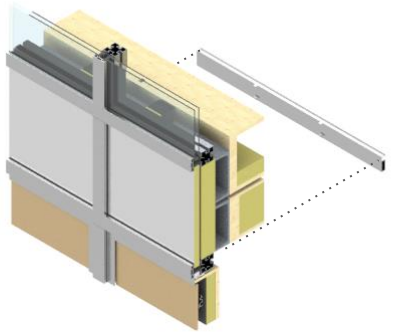

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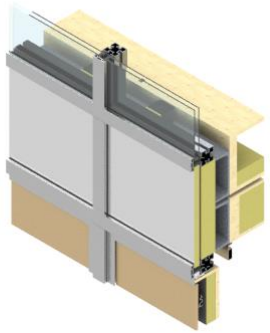

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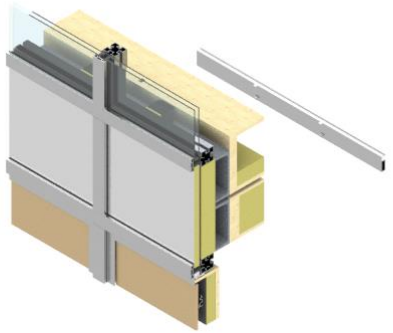

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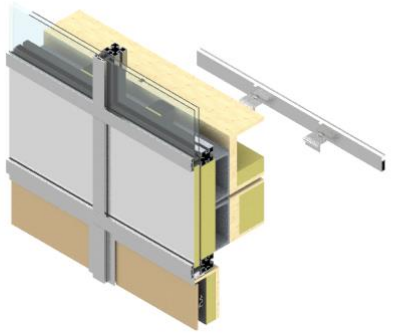

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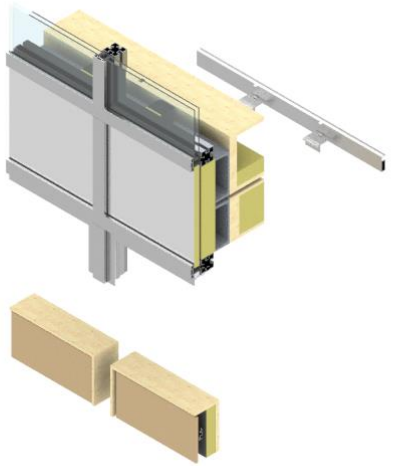

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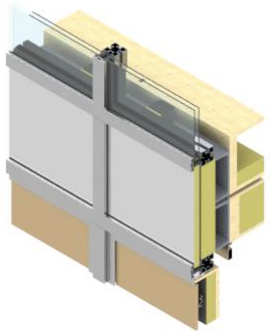

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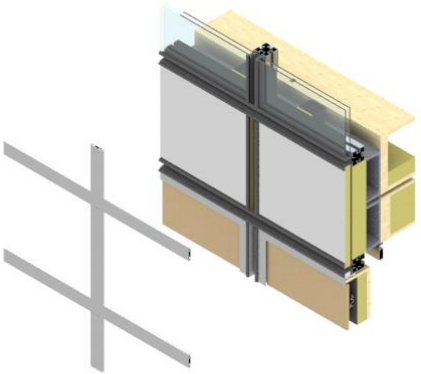

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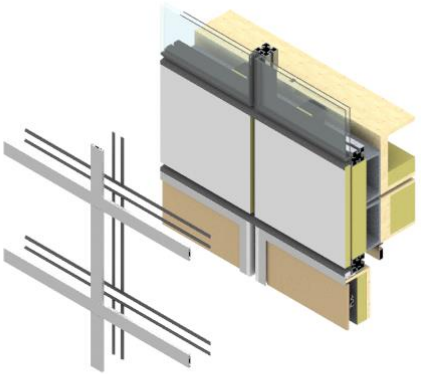

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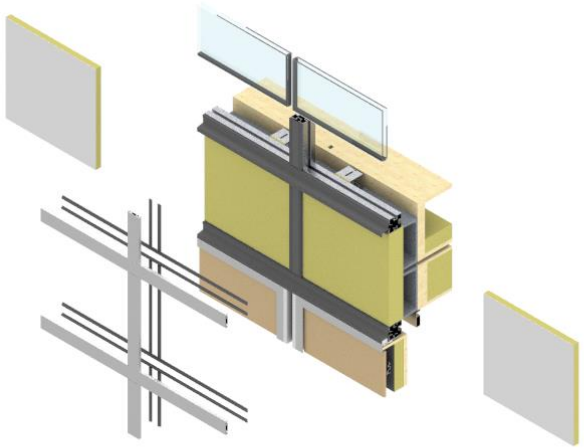

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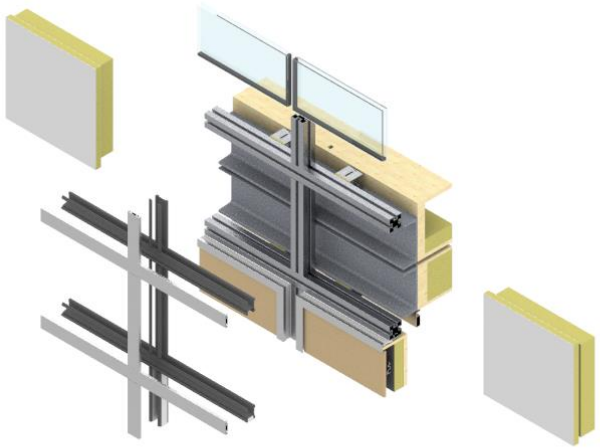
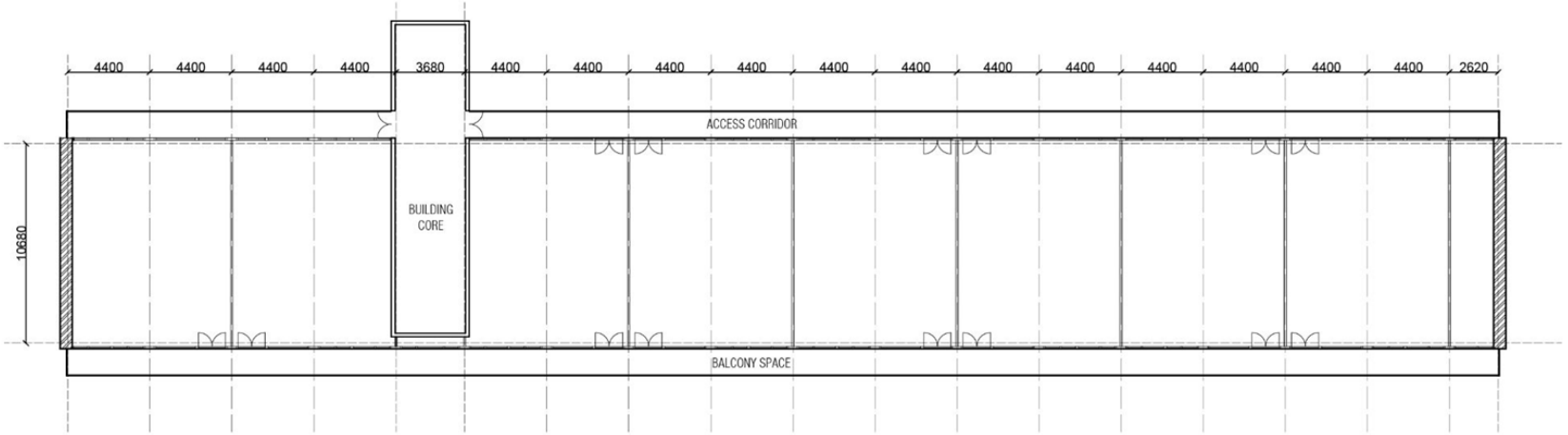


TOP-UP APPLICATION

Design proposal

TOP-UP APPLICATION

Menno ter braaklaan 1-271, Delft
Netherlands



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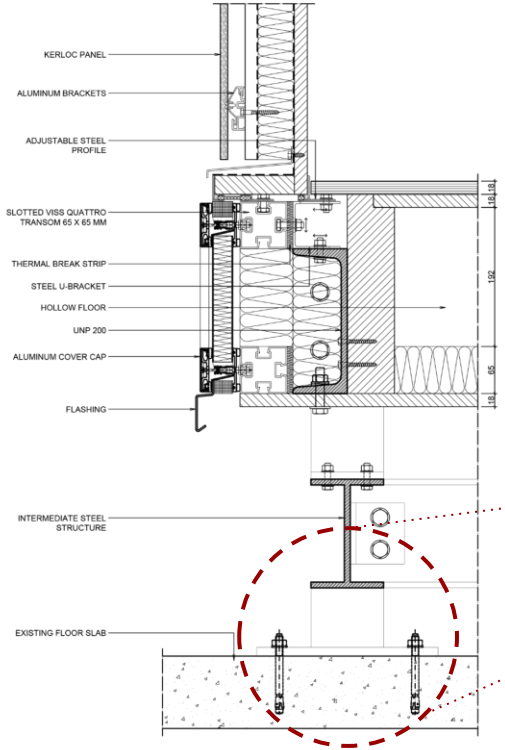

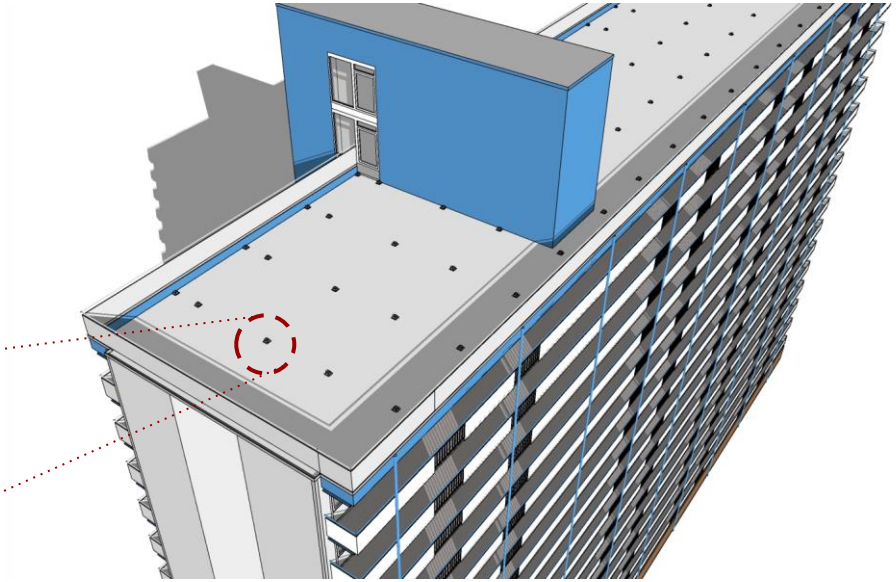

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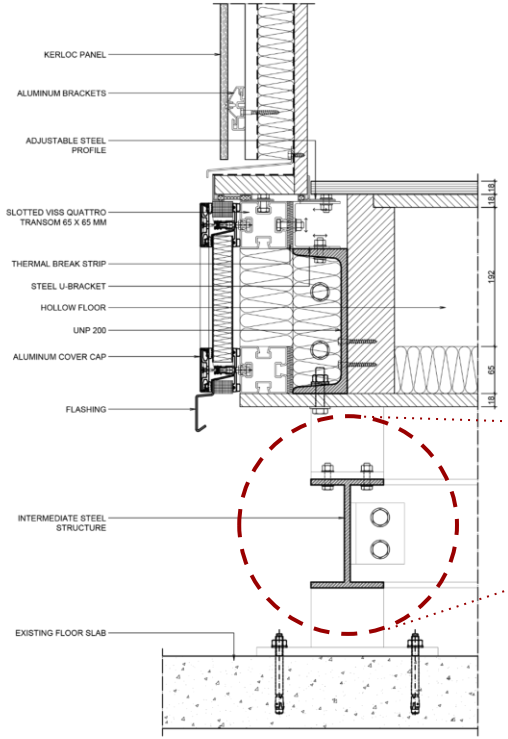

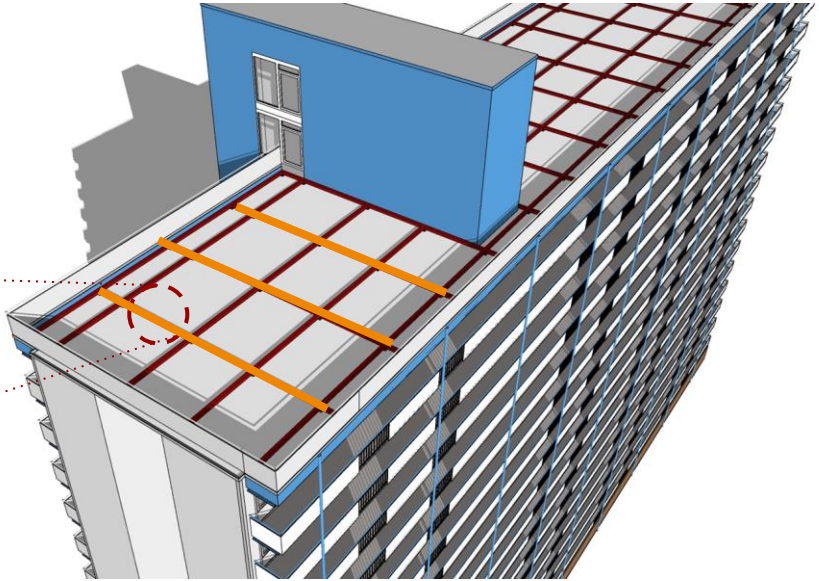

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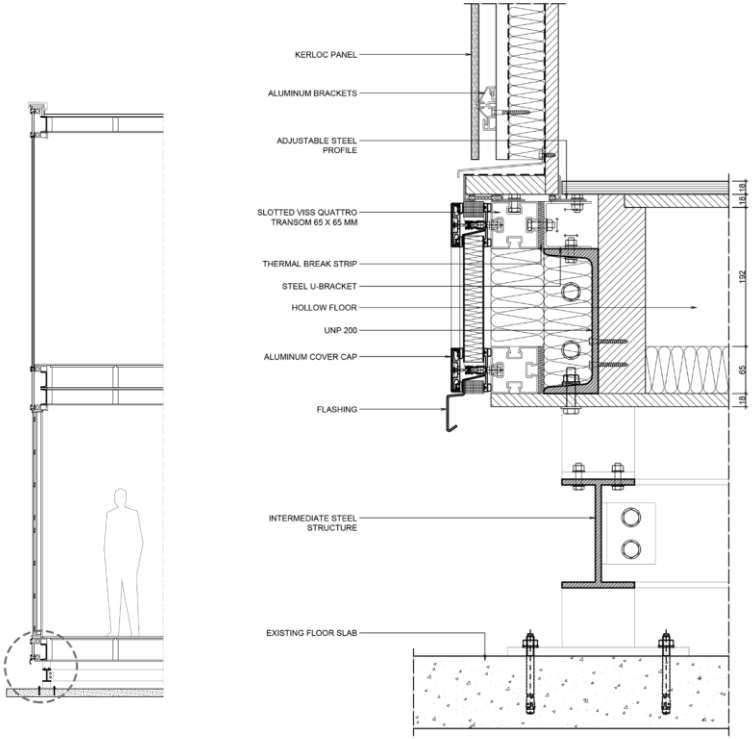

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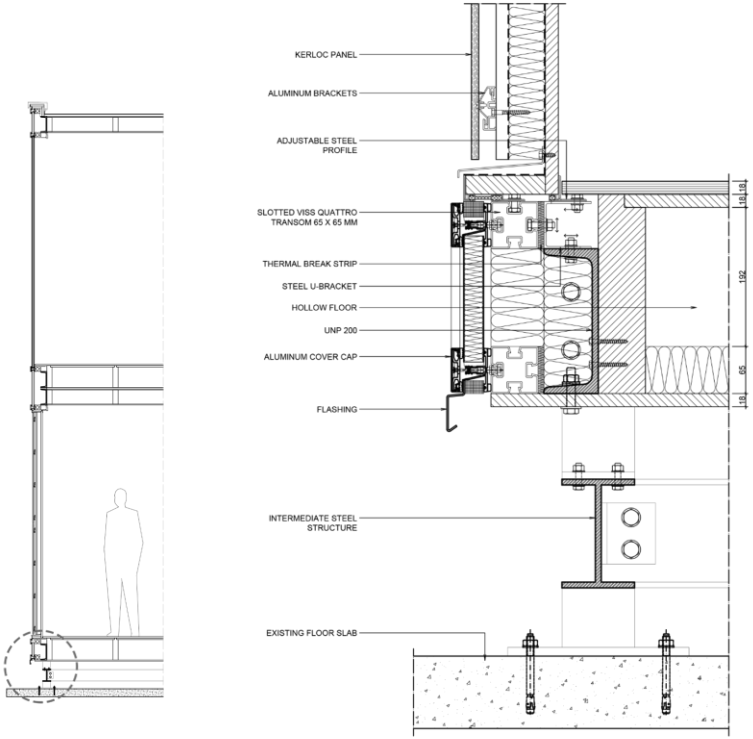

TOP-UP APPLICATION

TOP-UP APPLICATION

DESIGN

CONCLUSIONS

Research question | Limitations | Drawbacks

MAIN RESEARCH QUESTION

*How can flexibility of **Lightweight steel framing** (LSF) construction in prefabricated **Top-up dwellings** help improve its potential towards circularity with added benefits (Thermal and Acoustic)?*

1. **Flexible** steel components makes **reuse** of components possible thereby increasing its **life span.**
2. Building components **demountable**, which increases its potential for **reuse, reconfigure** and easier **separation of parts** for **recyclability.**
3. It serves a larger audience with dynamic wishes by:
    - Incorporation of **various facade panel** types and sizes
    - A wide variety of **modular room layouts** can be achieved catering to different **user demands** hence reducing **renovation** and **demolition** scenarios when **users change**.
    - A **flexible modular design** approach can cater to **different housing unit sizes** which makes it possible to mount them in **varying flat-roof** sizes.

1. **Added benefits** of current **thermal** and **acoustic** values for housing can be achieved with this system.

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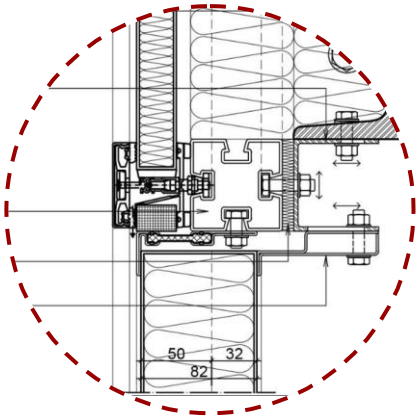
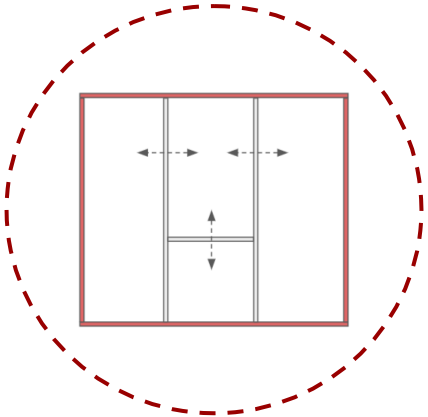
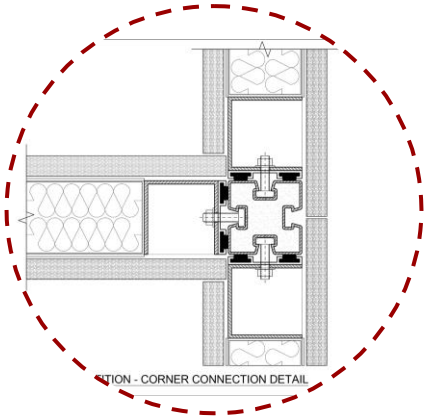
DESIGN RESEARCH QUESTION

How can the Jansen quattro steel profile be used in a flexible and circular manner?







CONCLUSION

DESIGN LIMITATIONS & DRAWBACKS

Limitations:

- Elements with **simple forms** are used
- **Transport** limitations for modular buildings
- Larger **spans and heights** are limited with Quattro profile used in the research
- **Thermal and acoustic problems** with steel lead to design limitations

Drawbacks:

- Initial cost might be **expensive**
- **Flexibility** is seen as an **added benefit**
- High **organisational cooperation** is needed for circular building strategies
- **Accessible connections** mean they are **visible** too which might not suit everyone
- **Modular** design strategy might tend to become **monotonous**

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THANK YOU

Questions?