Future proof buildings

A Sustainable approach for transforming 1960's high rise residential buildings.

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Introduction

Description of gallery flats

Challenges and improvement strategy for the high-rise flats

Case study

Add-on design

Performance analysis

Building design

Conclusions

Introduction

Sustainable development

The goal of sustainable development is to meet the needs of present generations

without jeopardising the ability of future generations to meet their needs.

(European commission, 2016)

Impact of the building industry

50%

Resources

40%

Energy

30%

Water

35%

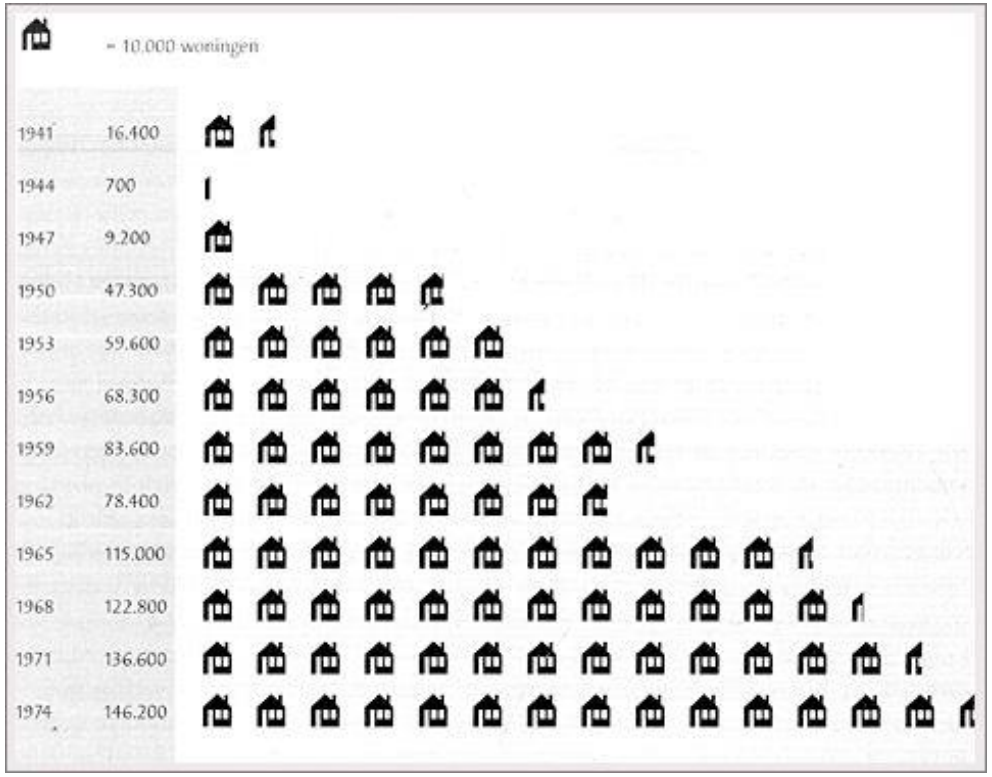
CO_2

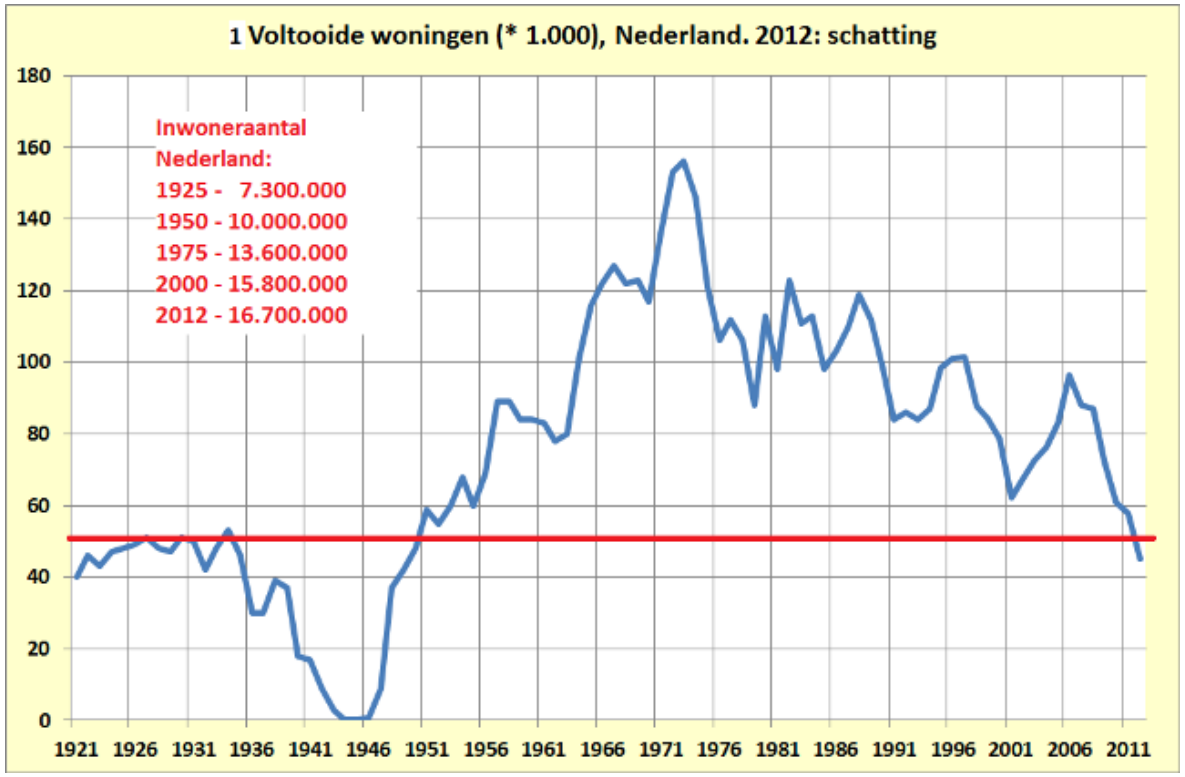
40%

Waste

(Ministerie van Infrastructuur en Milieu, 2016)

Aging building stock





More than 100.000 dwellings are currently reaching the age of 50 each year

(Canon volkshuisvesting Nederland)

Popularity of the high rise flats

Post WW2 housing shortages

Architectural views

Research Question

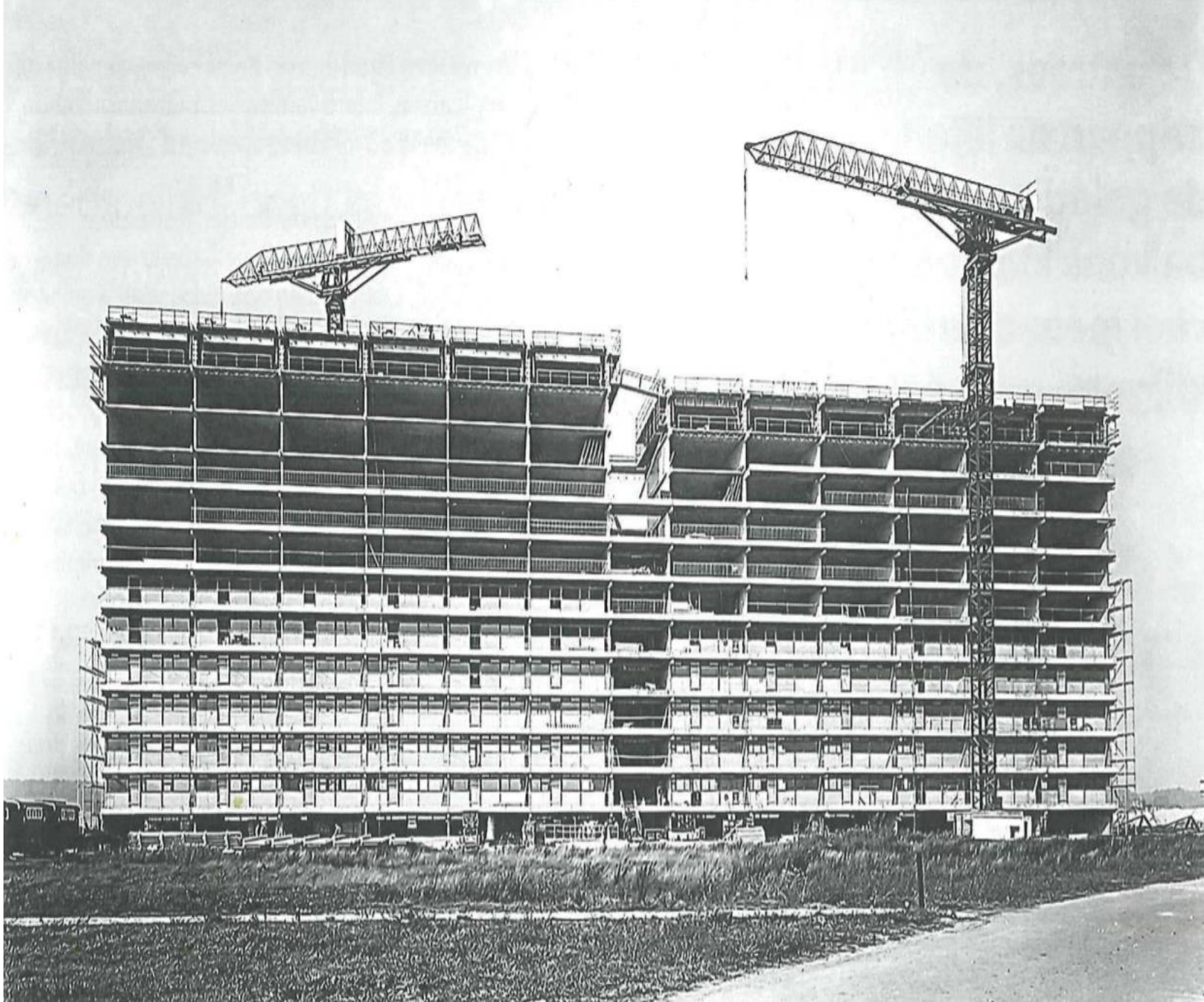
What type of approach can ensure that post world war 2 high-rise residential buildings can keep providing a high-quality living space for their inhabitants while at the same time meeting the current sustainability goals?

Description of gallery access flats

- 6.7% of the current housing stock consists of high rise buildings.

- 60% of these buildings were built during the nineteen sixties and seventies.

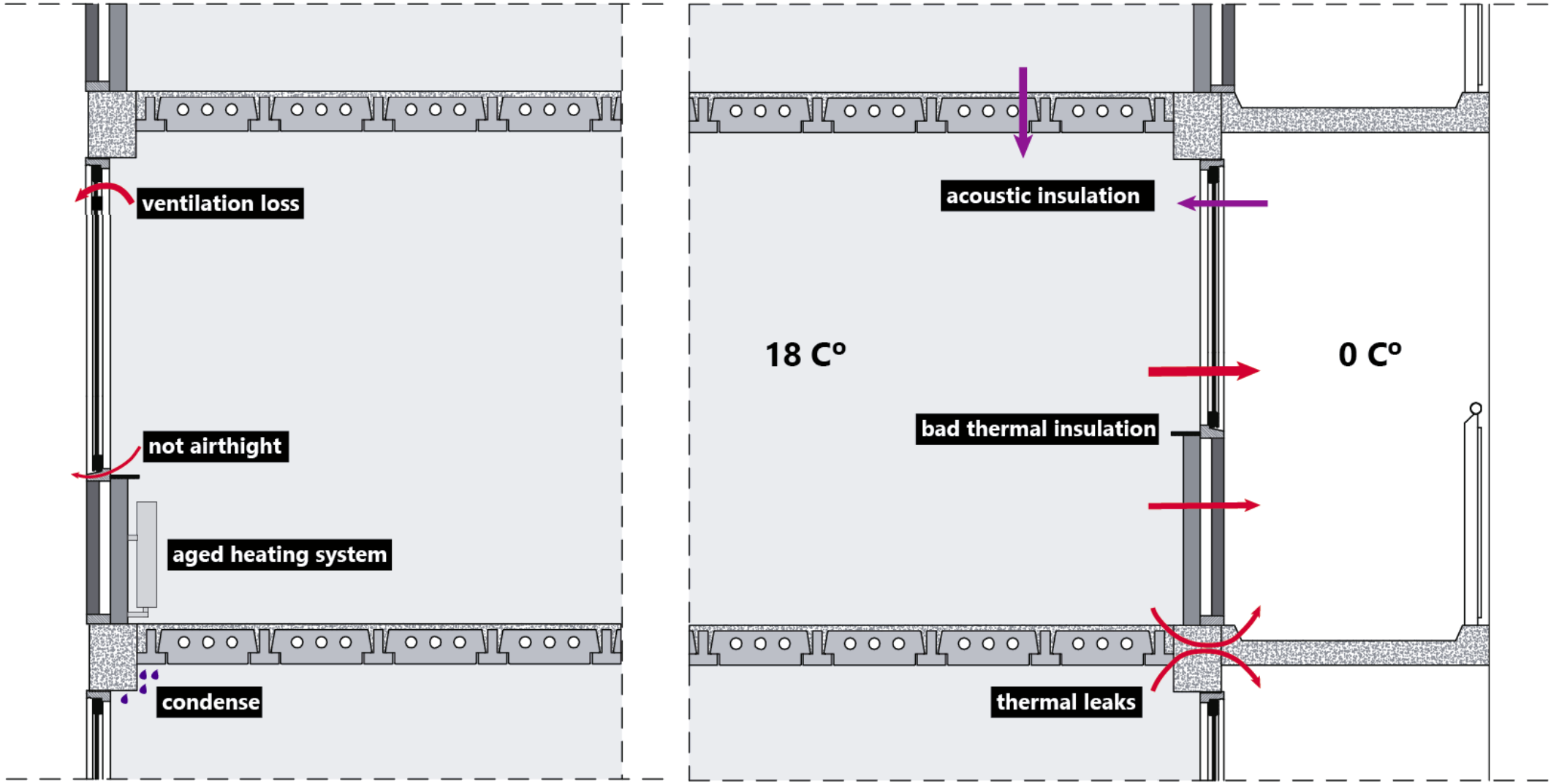
- made using concrete prefab construction methods developed after the war.
- The most common type of flat made during this era was the gallery flat
- 2% of the total building stock in the Netherlands consists of gallery access flats which account for 125.000 flats.
- High rise flats all share common spaces like the entrance hall, rubbish disposal, staircases and the lift.



Typical floorplan gallery flat

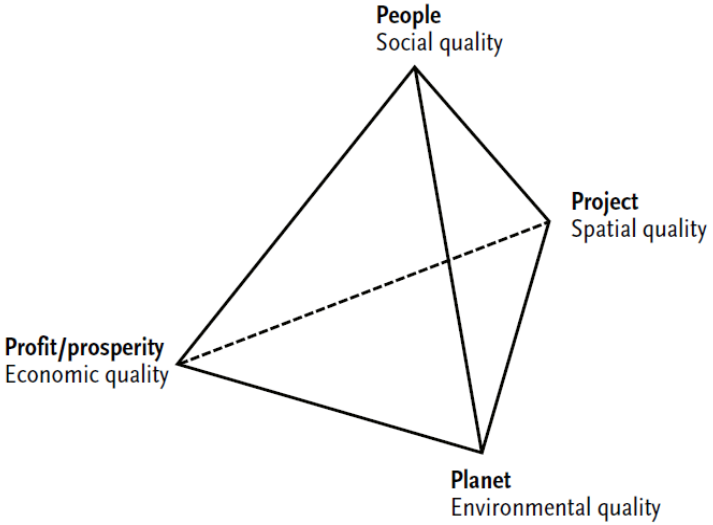
Challenges of high rise residential flats

Building physical challenges



Social, spatial and economic challenges

Space shortage



(Duijvestein & Dorst, 2004)

Bad accessibility

Monotony

Vandalism

Closed plinth

Possible improvement strategies

Nothing

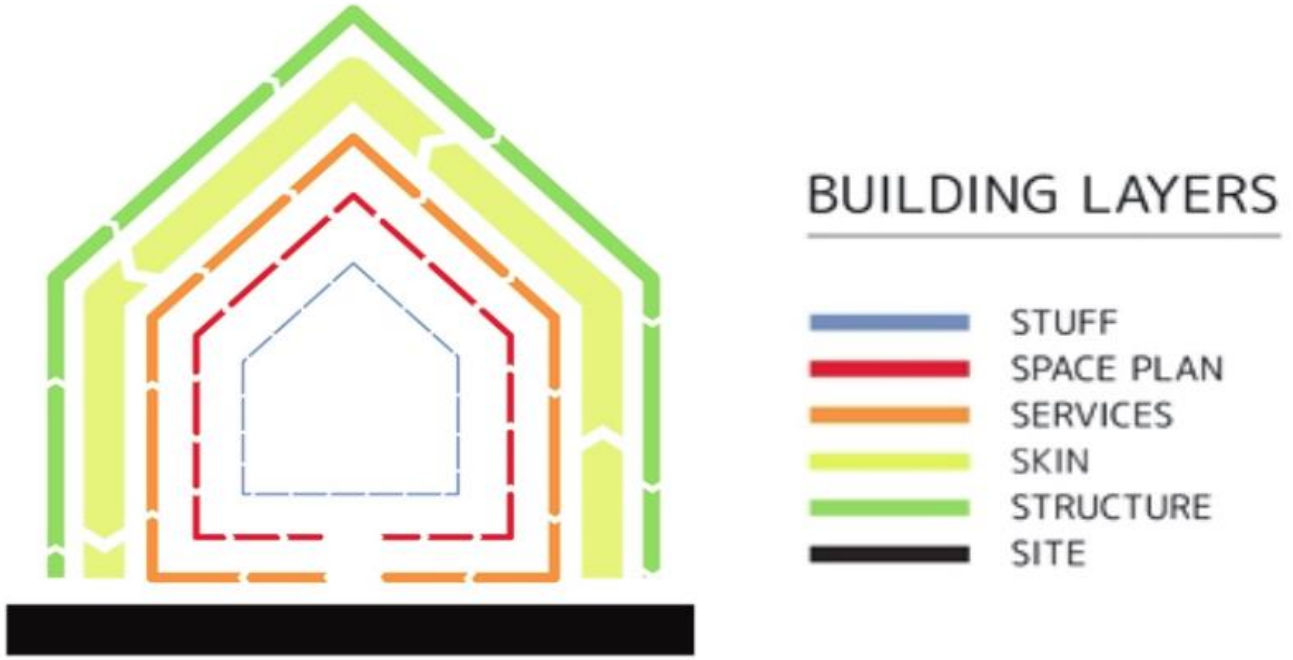
Maintenance

Renovation

Refurbishment

Demolition

Replacement

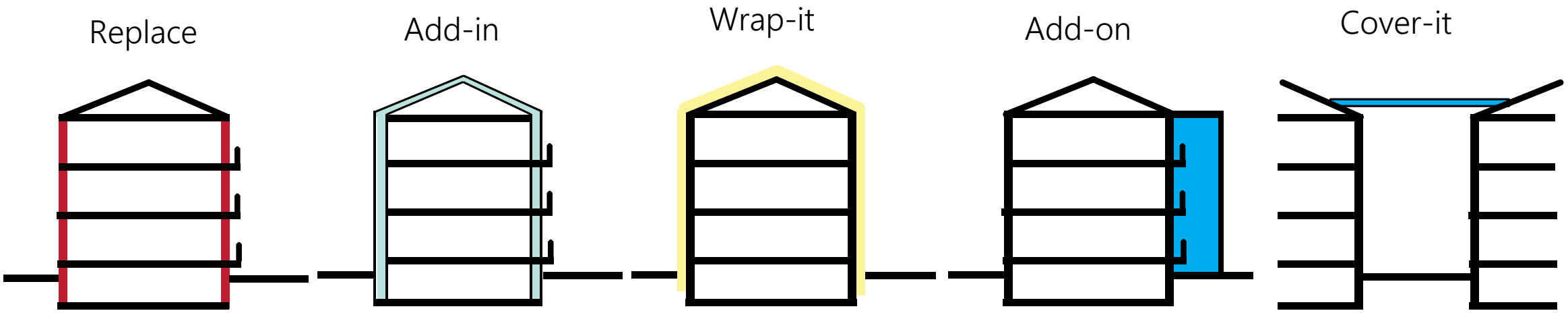


Building layers (Brand, 1994)

Choice → Refurbishment

- Able to deal with many of the challenges
- drastic approach with more possibilities
- Save energy and resources by maintaining the building

Façade refurbishment strategies



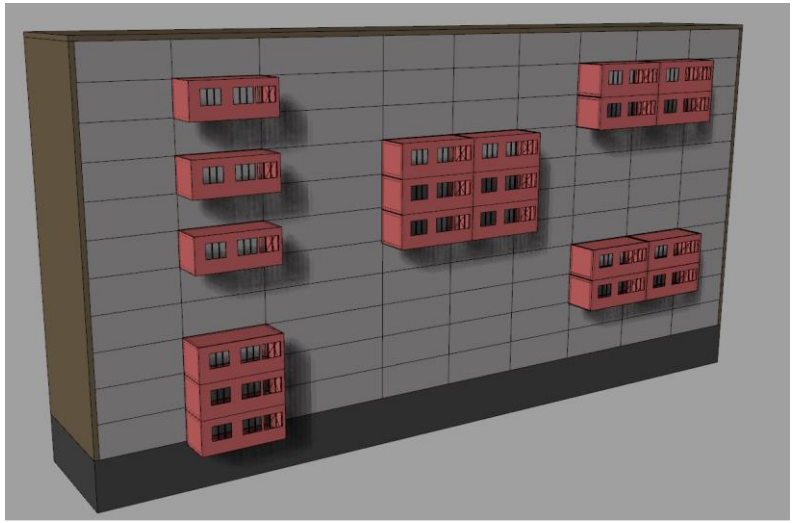
(Konstantinou, 2014)

Choice → Add-on strategy

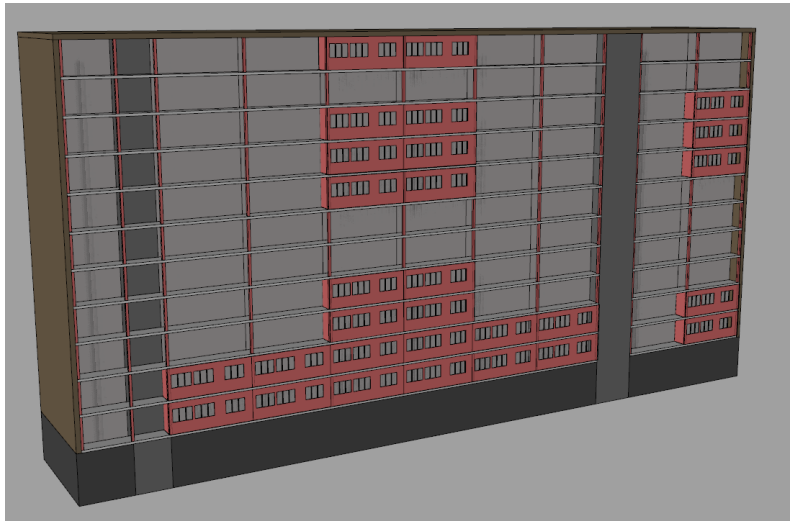
- Improved thermal insulation
- Short transformation period
- More unique appearance for building and dwellings
- A more flexible floorplan and extra space
- Demountable/ reusable elements

Addon options

The hanging addon



The half supported addon



The self-supporting addon

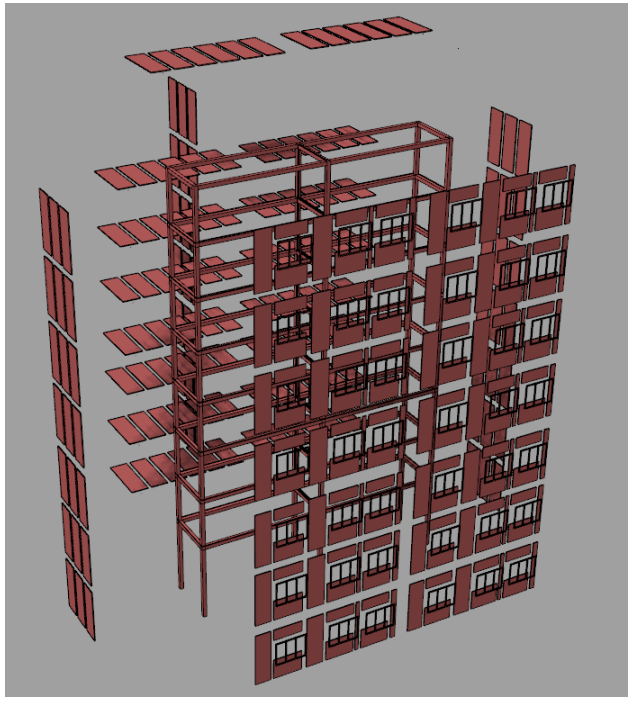
Choice

Self-supporting addon

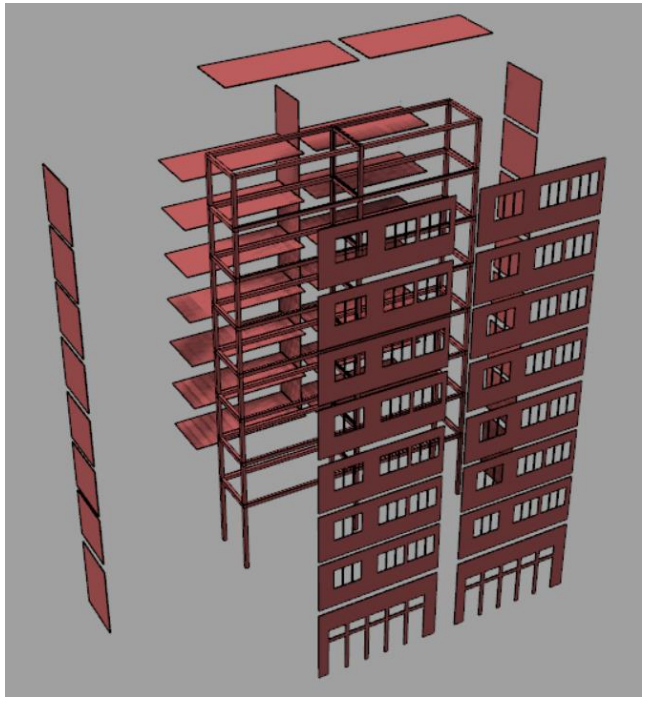
- Not restricted by weight
- drastic approach with
- more possibilities
- freedom in adapting the building

Addon built up

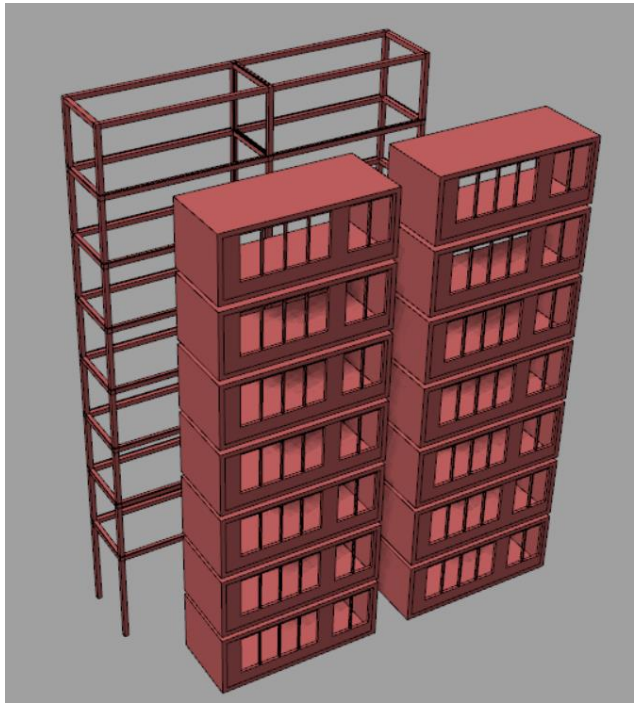
Small element built up



Large element built up



Unitized built up



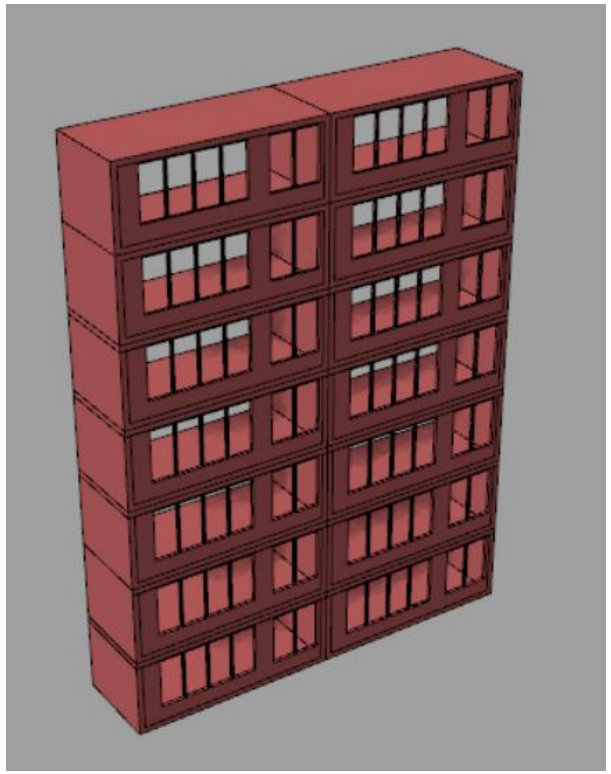
Choice

Unitized built up

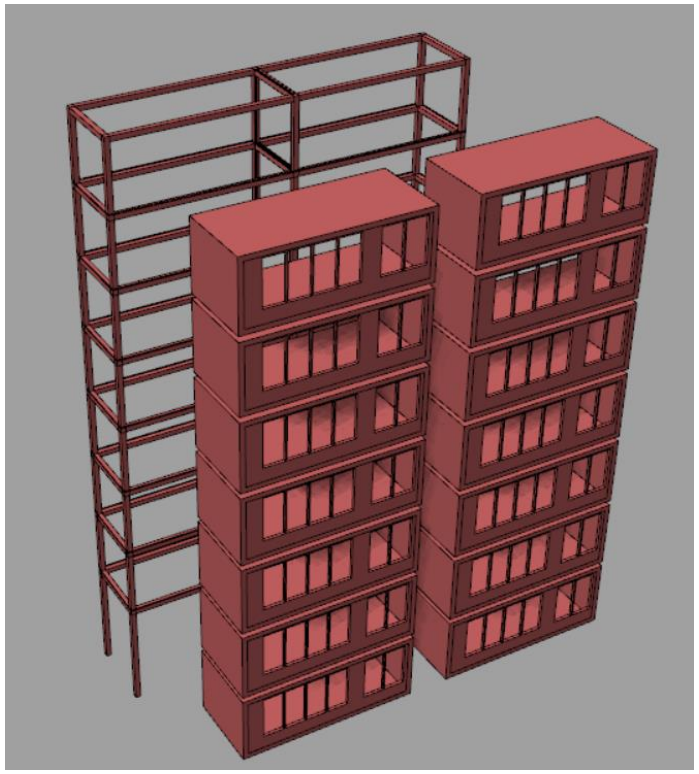
- Short built times
- Not at all labor intensive on site
- High finish due to build up in factory
- Little waste on site
- Demountable / reusable in one piece

Structural built up

Stacking of the units



Units in frame construction



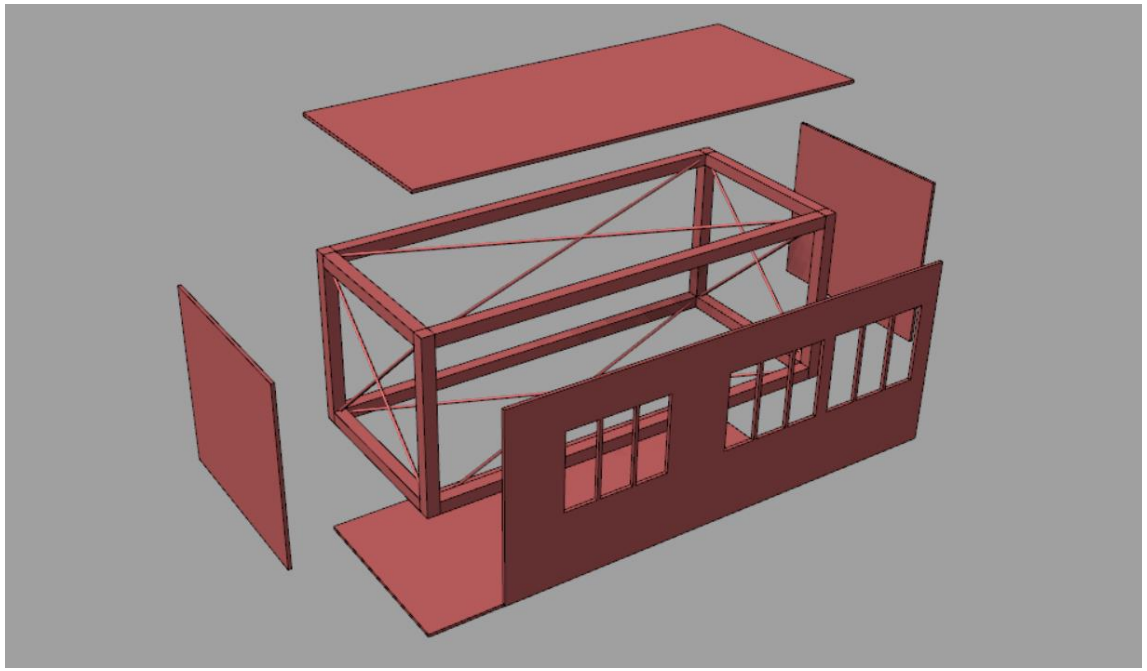
Choice

Units in frame construction

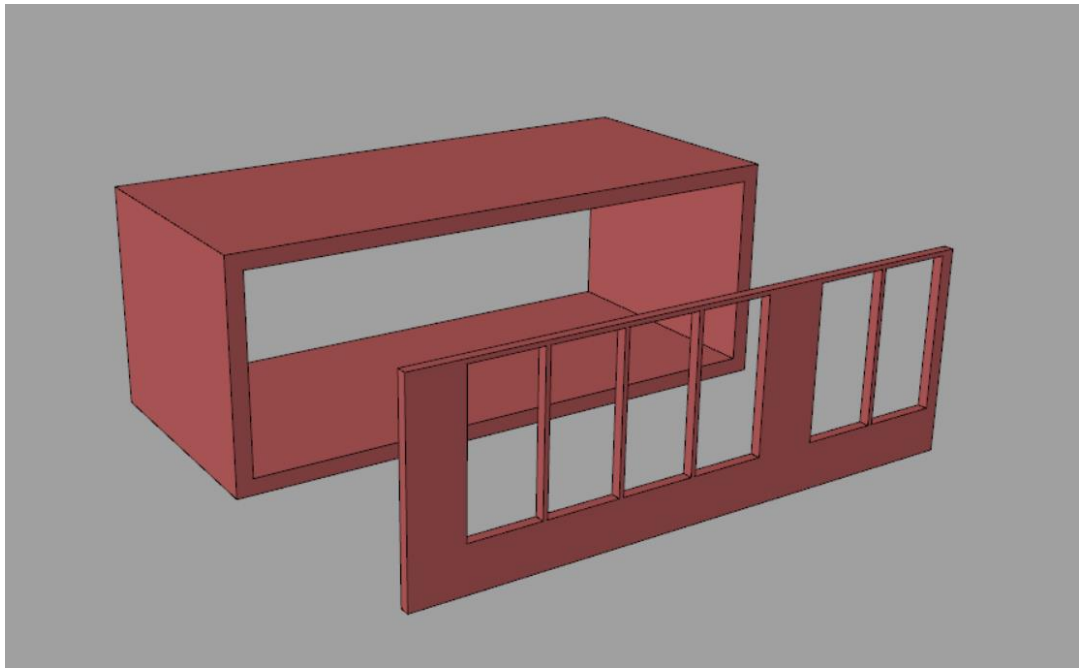
- Separately demountable
- Same structure regardless of placement

Unit built up

Frame unit



Shell unit



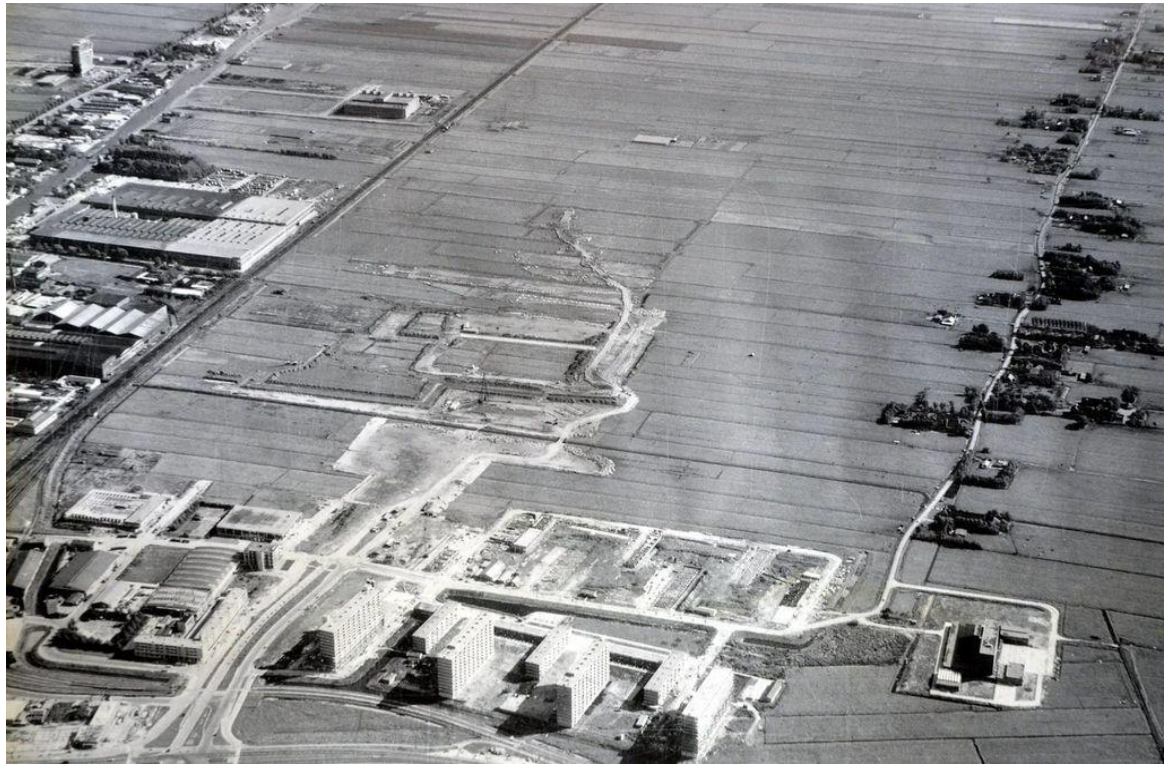
Choice

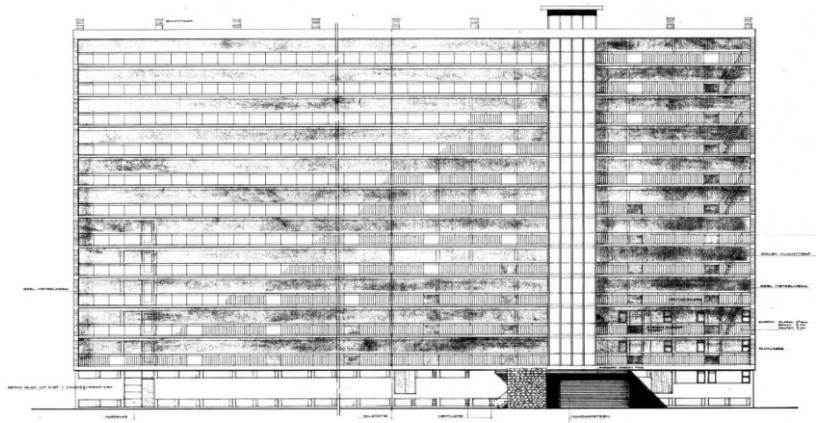
Shell unit

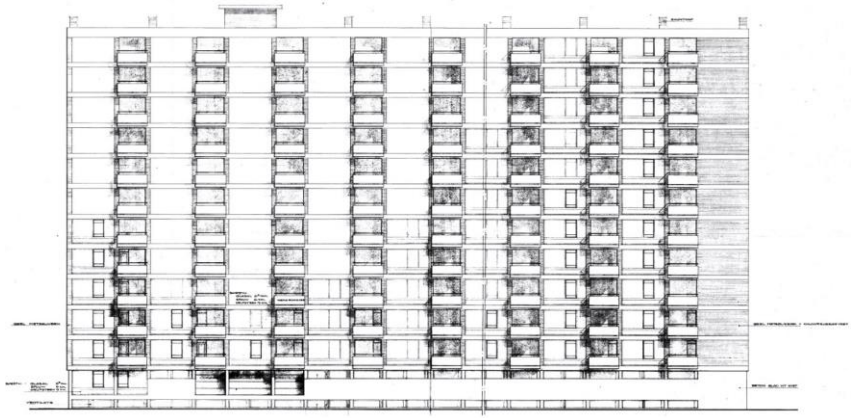
- Minimal height/thickness due to combination of façade and structure into one shell
- Demountable into large elements
- Structural integrity by itself

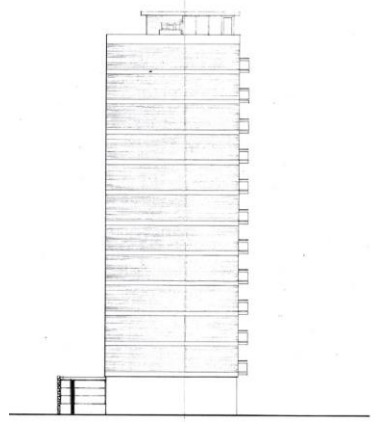
Case study

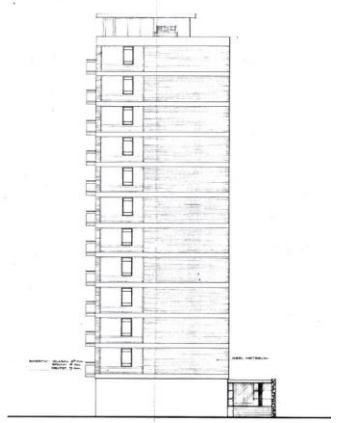
Historic & archival images Poptahof











Current situation

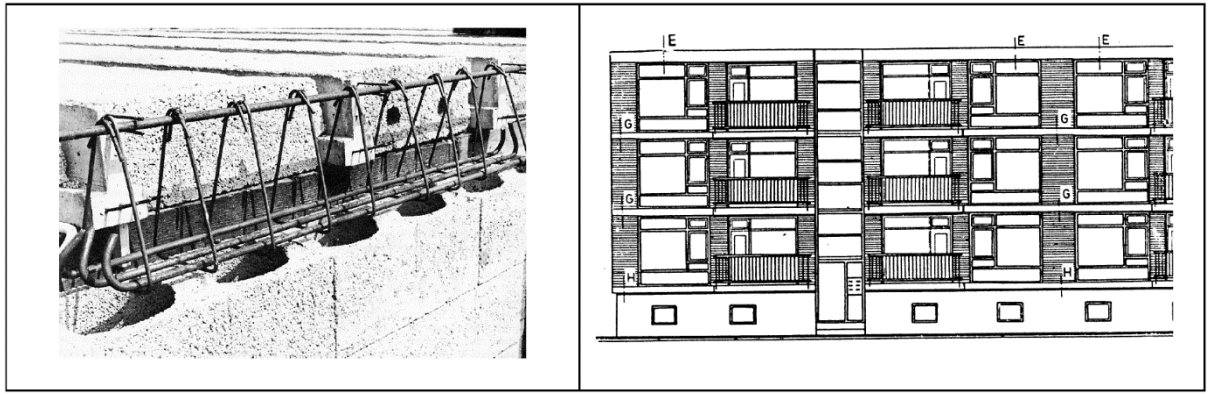
Pictures case study flat balcony side

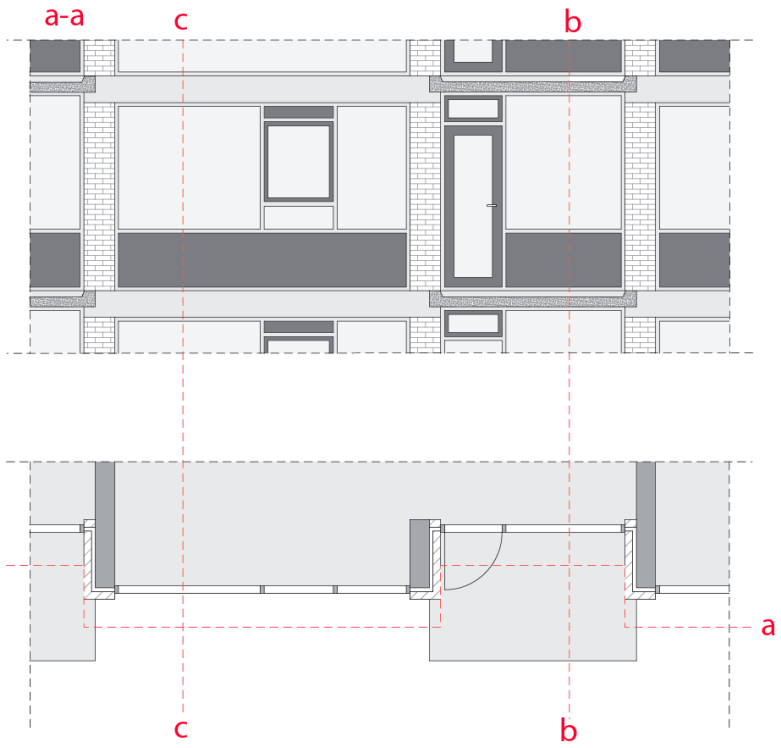
Pictures case study flat gallery side

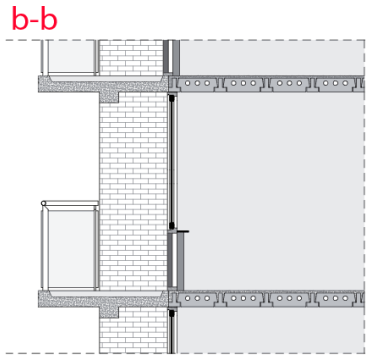
Building system & sections

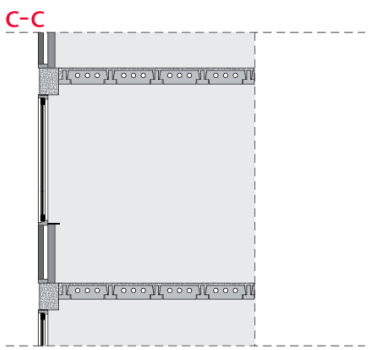
MUWI building system

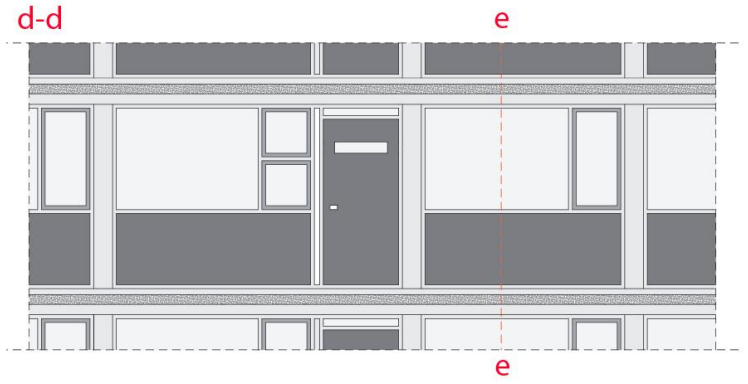
- Building blocks 50x19x21 cm
- Lightweight concrete floors on T shaped beams 60 cm apart
- Reinforced lintel

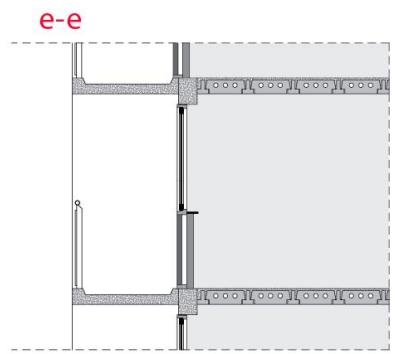


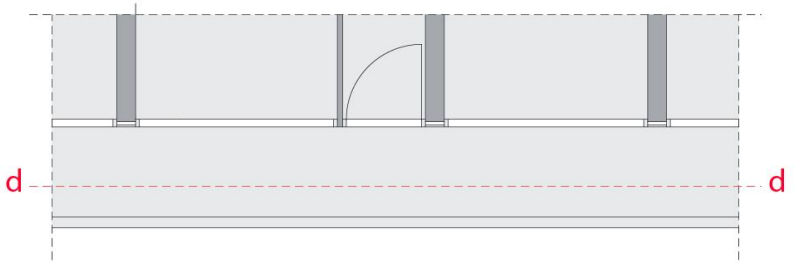




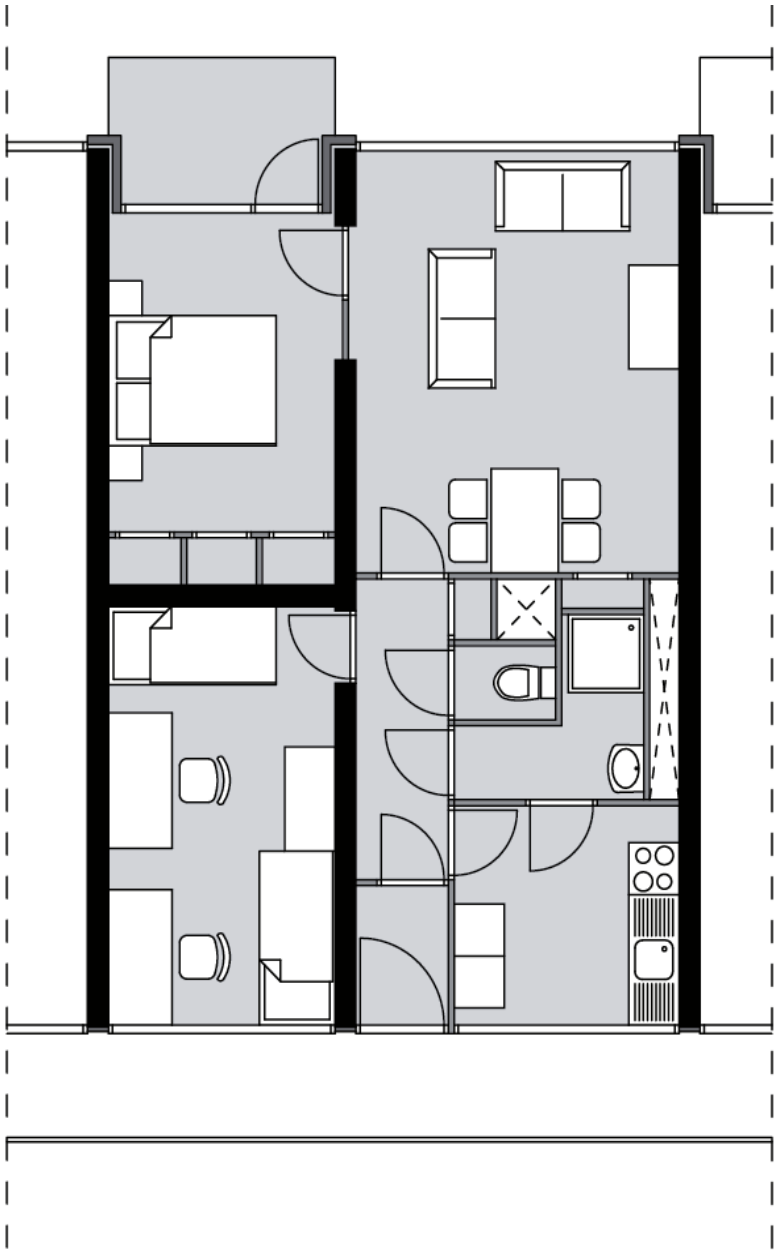




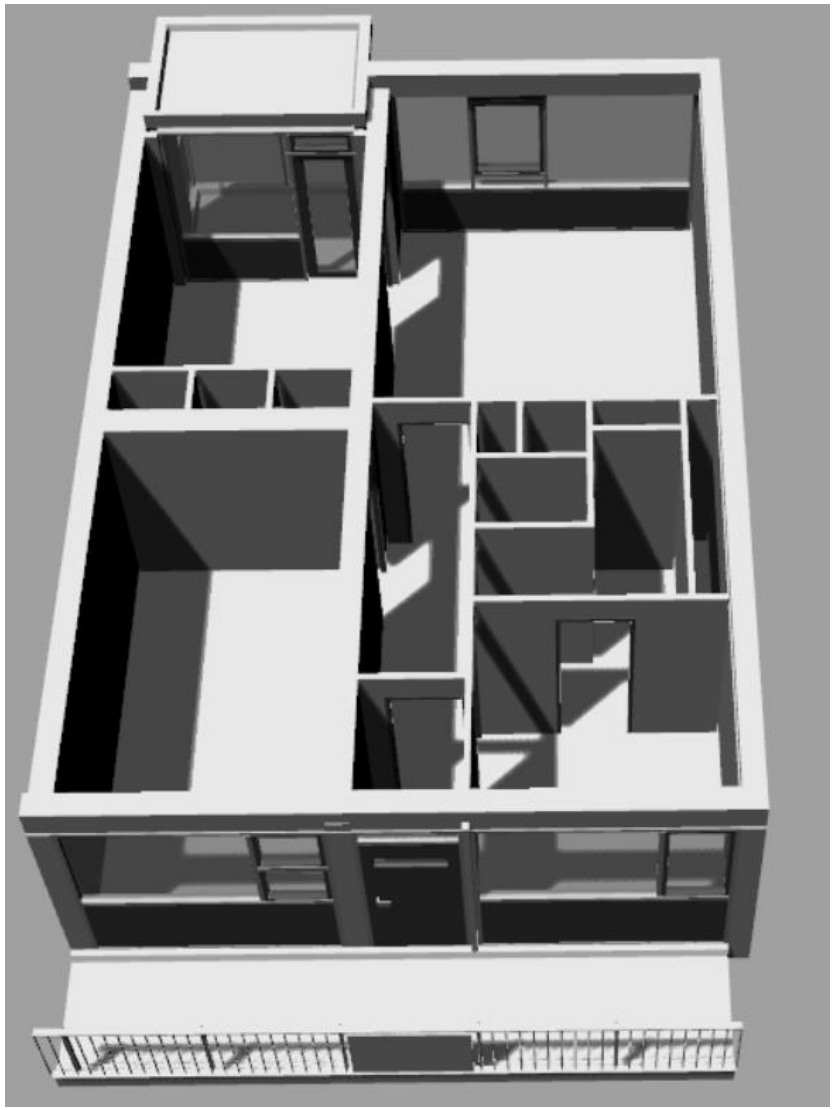




Single dwelling facades and floorplan layout

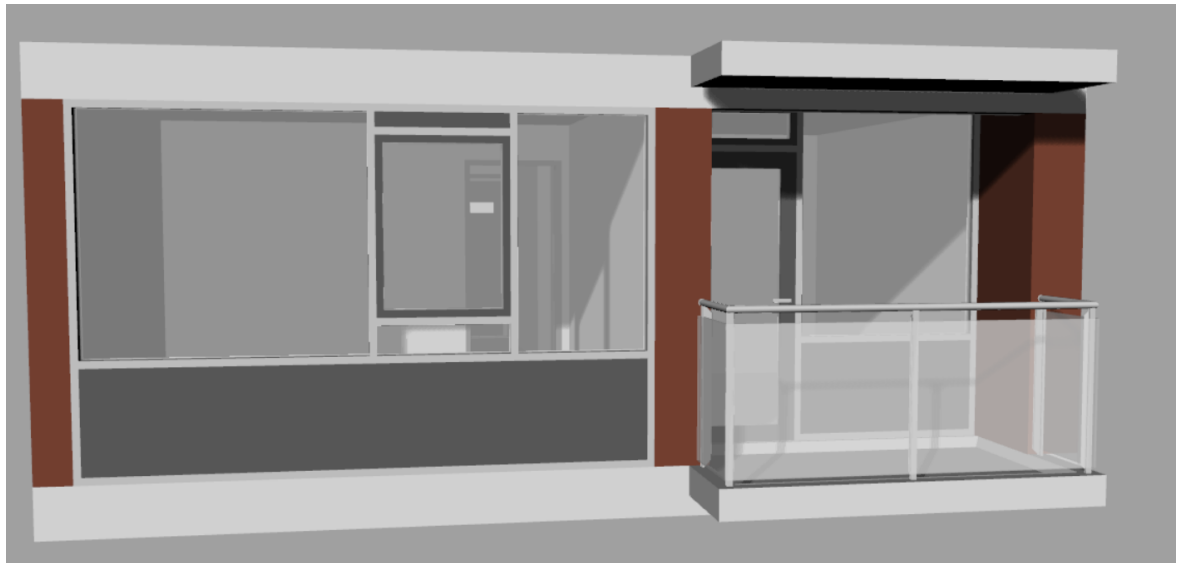


Rooms	Current dimensions (m2)	Required dimensions (m2)
Living room	18.65	14.81
Dining room	-	9.99
Main bedroom	13.0	10.4
Second bedroom	11.56	6.16
Kitchen	6.75	6.48
Bathroom	3.18	2.72
Toilet	1.03	0.98
Outdoor space	4.31	4.93
Storage room	5.0	5.0

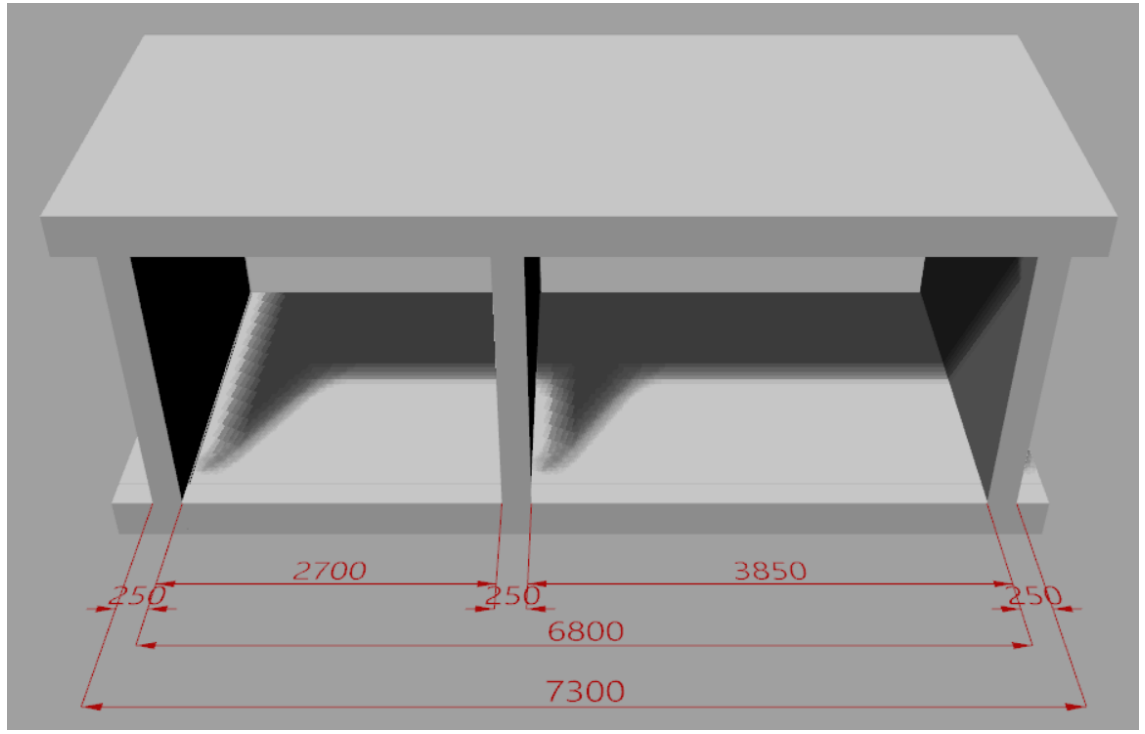


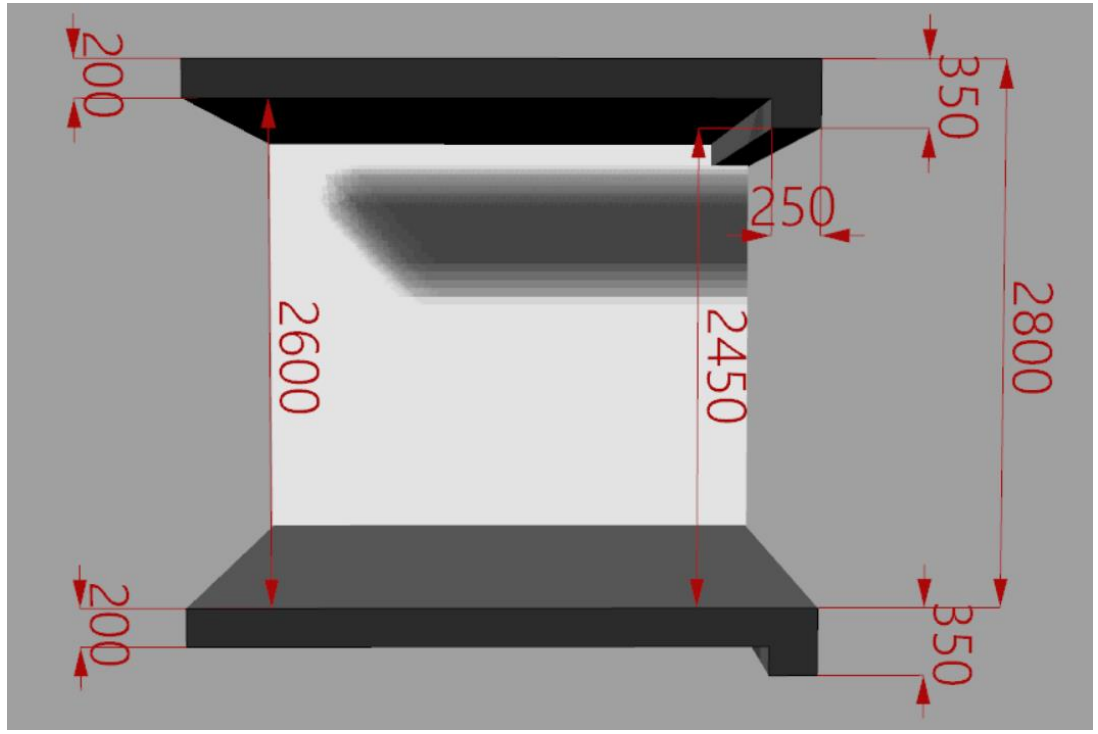
Add-on design

Single dwelling facades

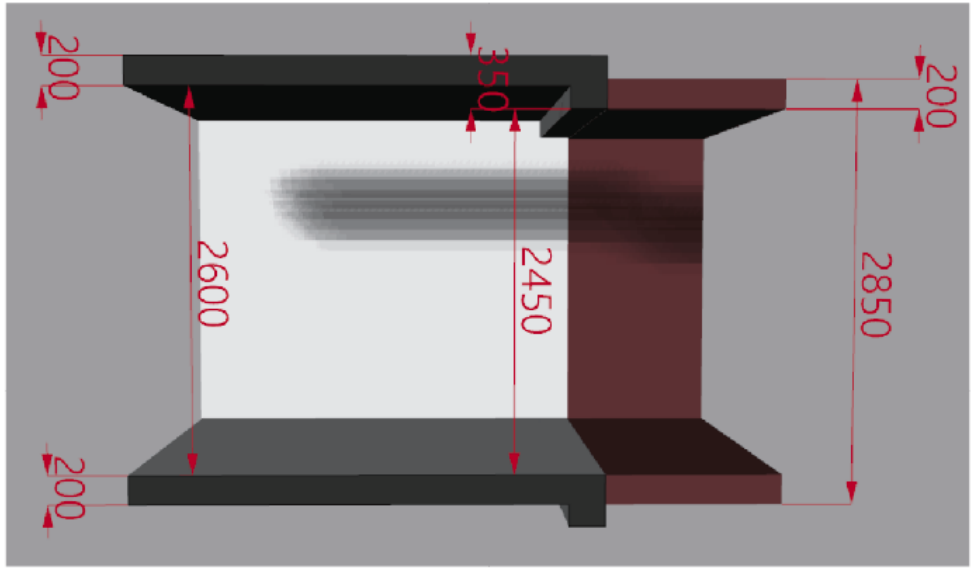


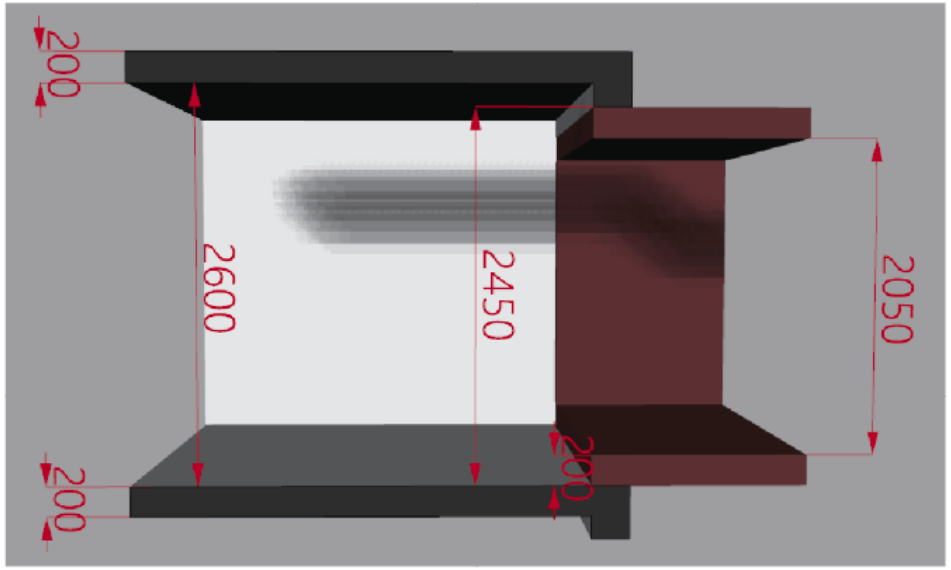
Single dwelling structural dimensions

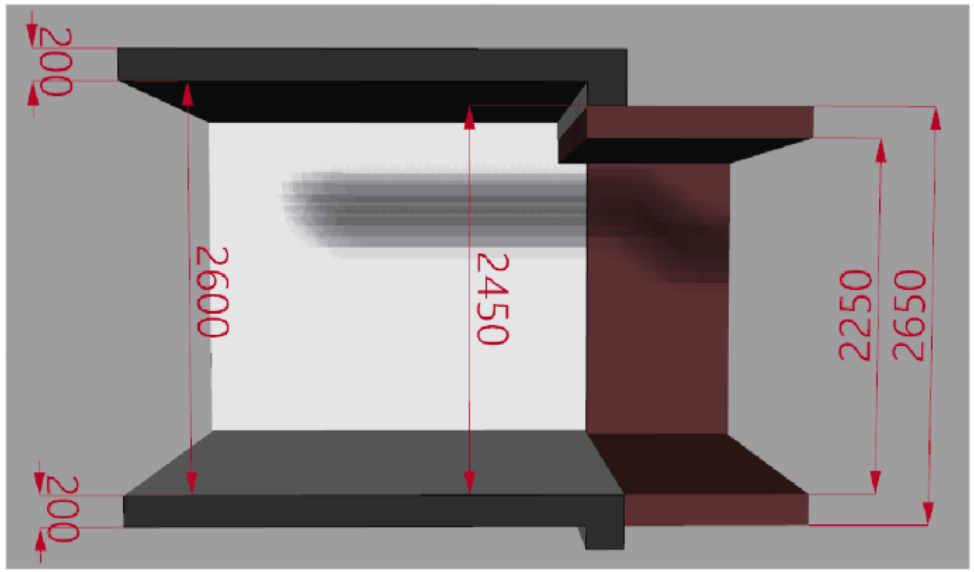


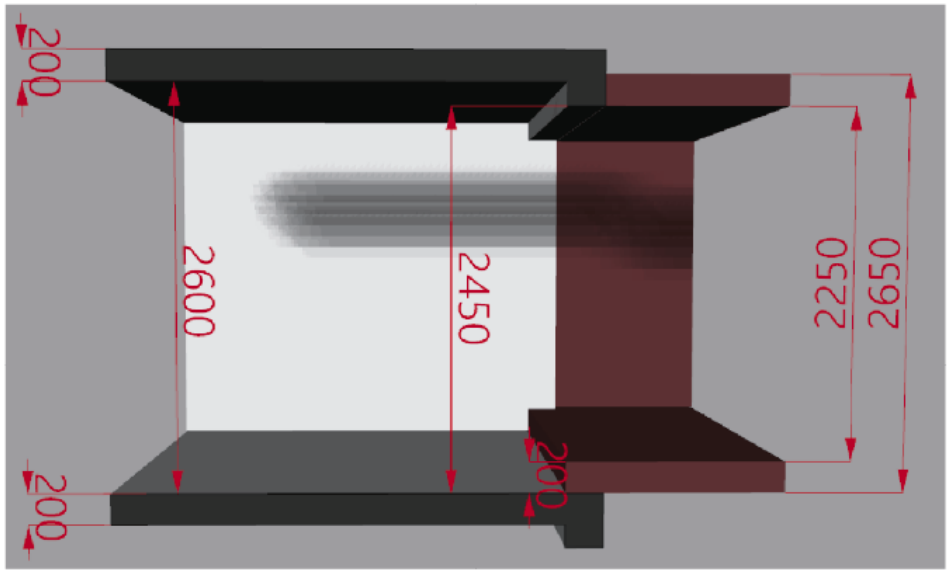


Addon placement

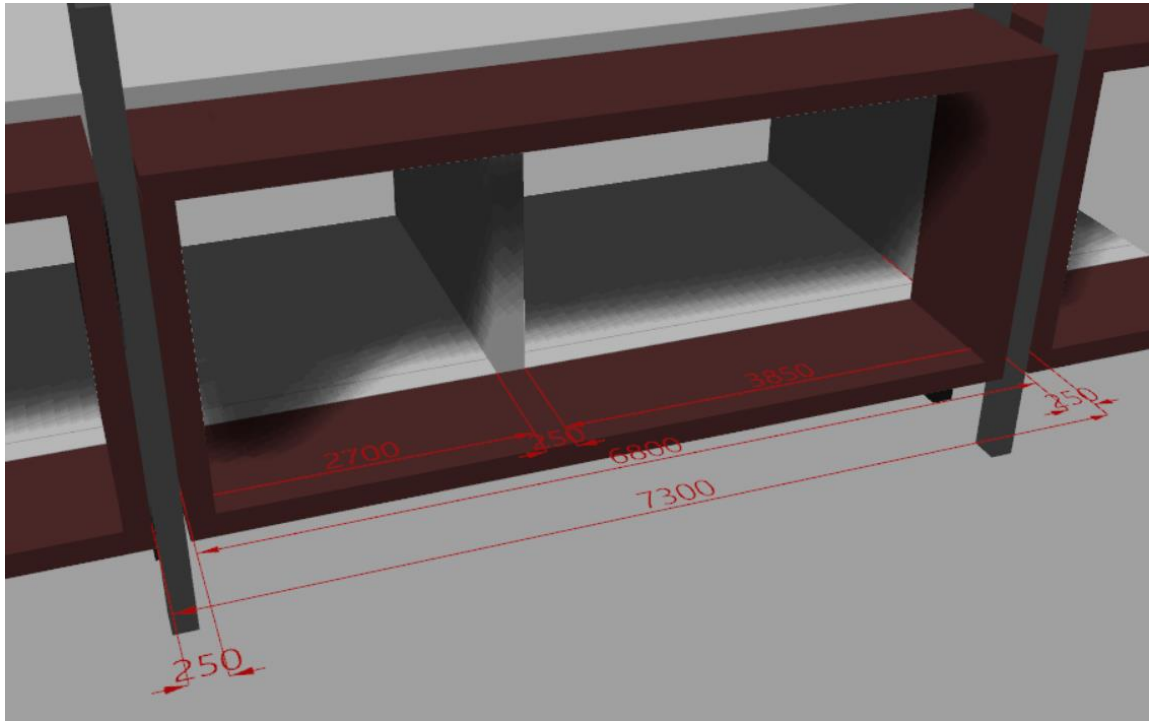


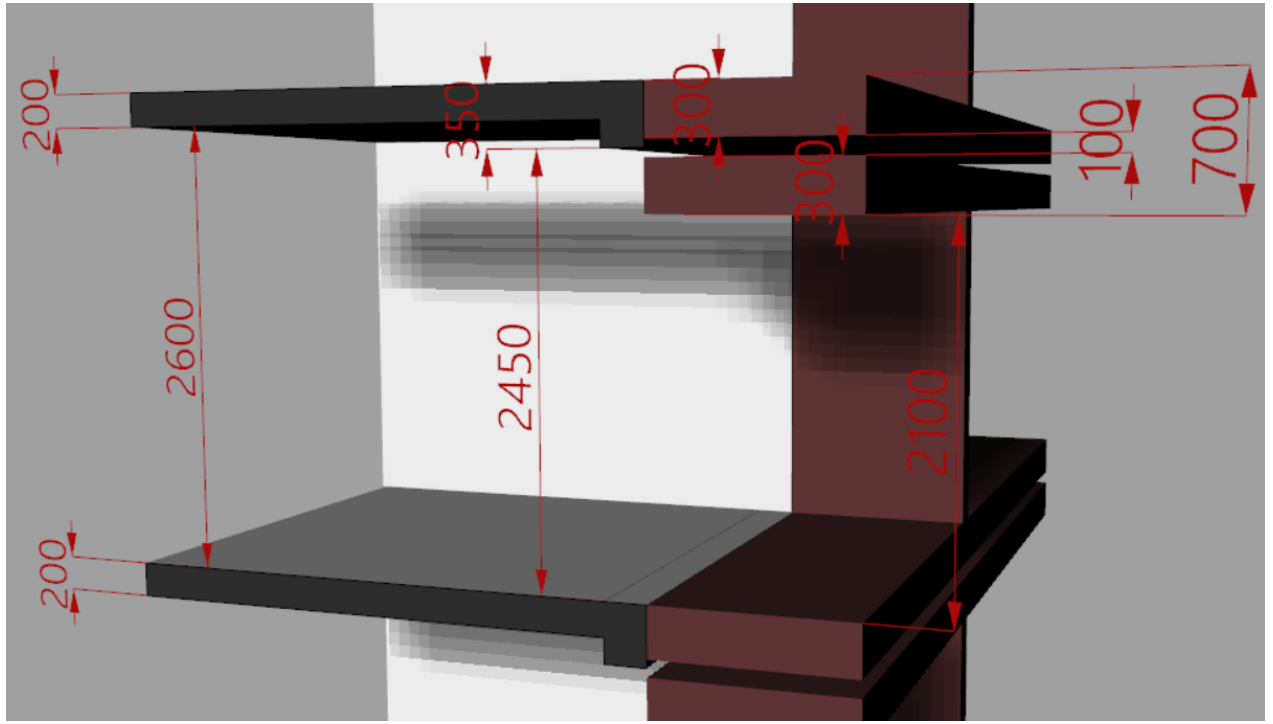


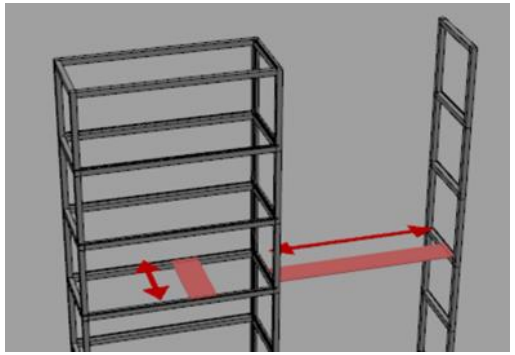




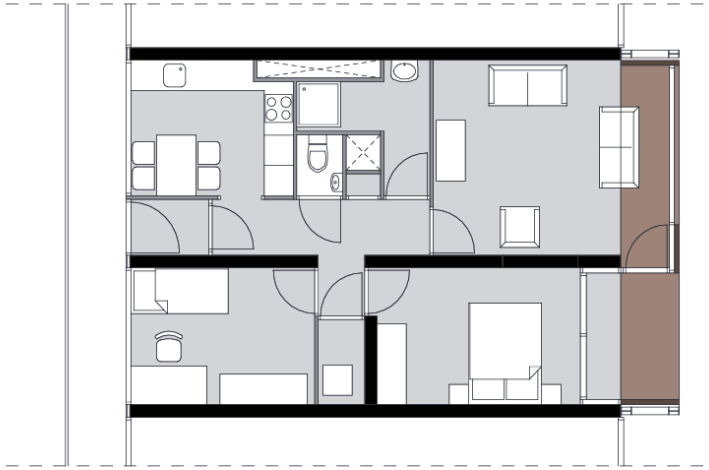
Limits add-on dimensions

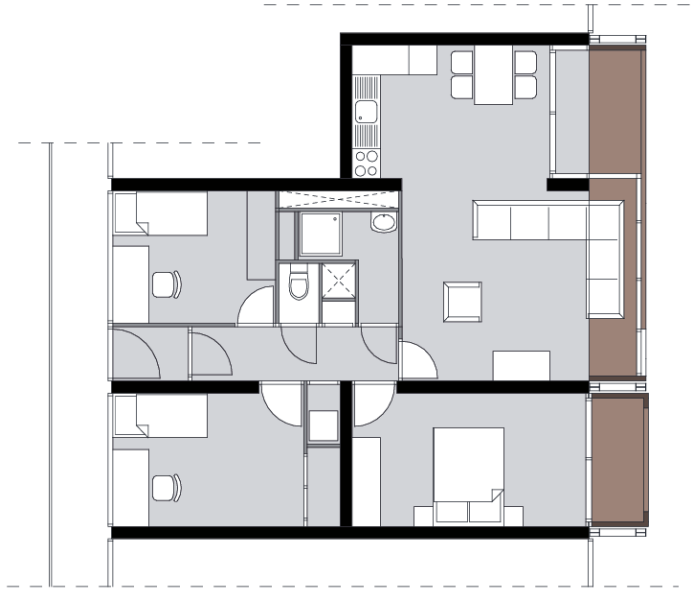


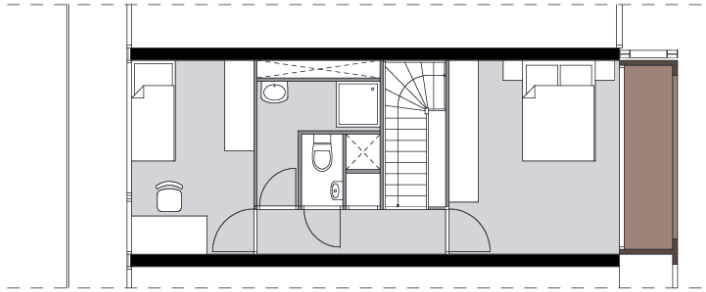


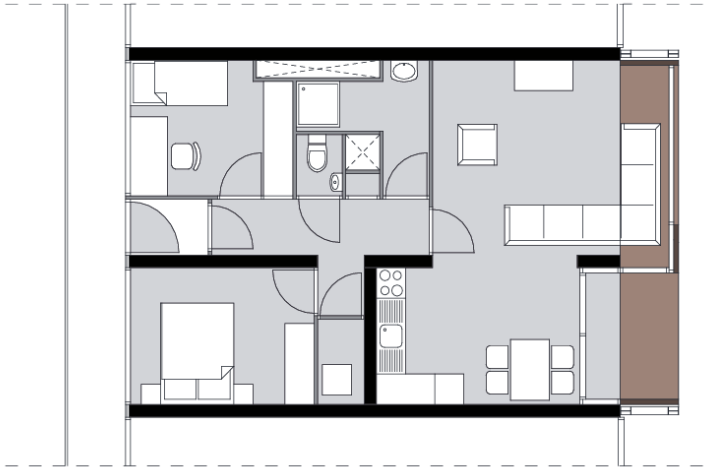


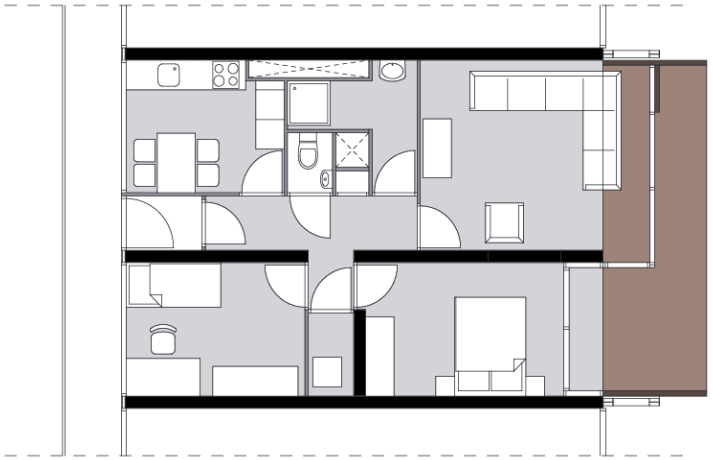
Potential floorplans with add-on

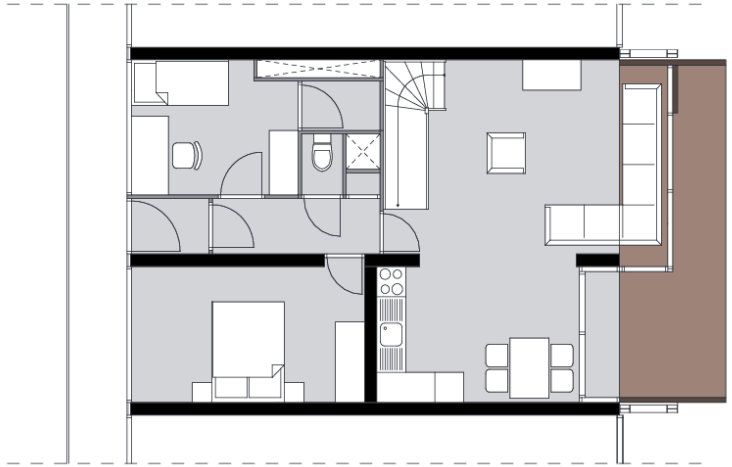




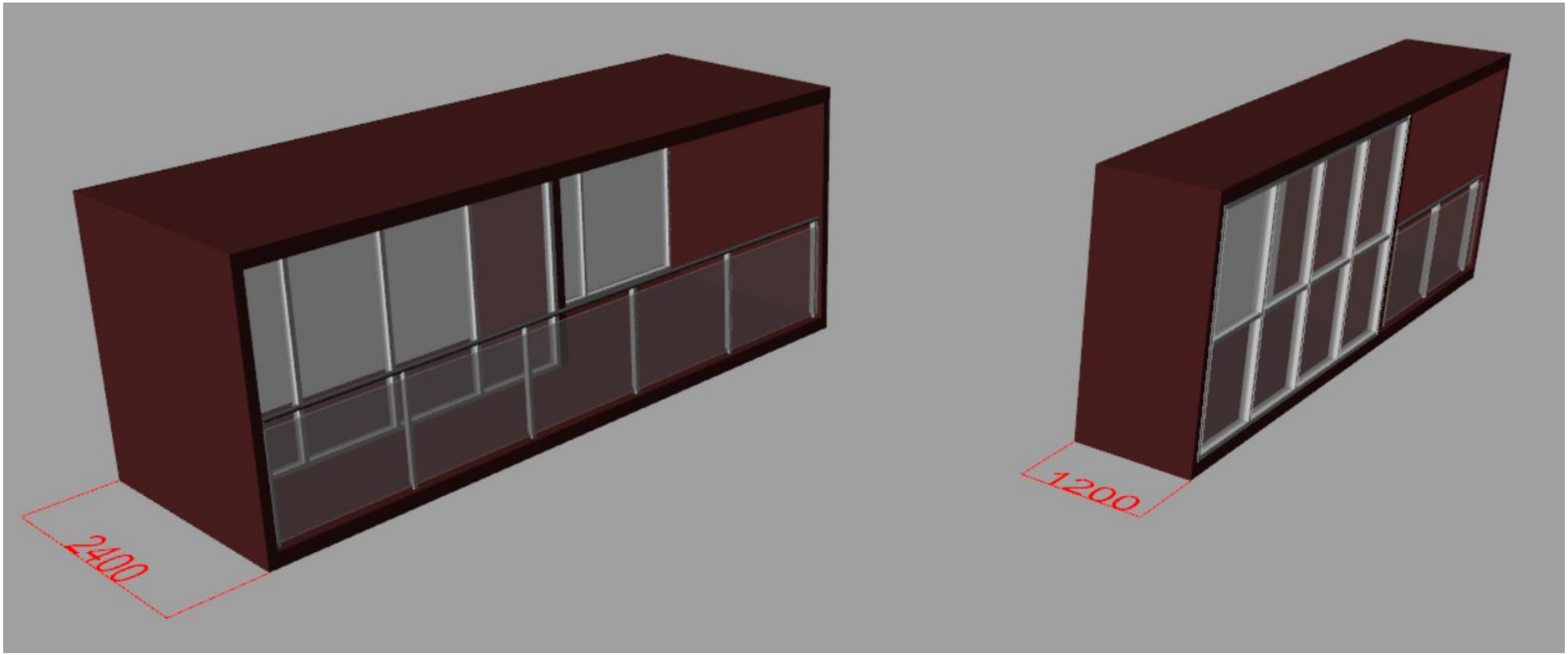




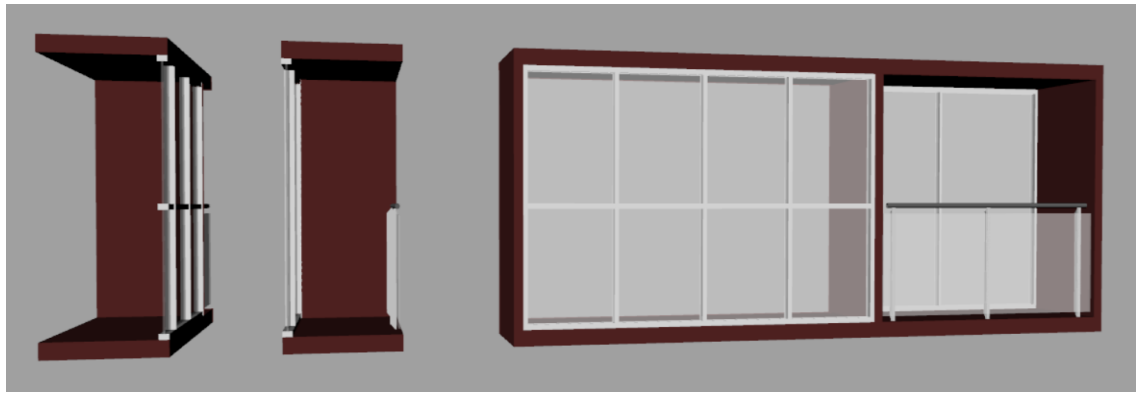


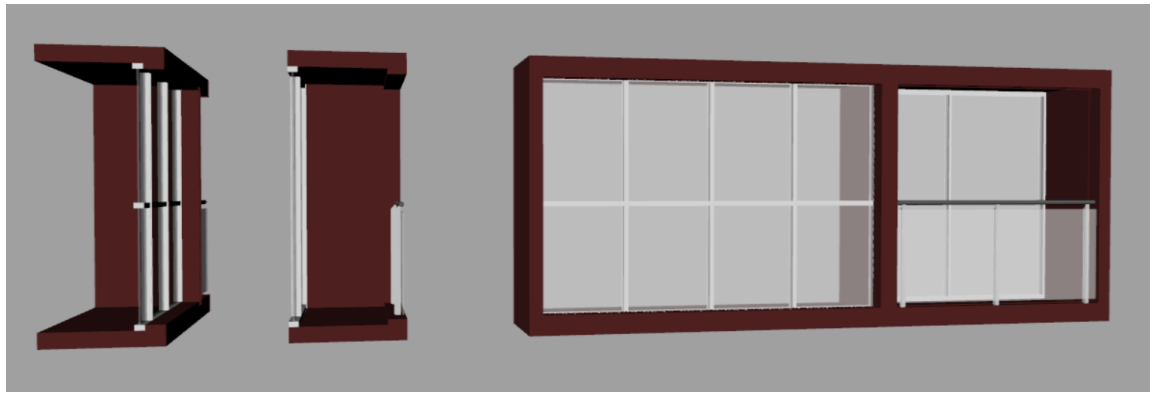


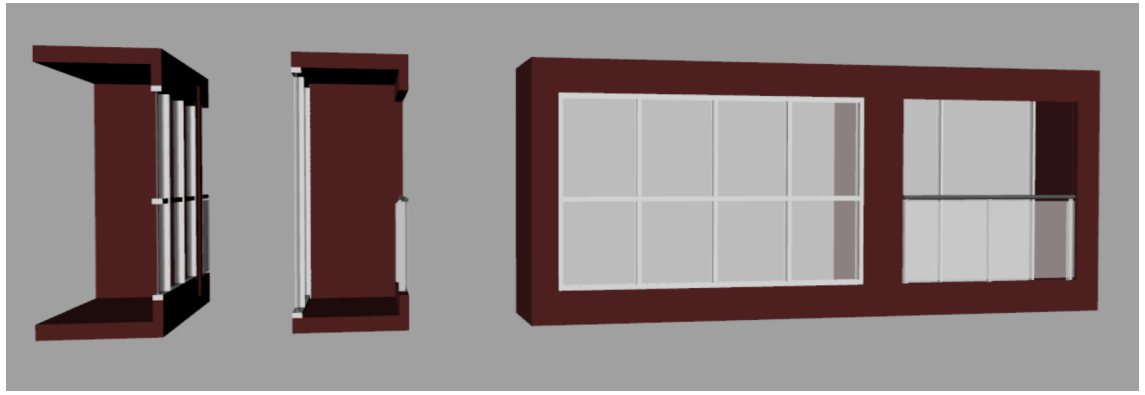
Addon two variants in depth

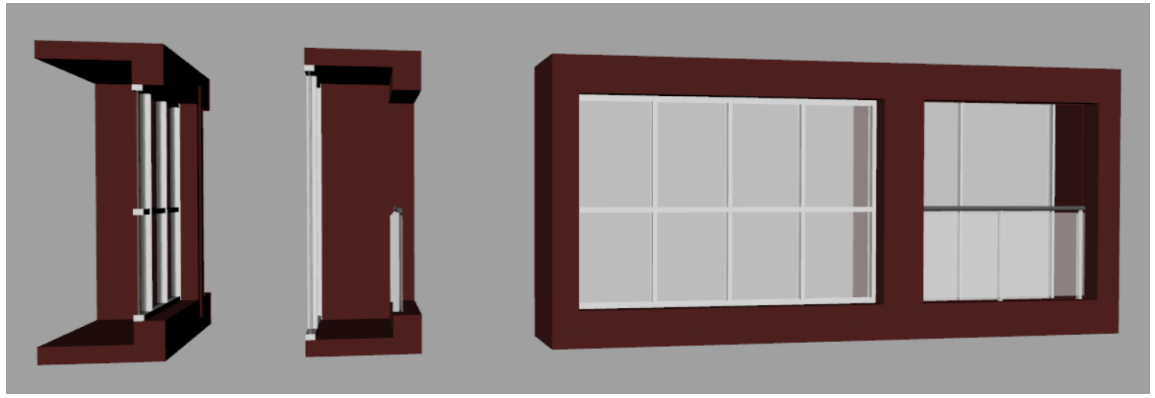


Window frame placement



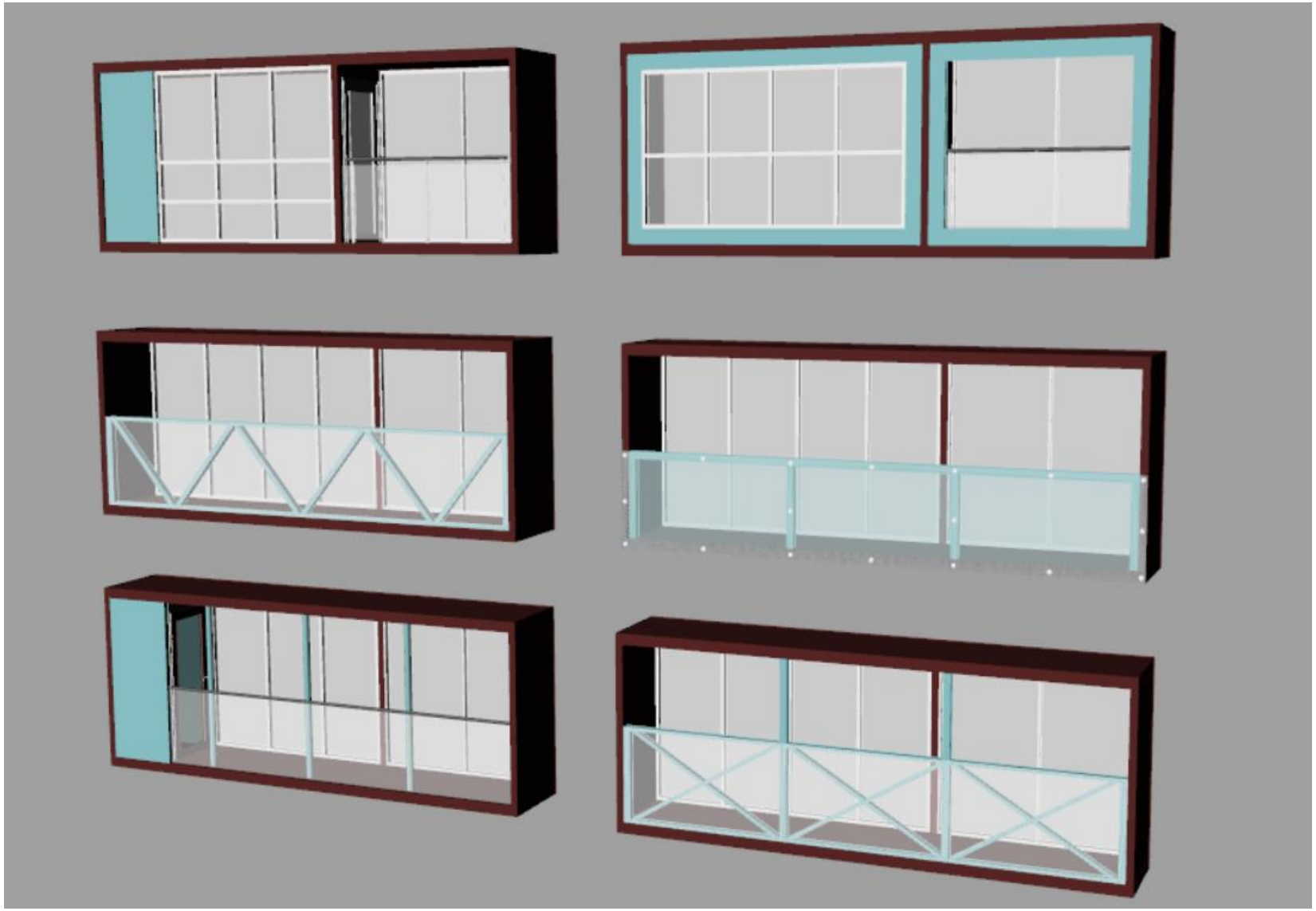






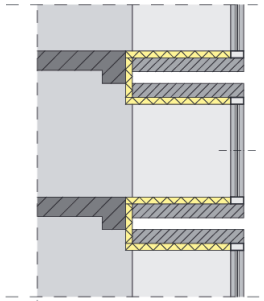
performance options

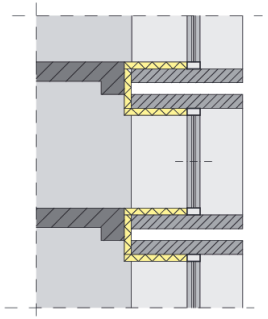
- Slab
- Framework
- Lattice girder
- Laminated glass
- Double slab and columns
- Columns with scaffolding

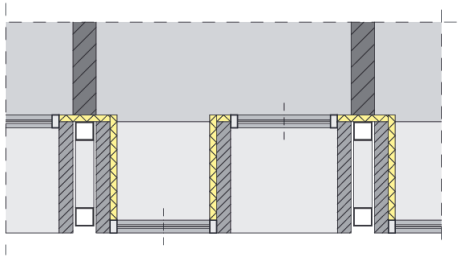


Placement isolation

1







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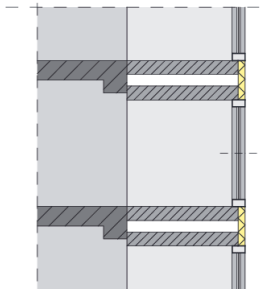

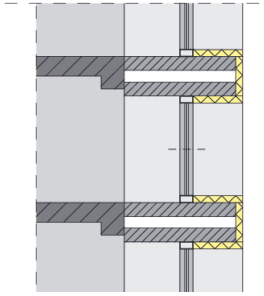

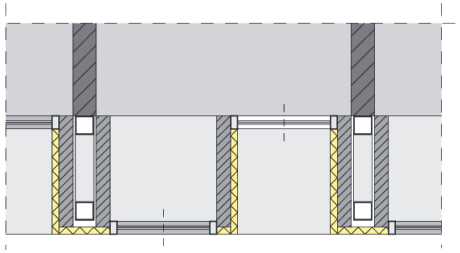

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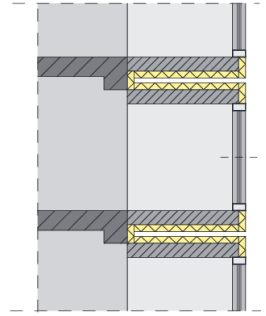

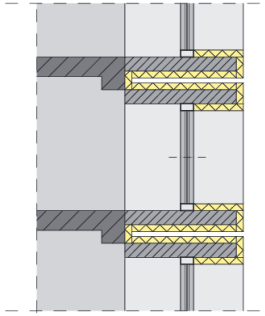

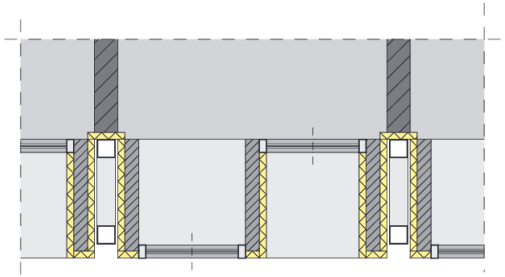

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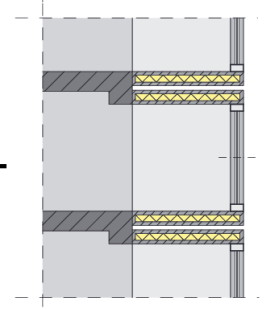
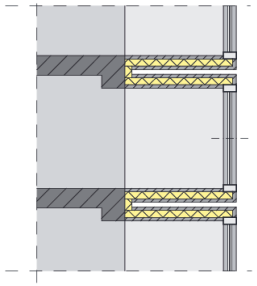
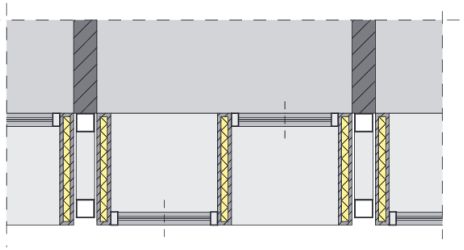
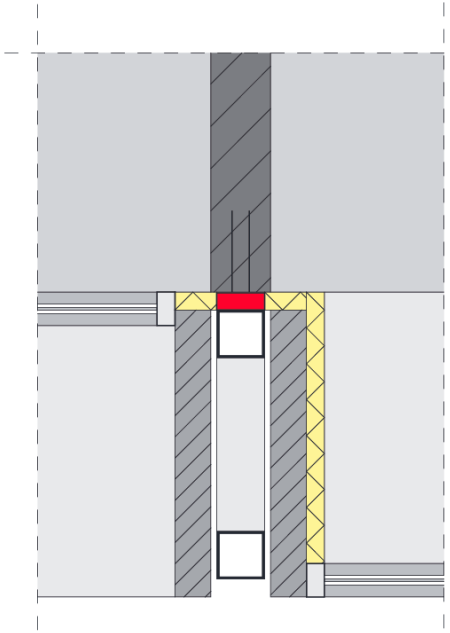
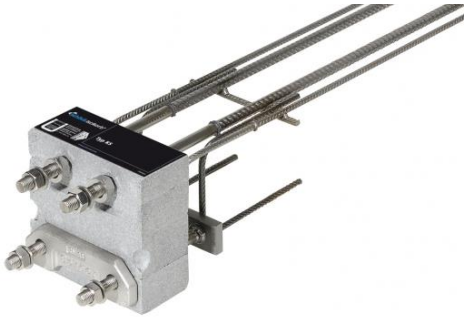






- Inside insulation
- Outside insulation (combined)
- Outside insulation (separate)
- Sandwich insulation

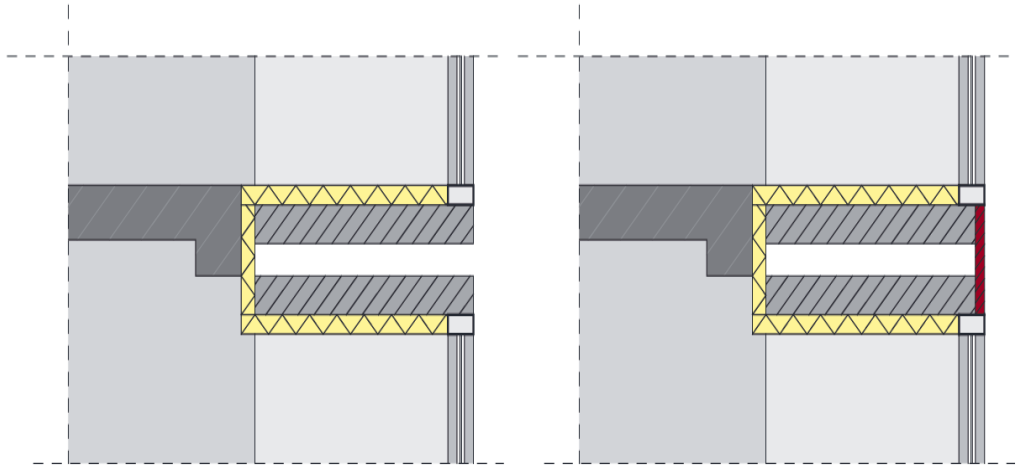


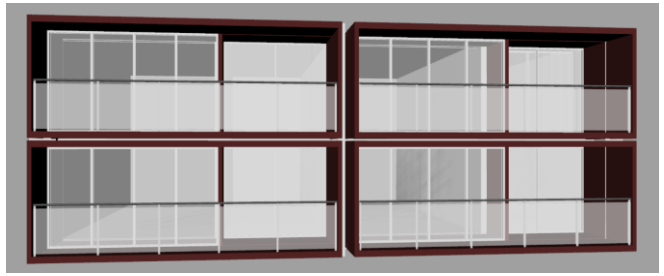


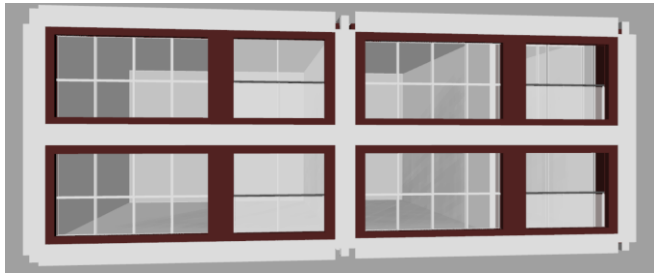
Choice 1 and 4

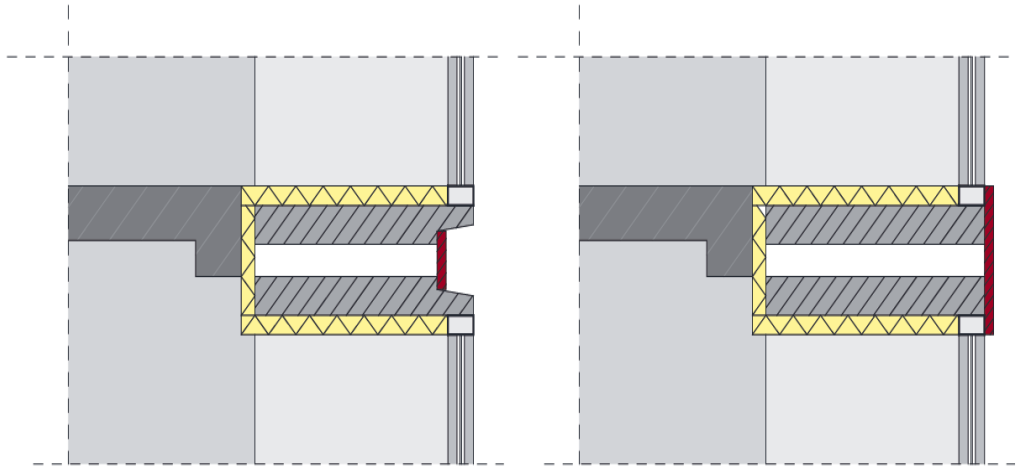
Thermal bridging and prefabrication

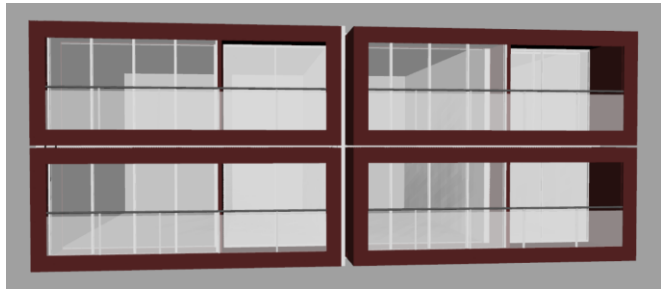
Façade with or without panel finish

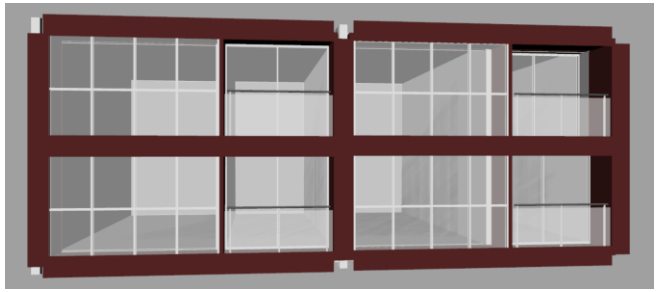




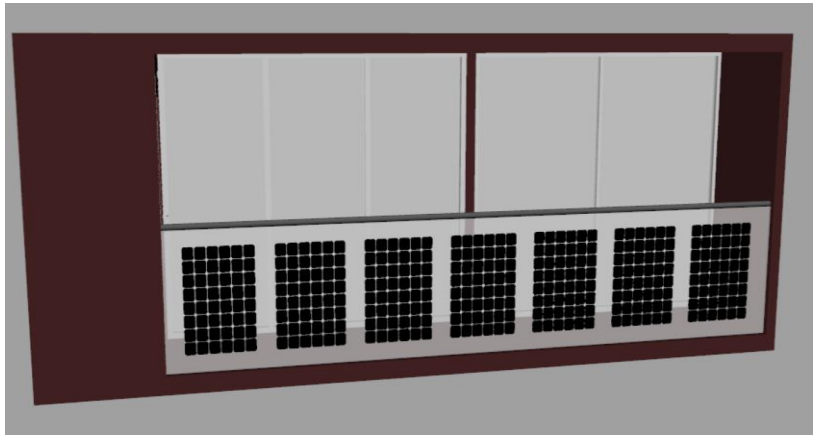
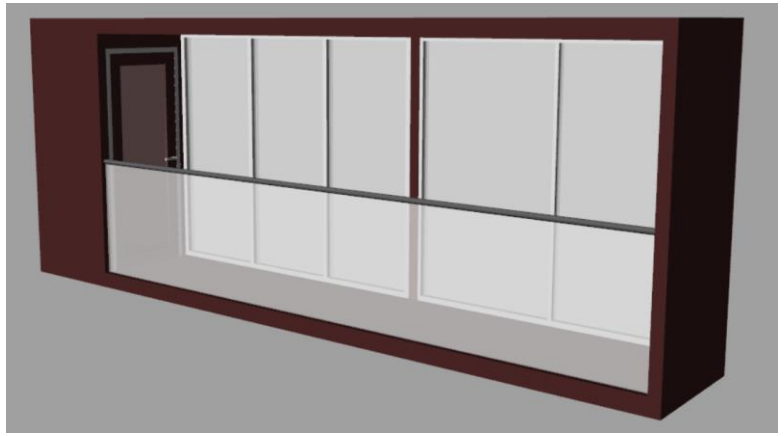


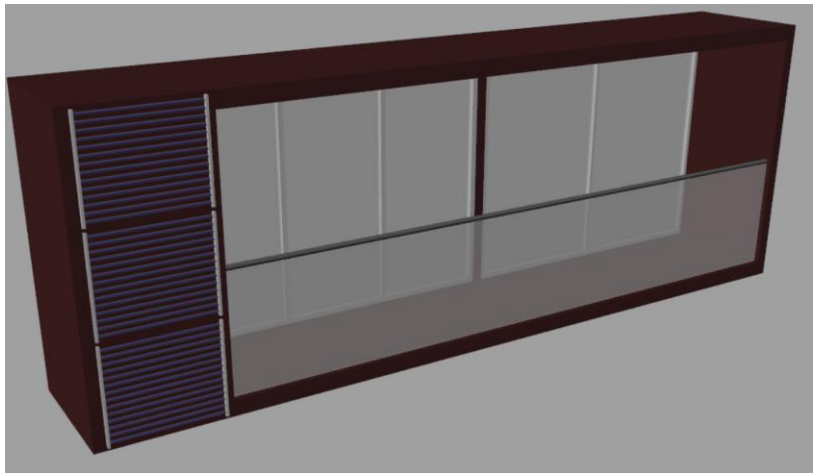
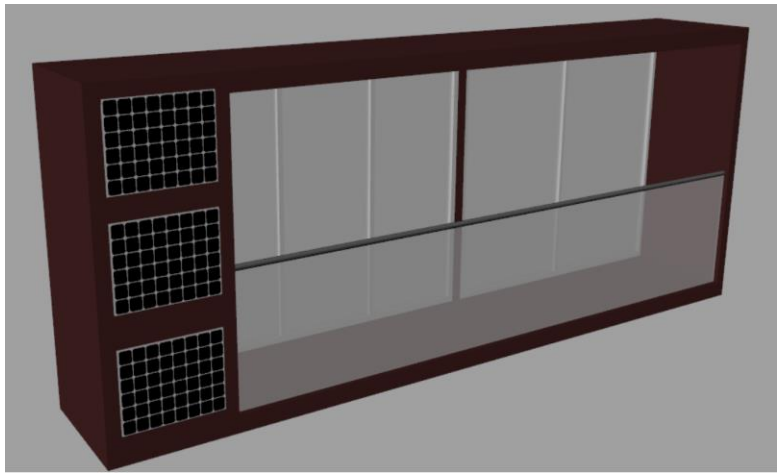






Addon extra functions


Material choice add-on units

Materials	Density kg/m³	Young's modulus GPa	Embodied energy MJ/kg	CO2 production kg CO2 / kg	Thermal conductivity λ in W/mK
GRP	1750	72-85	100	8.1	0.32
Glulam	450	12-14	12	0.84	0.13
High performance concrete	2800	25-27	3.58	0.48	2

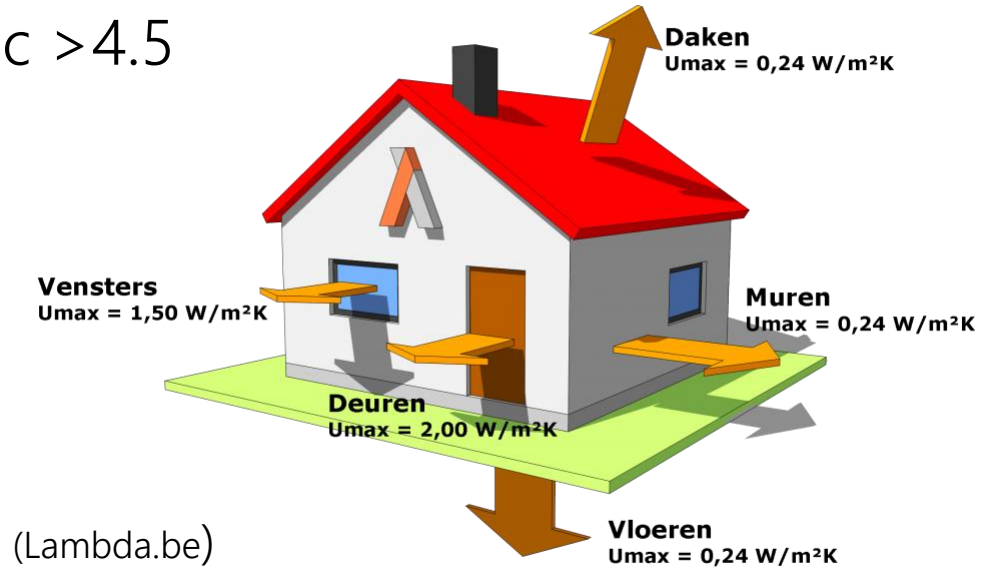
- Concrete (high performance)

- Laminated timber

- Fiber reinforced polymers (FRP)

Insulation material

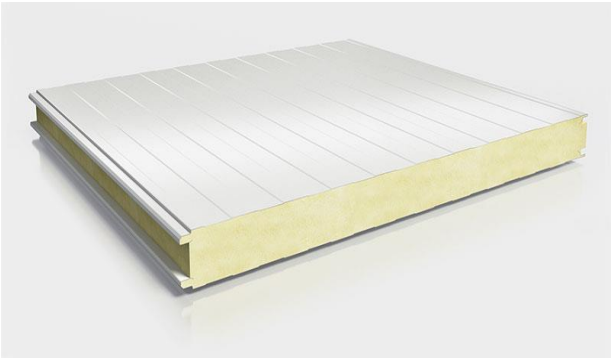
Rc >4.5



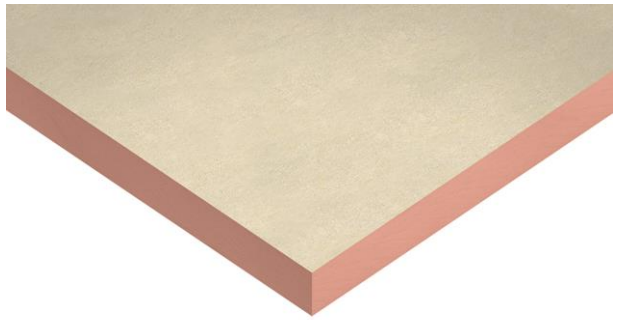
(Lambda.be)

Isolation materials	Thermal conductivity λ in W/mK	Thickness of panels in mm	Density kg/m3	Embodied energy MJ/kg	CO2 production kg CO2 eq	Shadow costs in € / kg	Life span years
Sheep wool	0.035	158	26	20.9	88.90	7.86	75
Cellulose	0.039	176	70	2.1	22.70	2.63	30
Flax	0.035	158	31	39.5	17.6	2.40	40
Cork	0.040	180	120	4	32.10	4.66	75
Wood fibres	0.038	171	55	17	19.30	2.11	40
Glass wool	0.035	158	25	28	6.41	0.93	75
Rock wool	0.035	158	48	16.8	8.01	0.81	75
Aerogel	0.013	59	135	53	-	-	75
XPS	0.038	171	33	109.2	59.20	3.76	75
EPS	0.040	180	15	88.6	15.80	1.79	75
PIR / PUR	0.023	104	33	101.5	21.90	1.84	75
Resol foam	0.020	95	36	88	17.10	1.88	75
Vacuum panel	0.007	32	195	81.9	-	-	75

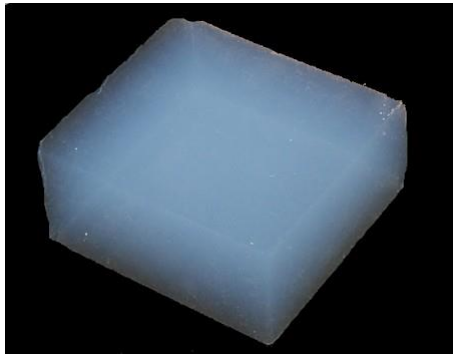
PUR/PIR



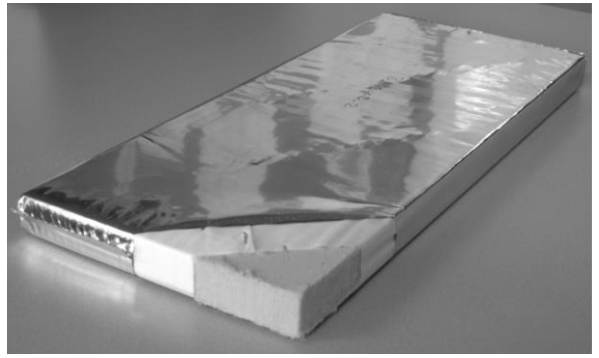
Phenolic Foam (Resol)



Aerogel



Vacuum panel



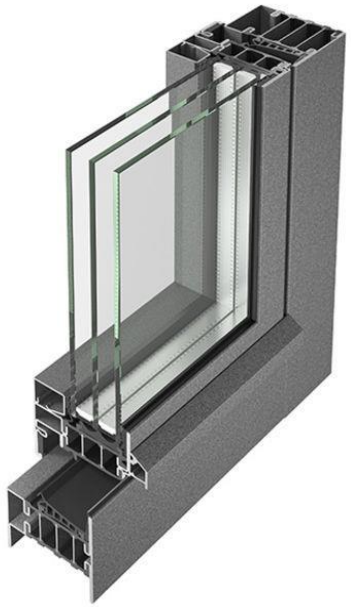
Window frames

Window frames	Density kg/m3	embodied energy MJ/kg	CO2 production kg CO2 eq / m2	Shadow costs in € / kg	Life span years
Wood (spruce)	450	12	12.7	1.61	35
Aluminium	2700	154	17.5	2.4	75
Steel	7800	20.1	31.8	2.79	100
PVC	1400	77.2	36.5	5.8	40
GRP	1750	100	37.5	-	50

Wood

Aluminium

Steel



PVC

GRP

Material choice load bearing structure

Materials	Density kg/m³	Young's modulus GPa	Embodied energy MJ/kg	CO2 production kg CO2 / kg	Thermal conductivity λ in W/mK
glulam	450	12-14	12	0.84	0.13
concrete (reinforced)	2400	100-140	1.125	0.1	2.0
steel	7800	200-215	20.1	1.37	50

Laminated timber

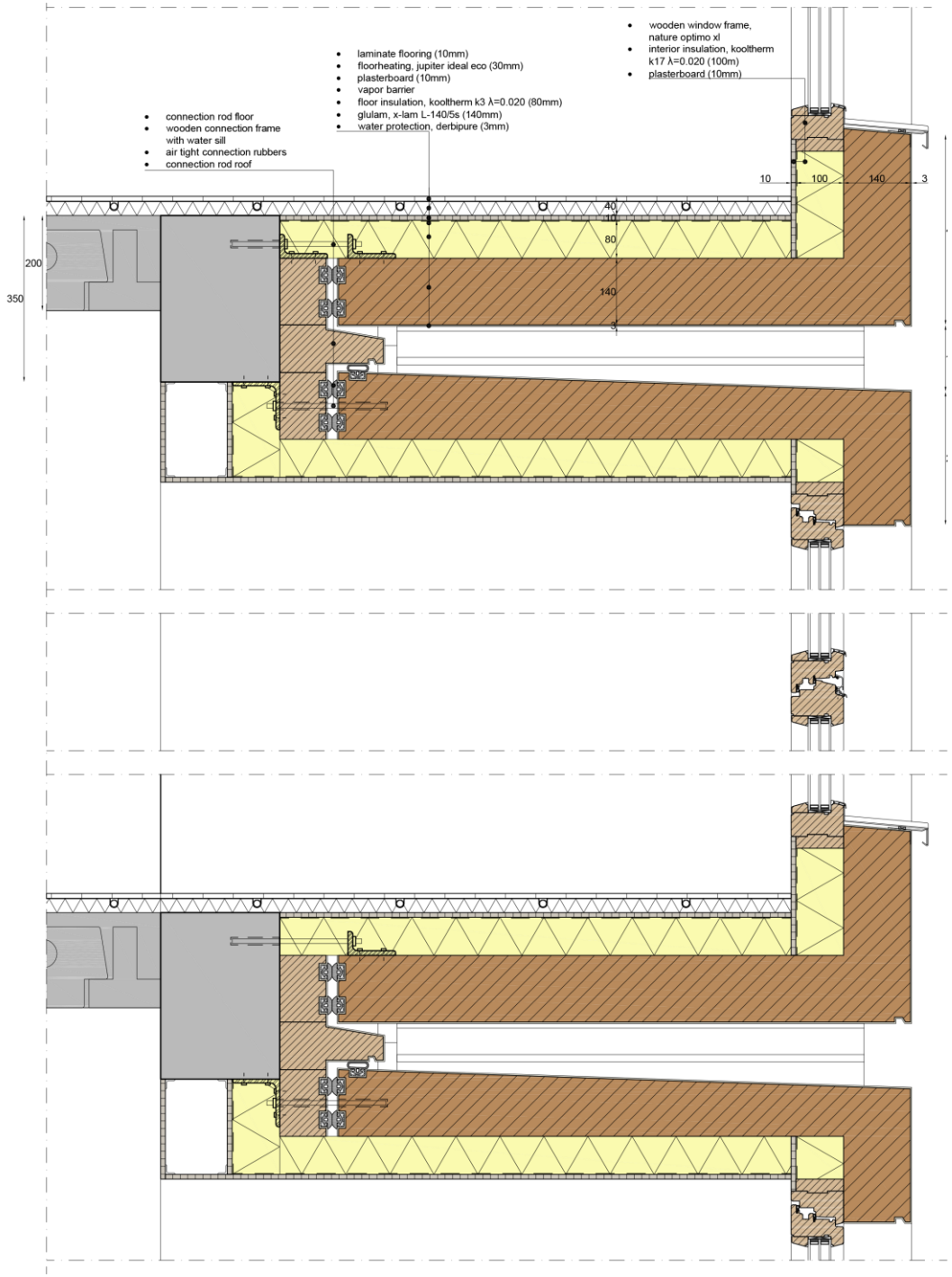
Concrete

Steel

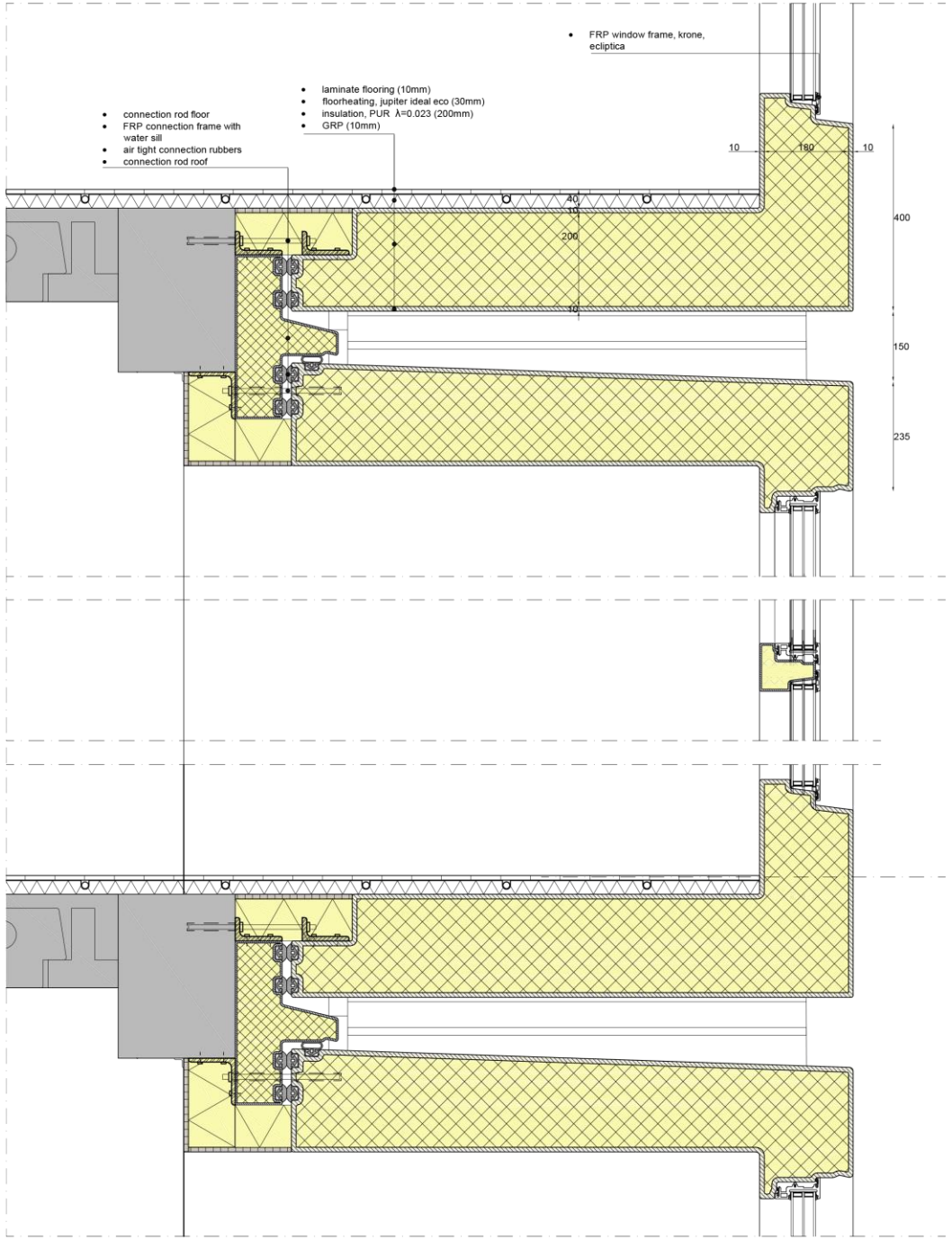
Choice

Steel structure

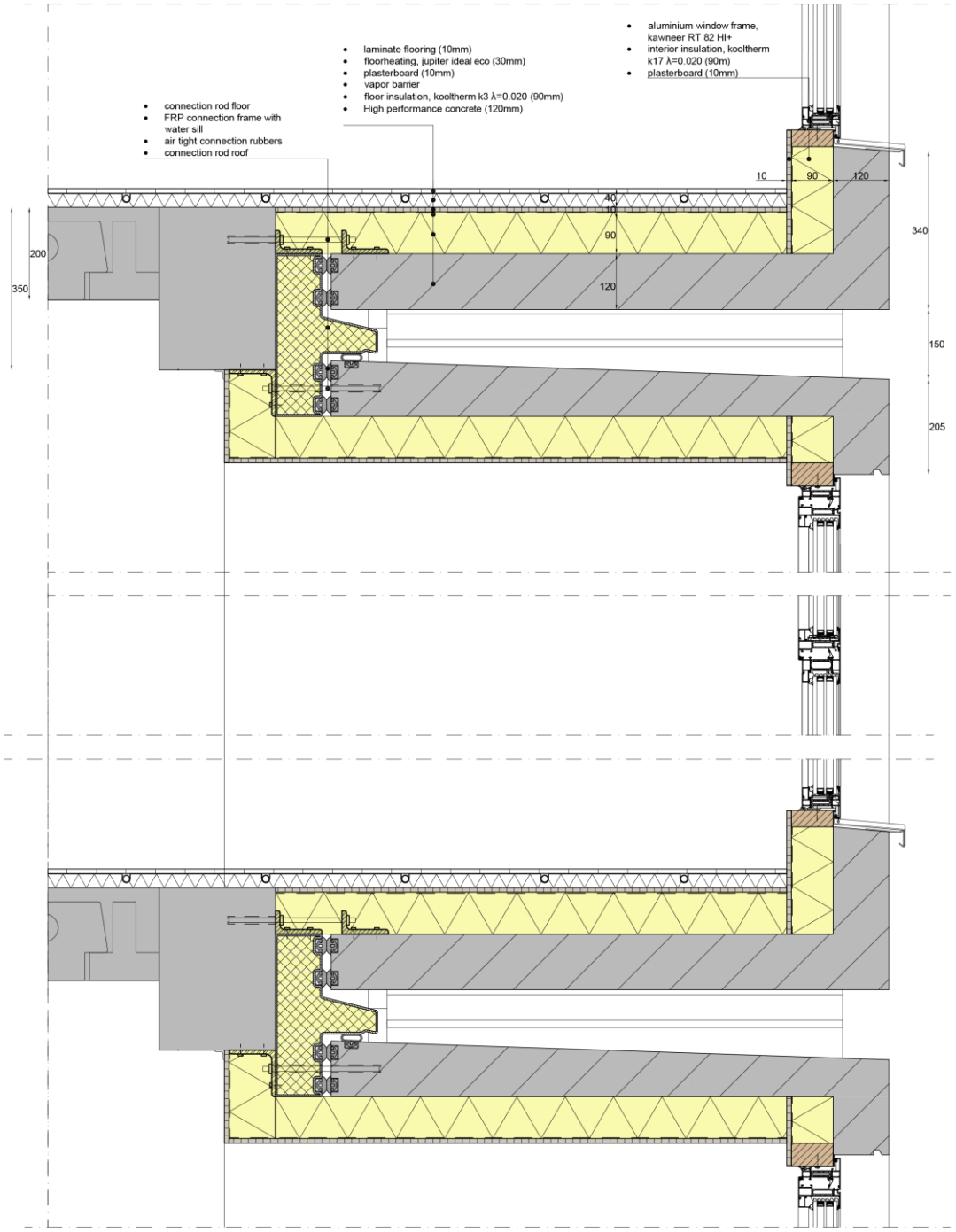
Add-on wood


connection rod floor
wooden connection frame with water sill
air tight connection rubbers
connection rod roof
laminate flooring (10mm)
floorheating, jupiter ideal eco (30mm)
plasterboard (10mm)
vapor barrier
floor insulation, kooltherm k3 λ=0.020 (80mm)
glulam, x-lam L-140/5s (140mm)
water protection, derbipure (3mm)
wooden window frame, nature optimo xl
interior insulation, kooltherm k17 λ=0.020 (100m)
plasterboard (10mm)
10
100
140
3
40
10
80
140
5
200
350

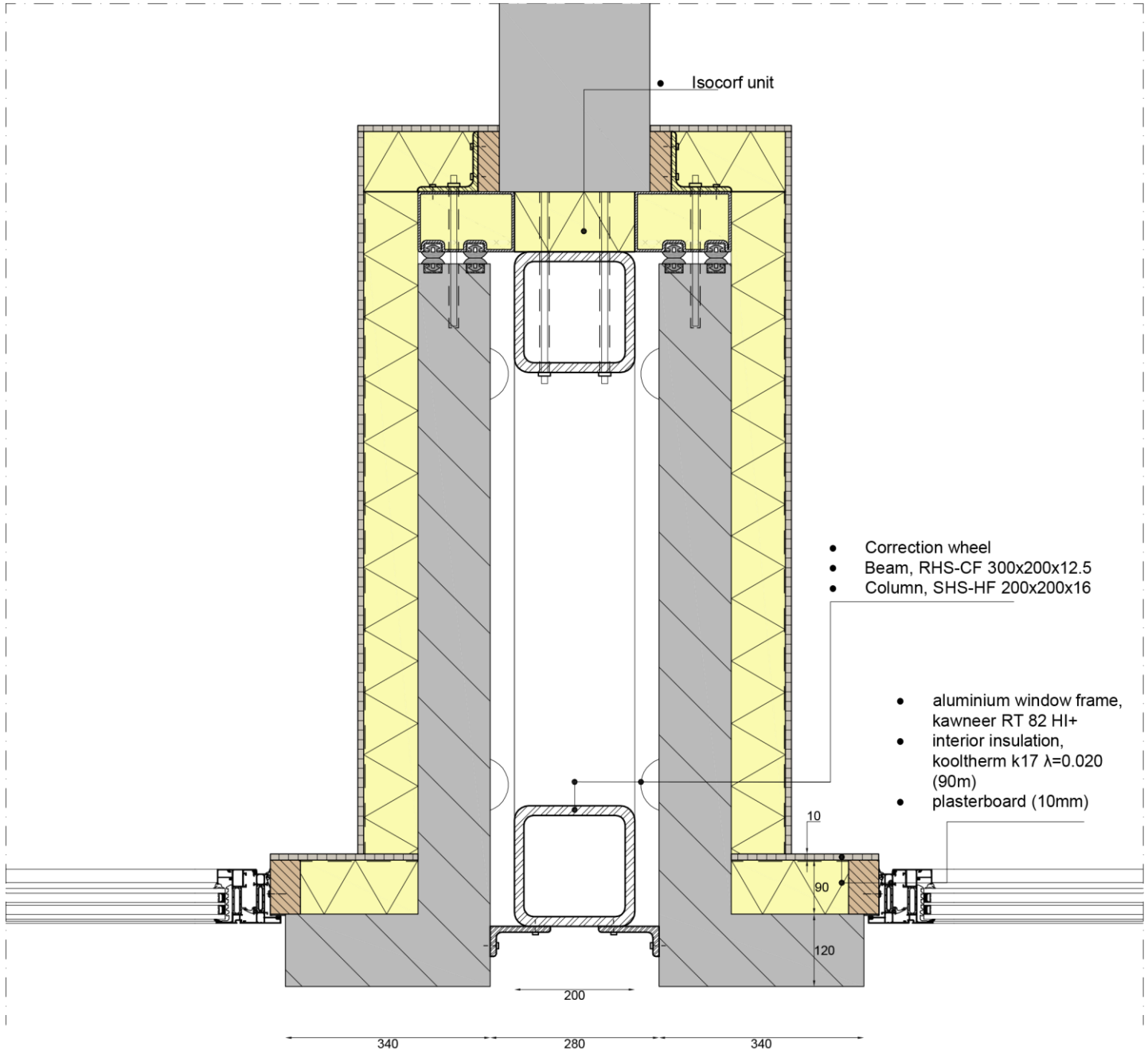
Add-on FRP


FRP window frame, krone, ecliptica
laminate flooring (10mm)
floorheating, jupiter ideal eco (30mm)
insulation, PUR λ=0.023 (200mm)
GRP (10mm)
connection rod floor
FRP connection frame with water sill
air tight connection rubbers
connection rod roof
10
180
10
40
10
200
10
400
150
235

Add-on concrete vertical

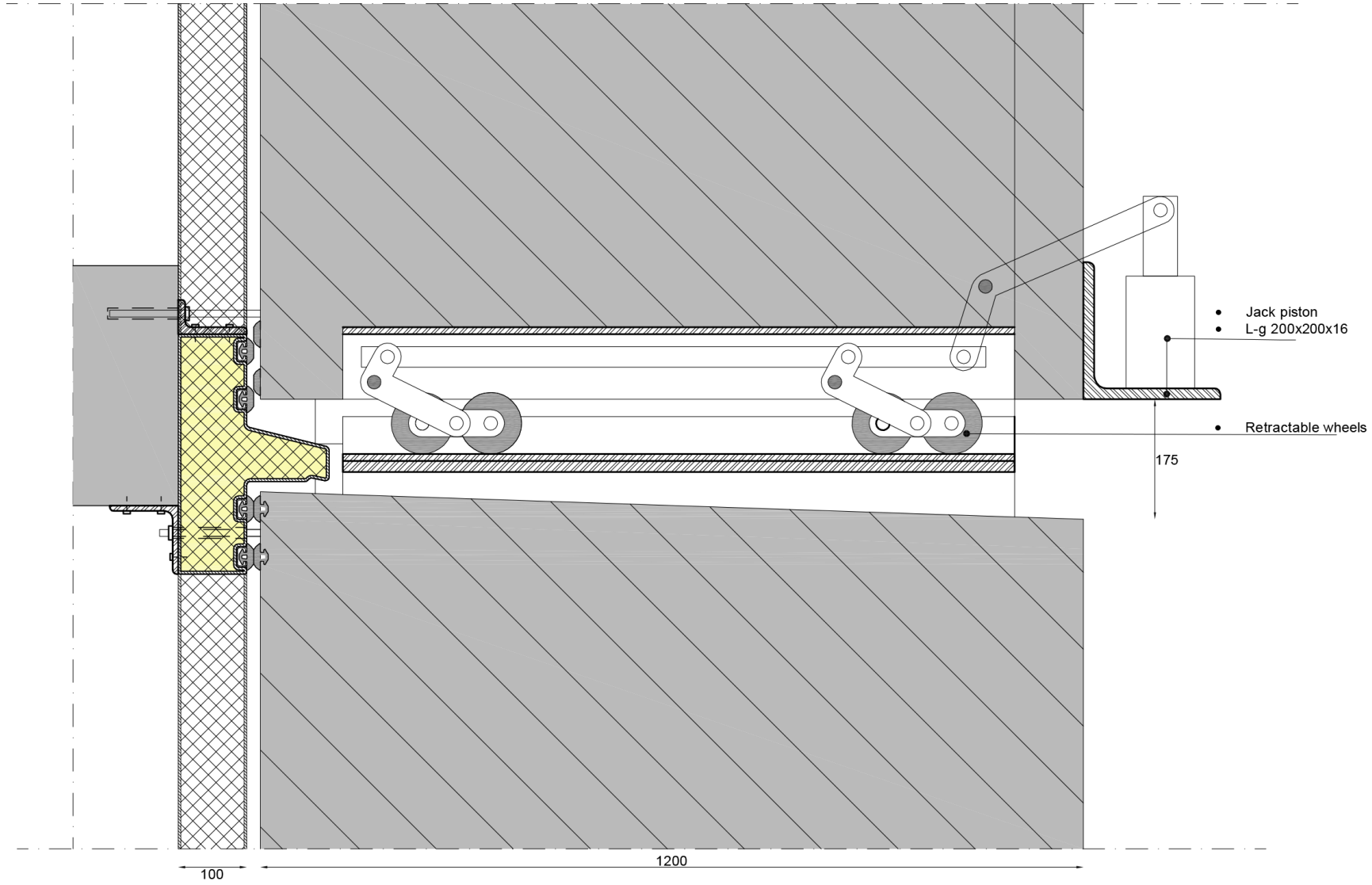


Add-on concrete horizontal

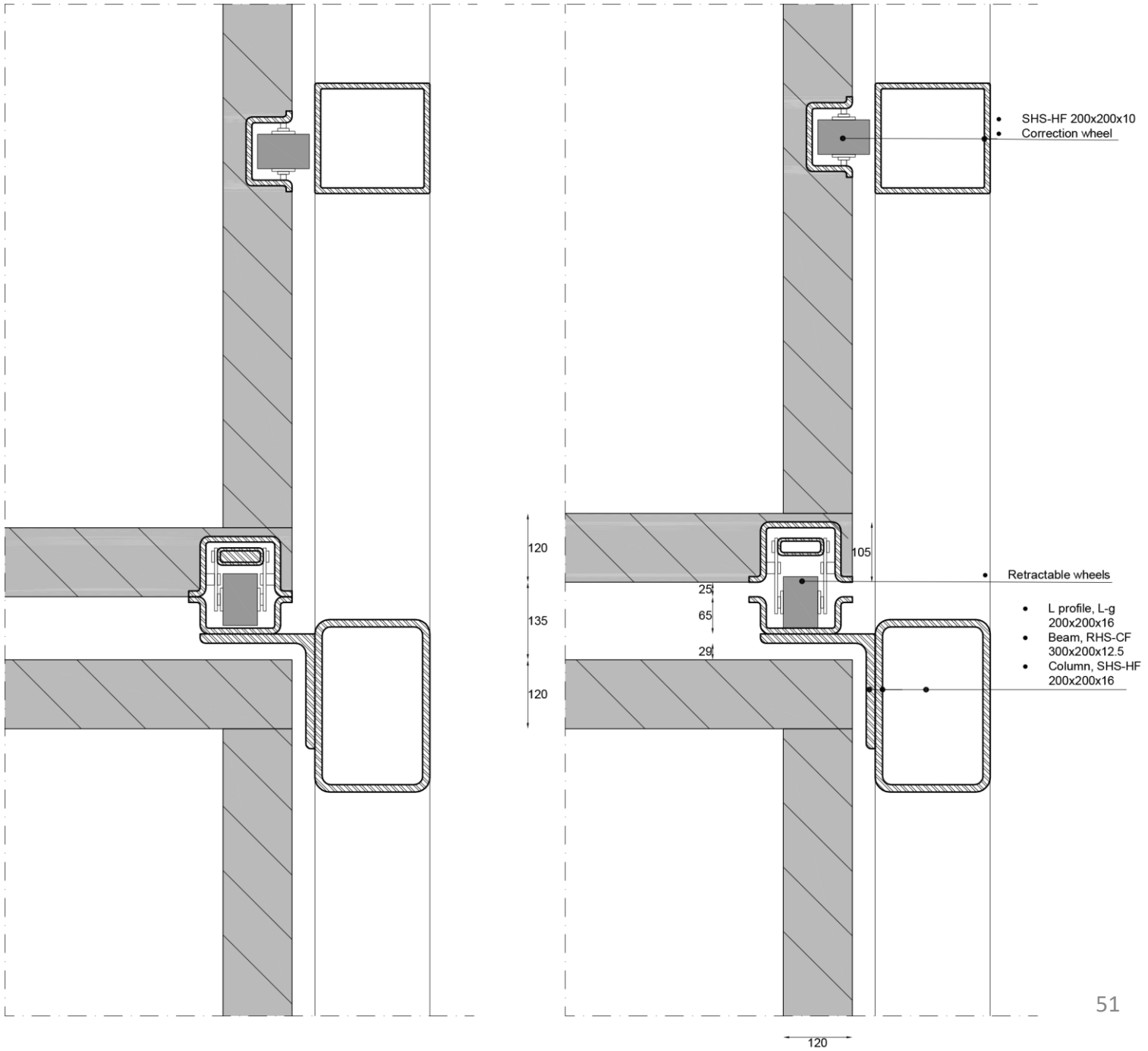


Add-on concrete wheels

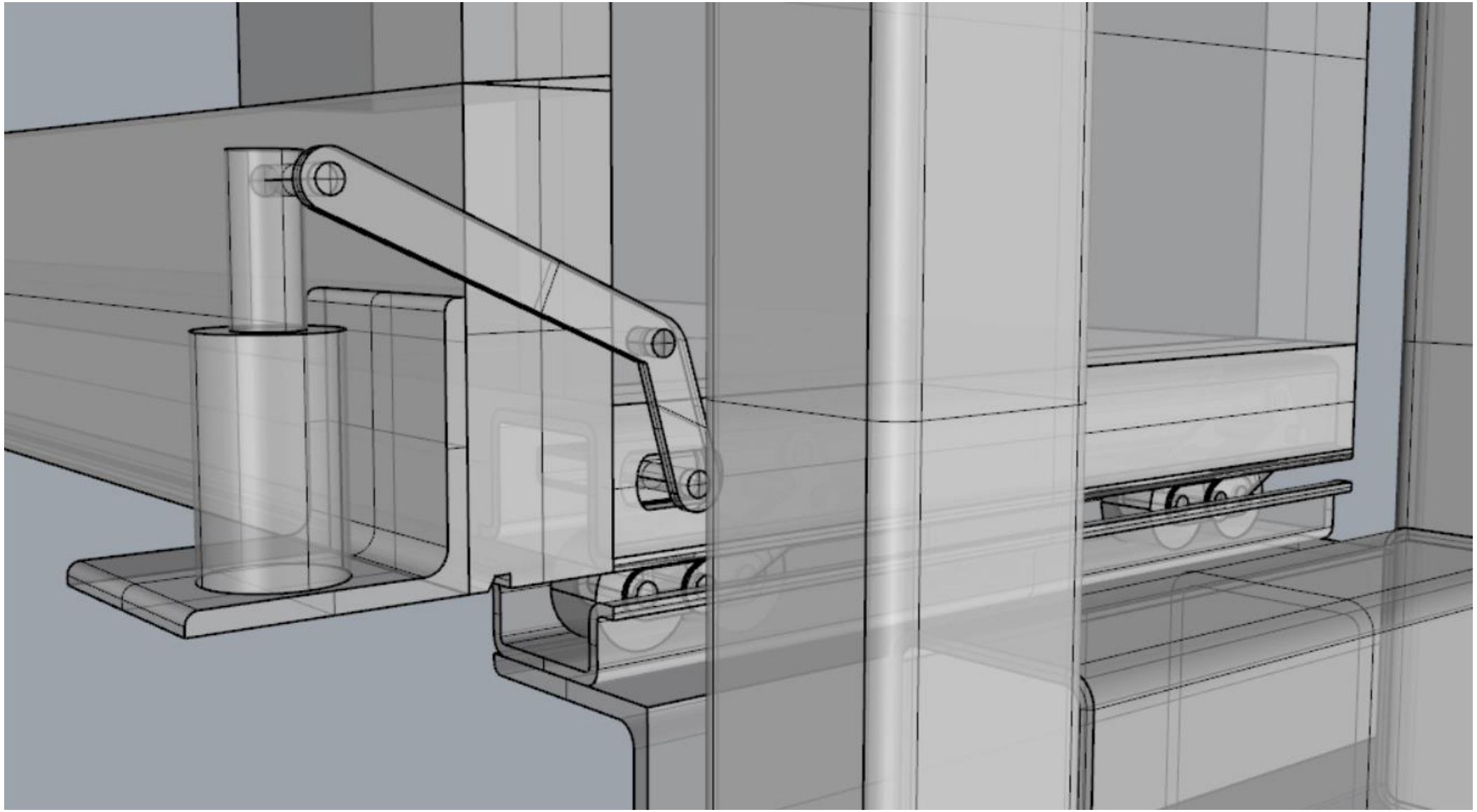
Add-on concrete wheels



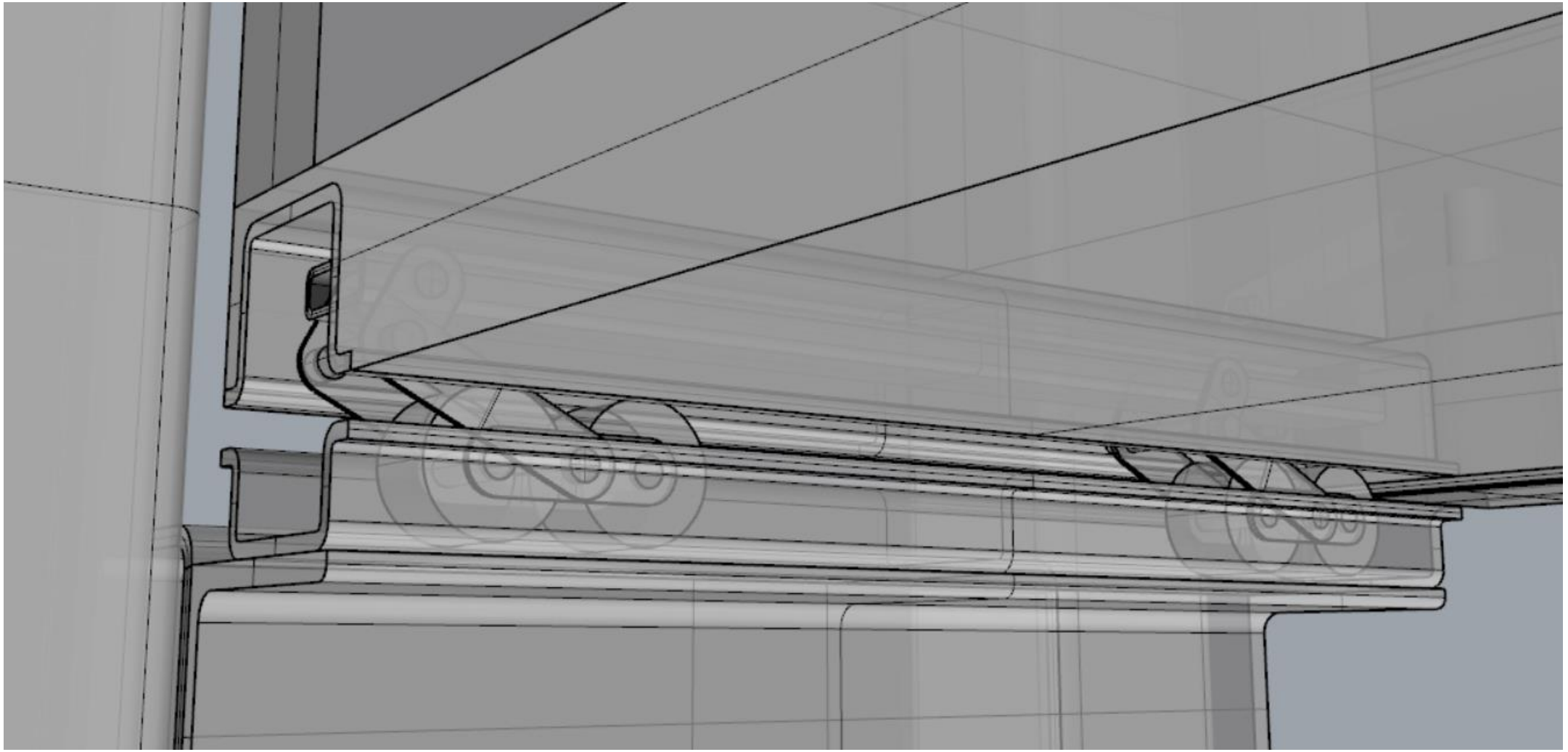
Concrete Add-on wheel



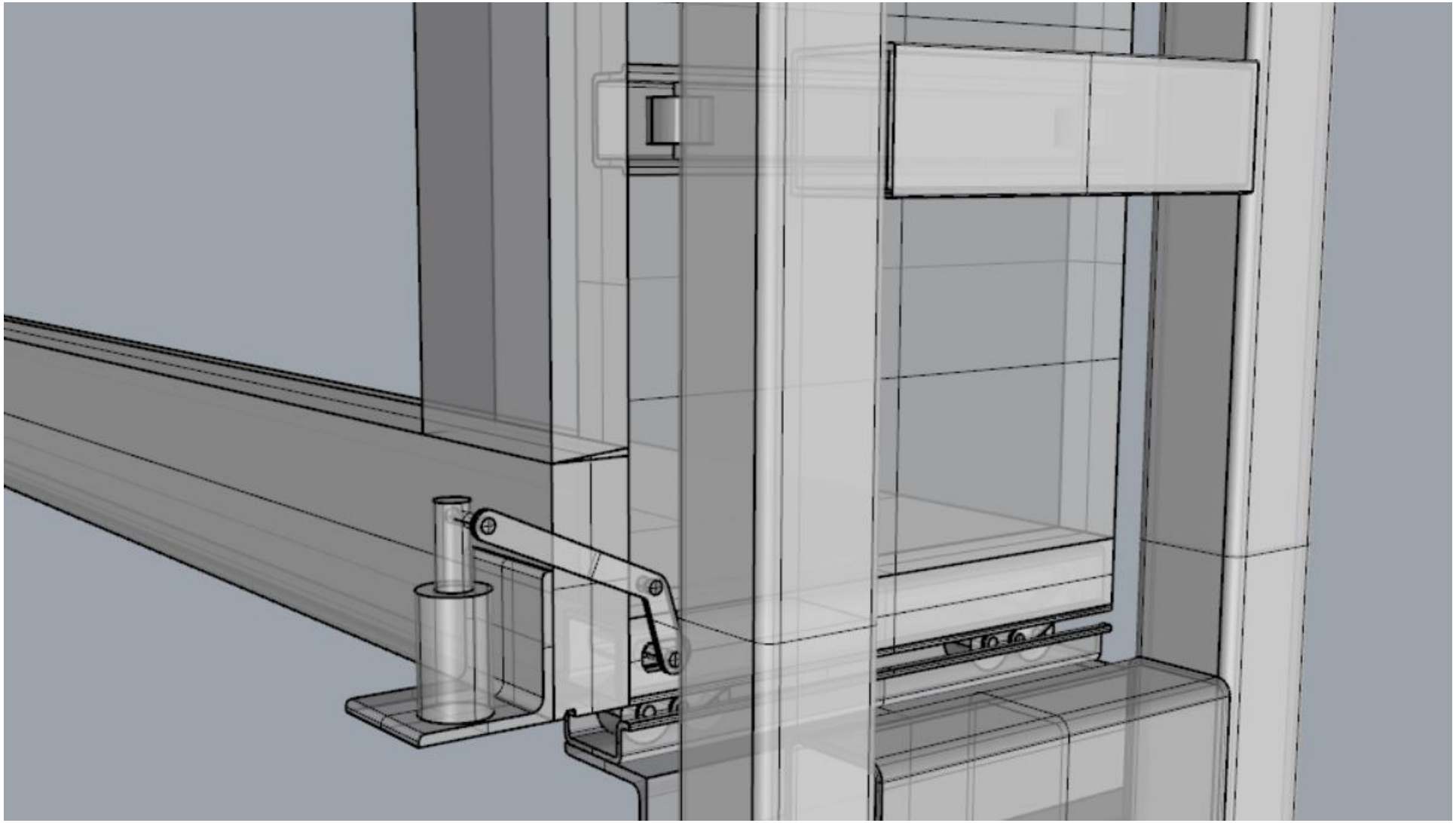
Concrete Add-on wheel system



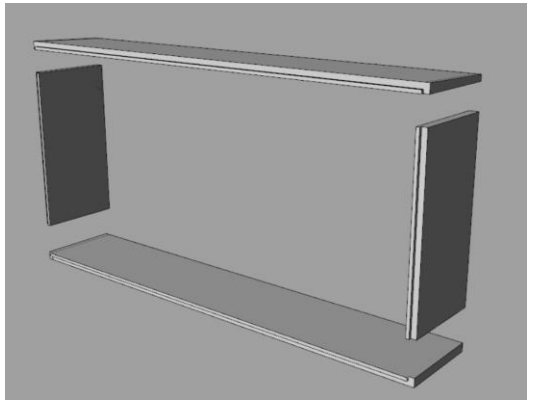
Concrete Add-on wheel system

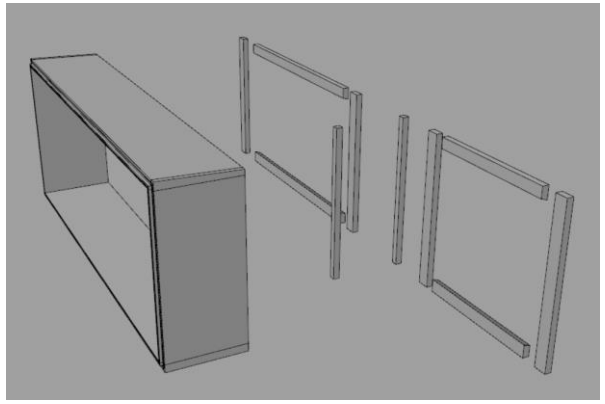


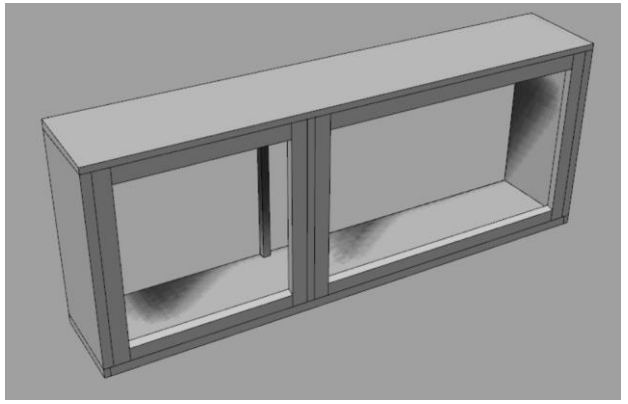
Concrete Add-on wheel system

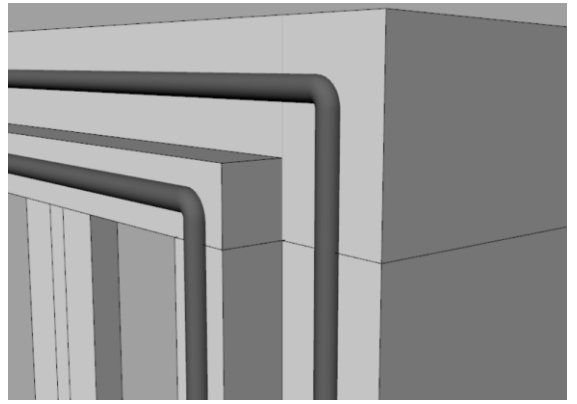


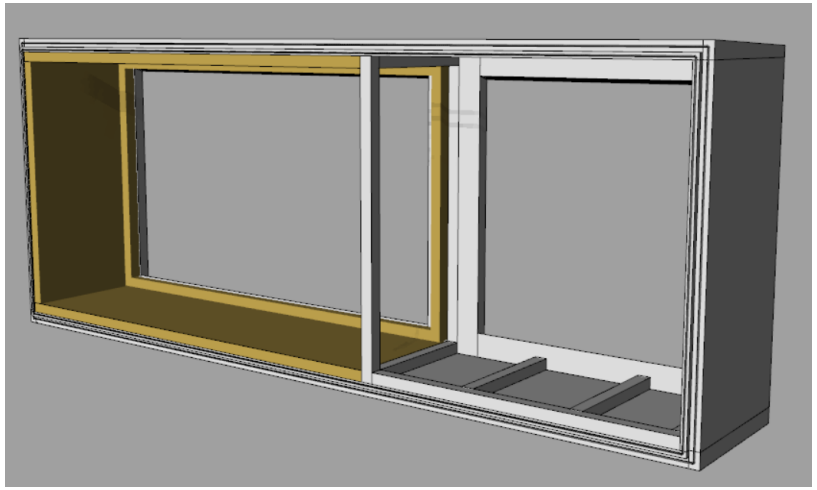
Assembly addon

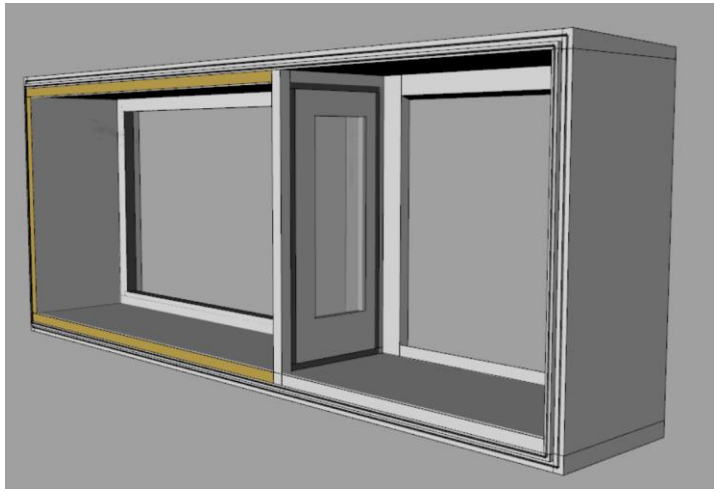


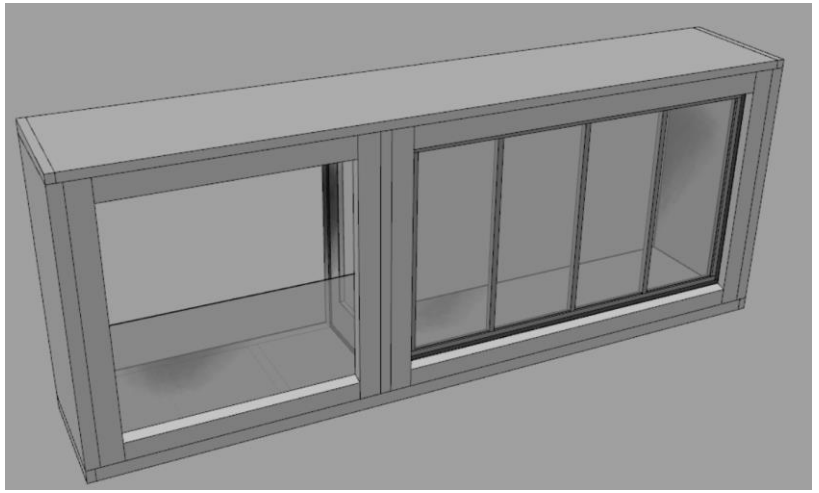




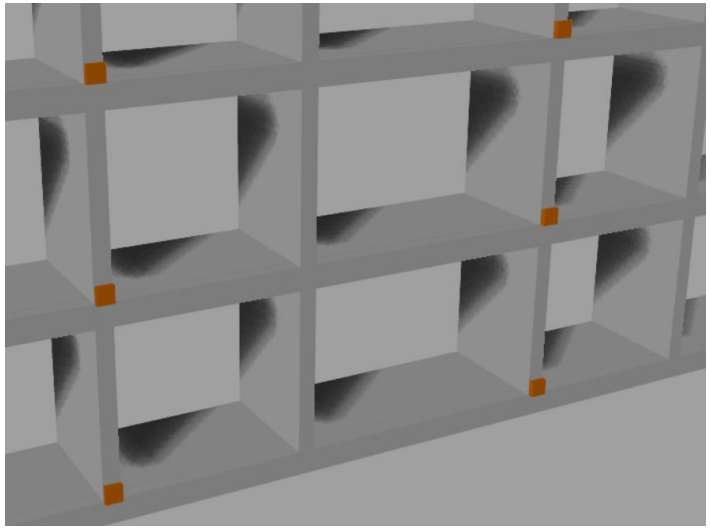


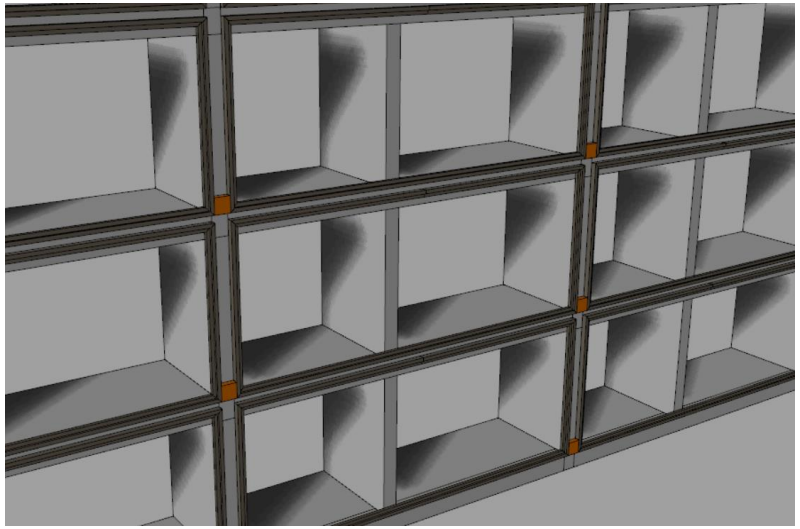


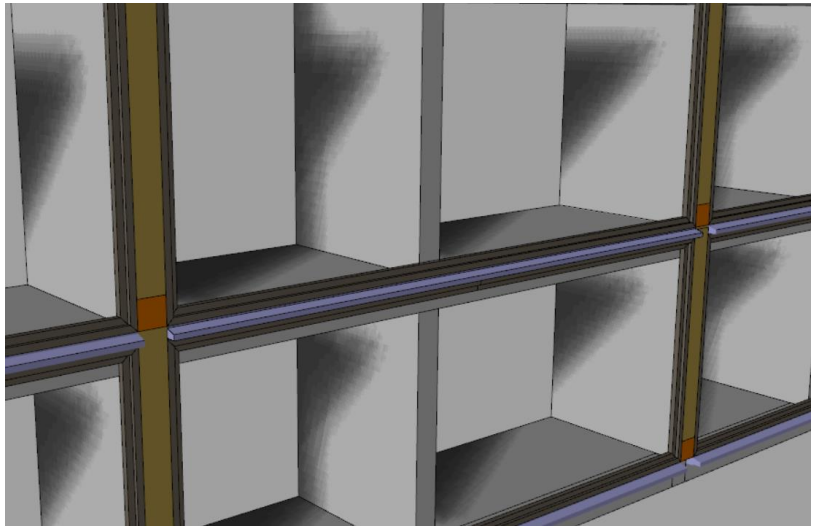


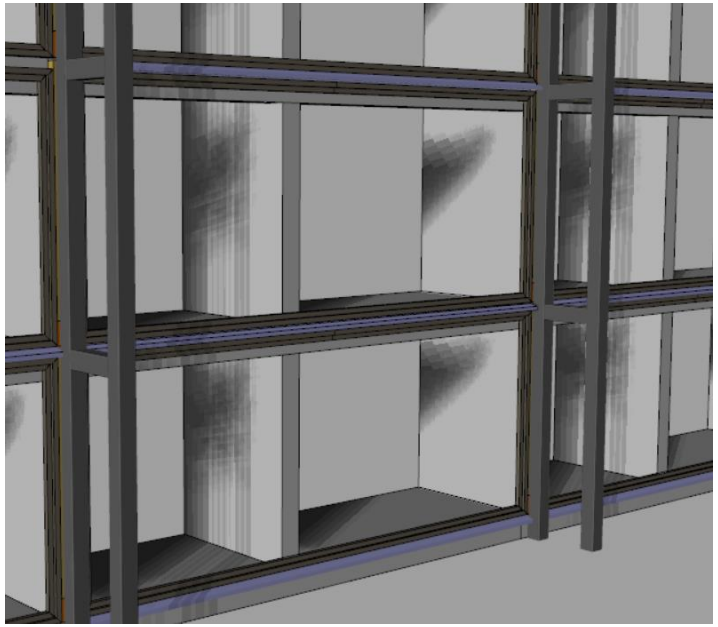


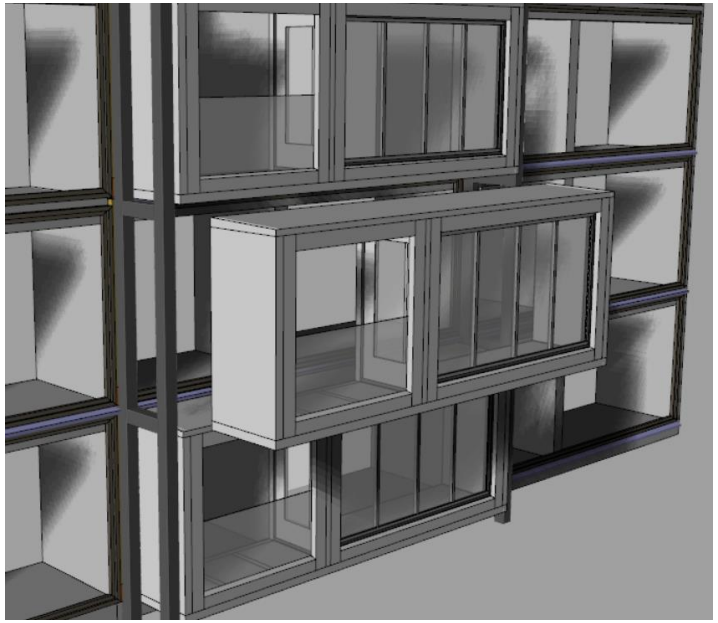
Assembly addon to building

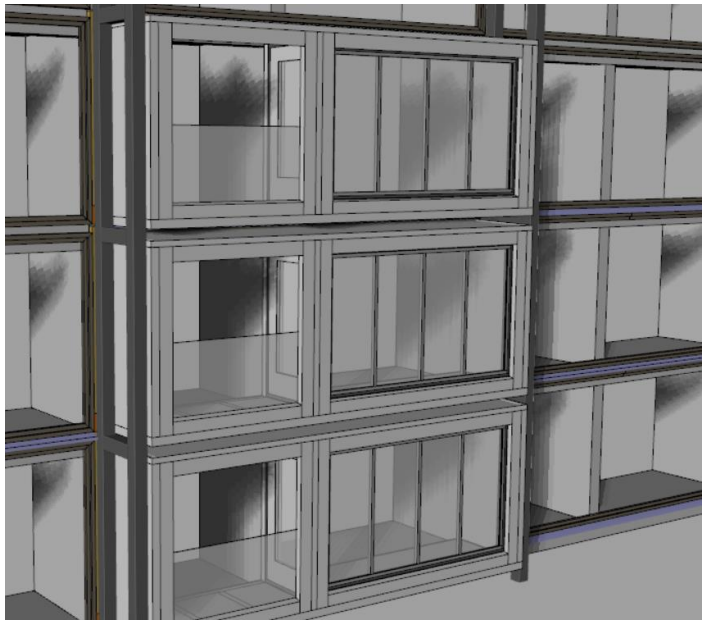












Performance

Thermal performance addons

Materials	Lambda λ in W/mK	Thickness of panels in m	Rc-value m^2K/W	Isolation materials	Lambda λ in W/mK	Thickness of insulation in m	Rc-value m^2K/W	Total Rc-value m^2K/W	U- value W/m^2K
GRP	0.32	0.020	0.06	PIR / PUR	0.023	0.20	8.7	8.76	0.112
Glulam	0.13	0.14	1.08	Phenolic foam	0.020	0.08	4	5.08	0.190
HP concrete	2	0.12	0.06	Phenolic foam	0.020	0.09	4.5	4.56	0.211

Add-on material	Window frames	U value W / m2K
Wooden add-on	Wood (M Sora, Nature Optimo XL)	0.89
HP Concrete add-on	Aluminium (Kawneer, RT 82 HI+	0.79
GRP add-on	GRP (Krone, Ecliptica)	0.71

Material impact embodied energy and CO2

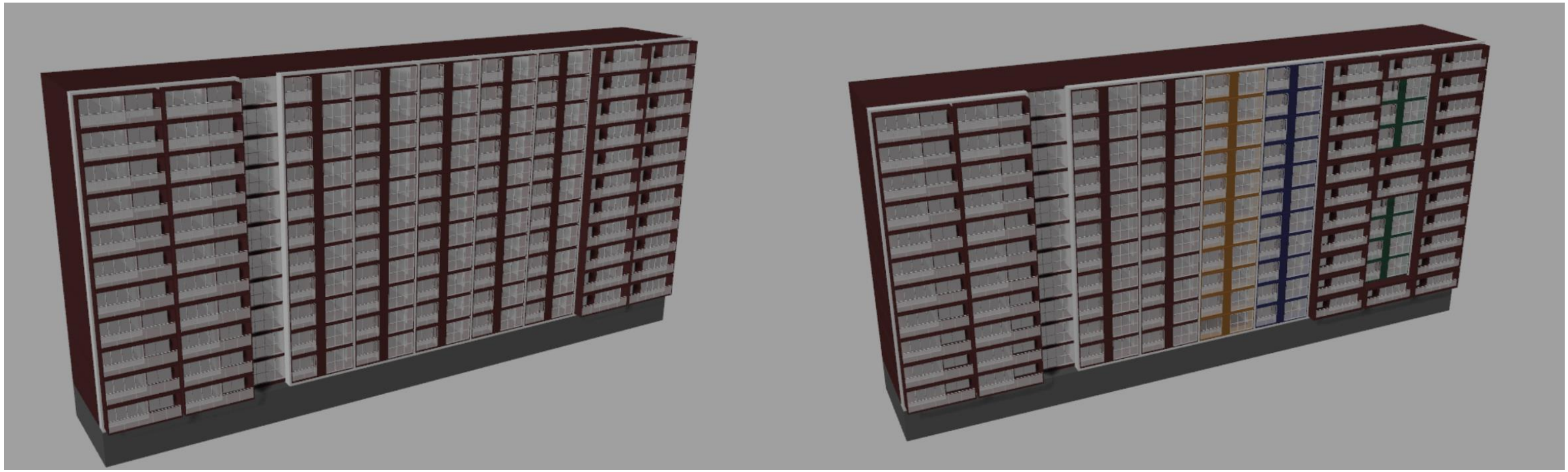
Wood add-on	Density kg/m³	Square meter m3	Kilo's kg	Embodied energy MJ/kg	CO2 production kg
Glulam 140mm	450	6.0	2700	32400	2268
Phenolic foam (Resol) 80mm	36	1.1	40	3520	684
Total			**2740**	**35920**	**2952**

Concrete (HPC) add-on	Density kg/m³	Square meter m3	Kilo's kg	Embodied energy MJ/kg	CO2 production kg
HPC 120mm	2800	2.74	7672	27465	3682
Phenolic foam (Resol) 90mm	36	1.2	43	3802	739
Total			**7715**	**31267**	**4421**

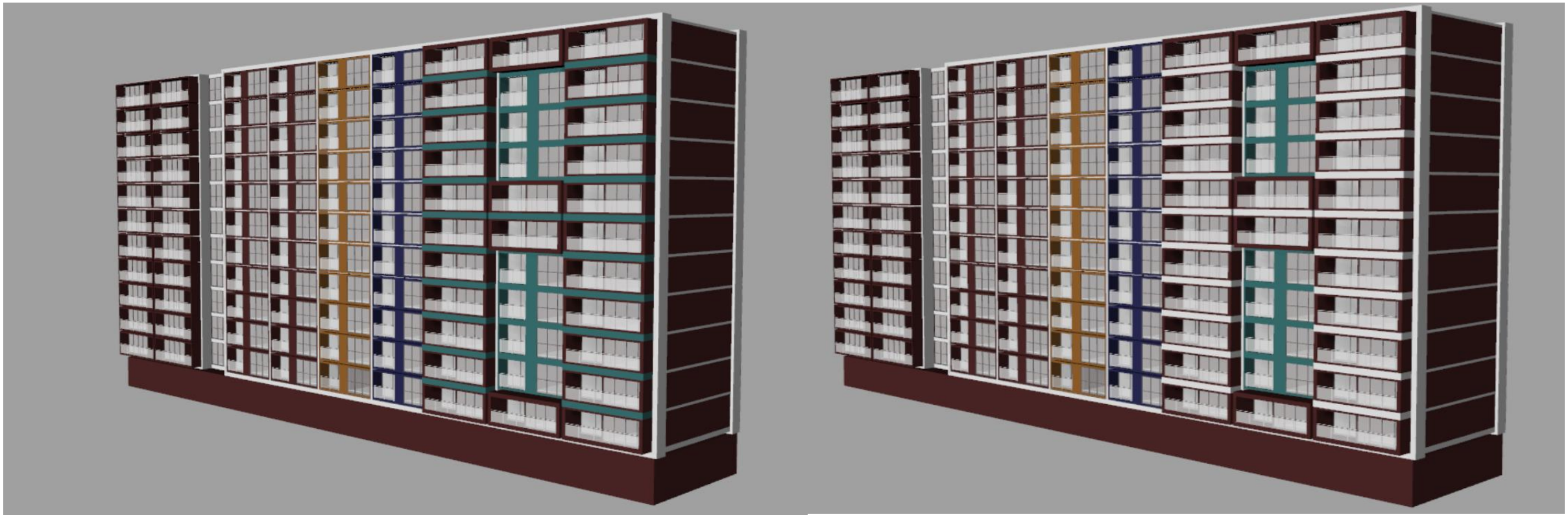
GRP add-on	Density kg/m³	Square meter m3	Kilo's kg	Embodied energy MJ	CO2 production kg
GRP 2*10mm	1750	0.5	875	87500	7088
PUR 200mm	33	5.6	185	18778	3164
Total			**1060**	**106278**	**10252**

Steel structure	Density kg/m³	Square meter m3	Kilo's kg	Embodied energy MJ/kg	CO2 production kg
Steel (11 add-ons)	7800	1.935	15093	303370	20677
Steel per add-on			1372	27579	1880

Building design



Design process building



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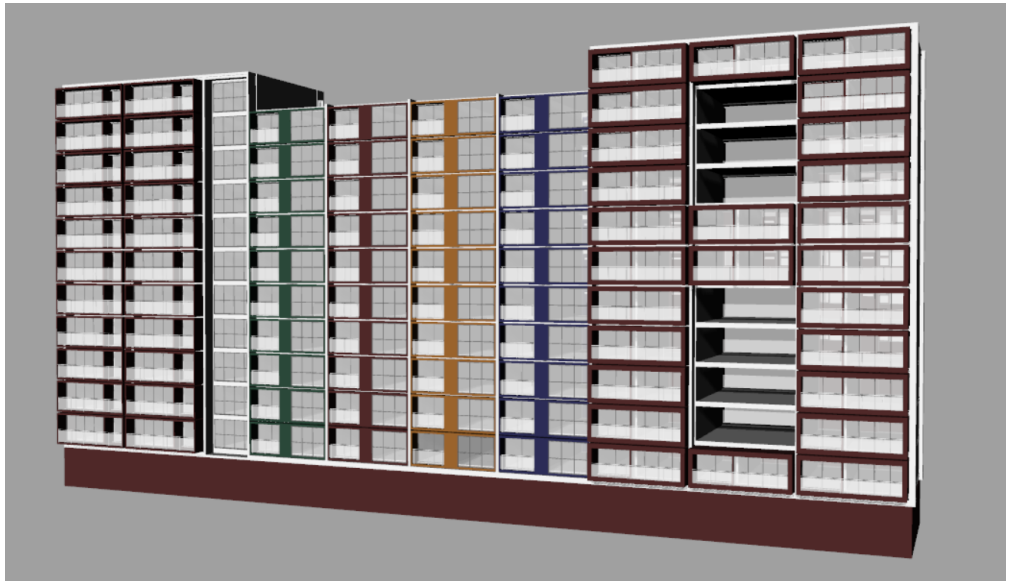
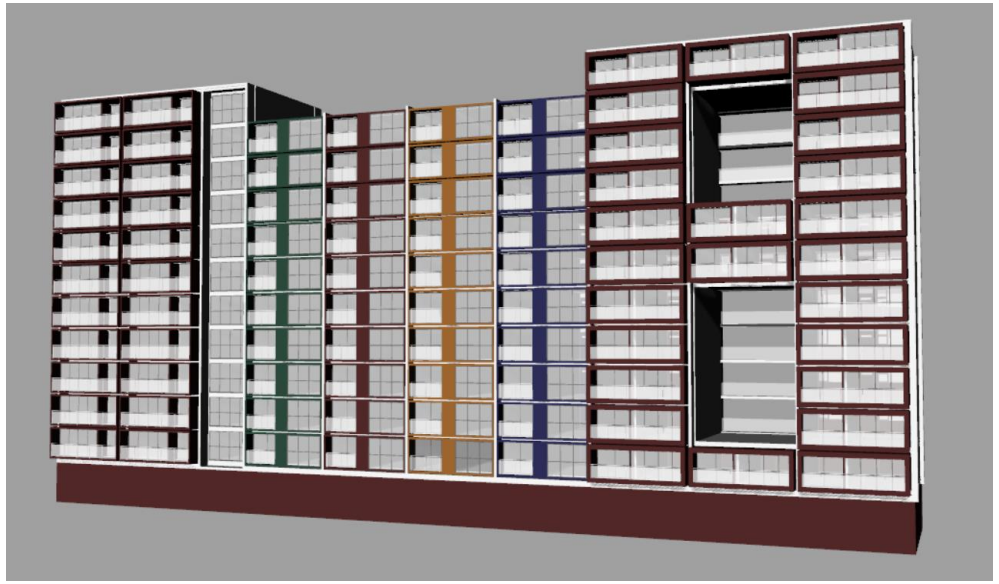
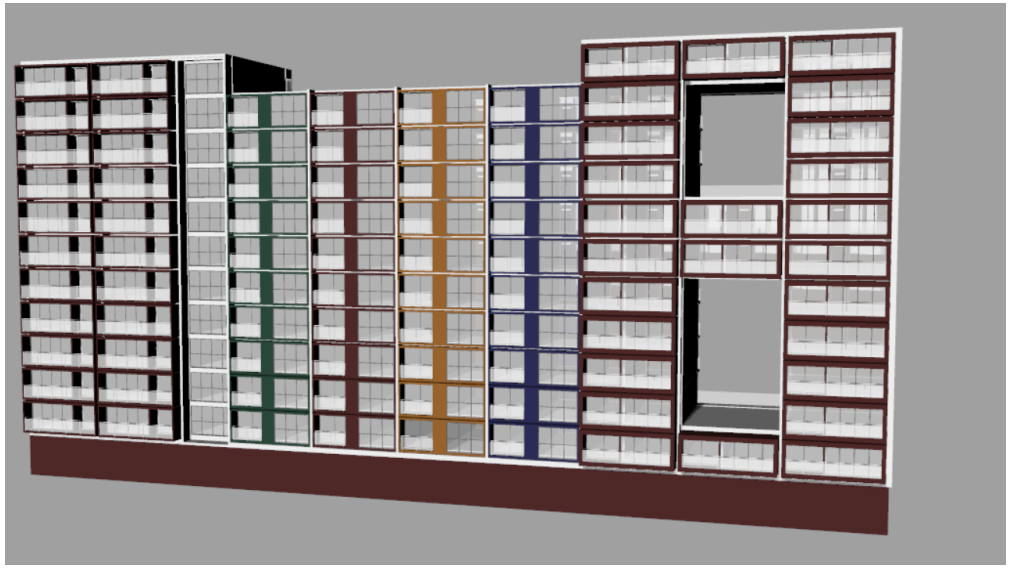
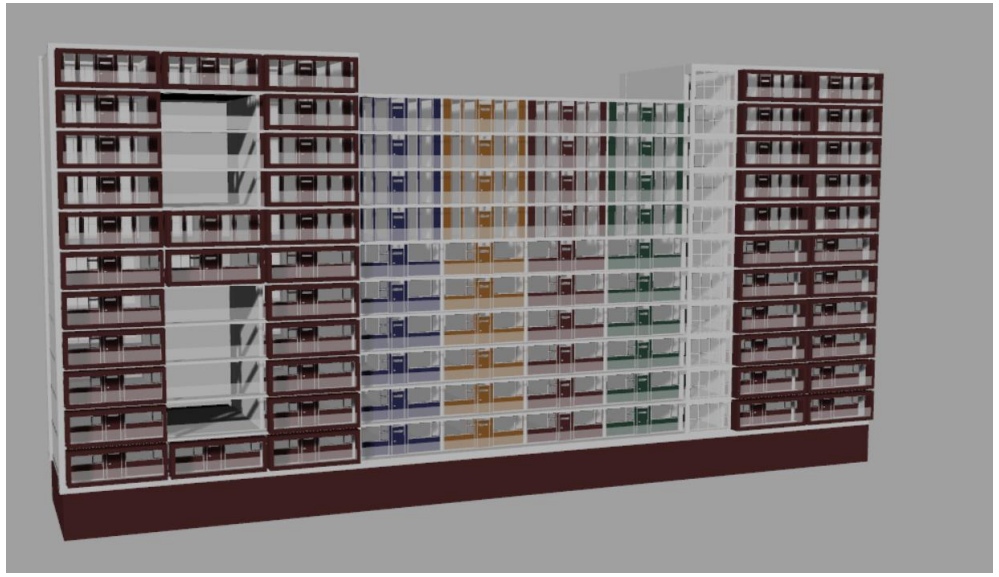
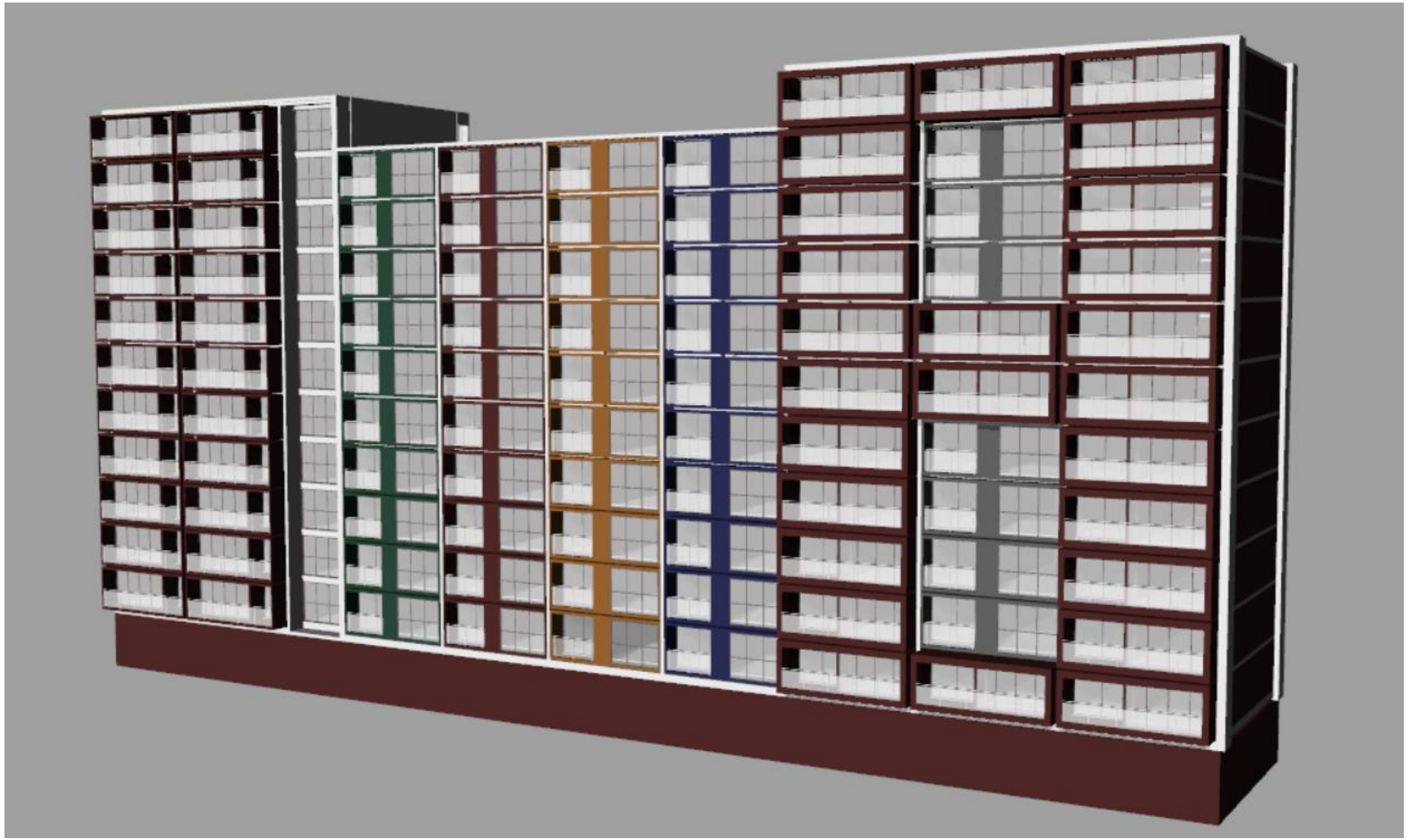
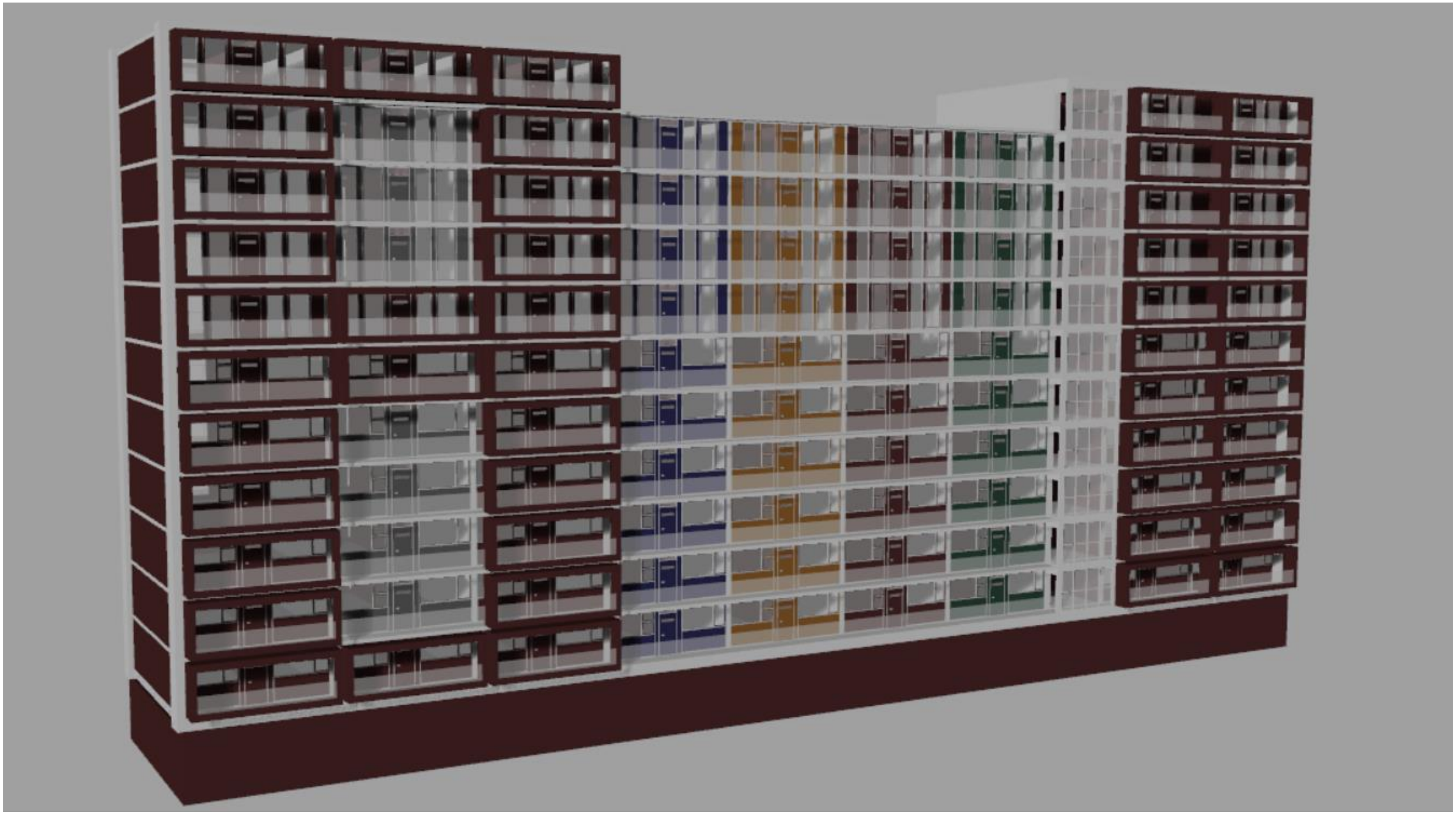


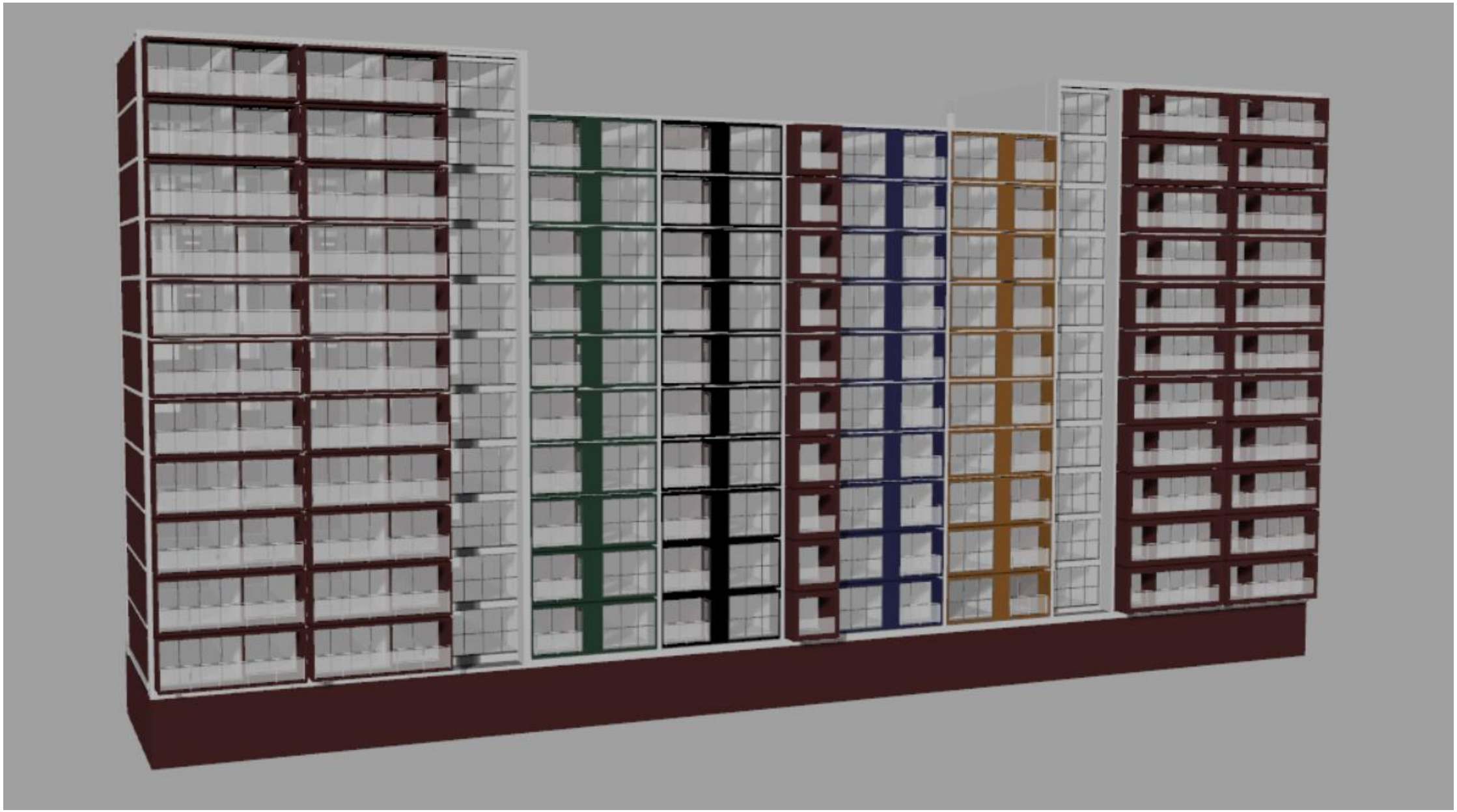


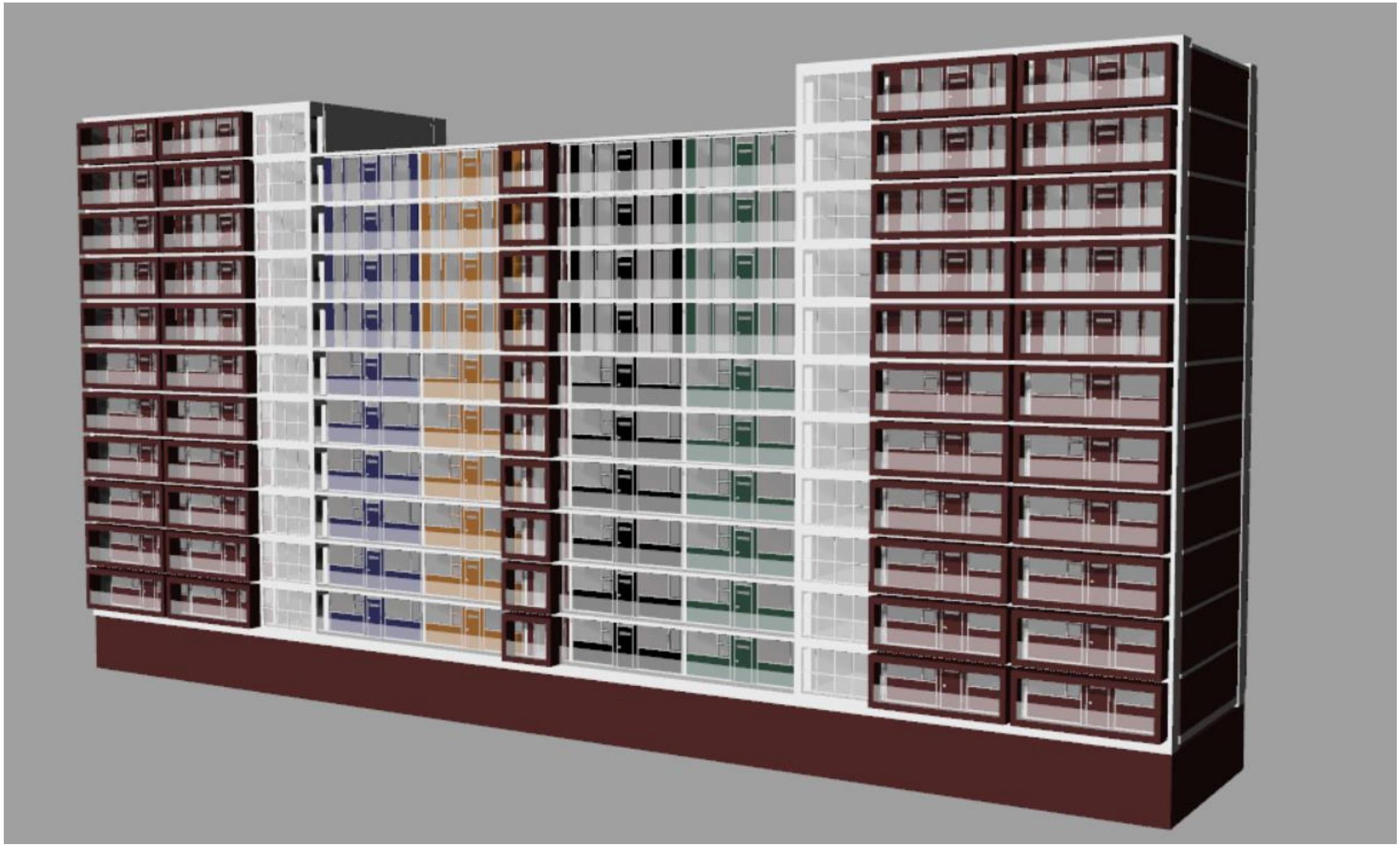




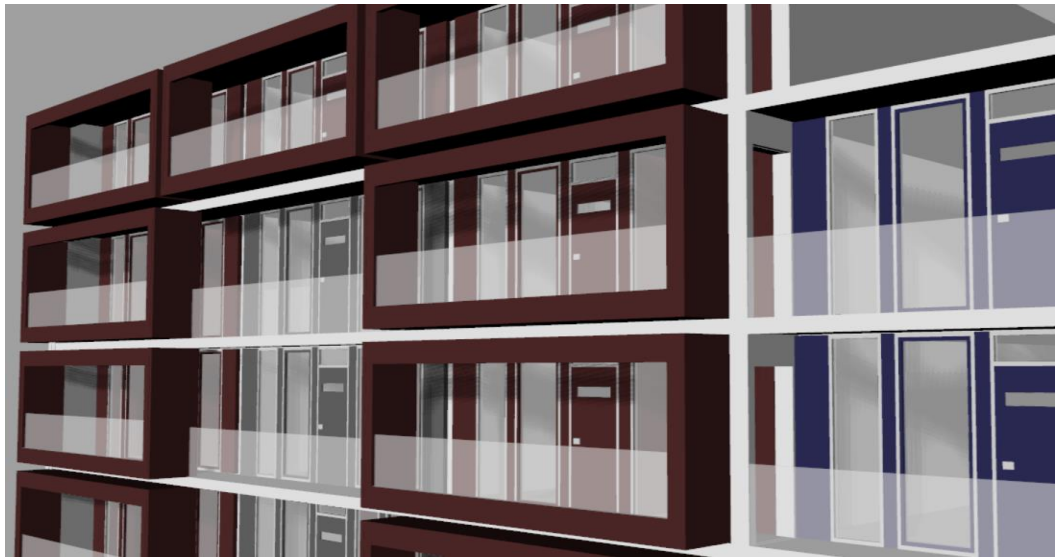


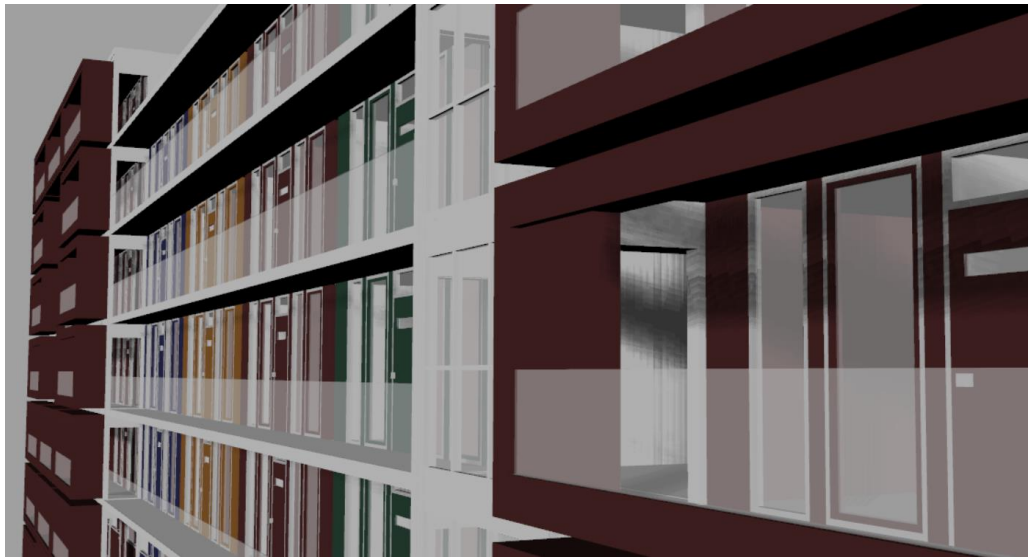


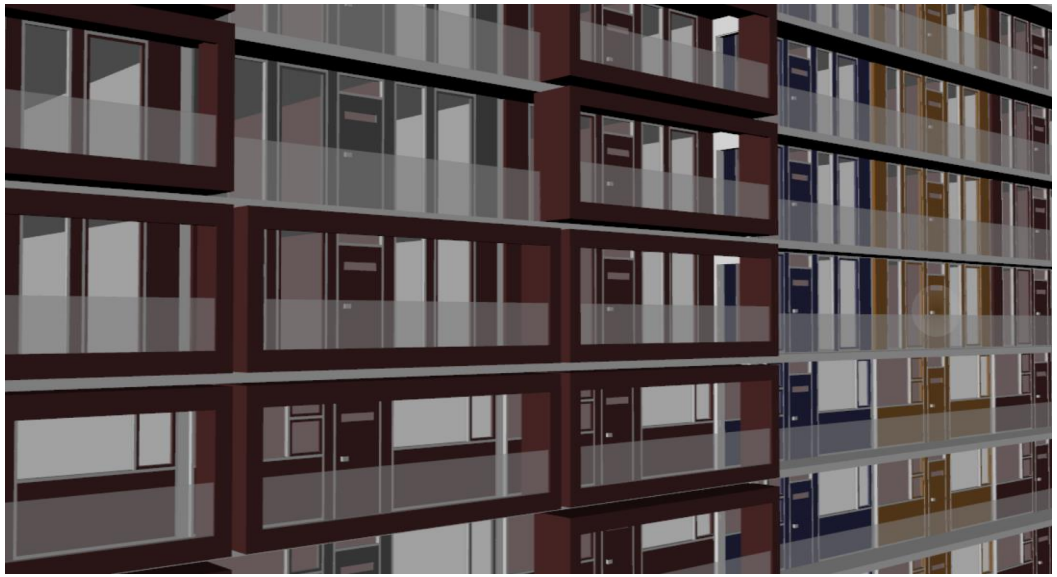


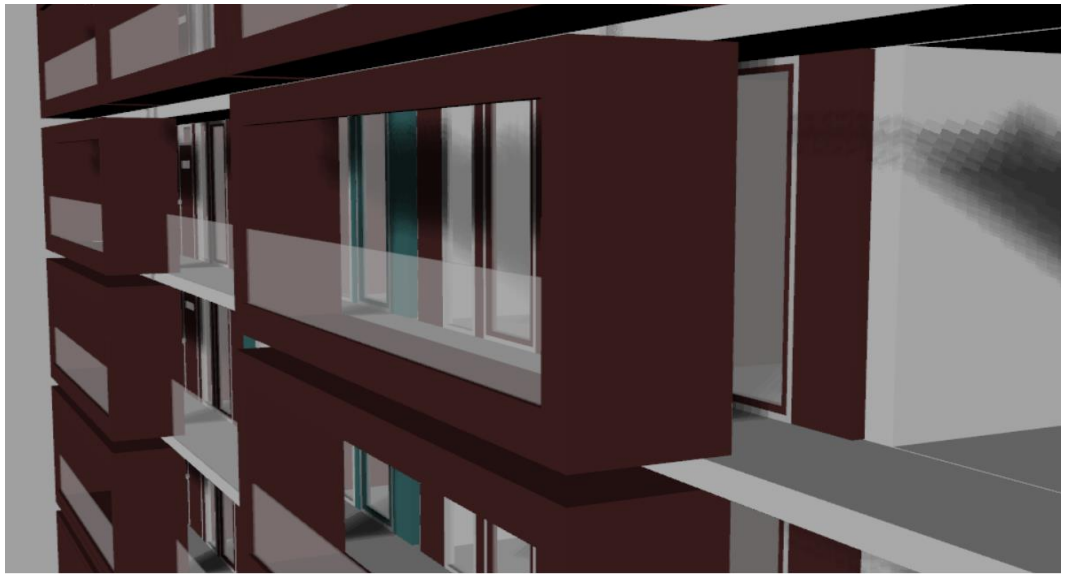


Design process building









Conclusions

Does the designed add-on contribute to good living conditions for the residents

while at the same time improving the sustainability of the building?

Technical aspects

- capable of dealing with the building physical challenges
- structurally viable

Spatial aspects

- extra space and more floorplan flexibility

Social aspects

- more diversified flats with a personal image

Environmental aspects

- extending the lifespan of an existing flat.
- flexible and reusable due to demountability

Financial aspects

- quick to install
- Possibly expensive compared to other methods