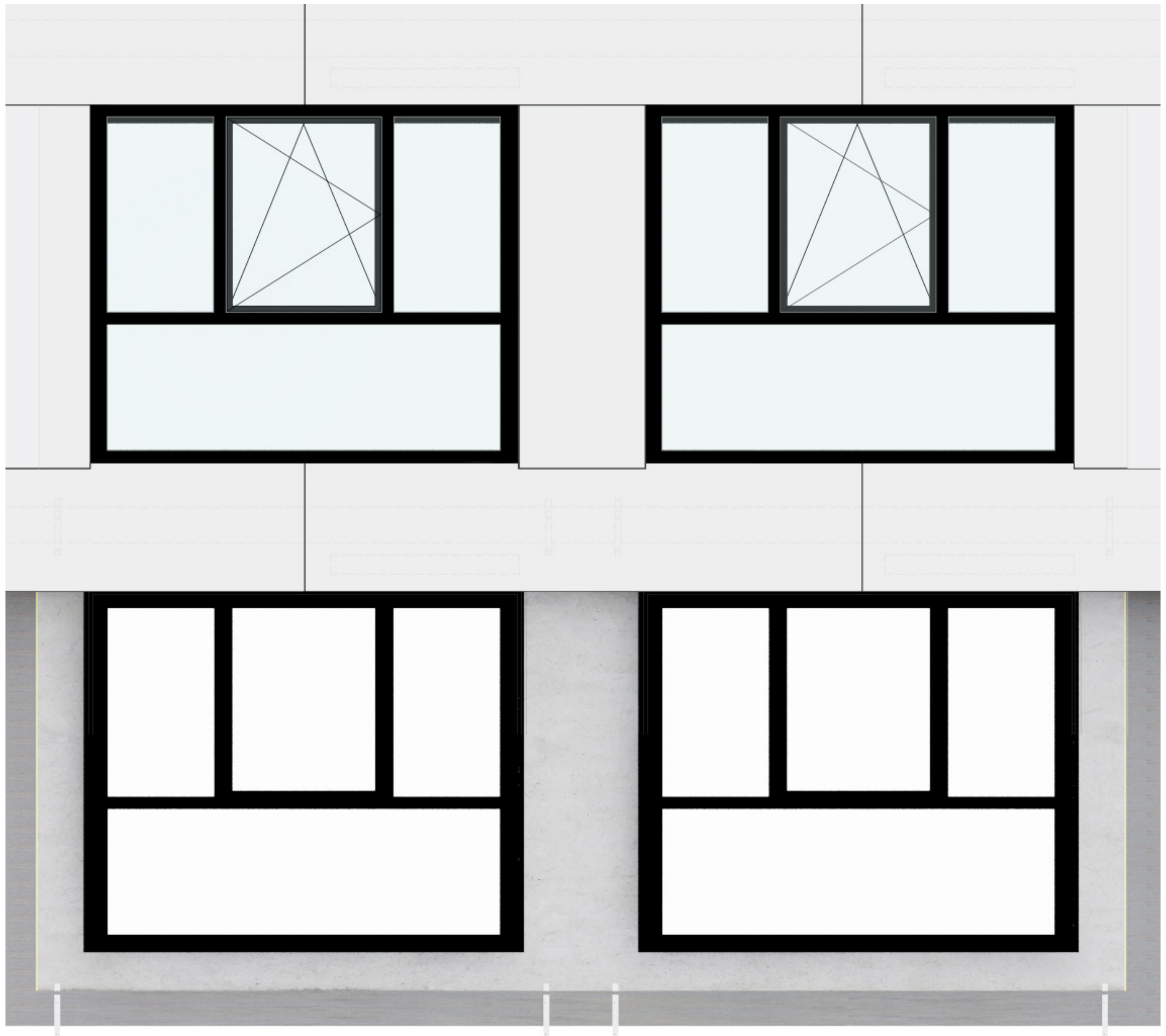


Studentenwoningen Stieltjesweg TUDelft

Student Accommodation in Delft

Facade Analysis - Group 16

Ekta Kapoor - 4735293
Julia Kapinga - 4342550
Milou Klein - 4389123
Electra Pangalou - 4691695

AR0115 Facade Design, AR0821 Materialization & The Future Envelope

CONTENTS

BUILDING INFORMATION

Location: Stieltjesweg
Delft, 2628 CK,
Province of South-Holland, Netherlands.

Year of design: 2014

Year of completion: 2017

Architect: RoosRos Architects

Constructor: IMd Raadgevende Ingenieurs

Installation Adviser: Engineering and consultancy firm Technion

Geo-technical Advisor: Geomet Advice

Contractor for existing construction: Groenendijk PGN

Contractor for new construction: Smit's Bouwbedrijf

Other specialists: BAM Infra Special Techniques
Alkondor Hengelo
Riboton

Client: Stieltjesweg Ontwikkeling (Leyten, Van Maren) and Bes de Blaay & Partners

Location Info: The location of the building under investigation is in the middle of the campus of Delft University of Technology. It used to be the location of the Knowledge institute Deltares. The offices and Institute were relocated into a more suitable locations and the developer along with the owner decided to transform the existing buildings into student accommodation so as to enrich the character and atmosphere of the whole surrounding area.

Architectural Concept: The project constitutes a combination of architectural reuse of the existing structure of the former offices and a new construction. As it was mentioned above it is at the heart of the TU district thus flexibility was the main principle followed both in terms of design and implementation. The aim was to provide the required spaces and facilities in the most cost-efficient way. The new construction (tower) was designed in such a way that the apartments could easily be merged into larger regular houses in the future when there is no need for student accommodation, making the design future proof and thus supporting the aim to create an area where the student can continue his entire living career; from group living and studying to working and living in an independent apartment.

The facade of the new building - and part of the existing building - emphasizes the technical character of the TU. An abstract pattern of the integral of a sinus and cosine graph can be seen across the facade. A reference to the work of Johannes Stieltjes, the famous mathematician whose name was given to the street.

Building Details

Tower
Height: 75,00 m
Nº of floors: 22
Nº of housing units: 525
Floor height: 3,00 m
Typical room area: 24,00 m²

Existing Structure
Height: 10,950 m
Nº of floors: 3
Nº of housing units: 186
Floor height: varies
Typical room area: 16,20 m²

Additional Functions
Supermarket: 196,30 m²
Student cafe: 242,00 m²
Commercial/Social space: 1.000,00 m²
Underground bicycle parking: 653,70 m²

Whole complex area: 30.000,00 m²

PHOTO REPORTAGE

Building overview

Facades overview

PHOTO REPORTAGE

Materialization

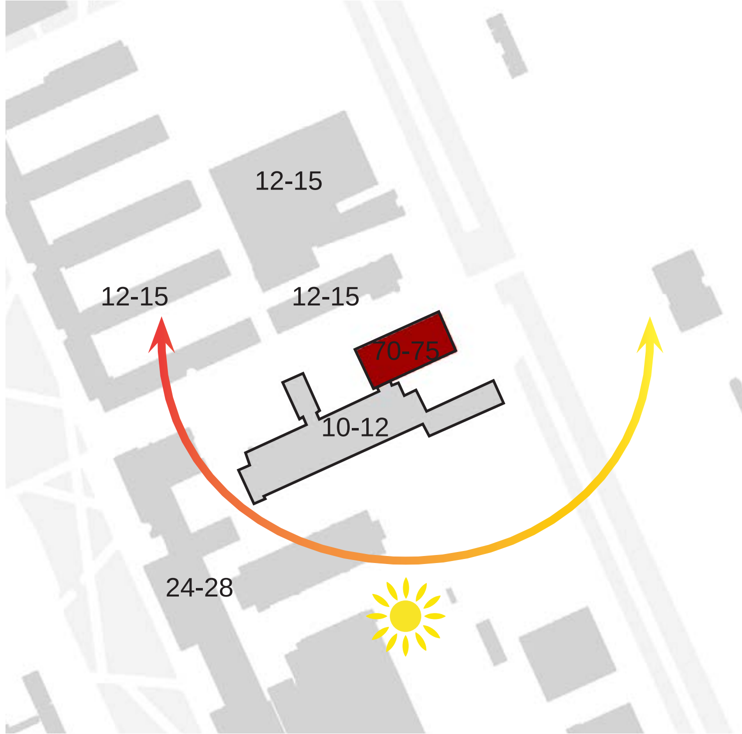


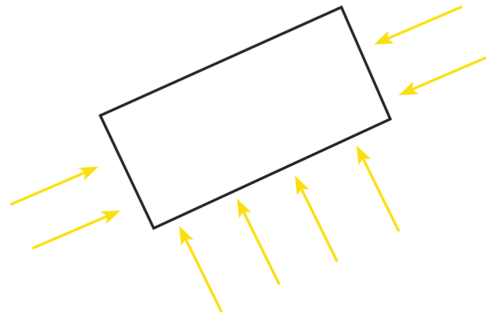

Close-up special details/ solutions



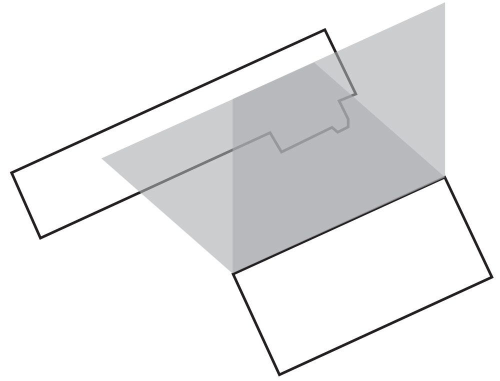

Site Location

Sun's Orientation





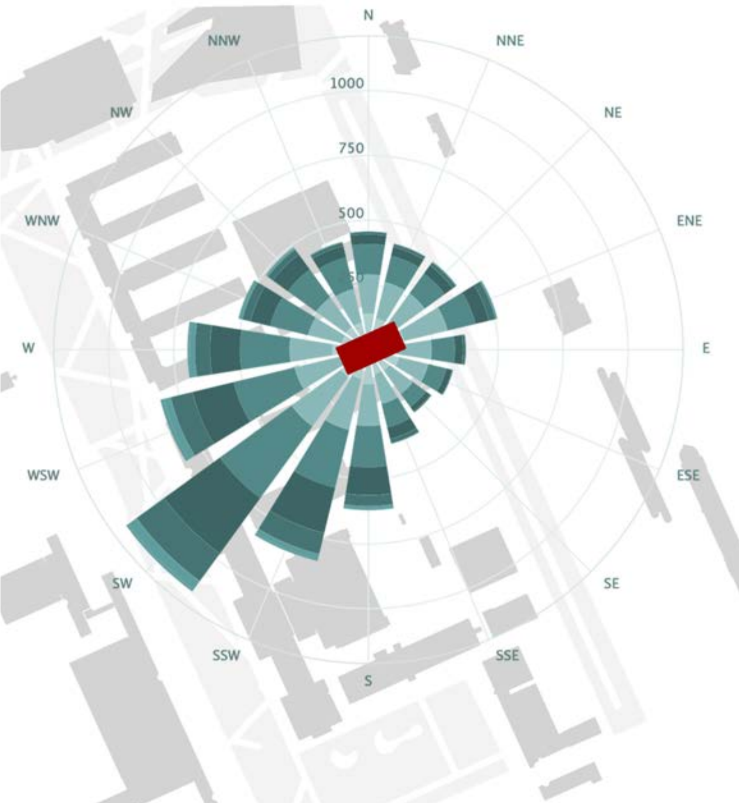
Daylight

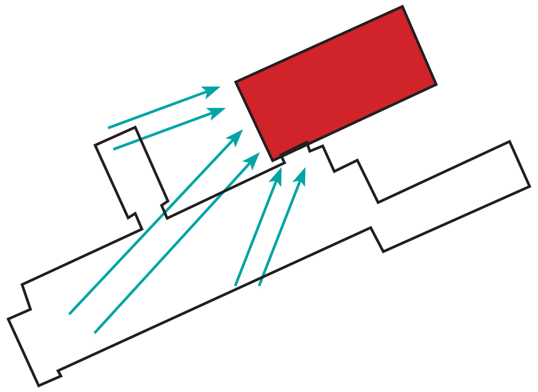


Shading

The construction of the high rise (tower) which is our focus for this project daylight is available in all housing units. Each unit has an individual window with interior shading devices.
The tower's influence on daylight to the surrounding buildings affects concerns only the TNO building opposite to the tower. Since the building functions as an office, shading coming from the tower protects the building from unwanted glare, consequently the negative effects are very limited.

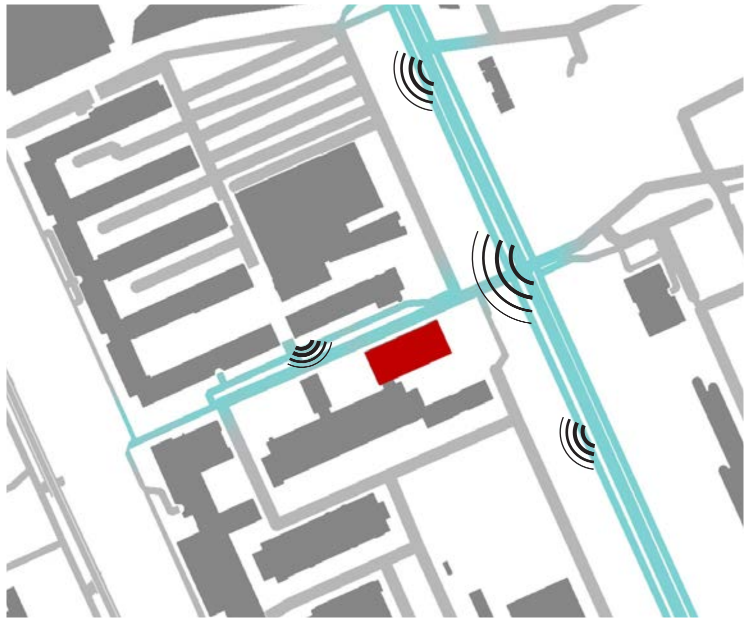
Prevailing Wind direction





The main wind direction is the South-West. Minimum wind-blowing facade surface (compared to the long side of the tower) thus no large overpressure that needs to escape. Yet, high wind speeds are expected and even though a high rise building was considered an unsuitable solution the project evolved in that direction due to its other benefits.

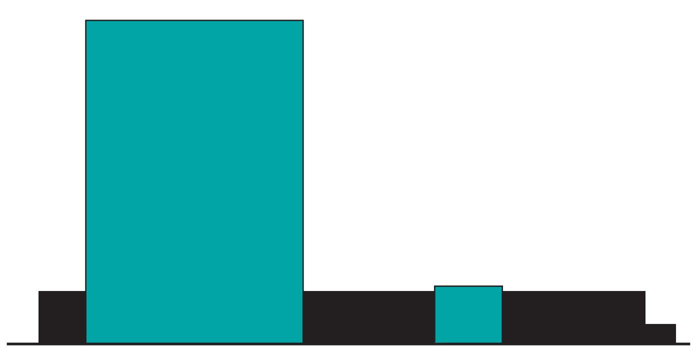
Noise



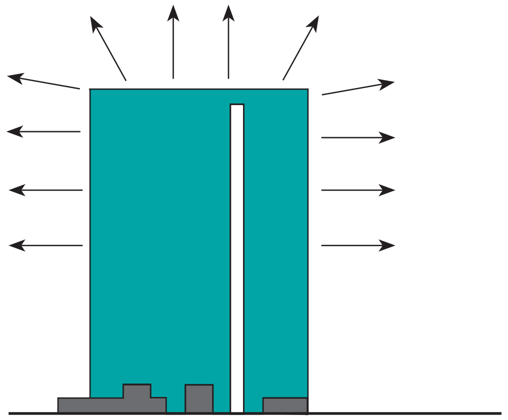
Loud noise comes from the high traffic Schoemakerstraat. The interior required levels are reached with the use of concrete structure (mass structure) and appropriate insulation thickness were as the exterior levels are kept to the maximum values which is 63 dB.

ARCHITECTURE

Concept

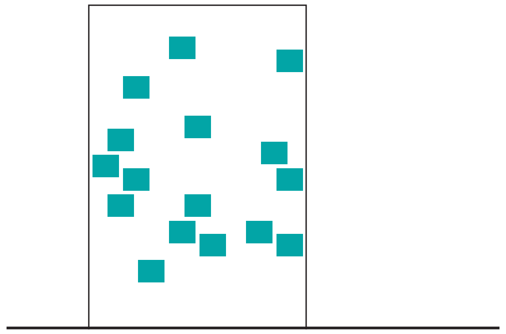


Architectural reuse + New construction
Sustainability



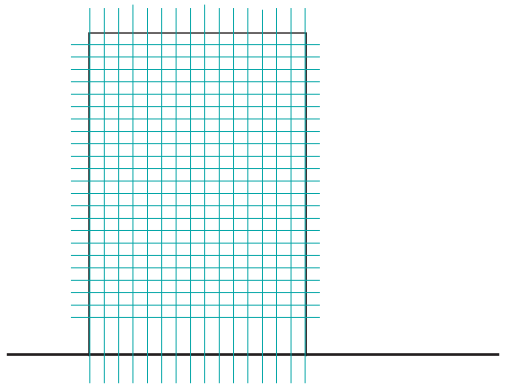
High rise

> Landmark (visible from different parts of the city, enrich east entrance of the campus)
> Views (rooms facing all directions, view towards Rotterdam, Hague etc.)
> Public use of ground floor, private use of above floors.



Mathematical Pattern

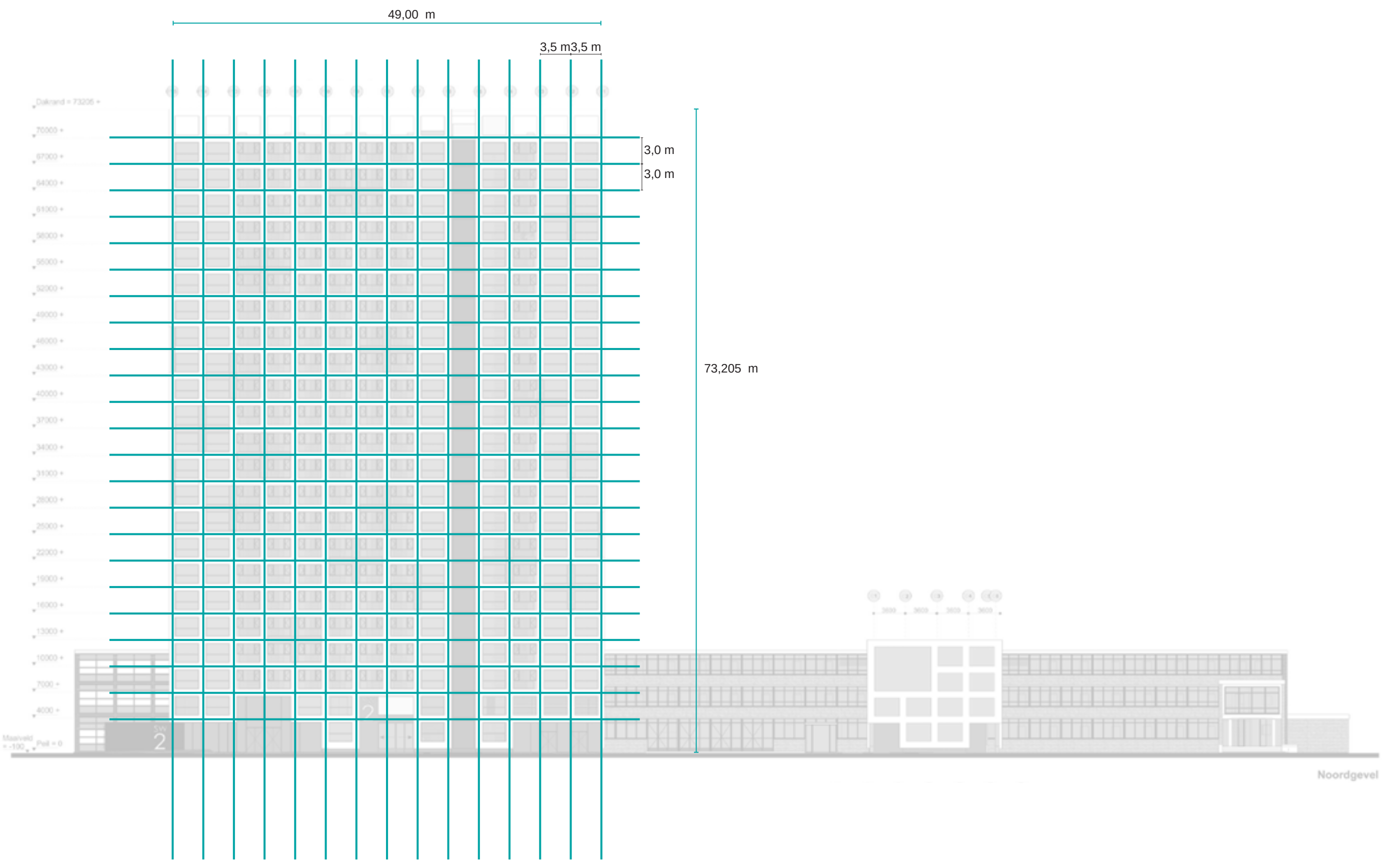
An abstract pattern of the integral of a sinus and cosine graph can be seen across the facade. A reference to the work of Johannes Stieltjes, the famous mathematician to whom the Stieltjesweg is named.



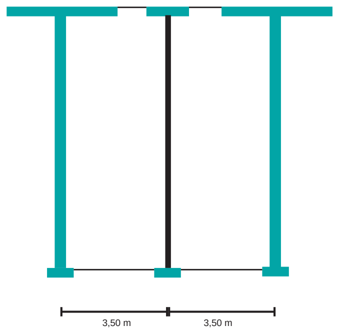
Cost and Time efficient Construction

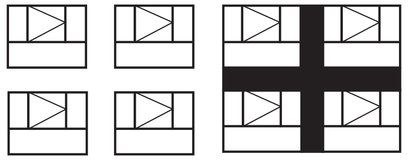
Prefabricated elements used in facade design. Constraints: Limited building space. Vibration-sensitive environment - research facilities in surrounding buildings.

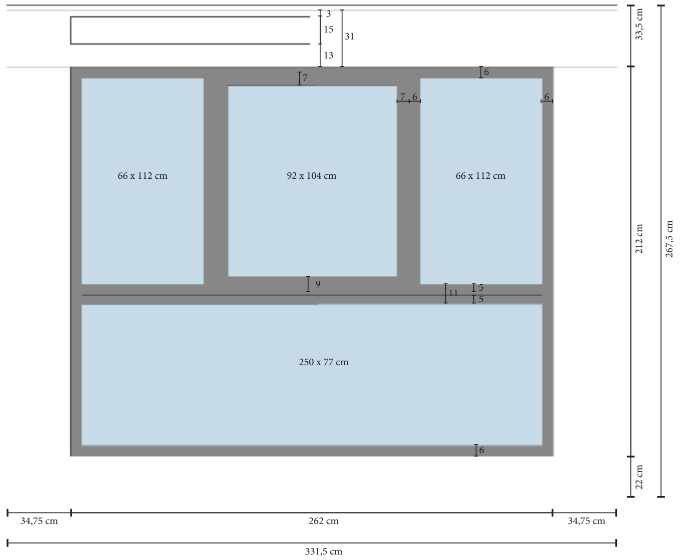
Facade Composition



Unit Composition





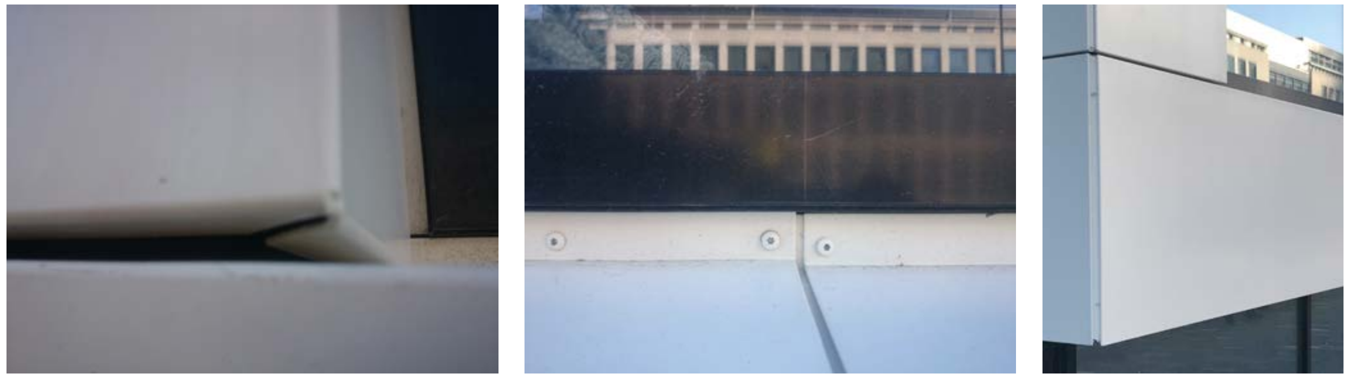


Two apartments fit into a main grid of seven meters. By separating this with a light wall, two apartments can easily be made into one large apartment in the future. Where the superstructure has a wall structure, a column structure has been chosen for the bottom two building layers. As a result, the commercial and technical spaces of the lower two storeys can be flexibly arranged.

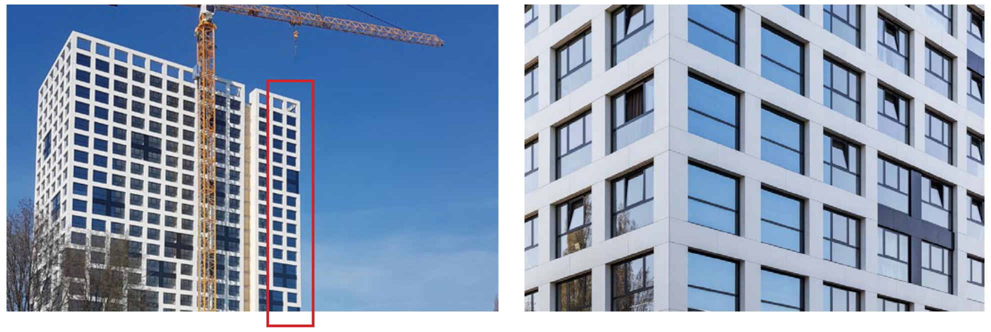
Facade Materialization - First Impressions

Steel Brackets supporting cladding

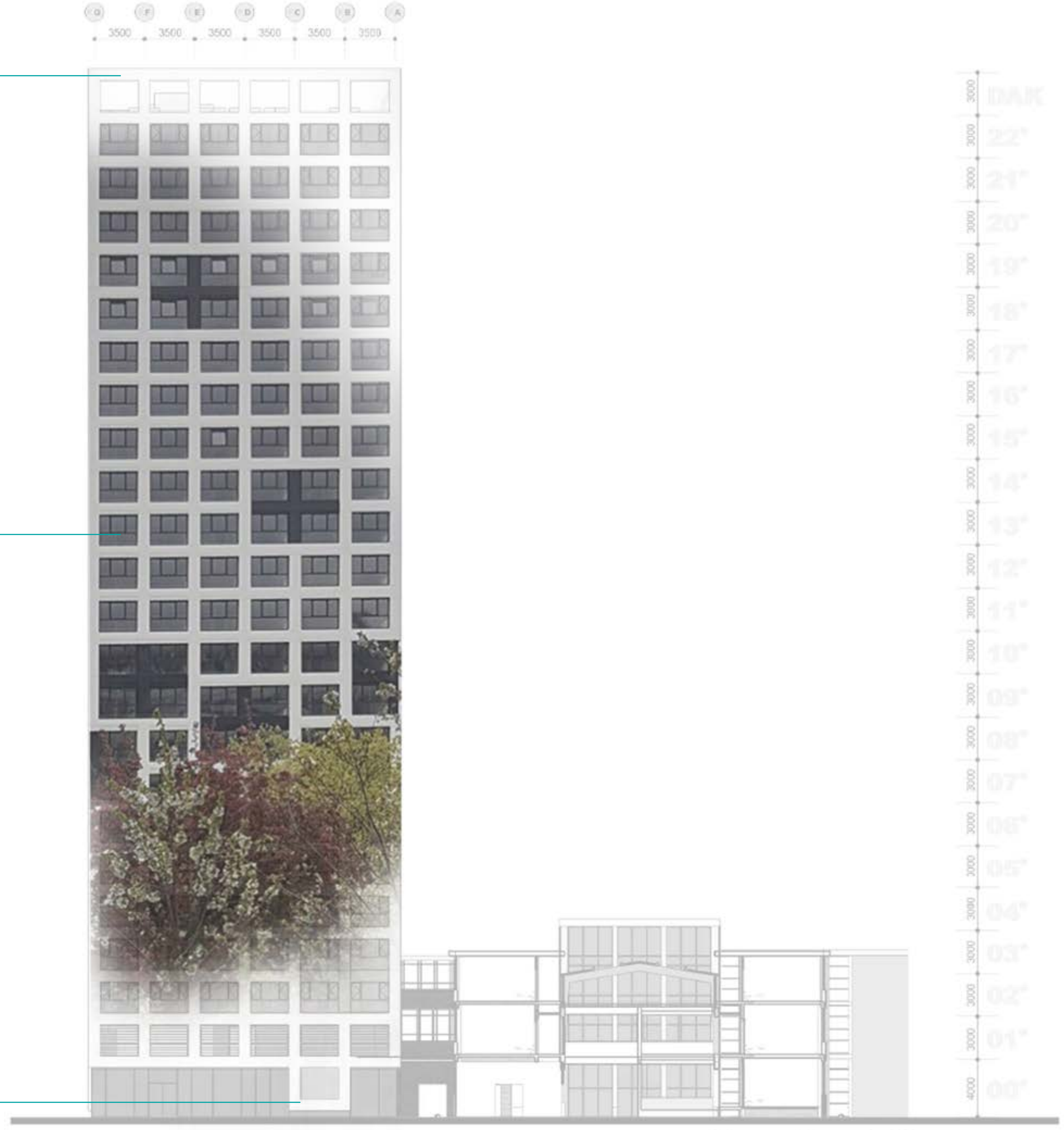
Black aluminium frame with double glazing and curtains as interior shading mechanism.



Prefabricated sandwich cladding. Light Grey Colour possibly colour 104 from manufacturer.

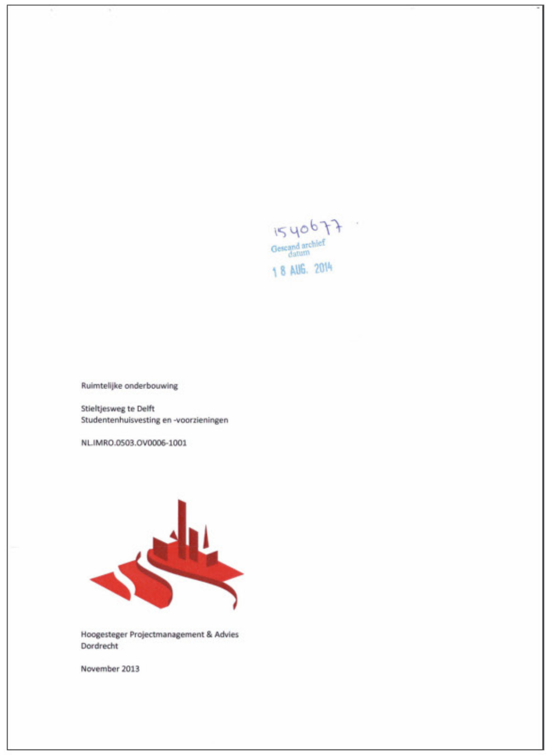


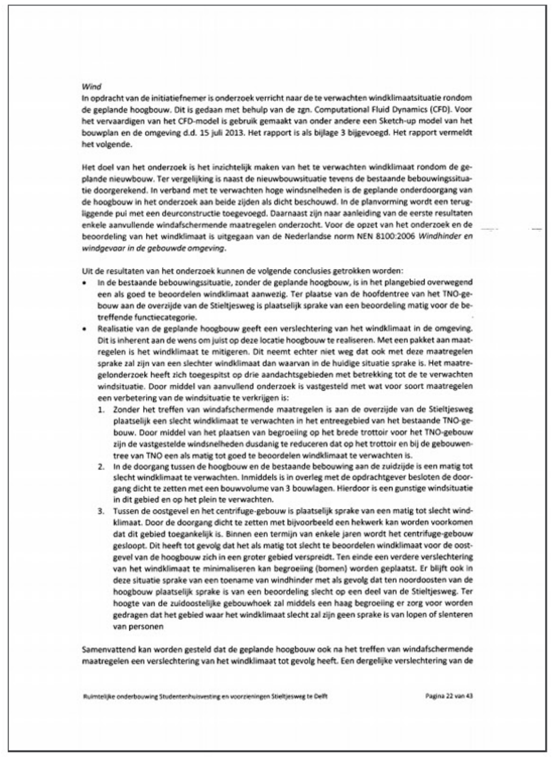
Hardglass sandwich panel to cover concrete wall providing wind stability.



LITERATURE RESEARCH

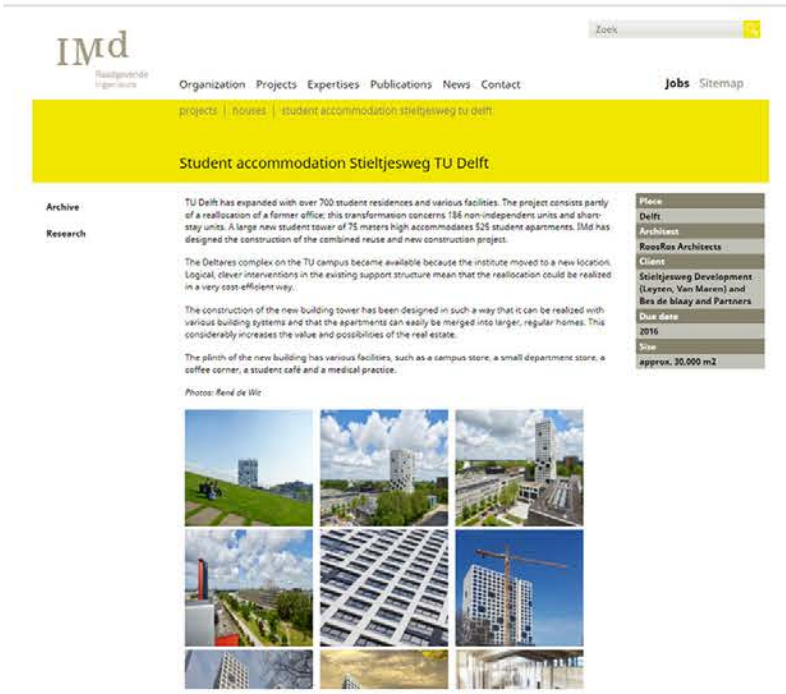
Planning report



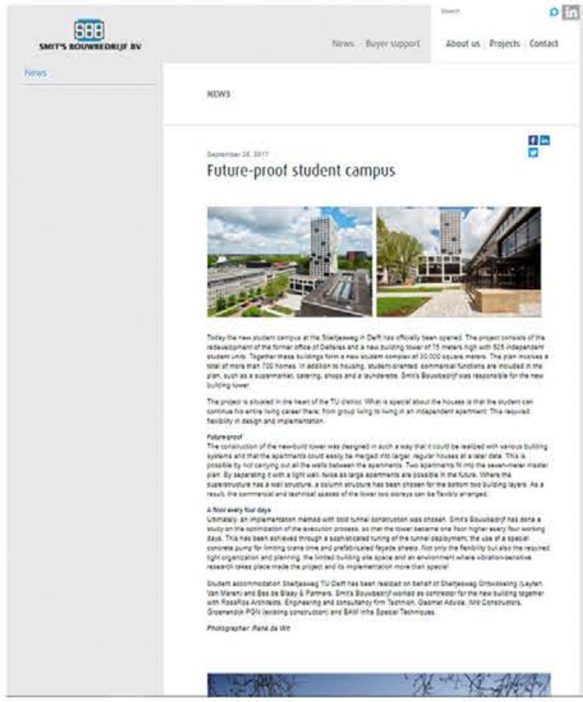


Architect’s official website

Constructor’s official website



Contractor’s official website



Other publications

Other publications

R-2015 en R-2016-2 Geïntegreerde stelkozijnen en stelkaders

Innovatieve kunststof stelsystemen: geïntegreerd in de prefabricage van de betonnen gevelelementen. Duurzaam, optimaal isolerend en 100% recyclebaar.

Doorlooptijd verkorten, risico's beperken en efficiënter bouwen

R-2015 R-2016-2

Perfecte verankering en waterkering gegarandeerd door kant-en-klaar kader

Voordelen	R-2015	R-2016-2
Door de instortfens hoeft het stelkozijn bij het instorten niet meer te worden voorzien van instortankers.	■	■
Door unieke profilering van het stelkozijn is de EPDM-slabbe in principe niet meer nodig.	■	■
Besparing op afbouwtijd en -kosten doordat stelkader functioneert als opleveringsklare dagkantafwerking na instorten.	□	■
Besparing op conventionele ankers en bouwtijd door dragende stelkaders van aluminium casettes.	□	■
Bouwfysisch gunstige detaillering	□	■

Recystel \ T +31 88 972 25 00 \ info@recystel.nl \ www.recystel.nl

RECYSTEL

Stelkozijnen en -kaders

Doorlooptijd verkorten met geïntegreerde stelkozijnen en stelkaders

'Het is noodzaak om het logistieke proces te doorgronden en continu te verbeteren'

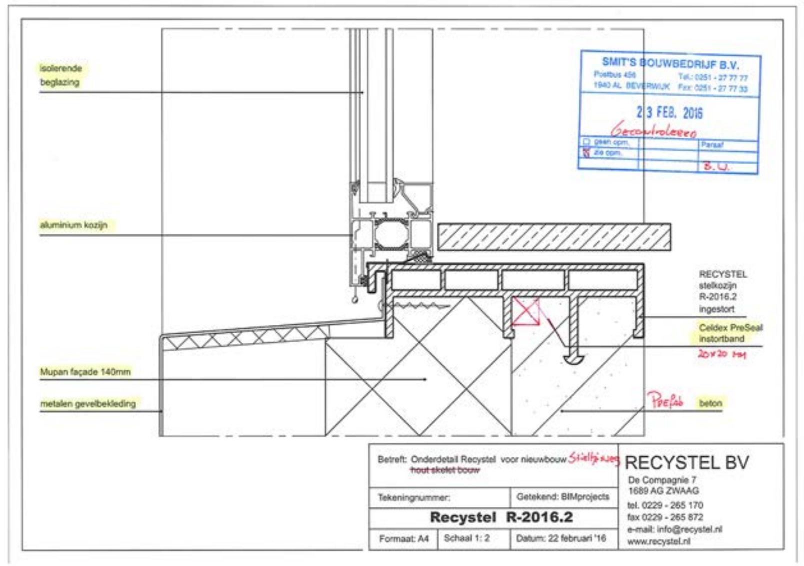
Stelkader inclusief dagkantafwerking

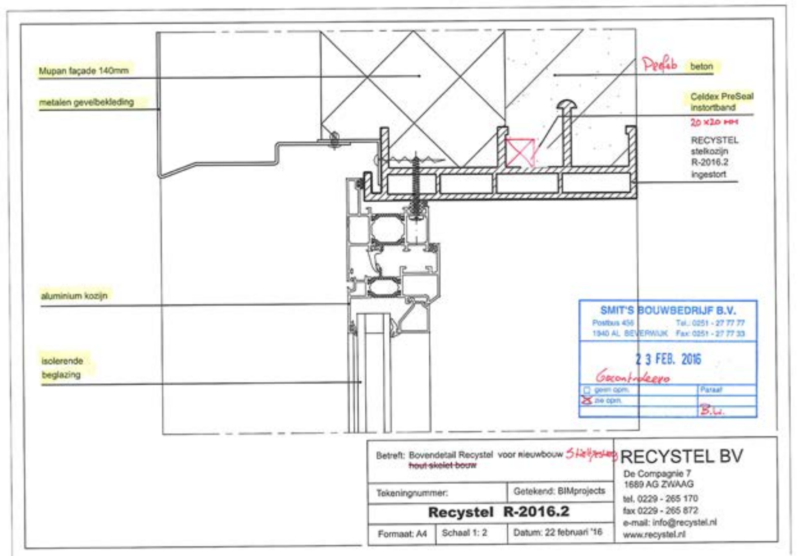
Tot op de minuut doorrekenen

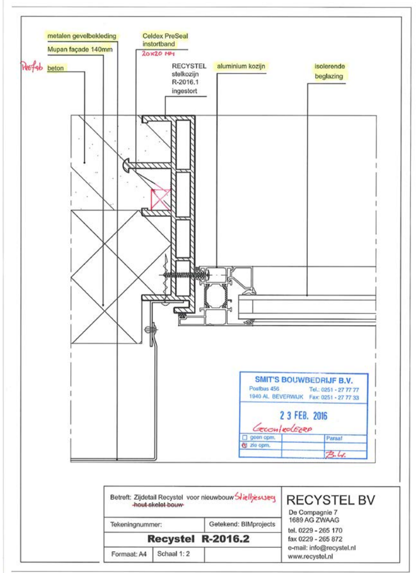
60 GEVELBOUW GEVELBOUW 61

Source: https://issuu.com/louwers_uitgevers/docs/gevelbouw_03_2016

Construction Details from Recystel

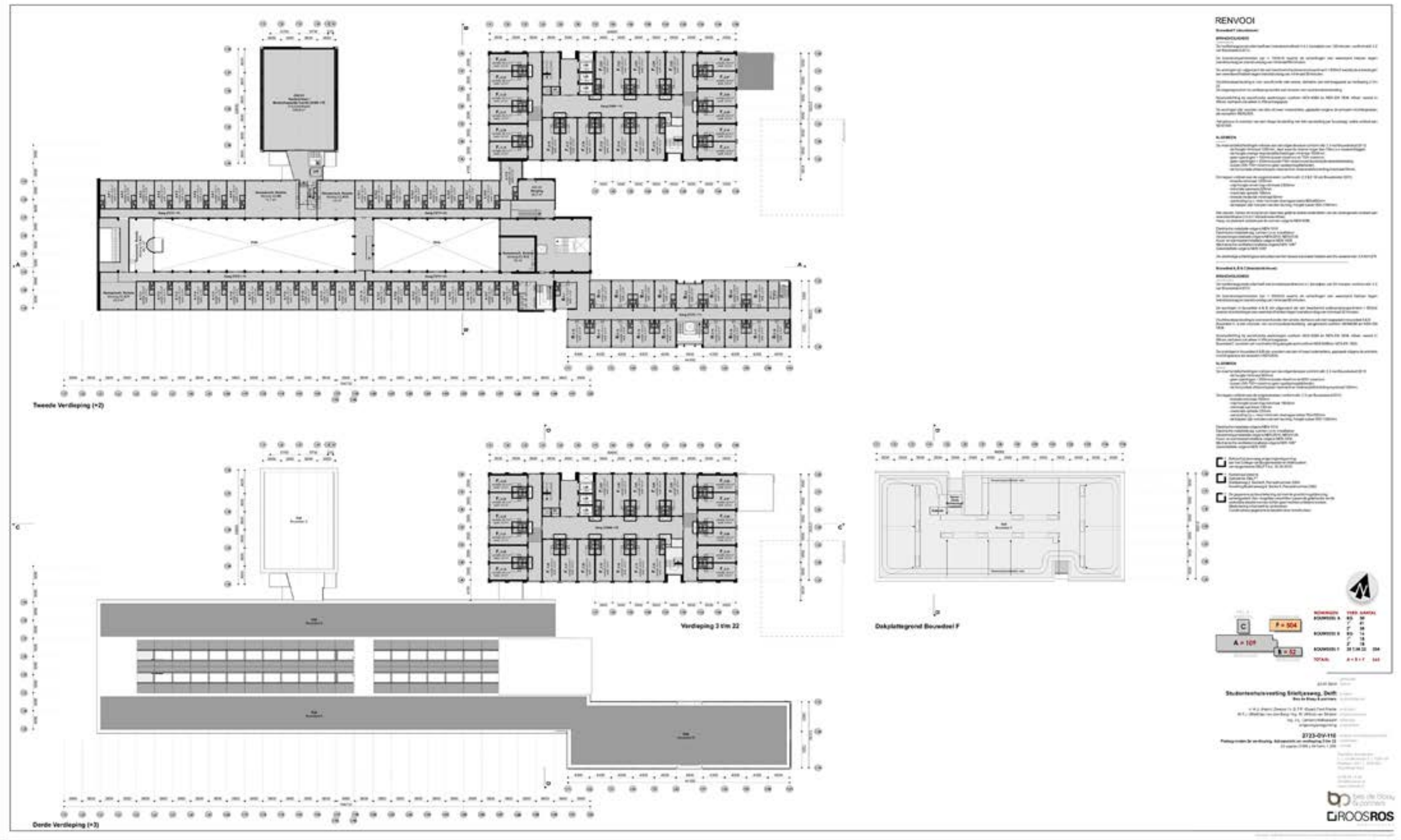




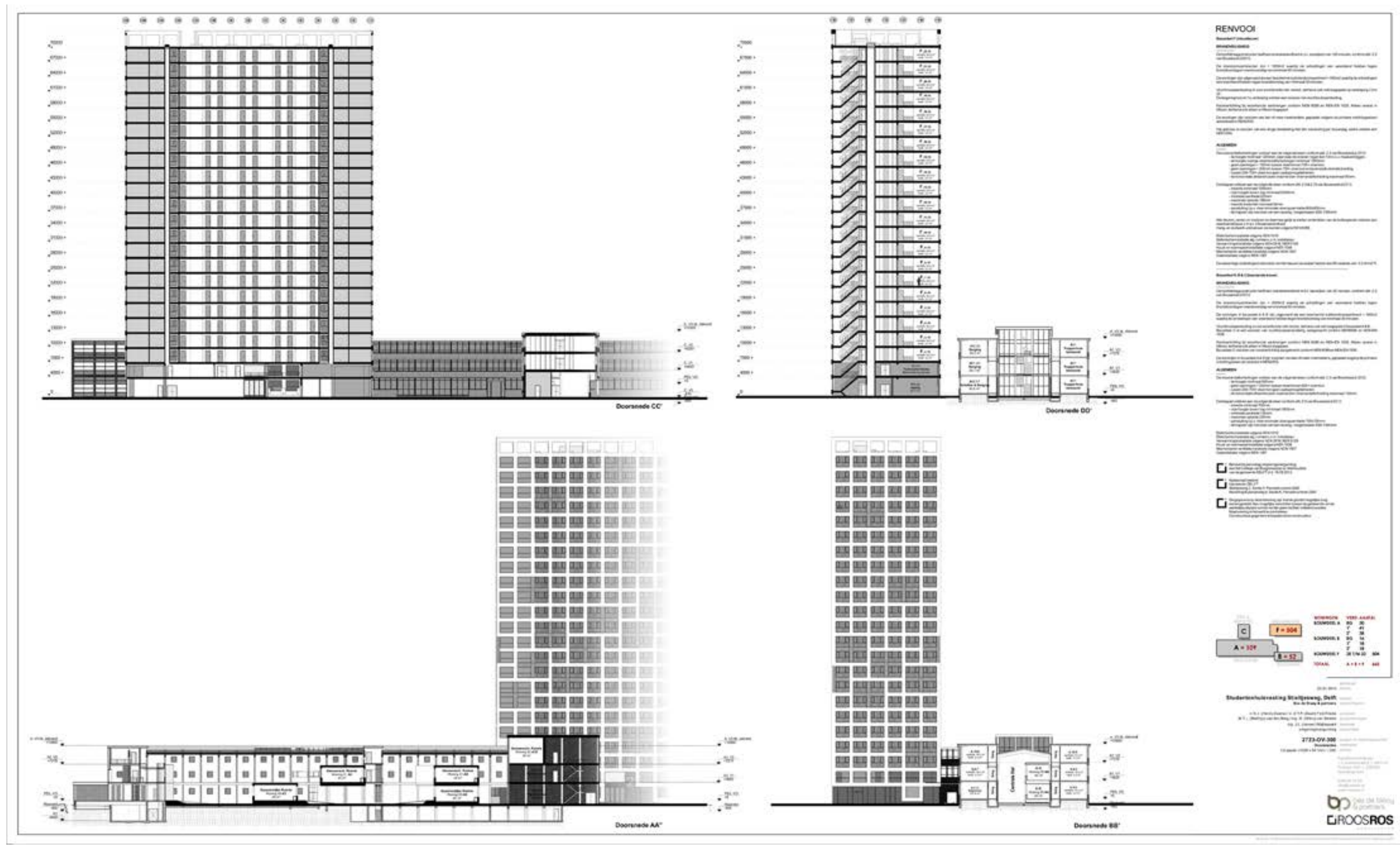


DOCUMENTS FROM ARCHITECTURAL PRACTICE

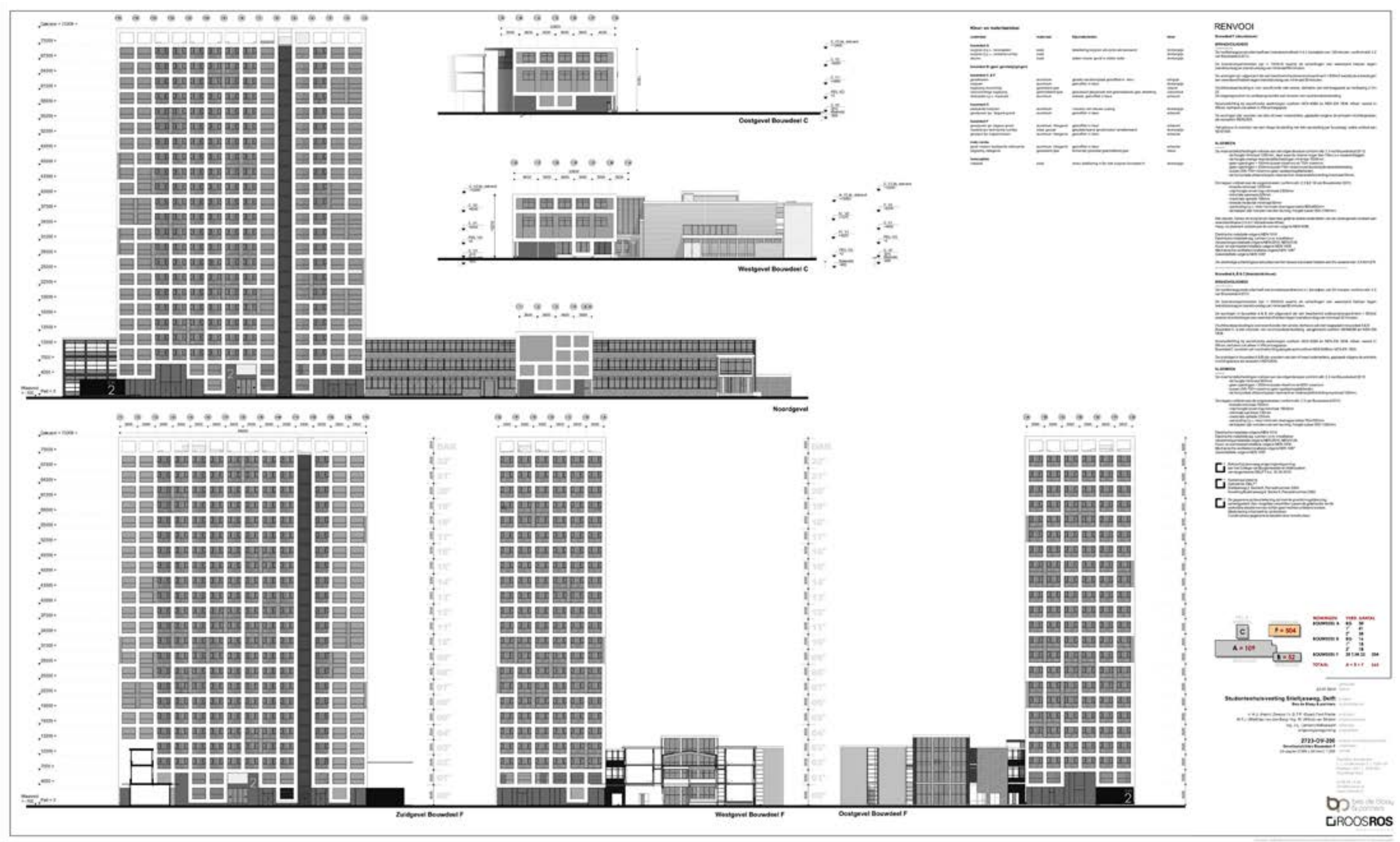
Roosros Architects



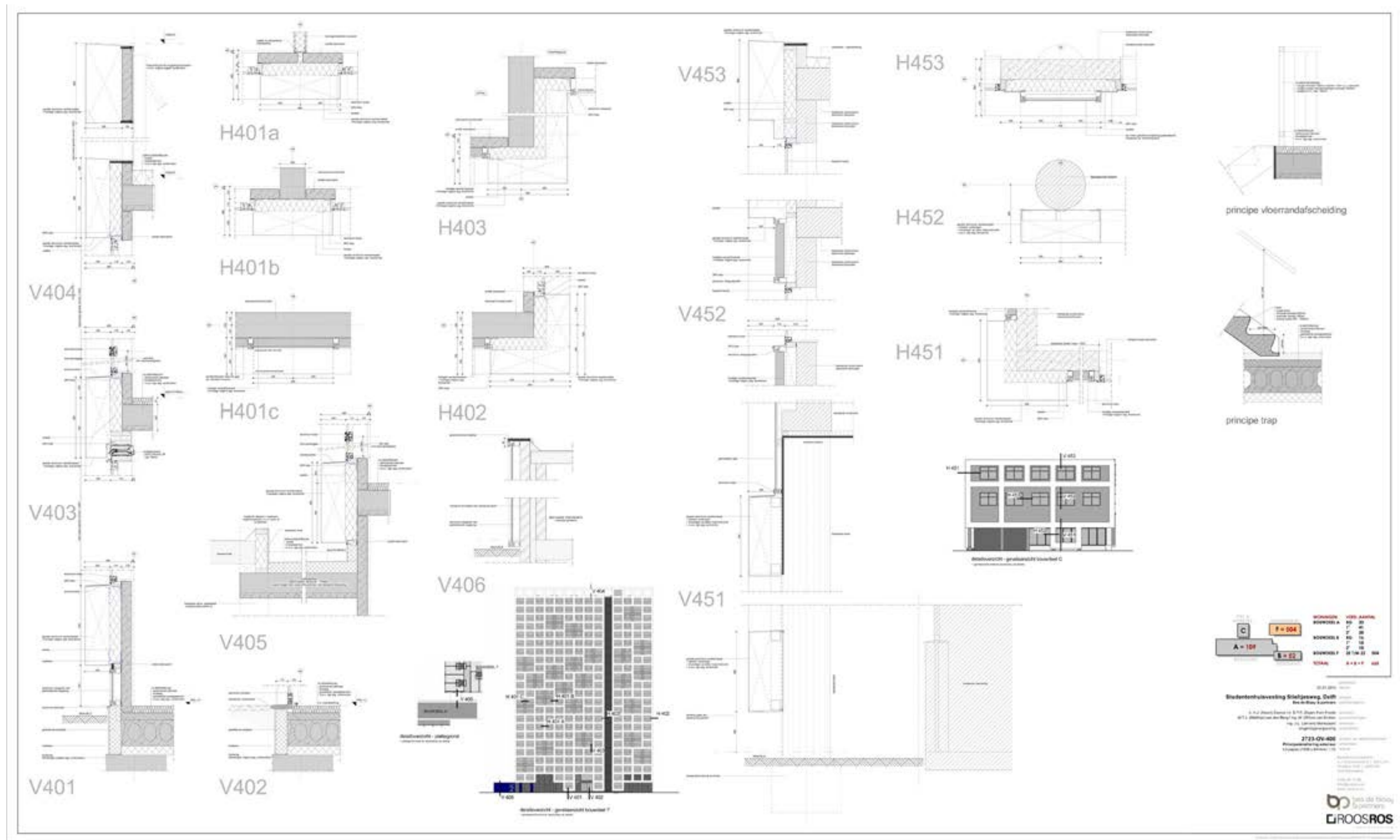
Plans



Sections

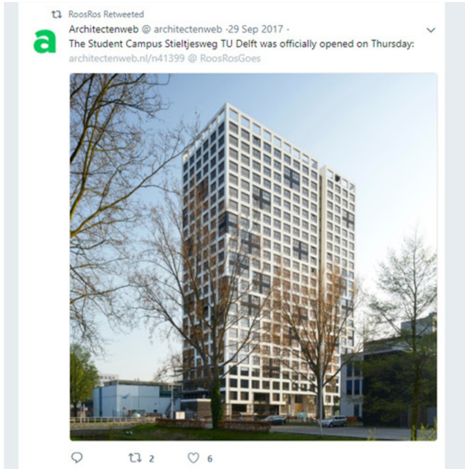


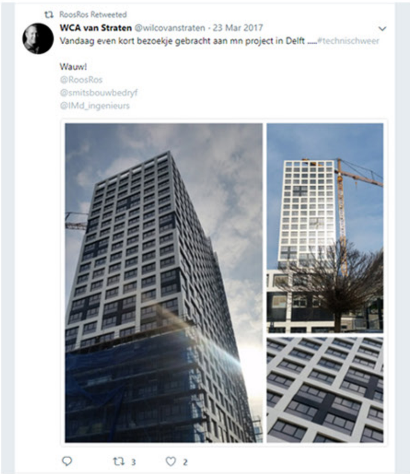
Elevations

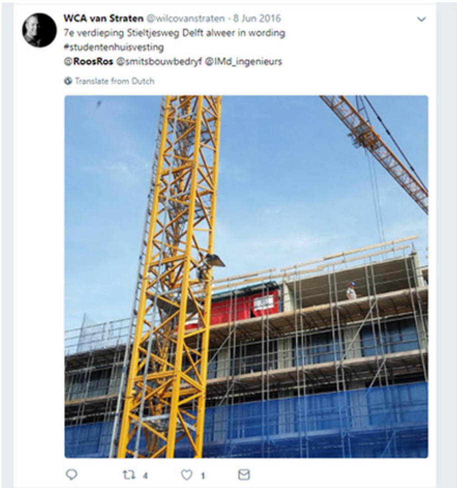


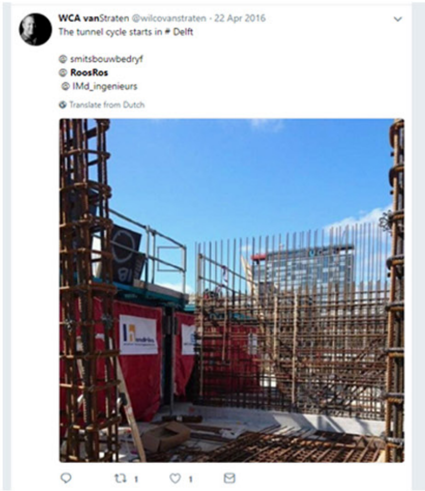
Details

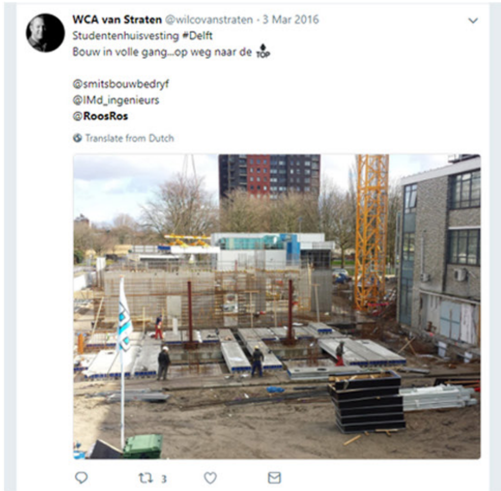
Roosros Architects twitter profile



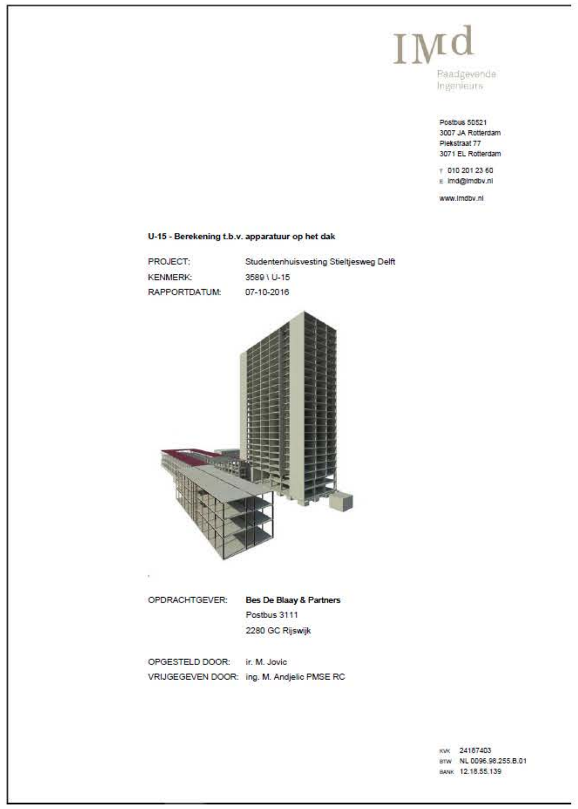


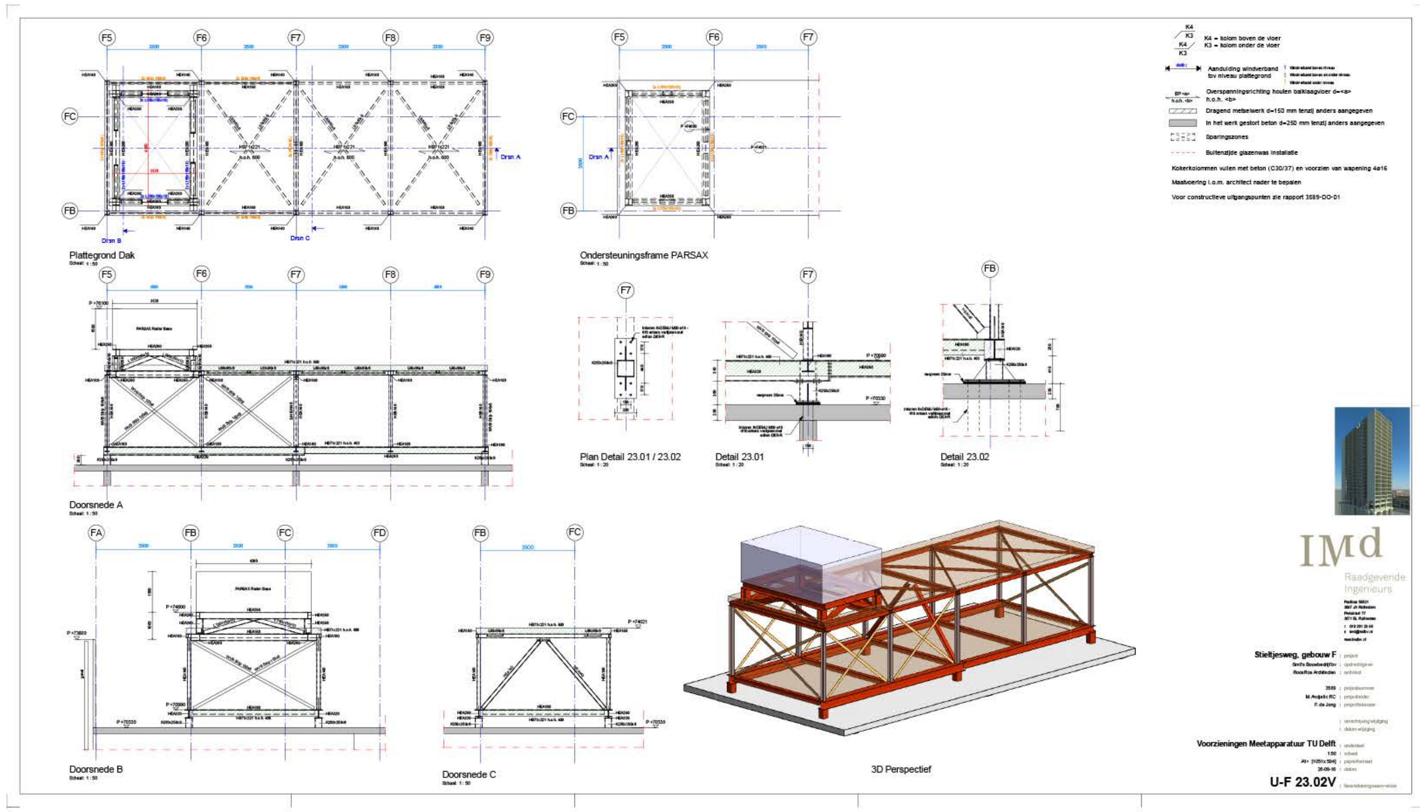


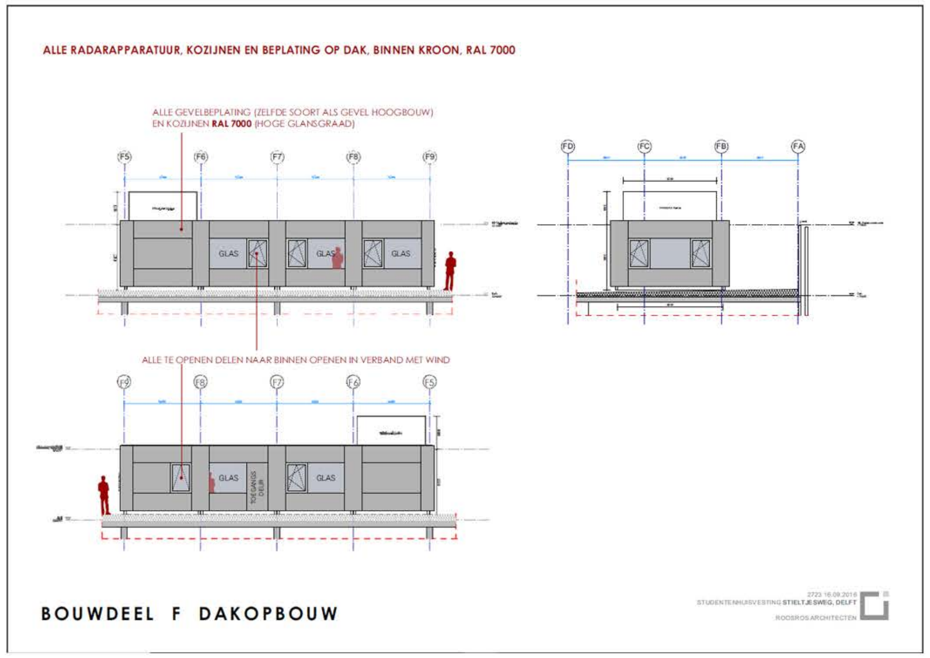


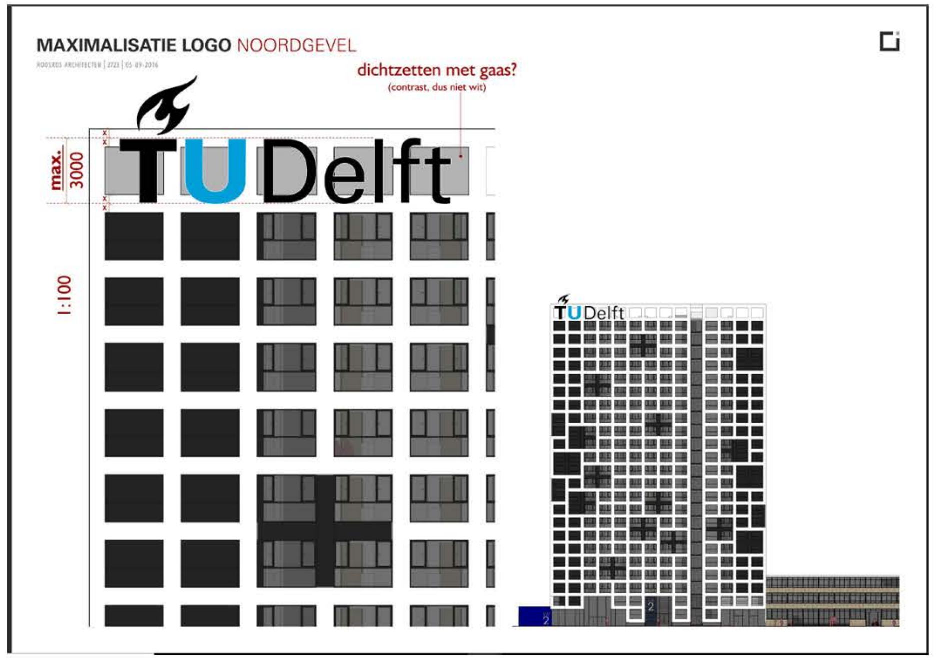


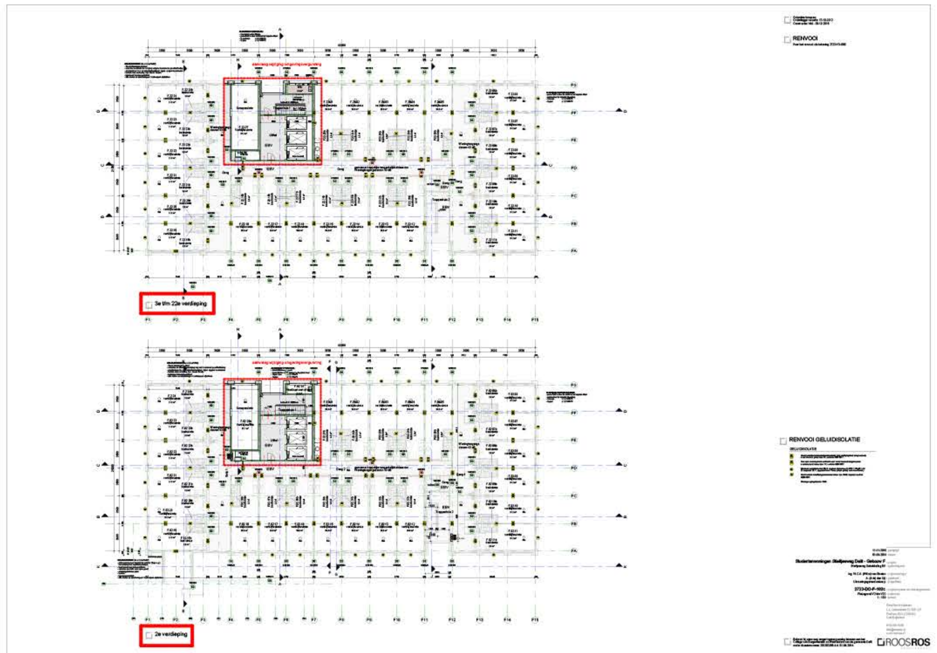
Source: https://twitter.com/RoosRos
https://twitter.com/RoosRosGoes


U-15 - Berekening t.b.v. apparatuur op het dak
PROJECT: Studentenhuisvesting Stieltjesweg Delft
KENMERK: 3589 \ U-15
RAPPORTDATUM: 07-10-2016
OPGESTELD DOOR: ir. M. Jovic
VRIJGEGEVEN DOOR: ing. M. Andjelic PMSE RC

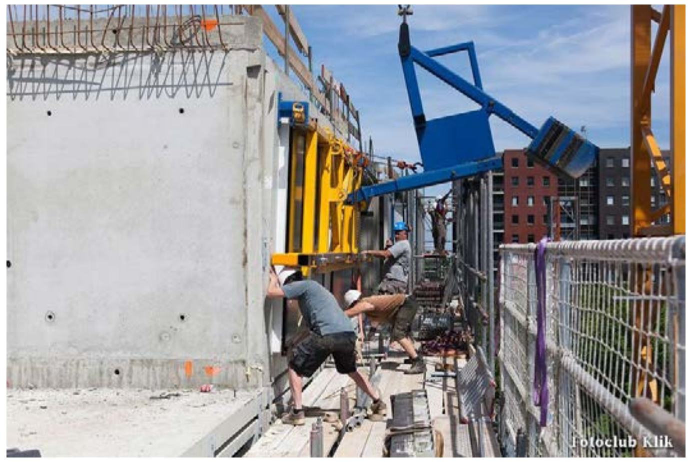

Plattegrond Dak
Ondersteuningsframe PARSAX
Doorsnede A
Doorsnede B
Doorsnede C
3D Perspectief
U-F 23.02V

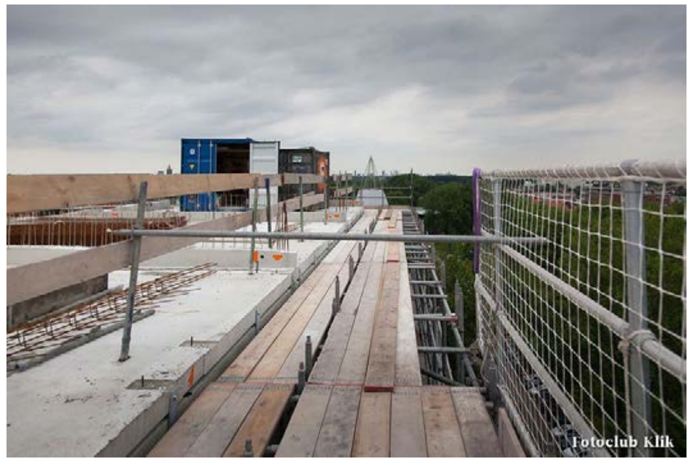

ALLE RADARAPPARATUUR, KOZIJNEN EN BEPLATING OP DAK, BINNEN KROON, RAL 7000
ALLE TE OPENEN DELEN NAAR BINNEN OPENEN IN VERBAND MET WIND
BOUWDEEL F DAKOPBOUW

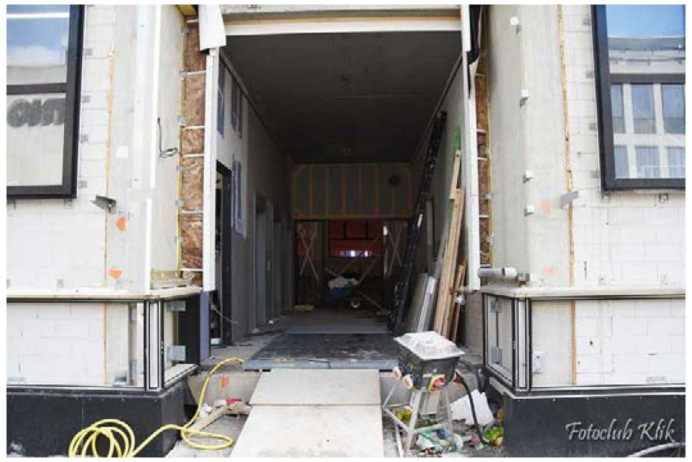

MAXIMALISATIE LOGO NOORDGEVEL
dichtzetten met gaas?
(contrast, dus niet wit)
max. 3000
1:100
TUDelft



OTHER RESOURCES: CONSTRUCTION PHOTOGRAPHS



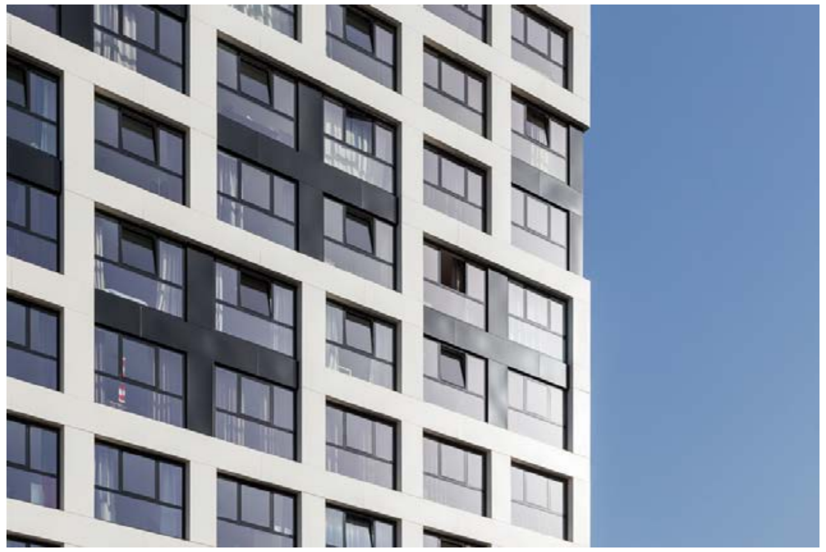


Source: https://fotoclubklik.nl/fotos-tu-delft/wppaspec/oc1/lnnl/cv0/ab14#wppa-container-1

Alkondor Hengelo supplier of window frames

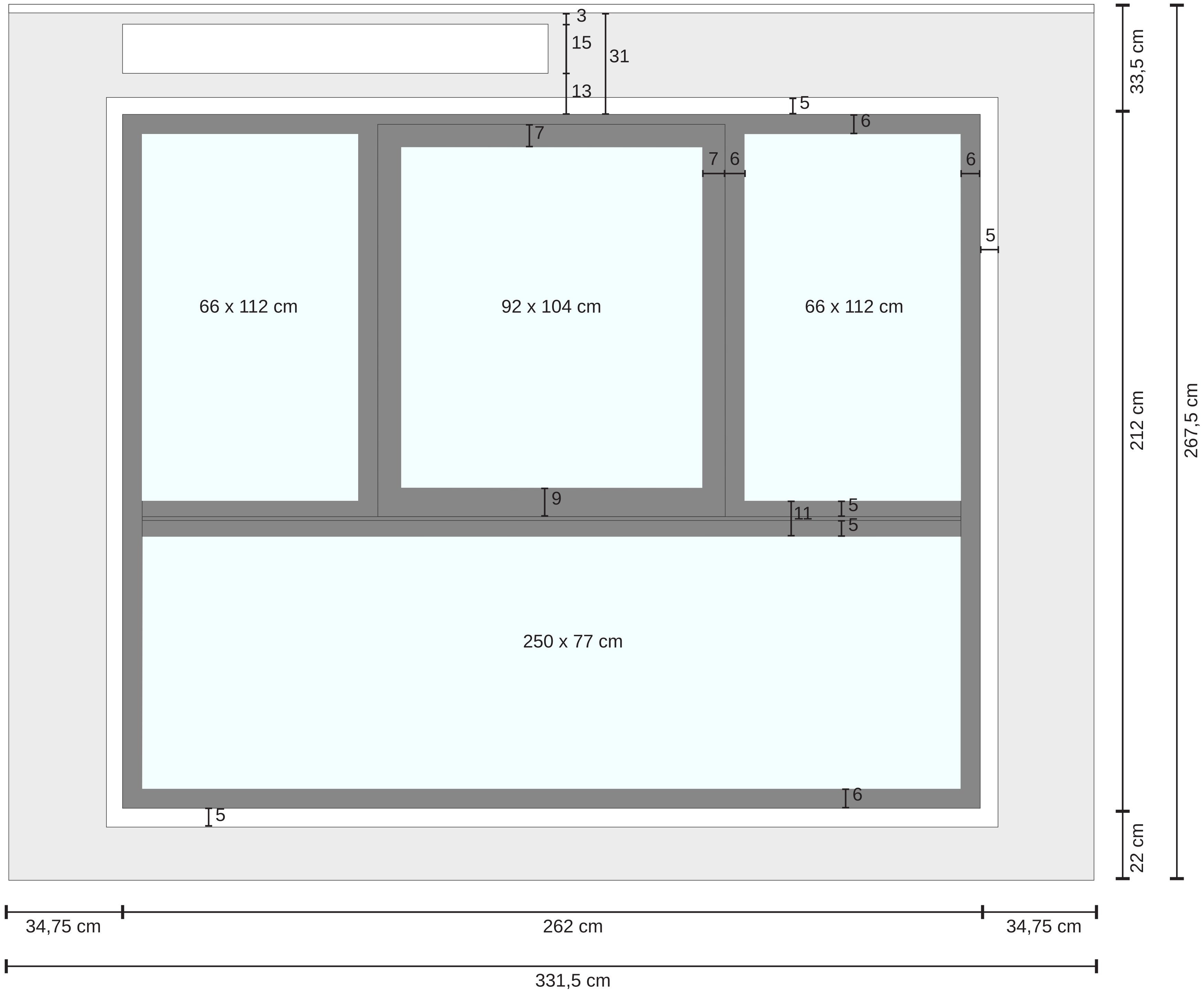
Commissioned by Smit's Bouwbedrijf in Beverwijk, Alkondor Hengelo supplies and assembles the window frames and curtain walls for the 70-meter high new-build tower. The tower accommodates 504 student apartments.

The majority of the window frames are built into the supplier of the concrete façade elements. Logistics offers great benefits. On the one hand, the use of the crane is minimized and on the other hand the building is quickly wind and watertight so that the reduction can start soon. Various facilities are to be found in the plinth of the new building, such as a campus store, a small department store, a coffee corner, a student café and a medical practice.



Photographs from: http://www.alkondor.nl/projecten

OTHER RESOURCES: ON SITE MEASUREMENTS

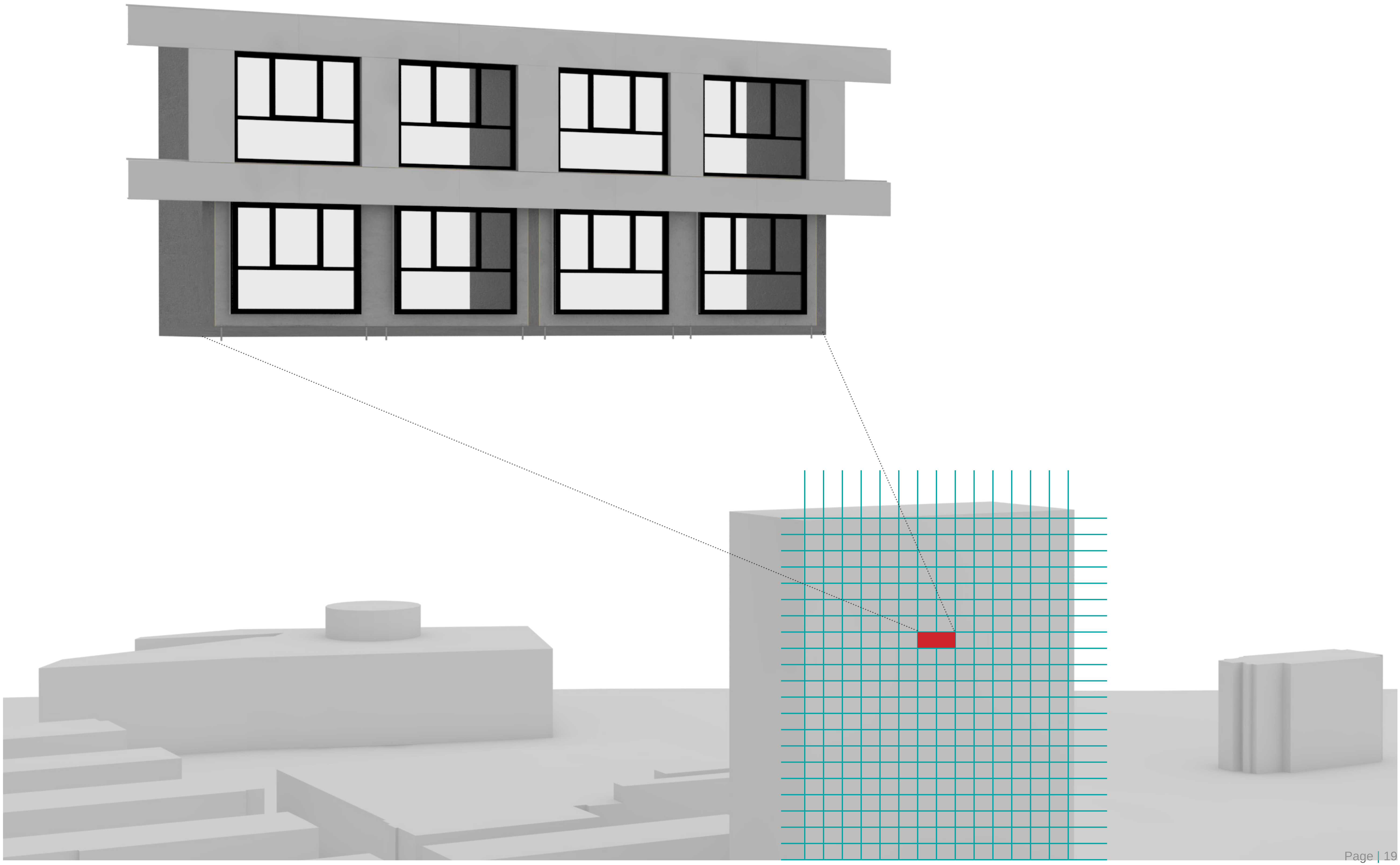


Since the drawings we got from the municipality and the architectural office seemed a lot different from the actual situation, we decided to measure in one of the rooms. It helped us with making the Rhino model and calculations for the structure.

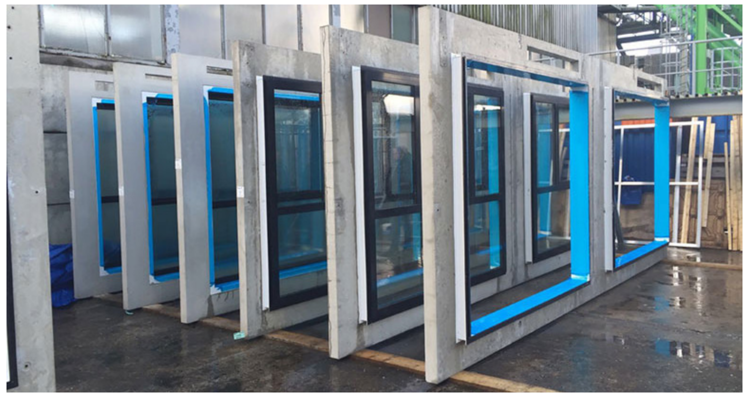
From the inside this was easy, because we were able to enter a room. But for the outside it was a bit more difficult, since the ground floor does not have the same measurements as the levels above, so we had to make assumptions for those measurements.

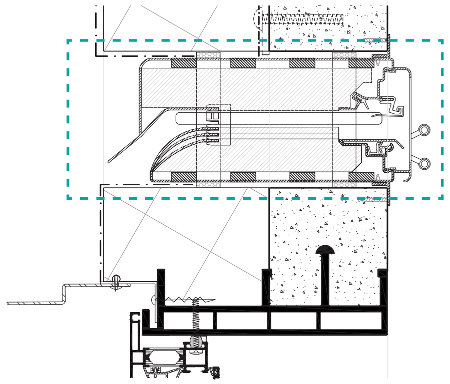
Julia measuring the window frames

CHOSEN FRAGMENT

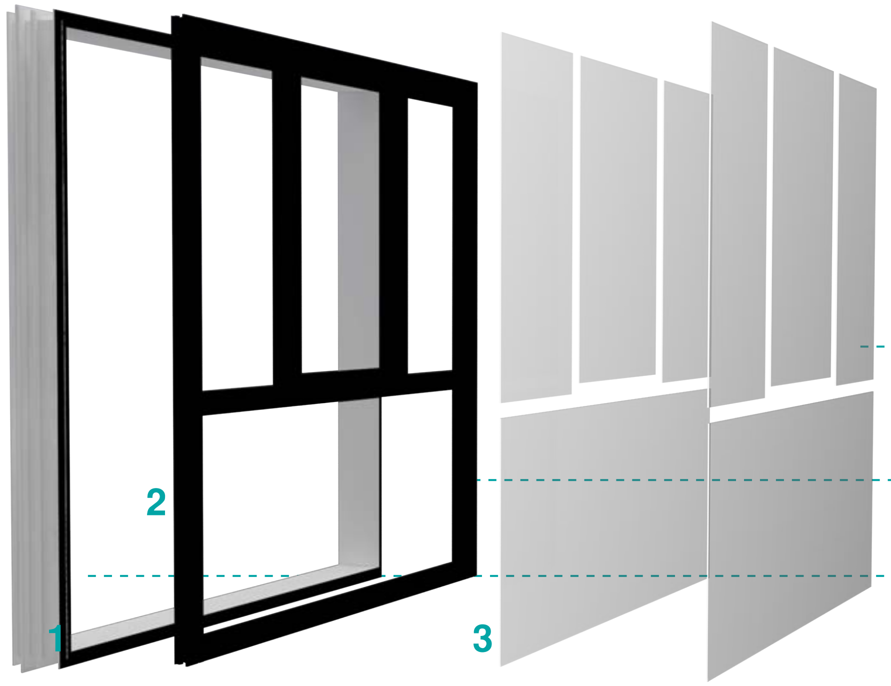


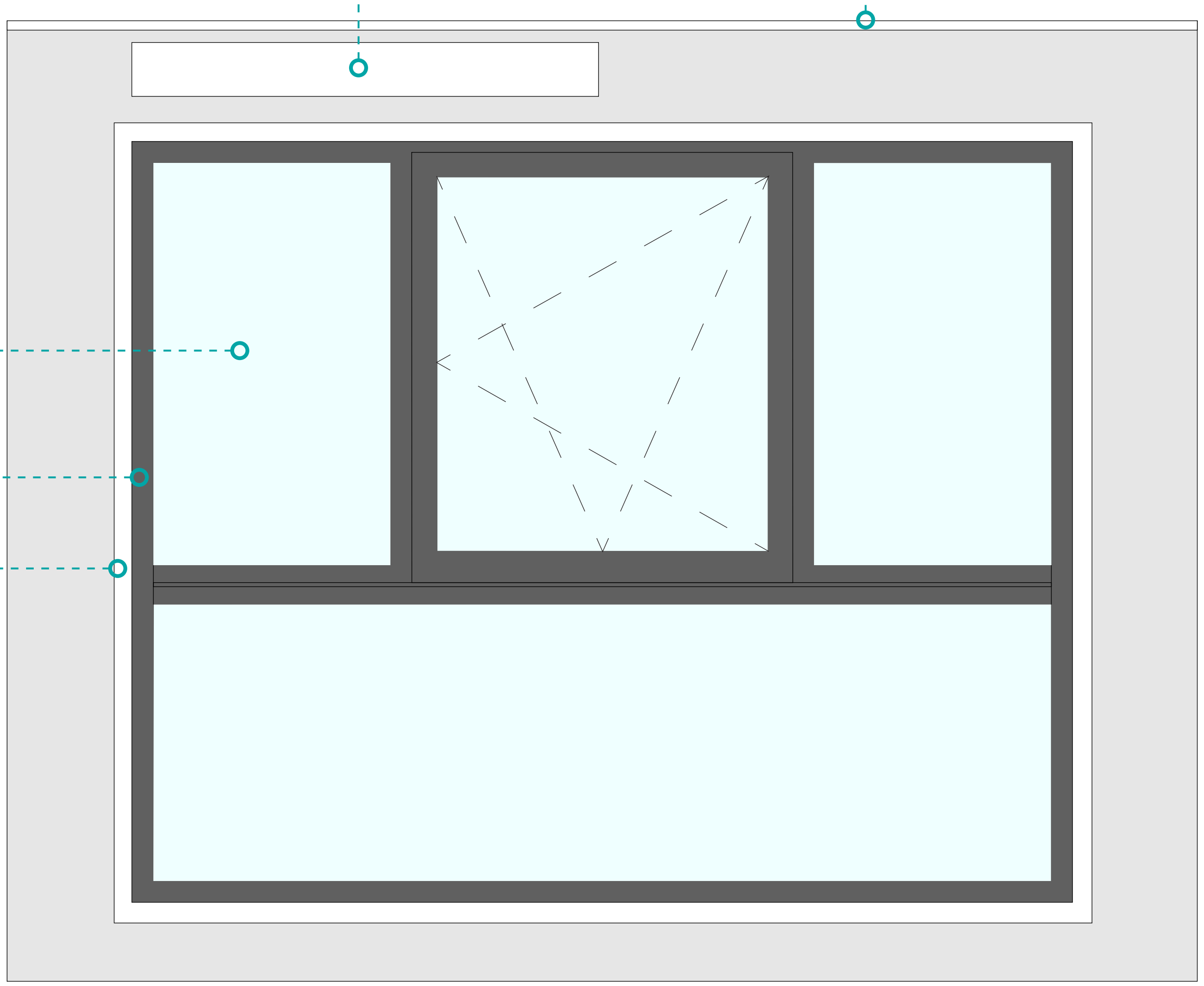
Prefabricated Components of the facade

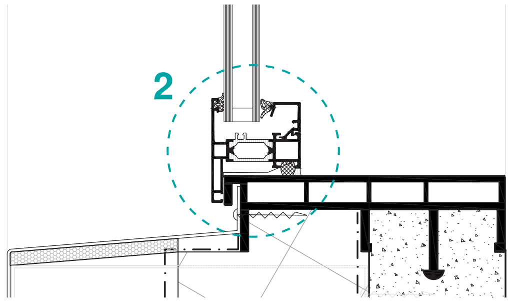

Prefabricated concrete panel[1]


Opening for ventilation vent


Hard plastic element with rails milled into the surface, used to hang the curtains, installed later on.



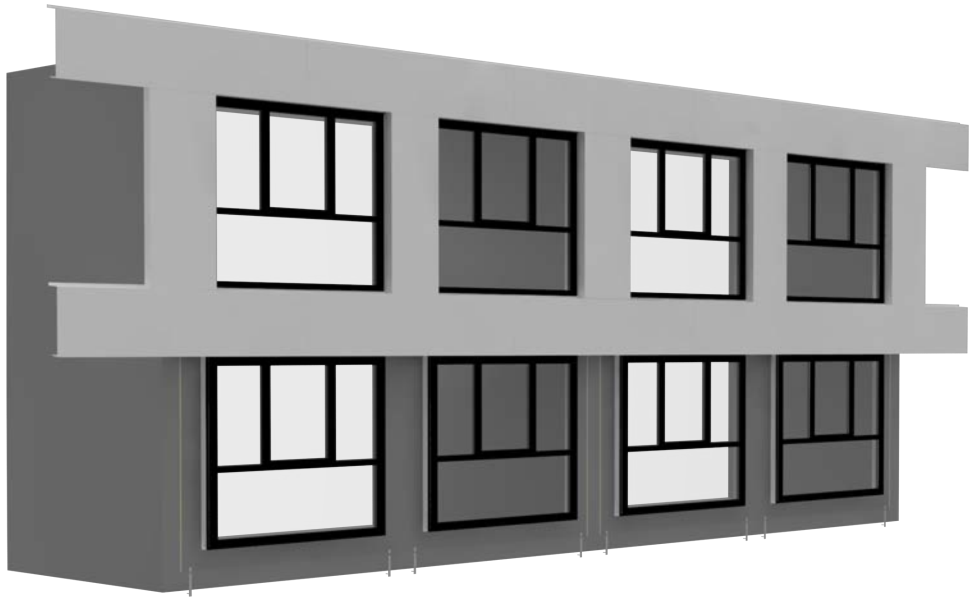


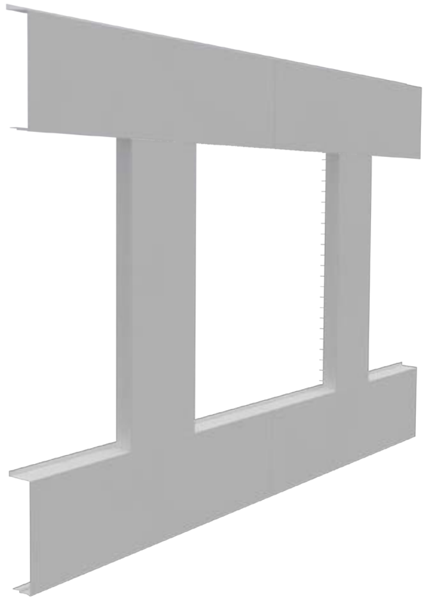


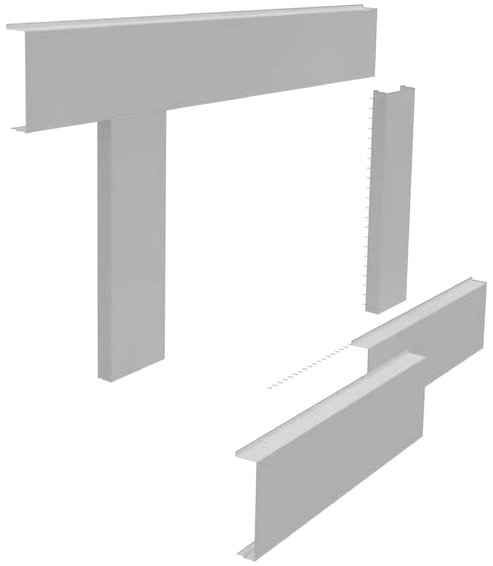
1. Glass Fiber Reinforced Polymer
2. Aluminum Window Frame, extrusion profiles
3. Double glazing. The window in the middle (top row) is used for natural ventilation in each housing unit.

[1] Source: http://www.gevelbouw.info/doorlooptijd-verkorten-met-geintegreerde-stelkozijnen-en-stelkaders/

Aluminium Composite Panels

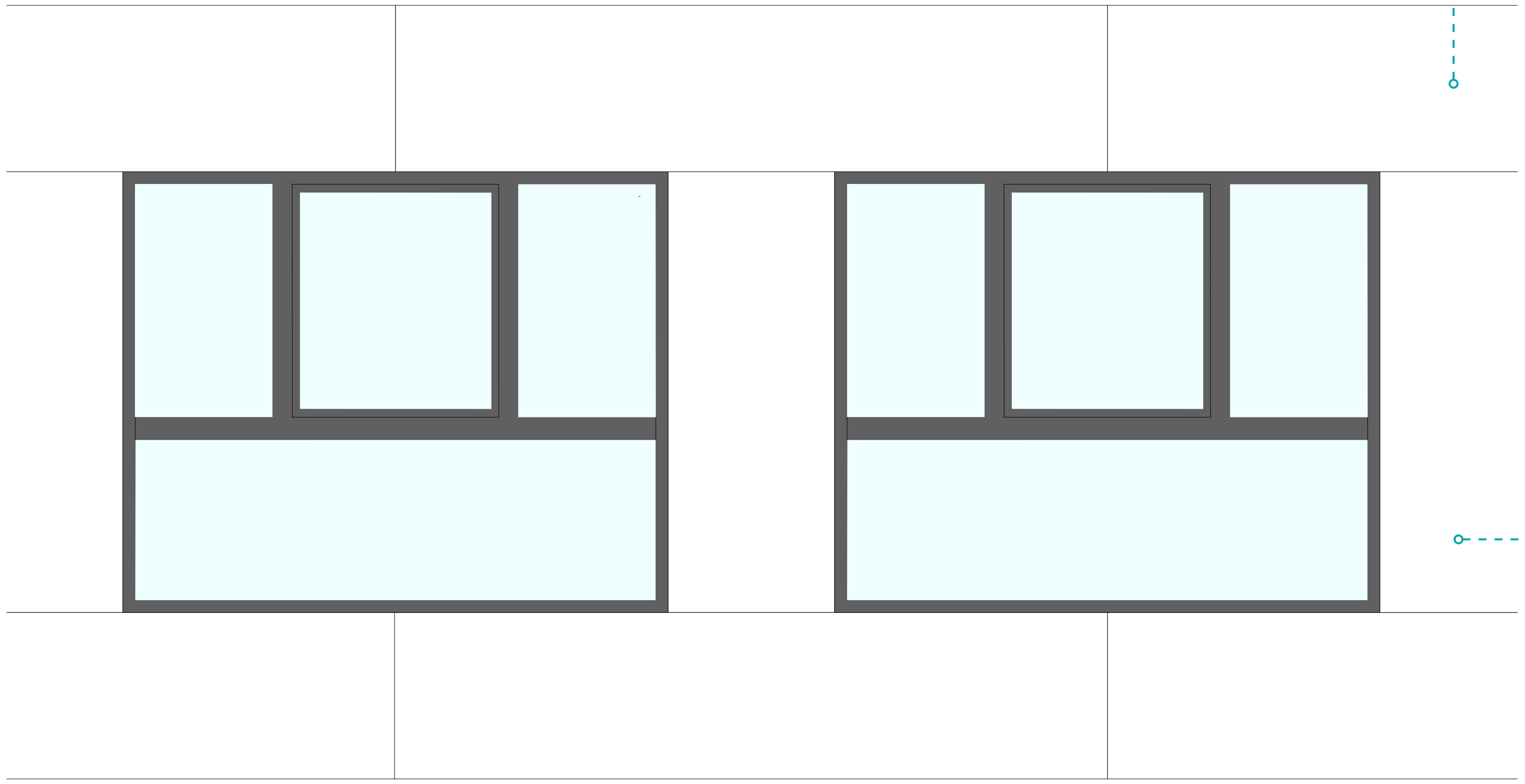


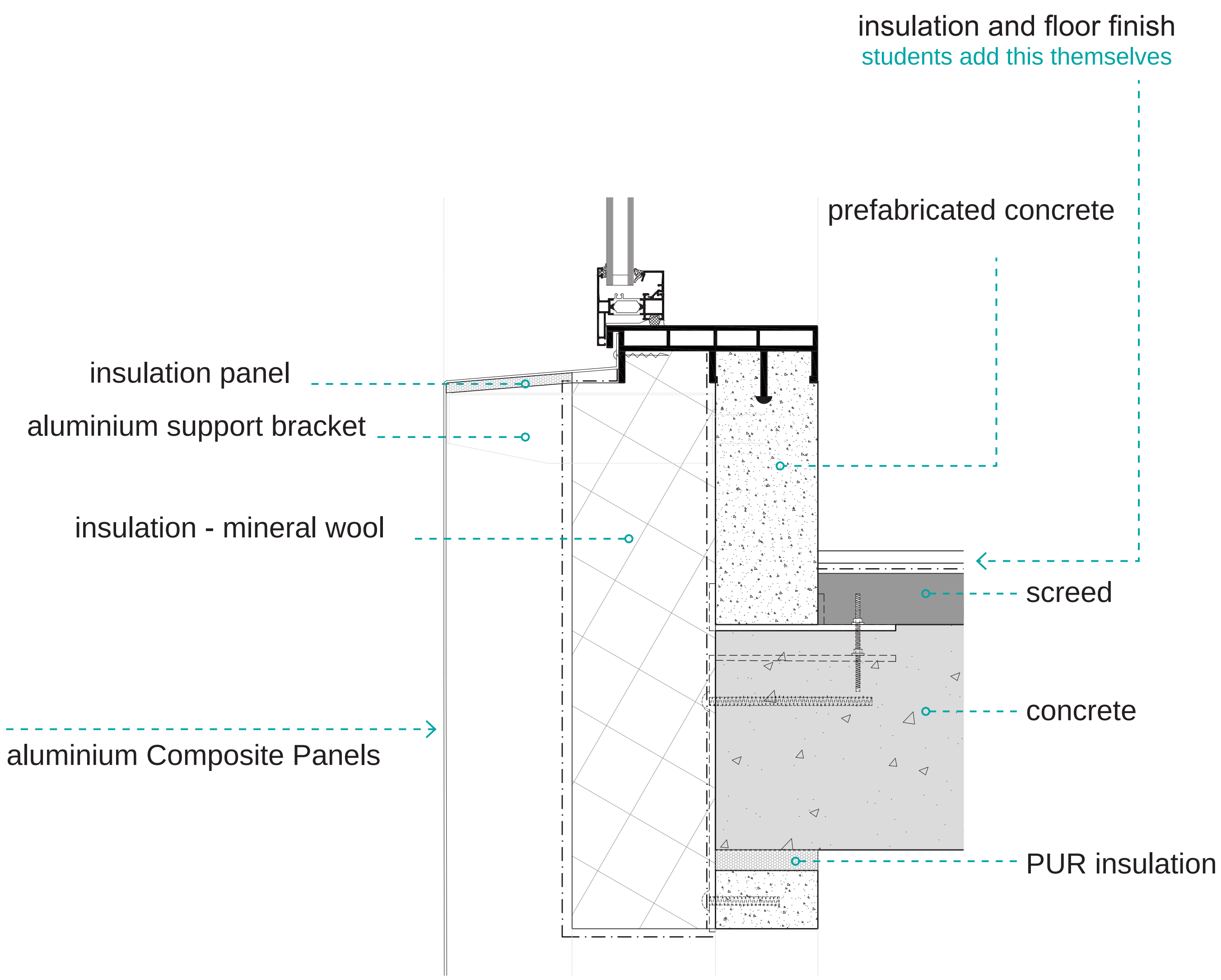




Students have to finish their own rooms, in this case the walls were finished with paint and a laminated floor was

The horizontal panels are bigger than the vertical panels.
We estimated the sizes of the panels as follows:
Horizontal panel: ~ 80 x 342 cm
Vertical panel: ~ 212 x 80 cm





Glass Fiber Reinforced Polymer

The complete facade system of the building can be considered innovative in terms of design, detailing and assembly.
The building components were designed to reduce construction time. This resulted in per-fabricated facade components that were prepared in a factory and 'fit-in' on site.
The per-fabricated panel consist of the whole window system embedded in a concrete wall.
The most innovative part of the panel itself is the mounting frame on top of which sits the aluminium window frame. Initially, the concrete panel is cast around the mounting frame. When this process is complete the aluminium frame of the window is bolted on this mounting frame.

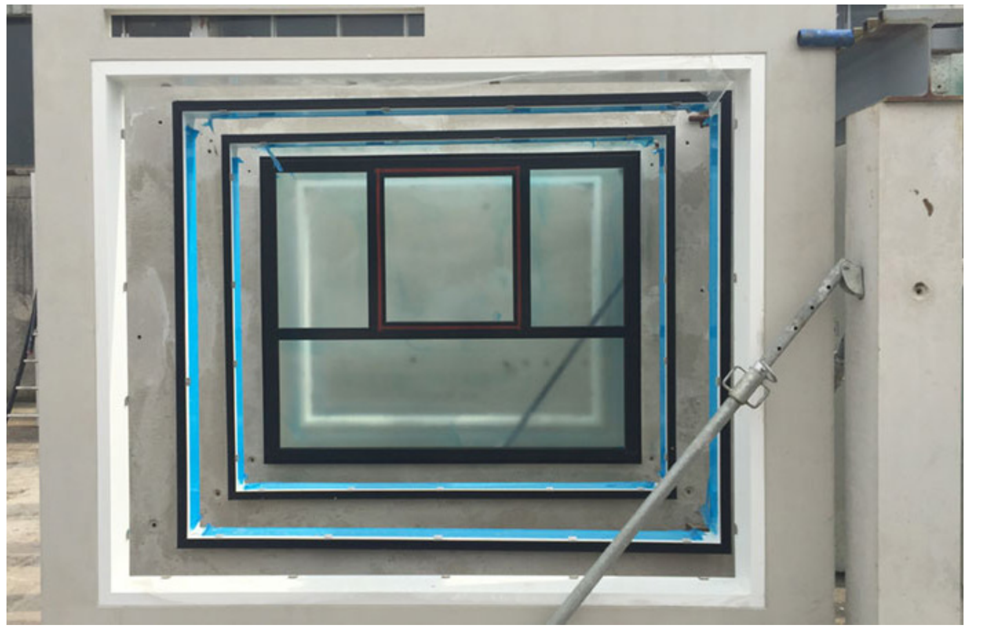
It is the most critical member of the facade system as it needs to strong enough to carry the oncoming load of the concrete. A steel profile would work well for this purpose. But a steel member would mean a direct thermal bridge between the indoor to outdoor. Thus the material of the element should be thermally insulating. Since the profile is embedded into the concrete, it should have a thermal expansion coefficient similar to concrete otherwise the system will fail.
These criteria lead to choosing GRP (glass fibre reinforced polymer) as the suitable material for producing this profile. It has high value of young's modulus and has a thermal expansion coefficient similar to concrete.

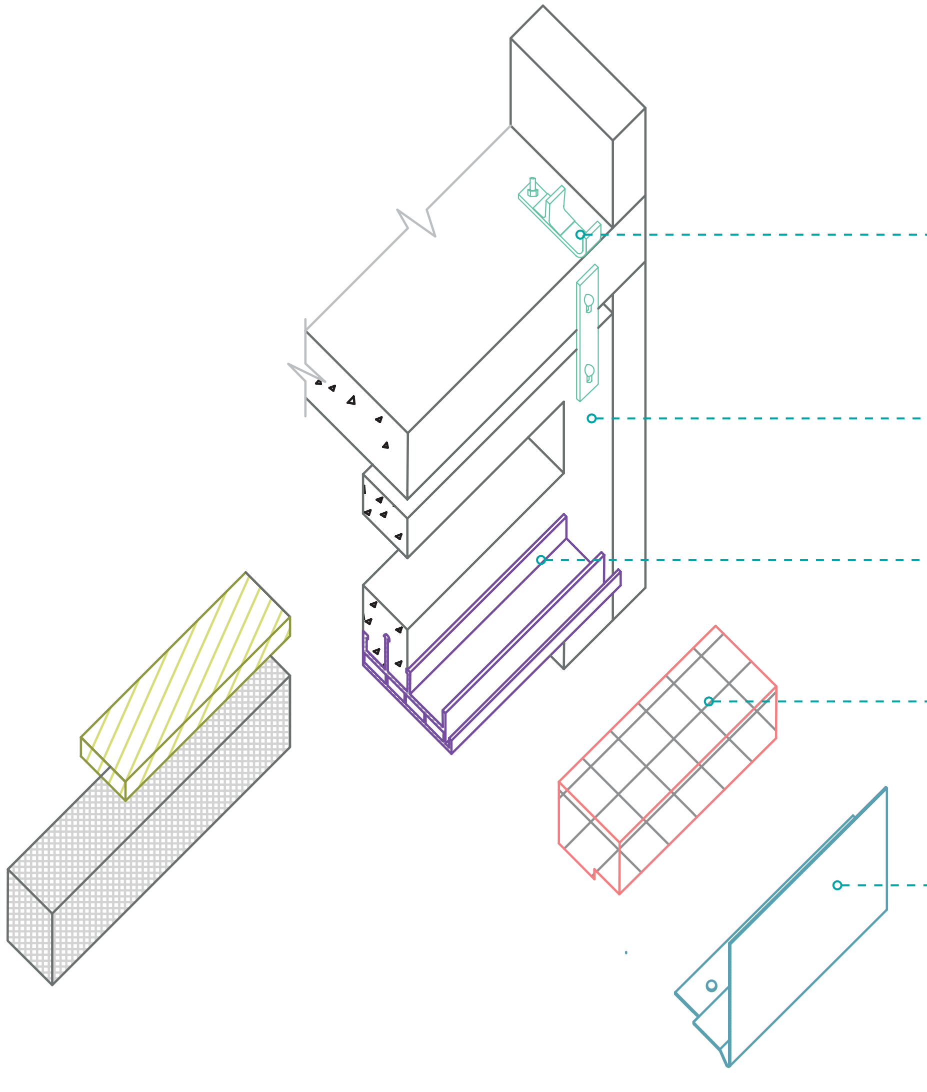
The section has PVC foam in the centre and the GRP on the outside. The member also has a finishing laminate layer of coex in black and white colour.

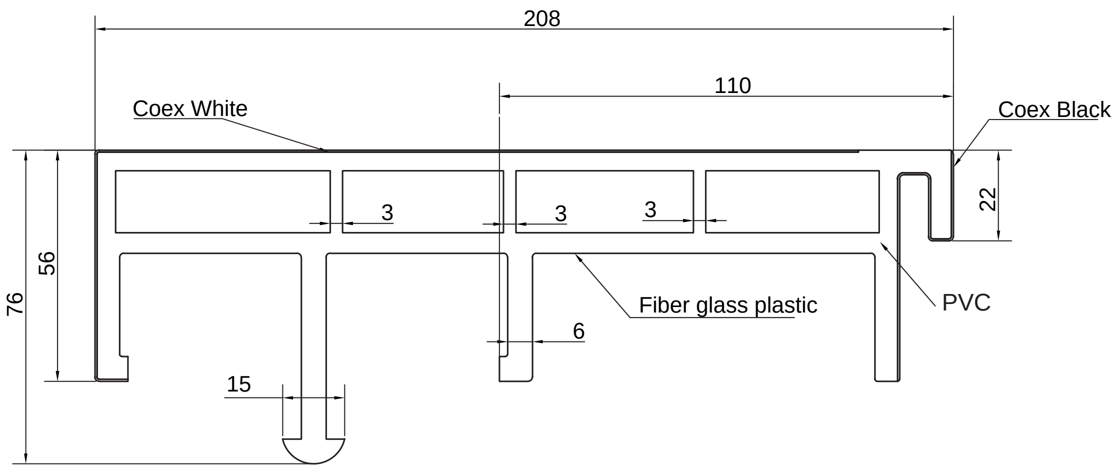
$e_{\text{concrete}} = 13 - 14 \times 10^{-6}\ K^{-}$

$e_{\text{GRP}} = 15 \times 10^{-6}\ K^{-}$

* The actual thermal expansion coefficient of the GRP depends on the particular composition which is unknown to us but we can assume that is even closer than our general rule of thump value.

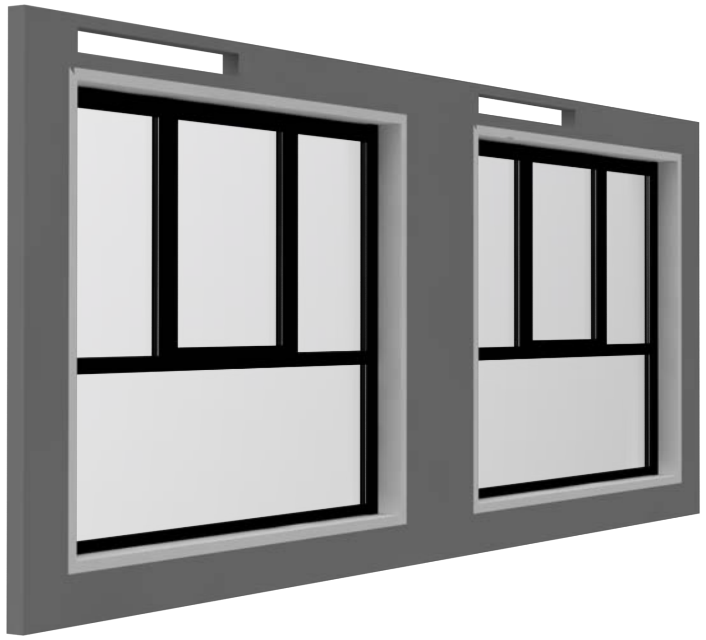




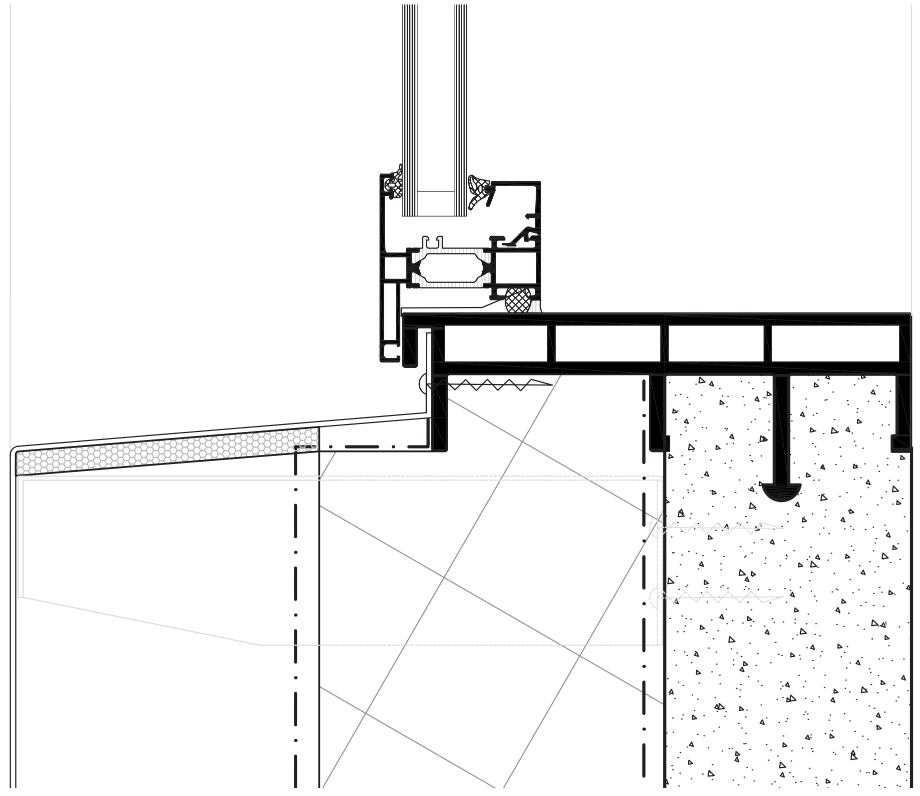


GRP composition

exterior view



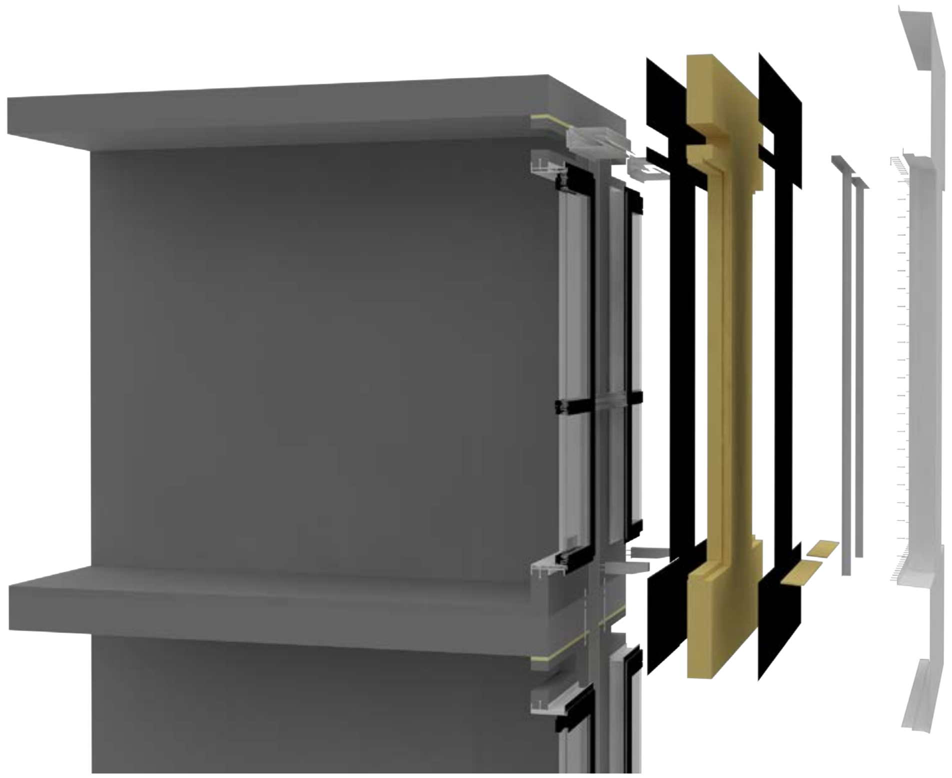
interior view



2D detail

3D detailed view

Facade Elements



The student housing at stieltjesweg was constructed on a short timeline which lead to the prefabricated construction of the structural elements. The main structure is load bearing with concrete walls and floor slabs. A pre-cast facade panel is composed of 2 window units cast in concrete with a window to wall ratio of 60%. The panels were fit in the main structure and rest on two support brackets on either side of the floor slab. The top of the panels were bolted to the slab of the upper floor by an L- angled bracket whose perpendicular edge is embedded in the concrete of the slab for added strength.
Once the panels were in place, a layer of mineral wool insulation was added to the exterior surfaces. A permeable vapour barrier layer was applied on top of the insulation. The facade was finished with aluminium sandwich panels that are off-setted from the wall and attached on aluminium profiles.

Tolerances

Tolerances deal with the deviation in size of component compared to nominal dimensions and deviation in location compared to nominal position in plan and in level. These can occur during production, construction or assembly.

During construction, the chances of tolerance occurring in the structure were minimized by using pre-cast elements instead of to in situ casting where the chances of error are greater.
During assembly, the pre-cast panels had to be fitted into the main structure. The possible tolerances generated could be due to imprecise placement and positioning of the panels. Since the panels are not directly connected to another, if generated, these tolerances would be localised to a panel and would not effect the whole assembly.

In an another measure to accommodate any movements and tolerances in assembly, the panels are around 50mm shorter than the clear height between the slabs. The panels are supported on the bottom with guides on the side walls to correctly position vertically. The gap on top gives sufficient room for any adjustments.

Movements

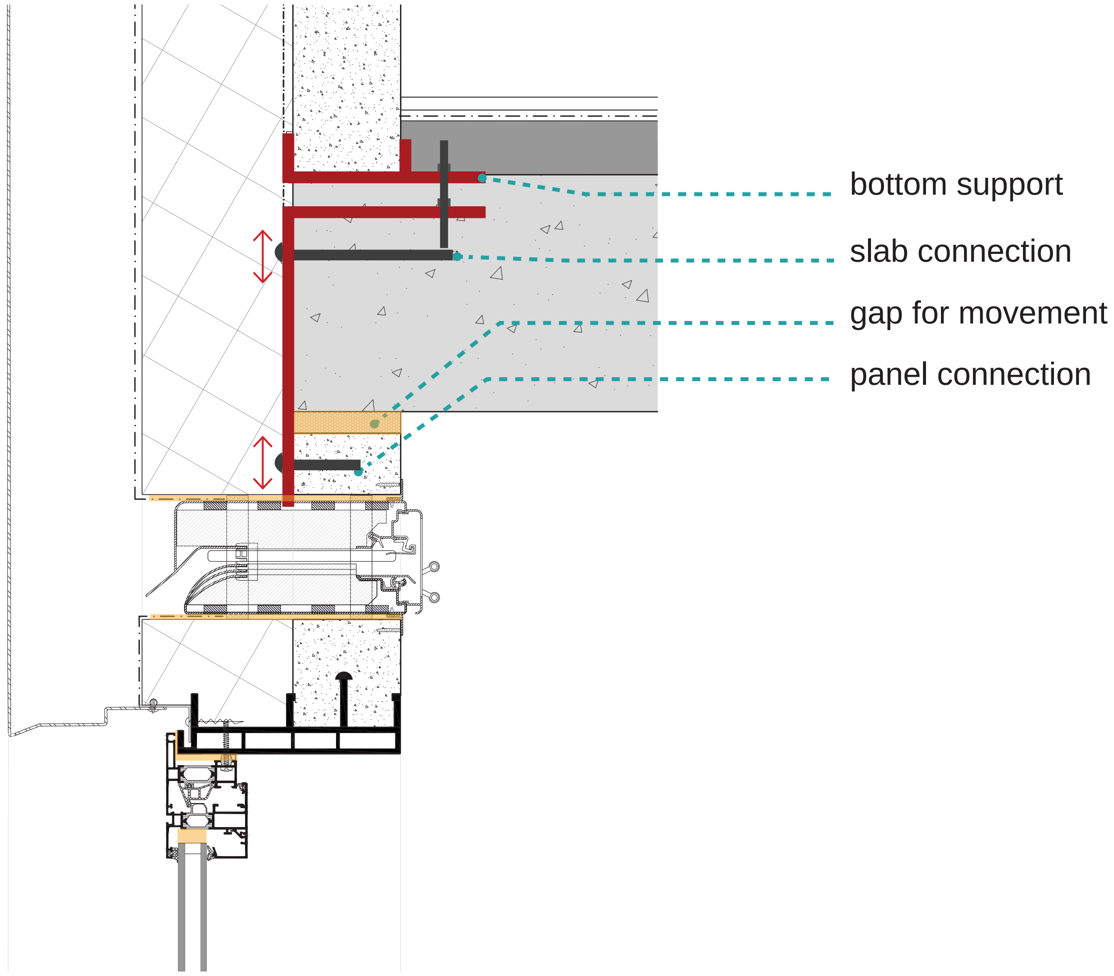
Movements are forced upon the facade panels by building structure. Causes of movement include wind sway, thermal expansion and contraction, settlement of foundations and structural deflections.

Movements in the prefabricated concrete panels
The prefabricated facade panels are supported at the bottom. Bottom-supported cladding has to accept deflection of the supporting structure and accommodate vertical movement of the beam above while it provides lateral restraint and allow lateral movement of the building in the plane of the cladding.

Vertical movement of the panels occur due to structural deflections. To allow for this, the top of the panels are fixed on the floor slab above by facade brackets that have slotted connections to facilitate movement. A gap is kept between the panel and the slab above so that there is enough space for movement.

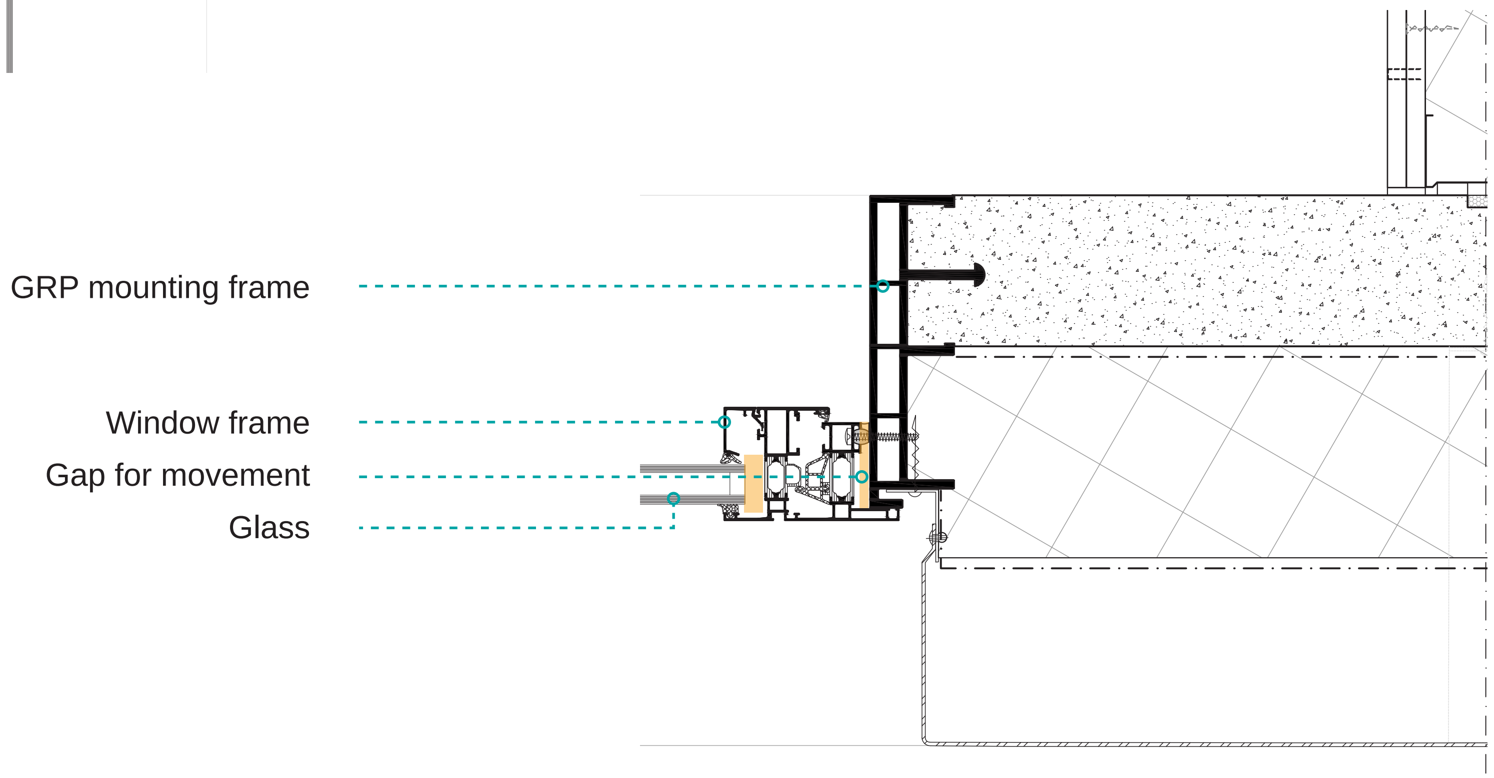
The window frame is fixed via a bolt to a GRP element that is embedded into the concrete during casting. The frame is separated from the GRP member by a cavity. This cavity can support small movements that may generate by wind or thermal expansion. The bolt connection is sealed against moisture by an assumed flexible material to allow compressions/ expansions.

A cavity is also seen between the frame that holds the glazing and glass to allow for any movements that affect the glass.



Vertical detail

3D anchor detail



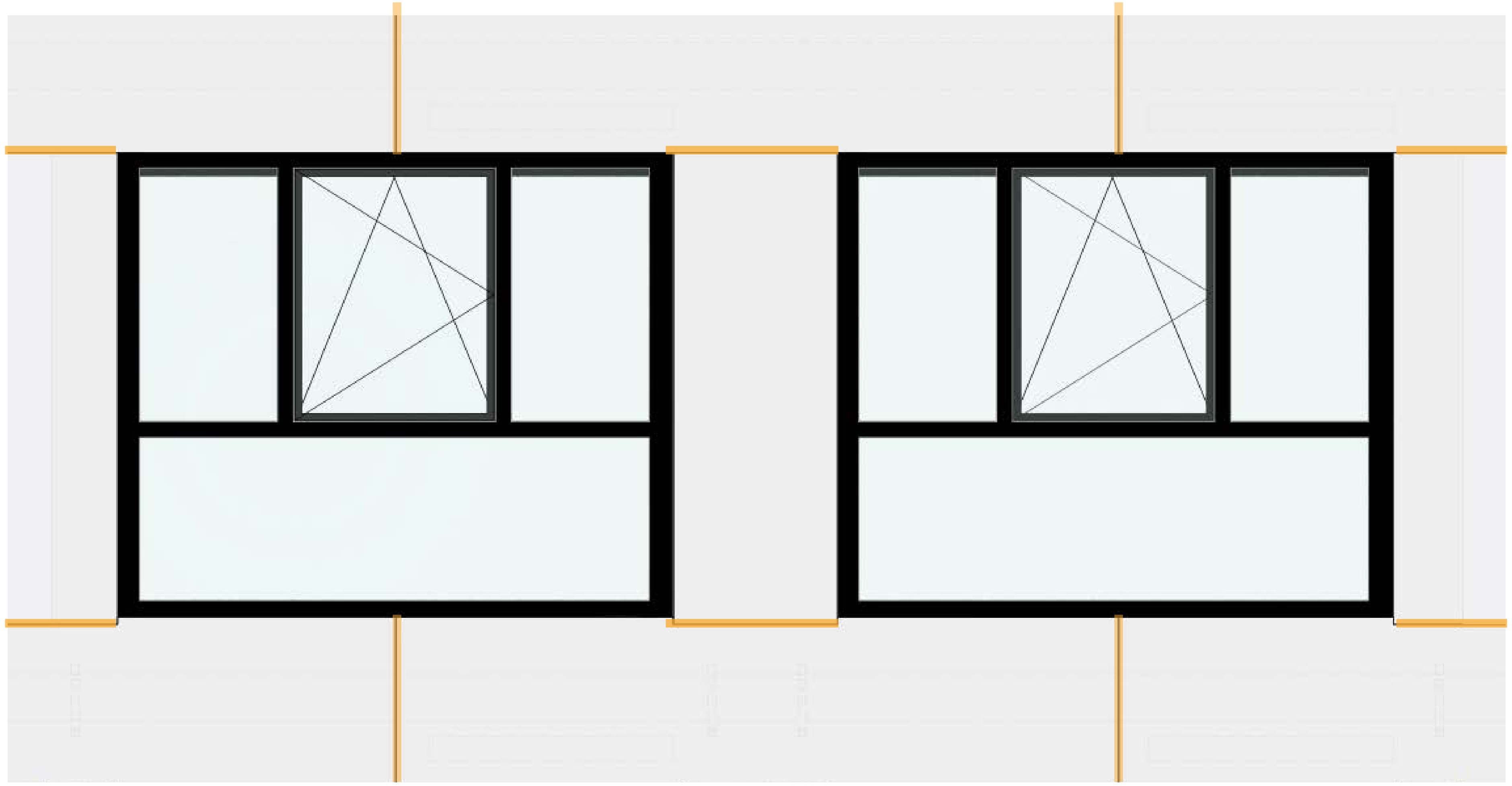
Horizontal detail

Thermal movements

All components need to be able to shrink and expand freely by change in temperature. Joints need to allow for expansion of cladding components which implies that they can only have one fixed connection point, other connections need to allow for movement, for example by using slotted holes or air gaps.

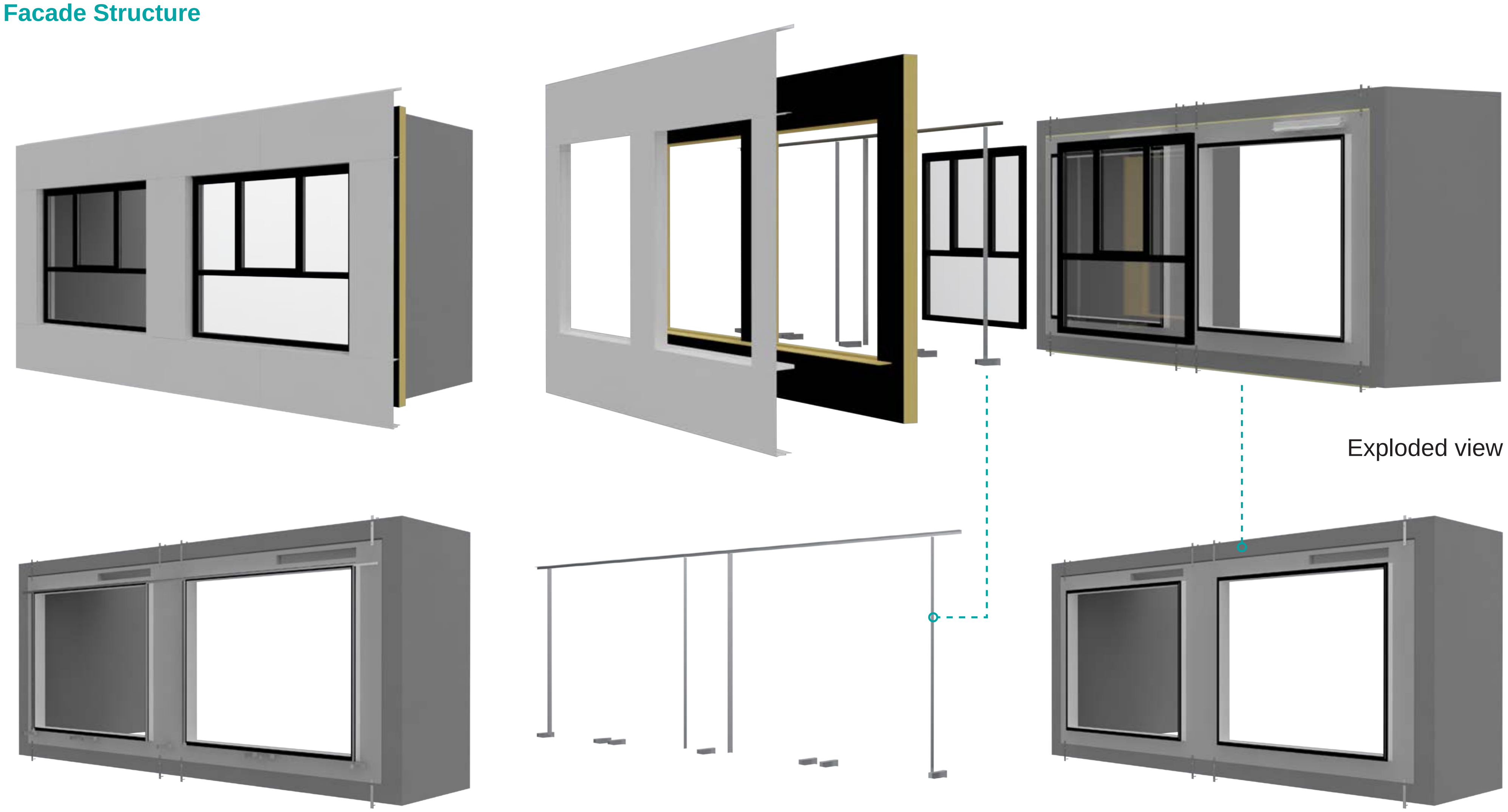
Since metals have a higher expansion rate, the exterior aluminium cladding is not directly fixed to the facade but is supported by an aluminium profile that is fixed to the concrete wall. Furthermore, there is an air gap between the insulation layer and the cladding aswell as a gap between different panels such that no panels are fixed to another.

The GRP member in the precast panel that holds together the concrete, insulation and window frame was a challenging element because it needed to be insultaing but a plastic member faced the risk of failure due to the different rate of expansion of plastics and concrete. To resolve this, GRP was chosen as the best material as it is strong, thermally insulating and has a similar thermal expasion coefficient as concrete as we have already mentioned before.



General Building Structure

Facade Structure



Structural elements of facade

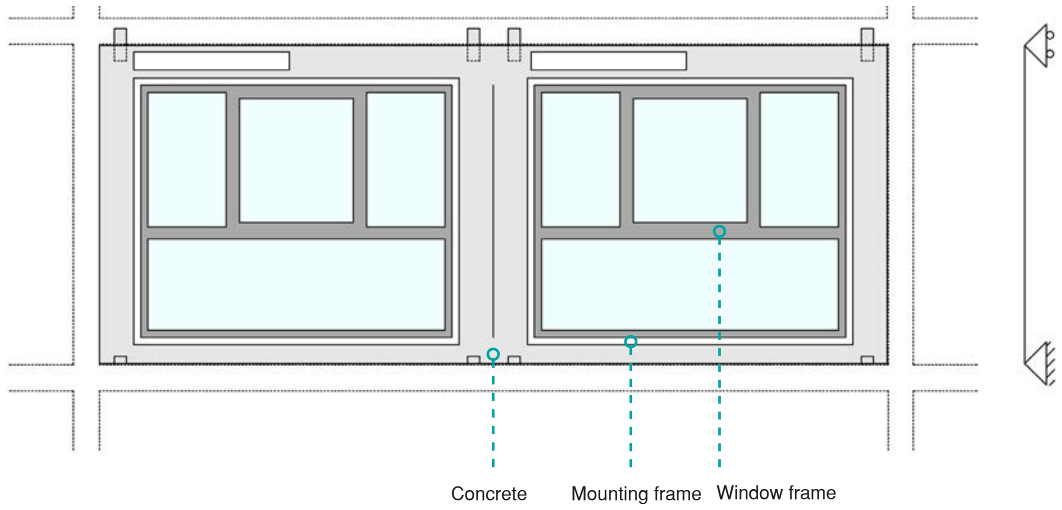
Secondary Structure

Primary structure

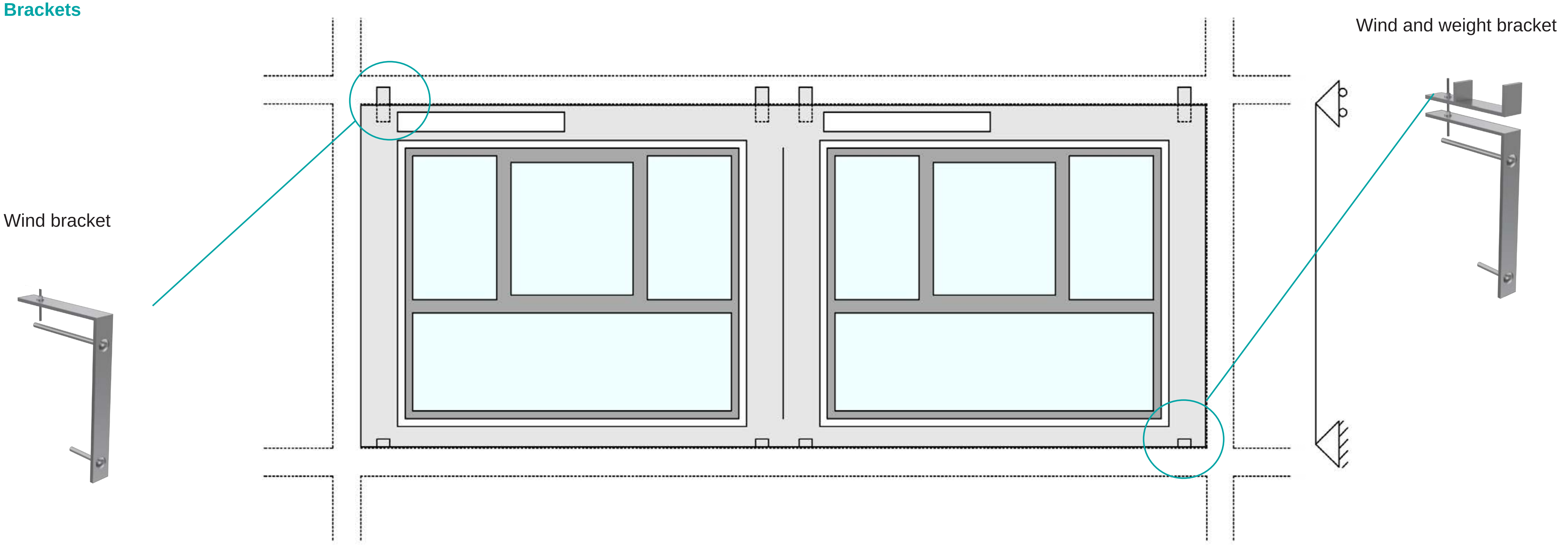
The primary load bearing structure of the building is a combination of concrete columns and load bearing walls. As shown in the image, the columns are located on the first two levels. The columns are placed here because of the huge spaces the public functions on the ground floor require. The upper levels are carried by the load bearing walls.

The horizontal forces are transferred through the planes at the side of the building. The planes in the other direction are not visible in this image. Also the elevator shafts ensure stability.

The primary structure of the facade consists of a concrete frame and a synthetic mounting frame. This concrete has a depth of 100 mm and carries it's own weight, the wind-load and the window. Each panel is attached to the main structure by eight brackets. The brackets at the bottom of the panels are weight and wind brackets, the ones at the top are wind-brackets. The wind-brackets are roll supports so they allow for movement in vertical direction which can be caused by deflections of the floor or forces within the panel.
The secondary structure comprises of aluminium facade brackets and L-shape steel profiles to carry the aluminium cladding.



Brackets



Estimation dead-weight

Material	Density	Weight
Concrete	2500 kg/m3	175.0 N
Aluminium profile	1.55 kg/m	2.9 N
Glass	2800 kg/m3	10.7 N

Dead-weight

See the table for the estimation of the dead-weight. In the table only the heavy weighted parts are present. The panels are quite heavy for a high rise facade structure because of the concrete.

Estimation wind-load

The wind-load in this location of The Netherlands with a building height of about 73 meters equals 1,44 kN/m^2.

Wind-load on one panel:

F = A x Qwind = 2,675 m x 3.315 m x 1.44 kN/m^2 = 17.74 kN

Calculated wind-load : 17.74 kN x 1.5 = 26.6 kN

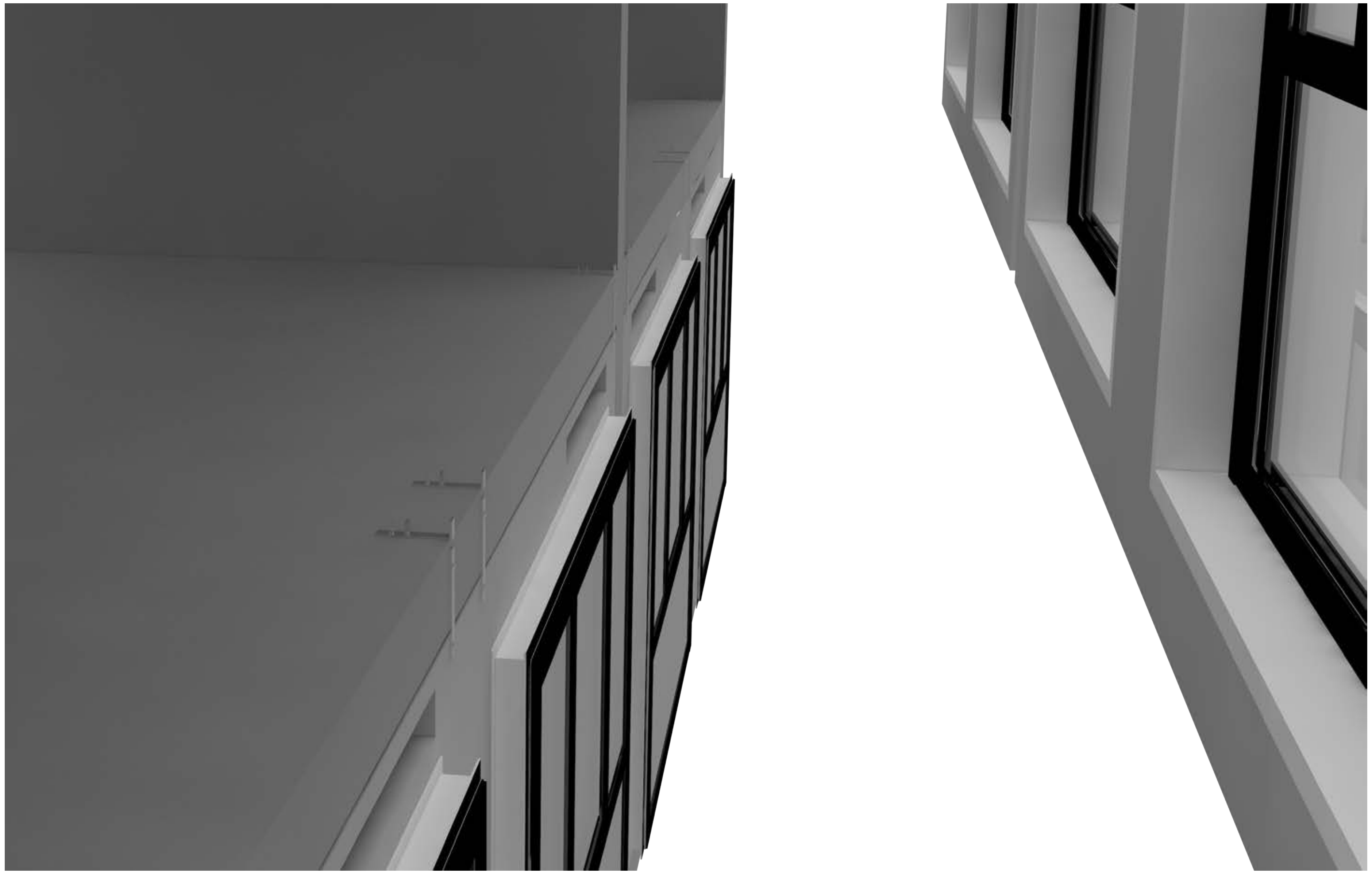
This wind-load will be transferred through eight brackets which attach the panel to the main structure. This means each bracket has to be able to transfer 26.6 kN / 8 = 3.3 kN. This value is quite low so we can be sure the brackets are sufficient.

NEN-EN 1991-1-4+A1+C2:2011/NB:2011 nl

U - value Facade

Material	Thickness	Conductivity	Resistance (R)
Inside surface	-	-	0.130 K m²/W
Concrete	0.100 m	2 W/m K	0.050 K m²/W
Rockwool	0.140 m	0.033 W/m K	4.242 K m²/W
Cavity	-	-	0.160 K m²/W
Aluminium cladding	0.025 m	205 W/m K	-
Outside surface	-	-	0.040 K m²/W
Total			4.620 K m²/W
U-value			0.22 W/m²K

The Dutch NEN standards mention that the R-value (resistance) for a facade is required of Rc=4.5. So this facade meets the required thermal insulation (NEN 1068+C;2016). Though the aluminium brackets for the facade cladding is not taken into acount in this calculation. The Rc value of the facade probably is lower because of the brackets so they might have used a better type of Rockwool in order to meet the NEN standards. Knowing this project, they would only have chosen for a better (more expensive) type of insulation if really necessary.

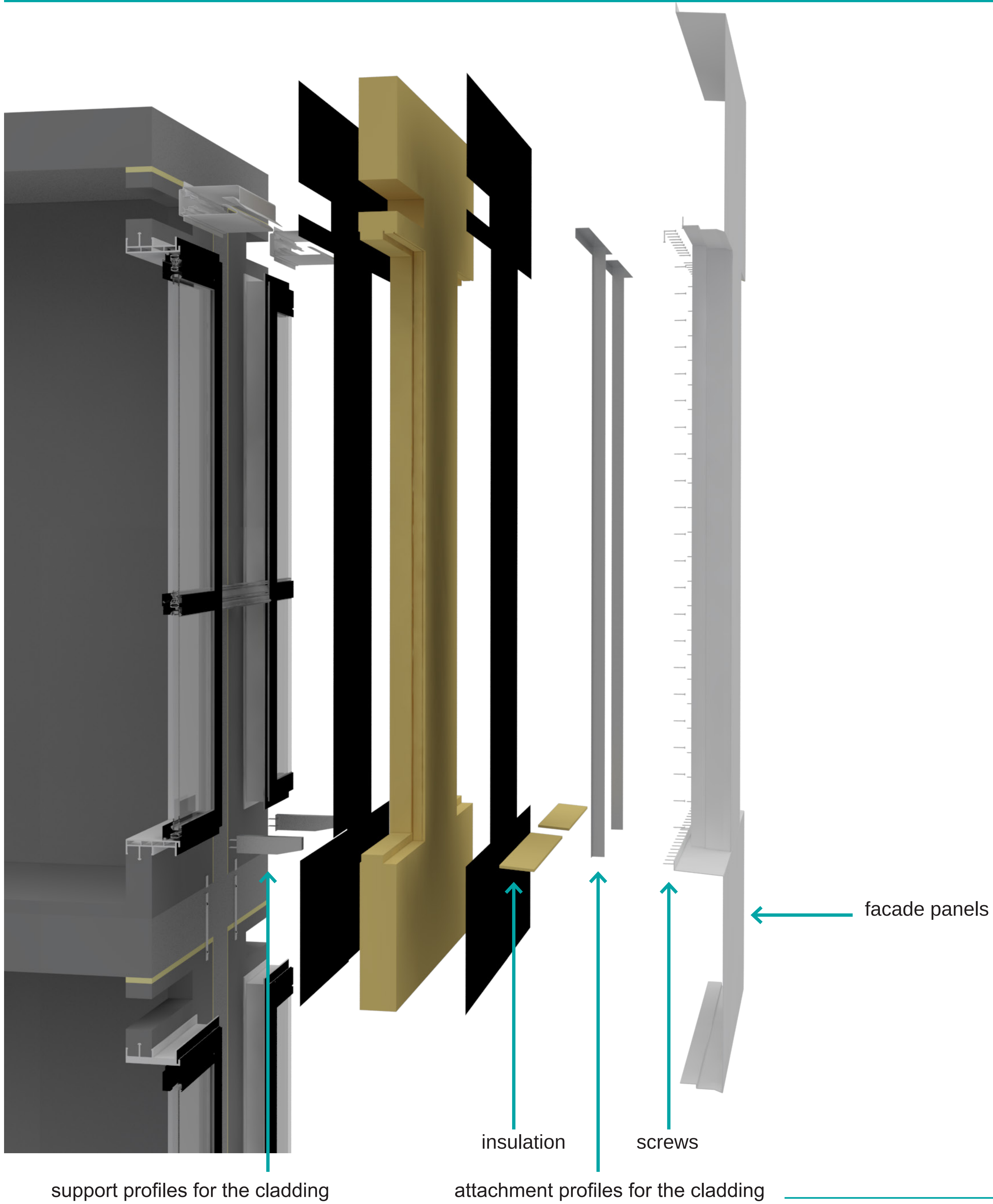


3D model perspective view

Fixing system of the concrete facade panels

The inner side of the facade consists of a prefabricated concrete panel with a GRP frame in which the aluminium frames are attached. The concrete panels are completely assembled in the factory and attached to the main structure on site. As seen on the top picture on the left, the panels are flown in with a crane and first attached on the bottom side of the panel. After that the panel is adjusted with the connecting mechanism on the top side. When this is fixed they repeat the process next to or above the panel, and so on till it is completely finished.

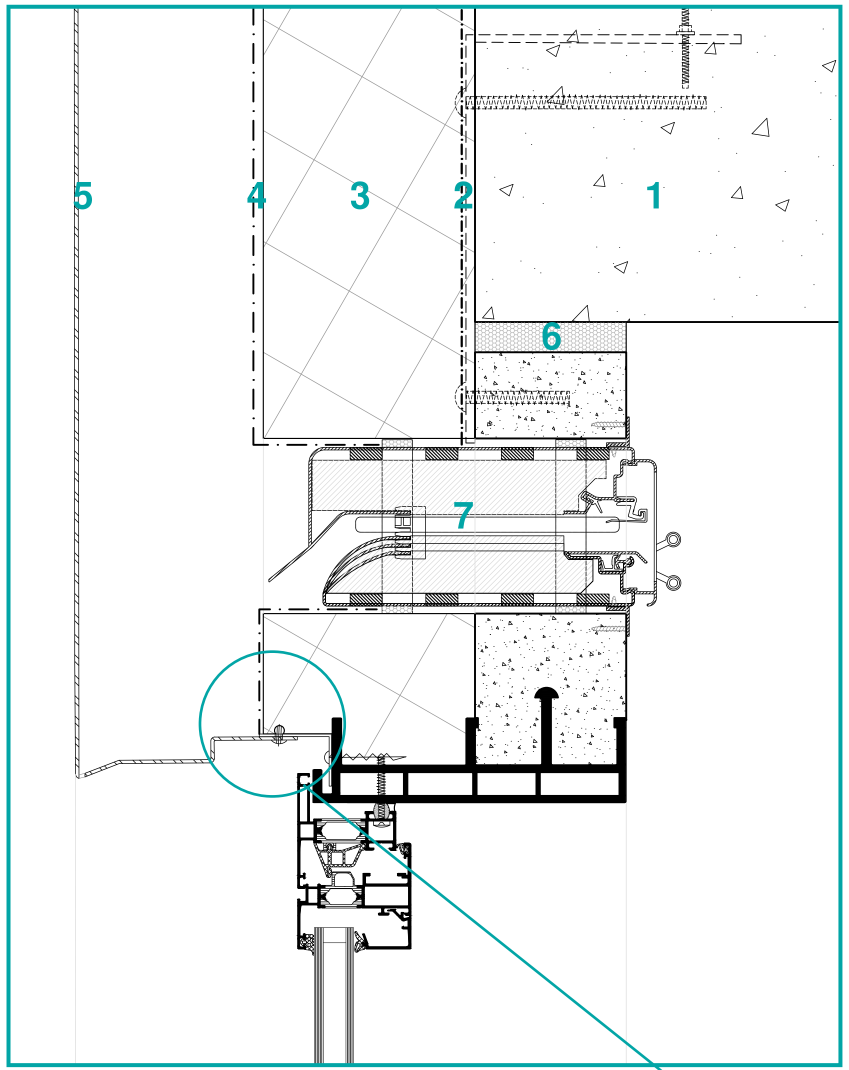
Source: https://fotoclubklik.nl/fotos-tu-delft/wppaspec/oc1/lnnl/cv0/ab14#wppa-container-1



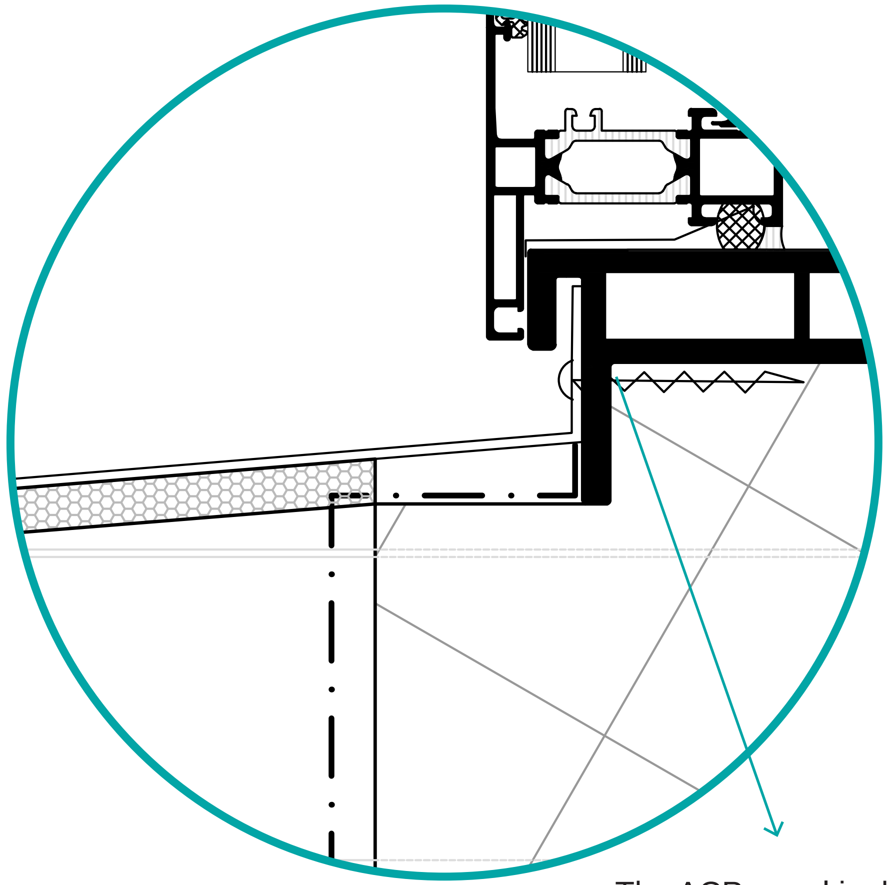
Fixing system of the aluminium finishing panels

The Aluminium Composite Panels are attached to the facade with aluminium profiles, screws and aluminium support brackets. The support brackets are installed before the insulation is put in place and the aluminium profiles are fixed to the Glass fiber Reinforced Polymer frame after the insulation is placed. The panels are screwed to the aluminium L-shaped profiles to fix them, except for the connection with the top part of the panels and the bottom of the window sill. There the ACP panels are directly attached to the GRP frame.

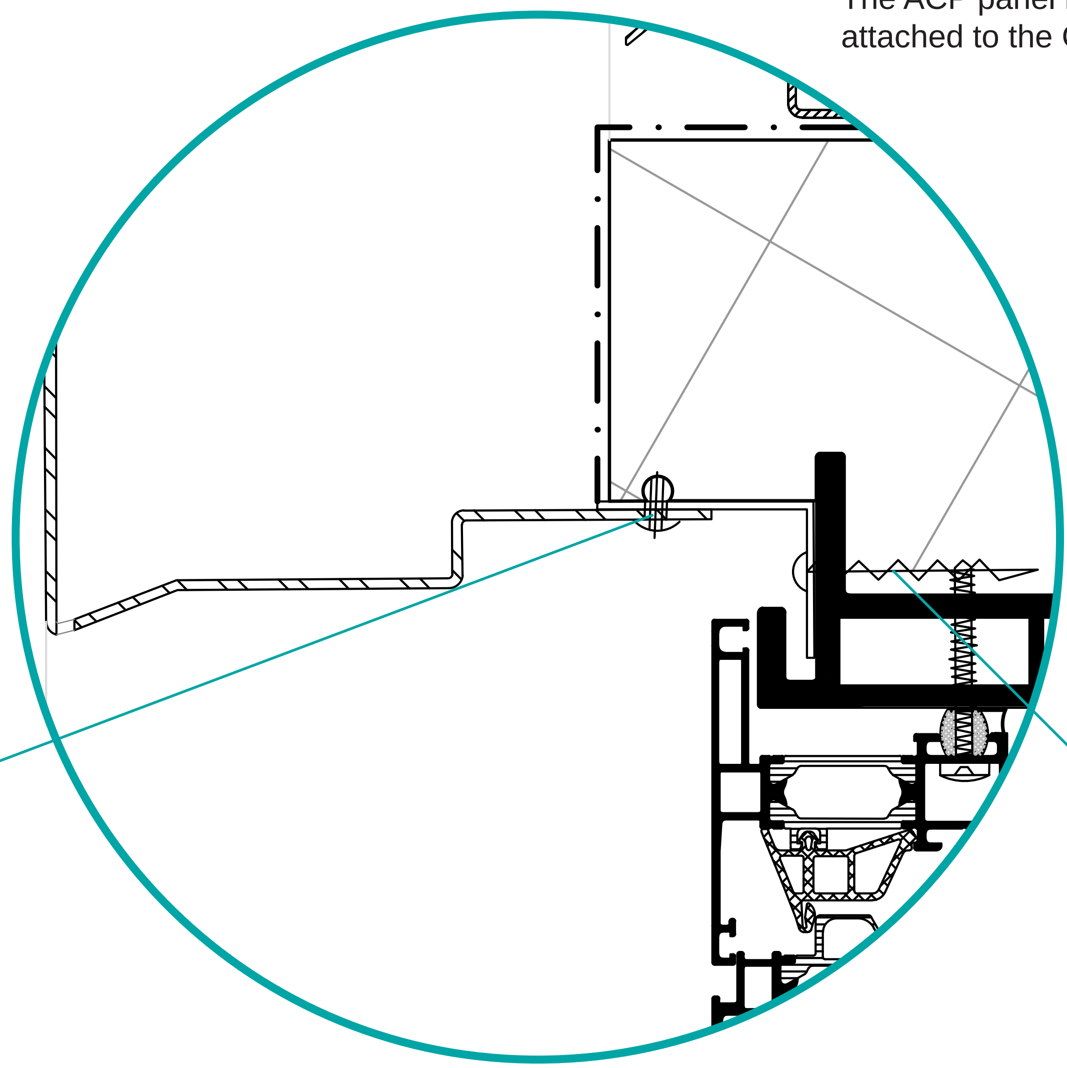
Detail A - Window/floor with ventilation
Scale 1:5



1. Concrete slab
2. Vapour barrier
3. Thermal insulation
4. Vapour permeable air barrier
5. Aluminium cladding
6. Pur insulation
7. Ventilation unit



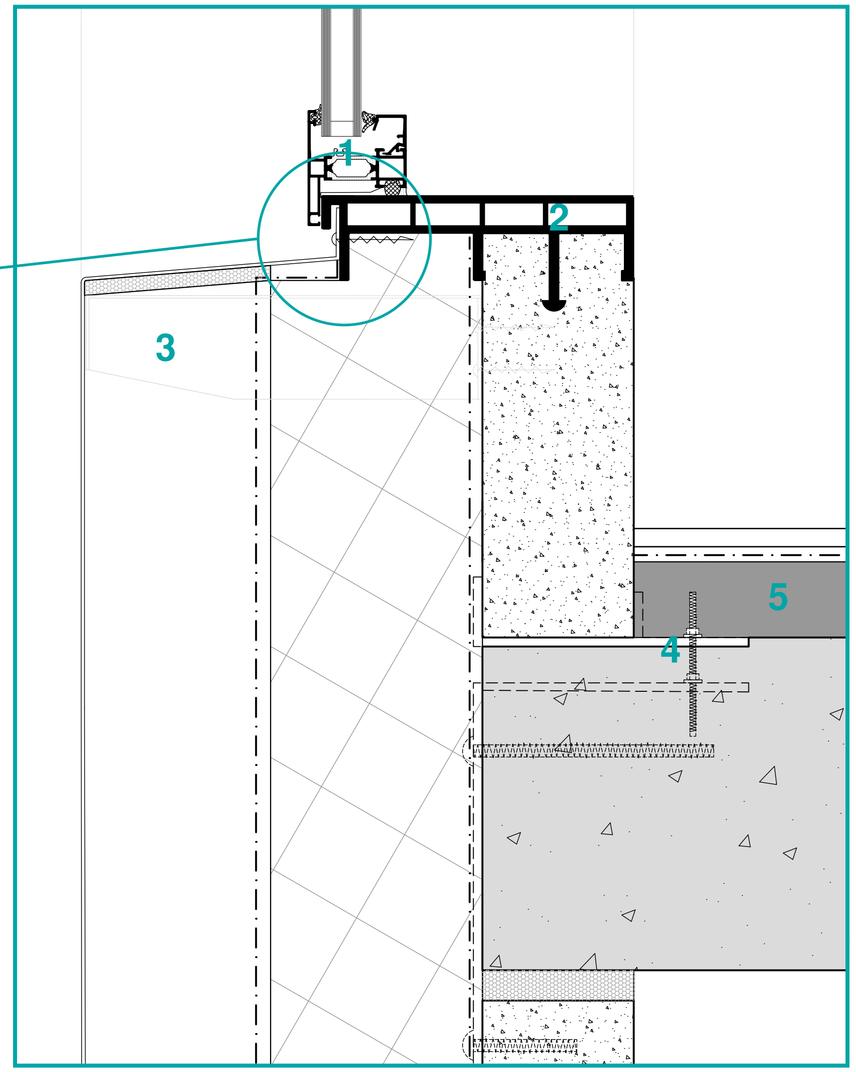
The ACP panel is directly attached to the GRP frame



Attachment of the ACP panel to the aluminium L-shaped profile

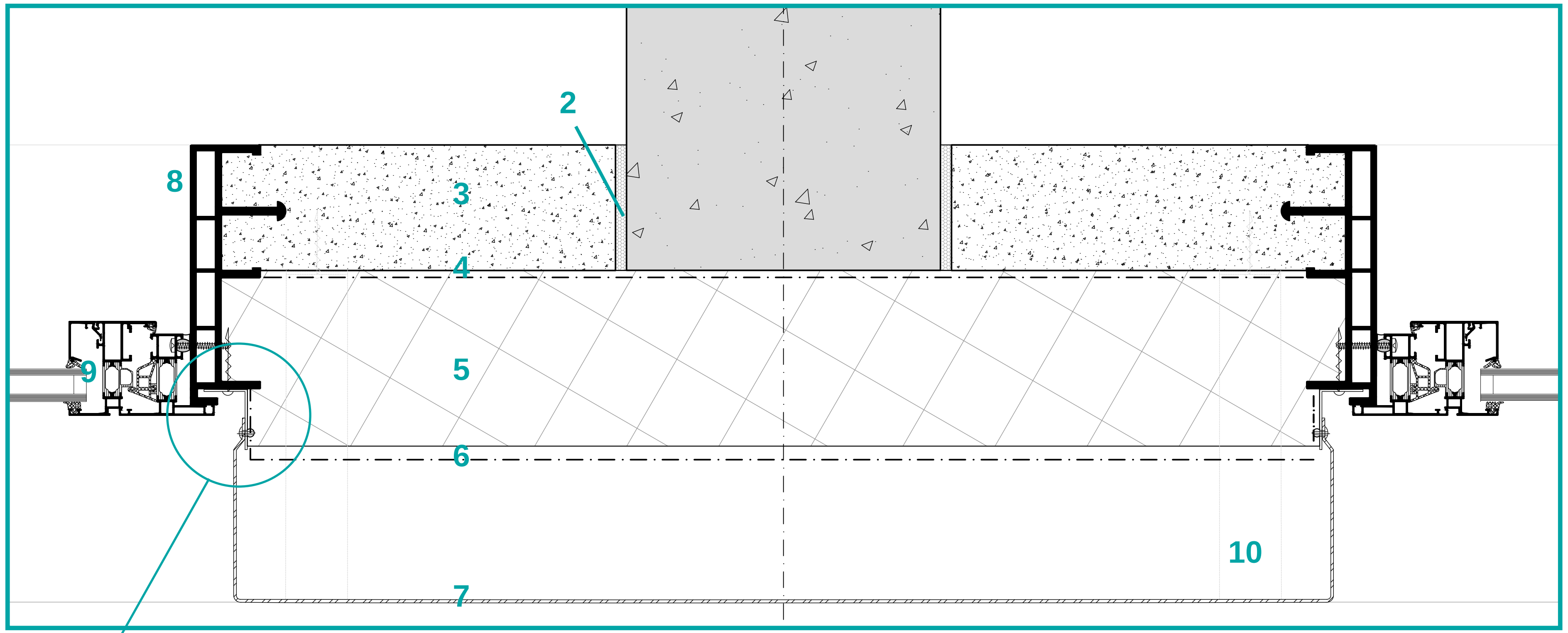
Attachment of the aluminium L-shaped profile to the GRP frame

Detail B - Floor/window
Scale 1:5

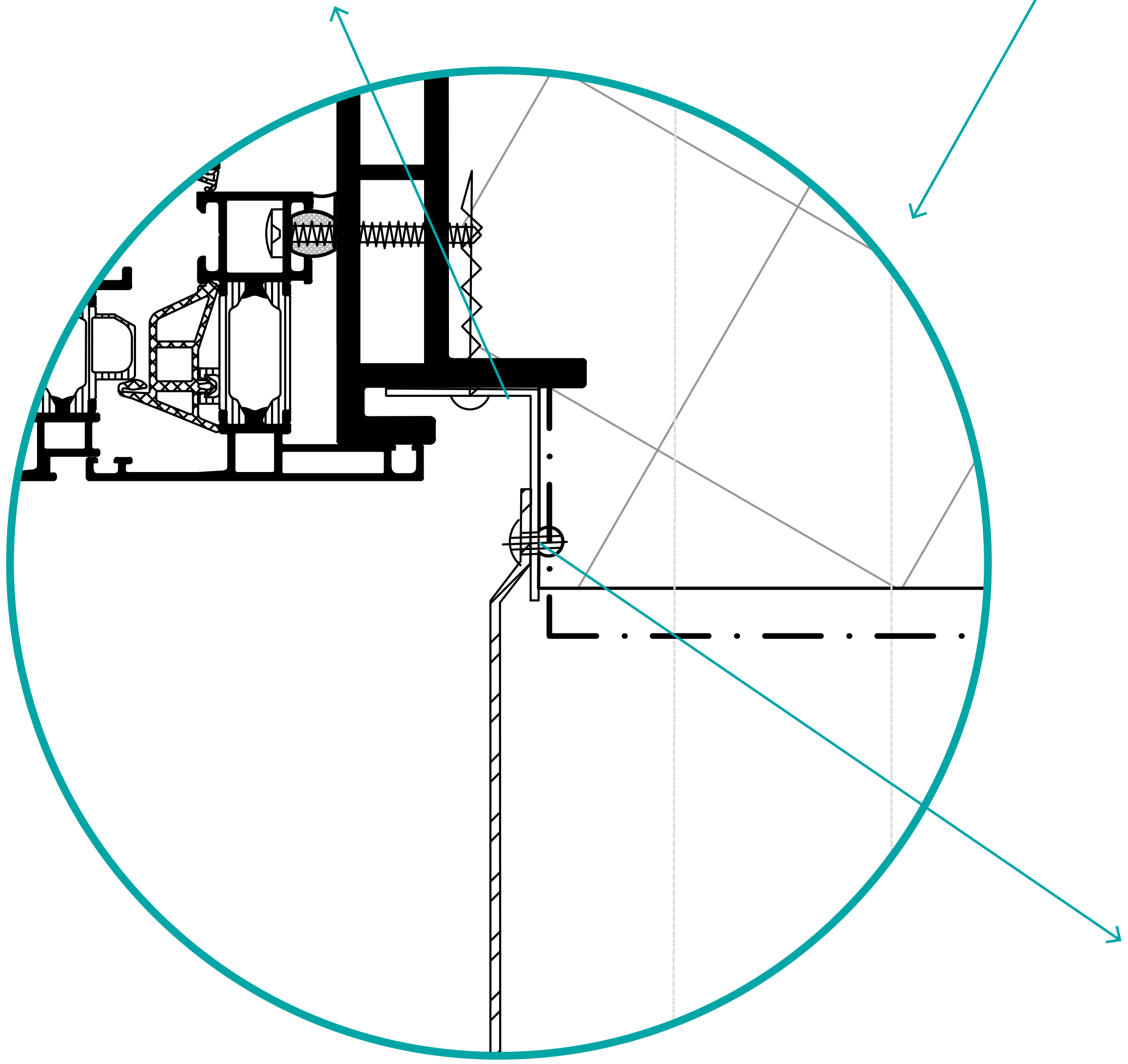


1. Aluminium window frame
2. GRP mounting frame
3. Aluminium profile for support facade cladding
4. Weight bracket facade panel
5. Screed
6. Insulation
7. Laminated floor

1. Concrete load bearing wall
2. Pur insulation
3. Concrete panel
4. Vapour barrier
5. Thermal insulation
6. Vapour permeable air barrier
7. Aluminium facade cladding
8. GRP mounting frame
9. Aluminium window frame
10. Aluminium profile for support facade cladding



Attachment of the aluminium L-shaped profile to the GRP frame



2 different types of attachment

There can be concluded that there are at least two different ways that the ACP panels are attached to the facade. In the details on this page and the page before, you can see that the panels are either directly screwed to the GRP frame or that a aluminium L-shaped profile is added between this connection.

Attachment of the ACP panel to the aluminium L-shaped profile

Air and water tightness of the construction

Water Barrier

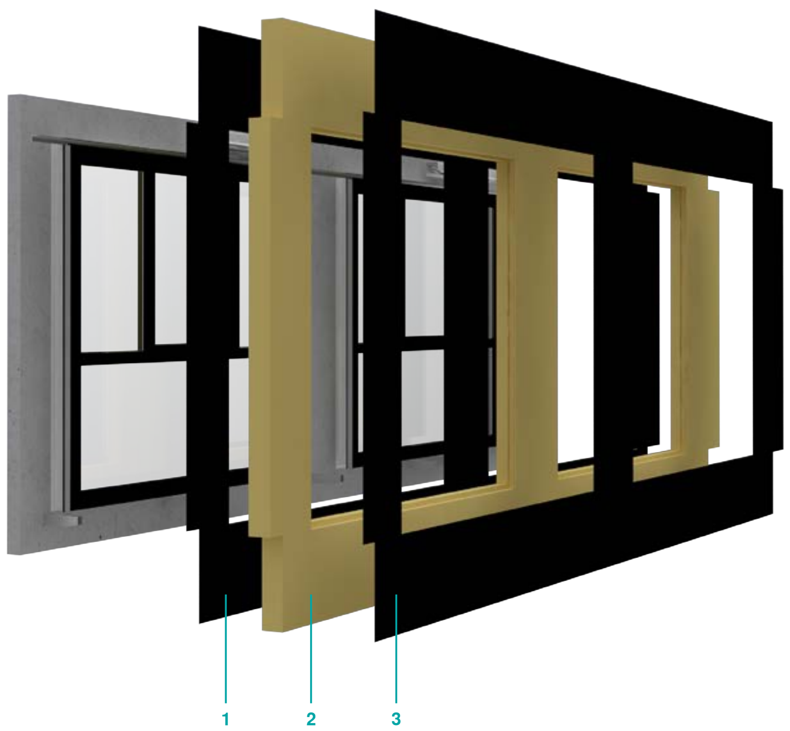
The first line of defence are the aluminium composite cladding as they will repel water on the surface. The panels below the window sill are sloping outwards to drain falling water.
But since the cladding panels assembly has a line of gap in between two panels, it becomes potential water inlets to the cavity.
To prevent this, the edges of the panel are profiled such that any water that gets inside will collect at the bottom of the panel which have weep holes to drain it out.

Air Barrier

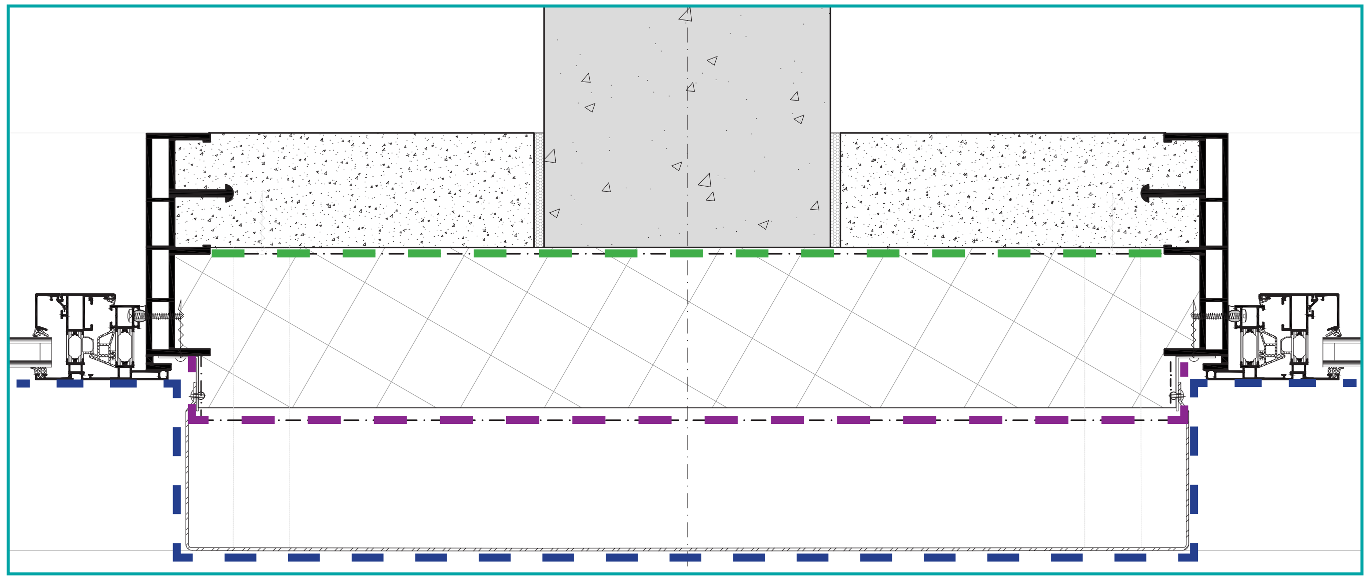
The exterior side of the mineral wool insulation is covered by an air barrier. This second line of defence is a vapour permeable membrane that stops air from passing through.

Vapour barrier

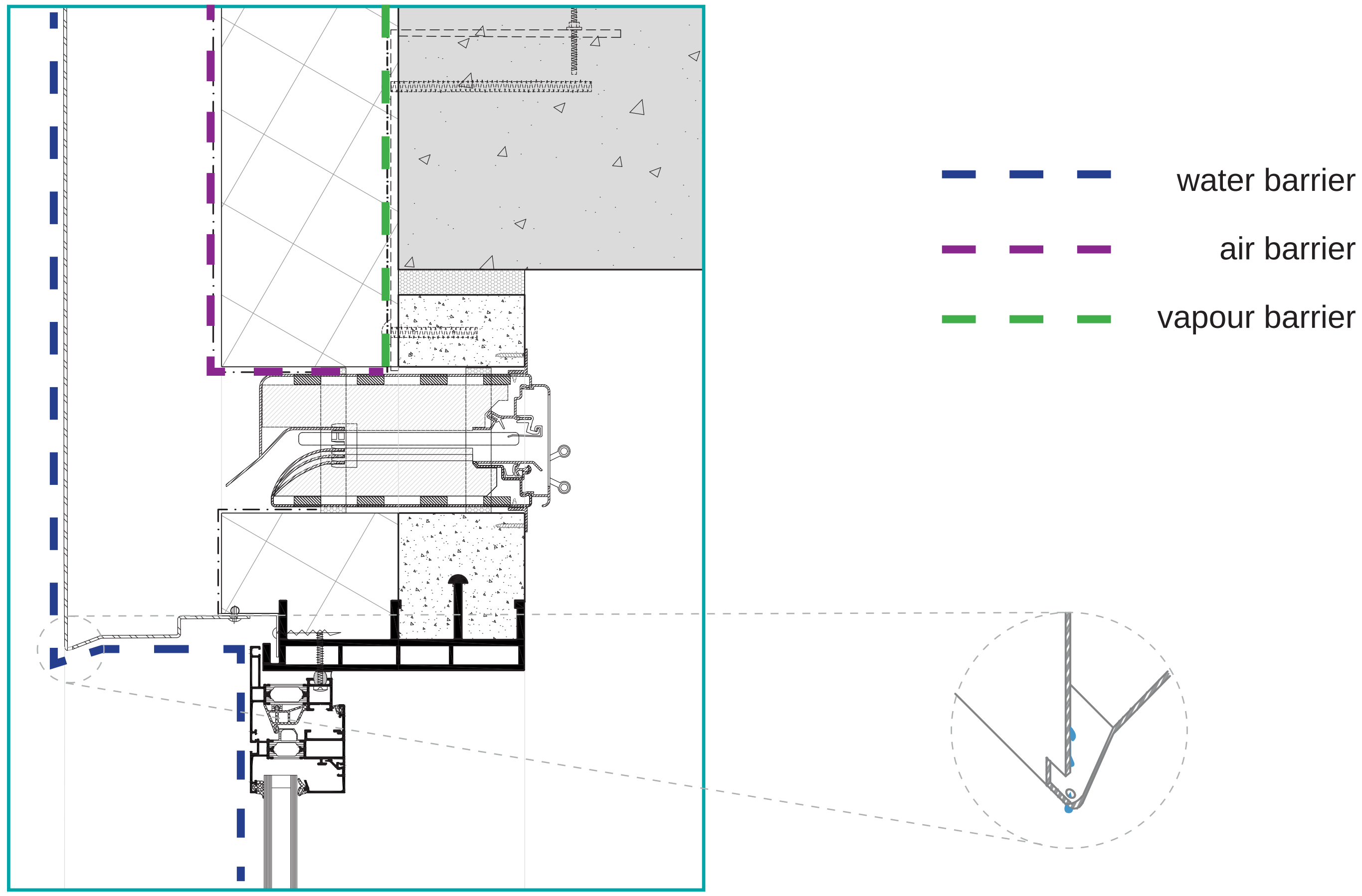
The vapour barrier layer constitutes are third line of defence. However, due to the fact that we are not 100% certain that their is a second layer behind the insulation which acts as a vapour barrier, there is a possibility that the concrete layer itself acts as the third line of defence against vaporous infiltration, which is a cheaper way of construction that matches with the concept of our building.



1 Vapour barrier
2 Thermal insulation layer
3 Vapour permeable air barrier

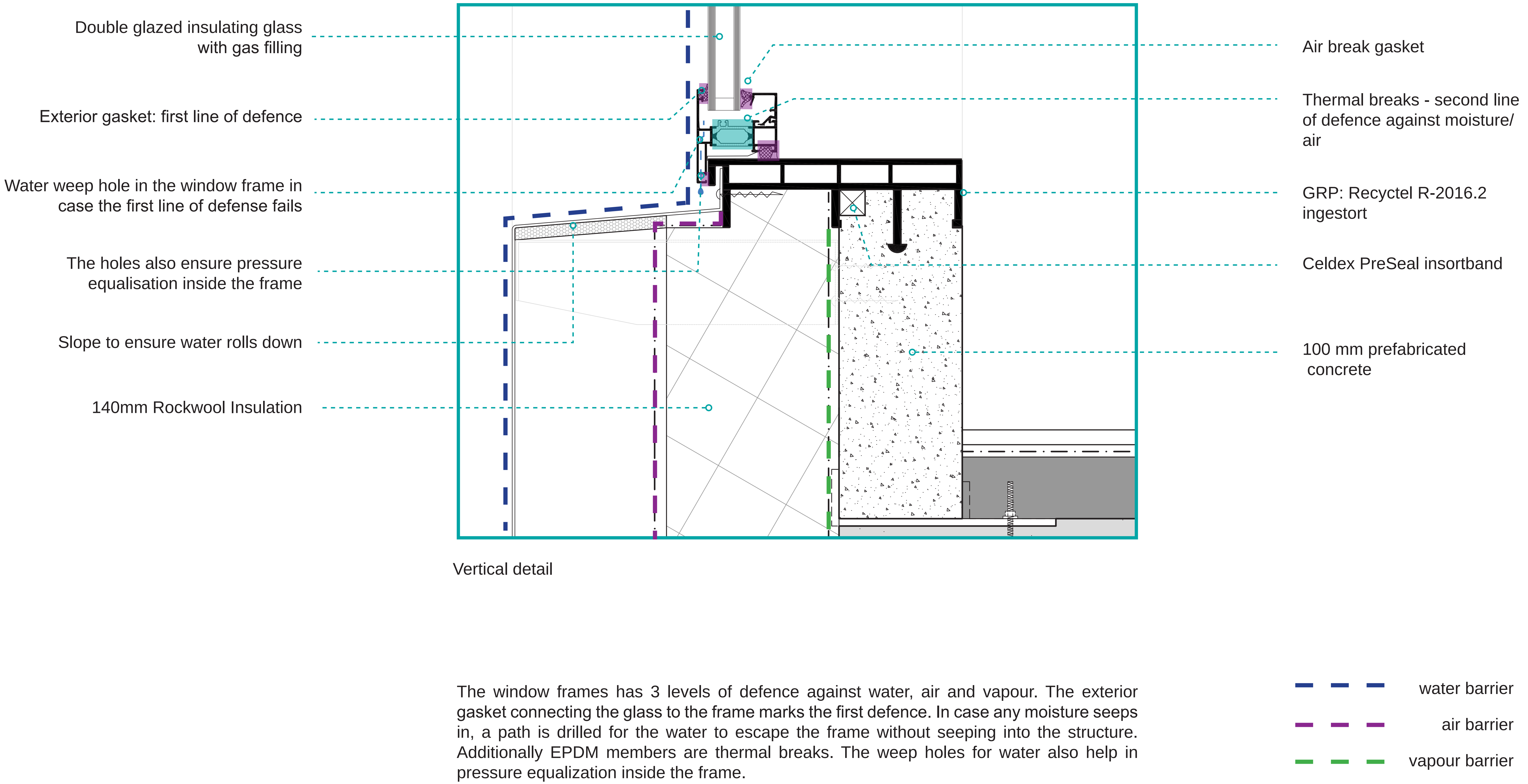


Horizontal detail



Vertical detail

Air tightness and water barrier in the window frame



Vertical detail

The window frames has 3 levels of defence against water, air and vapour. The exterior gasket connecting the glass to the frame marks the first defence. In case any moisture seeps in, a path is drilled for the water to escape the frame without seeping into the structure. Additionally EPDM members are thermal breaks. The weep holes for water also help in pressure equalization inside the frame.

Ventilation System

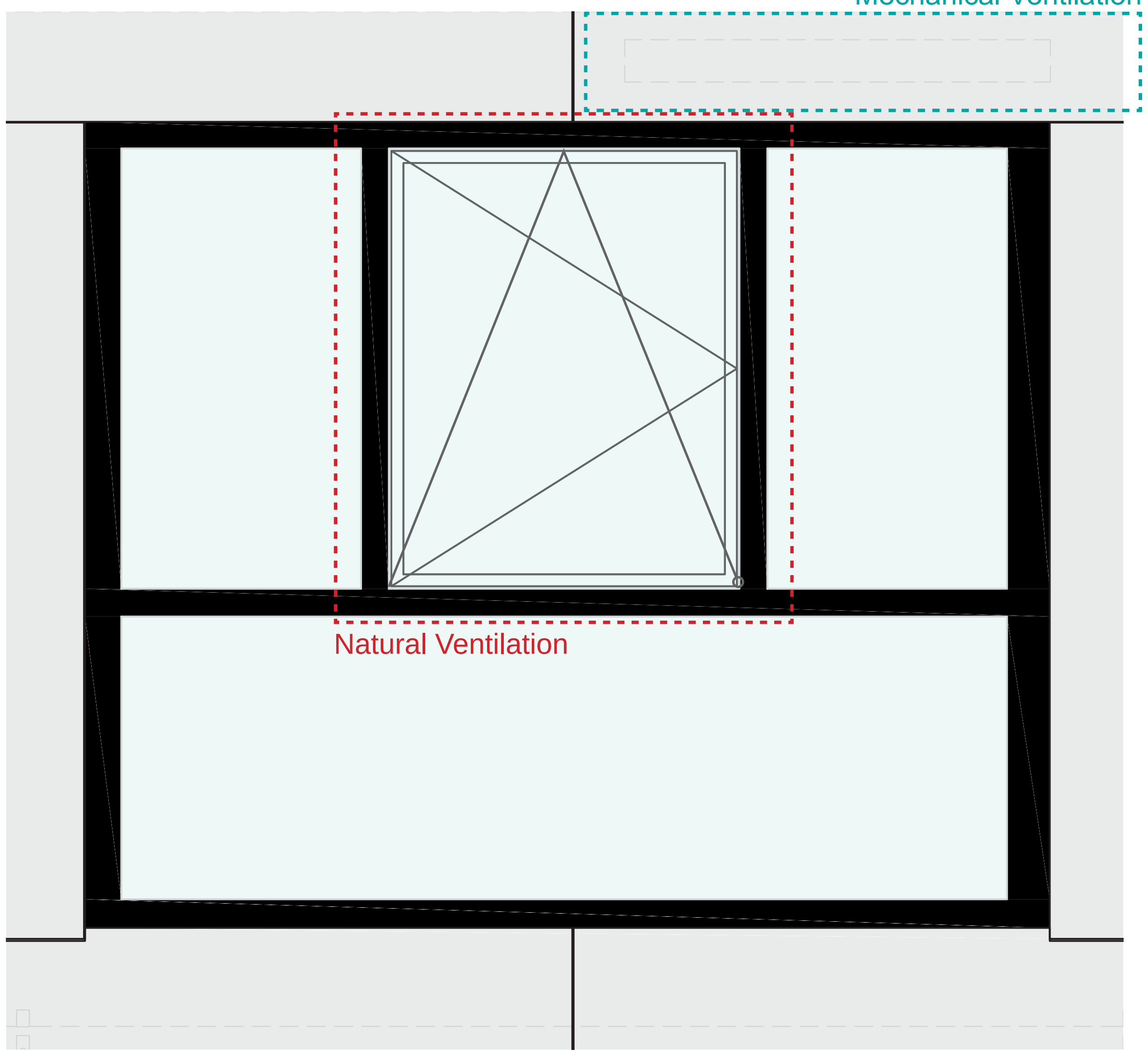
To ensure sufficient ventilation, a slot was created in the prefabricated concrete panels which was later fitted with a ventilation unit. The air flow inside the room can be changed by the occupant manually from the inside.

From the outside this unit is hidden behind the aluminium cladding. The inlets instead are in form of a grill on the underside of the panel just above the window. Doing this also prevents a direct path for water transmission.

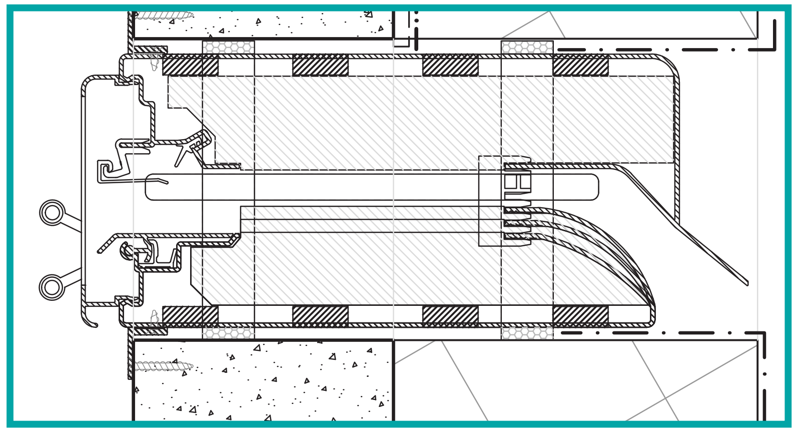
Additionally every window system has an open-able middle window which can be further used to improve ventilation. To prevent air infiltration, the windows have air barrier gaskets. The joints between construction have been sealed by pur.

Inlets- grills on the exterior

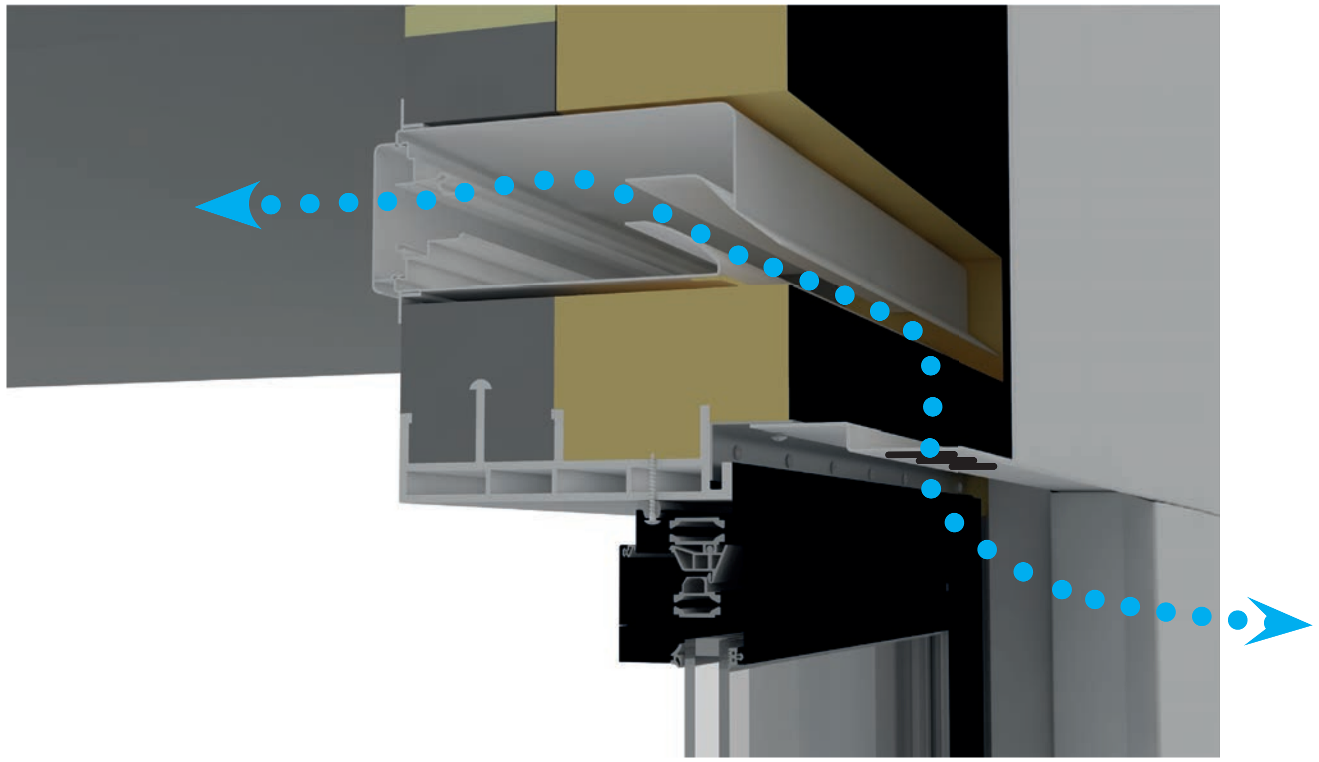
Outlet- ventilation unit on the interior



Elevation - Open-able window



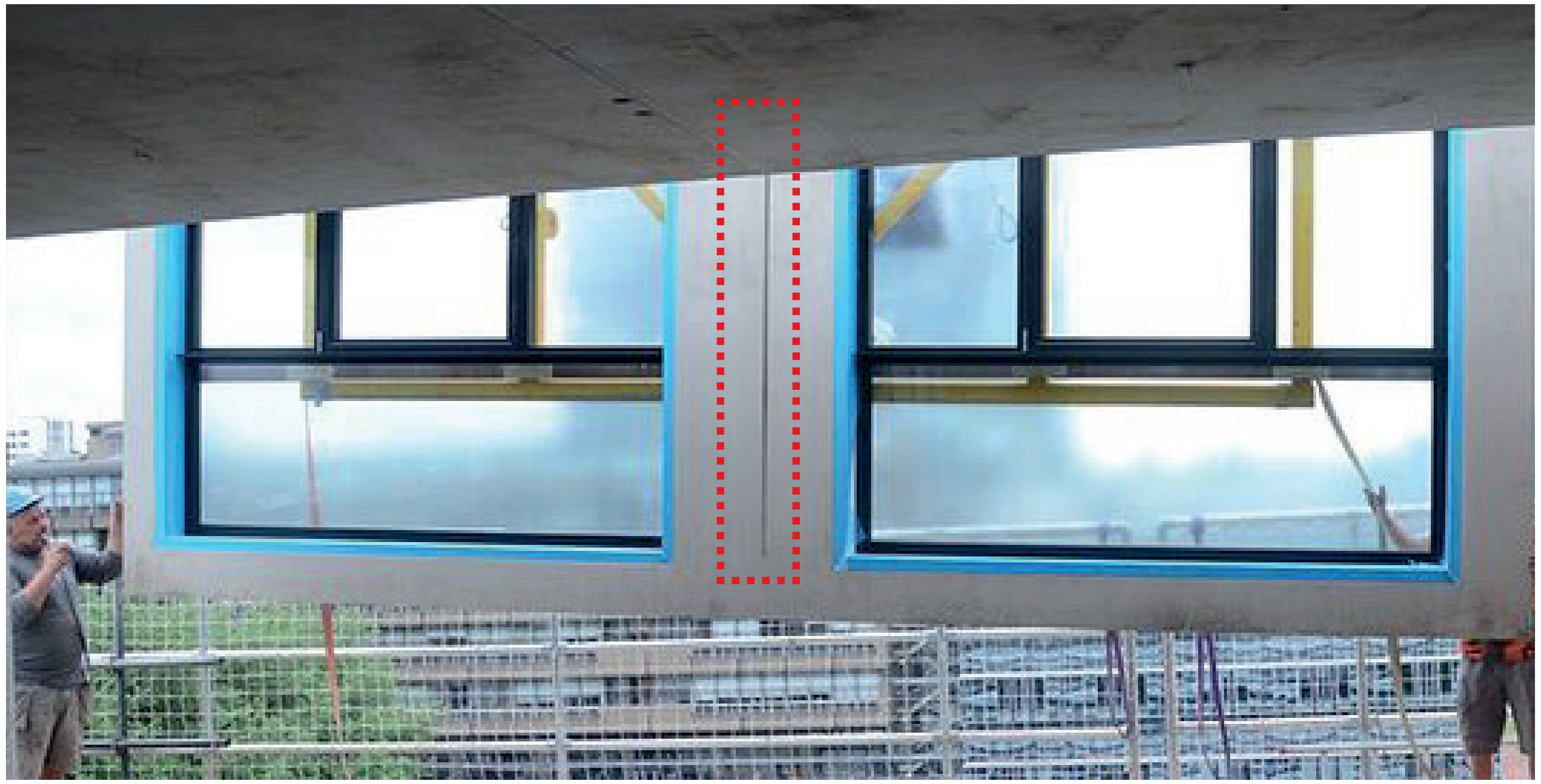
Ventilation system:
Duco Skymax ZR medio

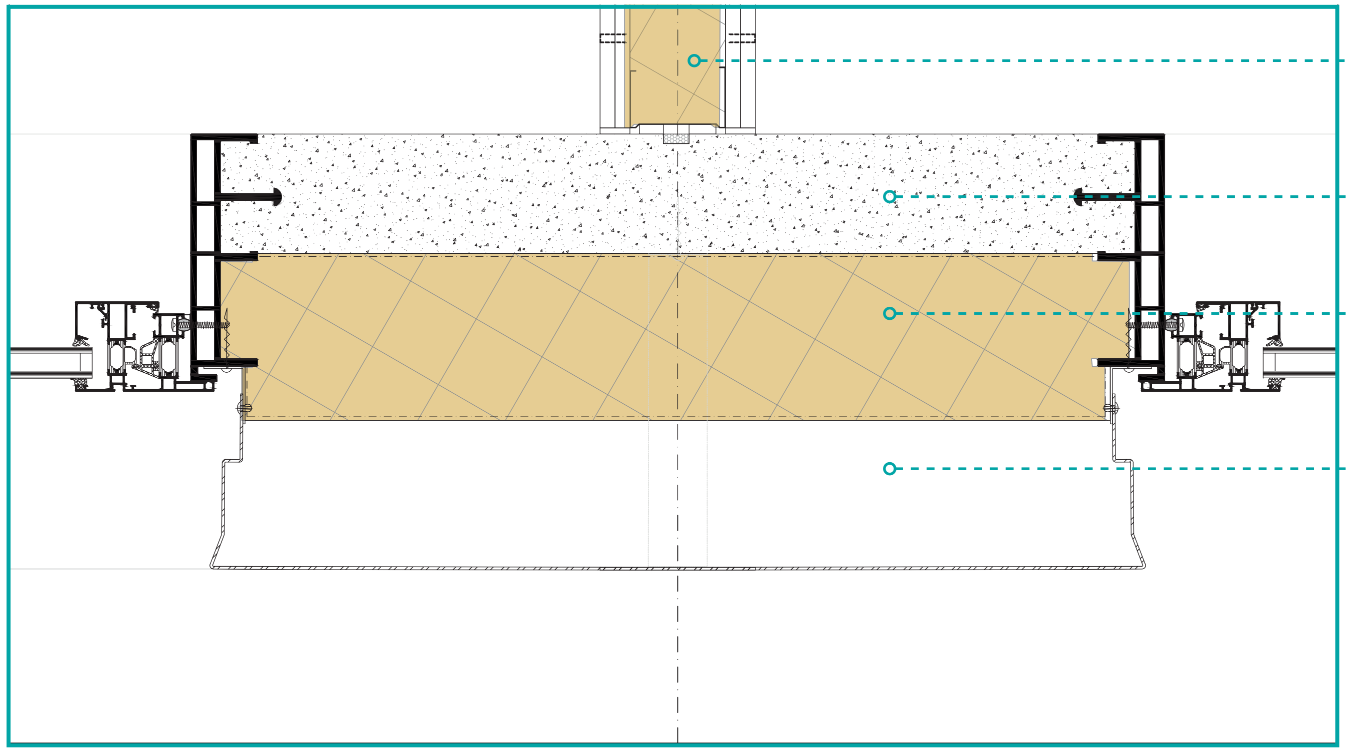


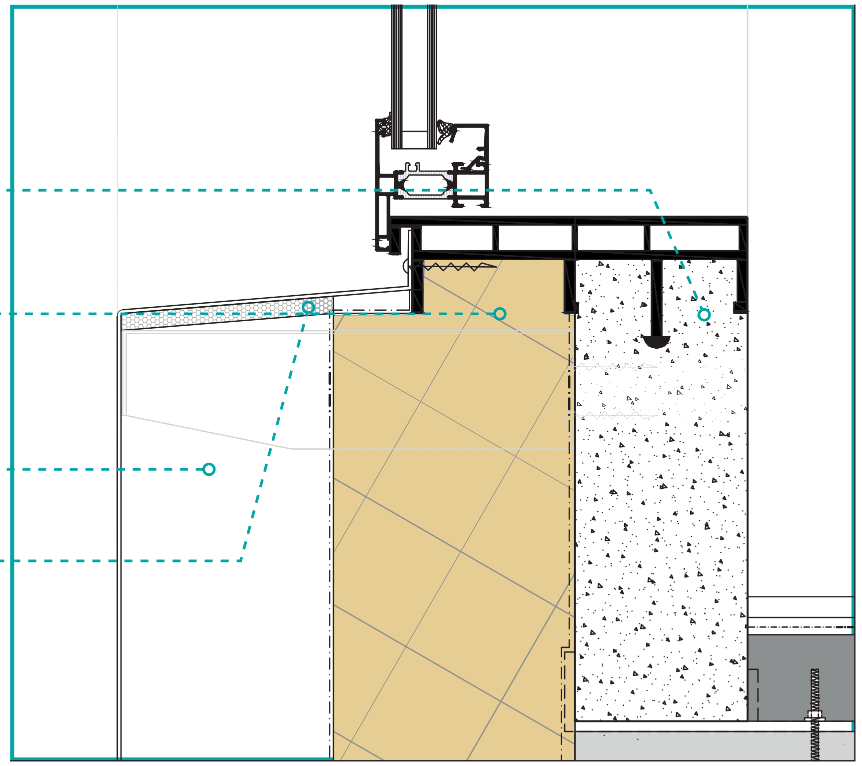
Cross sectional view

Acoustic Barrier

The project is located near a high traffic road which implies higher outside sound levels. In order to reduce the sound transmittance to the indoors, a variety of measures were taken.
The complete assembly acts as a cavity wall construction. The base layer of concrete provides the mass needed to dampen sound waves. The 140mm mineral wool insulation has non-directional fibres that trap sound waves and absorb vibration and adds an extra layer of sound insulation.
The air cavity can also improve the acoustic performance except for when cavity resonances might be induced.
Additionally, a layer of anti-drumming foil is added on the underside of the panel to prevent thumping sounds during rains.
The project with its pre-cast facade also considers the sound transfer to adjacent rooms via vibrations from the interior and exterior walls. Therefore, during casting of the facade panels, a slit was made in the panels where the internal wall will align. This gap was later filled with insulation as a sound barrier.
The internal walls are lined with insulation. But being on a student housing building, floor insulation was neglected as incoming students had to do that themselves. No quality was maintained and currently residents face issues of internal vertical sound transfer.







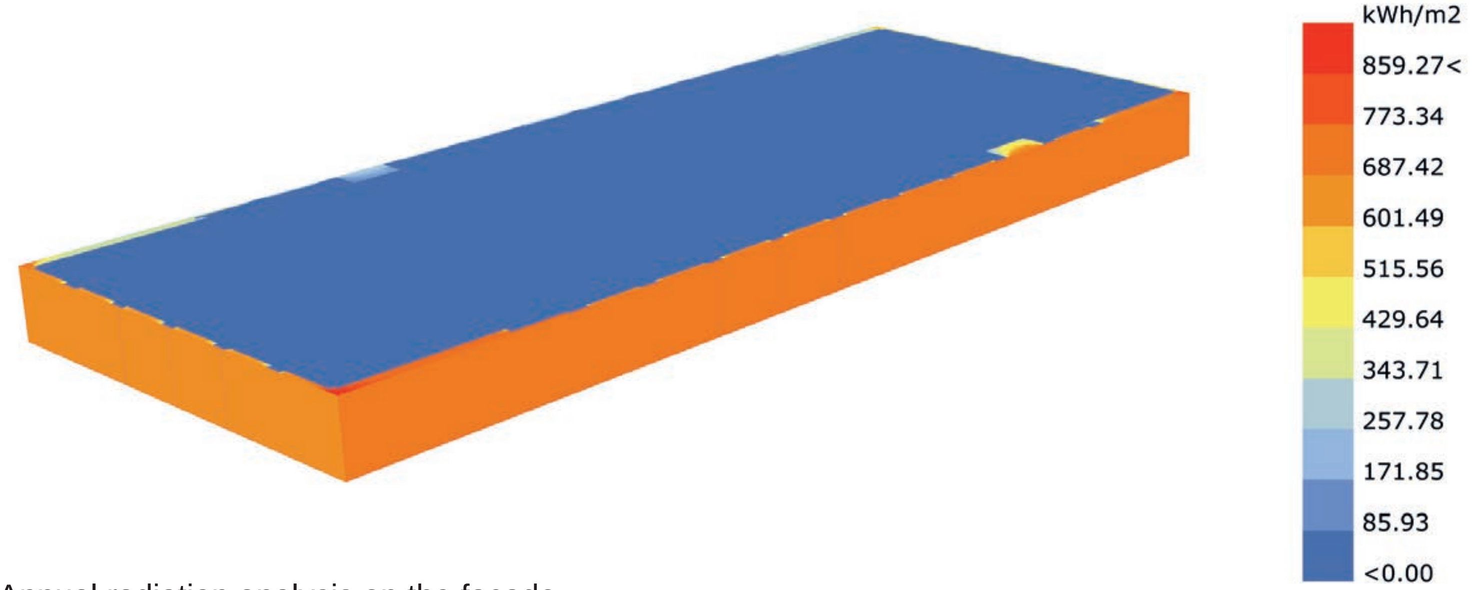
Solar Load

The project was simulated to understand the quantity of solar radiation that is received by the facade. A sample floor is analysed as per the weather data file available for Amsterdam.

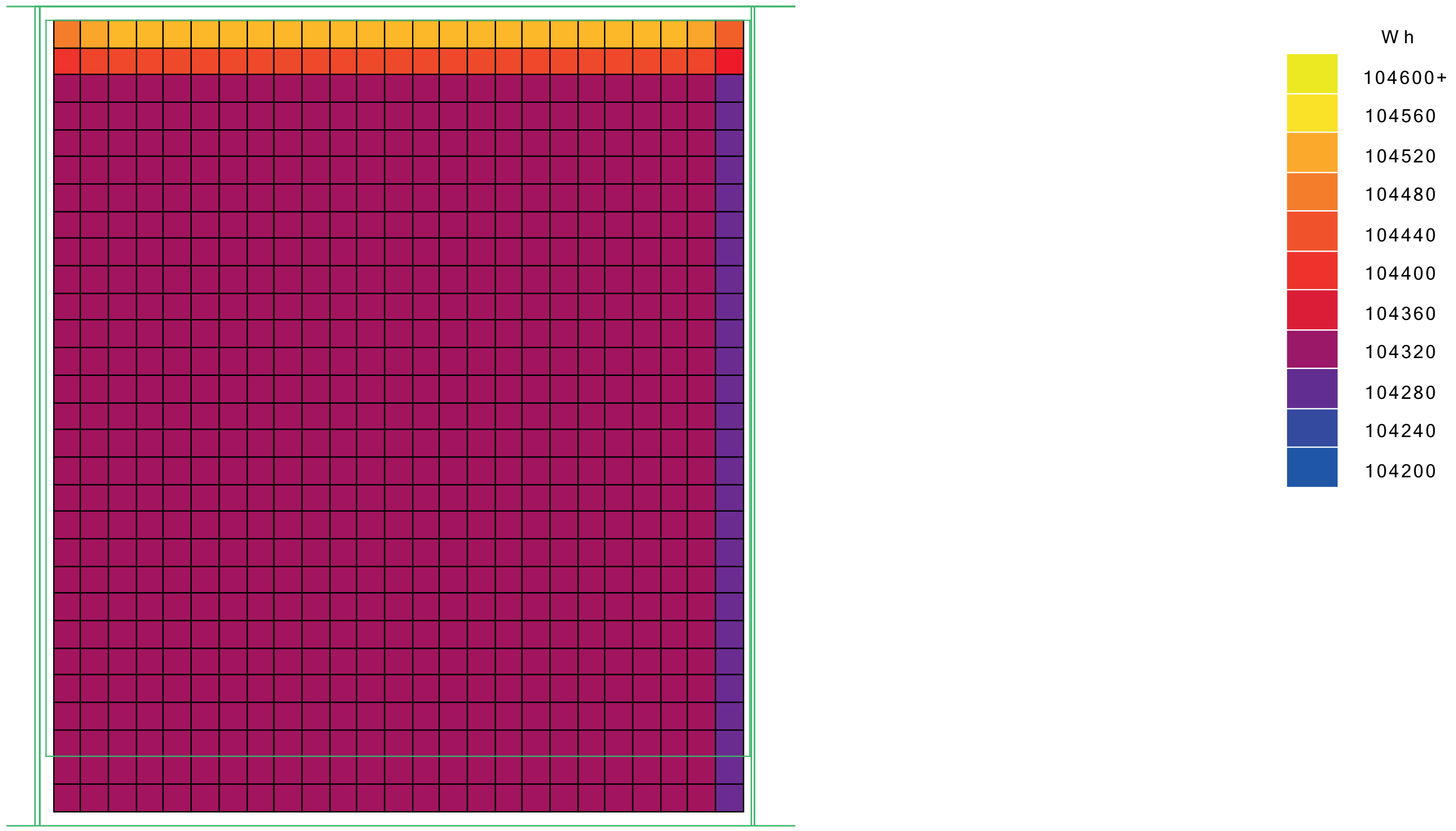
Being the tallest building in the context, it receives direct solar radiation. The annual radiation falling on building surface is useful for understanding the possible solar heat gain and the effect they might have on the energy performance of the building.

The most critical is the South-East facade which receives the highest radiation of nearly 687 kWh/m^2. The South-West receives around 600 kWh/m^2, North-East gets 343 kWh/m^2 and the north west gets only 257kWh/m^2

Visual examination of the facade does not show any specific measures to reduce the heat gain. There are no sun shades provided. The 60% wwr suggest higher transfer through the windows.
The glass is tinted dark which can block some radiation but the exact values are unknown.



Annual radiation analysis on the facade



Solar Insolation on a single South - East Facade

Daylight Analysis

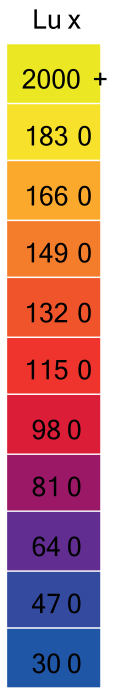
The building was modelled in “Ecotect” software and simulated to see the amount of daylight that is admitted in the building. Two rooms on each facade were analysed to get a wholesome idea about the performance.

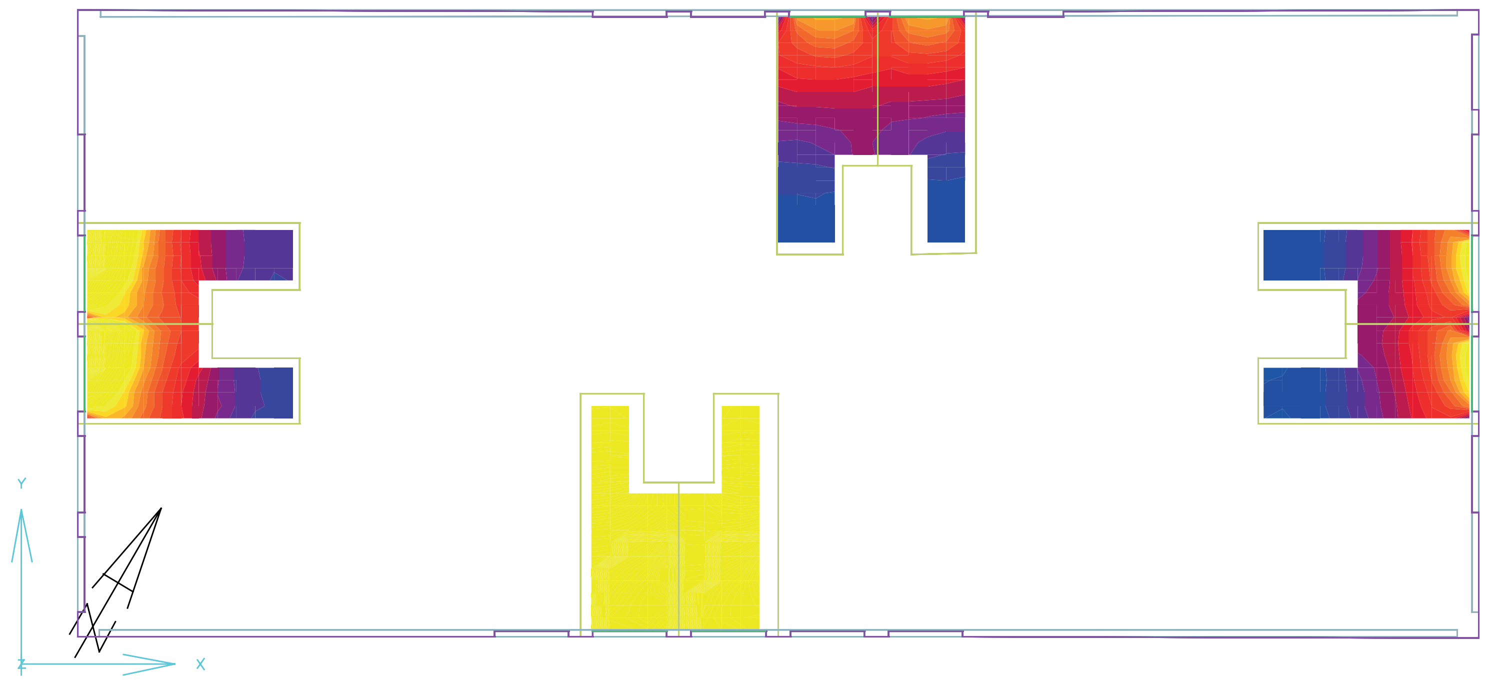
Some assumptions were made on the material reflectivity and visual light transmittance of glass. The glass installed has a black tinted film so a vlt of 50 is chosen as compared to 80 for clear glass.

The building has no external shading to block any sunlight received.

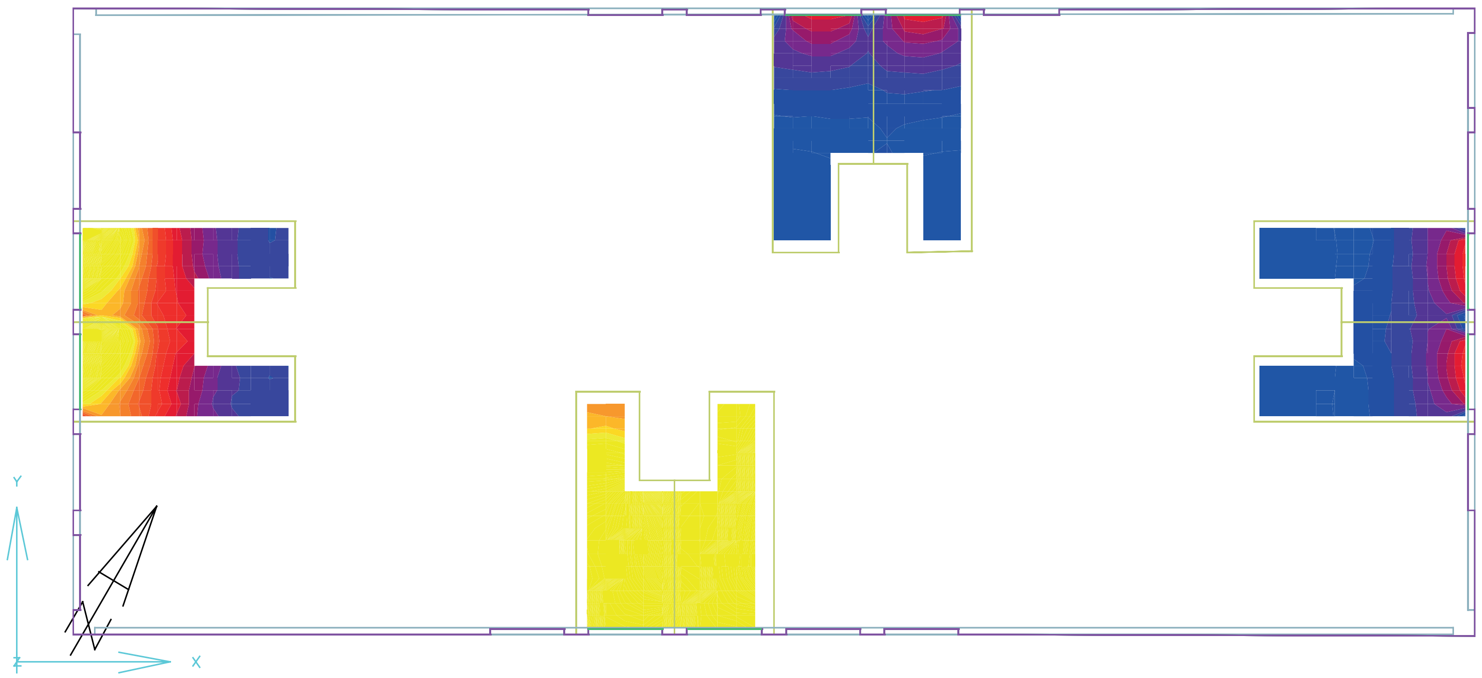
The model was simulated for its performance at 12:00 noon on summer solstice (21 June), winter solstice (21 December) and equinox (21 March). The result display range has been set from 300-2000 lux as per the usable daylight index (UDI) model. The results are discussed below.

The result shows that South-east facing rooms have a high value of glare through out the year. The southwest rooms also receive more that 2000 lux throughout the year.
It becomes critical to design some solar shading for these orientations for a comfortable indoor environment.

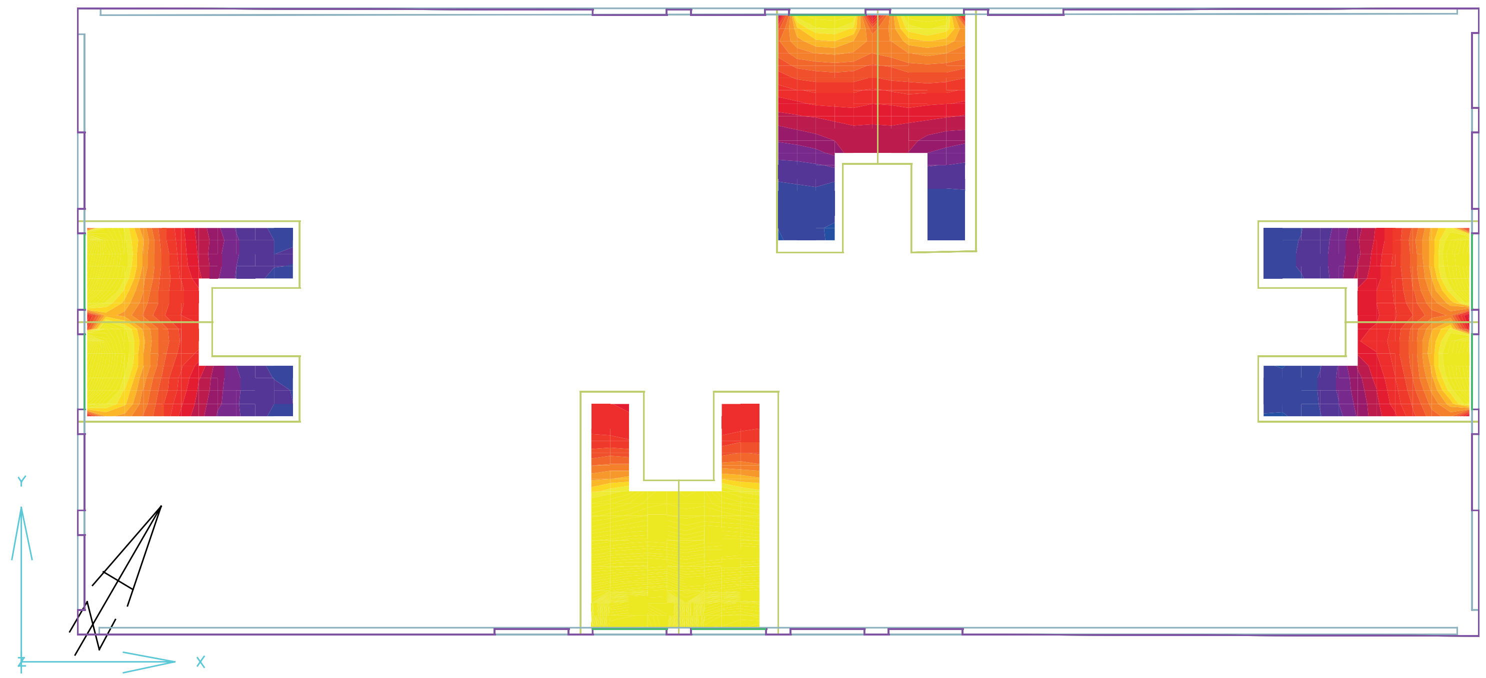




Expected daylight levels on 21 March



Expected daylight levels on 21 December

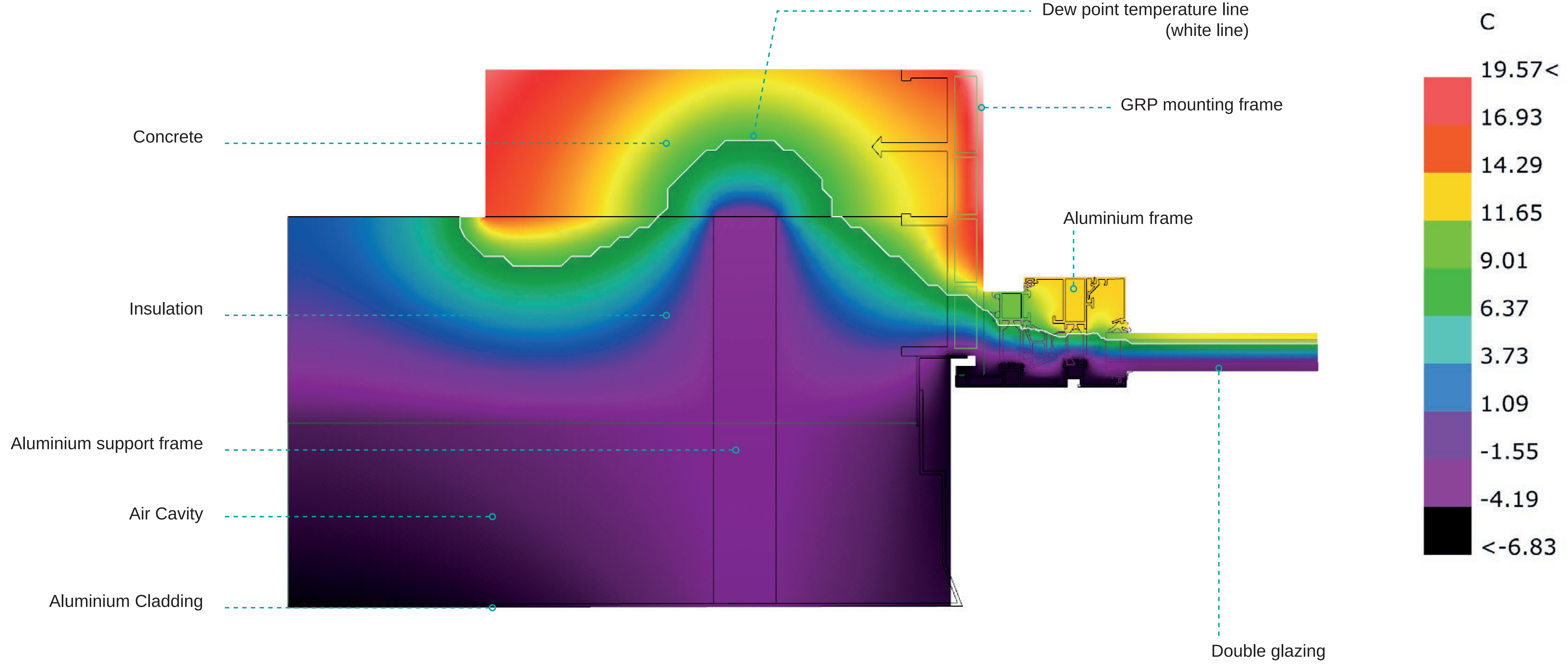


Expected daylight levels on 21 June

A section of the facade was analysed for risk of condensation that may occur due to surface temperatures reaching lower than the dew point temperature. The section was modelled and simulated for the weather data file for Amsterdam on an yearly average dew-point value.
The white line in the diagram represents the dew point temperature along the facade.
The critical segment here is the aluminium support frame for the exterior cladding that act as a cold bridge.

As per the analysis, the structure stand a risk of mould formation due to accumulation of water from condensation. The most probable place for this will between the concrete and insulation layer.

The materials of the construction selected for the simulation were limited to the material database of the software. Additionally, some material properties have been assumed as there was no clarity on the actual product use. These materials include the thermal bridge considered to be an aluminium frame. Any additional surface treatments that may have been done against condensation has not been accounted for.



NEN-6068

This norm is part of the Dutch regulations regarding fire safety. We have summarized the following to paragraphs, since we think that these are quite important to consider, especially when we start the re-design later on.

Paragraph 5.2.1 Fire behaviour of the facade

The facade of either a building in which the room is situated from which the resistance against fire spread is determined - or from a building in which the room is situated where towards the resistance against fire spread is determined - cannot contribute in a substantial way to the fire propagation on the facade.
It is considered that the façade complies to this when the outer face of the facade consists at least of 95% of building materials that have at least the classification B according to NEN-EN 13501-1.
This condition only counts when fire expansion via the cavity is not possible.

Paragraph 5.2.2. Fire resistance of façades and roofs

A part of a facade or roof should be assumed as an opening, unless this part is adequately fire resistant.

Paragraph 6.4.3 Determine the openings, semi-openings and closed parts

Openings are components of the façades and roofs, regarding fire resistance related to a separating function the direction in which the fire spread is considered is at least 5 min. (according to chapter 4 of NEN 6069). Parts with an assumed value of fire resistance regarding to the separating function related to the flame density cannot be more than 5 min., these are:
- standard float glass
- layered glass consisting of two layers of glass (with intermediate layers of resin or pvb-foil)
- laminated glass, in which at least one of the glass planes is produced with layered glass and that the layered glass consists of no more than two layers of glass.

Closed parts are components with an adequate fire resistance in the direction of the considered fire spread, according to NEN 6069. The fire resistance is adequate when the fire spread is equal to at least 30 min., unless the wbdbo-demand is 20 min., in that case 20 min. is enough.

Semi-open parts are components of a façade or roof that are neither a closed part or an opening. Components which an assumed value of fire resistance regarding the separating function related to the flame density of more than 5 min., are façade openings with:
- (Half) hardened glass
- layered glass consisting of more than three layers of glass
- multiple layers of glass of which one or more glass planes are layered

A semi-open part should be considered as both an opening and a closed part. Therefore two different calculations are necessary: one calculation considering all semi-openings as an opening and a calculation considering all semi-openings as a closed part. The lowest value of resistance against fire spread is decisive.

Sources:
https://connect.nen.nl/standard/openpdf/?artfile=579311&RNR=220038&token=6bd4f714-99e5-4181-a8bb-13e06dc5e4c9&type=pdf#pagemode=bookmarks
https://connect.nen.nl/standard/openpdf/?artfile=508514&RNR=138818&token=3c41f4a3-62d4-4e7e-af8b-9c9401a872fd&type=pdf#pagemode=bookmarks

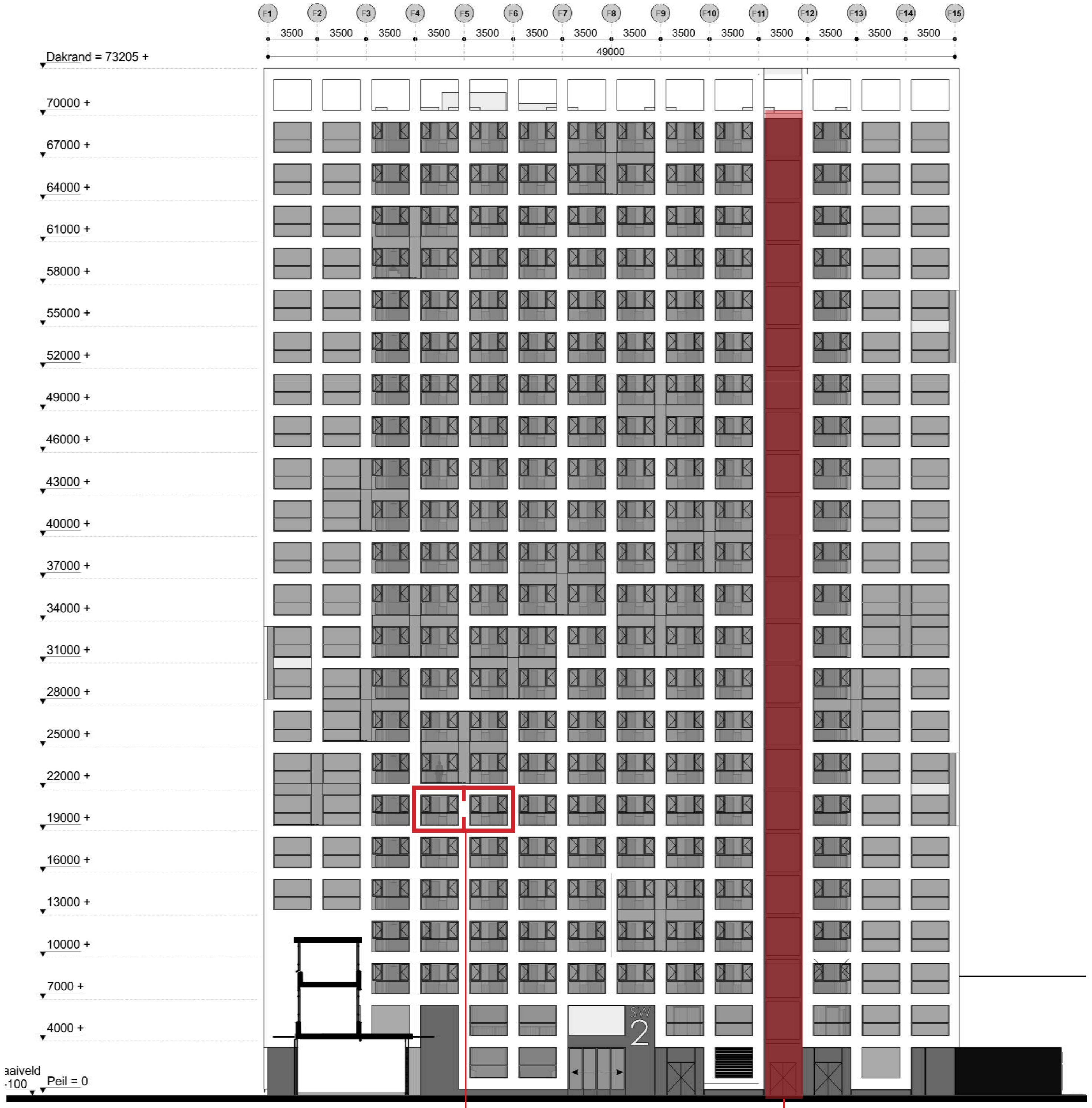
NEN-EN 13501-1

This norm is part of the Dutch regulations regarding fire safety, especially regarding materials. This document is already in English, so we have made a screen-shot of the classification of materials.

Table 1 — Classes of reaction to fire performance for construction products excluding floorings and linear pipe thermal insulation products

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 [a] and	$\Delta T \leq 30$ °C; and $\Delta m \leq 50$ %; and $t_f = 0$ (i.e. no sustained flaming)	-
	EN ISO 1716	$PCS \leq 2{,}0$ MJ/kg [a] and $PCS \leq 2{,}0$ MJ/kg [b c] and $PCS \leq 1{,}4$ MJ/m² [d] and $PCS \leq 2{,}0$ MJ/kg [e]	-
A2	EN ISO 1182 [a] or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ s	-
	EN ISO 1716 and	$PCS \leq 3{,}0$ MJ/kg [a] and $PCS \leq 4{,}0$ MJ/m² [b] and $PCS \leq 4{,}0$ MJ/m² [d] and $PCS \leq 3{,}0$ MJ/kg [e]	-
	EN 13823	$FIGRA \leq 120$ W/s and LFS < edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production [f] and Flaming droplets/particles [g]
B	EN 13823 and	$FIGRA \leq 120$ W/s and LFS < edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
C	EN 13823 and	$FIGRA \leq 250$ W/s and LFS < edge of specimen and $THR_{600s} \leq 15$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$mm within 60 s	
D	EN 13823 and	$FIGRA \leq 750$ W/s	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
E	EN ISO 11925-2 [i]: Exposure = 15 s	$F_s \leq 150$ mm within 20 s	Flaming droplets/particles [h]
F	No performance determined		

[a] For homogeneous products and substantial components of non-homogeneous products.
[b] For any external non-substantial component of non-homogeneous products.
[c] Alternatively, any external non-substantial component having a $PCS \leq 2{,}0$ MJ/m², provided that the product satisfies the following criteria of EN 13823: $FIGRA \leq 20$ W/s, and LFS < edge of specimen, and $THR_{600s} \leq 4{,}0$ MJ, and s1, and d0.
[d] For any internal non-substantial component of non-homogeneous products.
[e] For the product as a whole.
[f] In the last phase of the development of the test procedure, modifications of the smoke measurement system have been
introduced, the effect of which needs further investigation. This may result in a modification of the limit values and/or parameters for the evaluation of the smoke production.
s1 = $SMOGRA \leq 30$m²/s² and $TSP_{600s} \leq 50$m² ; **s2** = $SMOGRA \leq 180$m²/s² and $TSP_{600s} \leq 200$m²; **s3** = not s1 or s2
[g] **d0** = No flaming droplets/ particles in EN 13823 within 600 s;
d1 = no flaming droplets/ particles persisting longer than 10 s in EN 13823 within 600 s;
d2 = not d0 or d1.
Ignition of the paper in EN ISO 11925-2 results in a d2 classification.
[h] Pass = no ignition of the paper (no classification);
Fail = ignition of the paper (**d2** classification).
[i] Under conditions of surface flame attack and, if appropriate to the end–use application of the product, edge flame attack.



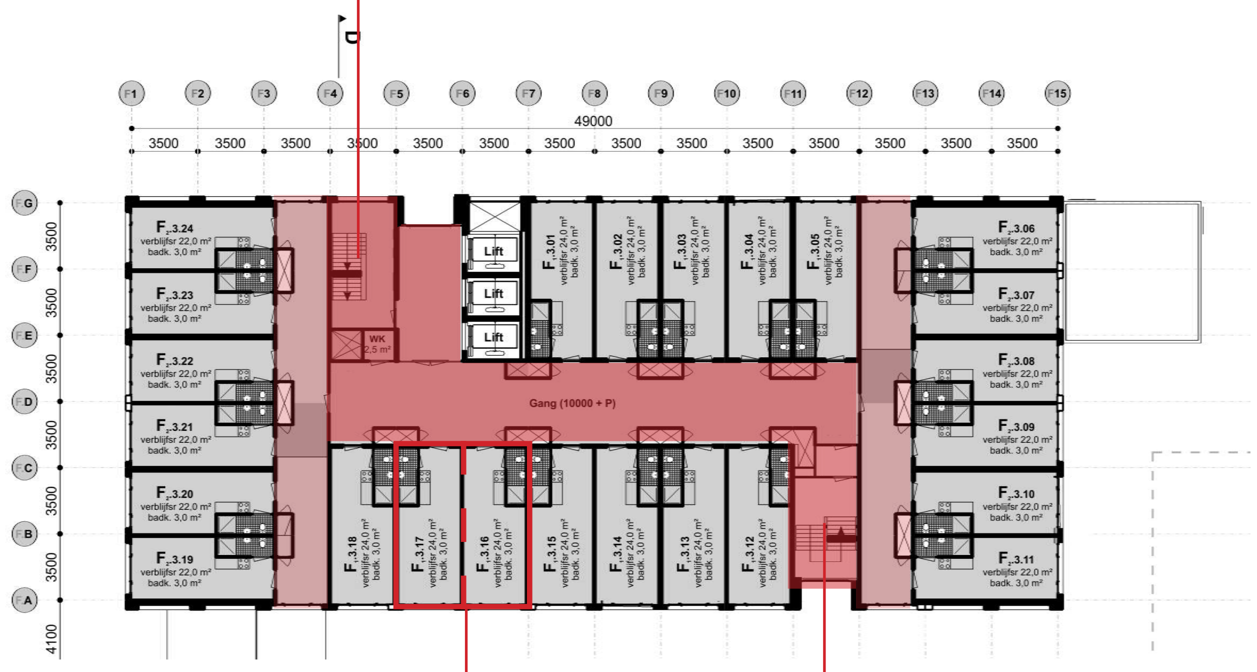
Compartment

Fire-safe glass > staircases are behind this
There is one on both the North and South side

Primary fleeing route

Secondary fleeing route

Main Staircase
North side of the building



Compartment

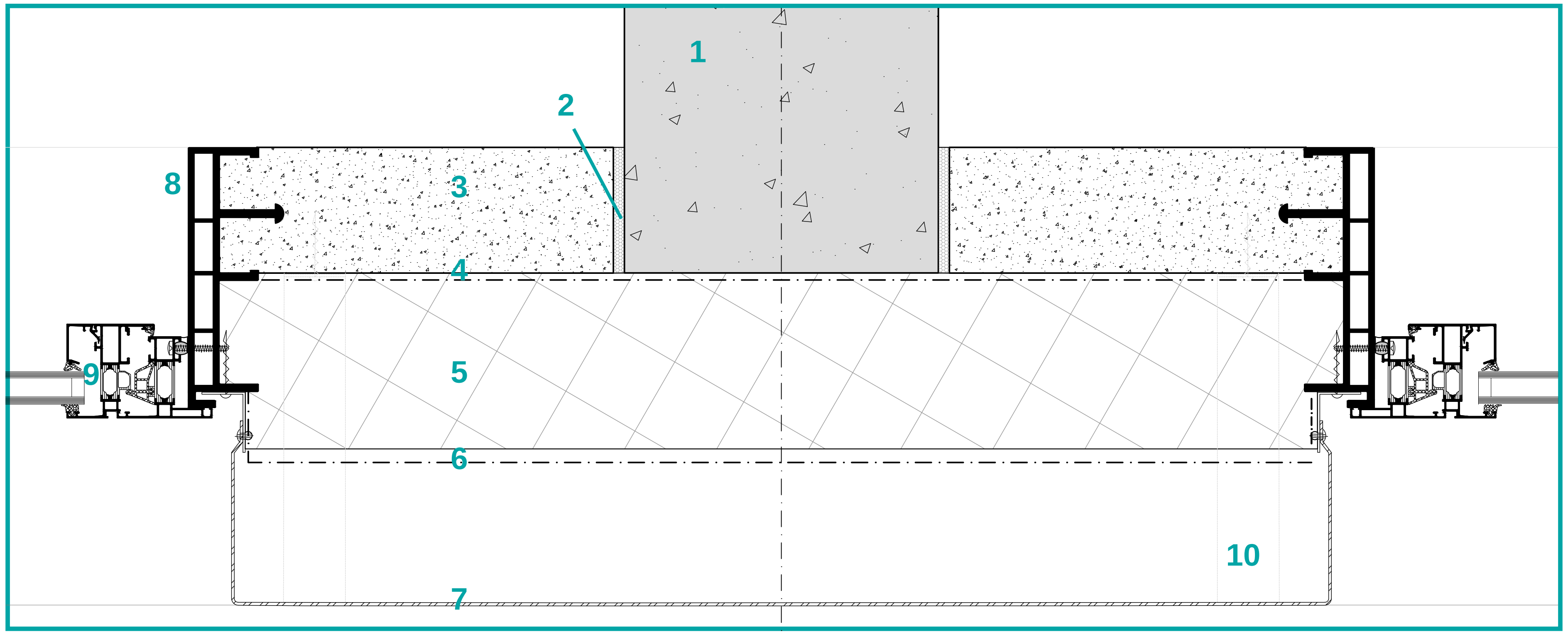
Emergency exit stairs
South side of the building

Fire concept

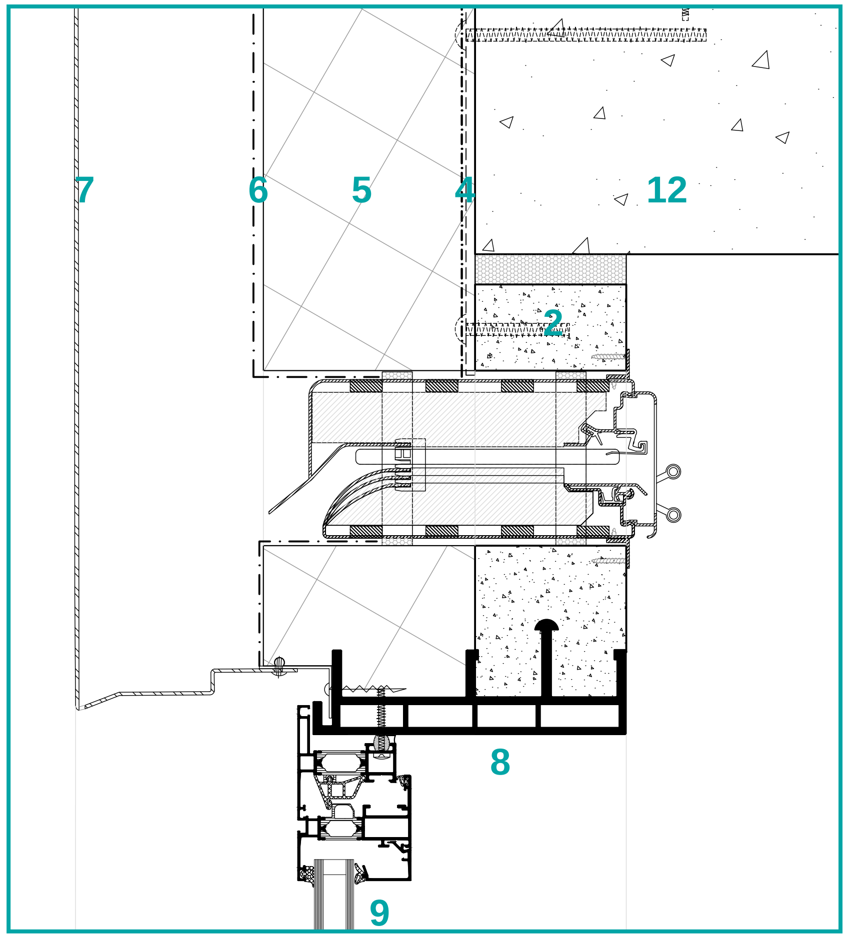
The compartmentalization of the building is per two rooms, so between two concrete walls (one full panel). Within these compartments there are two sub-compartments, which is one apartment. The partition walls between those have gypsum finish, a material that has a good fire resistance.

The apartments on the North and South side of the building are directly situated next to the hallway that leads to the two main emergency staircases. The apartments on the East and West side of the building are connected to another hallway which has an entrance to the main hallway which leads to the emergency staircases.

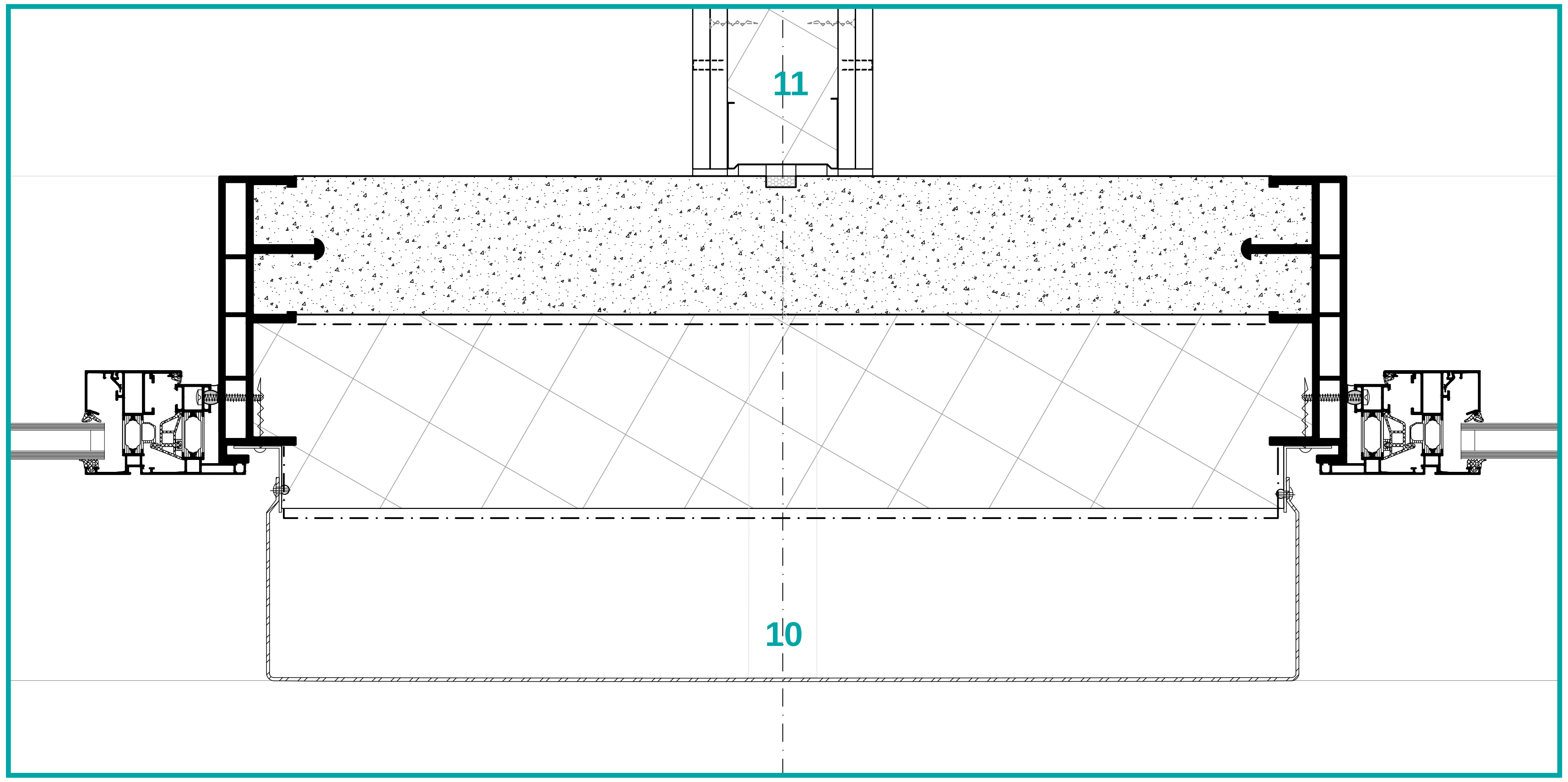
Due to the fact that almost all rooms have only a facade panel with a almost room-wide window, it is most likely that mainly internal fires happen. If the fire gets close to the facade, the glass will eventually break and a huge amount of air will get into the room keeping the fire away from the facade (at least for a while).



Horizontal section - load-bearing concrete wall



Vertical section - Top view of window



Horizontal section - partition wall

Overview of materials

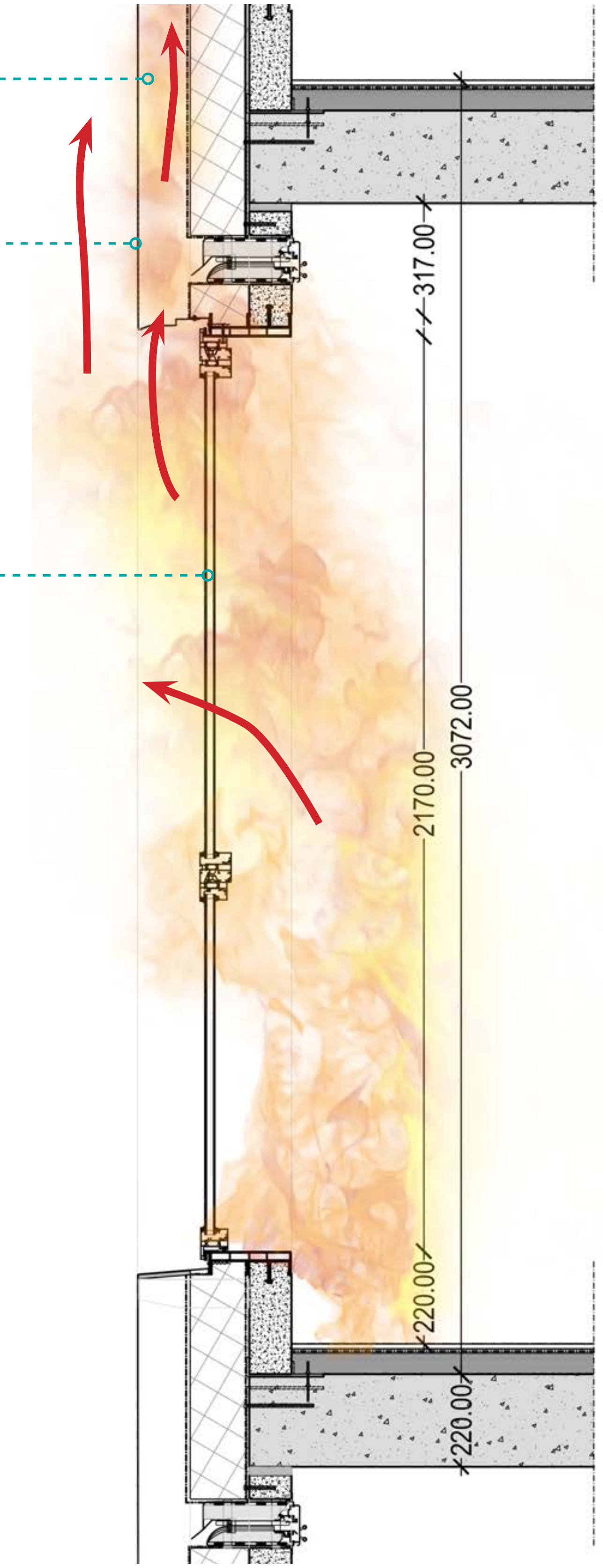
1. Concrete load bearing wall - Concrete has a high fire resistance classification (class A1)
2. Pur insulation - since it is only used for small linear gaps, the fire safety of this material is considered. Pur is only dangerous in large amounts, because of the toxics that can be freed in high temperatures. (class B)
3. Concrete panel - (class A1)
4. Vapour barrier - most vapour barriers are not a risk regarding fire
5. Thermal insulation - mineral wool, which is naturally fire resistant (according to Rock-wool) (class A1)
6. Air barrier - most air barriers are not a risk regarding fire
7. Aluminium facade cladding - Aluminium has a melting temperature which are often soon reached with fires, so the material will melt quite soon. Though it is known of ACP panels that they are very often coated with a fire resistant coating. (class B)
8. GRP mounting frame - GRP is not a fire conductive material but it melts at high temperatures and creates smoke. It is often compared to aluminium, but has the advantage that fire retardants can be easily added and therefore making it more fire resistant. (class B)
9. Aluminium window frame - (class B)
10. Aluminium profile for support facade cladding - (class B)
11. Partition wall - We think that the partition wall has a gypsum finish, and therefore has a quite good fire resistance.(class A1)
12. Concrete floor slab - (class A1)

While glass allows fire to spread (enter or exit) the cladding can be used to either allow or prevent the spreading

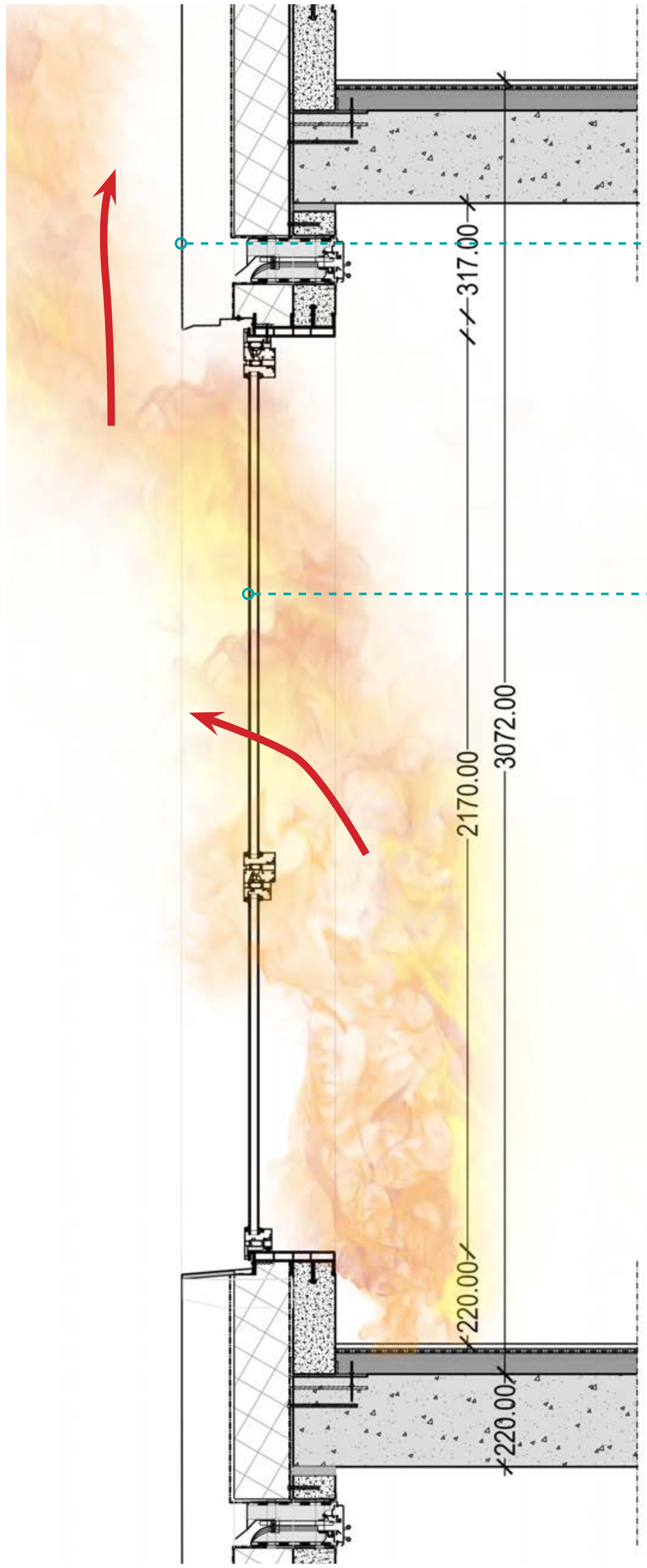
The fire looks for a way out through the cavity where it spreads 5-10 times faster

Fire spreads upwards due to a combustible cladding, thereby contributing to the fire

Fire breaks in and out through the glass



Option 1 - Rapid fire spread



Option 2 - Restricted fire spread

Fire spread is restricted due to a Fire Retardant or Non-Combustible cladding material system

Fire breaks in and out through the glass

Due to the height of the building, as well as its use - student accommodation - inside TUDelft's campus we believe that the aluminium composite cladding system is a Fire-Retardant or Non-Combustible cladding system that meets the regulations. Otherwise the aluminium cladding and the amount of glazing in the building would have disastrous consequences. The restricted fire spread doesn't mean that fire will not spread but it can be more easily controlled. The same treatment can be done for the GRP mounting frame.

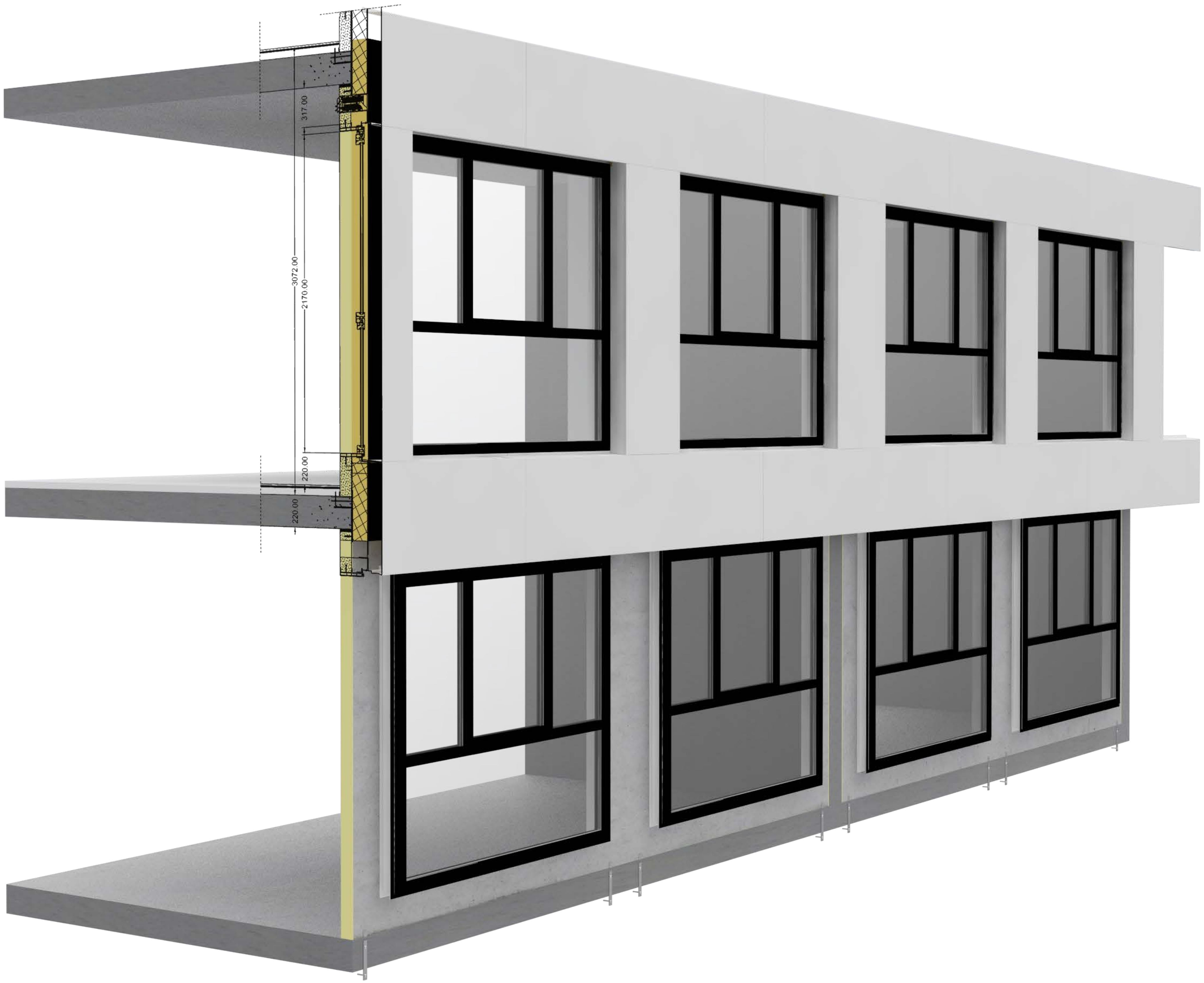
Conclusion fire safety

When considering the facade of this building, it seems as if it is not as fire safe as it should be. However when we compare the data to the regulations the results are not as bad as it could be.

All materials (of which we were able to find the classification) have a classification of at least B, therefore it complies with paragraph 5.2.1 of the NEN 6068.

As for the fire spread and flash-over situation. Because there is a large opening on the facade and the facade is mostly considered as an opening. There are only two layers of glass the glass will break after 5 min. therefore allowing air to fill the room and keep the fire internally.

Overall it can be concluded that the fire safety of the building is agreeable according to the Dutch fire safety regulations.



Sectional perspective - Facade

3D DRAWING WORK - ASSEMBLY SEQUENCE

1. Structure phase

01a. Concrete Structure. Concrete walls cast on site.
Concrete slab: 220 mm
Concrete wall: 250 mm

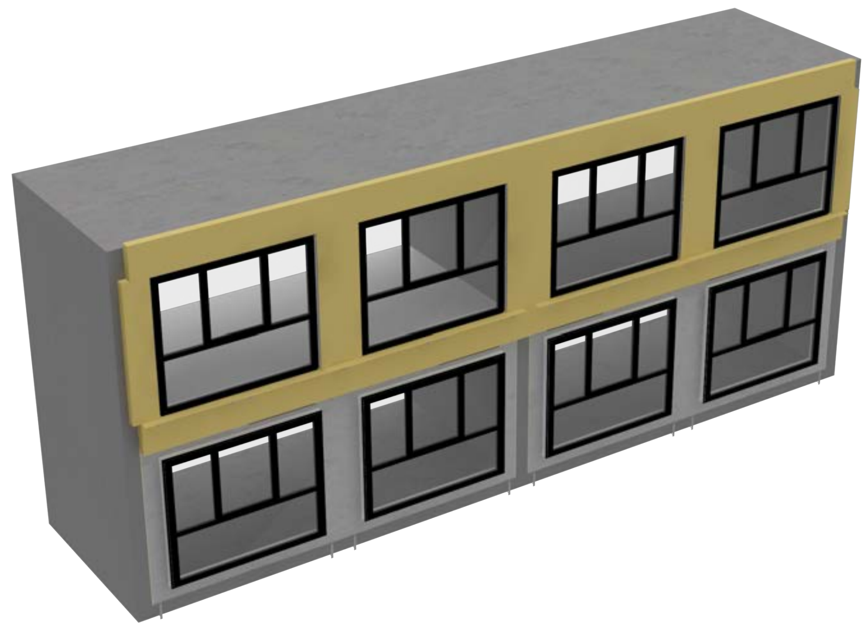
01b. Steel Anchors to support the prefabricated panels on the concrete slab.

01c. Prefabricated Concrete Panels (100mm) with GRP mounting frame with attached aluminium double glazing window frames.

2. Phase of closing

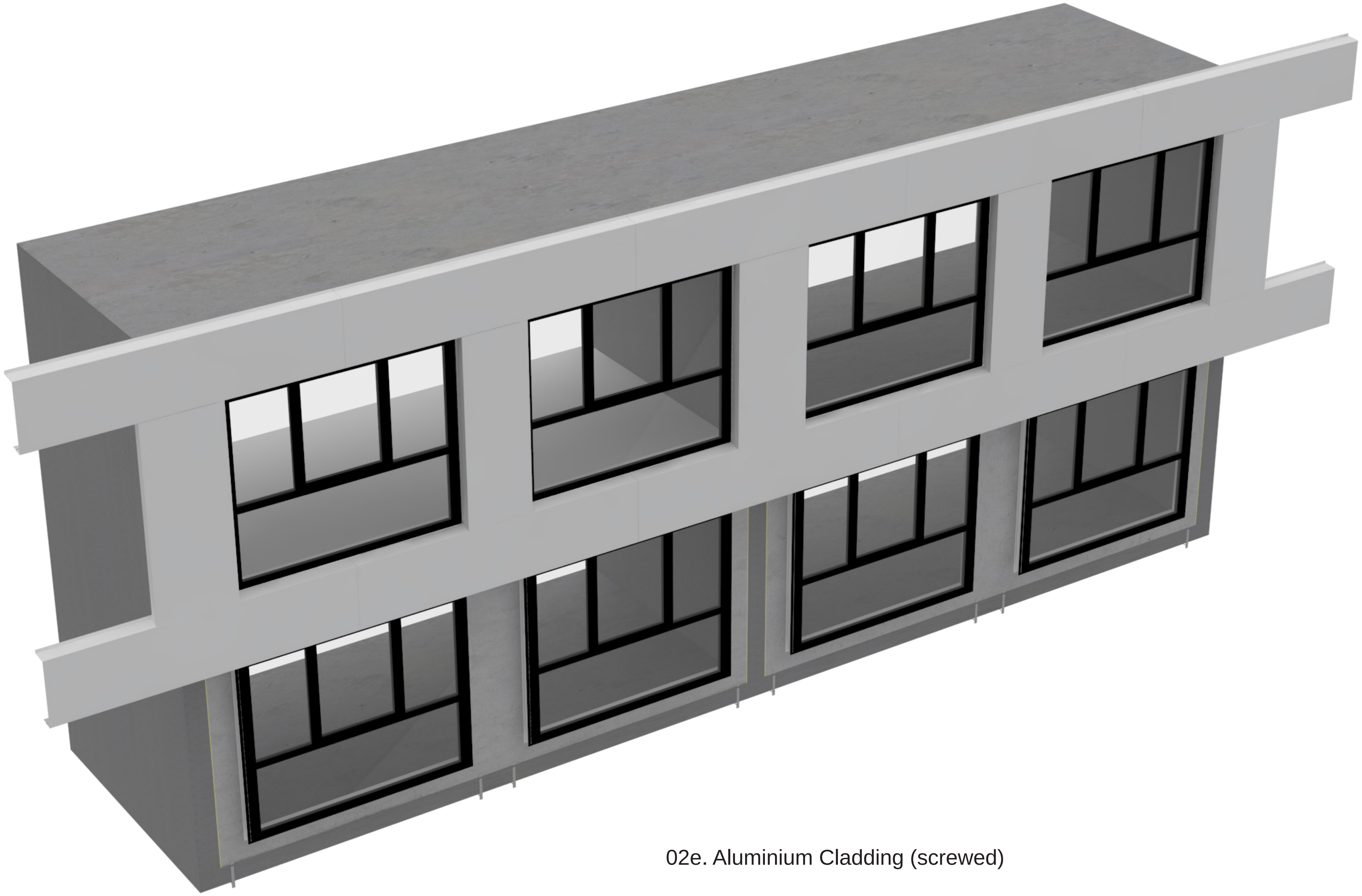
02a. Pur insulation and ventilation system installation
A screed layer is also place above the concrete slab so as to hide the anchors and reduce movements.
Screed: 50mm

02b. Steel profiles and brackets to support aluminium cladding. The aluminium cladding will be screwed on the secondary support system.

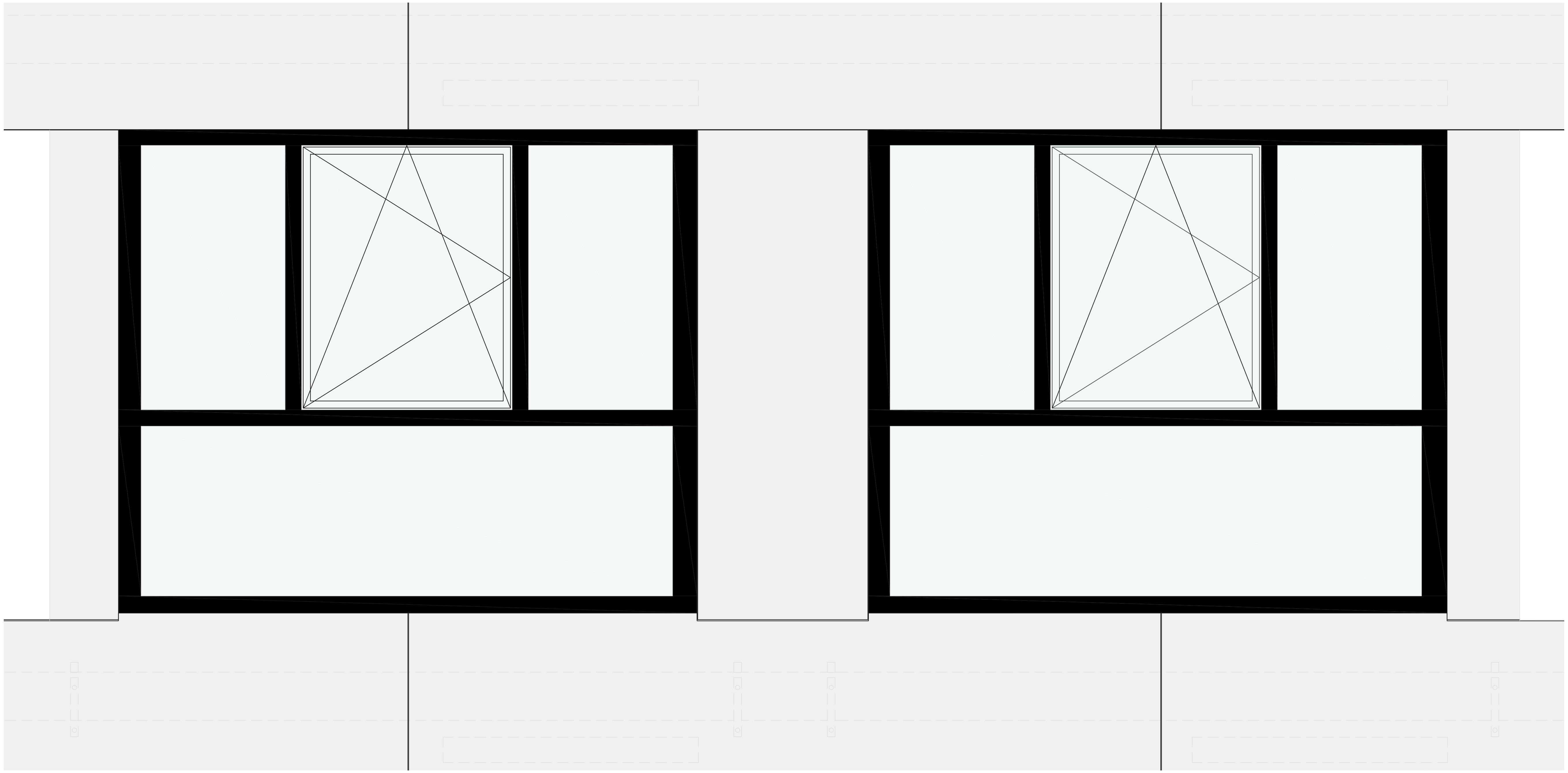


02c. Rockwool insulation 140 mm

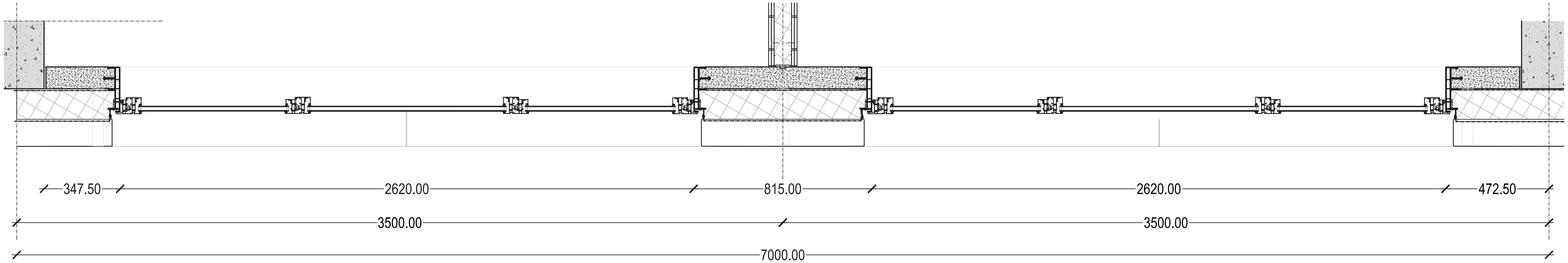
02d. Vapour permeable air barrier



02e. Aluminium Cladding (screwed)

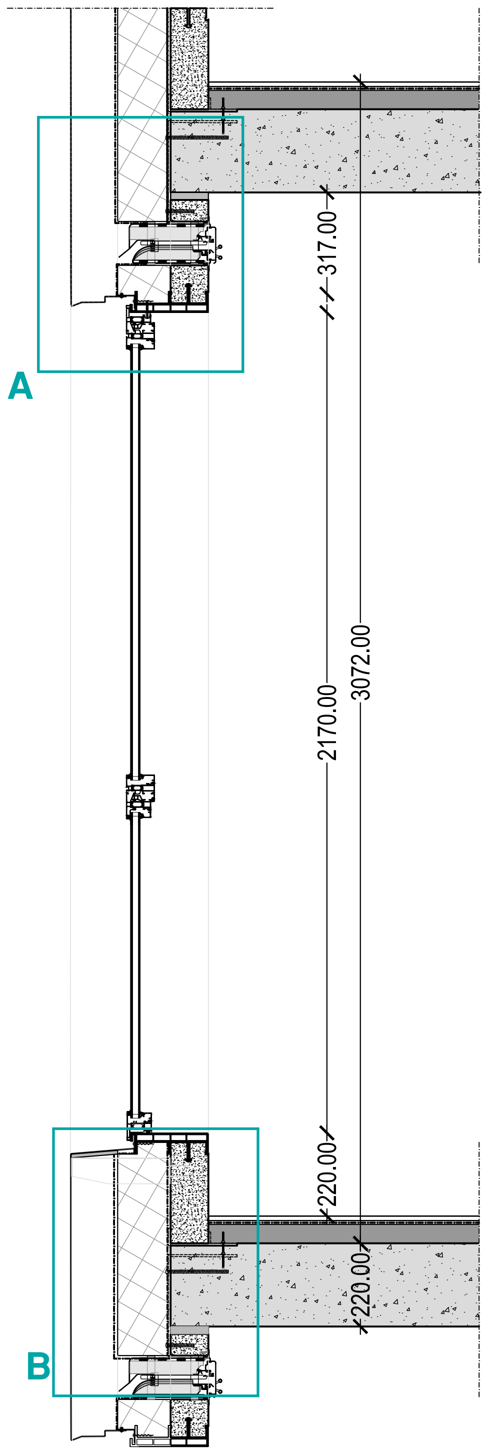


Part Elevation, scale 1:20



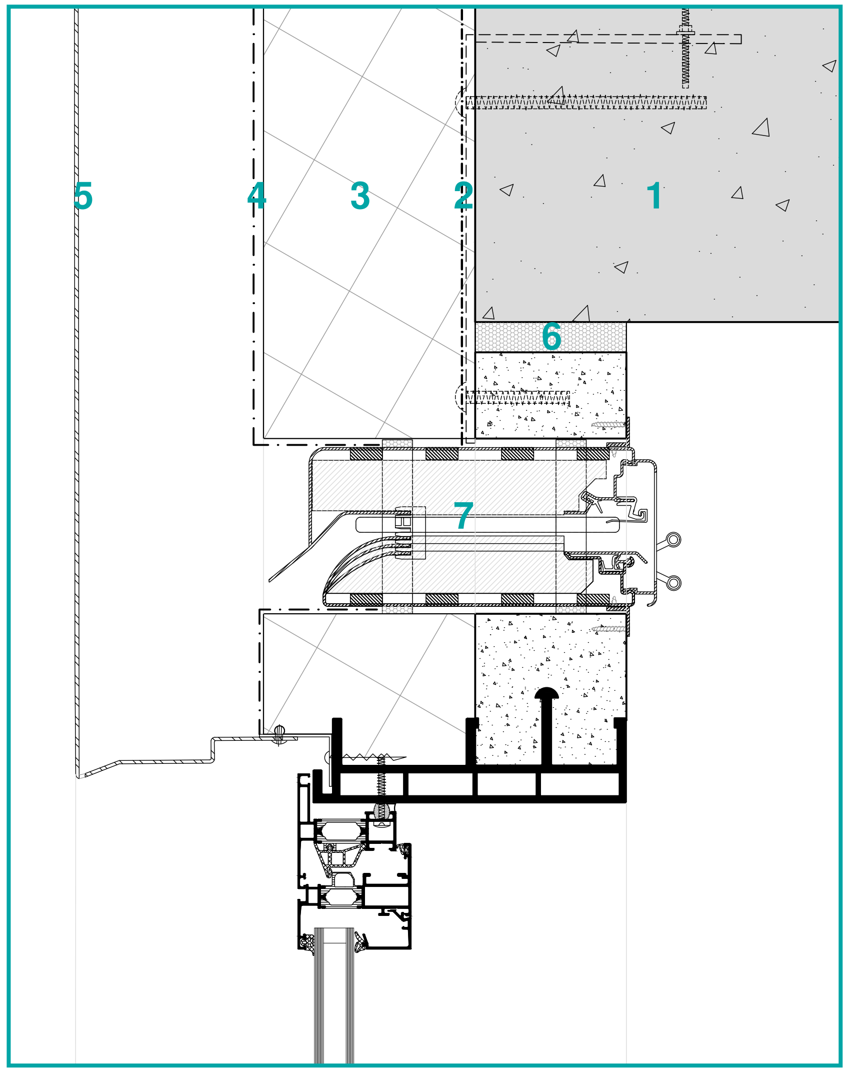
Part Plan, scale 1:20

Section - Scale 1:20



Detail A - Vertical Detail, Scale 1:5

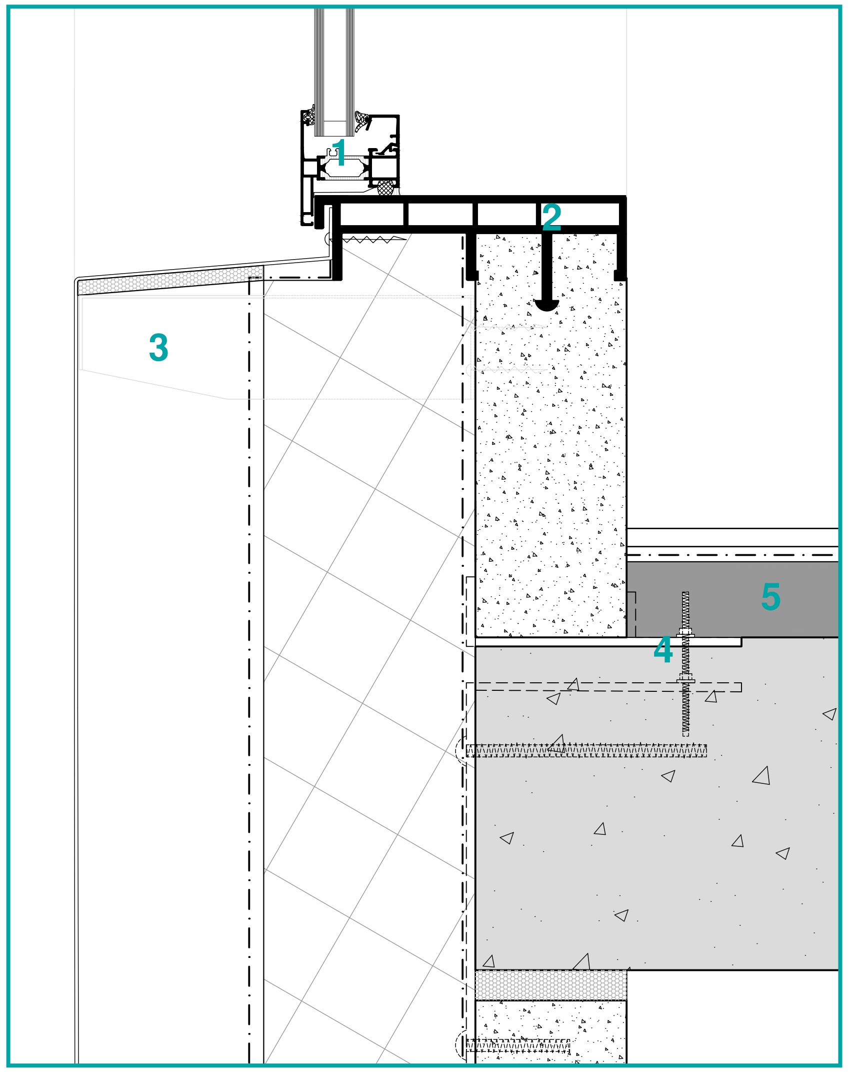
Floor/Window with ventilation



1. Concrete slab
2. Vapour barrier
3. Thermal insulation
4. Vapour permeable air barrier
5. Aluminium cladding
6. Pur insulation
7. Ventilation unit

Detail B - Vertical Detail, Scale 1:5

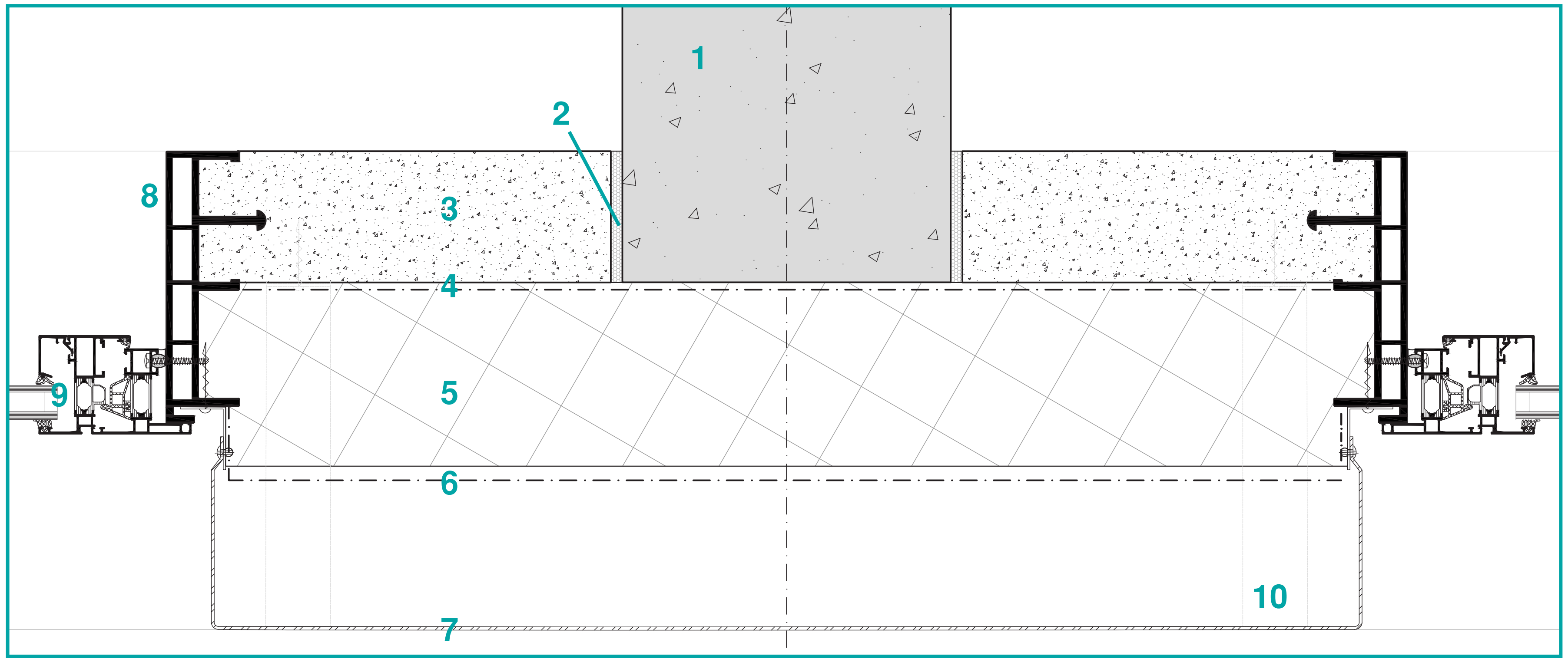
Floor/window



1. Aluminium window frame
2. GRP mounting frame
3. Aluminium profile for support facade cladding
4. Weight bracket facade panel
5. Screed
6. Insulation
7. Laminated floor

Detail C - Horizontal section, Scale 1:5

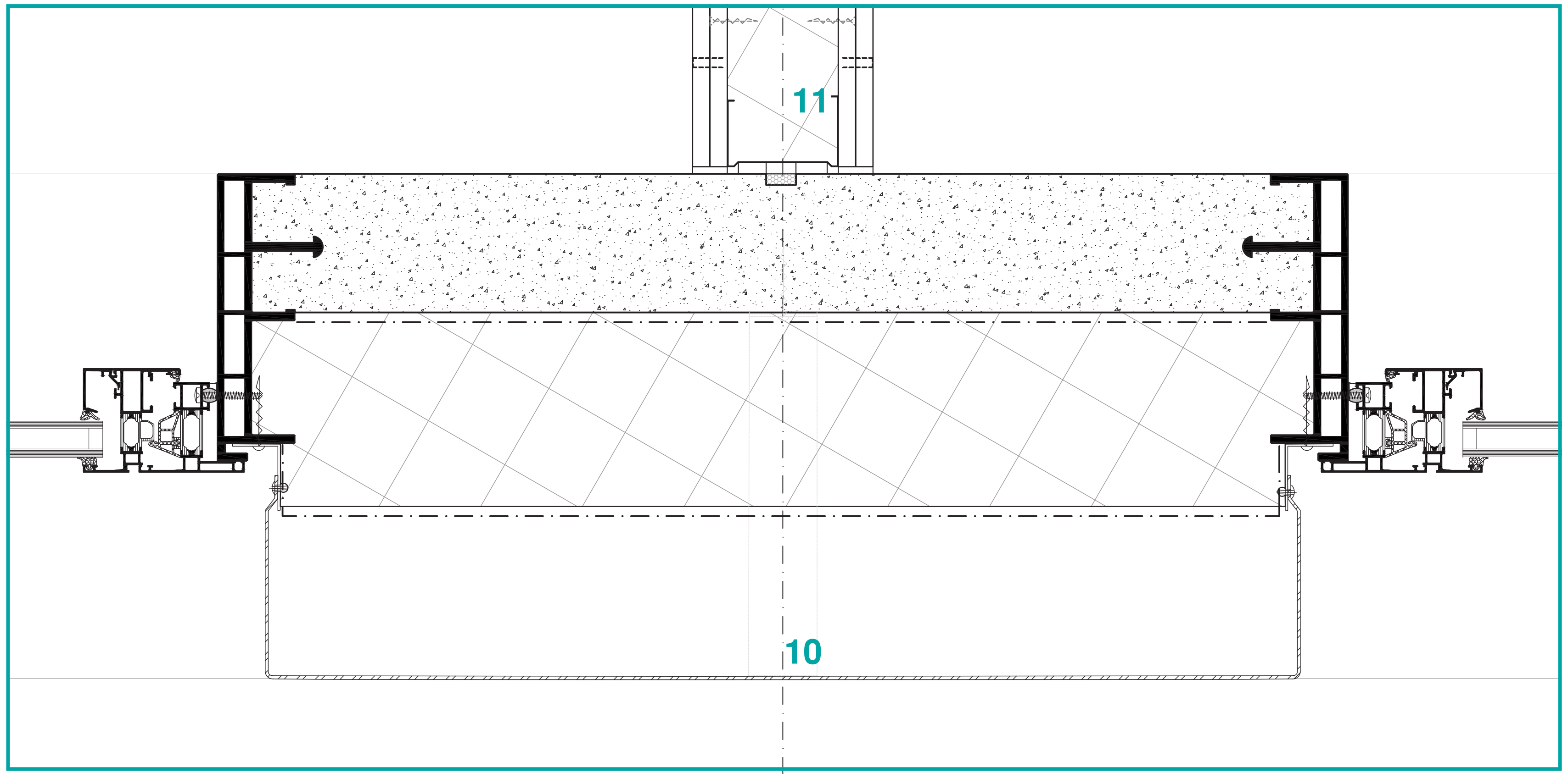
Concrete Wall with Prefabricated concrete panels and aluminium panels

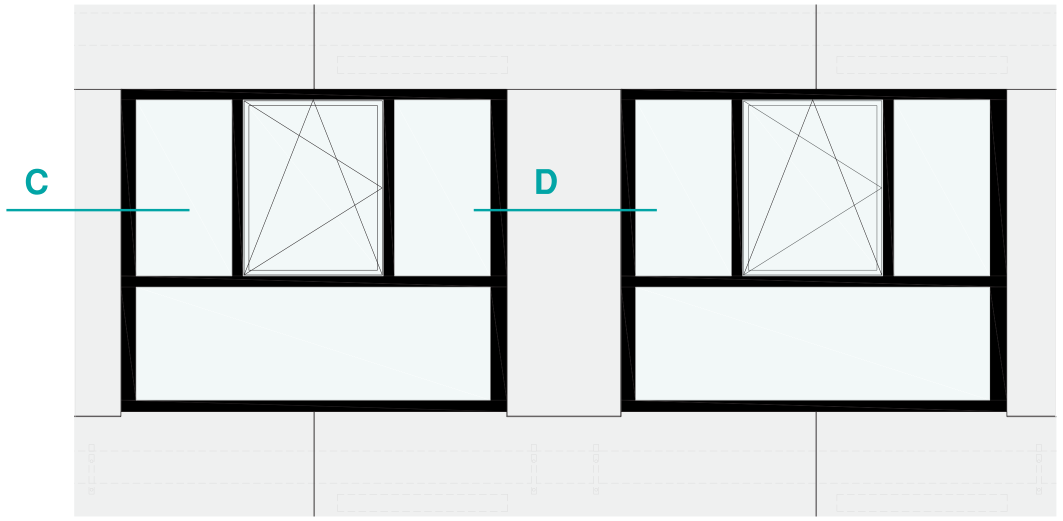


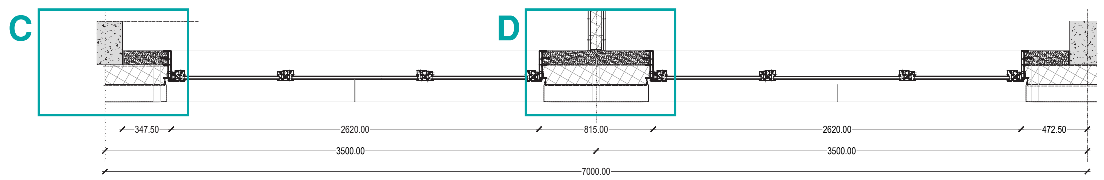
1. Concrete load bearing wall
2. Pur insulation
3. Concrete panel
4. Vapour barrier
5. Thermal insulation
6. Vapour permeable air barrier
7. Aluminium facade cladding
8. GRP mounting frame
9. Aluminium window frame
10. Aluminium profile for support facade cladding
11. Partition wall

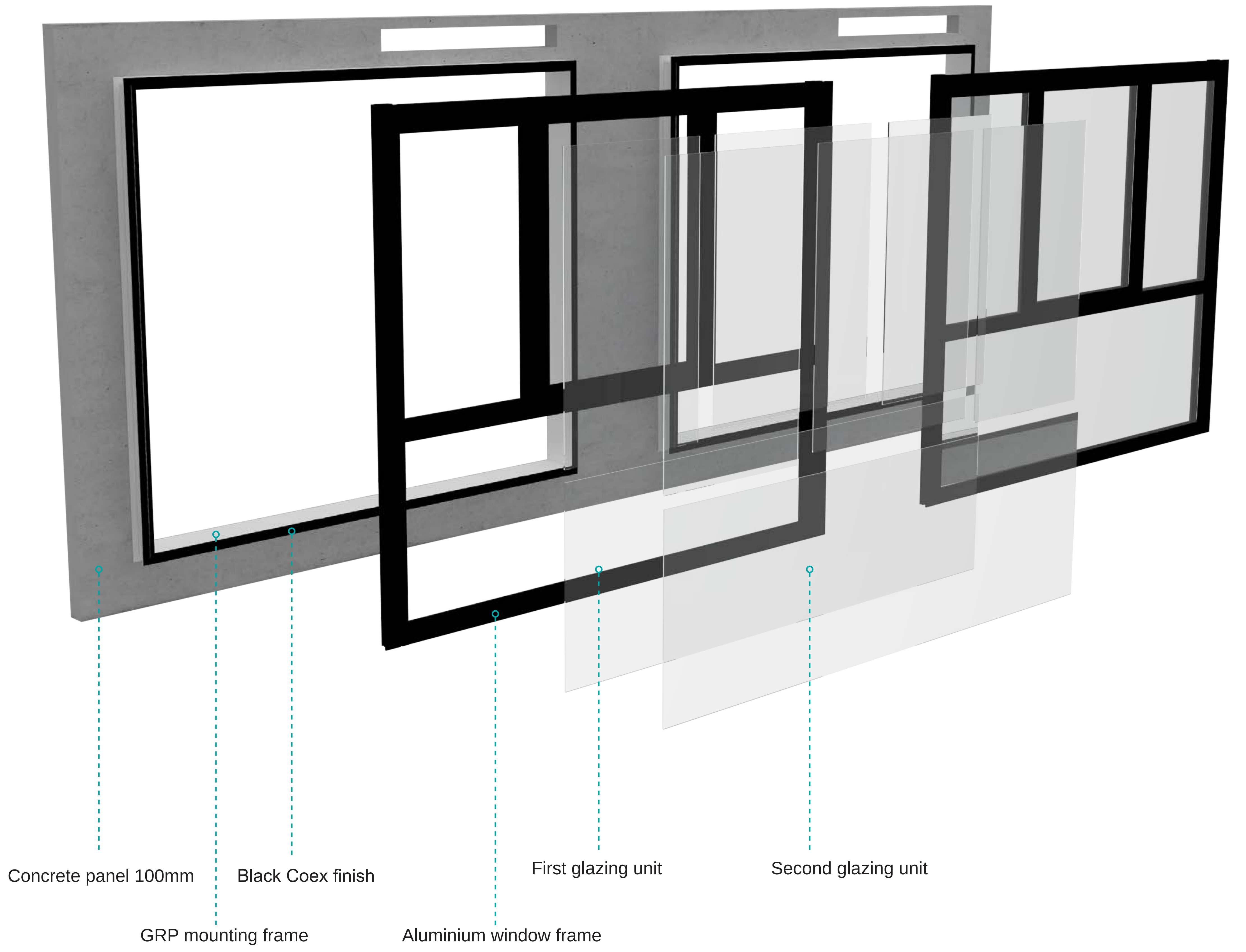
Detail D - Horizontal section, Scale 1:5

Gypsum wall with Prefabricated concrete panels and aluminium panels

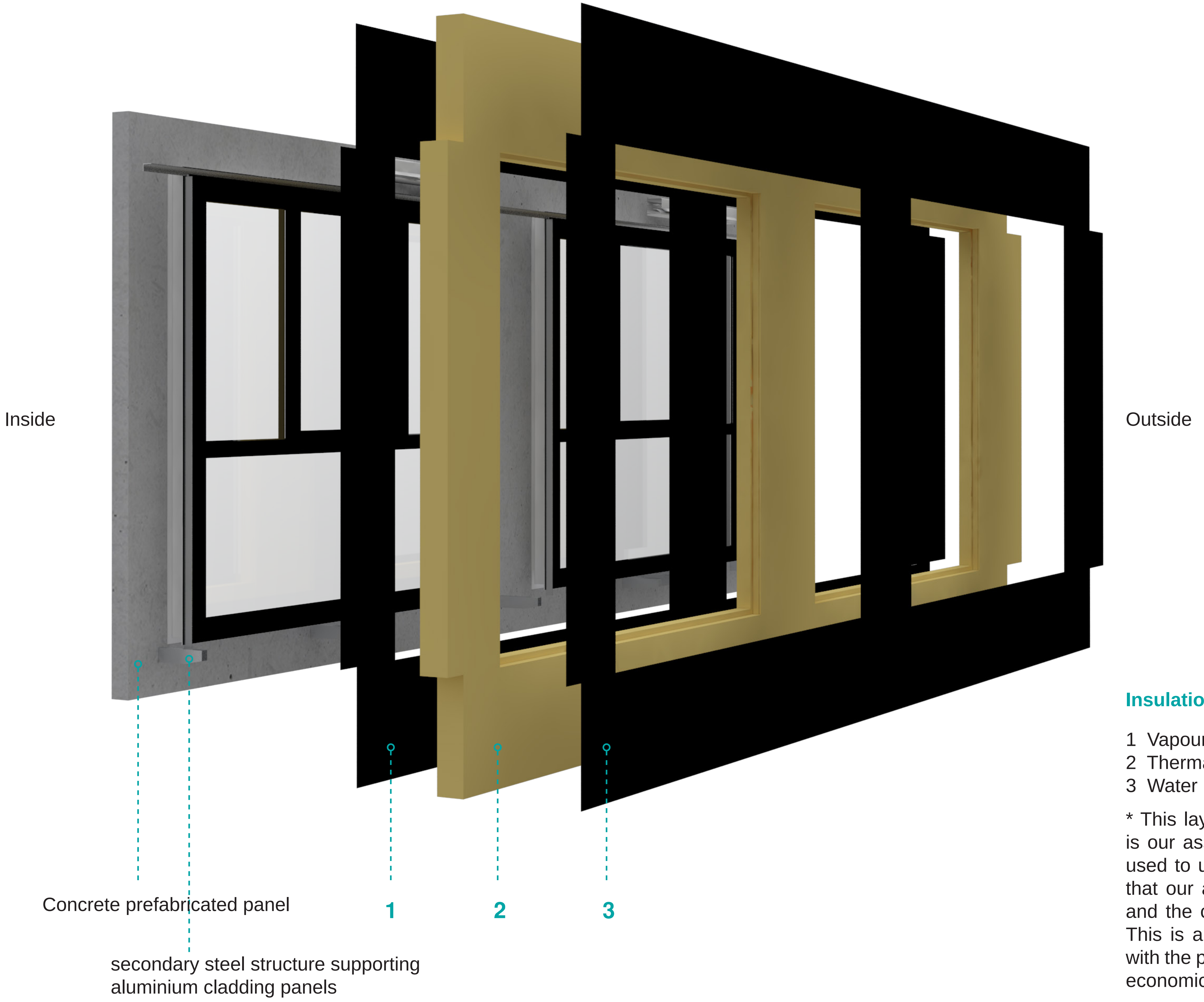








Anchor supporting the whole panel

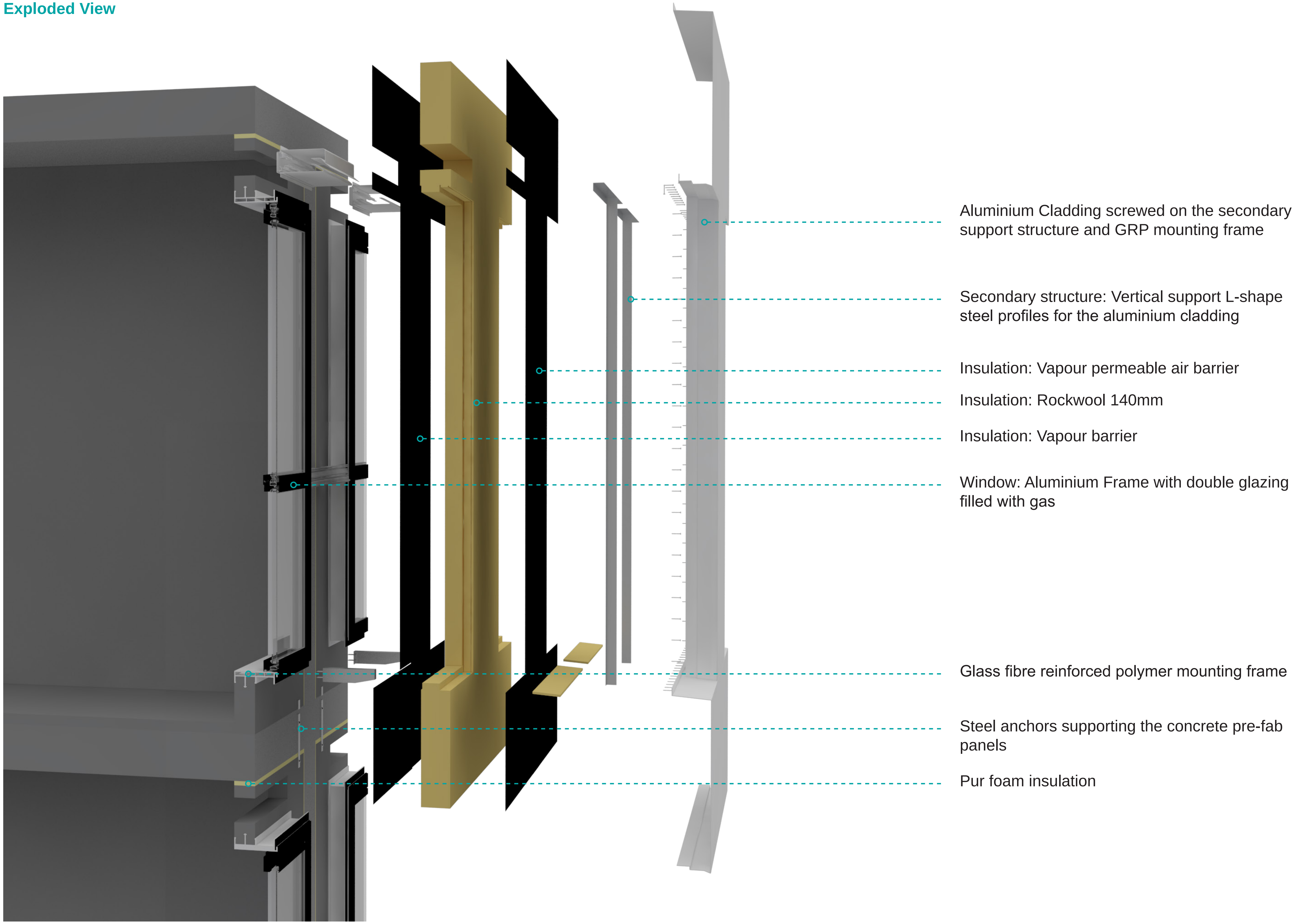


Insulation

1 Vapour barrier*
2 Thermal insulation layer
3 Water resistant layer

* This layer is not visible in the drawings we got of the building. It is our assumption based on the construction photographs that we used to understand the structural assembly of our facade. In case that our assumption is incorrect and back layer would be missing and the concrete prefabricated panel would act as vapour barrier. This is a cheaper way of ensuring watertightness which complies with the primary concept of the building to be constructed as fast and economically as possible.

Exploded View



Interior View

Our experience

Our study of Studentenwoningen Stieltjesweg TUDelft, reflects that the use of a building or the time for construction can define the details of the construction. Being a student housing, it can be seen in a lot of places how the short-cuts/ cheap ways were adopted. Still the project managed to get an A certification for full filling the building decree requirements.

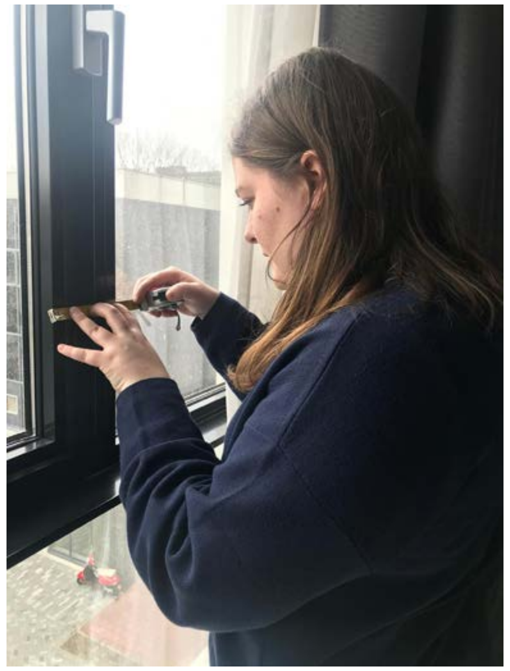
The real challenge of analysing the facade of this building was the unavailability of technical drawings. The municipality had a set of drawings that were of a tender stage and depicted nothing of the currently standing building. The architect provided some data which also differed from the existing building but it gave up an idea of the architectural concept, context and structure. The difference may be due to the fact that the contractors who were responsible for the construction, updated details. Upon asking, they refused to provide any data on the building. The company that engineered a facade component provided the details of the window frame to concrete connection. All of the primary hypothesis on functioning of the facade is based on these documents.

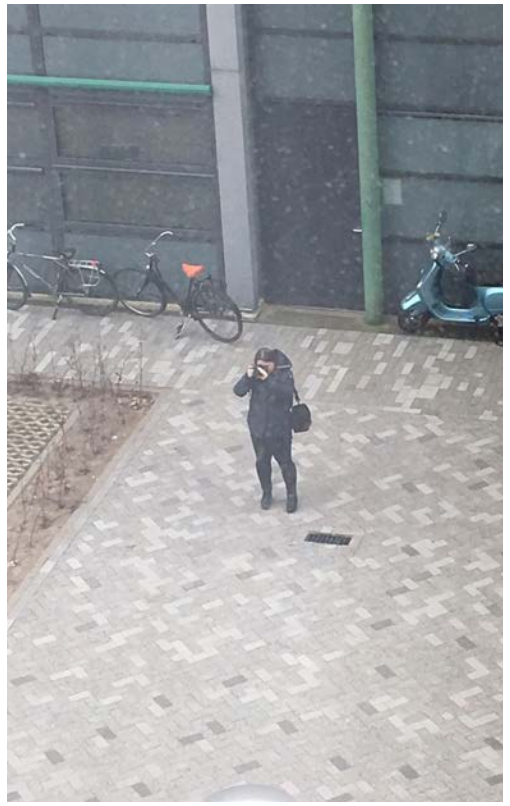
The on-site study did not reveal any details as every part of the structure is hidden. The external cladding hide what goes behind on the wall. In the interior, ceilings are plastered with false ceiling and drywall partitions. Nevertheless, the visit to the project was useful in dimensioning and cross-checking with the drawings to identify a co-relation. A flame test was done to find out what type of glass was installed in the windows.

The next big support was photographs. Pictorial data of different stages of construction helped in understanding important details such as cladding connection and lines of defence against water and air, and other details that were absent from the drawing.

The drawback of getting information from photographs is that a lot of information is based on assumptions that eventually affect the analysis. The thermal analysis requires thermal properties material properties but uncertainty may have resulted in differing results. Similar applies for the daylighting results.

Despite these shortcomings, the whole exercise was a great learning experience. The learnings about the structure, movements, tolerances, environmental and safety are a major take away from the course. Also the inclusion of virtual reality gave an extra dimension to understand and then explain the project better as well as improve our technical skills.





Thoughts on re-designing

The Studentenwoningen Stieltjesweg TUDelft is a student housing building built on a budget and limited time frame and on a constricted site on the TU Delft campus. This lead to the decision of using pre-cast components to speed up the construction time and effectively manage the use of heavy machinery on site. The panel system construction allows a great degree of flexibility in terms of combining rooms to make a bigger one and easy docking of the facade to the structure.

The building follows the Dutch building decree norms and is certified as a ‘label A’ building as per DUWO who manage the building.

Even though the project team says that the facade panels are recyclable, they actually might just be reusable as an entire panel in another facade. Otherwise they can only be down-cycled. No measures have been taken to have to reduce the ecological footprint and do not address any of the environmental issues.

The project team chose a high rise construction for the sole purpose of making it a landmark building. In this sense, the effect of wind was ignored. Even though the building has measure to counter the wind forces, the surrounding areas get affected by the wind tunnel effect. A cautious design would be better for the context but not for revenue which won in this case.

For the purpose of this project only a part of the facade was chosen to be analysed in detail. A south-east facing facade was found to be the worst performing facade in terms of solar loads and glare effect. As there is no sun shading designed as part of the building, residents have to depend upon internal shading which are not as effective in blocking solar gains.

It is not good for student housing to install the floor insulation on their own without any guidelines or baseline performance criteria. This effects the overall acoustic performance in the rooms.

In an opportunity to improve upon the existing facade, the following are be proposed :
1. Utilising the wind and solar gains for energy production
2. Use of sustainable materials with low carbon footprint
3. Methods of construction that allow for dis-assembly
4. Shading devices to block solar gains
5. Alternate methods for fixing of the cladding to the structure to minimise thermal bridging