

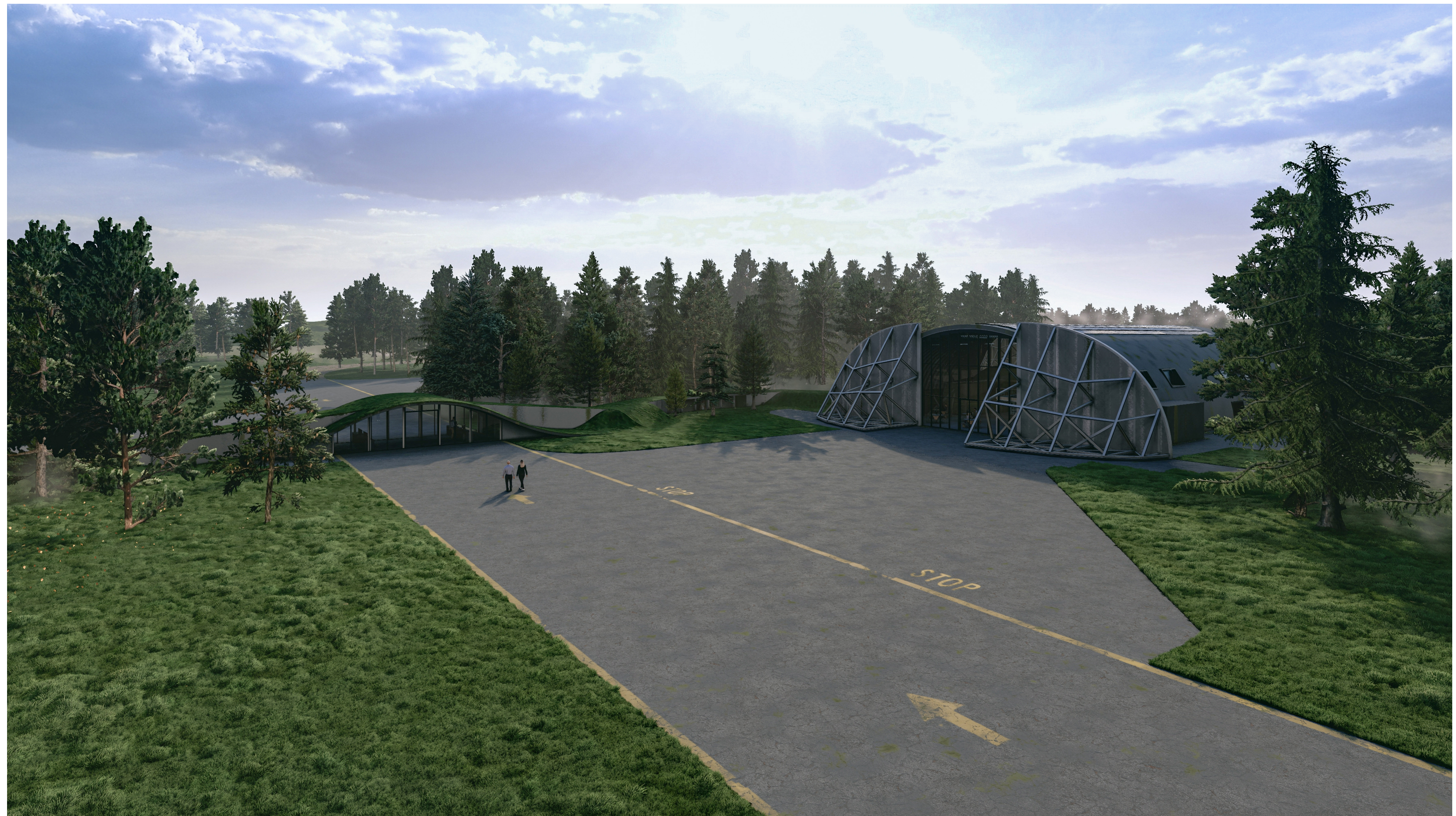
HIDDEN IN PLAIN SIGHT
FROM SHELTER TO MEDIATED SEQUENCE

DRAWING SET

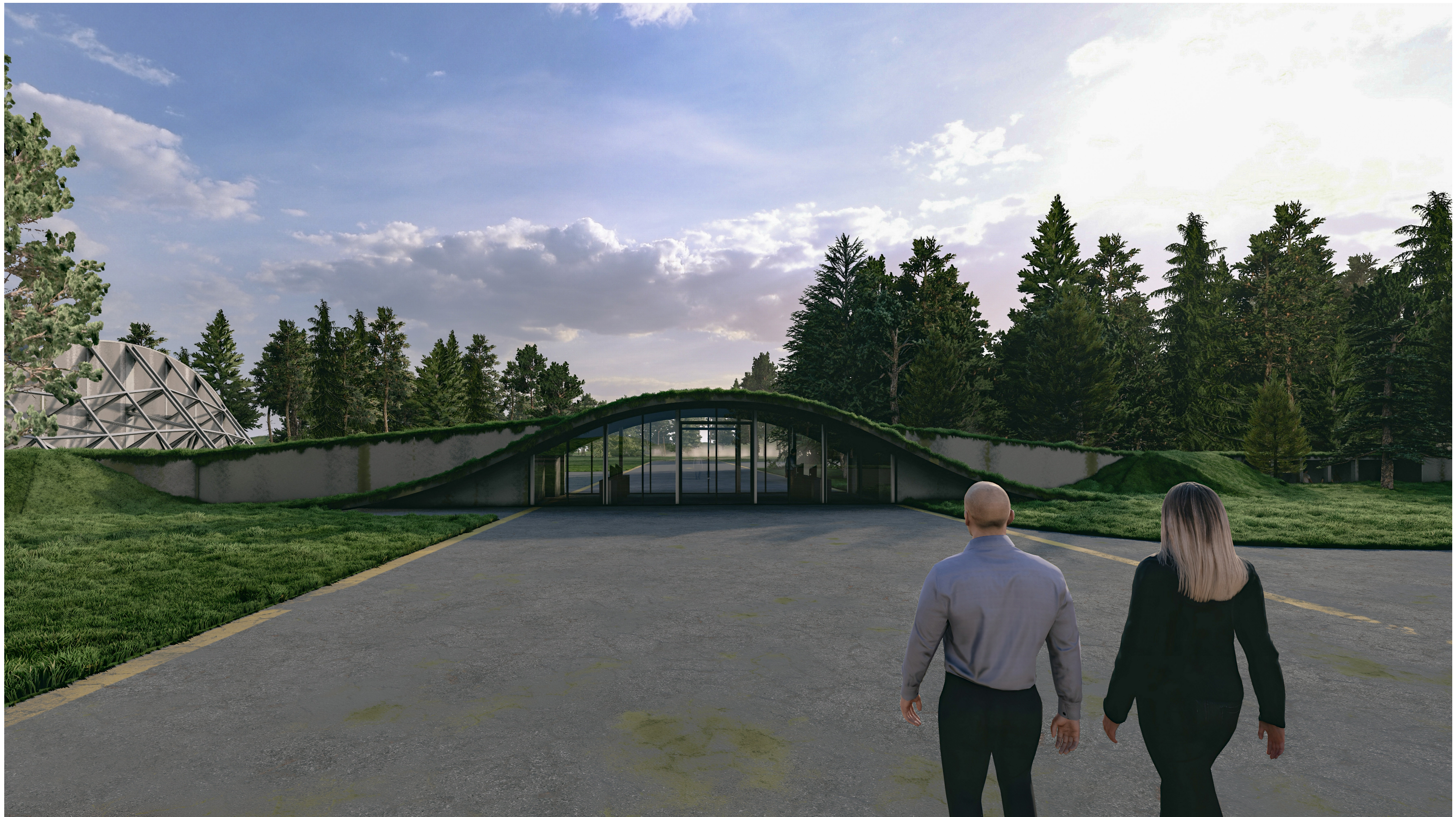
AR4AH120 | Adaptive Reuse of Heritage Graduation Studio
24-06-2026

DAMIAN KLEIN

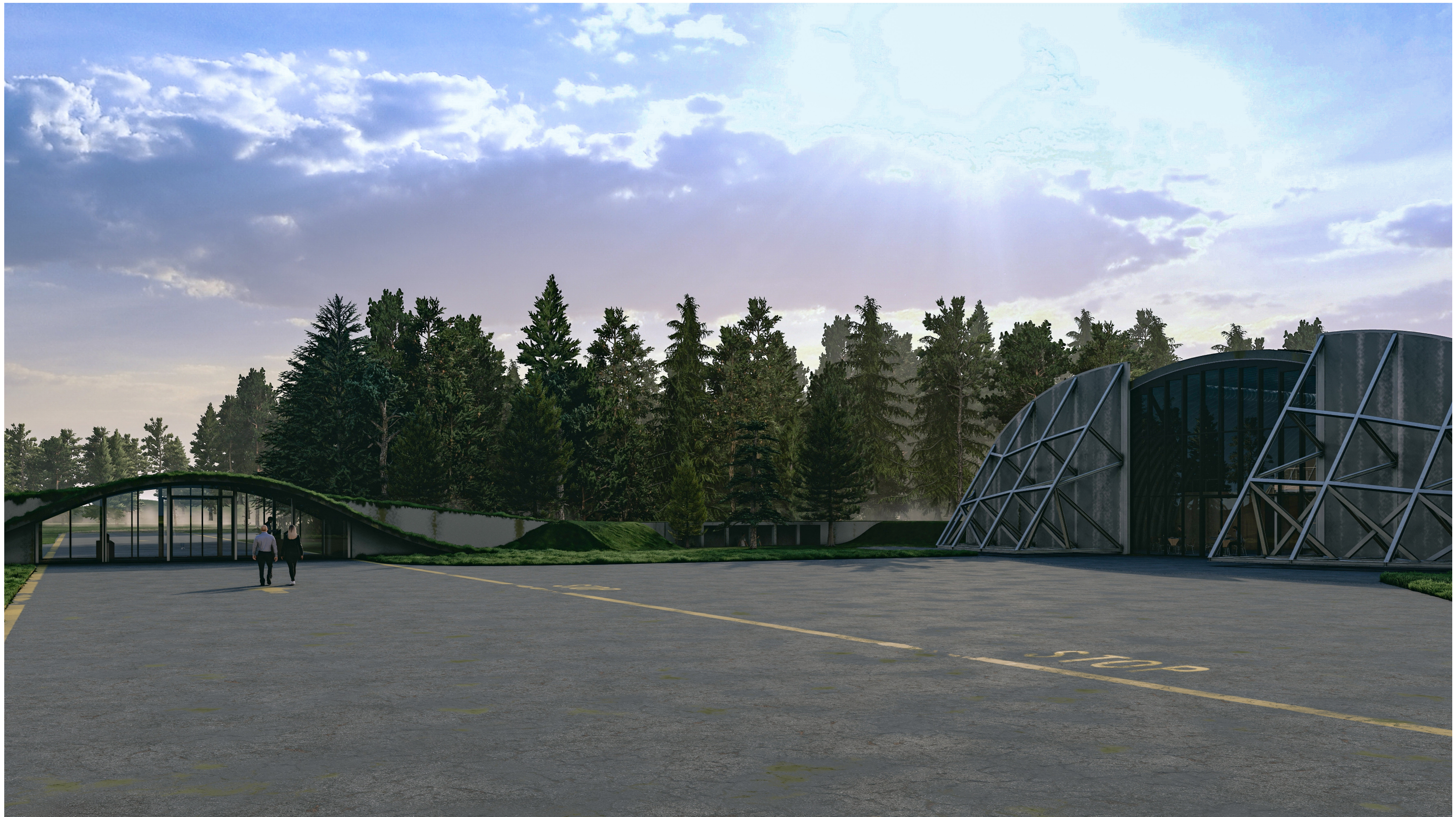
ATMOSPHERIC IMPRESSION - OVERVIEW



VISUALISATION - TAXIWAY PAVILION



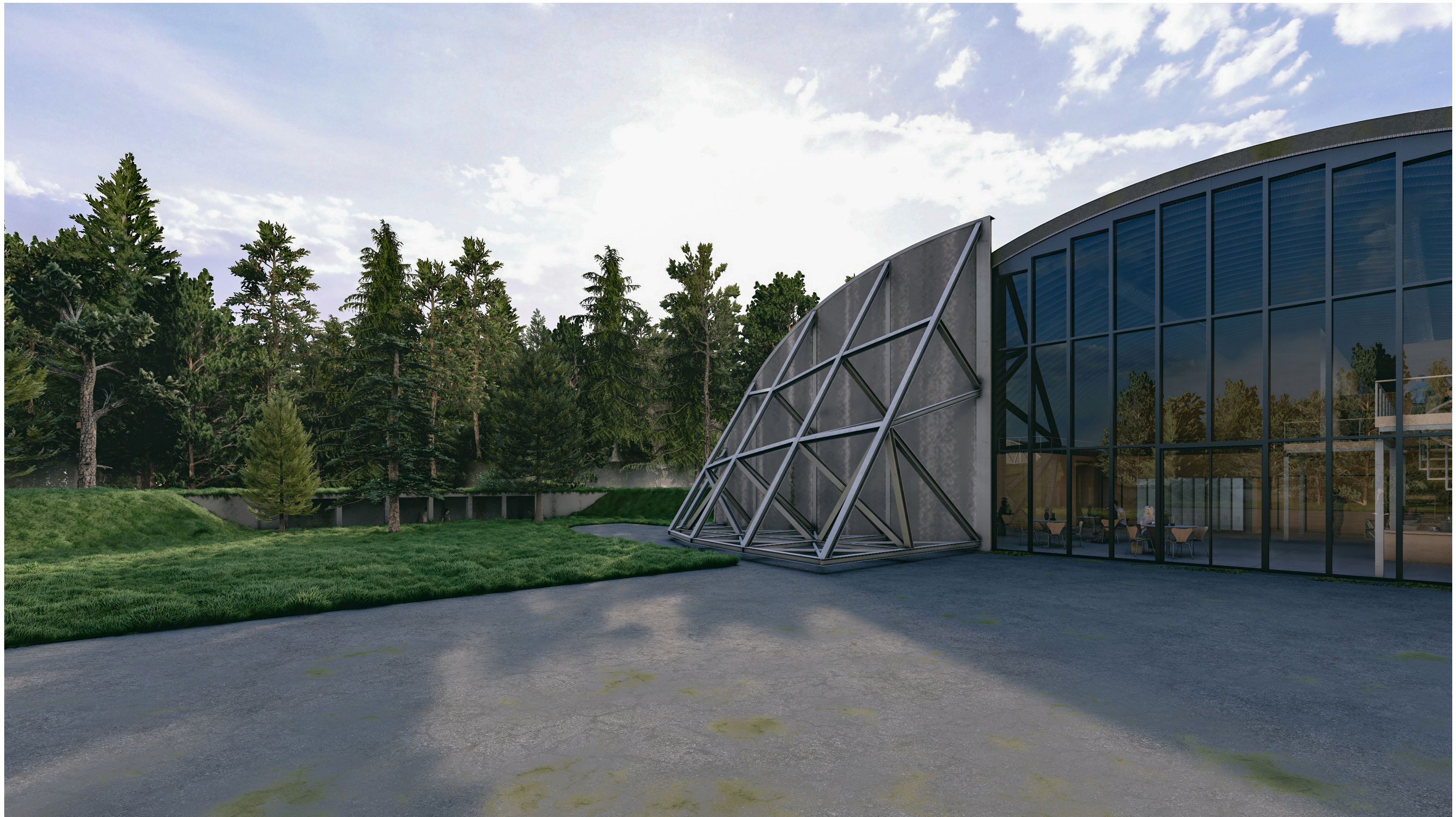
VISUALISATION - OVERVIEW 2



ATMOSPHERIC IMPRESSION - CORRIDOR



ATMOSPHERIC IMPRESSION - VISITOR & EVENT CENTER AND CORRIDOR



VISUALISATION - VISITOR & EVENT CENTER FACADE



VISUALISATION - VISITOR & EVENT CENTER INTERIOR 1



VISUALISATION - VISITOR & EVENT CENTER INTERIOR 2



VISUALISATION - VISITOR & EVENT CENTER INTERIOR 3



VISUALISATION - VISITOR & EVENT CENTER INTERIOR 3



BERLIN, 13. AUGUST 1961

MAUERBAU

Die Welt hält den Atem an
Niemand hat die Absicht,
eine Mauer zu errichten!



NORWEGEN

OSTSEE

POLEN

UDSSR

TSCHECHO-SLOWAKEI

SCHWARZES MEER



Hidden in Plain Sight

From Shelter to Mediated Sequence

AR4AH120 | Adaptive Reuse of Heritage Graduation Studio (2025/26)



LOCKHEED F-104G STARFIGHTER
32 TACTICAL FIGHTER SQUADRON
USAFE
Soesterberg, the Netherlands



THE COLD WAR

A time of tension.
A world divided.
Technology, power
and ideology in
constant balance.
And fear of the
unknown.



Damian Klein | 5085535

10-06-2026

ir. A.W. Hermkens,
dr. I. Nevzgodin

MASTERPLAN

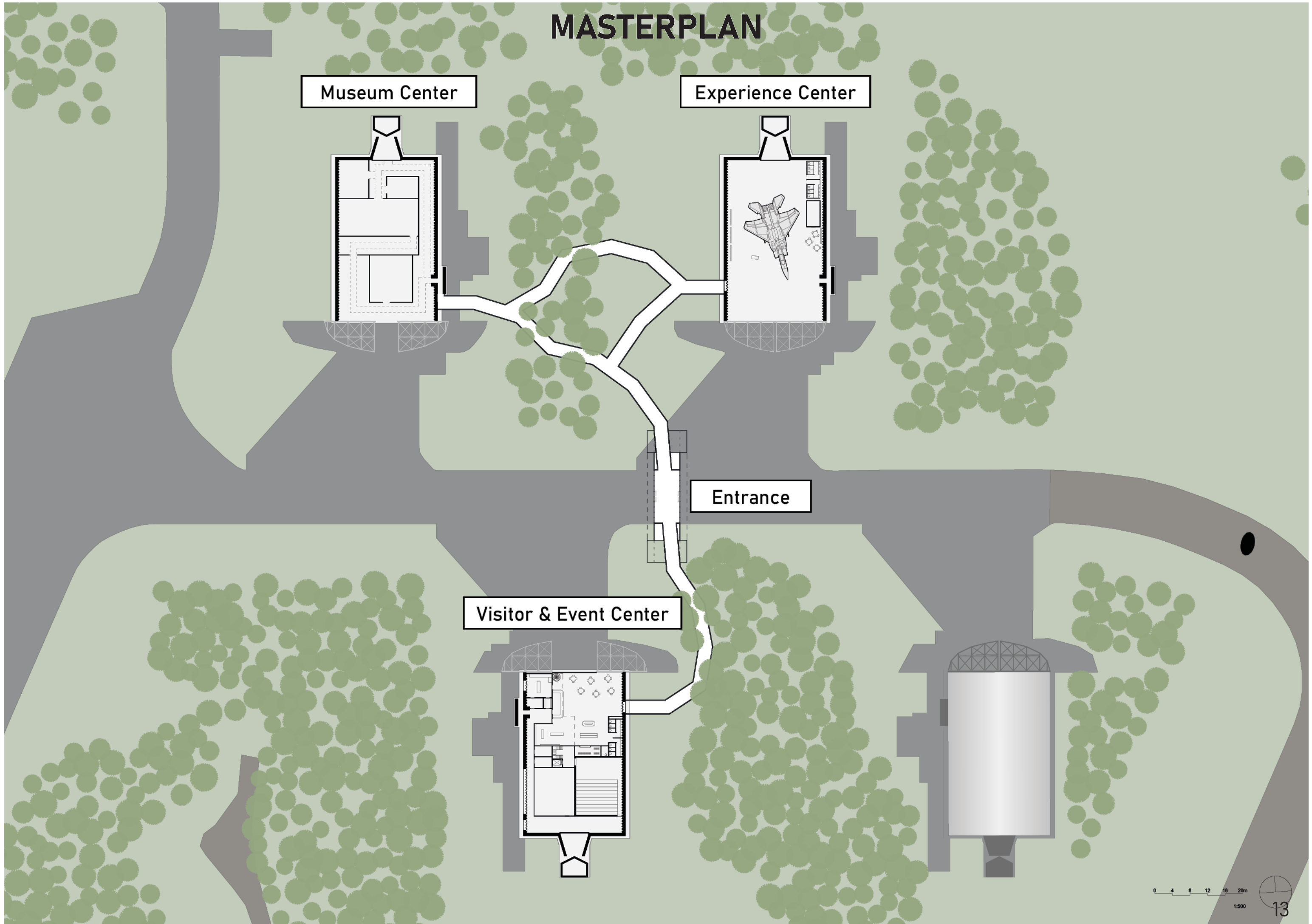
Museum Center

Experience Center

Entrance

Visitor & Event Center

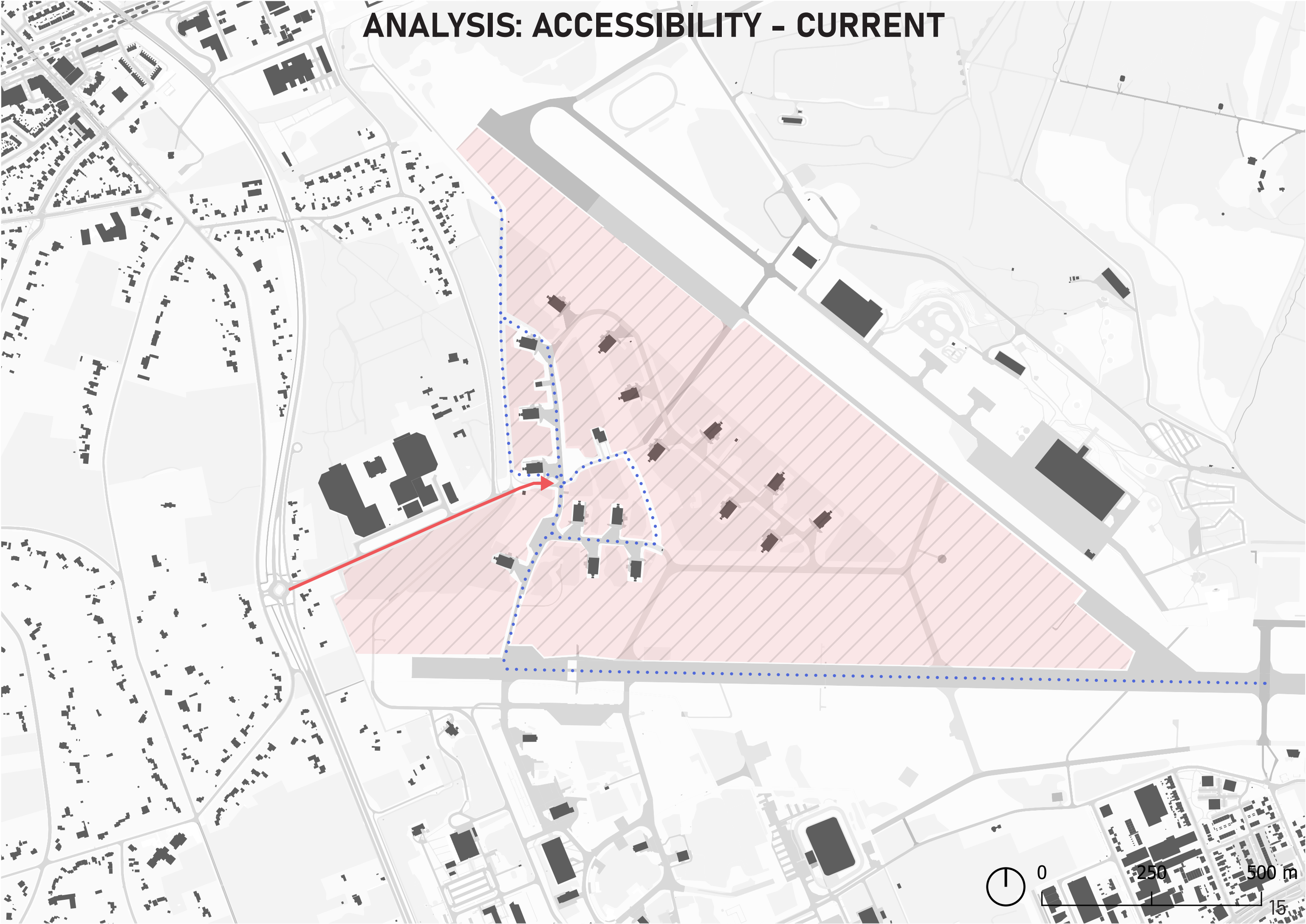
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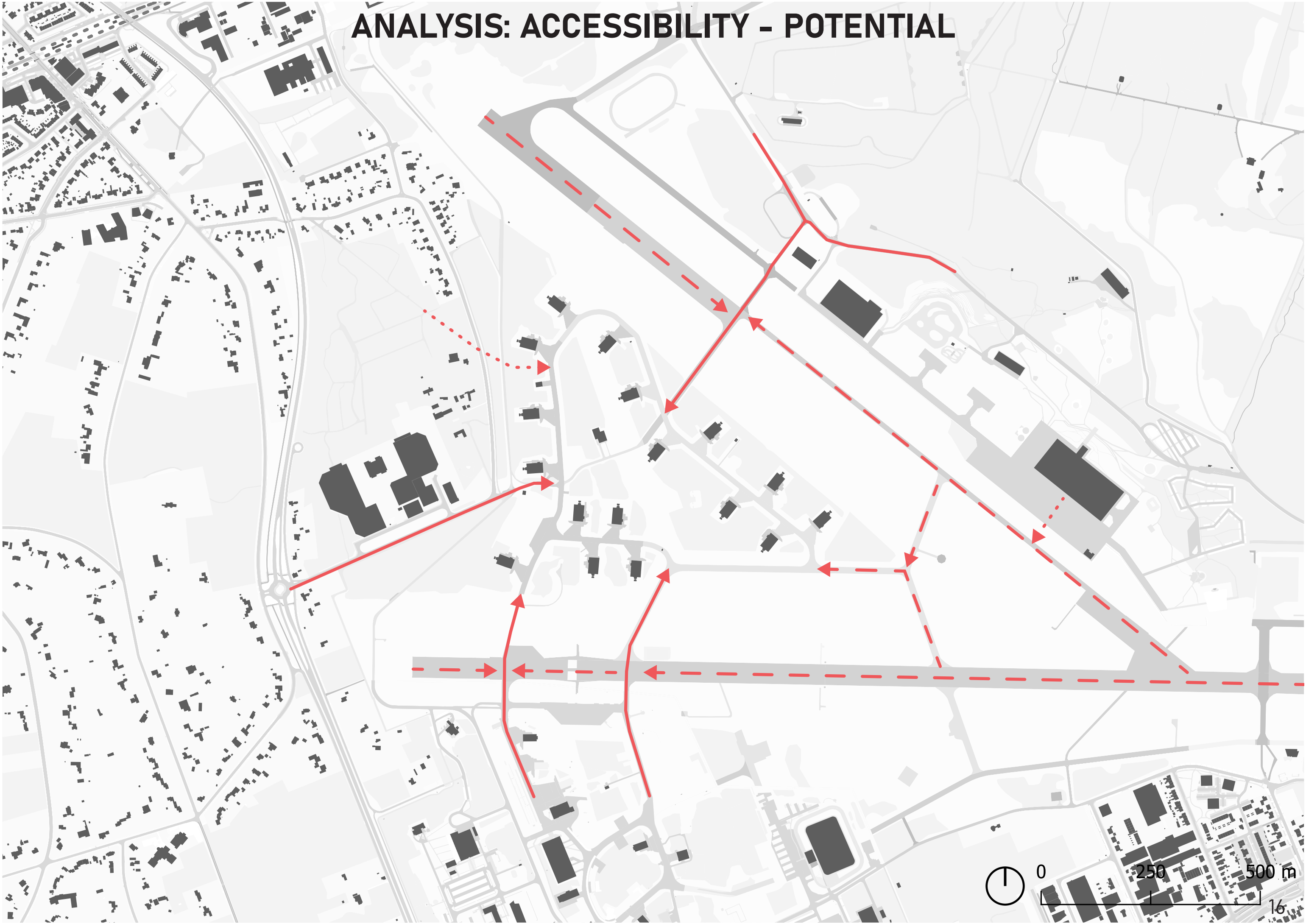
CONTEXT SHELTERS



ANALYSIS: ACCESSIBILITY - CURRENT

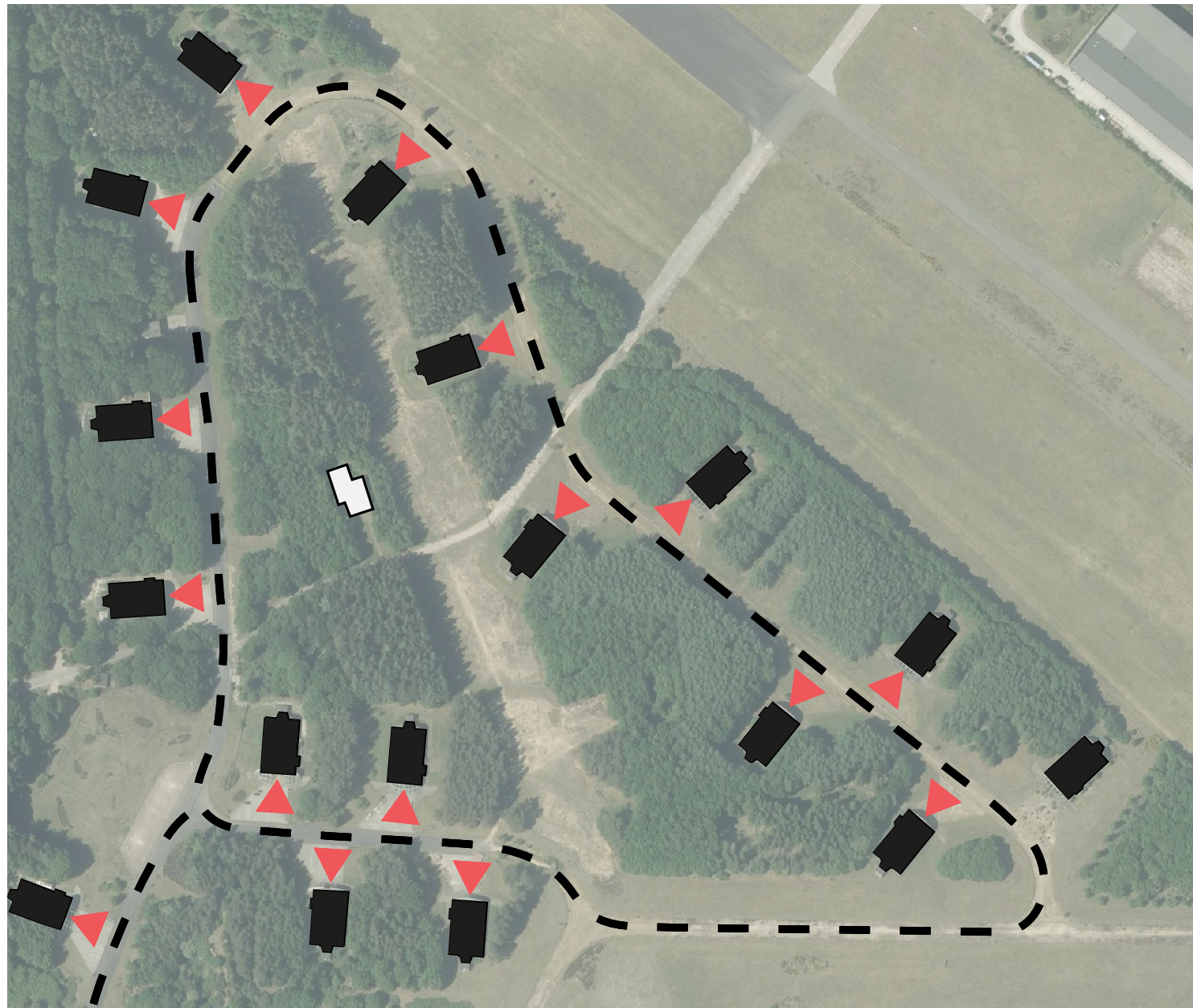


ANALYSIS: ACCESSIBILITY - POTENTIAL



ANALYSIS: SHELTERS ACCESS & USE/DECAY

SHELTERS ACCESS

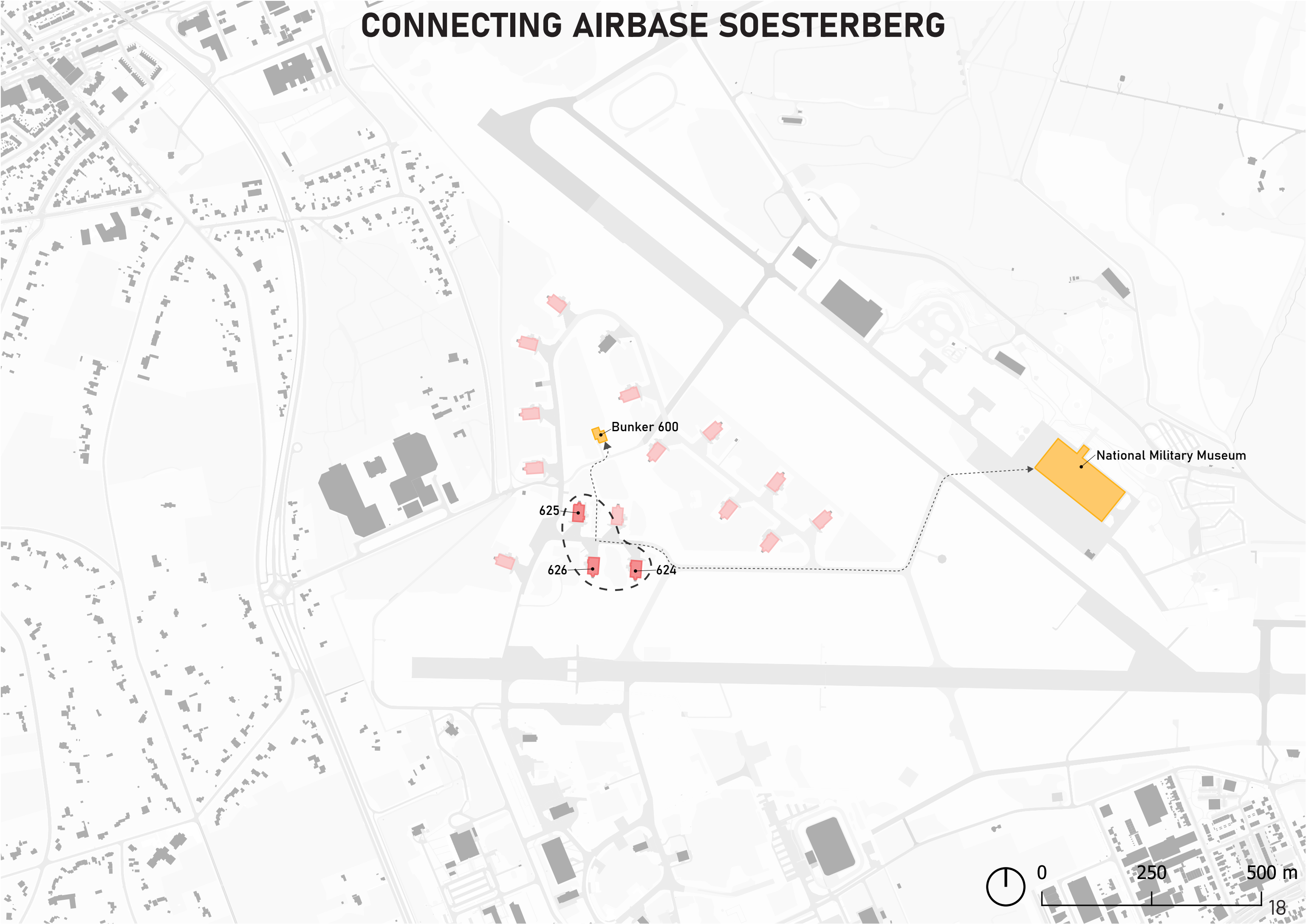


USE/DECAY



 Repurposed  Left for decay

CONNECTING AIRBASE SOESTERBERG



SHELTER ENSEMBLE

Museum Center

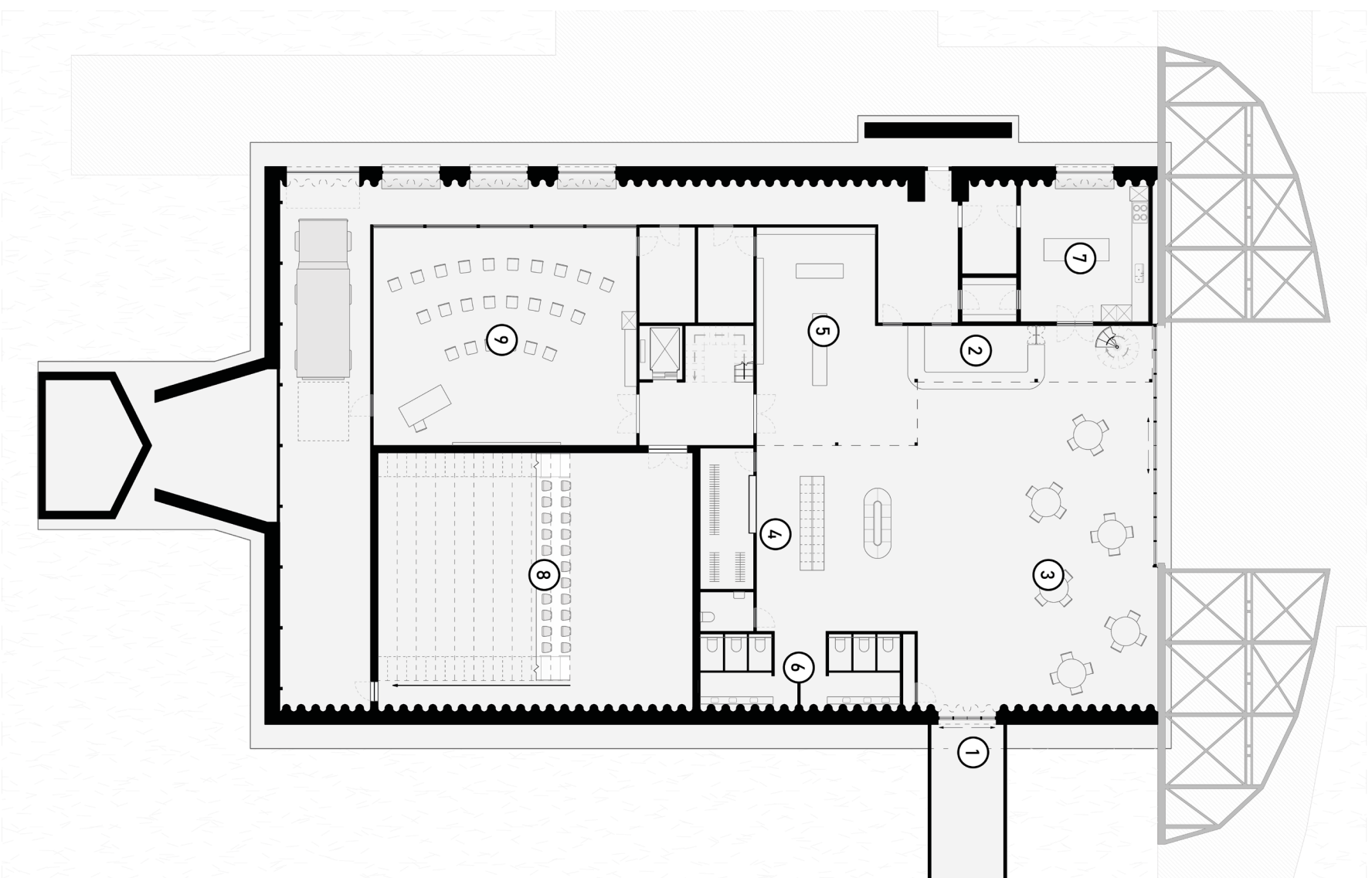
Experience Center

Visitor & Event Center



0 50 100 m

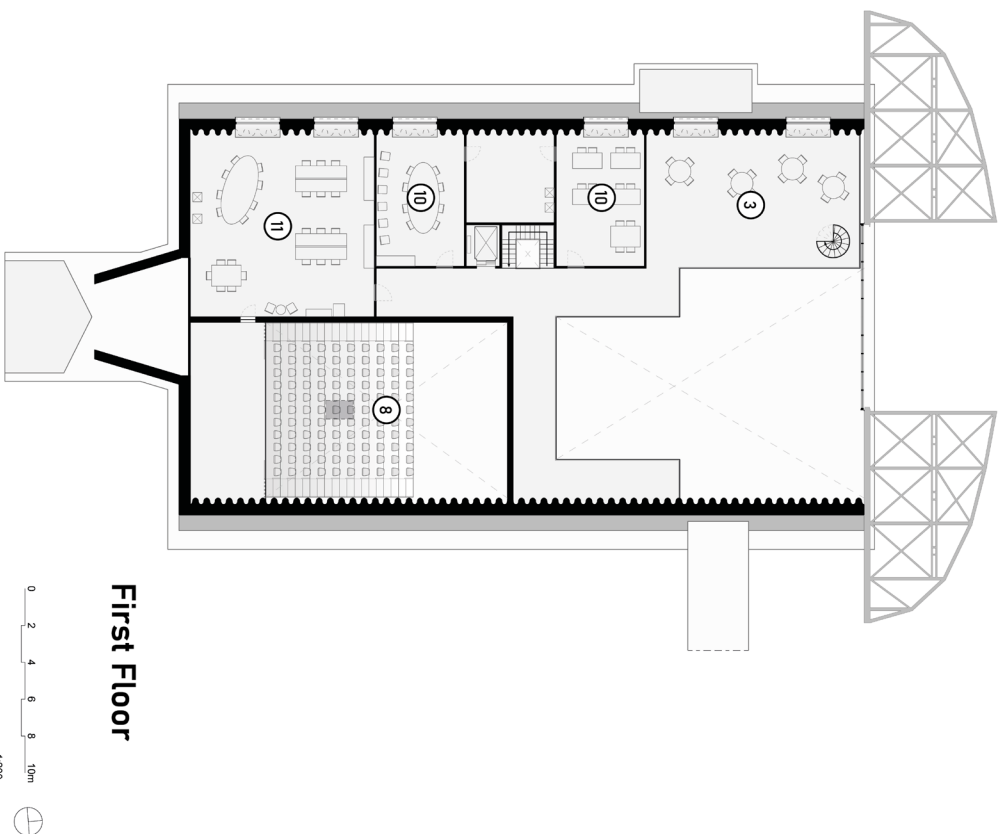
VISITOR CENTER - OVERVIEW



- Visitor & Event Center**
1. Entrance from corridor
 2. Multifunctional reception
 3. Café
 4. Wardrobe
 5. Shop
 6. Toilets
 7. Kitchen
 8. Auditorium
 9. Small event space
 10. Workshop rooms
 11. Offices
 12. Installations

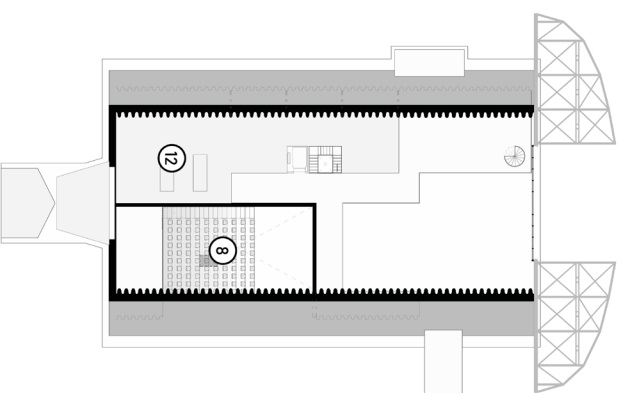
Ground Floor

0 2 4 6 8 10m
1:200

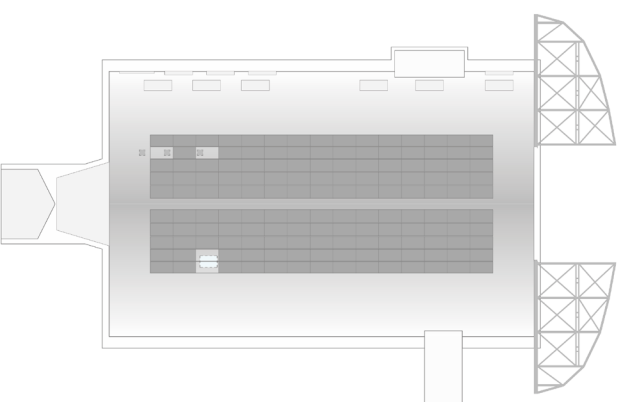


First Floor

0 2 4 6 8 10m
1:200



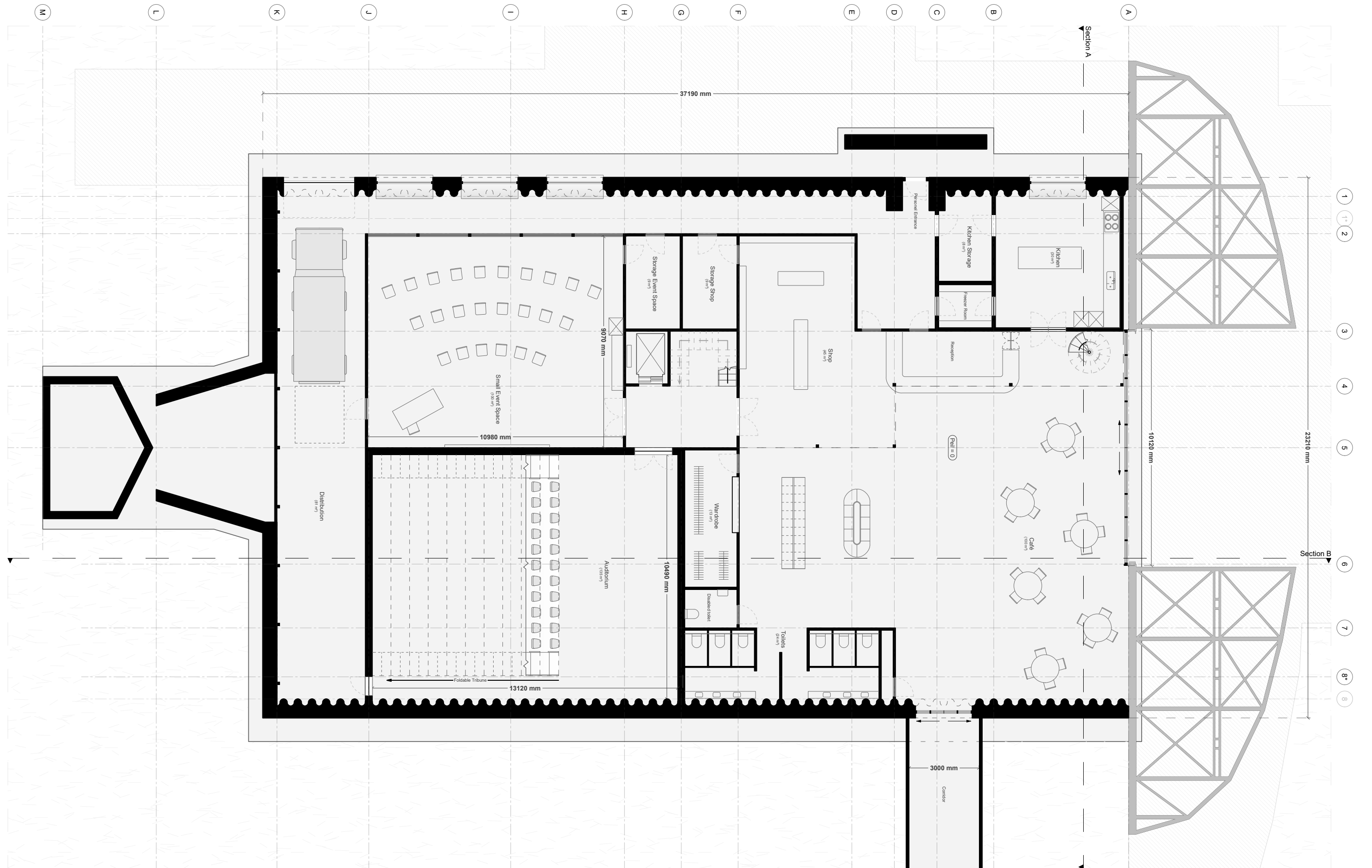
Second Floor



Roof

0 2 4 6 8 10m
1:200

VISITOR CENTER - GROUND FLOOR

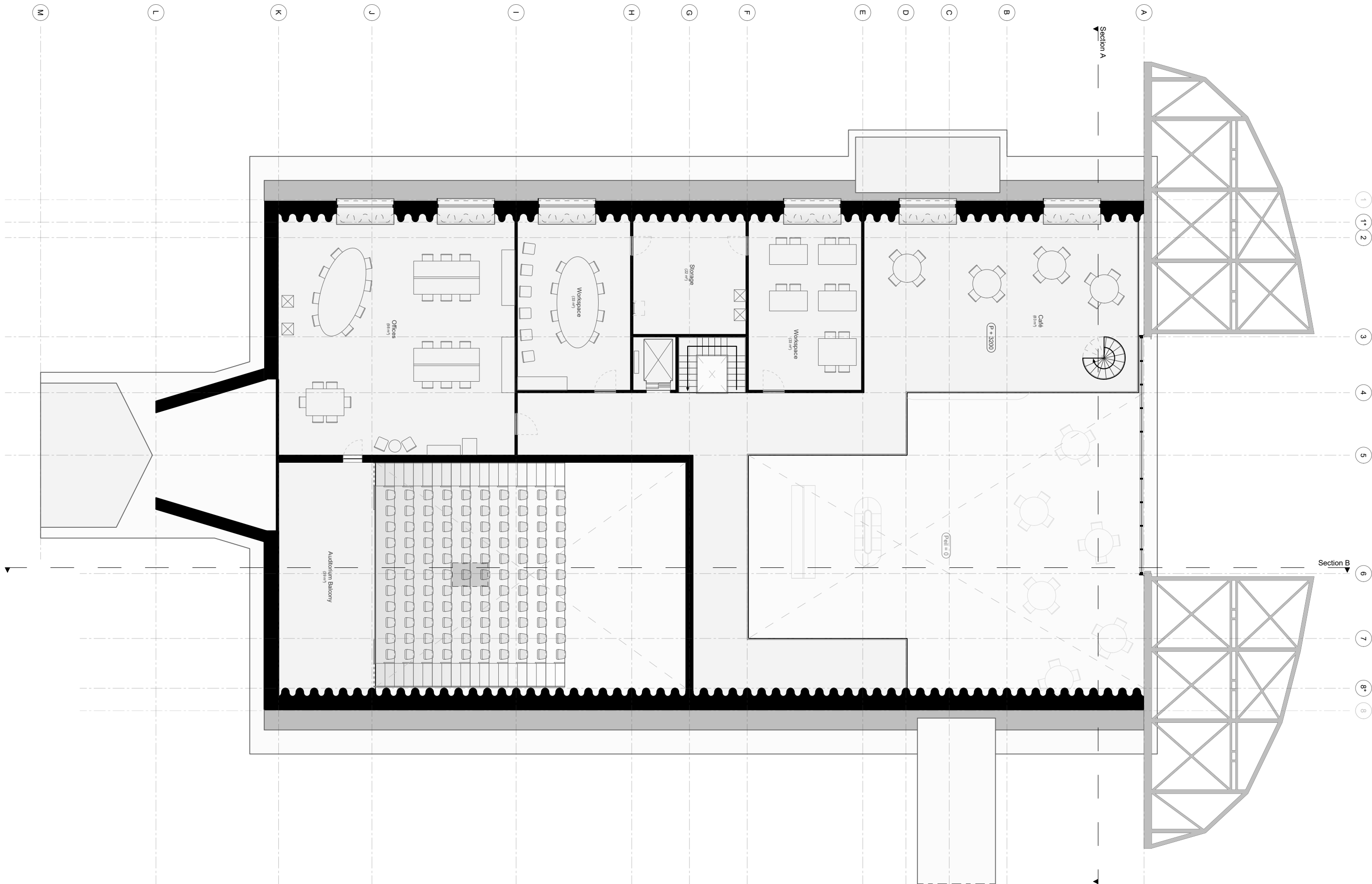


0 2 4 6 8 10m



1:200

VISITOR CENTER - FIRST FLOOR

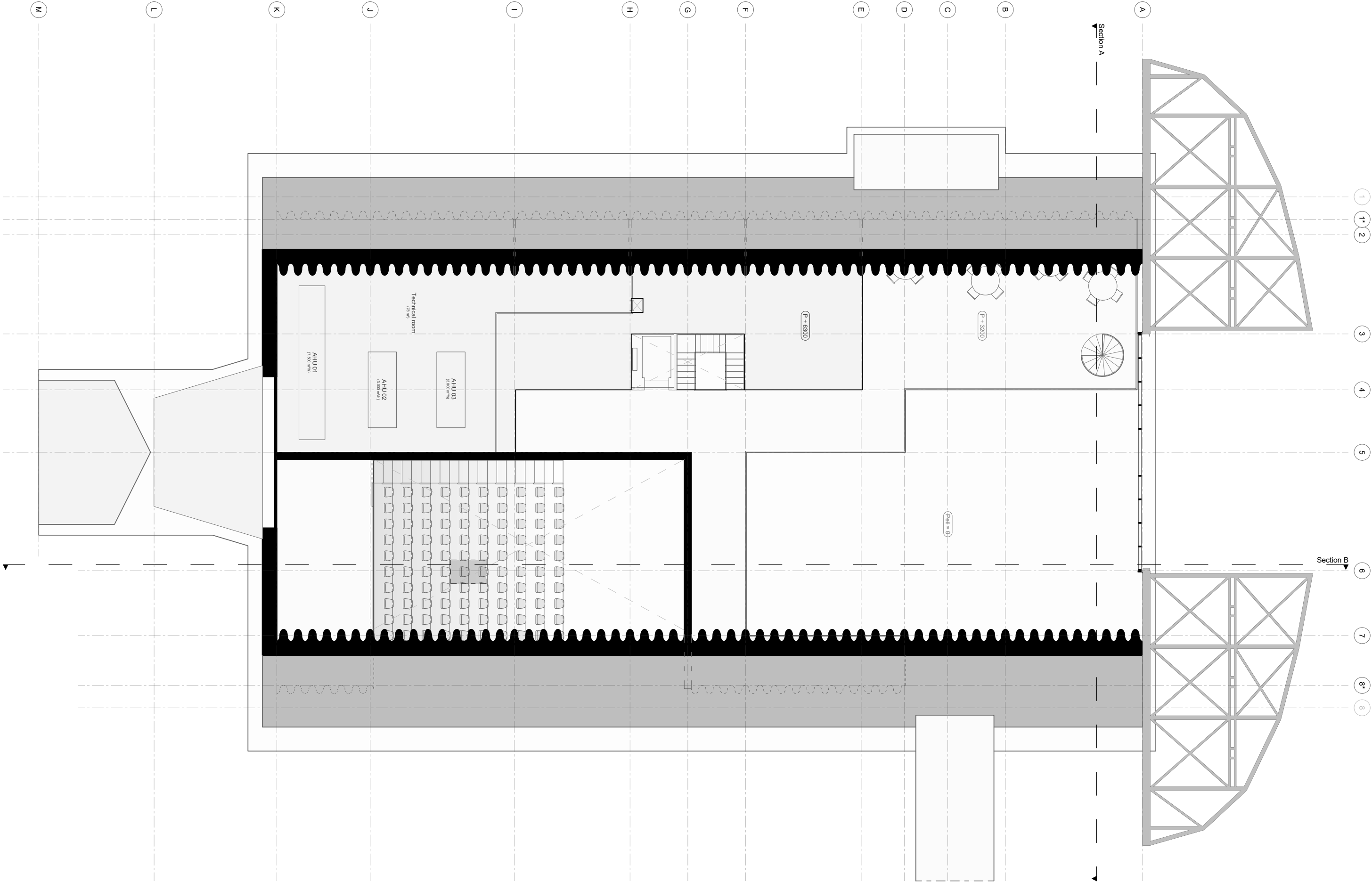


0 2 4 6 8 10m

1:200



VISITOR CENTER - SECOND FLOOR

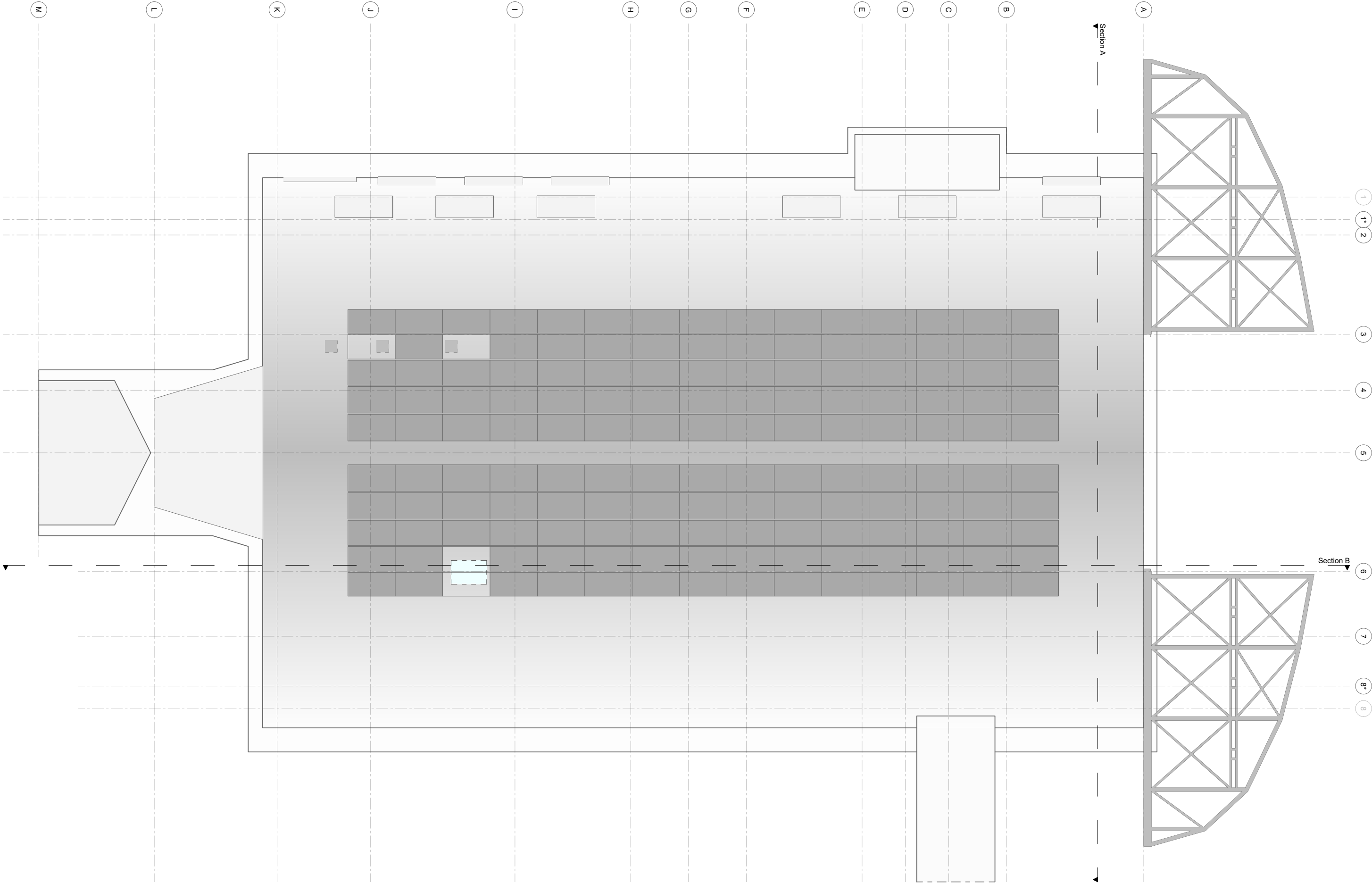


0 2 4 6 8 10m

1:200



VISITOR CENTER - ROOF

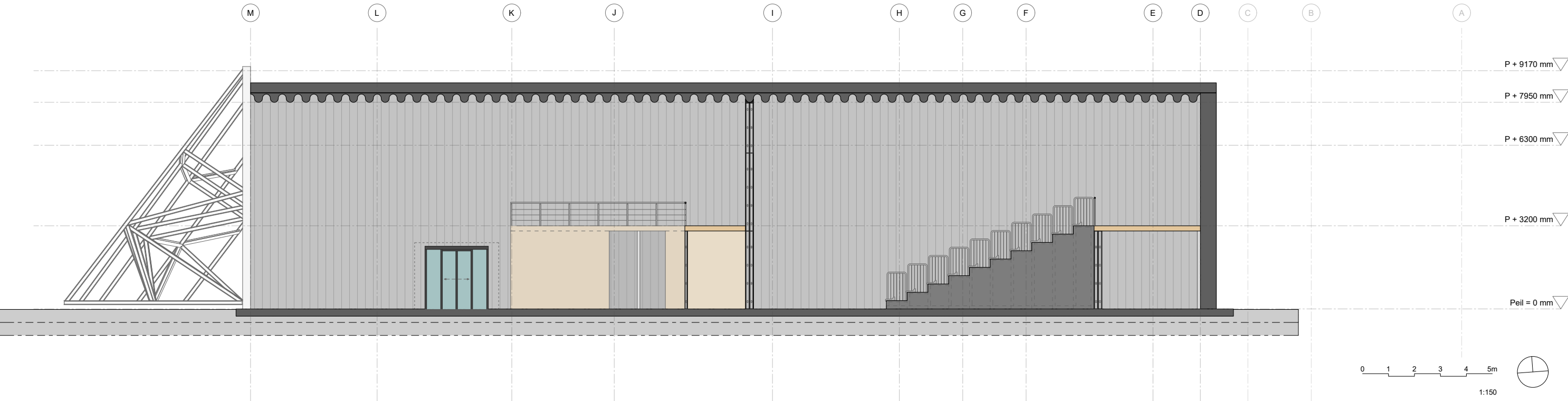


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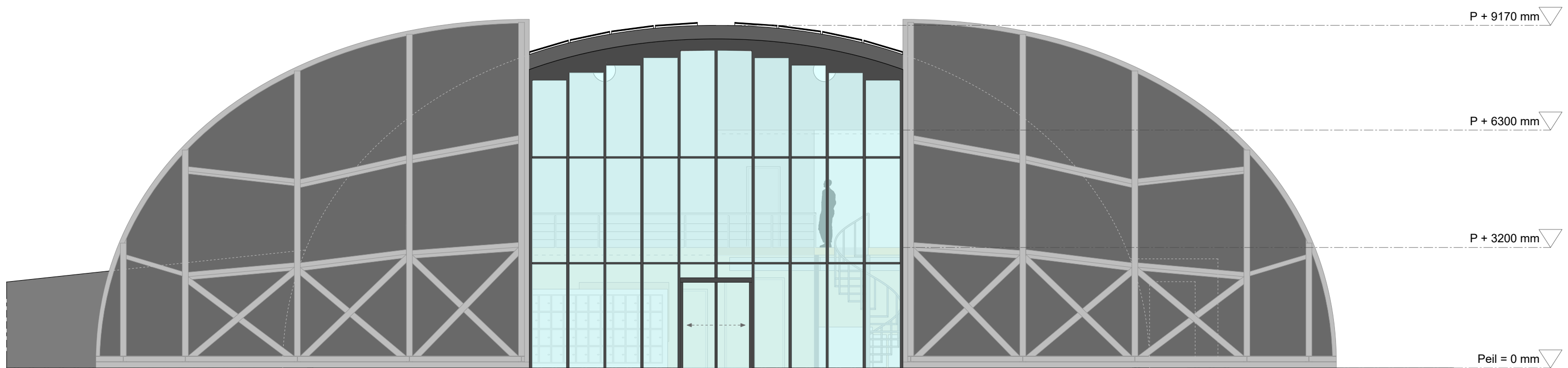
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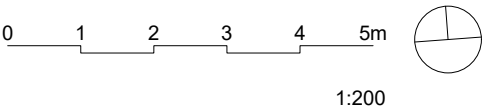
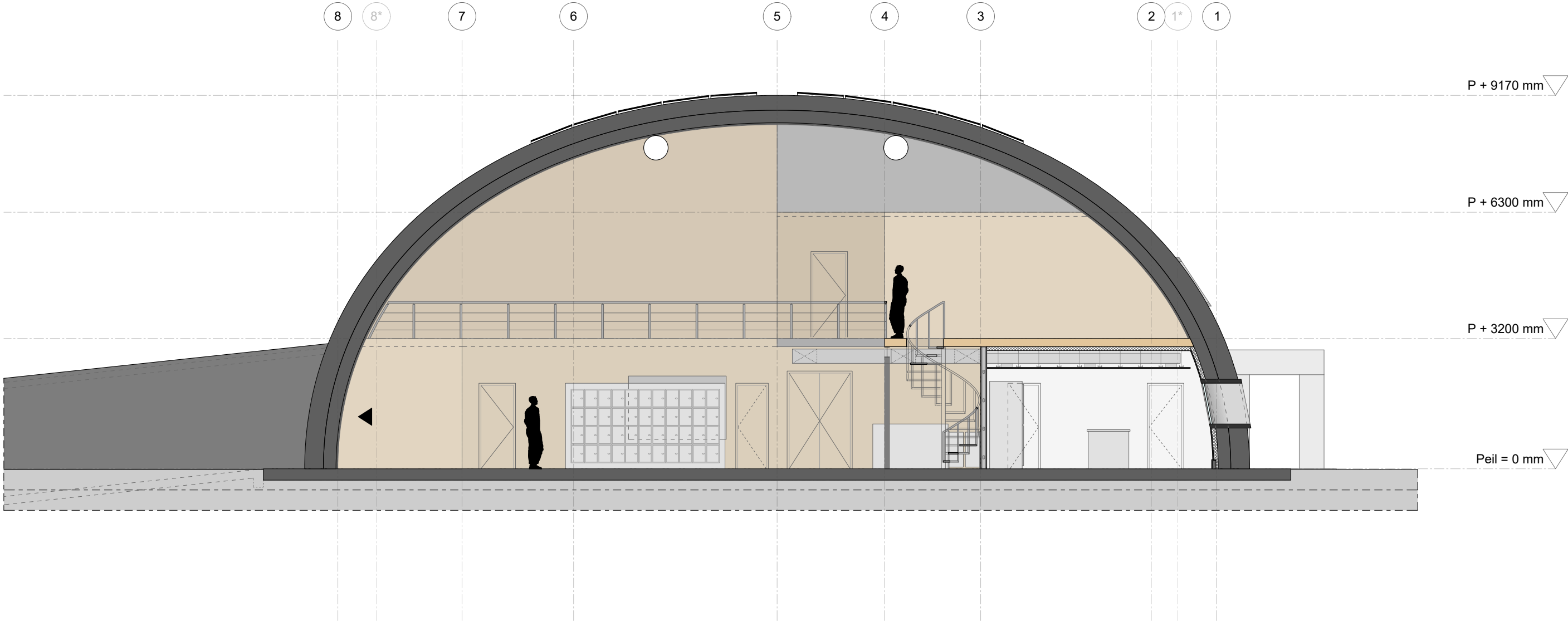
VISITOR CENTER - SECTION B



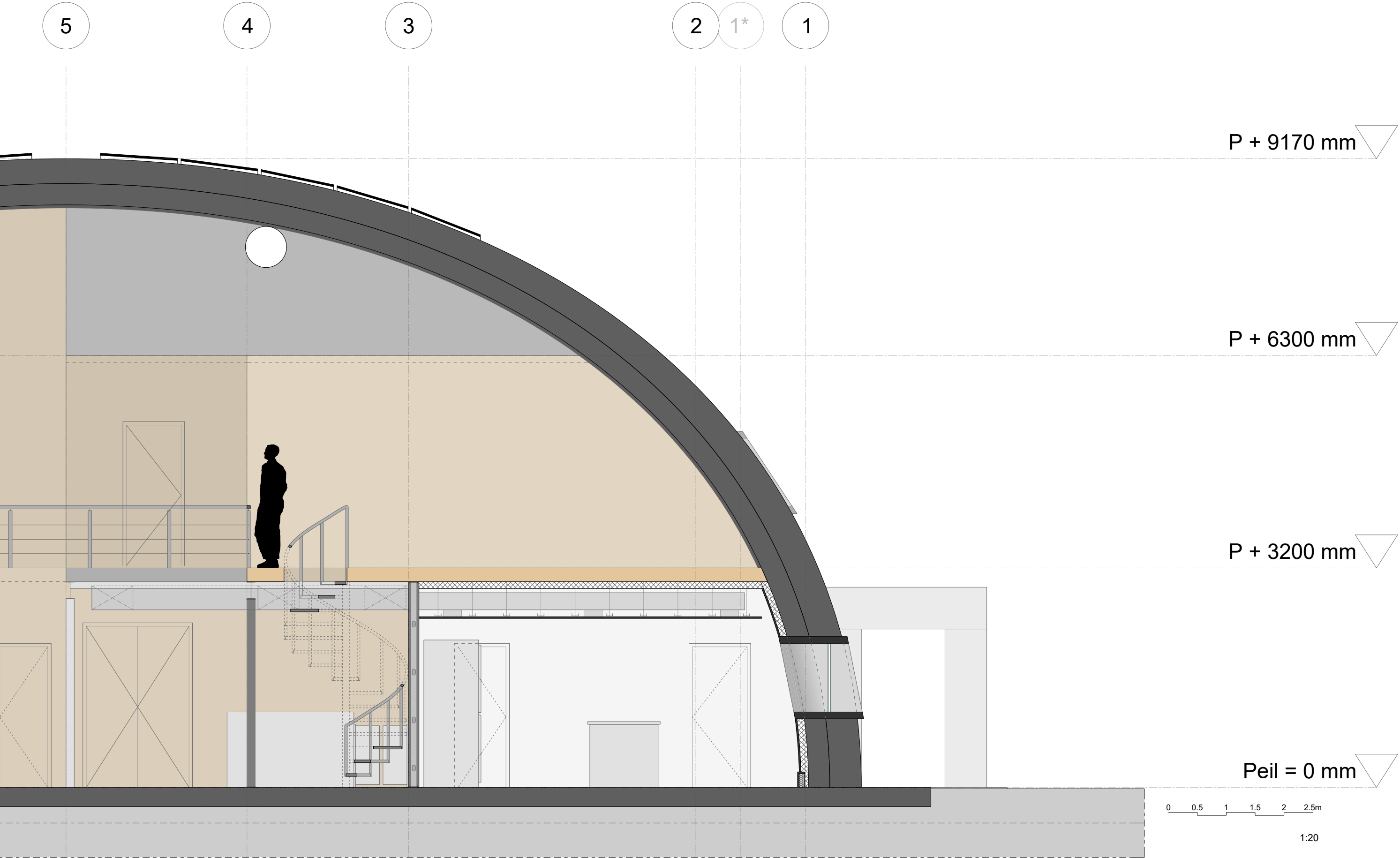
VISITOR CENTER - NORTH FACADE



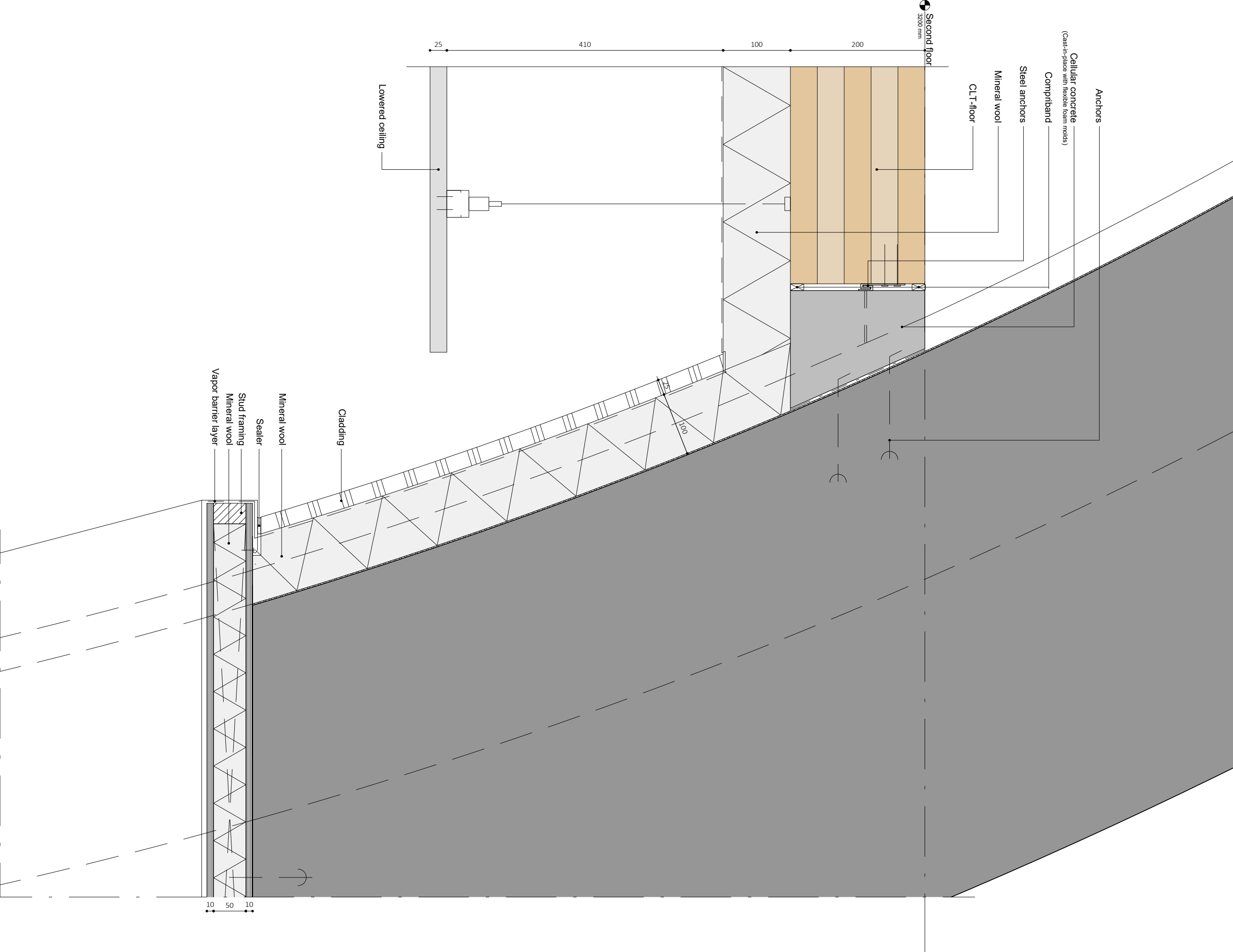
VISITOR CENTER - SECTION A



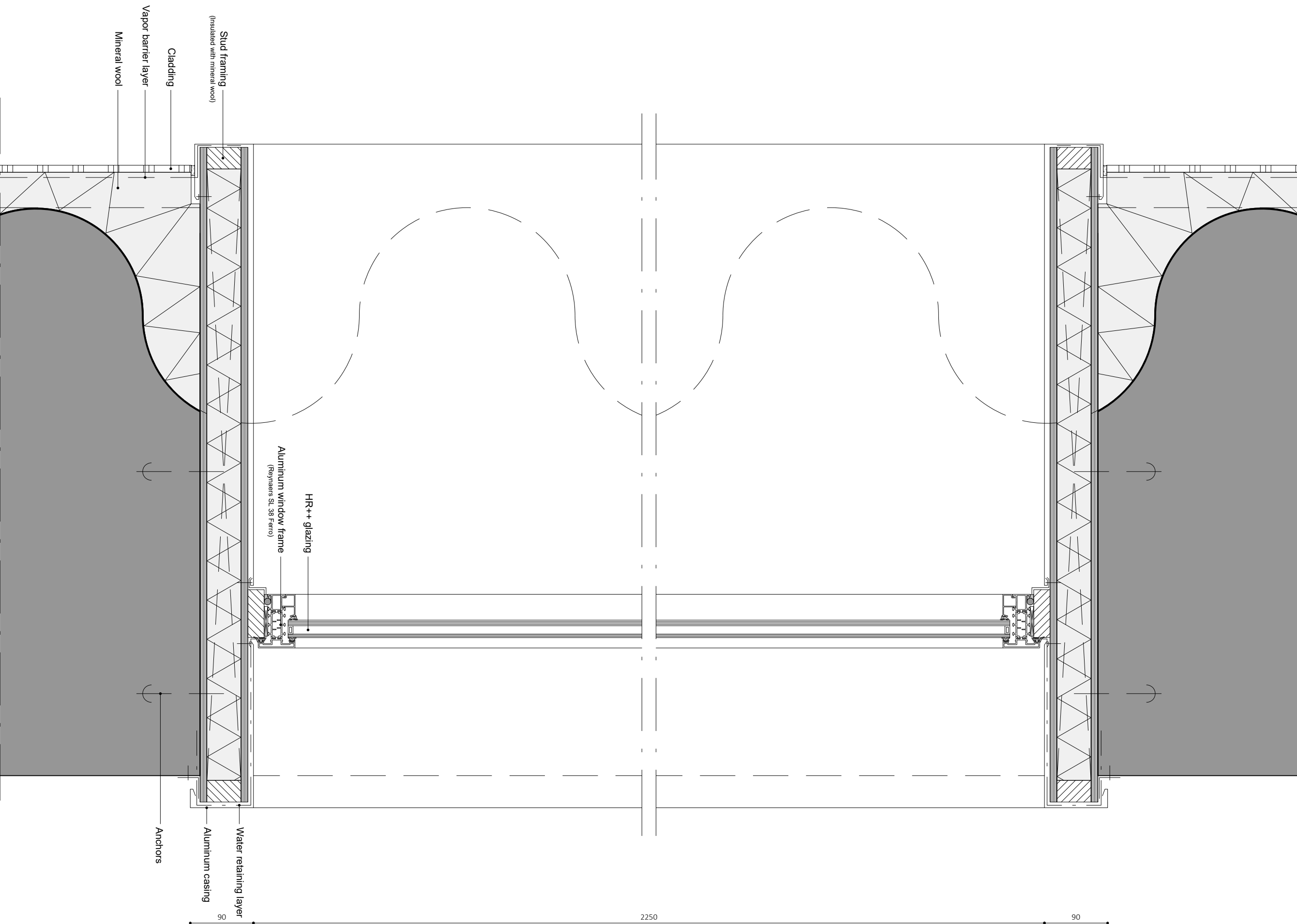
VISITOR CENTER - FRAGMENT



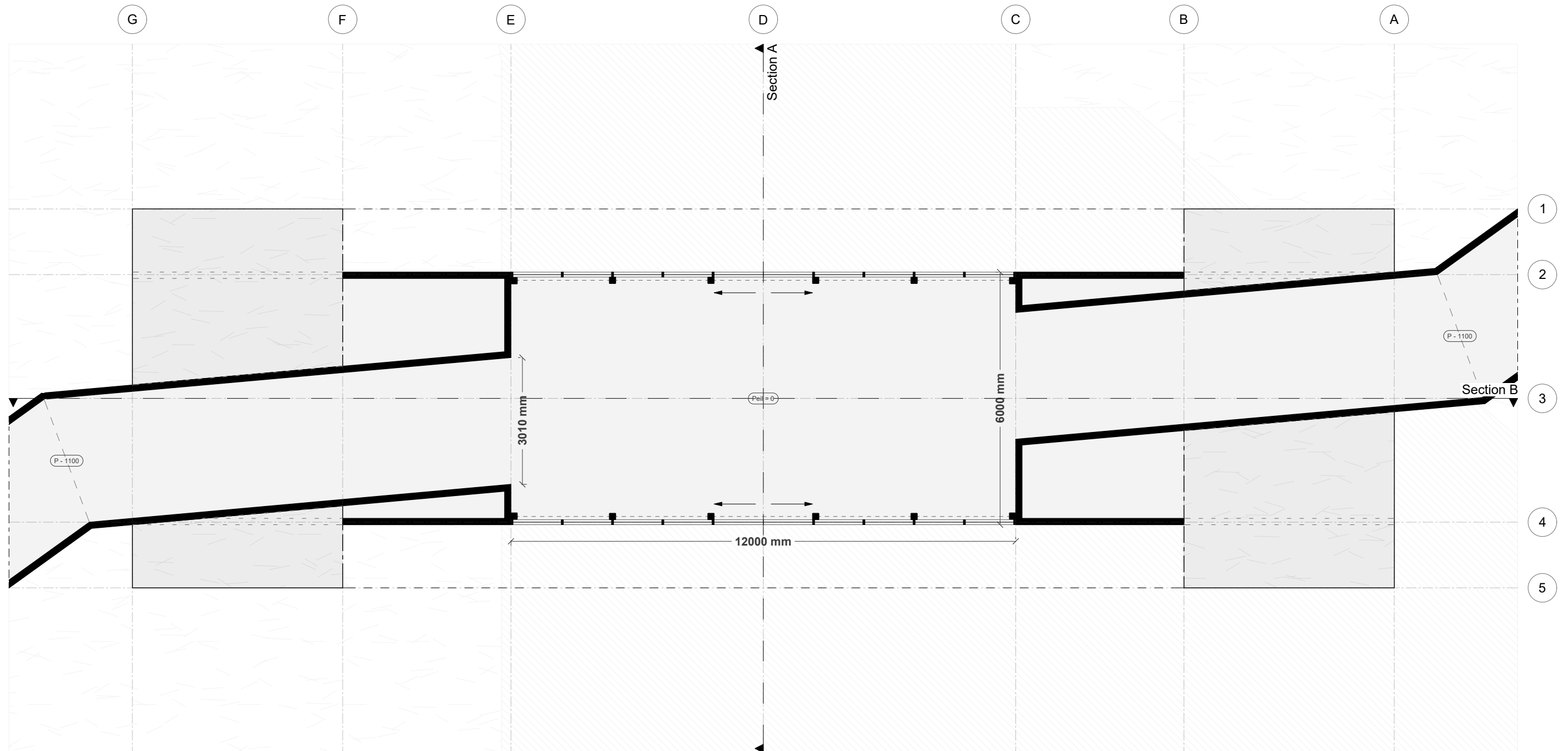
VISITOR CENTER - VERTICAL DETAIL WINDOW/FIRST FLOOR



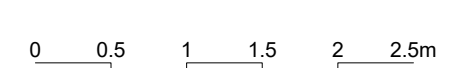
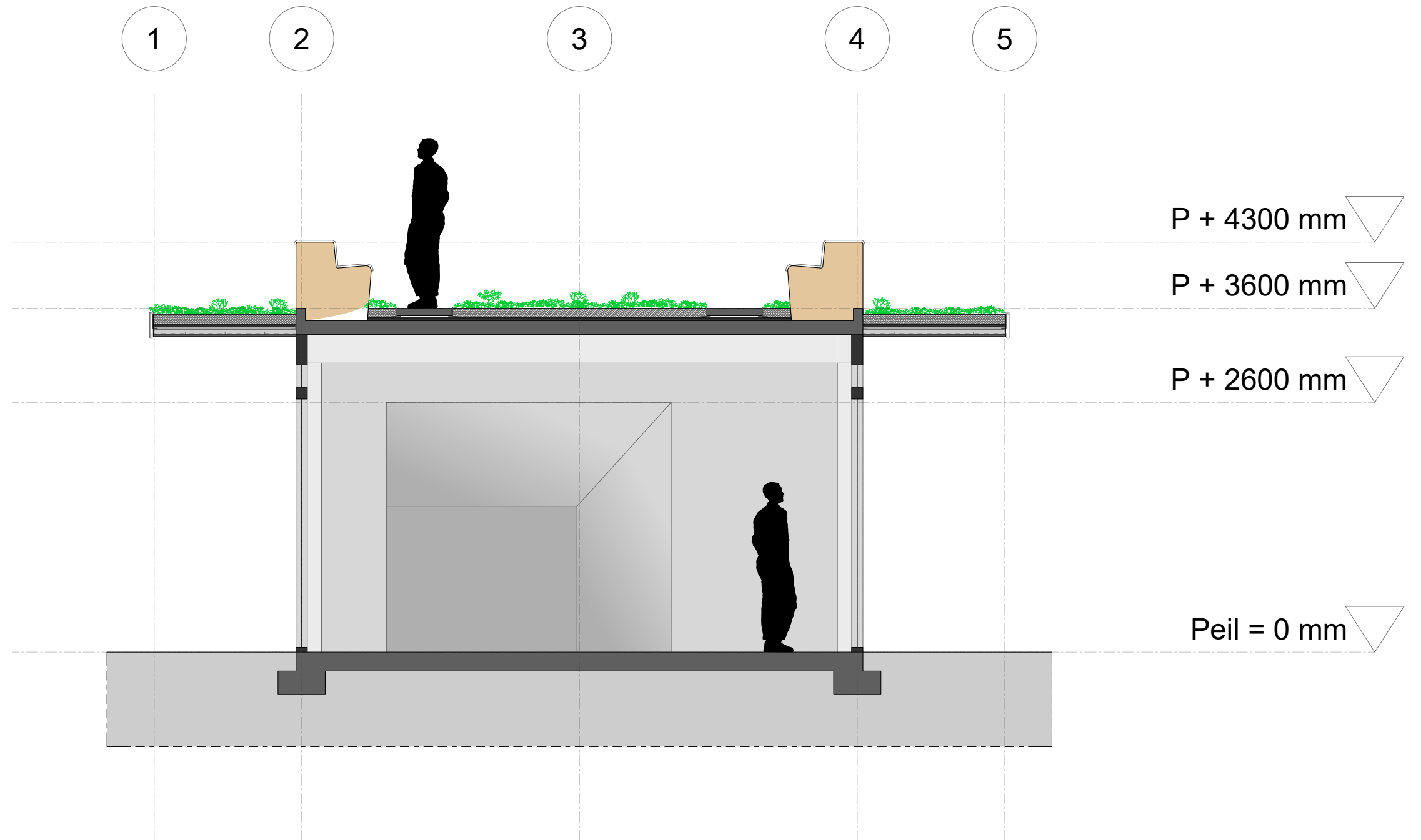
VISITOR CENTER - HORIZONTAL DETAIL WINDOW



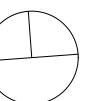
TAXIWAY PAVILION - FLOORPLAN



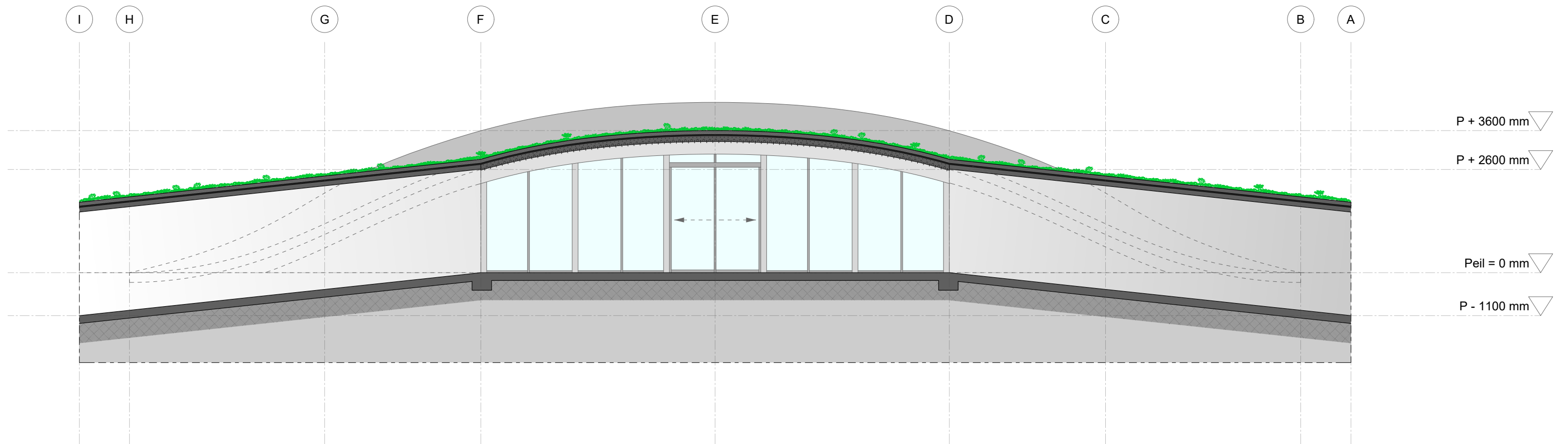
TAXIWAY PAVILION - SECTION A



1:50

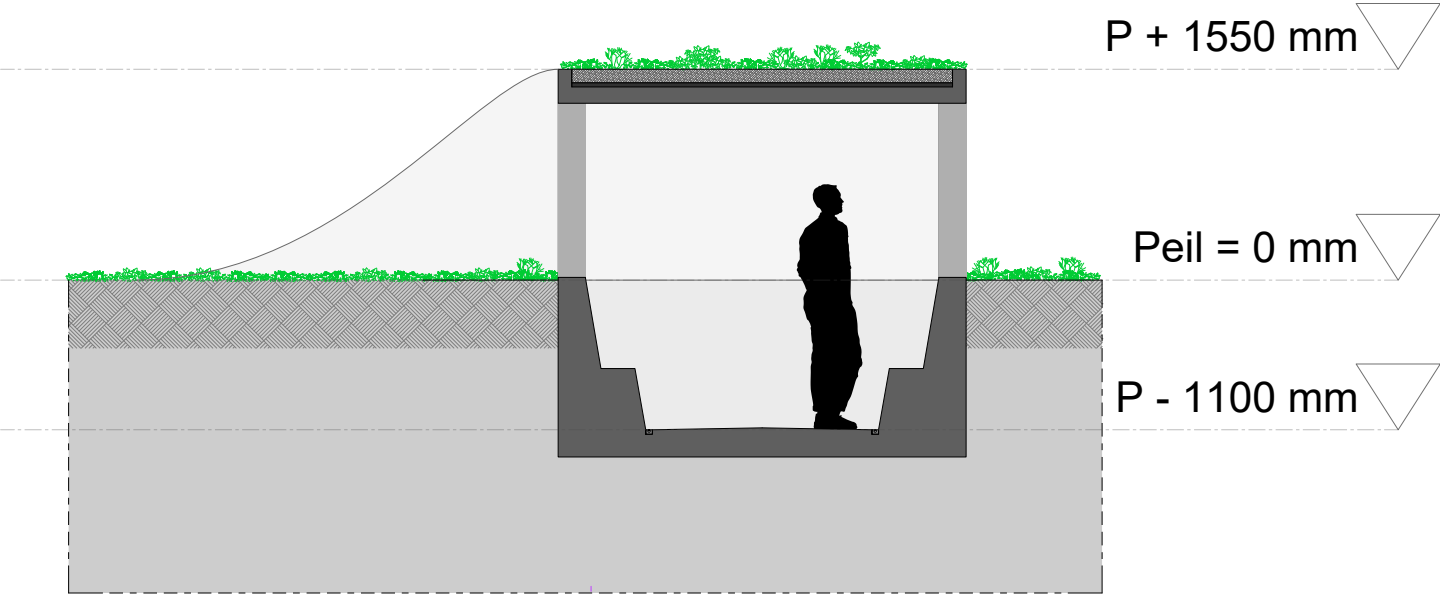


TAXIWAY PAVILION - SECTION B

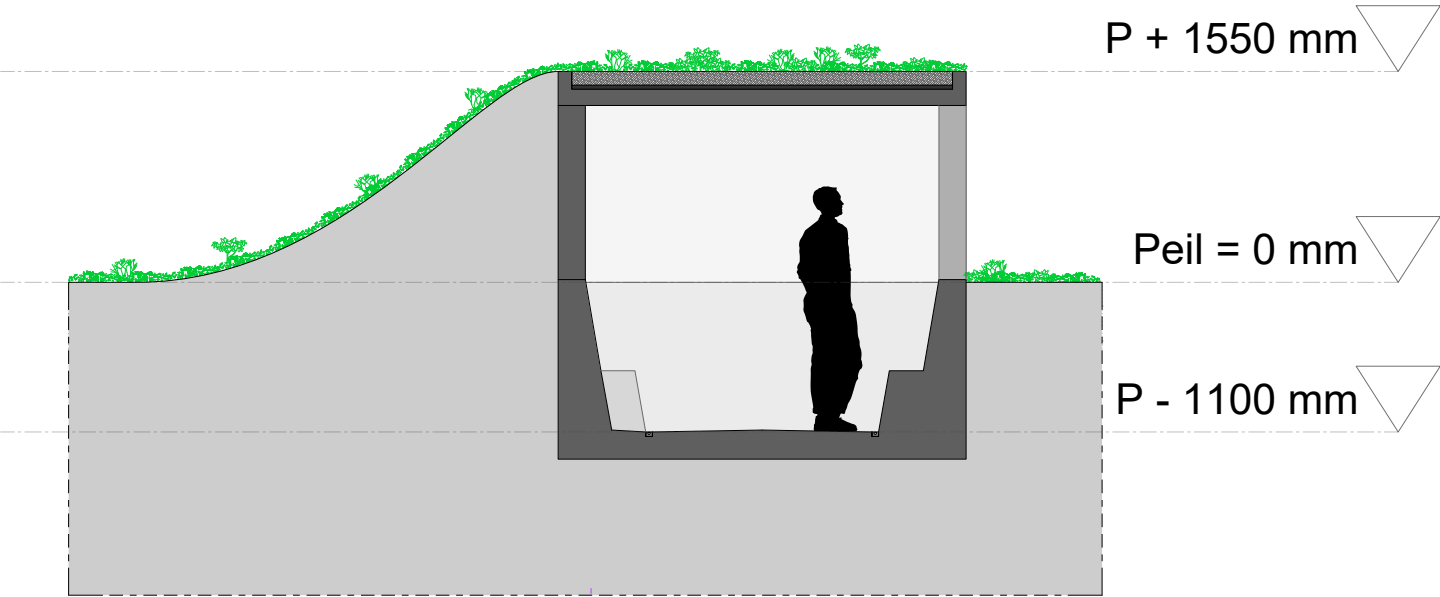


CORRIDOR - SECTIONS A / A* & B

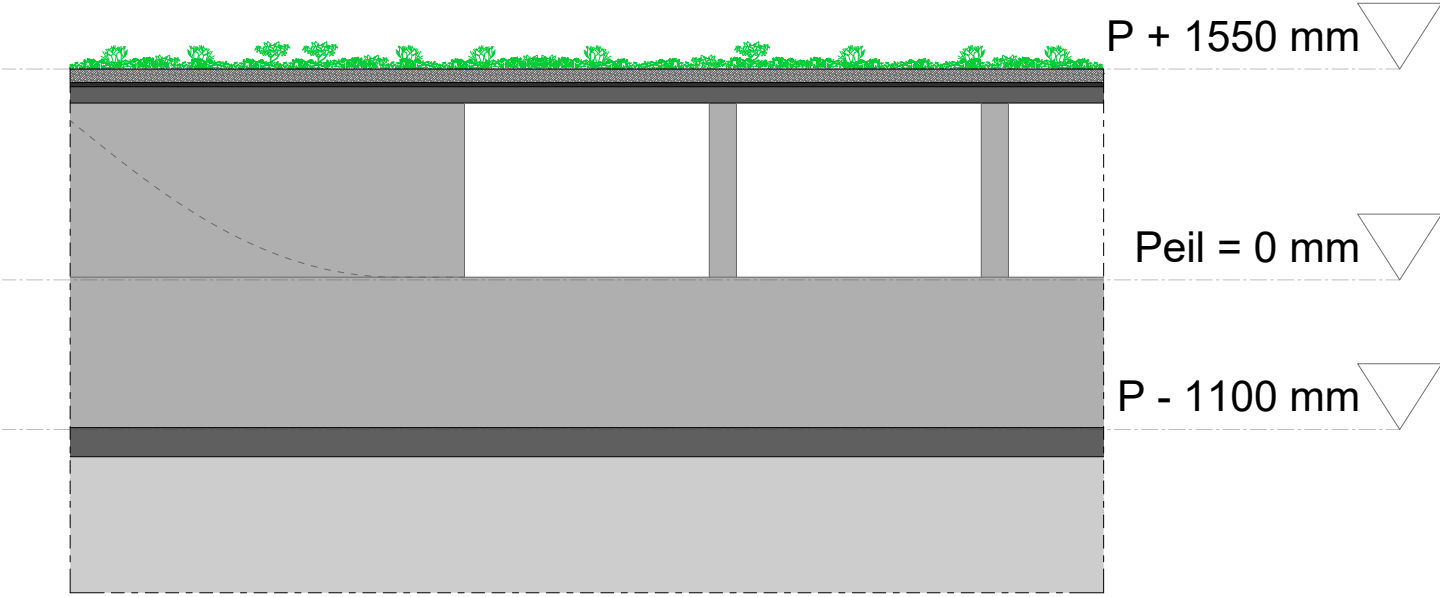
Section A



Section A*



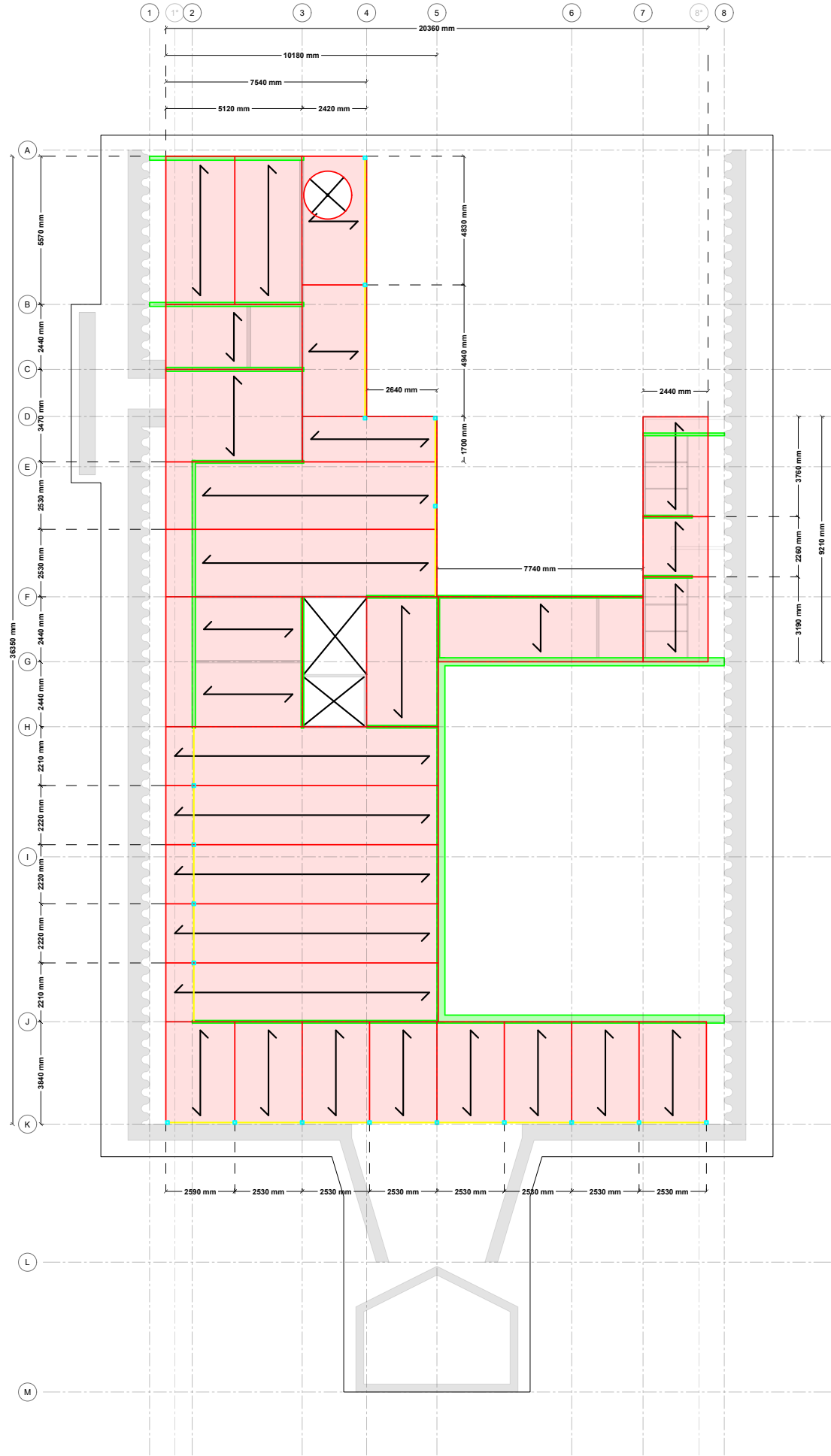
Section B



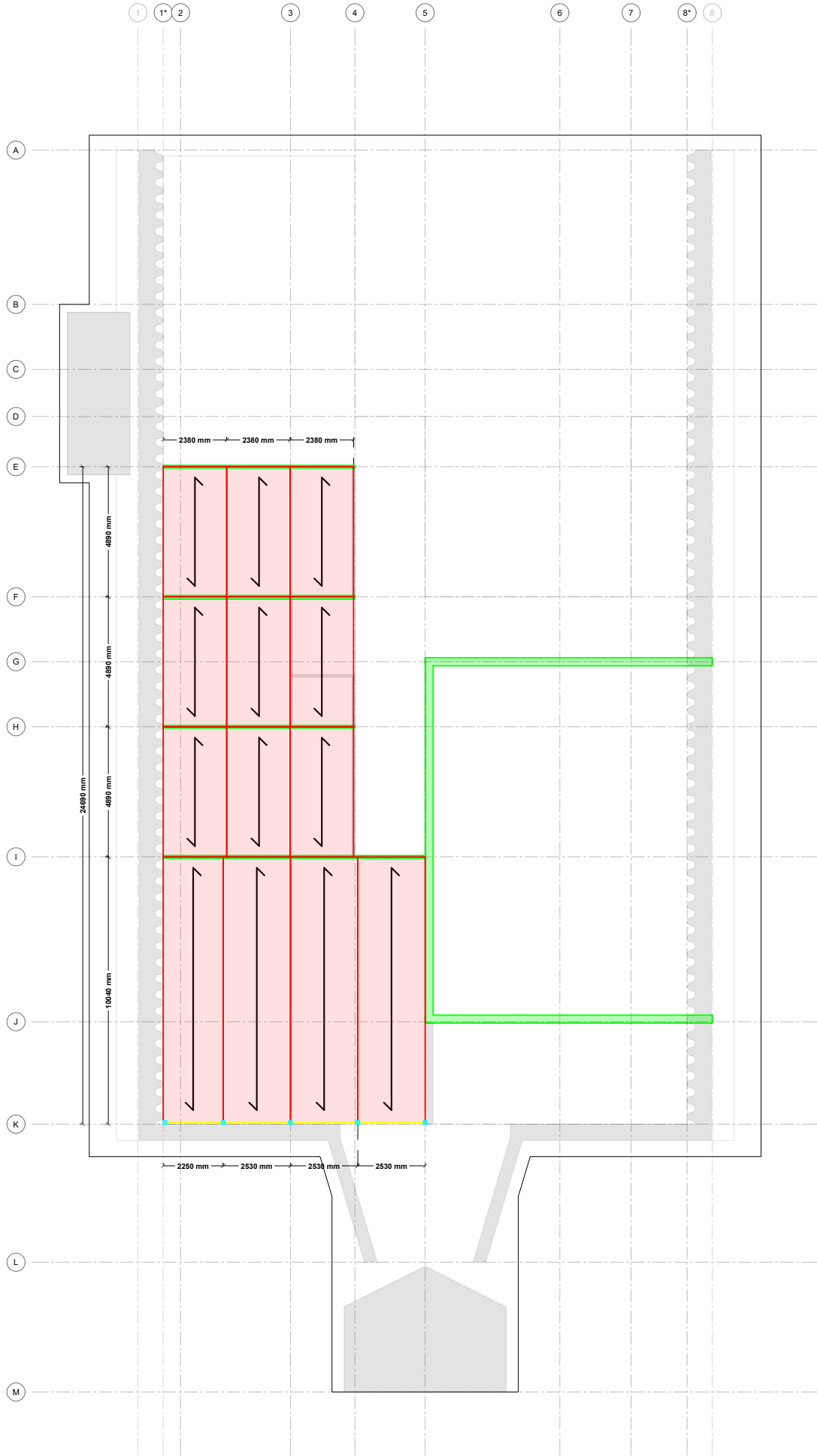
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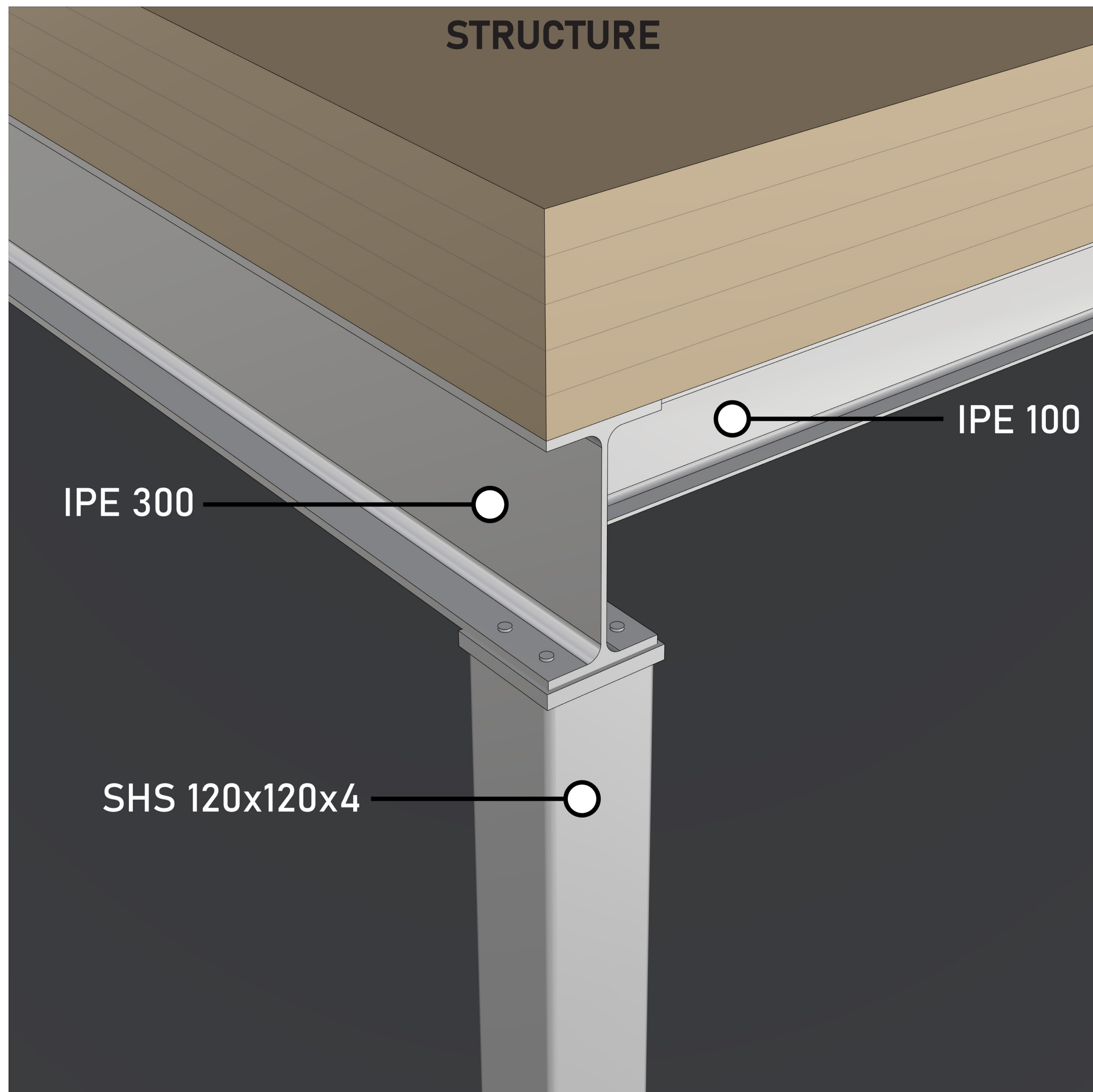
STRUCTURE

Ground Floor

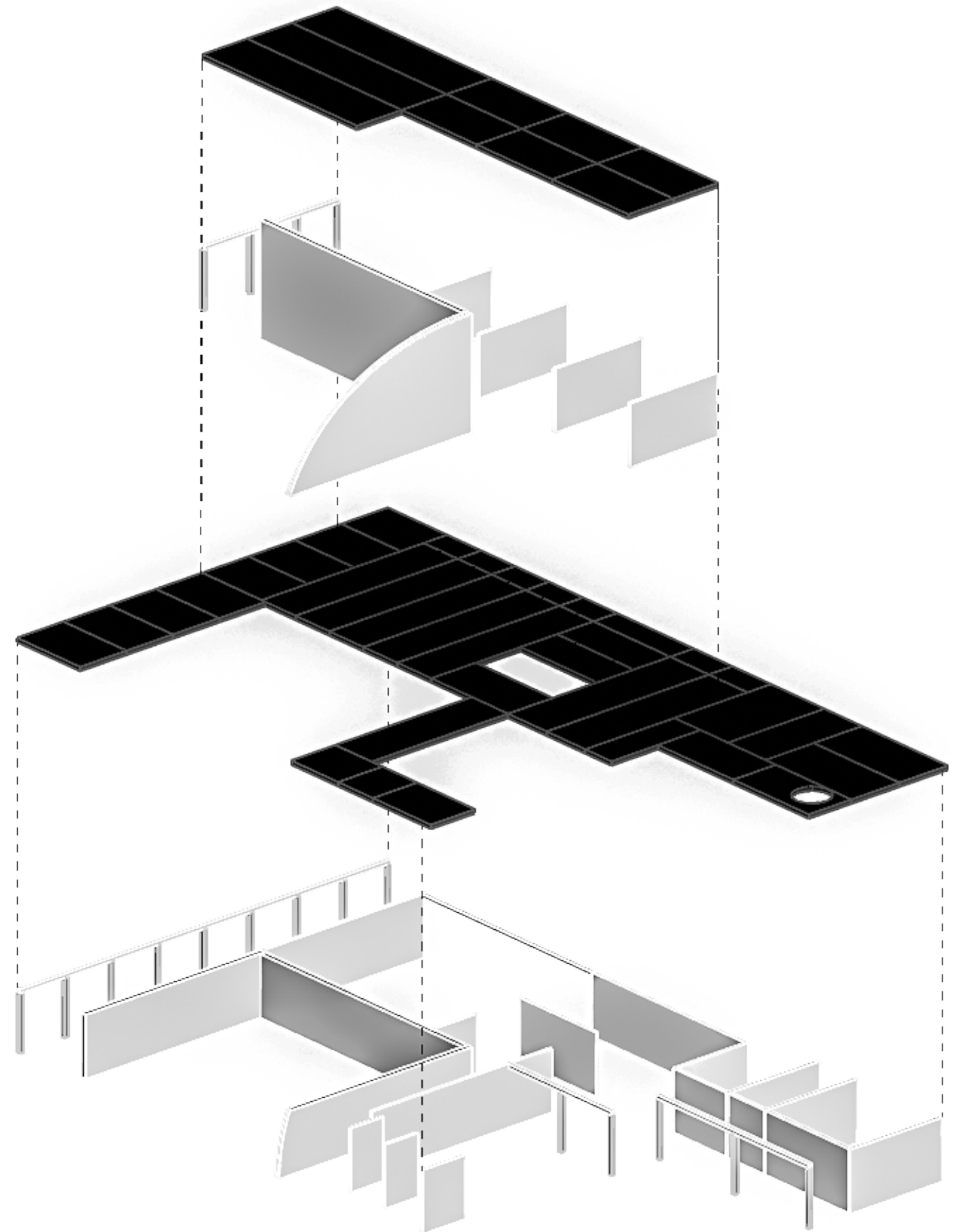
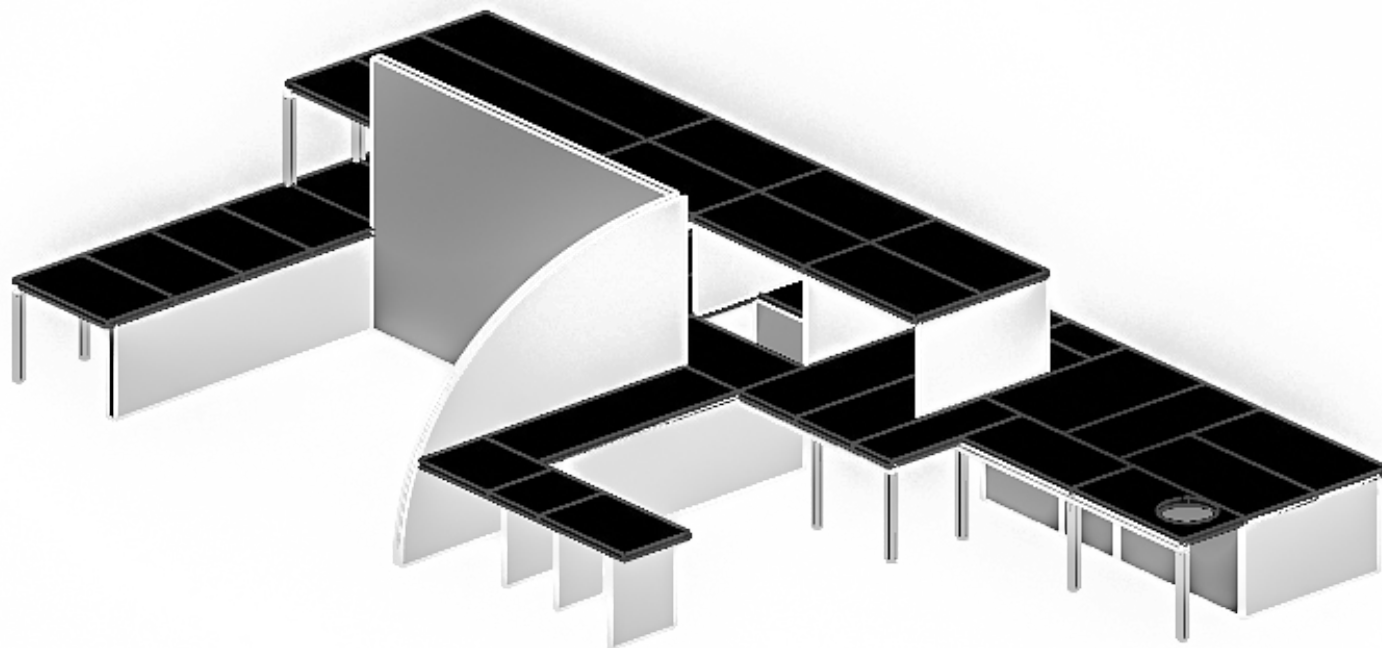


First Floor



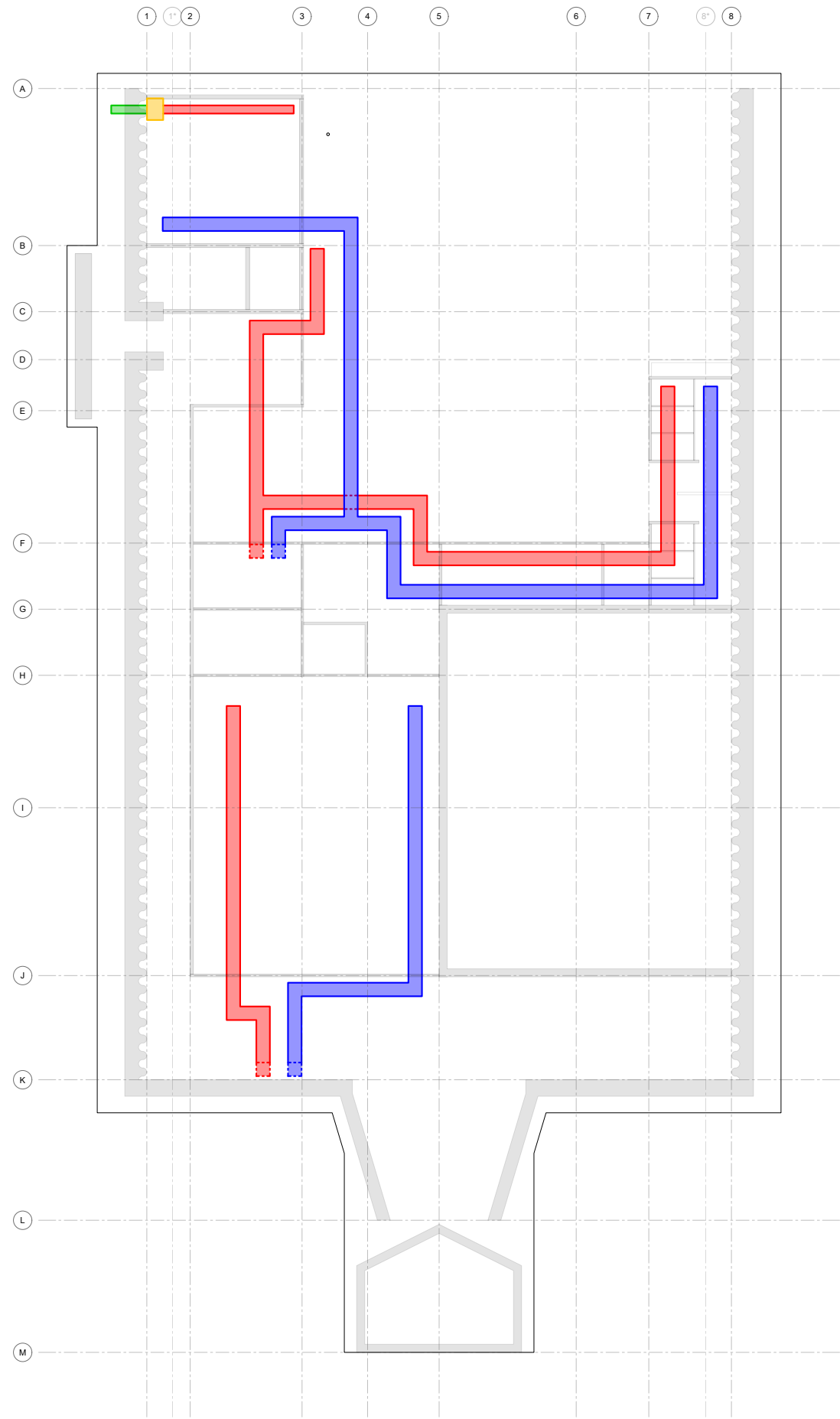


STRUCTURE

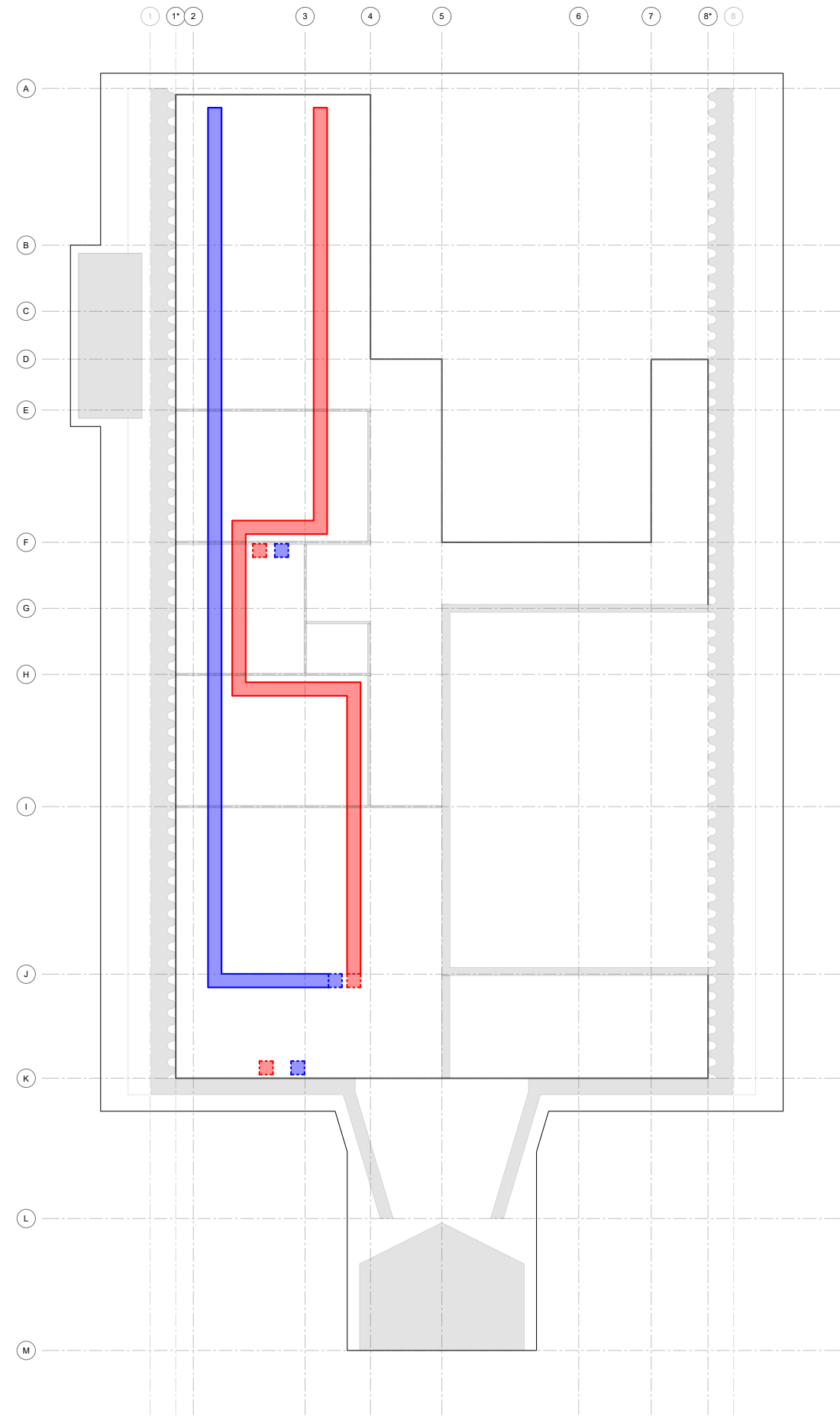


CLIMATE

Ground Floor



First Floor



APPENDIX

Value Assessment Matrix — Existing Air Shelter Area

Assessment of existing heritage, ecological and use values + design response actions

Existing element / layer	Main value	Value	Vulnerability	Design action	Design implication
Shelter ensemble: 17 third-generation HAS shelters + central bunker	Historical, military, ensemble value	+++	High	● + →	Retain the ensemble logic and keep the shelters readable as a collective Cold War system.
Individual shelter shell	Architectural, structural, age value	+++	High	● + ◐	Preserve the concrete shell, curved geometry, massiveness, weathering and traces of ageing.
Concrete blast doors and rail system	Historical, technical, experiential value	+++	Medium	● +	Keep the door mechanism, rails and threshold condition visible as part of the military narrative.
Interior spatial character	Spatial, experiential value	+++	High	● ◐	Preserve the introverted atmosphere: darkness, silence, long axis, heavy enclosure and controlled entry.
Existing openings and service entrance	Functional, historical, use value	++	Medium	◐ +	Use existing openings as much as possible before making new cuts. They already explain access, control and operation.
Jet blast deflector / exhaust zone	Technical, military-use value	++	Medium	● +	Keep as evidence of the original aircraft function and the relation between shelter and runway logic.
Existing technical systems: cables, lamps, pipes, door	Use, nostalgic, process value	++	Medium	+ ◐	Selectively reveal; keep representative traces, but remove only damaged or obstructive fragments.
Patina, moss, stains, weathering	Age, material, atmospheric value	++	High	● ×	Avoid over-restoration; cleaning should not erase the sense of time.
Shelter floor markings / paint lines	Use, process, nostalgic value	++	High	● +	Retain where possible, because they show former workflows and aircraft positioning.
Surrounding forest edge / camouflage	Landscape, rarity, experiential value	+++	High	● → ×	Preserve the hidden character; guide visitors rather than opening the landscape completely.
Existing paths, roads and hardened surfaces	Functional, historical, ecological value	++	Medium	→ ◐	Concentrate movement on existing hardened surfaces to protect vulnerable habitats.
Vulnerable grassland, heath and ecological zones	Ecological value	+++	Very high	× →	Avoid new access or informal routes; use restriction as part of the visitor experience.
Later fences, barriers and security remains	Historical / atmospheric value	+ / ++	Low-medium	◐ −	Keep representative fragments, but remove elements that block public understanding or safe routing.
Later clutter, loose storage, non-original additions	Limited or conflicting value	0 / −	Low	−	Remove where it weakens the legibility of the shelter and landscape.
Damaged or redundant technical additions	Limited value	0 / −	Low	− / ◐	Remove if they confuse the Cold War narrative, unless they show meaningful later use.
Current event/use infrastructure	Contemporary use value, but potential ecological conflict	+ / −	Medium	→ ×	Allow only controlled use; avoid high-impact use where it conflicts with ecology, silence or spatial atmosphere.

Value level

+++ High / essential to retain ++ Positive / adaptable + Supporting 0 Neutral − Conflicting or removable

Design actions

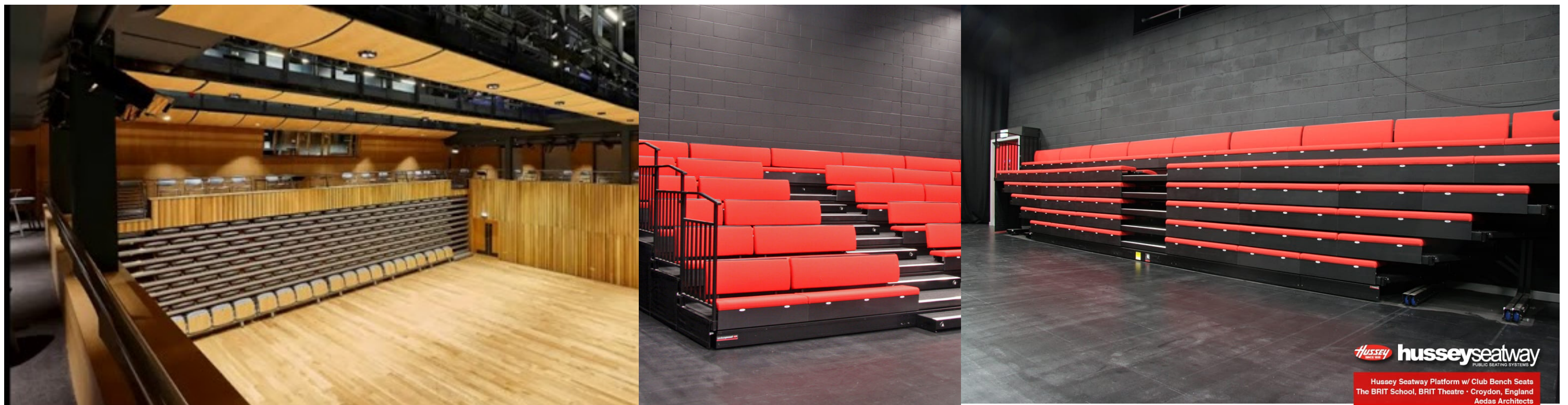
● Retain ◐ Adapt carefully + Reveal → Guide × Avoid − Remove

RETRACTABLE SEATING

HUSSEY SEATWAY

Hussey Seatway Company

<https://www.husseyseating.com/products/seatway-tp/>
<https://www.husseyseating.com/catalog/>



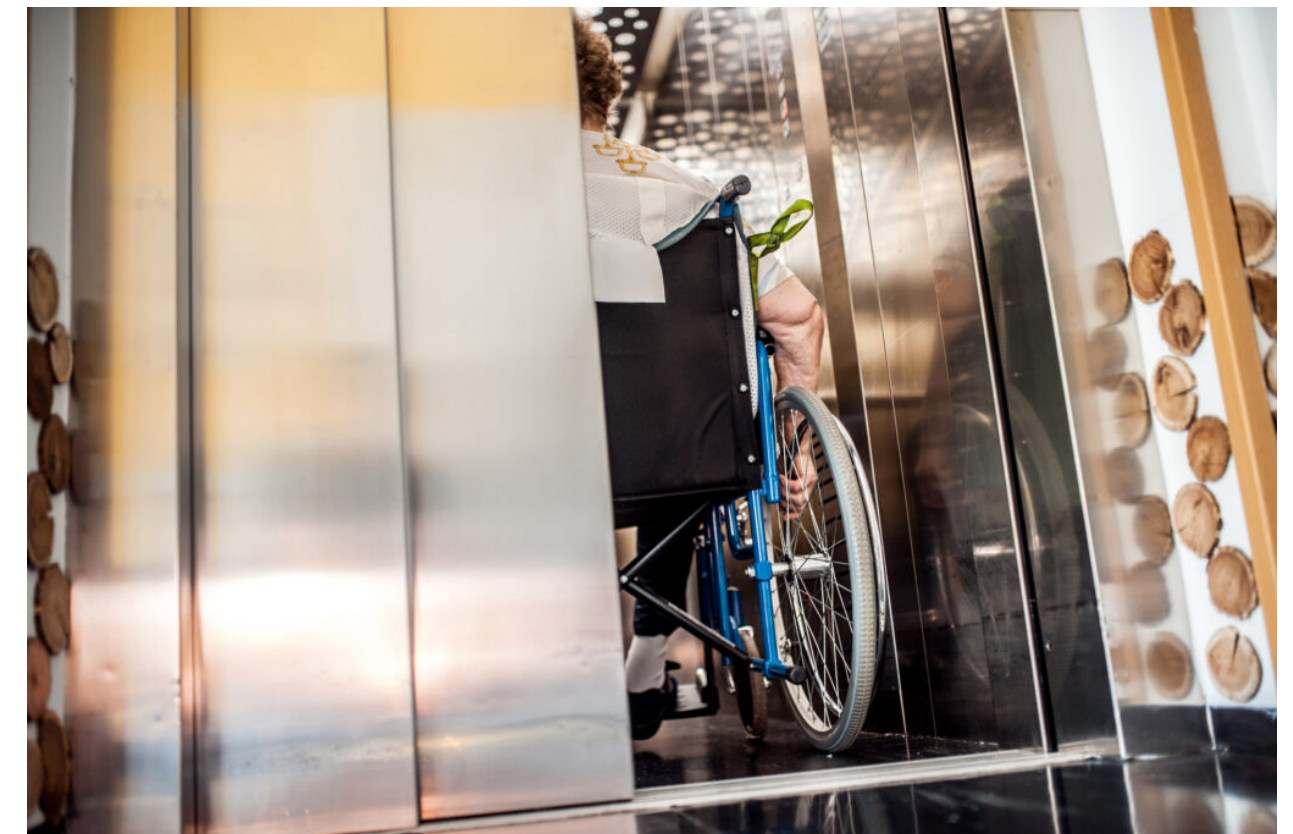
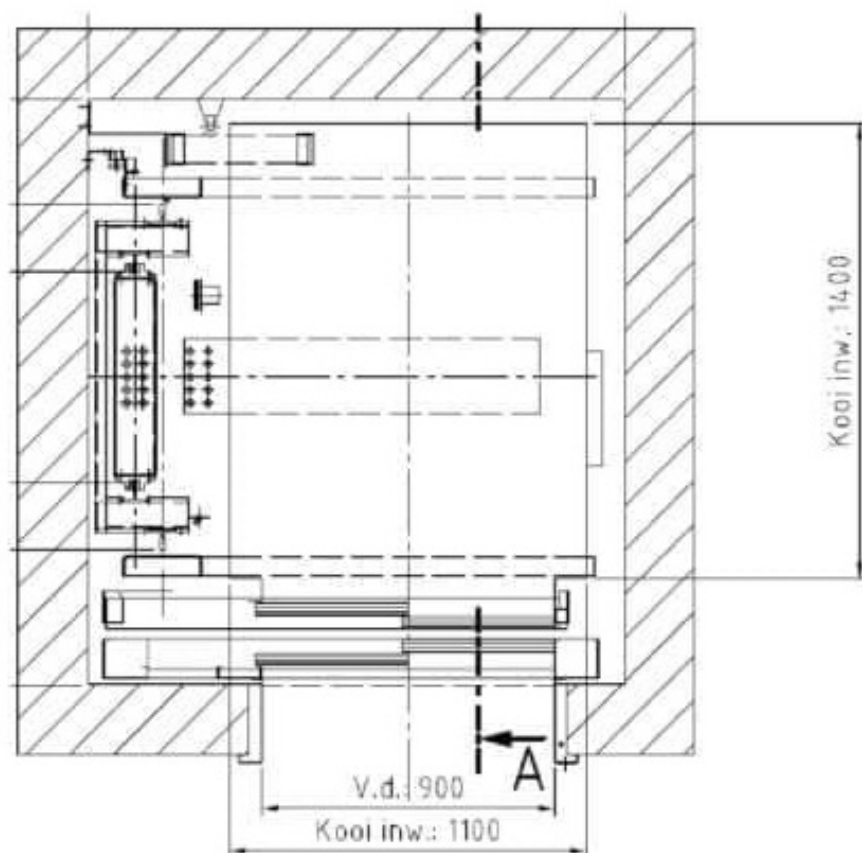
Mitsubishi Elevator Europe

<https://www.mitsubishi-liften.nl/liften/rolstoelliften/>

Eisen en aanbevelingen rolstoellift

In het Handboek Toegankelijkheid stelt de Nederlandse overheid bepaalde eisen aan een rolstoellift. Rolstoelgebruikers moeten niet alleen in de lift passen: ze moeten er ook eenvoudig in en uit kunnen komen en de lift kunnen bedienen. Dat betekent bijvoorbeeld dat de knoppen goed te bereiken zijn als je zit. En dat er rondom de uitgang van de lift op iedere verdieping genoeg ruimte is om met een rolstoel een draai te maken. Klinkt logisch? Toch houden veel fabrikanten hier niet altijd rekening mee.

- Omvang: 1.050 x 1.350 mm
- Afmetingen deur: 900 mm
- Hefvermogen: 630 kg
- Vrije draairuimte voor de toegang van de lift
- Leuning aan de zijwanden van de liftkooi
- Bedieningsknoppen makkelijk bereikbaar
- Een spiegel aan de overzijde van de deuren
- Een bereikbare alarmknop of noodtelefoon
- Een combinatie van beeld en geluid om informatie over te brengen



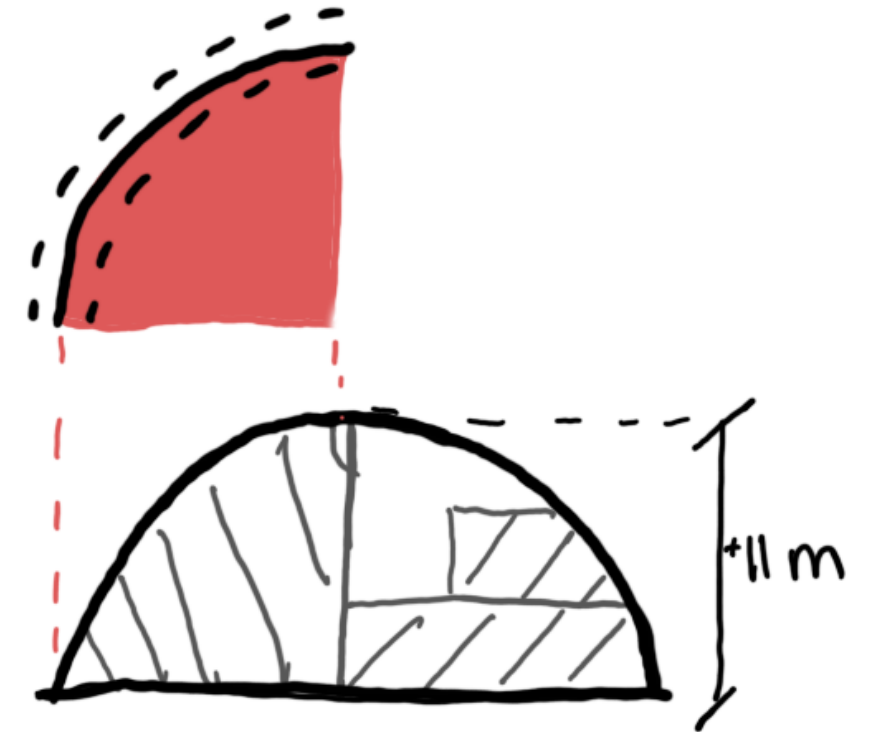
MATERIALIZATION

PROBLEM STATEMENT

- Arched shelter structure
- Height up to ± 11 m
- Non-linear wall conditions and varying heights

Program:

- Public: café, auditorium
- Technical: kitchen, sanitary
- Flexible: education, office



A single material system cannot meet all requirements

MATERIALIZATION

MATERIAL SYSTEMS

System	Perfoms well in	Fails in
Metal stud	▪ partitions ▪ service integration ▪ wet areas	▪ structural height ▪ spatial expression
CFMF (load-bearing cold-formed steel framing)	▪ load-bearing walls ▪ short spans ▪ repetitive layouts	▪ large spans ▪ flexibility
HSB (timber-frame)	▪ dry spaces ▪ biobased applications	▪ robustness ▪ limited advantage over stud
CLT	▪ spatial elements ▪ public-facing areas ▪ fixed geometry (i.e. floor)	▪ curved geometry ▪ flexibility ▪ acoustics

- Metal stud / HSB → insufficient at large height (structural system required)
- CLT → inefficient in curved geometry (custom cutting, waste and reusability)

Sources:

- Neufert, E. (2012). *Architects' Data* (4th ed.).
- KLH Massivholz GmbH. (2020). *CLT Handbook: Cross-Laminated Timber* (European Edition).
- Long, M. (2014). *Architectural Acoustics* (2nd ed.). Academic Press.

MATERIALIZATION

SUSTAINABILITY

System	Material impact	System impact	Conclusion
CLT	+ low CO ₂ / storage	- inflexible	suitable for permanent elements
Metal stud	- high CO ₂	+ adaptable	sustainable in use-phase
Steel	- high CO ₂	+ reusable	high circular potential
HSB	+ biobased	± moderate reuse	limited advantage

Source:

- Cabeza, L. F., et al. (2014). *Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings: A review*. Renewable and Sustainable Energy Reviews.

MATERIALIZATION

POSITIONING CLT: FLOOR VS WALL

Aspect	CLT as Floor	CLT as Wall
Geometry	flat → efficient	curved → inefficient
Structural role	spanning element	full structural system required
Acoustics	resolved in layers	problematic without cavity
Flexibility	independent from layout	fixed spatial system

MATERIALIZATION
PROGRAM VS MATERIAL

Function	Key requirement	MS / CFMF	HSB	CLT
Auditorium	height + acoustics	++	+	--
Cafe	atmosphere + comfort	+	+	++
Kitchen	hygiene + moisture	++	--	--
Sanitary	moisture + maintenance	++	--	--
Education	flexibility + acoustics	++	+	-
Office	adaptability	++	+	--

(++ strong / + adequate / - weak / -- unsuitable)

MATERIALIZATION

AUDITORIUM

Only space that:

- reaches the full height (~11 m)
- connects to the arch
- requires acoustic control

Required system logic:

- structural support → stability
- cavity build-up → sound insulation
- absorption layer → acoustic performance
- finish layer → spatial quality

Material implications:

- CLT only viable as surface element, not primary system
- steel structure required for height and stability
- metal stud for layered acoustic build-up
- timber acoustic panels as finish layer

→ A layered system is required, not a single material

MATERIALIZATION

PUBLIC ZONES (CAFÉ, ENTRANCE, CIRCULATION)

Space that:

- are publicly accessible and highly occupied
- require spatial *identity and comfort*
- operate at lower heights (no full arch connection)

Required system logic:

- light supporting structure → minimal intervention
- acoustic surface treatment → reduce reverberation
- tactile finish layer → atmosphere and identity

Material implications:

- timber (CLT floor or applied finish) becomes viable
- no need for heavy structural systems
- acoustic performance integrated in finish

→ Material expression is primary, structure is secondary

MATERIALIZATION

WET / TECHNICAL SPACES (KITCHEN, SANITARY)

Space that:

- are functionally driven
- involve moisture, cleaning and technical installations
- are enclosed and non-public

Required system logic:

- closed wall systems → hygiene and durability
- moisture-resistant layers → prevent degradation
- integrated services → plumbing

Material implications:

- metal stud + technical boards (cement, tile, HPL)
- no exposed timber surfaces
- no structural expression required

→ Performance excludes material expression

MATERIALIZATION

REMAINING SPACES (EDUCATION, OFFICE)

Space that:

- require adaptability over time
- operate at moderate heights
- demand acoustic separation but not full performance

Required system logic:

- lightweight partition systems → flexibility
- cavity walls → acoustic separation

Material implications:

- metal stud / CFMF + CLT floor as horizontal layer
- optional timber finished where needed
- no heavy or permanent systems

→ Flexibility is more important than material permanence

MATERIALIZATION

SPATIAL SYSTEM MATRIX

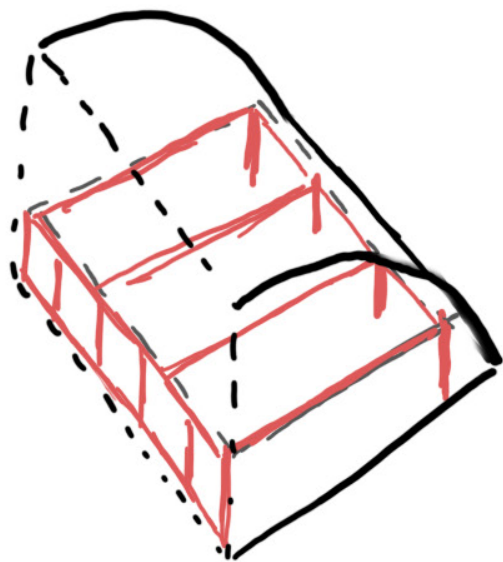
Space Type	Key Conditions	Required System Logic	Material Implications
Auditorium	- Full height (~11 m) - Connects to arch - High acoustic control	- Structural layer (height) - Cavity build-up (insulation) - Absorption layer - Finish layer	- Steel structure required - Stud system for acoustic build-up - Timber/acoustic panels as finish - CLT only as surface element
Public Zones	- High occupancy - Spatial experience - No full height required	- Light support - Acoustic surface treatment - Expressive finish layer	- Timber viable (CLT or finish) - Lightweight structure sufficient - No heavy system required
Wet / Technical	- Moisture - Hygiene - Services integration	- Closed wall systems - Moisture-resistant layers - Integrated installations	- Metal stud + technical boards - No exposed timber - No structural expression
Remaining Spaces	- Flexibility - Moderate height - Acoustic separation	- Lightweight partitions - Cavity walls - Replaceable finishes	- Metal stud / HSB primary - Optional timber finish - No heavy systems

MATERIALIZATION

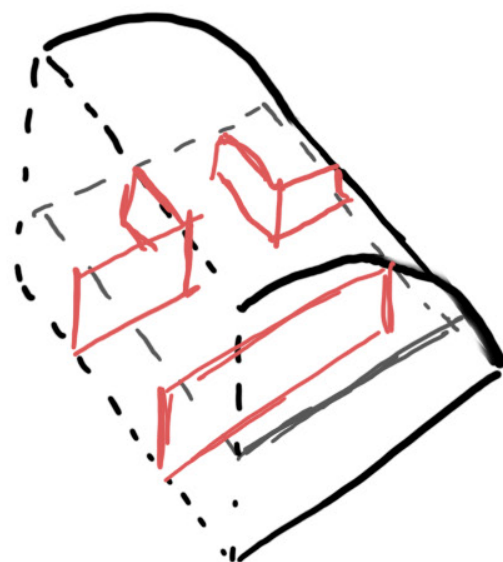
HYBRID SYSTEM (LAYERED LOGIC)

Layer	Role	System
Primary	structure	carries load
Secondary	partition	organizes space
Tertiary	finish	defines experience
Horizontal	slab	floor

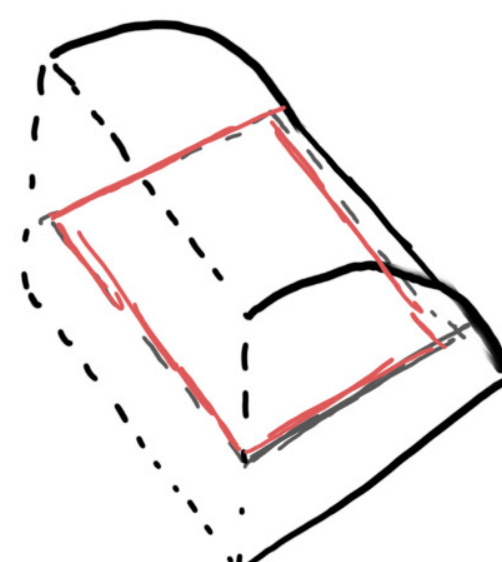
→ Each layer performs a single role and remains independent.



Structure



Partition



Slab



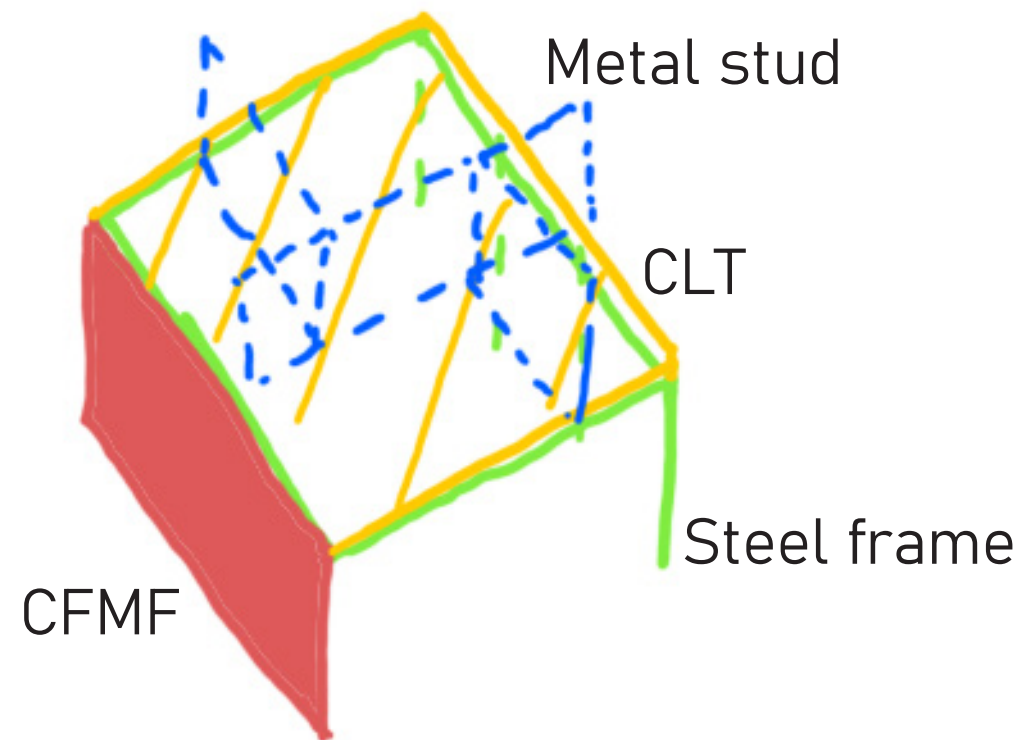
Finish

MATERIALIZATION

STRUCTURAL STRATEGY

System	Role	Application
CFMF (load-bearing walls)	primary load-bearing walls	supports intermediate floor below
Steel frame	local vertical support*	local spans / open zones
CLT	horizontal spanning element	intermediate floor
Metal stud	non-loadbearing partitions	spatial division only

→ The intermediate floor is supported by a **hybrid system** of load-bearing CFMF walls and local steel elements, with a CLT floor as the horizontal structure. Non-loadbearing metal stud partitions remain independent from the structural system.



*Steel columns resolve the unsupported edge created by the curved shelter geometry.

MATERIALIZATION

MATERIAL STRATEGY

1. Auditorium

- | | |
|-------------------------------|-------------------|
| ▪ structural system (height): | steel frame |
| ▪ layered acoustic build-up: | stud + insulation |
| ▪ (acoustic) finish: | timber-based |

2. Public zones

- | | |
|-------------------------------------|--------------|
| ▪ timber as visible material layer: | timber-based |
|-------------------------------------|--------------|

3. Wet/technical spaces

- | | |
|------------------------------|-----------|
| ▪ purely technical finished: | no timber |
|------------------------------|-----------|

4. Remaining spaces

- | | |
|----------------------------------|--------------------|
| ▪ lightweight partition systems: | metal stud (/ HSB) |
| ▪ flexible and demountable | |

5. Intermediate floor

- | | |
|----------------------|--------------------------|
| ▪ primary structure: | CFMF (+ steel structure) |
| ▪ floor plane: | CLT |



Conclusion

- structure where *necessary*
- flexibility where *possible*
- expression where *experienced*

MATERIALIZATION

REFERENCES

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file:///F:/Downloads/20230424132810!Sci_p360.pdf > P47

file:///F:/Downloads/clt_24_handbook_complete_version_www_fpinnovations_ca.pdf

MATERIALIZATION

REFERENCES



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■ News

AISC launches Arup-authored design guide for hybrid steel-timber, a flexible and low embodied-carbon option

Arup has authored the first-ever set of US recommendations for hybrid steel frames with mass timber floors. Design Guide 37: Hybrid Steel Frames with Wood Floors encourages the use of mass timber floor systems in construction.



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Last updated: 23rd May 2022

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Source:

• <https://www.arup.com/news/aisc-launches-arup-authored-design-guide-for-hybrid-steel-timber-a-flexible-and-low-embodied-carbon-option>

MATERIALIZATION

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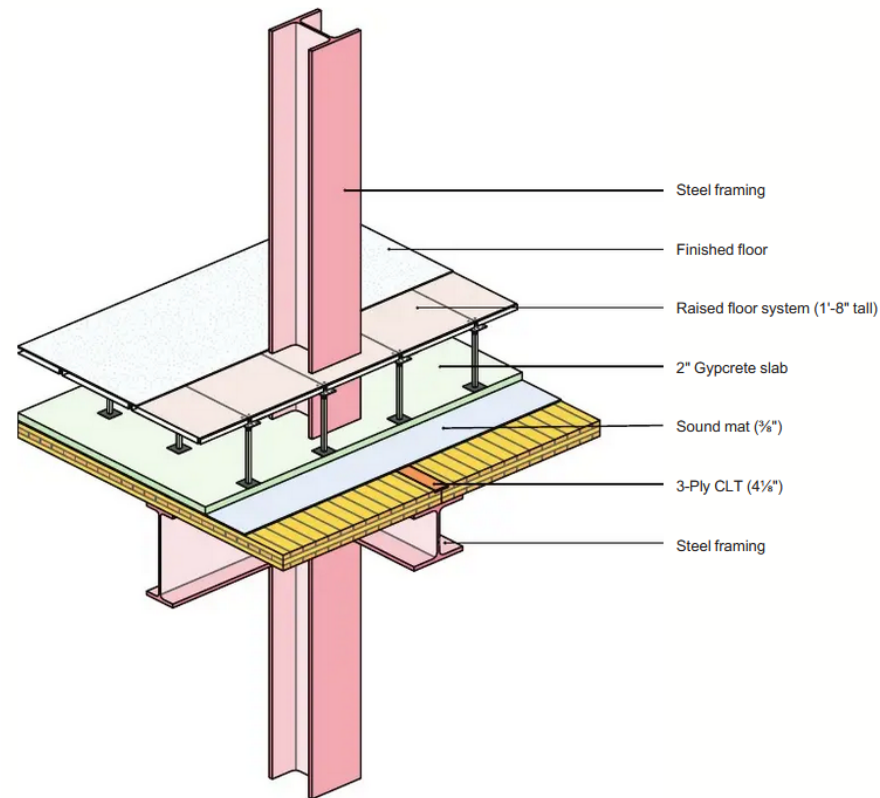


Fig. 2-13. Hybrid steel and CLT floor build-up (image credit: Kevin Daly Architects with Productora).

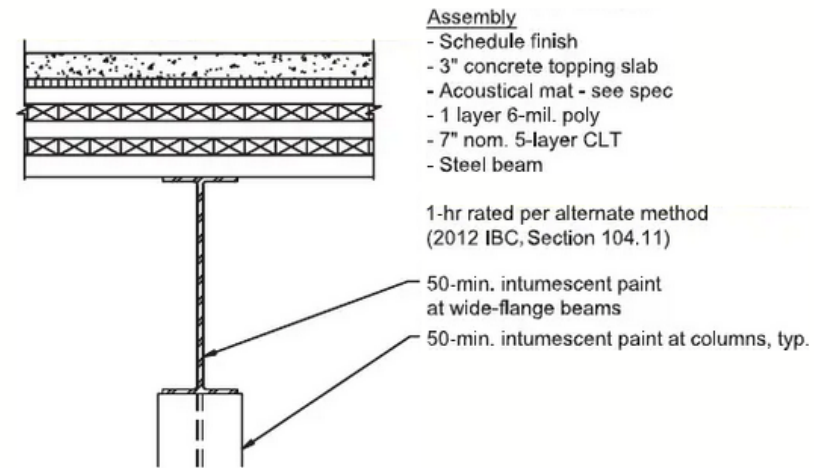


Fig. 2-9. Typical floor assembly (credit: Delineate studio).

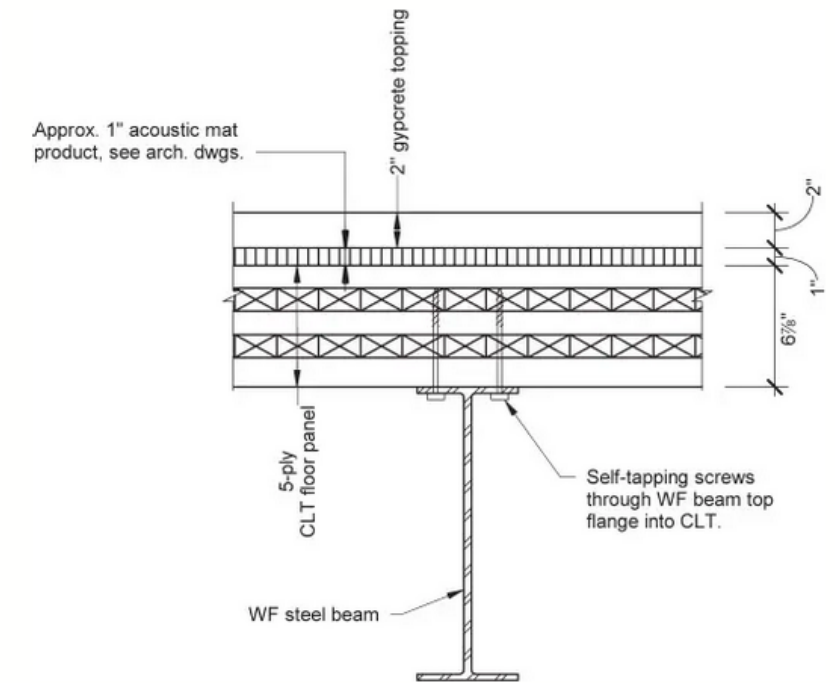


Fig. 2-5. Typical RISD floor system (image credit: Odeh Engineers, Inc.).



Fig. 2-8. CLT panels supported on steel beams (photo courtesy of David Barber).

Source:

- <https://www.scribd.com/document/654785860/AISC-DG-37-Hybrid-Steel-Frames-with-CLT>

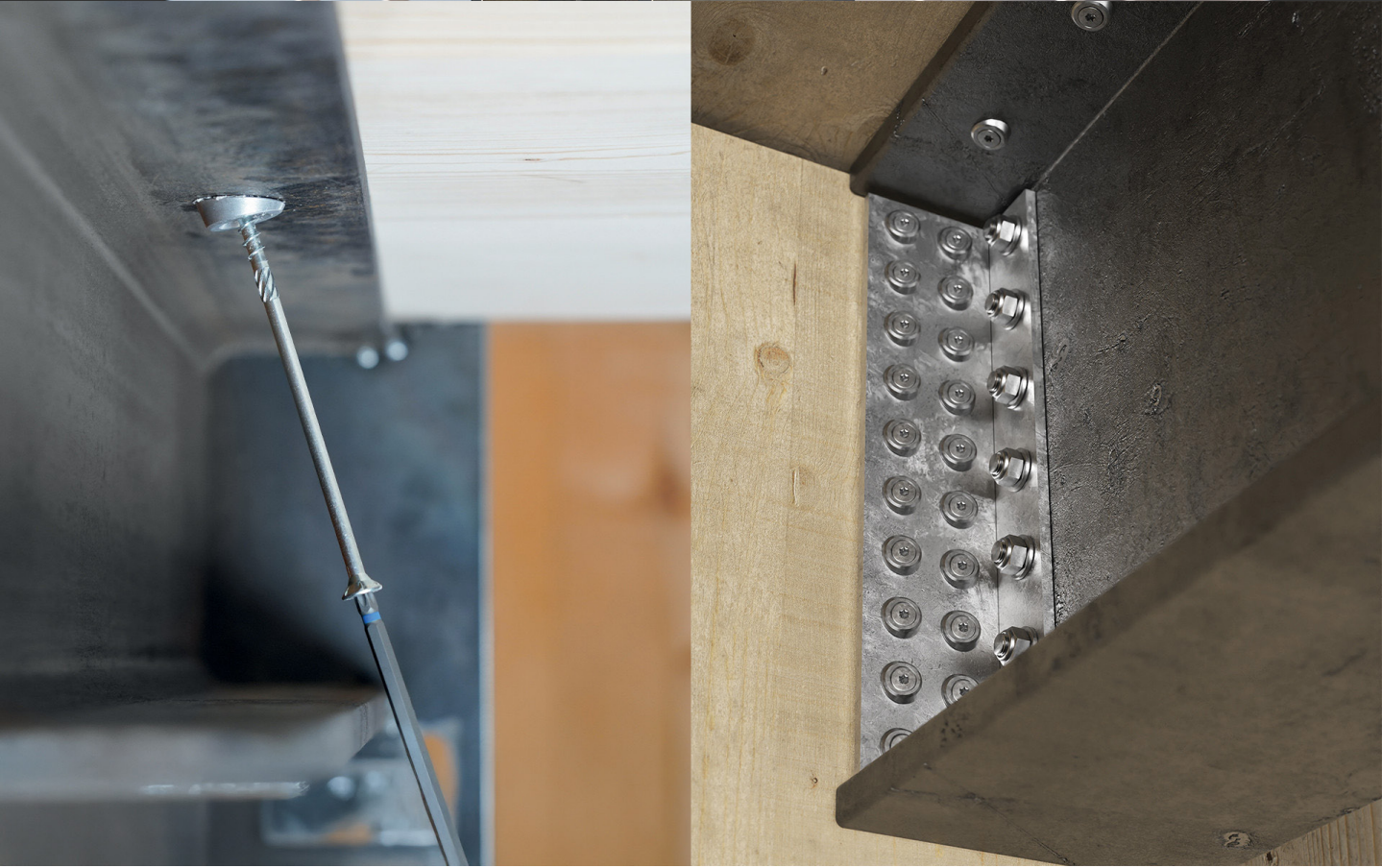
MATERIALIZATION

REFERENCES

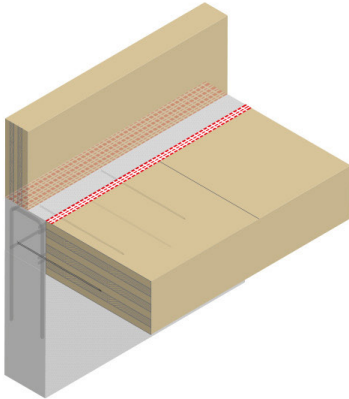
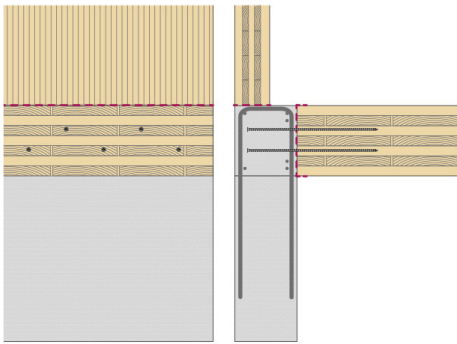
STRUCTURAL VALUES | HARDWOOD

geometry				SHEAR				TENSION				
				hardwood-hardwood $\varepsilon=90^\circ$	hardwood-hardwood $\varepsilon=0^\circ$	steel-hardwood thin plate	steel-hardwood thick plate	thread withdrawal $\varepsilon=90^\circ$	thread withdrawal $\varepsilon=0^\circ$	head pull-through		
d ₁	L	b	A	R _{V,90,k}	R _{V,0,k}	S _{PLATE}	R _{V,k}	S _{PLATE}	R _{V,k}	R _{ax,90,k}	R _{ax,0,k}	R _{head,k}
[mm]	[mm]	[mm]	[mm]	[kN]	[kN]	[mm]	[kN]	[mm]	[kN]	[kN]	[kN]	[kN]
6	80	50	30	3,21	2,06	3	4,27	6	5,33	6,80	2,04	4,15
	100	60	40	3,61	2,42		4,61		5,67	8,16	2,45	4,15
	120	70	50	3,61	2,66		4,95		6,01	9,52	2,86	4,15
	140	80	60	3,61	2,76		5,14		6,35	10,88	3,26	4,15
	160	90	70	3,61	2,86		5,14		6,69	12,24	3,67	4,15
	120	70	50	5,35	3,65		7,31		9,02	12,69	3,81	5,20
8	140	80	60	5,43	4,02	4	7,76	8	9,47	14,50	4,35	5,20
	160	90	70	5,43	4,35		8,21		9,92	16,32	4,89	5,20
	180	100	80	5,43	4,42		8,27		10,38	18,13	5,44	5,20
	200	100	100	5,43	4,42		8,27		10,38	18,13	5,44	5,20
	220	100	120	5,43	4,42		8,27		10,38	18,13	5,44	5,20
	240	100	140	5,43	4,42		8,27		10,38	18,13	5,44	5,20

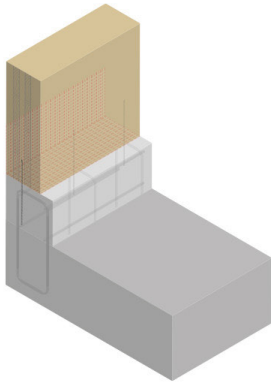
ε = screw-to-grain angle



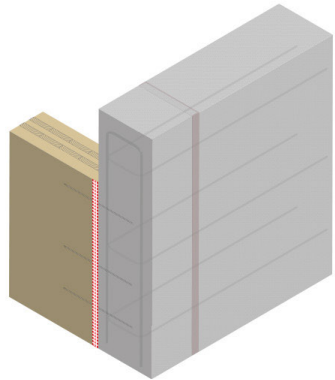
FLOOR-WALL CONNECTION



WALL-FOUNDATION CONNECTION



WALL-WALL CONNECTION



Source:
• <https://www.rothoblaas.de/blog/verbindungen-auf-der-hybridbaustelle-schrauben-fur-holz-holz-holz-stahl-holz-beton-verbindungen>

MATERIALIZATION

REFERENCES



Source:
• <https://www.holmes.us/portfolio-articles/microsoft-silicon-valley-campus/>



CONSTRUCTION GREEN ROOF



Utrechtse Heuvelrug in 2050
Landschapsgedoeutrecht

DROGE SCHRAALLANDEN, AKKERS EN ENGEN

Op de zandige zuidhellingen van de stuwwal en in zandgroeves komen bijzondere vegetaties voor die alleen groeien op voedselarme zandbodems: de droge schraallanden. Het grootste schraallandcomplex van de provincie is de Vliegbasis Soesterberg: een refugium voor zeldzame soorten als de veldleeuwerik, kommavinder en allerlei zandbijen.

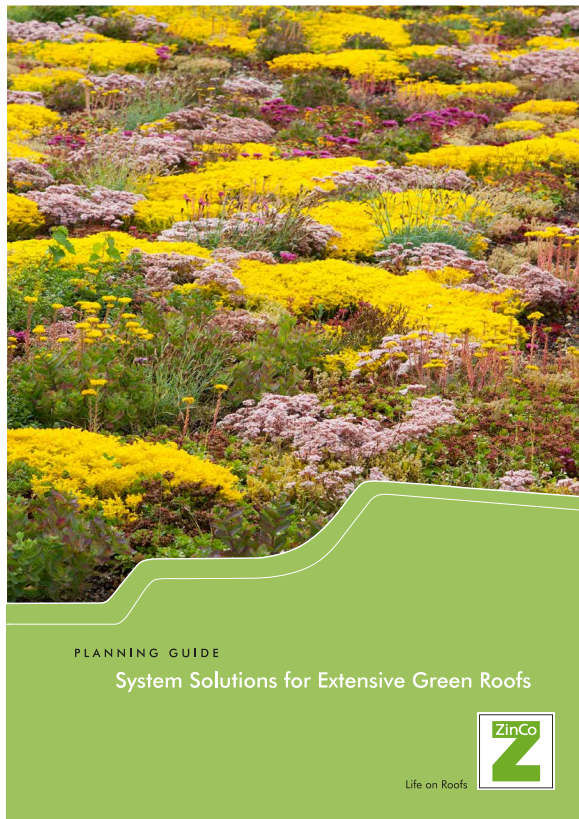
Een deel van de historische engen, o.a. op de flanken, is in gebruik als (natuur)akker met bedreigde akkerkruiden en de insecten die daarvan afhankelijk zijn.

TOEKOMSPERSPECTIEF (2050)

Samen met het bos en de heideterreinen, vormen de schraallanden en (natuur)akkers een gezond boslandschap.

Rust, ruimte en voedsel zijn gegarandeerd. De kruidenrijke natuurakkers, met een veelheid aan graanrassen, zijn voedselleverancier voor insecten, (akker)vogels en kleine zoogdieren. Omdat de bodem van de schraallanden niet meer belast wordt door een te veel aan voedingsstoffen, komen voedselarme plantensoorten hier tot hun recht.

Vliegbasis Soesterberg functioneert als kraamkamer: soorten verspreiden zich van hieruit via faunapassages en ecologische verbindingen over de Utrechtse Heuvelrug. Alle biotopen vullen elkaar aan, zodat er overal ruimte is voor planten en dieren om zich voort te planten, te verspreiden, te broeden, op te groeien, te spelen, te rusten, foerageren, jagen en sterven.



System Build-up "Bee Pasture" with Floradrain® FD 25-E



There is plenty of proof of a strong decrease in the concentration of wild bees and honey bees due to globalized, industrial forms of land use (mono-culture, chemical crop protection, etc.). The resulting lack of pollination by bees will have fatal consequences for food production.

In order to counter this development, we have created an efficient compensation site on the roof with the system build-up Bee Pasture.

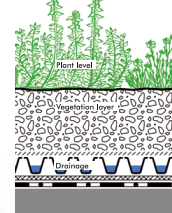
This extensive green roof focuses specifically on the long-term supply of nectar and pollen.

The plant mixture, which is specifically adapted to meet the needs of the bees, therefore, provides a constantly blossoming "landing zone" from April to September. The vegetation layer comprises plug plants included in the ZinCo "Bee Pasture" plant list.

As a result, partial areas can be occupied sub-annually "per bee". Additional irrigation is required to maintain the nectar and pollen production during drought periods.



System Build-up with EPD verification. Details on Page 15.



Weight kg/m²	Height cm
100	140
3	12
103	152

Build-up height: ca. 13 cm
Weight, saturated: ca. 155 kg/m²
Water retention capacity: ca. 49 l/m²

Plug Plants as per plant list "Bee Pasture"

System Substrate "Rocky Type Plants", ca. 100 mm

Filter Sheet SF
Floradrain® FD 25-E
Protection Mat SSM 45
Root Barrier WSF 40, if waterproofing is not root-resistant

ZinCo Green Roofing Systems now with European Technical Assessment!

At the request of the European Commission, the European Technical Assessment (ETA) has been carried out for the ZinCo Green Roofing Systems. The ETA is a technical assessment of the products and systems, which is based on the European Technical Assessment (ETA) and the European Technical Assessment (ETA).	On the one hand, this is a prerequisite for standardization in the European Union. On the other hand, it is a prerequisite for the European Commission to be able to issue a decision on the technical assessment of the products and systems, which is based on the European Technical Assessment (ETA) and the European Technical Assessment (ETA).
Product name: ZinCo Green Roofing System	Product name: ZinCo Green Roofing System
Product description: ZinCo Green Roofing System	Product description: ZinCo Green Roofing System
Product type: ZinCo Green Roofing System	Product type: ZinCo Green Roofing System
Product class: ZinCo Green Roofing System	Product class: ZinCo Green Roofing System
Product standard: ZinCo Green Roofing System	Product standard: ZinCo Green Roofing System

ENVIRONMENTAL PRODUCT DECLARATION (EPD)

The Environmental Product Declaration (EPD) is a document that provides information on the environmental impact of a product or service. It is based on the European Technical Assessment (ETA) and the European Technical Assessment (ETA).

An Environmental Product Declaration (EPD) is a document that provides information on the environmental impact of a product or service. It is based on the European Technical Assessment (ETA) and the European Technical Assessment (ETA).

Green Oases for Our Cityscapes

The environmental, urban development and engineering advantages of green roofs:

Protection of the Roof Membrane	New Habitat	Rainwater Retention	Dust Binding	Reduction of Energy Costs	Noise Protection
• Protects the roof membrane from UV radiation, heat, and cold and hail	• Avoids sealing and creates new habitat for plants and animals	• Reduces run-off	• Enhances the microclimate by filtering out dust and smog particles	• Thermal protection and reduction in heating and cooling costs	• Enhances sound insulation

Features

Unlike intensive green roofs, extensive green roofs require little upkeep or maintenance.

The features at a glance:

- **Minimum maintenance:**
 - Inspection and maintenance once or twice per year
 - Water and nutrient supply mostly by natural means
- **Plant communities close to nature:**
 - Undemanding
 - Extensive
 - Self-regenerating
- **Low loads and build-up heights:**
 - Mainly substrates with layer depths of up to about 120 mm
 - Loads about 70–150 kg/m²
- **Low-cost:**
 - For set-up and maintenance

Climate conditions

The system build-ups described in this planning guide and the corresponding plant communities were developed for the moderate continental climate of Central Europe and some of these systems have been well tried and tested for decades.

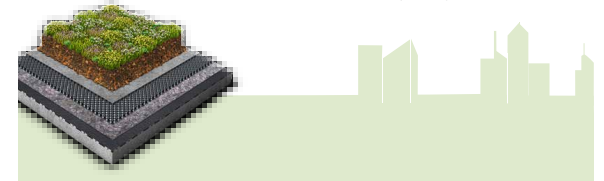
In extremely dry areas, we recommend increasing the substrate depth in order to provide the plants with water over a longer period of time.

Biodiversity



The picture shows build-ups with a uniform height. The range of species in the roof habitat can be expanded by varying the substrate depth or type, by installing shrubs, sand or gravel surfaces and/or by introducing deadwood or stones. This also contributes to increased biodiversity. The most important thing is to ensure that this is permitted from a roof structural point of view.

More information to be found in our planning guide "Biodiversity Green Roof" at <https://zinco-greenroof.com/downloads>



CONSTRUCTION

CALCULATIONS - ROOF CONCRETE

Berekening Dak

Berekening niet-toegankelijk groen dak, L = 3,0 m:

- Overspanning: L = **3,0m**
- Bee Pasture verzadigd: **1,55 kN/m²** (Zinco Extensive Green Roofs)
- Gewapend beton: 2500 kg/m³ ≈ **25 kN/m²** (Vademecum)
- Elasticiteitsmodulus beton C20/25: Ecm = **30.000 N/mm²**
- Betonsterkte C20/25: fm,d = **20 N/mm²**
- Dakbelasting klasse H, niet toegankelijk, 0-15°: **1,0 kN/m²**
- Sneeuw NL: **sk = 0,7 kN/m²**
- Gevolgklasse CC2: γG = **1,2**, γQ = **1,5**

150mm gewapend beton:

- Eigen gewicht: 0,15 x 25 = **3,75 kN/m²**
- Permanente belasting: Gk = 3,75 + 1,55 = **5,30 kN/m²**
- UGT, conservatief alles ongunstig: qd = 1,2 x 5,30 + 1,5 x 1,0 + 1,5 x 0,7 = **8,91 kN/m²**
- Moment: MEd = qL²/8 = 8,91 x 3² / 8 = **10,0 kNm/m**
- Dwarskracht: VEd = qL/2 = 8,91 x 3 / 2 = **13,4 kN/m**

- Weerstandsmoment rechthoekige doorsnede: W = b x h² / 6 = 1000 x 150² / 6 = **3.750.000 mm³**
- UGT (sterkte) buigspanning: σm,d = MEd / W = 10,0 x 10⁶ / 3.750.000 = **2,67 N/mm²**
- Unity Check UGT buiging: U.C. = σm,d / fm,d = 2,67 / 20 = **0,13 < 1,0 → voldoet**
- Wnodig = U.C. x Woud = 0,13 x 3.750.000 = **487.500 mm³**
- Bij rechthoekige doorsnede: W = b x h² / 6 → hnodig,UGT = √(6 x Wnodig / b) = √(6 x 487.500 / 1000) = **54 mm**

- BGT (stijfheid): q = 5,30 + 1,0 + 0,7 = **7,00 kN/m²**
- Traagheidsmoment rechthoekige doorsnede: I = b x h³ / 12 = 1000 x 150³ / 12 = **281.250.000 mm⁴**
- Doorbuiging: w = 5/384 x qL⁴ / EI = 5/384 x 7,0 x 3000⁴ / (30.000 x 281.250.000) = **0,88 mm**
- Toetsing: w ≤ 0,004L geeft wmax = 0,004 x 3000 = 12mm
- Unity Check BGT doorbuiging: U.C. = w / wmax = 0,88 / 12 = **0,07 < 1,0 → voldoet ruim**
- Inodig = U.C. x Ioud = 0,07 x 281.250.000 = **19.687.500 mm⁴**
- Bij rechthoekige doorsnede: I = b x h³ / 12 → hnodig,BGT = ³√(12 x Inodig / b) = ³√(12 x 19.687.500 / 1000) = **62 mm**

- Benodigd op sterkte: **54 mm**
- Benodigd op stijfheid: **62 mm**
- Maatgevend: hnodig = max(54,62) = **62mm → h = 70 mm gewapend beton**

Controle met h = 70mm gewapend beton:

- Eigen gewicht: 0,07 x 25 = **1,75 kN/m²**
- Permanente belasting: Gk = 1,75 + 1,55 = **3,30 kN/m²**
- UGT: qd = 1,2 x 3,30 + 1,5 x 1,0 + 1,5 x 0,7 = **6,51 kN/m²**
- Moment: MEd = 6,51 x 3² / 8 = **7,3 kNm/m**
- W = 1000 x 70² / 6 = **816.667 mm³**
- σm,d = 7,3 x 10⁶ / 816.667 = **8,96 N/mm²**
- Unity Check UGT buiging: U.C. = 8,96 / 20 = **0,45 < 1,0 → voldoet**
- BGT: q = 3,30 + 1,0 + 0,7 = **5,00 kN/m²**
- I = 1000 x 70³ / 12 = **28.583.333 mm⁴**
- w = 5/384 x 5,0 x 3000⁴ / (30.000 x 28.583.333) = **6,1 mm**
- wmax = 0,004 x 3000 = **12 mm**
- Unity Check BGT doorbuiging: U.C. = 6,1 / 12 = **0,51 < 1,0 → voldoet**

Conclusie: 70 mm gewapend beton zou moeten voldoen. Maar 120mm geldt als praktische ondergrens voor een constructieve plaat. Daarom is 120mm logischer als ontwerpmaat.

120 mm gewapend beton

Berekening toegankelijk groen dak, L = 6,0 m + 2 x 1,5 m uitkraging:

- Overspanning: L = **6,0m**
- Uitkraging: **a = 1,5m** aan beide zijden
- Totale dakbreedte: 1,5 + 6,0 = **9,0m**
- Bee Pasture verzadigd: **1,55 kN/m²** (Zinco Extensive Green Roofs)
- Gewapend beton: 2500 kg/m³ ≈ **25 kN/m²** (Vademecum)
- Elasticiteitsmodulus beton C20/25: Ecm = **30.000 N/mm²**
- Betonsterkte C20/25: fm,d = **20 N/mm²**
- Dakbelasting wel toegankelijk → Categorie C3: **5,0 kN/m²**
- Sneeuw NL: sk = **0,7 kN/m²**
- Gevolgklasse CC2: γG = **1,2**, γQ = **1,5**

150mm gewapend beton:

- Eigen gewicht: 0,15 x 25 = **3,75 kN/m²**
- Permanente belasting: Gk = 3,75 + 1,55 = **5,30 kN/m²**
- UGT, conservatief alles ongunstig: qd = 1,2 x 5,30 + 1,5 x 5,0 + 1,5 x 0,7 = **14,91 kN/m²**
- Steuvmoment (met uitkraging): MEd,steun = qd x a² / 2 = 14,91 x 1,5² / 2 = **16,8 kNm/m**
- Veldmoment (in L=6m): MEd, veld = qd x (L²/8 - a²/2) = 14,91 x (6,0²/8 - 1,5²/2) = **50,3 kNm/m**
- Totale belasting per meter strook: 14,91 x 9,0 = **134,2 kN/m**
- Reactie per steunpunt: R = 134,2 / 2 = **67,1 kN/m**
- Dwarskracht: VEd = R - qd x 1,5 = 67,1 - 14,91 x 1,5 = **44,7 kN/m**

- Weerstandsmoment rechthoekige doorsnede: W = b x h² / 6 = 1000 x 150² / 6 = **3.750.000 mm³**
- UGT (sterkte) buigspanning veld: σm,d,veld = MEd,veld / W = 50,3 x 10⁶ / 3.750.000 = **13,41 N/mm²**
- Unity Check UGT veldmoment: U.C. = σm,d,veld / fm,d = 13,41 / 20 = **0,67 < 1,0 → voldoet**
- Wnodig = U.C. x Woud = 0,67 x 3.750.000 = **2.512.500 mm³**
- Bij rechthoekige doorsnede: W = b x h² / 6 → hnodig,UGT = √(6 x Wnodig / b) = √(6 x 2.512.500 / 1000) = **123 mm**

- BGT (stijfheid): q = 5,30 + 5,0 + 0,7 = **11,00 kN/m²**
- Traagheidsmoment rechthoekige doorsnede: I = b x h³ / 12 = 1000 x 150³ / 12 = **281.250.000 mm⁴**
- Doorbuiging: w = q / EI x (5L⁴/384 - a²L²/16) = 11,0 / (30.000 x 281.250.000) x ((5 x 6000⁴ / 384) - (1500² x 6000² / 16)) = **15,4 mm**
- Toetsing: w ≤ 0,004L geeft wmax = 0,004 x 6000 = 24mm
- Unity Check BGT doorbuiging: U.C. = w / wmax = 15,4 / 24 = **0,64 < 1,0 → voldoet**
- Inodig = U.C. x Ioud = 0,64 x 281.250.000 = **180.000.000 mm⁴**
- Bij rechthoekige doorsnede: I = b x h³ / 12 → hnodig,BGT = ³√(12 x Inodig / b) = ³√(12 x 180.000.000 / 1000) = **129 mm**

- Benodigd op sterkte: **123 mm**
- Benodigd op stijfheid: **129 mm**
- Maatgevend: hnodig = max(123, 129) = **129 mm → h = 130 mm gewapend beton**

Controle met h = 130mm gewapend beton:

- Eigen gewicht: 0,13 x 25 = **3,25 kN/m²**
- Permanente belasting: Gk = 3,25 + 1,55 = **4,80 kN/m²**
- UGT: qd = 1,2 x 4,80 + 1,5 x 5,0 + 1,5 x 0,7 = **14,31 kN/m²**
- Steuvmoment: MEd,steun = 14,31 x 1,5² / 2 = **16,1 kNm/m**
- Veldmoment: MEd,veld = 14,31 x (6,0²/8 - 1,5²/2) = **48,3 kNm/m**
- W = 1000 x 130² / 6 = **2.816.667 mm³**
- σm,d,veld = 48,3 x 10⁶ / 2.816.667 = **17,16 N/mm²**
- Unity Check UGT veldmoment: U.C. = 17,16 / 20 = **0,86 < 1,0 → voldoet**
- σm,d,steun = 16,1 x 10⁶ / 2.816.667 = **5,72 N/mm²**
- Unity Check UGT steuvmoment: U.C. = 5,72 / 20 = **0,29 < 1,0 → voldoet ruim**
- BGT: q = 4,80 + 5,0 + 0,7 = **10,50 kN/m²**
- I = 1000 x 130³ / 12 = **183.083.333 mm⁴**
- w = 10,5 / (30.000 x 183.083.333) x ((5 x 6000⁴ / 384) - (1500² x 6000² / 16)) = **22,3 mm**
- wmax = 0,004 x 6000 = **24 mm**
- Unity Check BGT doorbuiging: U.C. = 22,3 / 24 = **0,93 < 1,0 → voldoet net**

Conclusie: 130 mm gewapend beton zou theoretisch voldoen, maar niet ruim bij U.C. BGT (0,93). Daarom is 150mm logischer als ontwerpmaat.

150 mm gewapend beton

CONSTRUCTION

CALCULATIONS - CONCRETE COLUMNS

Berekening Kolommen (Beton)

Berekening globale dimensionering betonkolom onder niet-toegankelijk groen dak, L = 3,0 m:

- Kolomtype: **vierkante gewapende betonkolom**
- Kolomhoogte: hkolom = **1300 mm** (geeft kniklengte: lcr = **1300mm**)
- H.o.h. kolommen: s = **2,0 m**
- Overspanning dakplaat: L = **3,0m**
- Dragend oppervlak per kolom: Aroof = $L/2 \times s = 3,0/2 \times 2,0 = \mathbf{3,00\ m^2}$
- Dakplaat: 120 mm gewapend beton (2500 kg/m³ ≈ 25 kN/m³) + Bee Pasture verzadigd: 1,55 kN/m²
- Betonsterkte C20/25: fm,d = **20 N/mm²**
- Dakbelasting klasse H, niet toegankelijk, 0–15°: **1,0 kN/m²**
- Sneeuw NL: **sk = 0,7 kN/m²**
- Gevolgklasse CC2: γG = **1,2**, γQ = **1,5**
- Rekenwaarde druksterkte beton: fcd = fck / γC = 20 / 1,5 = **13,3 N/mm²**
- Elasticiteitsmodulus beton C20/25: Ecm = **30.000 N/mm²**
- Vuistregel betonkolom: b = hkolom / 10 = 1300 / 10 = **130 mm**

130x130 gewapend beton:

- Eigen gewicht dakplaat: $0,12 \times 25 = \mathbf{3,00\ kN/m^2}$
- Permanente dakbelasting: Gk,dak = 3,00 + 1,55 = **4,55 kN/m²**
- Permanente dakbelasting op kolom: Gk,dak,kolom = 4,55 × 3,00 = **13,65 kN**
- Eigen gewicht kolom: Gk,kolom = 0,13 × 0,13 × 1,30 × 25 = **0,55 kN**
- Totale permanente belasting: ΣGk = 13,65 + 0,55 = **14,20 kN**
- Veranderlijke dakbelasting op kolom: Qk = 1,0 × 3,00 = **3,00 kN**
- Sneeuwbelasting op kolom: Sk = 0,7 × 3,00 = **2,10 kN**

- UGT kolombelasting: Fc,d = 1,2 × 14,20 + 1,5 × 3,00 + 1,5 × 2,10 = **24,7 kN**
- Kolomdoorsnede: A = b × b = 130 × 130 = **16.900 mm²**
- Drukspanning: σc,d = Fc,d / A = 24,7 × 10³ / 16.900 = **1,46 N/mm²**
- Unity Check UGT druksterkte: U.C. = σc,d / fcd = 1,46 / 13,3 = **0,11 < 1,0 → voldoet ruim**
- Benodigde doorsnede druksterkte: Anodig = U.C. × Aoud = 0,11 × 16.900 = **1.859 mm²**
- Bij vierkante doorsnede: bnodig,druk = √Anodig = √1.859 = **43 mm**

- Kwadratisch oppervlaktmoment vierkante doorsnede: I = b⁴ / 12 = 130⁴ / 12 = **23.800.833 mm⁴**
- Kritische knikkracht: Fcr = π² × E × I / lcr² = π² × 30.000 × 23.800.833 / 1300² = 4.169.000 N = **4.169 kN**
- Knikgetal: n = Fcr / Fc,d = 4.169 / 24,7 = **169**
- Toetsing knikgetal: n ≥ 5 geeft **169 ≥ 5 → voldoet ruim**
- Unity Check knik: U.C. = 5 × Fc,d / Fcr = 5 × 24,7 / 4.169 = **0,03 < 1,0 → voldoet ruim**
- Benodigd traagheidsmoment knik: Inodig = U.C. × Ioud = 0,03 × 23.800.833 = **714.025 mm⁴**
- Bij vierkante doorsnede: I = b⁴ / 12 → bnodig,knik = ⁴√(12 × Inodig) = ⁴√(12 × 714.025) = **54 mm**

- Benodigd op druksterkte: **43 mm**
- Benodigd op knik: **54 mm**
- Maatgevend: bnodig = max(43, 54) = **54 mm → 60 × 60 mm gewapend betonkolom**

Controle met 60 × 60 mm:

- Eigen gewicht kolom: Gk,kolom = 0,06 × 0,06 × 1,30 × 25 = **0,12 kN**
- Totale permanente belasting: ΣGk = 13,65 + 0,12 = **13,77 kN**
- UGT kolombelasting: Fc,d = 1,2 × 13,77 + 1,5 × 3,00 + 1,5 × 2,10 = **24,2 kN**
- Kolomdoorsnede: A = 60 × 60 = **3.600 mm²**
- Drukspanning: σc,d = Fc,d / A = 24,2 × 10³ / 3.600 = **6,72 N/mm²**
- Unity Check UGT druksterkte: U.C. = σc,d / fcd = 6,72 / 13,3 = **0,51 < 1,0 → voldoet**
- Kwadratisch oppervlaktmoment vierkante doorsnede: I = b⁴ / 12 = 60⁴ / 12 = **1.080.000 mm⁴**
- Kritische knikkracht: Fcr = π² × E × I / lcr² = π² × 30.000 × 1.080.000 / 1300² = 189.200 N = **189,2 kN**
- Knikgetal: n = Fcr / Fc,d = 189,2 / 24,2 = **7,8**
- Toetsing knikgetal: **7,8 ≥ 5 → voldoet**
- Unity Check knik: U.C. = 5 × Fc,d / Fcr = 5 × 24,2 / 189,2 = **0,64 < 1,0 → voldoet**

Conclusie: hoewel een 60x60 mm gewapend betonkolom voldoet, is deze maat niet realistisch en onpraktisch als gewapende betonkolom, aangezien kolommen standaard verkrijgbaar zijn vanaf 200x200 mm.



200 x 200 mm gewapend beton

Berekening globale dimensionering betonkolom onder toegankelijk groen dak, L = 6,0 m + 2 × 1,5 m uitkraging

- Kolomtype: **vierkante gewapende betonkolom**
- Kolomhoogte maximaal: hkolom = **3500 mm** (geeft kniklengte: lcr = **3500mm**)
- H.o.h. kolommen: s = **2,4 m**
- Overspanning dakplaat: L = **6,0m**
- Uitkraging: a = **1,5m** aan beide zijden
- Dragend oppervlak per kolom: Aroof = $(L/2 + a) \times s = (6,0/2 + 1,5) \times 2,4 = \mathbf{10,80\ m^2}$
- Dakplaat: 150 mm gewapend beton (2500 kg/m³ ≈ 25 kN/m³) + Bee Pasture verzadigd: 1,55 kN/m²
- Betonsterkte C20/25: fm,d = **20 N/mm²**
- Dakbelasting wel toegankelijk → Categorie C3: **5,0 kN/m²**
- Sneeuw NL: **sk = 0,7 kN/m²**
- Gevolgklasse CC2: γG = **1,2**, γQ = **1,5**
- Rekenwaarde druksterkte beton: fcd = fck / γC = 20 / 1,5 = **13,3 N/mm²**
- Elasticiteitsmodulus beton C20/25: Ecm = **30.000 N/mm²**
- Vuistregel betonkolom: b = hkolom / 10 = 3500 / 10 = **350 mm**

350x350 gewapend beton:

- Eigen gewicht dakplaat: $0,15 \times 25 = \mathbf{3,75\ kN/m^2}$
- Permanente dakbelasting: Gk,dak = 3,75 + 1,55 = **5,30 kN/m²**
- Permanente dakbelasting op kolom: Gk,dak,kolom = 5,30 × 10,80 = **57,24 kN**
- Eigen gewicht kolom: Gk,kolom = 0,35 × 0,35 × 3,50 × 25 = **10,72 kN**
- Totale permanente belasting: ΣGk = 57,24 + 10,72 = **67,96 kN**
- Veranderlijke dakbelasting op kolom: Qk = 5,0 × 10,80 = **54,00 kN**
- Sneeuwbelasting op kolom: Sk = 0,7 × 10,80 = **7,56 kN**

- UGT kolombelasting: Fc,d = 1,2 × 67,96 + 1,5 × 54,00 + 1,5 × 7,56 = **173,9 kN**
- Kolomdoorsnede: A = b × b = 350 × 350 = **122.500 mm²**
- Drukspanning: σc,d = Fc,d / A = 173,9 × 10³ / 122.500 = **1,42 N/mm²**
- Unity Check UGT druksterkte: U.C. = σc,d / fcd = 1,42 / 13,3 = **0,11 < 1,0 → voldoet ruim**
- Benodigde doorsnede druksterkte: Anodig = U.C. × Aoud = 0,11 × 122.500 = **13.475 mm²**
- Bij vierkante doorsnede: bnodig,druk = √Anodig = √13.475 = **116 mm**

- Kwadratisch oppervlaktmoment vierkante doorsnede: I = b⁴ / 12 = 350⁴ / 12 = **1.250.520.833 mm⁴**
- Kritische knikkracht: Fcr = π² × E × I / lcr² = π² × 30.000 × 1.250.520.833 / 3500² = 30.226.000 N = **30.226 kN**
- Knikgetal: n = Fcr / Fc,d = 30.226 / 173,9 = **174**
- Toetsing knikgetal: n ≥ 5 geeft **174 ≥ 5 → voldoet ruim**
- Unity Check knik: U.C. = 5 × Fc,d / Fcr = 5 × 173,9 / 30.226 = **0,03 < 1,0 → voldoet ruim**
- Benodigd traagheidsmoment knik: Inodig = U.C. × Ioud = 0,03 × 1.250.520.833 = **37.515.625 mm⁴**
- Bij vierkante doorsnede: I = b⁴ / 12 → bnodig,knik = ⁴√(12 × Inodig) = ⁴√(12 × 37.515.625) = **146 mm**

- Benodigd op druksterkte: **116 mm**
- Benodigd op knik: **146 mm**
- Maatgevend: bnodig = max(116, 146) = **146 mm → 150 × 150 mm gewapend betonkolom**

Controle met 150 × 150 mm:

- Eigen gewicht kolom: Gk,kolom = 0,15 × 0,15 × 3,50 × 25 = **1,97 kN**
- Totale permanente belasting: ΣGk = 57,24 + 1,97 = **59,21 kN**
- UGT kolombelasting: Fc,d = 1,2 × 59,21 + 1,5 × 54,00 + 1,5 × 7,56 = **163,4 kN**
- Kolomdoorsnede: A = 150 × 150 = **22.500 mm²**
- Drukspanning: σc,d = Fc,d / A = 163,4 × 10³ / 22.500 = **7,26 N/mm²**
- Unity Check UGT druksterkte: U.C. = σc,d / fcd = 7,26 / 13,3 = **0,55 < 1,0 → voldoet**
- Kwadratisch oppervlaktmoment vierkante doorsnede: I = b⁴ / 12 = 150⁴ / 12 = **42.187.500 mm⁴**
- Kritische knikkracht: Fcr = π² × E × I / lcr² = π² × 30.000 × 42.187.500 / 3500² = 1.019.700 N = **1.019,7 kN**
- Knikgetal: n = Fcr / Fc,d = 1.019,7 / 163,4 = **6,2**
- Toetsing knikgetal: **6,2 ≥ 5 → voldoet**
- Unity Check knik: U.C. = 5 × Fc,d / Fcr = 5 × 163,4 / 1.019,7 = **0,80 < 1,0 → voldoet**

hoewel een 150x150 mm gewapend betonkolom voldoet, is deze maat niet realistisch en onpraktisch als gewapende betonkolom, aangezien kolommen standaard verkrijgbaar zijn vanaf 200x200 mm.



200 x 200 mm gewapend beton

CONSTRUCTION

CALCULATIONS - STEEL COLUMNS

Berekening Kolommen (Staal)

Berekening globale dimensionering betonkolom onder niet-toegankelijk groen dak, L = 3,0 m:

- Kolomtype: **vierkante stalen kokerkolom**
- Kolomhoogte: hkolom = **1300 mm** (geeft kniklengte: lcr = **1300mm**)
- H.o.h. kolommen: s = **2,0 m**
- Overspanning dakplaat: L = **3,0m**
- Dragend oppervlak per kolom: Aroof = $L/2 \times s = 3,0/2 \times 2,0 = \mathbf{3,00\ m^2}$
- Dakplaat: 120 mm gewapend beton ($2500\ \text{kg/m}^3 \approx 25\ \text{kN/m}^3$) + Bee Pasture verzadigd: **1,55 kN/m²**
- Staalkwaliteit: **S235**
- Rekenwaarde vloeigrens S235: fy,d = **235 N/mm²**
- Elasticiteitsmodulus staal: **E = 210.000 N/mm²**
- Volumieke massa staal: $\rho = 7850\ \text{kg/m}^3 \approx \mathbf{78,5\ \text{kN/m}^3}$
- Dakbelasting klasse H, niet toegankelijk, 0–15°: **1,0 kN/m²**
- Sneeuw NL: **sk = 0,7 kN/m²**
- Gevolgklasse CC2: $\gamma_G = \mathbf{1,2}$, $\gamma_Q = \mathbf{1,5}$

- Vuistregel stalen kolom: $b = h_{\text{kolom}} / 25 = 1300 / 25 = \mathbf{52\ mm}$
- Geschat profiel: **SHS 60 × 60 × 4 mm**

SHS 60 × 60 × 4 mm:

- Buitenmaat: b = **60 mm**
- Wanddikte: t = **4 mm**
- Binnenmaat: bi = $b - 2t = 60 - 2 \times 4 = \mathbf{52\ mm}$
- Doorsnede: $A = b^2 - bi^2 = 60^2 - 52^2 = \mathbf{896\ mm^2}$
- Kwadratisch oppervlaktemoment: $I = (b^4 - bi^4) / 12 = (60^4 - 52^4) / 12 = \mathbf{470.699\ mm^4}$

- Eigen gewicht dakplaat: $0,12 \times 25 = \mathbf{3,00\ kN/m^2}$
- Permanente dakbelasting: $G_{k,dak} = 3,00 + 1,55 = \mathbf{4,55\ kN/m^2}$
- Permanente dakbelasting op kolom: $G_{k,dak,kolom} = 4,55 \times 3,00 = 13,65\ \text{kN}$
- Eigen gewicht kolom: $G_{k,kolom} = 0,000896 \times 1,30 \times 78,5 = \mathbf{0,09\ kN}$
- Totale permanente belasting: $\Sigma G_k = 13,65 + 0,09 = \mathbf{13,74\ kN}$
- Veranderlijke dakbelasting op kolom: $Q_k = 1,0 \times 3,00 = \mathbf{3,00\ kN}$
- Sneeuwbelasting op kolom: $S_k = 0,7 \times 3,00 = \mathbf{2,10\ kN}$

- UGT kolombelasting: $F_{c,d} = 1,2 \times 13,74 + 1,5 \times 3,00 + 1,5 \times 2,10 = \mathbf{24,1\ kN}$
- Drukspanning: $\sigma_{c,d} = F_{c,d} / A = 24,1 \times 10^3 / 896 = \mathbf{26,9\ N/mm^2}$
- Unity Check UGT druksterkte: $U.C. = \sigma_{c,d} / f_{y,d} = 26,9 / 235 = \mathbf{0,11 < 1,0} \rightarrow \mathbf{voldoet\ ruim}$

- Kritische knikkracht: $F_{cr} = \pi^2 \times E \times I / l_{cr}^2 = \pi^2 \times 210.000 \times 470.699 / 1300^2 = 577.300\ \text{N} = \mathbf{577,3\ kN}$
- Knikgetal: $n = F_{cr} / F_{c,d} = 577,3 / 24,1 = \mathbf{23,9}$
- Toetsing knikgetal: $n \geq 5$ geeft **23,9 ≥ 5 → voldoet ruim**
- Unity Check knik: $U.C. = 5 \times F_{c,d} / F_{cr} = 5 \times 24,1 / 577,3 = \mathbf{0,21 < 1,0} \rightarrow \mathbf{voldoet\ ruim}$

- Benodigde doorsnede druksterkte: $A_{\text{nodig}} = U.C. \times A_{\text{oud}} = 0,11 \times 896 = \mathbf{99\ mm^2}$
- Benodigd traagheidsmoment knik: $I_{\text{nodig}} = U.C. \times I_{\text{oud}} = 0,21 \times 470.699 = \mathbf{98.847\ mm^4}$

- Maatgevend: **knik**
- Profiel met minimaal Inodig: **SHS 40 × 40 × 3 mm**

Controle met SHS 40 × 40 × 3 mm:

- Buitenmaat: b = **40 mm**
- Wanddikte: t = **3 mm**
- Binnenmaat: bi = $40 - 2 \times 3 = \mathbf{34\ mm}$
- Doorsnede: $A = 40^2 - 34^2 = \mathbf{444\ mm^2}$
- Kwadratisch oppervlaktemoment: $I = (40^4 - 34^4) / 12 = \mathbf{101.972\ mm^4}$
- Eigen gewicht kolom: $G_{k,kolom} = 0,000444 \times 1,30 \times 78,5 = \mathbf{0,05\ kN}$
- Totale permanente belasting: $\Sigma G_k = 13,65 + 0,05 = \mathbf{13,70\ kN}$
- UGT kolombelasting: $F_{c,d} = 1,2 \times 13,70 + 1,5 \times 3,00 + 1,5 \times 2,10 = \mathbf{24,1\ kN}$
- Drukspanning: $\sigma_{c,d} = F_{c,d} / A = 24,1 \times 10^3 / 444 = \mathbf{54,2\ N/mm^2}$
- Unity Check UGT druksterkte: $U.C. = 54,2 / 235 = \mathbf{0,23 < 1,0} \rightarrow \mathbf{voldoet}$
- Kritische knikkracht: $F_{cr} = \pi^2 \times 210.000 \times 101.972 / 1300^2 = 125.100\ \text{N} = \mathbf{125,1\ kN}$
- Knikgetal: $n = F_{cr} / F_{c,d} = 125,1 / 24,1 = \mathbf{5,2}$
- Toetsing knikgetal: $n \geq 5$ geeft **5,2 ≥ 5 → voldoet**
- Unity Check knik: $U.C. = 5 \times F_{c,d} / F_{cr} = 5 \times 24,1 / 125,1 = \mathbf{0,96 < 1,0} \rightarrow \mathbf{voldoet\ net}$

Conclusie: SHS 40 × 40 × 3 mm voldoet volgens de globale Vademecum-berekening, maar zit op knik net onder de grens. SHS 60 × 60 × 4 mm is logischer als ontwerpmaat.

SHS 60 x 60 x 4 mm

Berekening globale dimensionering stalen kolom onder toegankelijk groen dak, L = 6,0 m + 2 × 1,5 m uitkraging:

- Kolomtype: **vierkante stalen kokerkolom**
- Kolomhoogte maximaal: hkolom = **3500 mm** (geeft kniklengte: lcr = **3500mm**)
- H.o.h. kolommen: s = **2,4 m**
- Overspanning dakplaat: L = **6,0m**
- Uitkraging: a = **1,5m** aan beide zijden
- Dragend oppervlak per kolom: Aroof = $(L/2 + a) \times s = (6,0/2 + 1,5) \times 2,4 = \mathbf{10,80\ m^2}$
- Dakplaat: 150 mm gewapend beton ($25\ \text{kN/m}^3$) + Bee Pasture verzadigd: **1,55 kN/m²**
- Staalkwaliteit: **S235**
- Rekenwaarde vloeigrens S235: fy,d = **235 N/mm²**
- Elasticiteitsmodulus staal: **E = 210.000 N/mm²**
- Volumieke massa staal: $\rho = 7850\ \text{kg/m}^3 \approx \mathbf{78,5\ kN/m^3}$
- Dakbelasting wel toegankelijk → Categorie C3: **5,0 kN/m²**
- Sneeuw NL: **sk = 0,7 kN/m²**
- Gevolgklasse CC2: $\gamma_G = \mathbf{1,2}$, $\gamma_Q = \mathbf{1,5}$

- Vuistregel stalen kolom: $b = h_{\text{kolom}} / 25 = 3500 / 25 = \mathbf{140\ mm}$
- Geschat profiel: **SHS 150 × 150 × 5 mm**

SHS 150 × 150 × 5 mm:

- Buitenmaat: b = **150 mm**
- Wanddikte: t = **5 mm**
- Binnenmaat: bi = $b - 2t = 150 - 2 \times 5 = \mathbf{140\ mm}$
- Doorsnede: $A = b^2 - bi^2 = 150^2 - 140^2 = \mathbf{2.900\ mm^2}$
- Kwadratisch oppervlaktemoment: $I = (b^4 - bi^4) / 12 = (150^4 - 140^4) / 12 = \mathbf{10.174.167\ mm^4}$

- Eigen gewicht dakplaat: $0,15 \times 25 = \mathbf{3,75\ kN/m^2}$
- Permanente dakbelasting: $G_{k,dak} = 3,75 + 1,55 = \mathbf{5,30\ kN/m^2}$
- Permanente dakbelasting op kolom: $G_{k,dak,kolom} = 5,30 \times 10,80 = \mathbf{57,24\ kN}$
- Eigen gewicht kolom: $G_{k,kolom} = 0,002900 \times 3,50 \times 78,5 = \mathbf{0,80\ kN}$
- Totale permanente belasting: $\Sigma G_k = 57,24 + 0,80 = \mathbf{58,04\ kN}$
- Veranderlijke dakbelasting op kolom: $Q_k = 5,0 \times 10,80 = \mathbf{54,00\ kN}$
- Sneeuwbelasting op kolom: $S_k = 0,7 \times 10,80 = \mathbf{7,56\ kN}$

- UGT kolombelasting: $F_{c,d} = 1,2 \times 58,04 + 1,5 \times 54,00 + 1,5 \times 7,56 = \mathbf{162,0\ kN}$
- Drukspanning: $\sigma_{c,d} = F_{c,d} / A = 162,0 \times 10^3 / 2.900 = \mathbf{55,9\ N/mm^2}$
- Unity Check UGT druksterkte: $U.C. = \sigma_{c,d} / f_{y,d} = 55,9 / 235 = \mathbf{0,24 < 1,0} \rightarrow \mathbf{voldoet\ ruim}$

- Kritische knikkracht: $F_{cr} = \pi^2 \times E \times I / l_{cr}^2 = \pi^2 \times 210.000 \times 10.174.167 / 3500^2 = 1.721.400\ \text{N} = \mathbf{1.721,4\ kN}$
- Knikgetal: $n = F_{cr} / F_{c,d} = 1.721,4 / 162,0 = \mathbf{10,6}$
- Toetsing knikgetal: $n \geq 5$ geeft **10,6 ≥ 5 → voldoet**
- Unity Check knik: $U.C. = 5 \times F_{c,d} / F_{cr} = 5 \times 162,0 / 1.721,4 = \mathbf{0,47 < 1,0} \rightarrow \mathbf{voldoet}$

- Benodigde doorsnede druksterkte: $A_{\text{nodig}} = U.C. \times A_{\text{oud}} = 0,24 \times 2.900 = \mathbf{696\ mm^2}$
- Benodigd traagheidsmoment knik: $I_{\text{nodig}} = U.C. \times I_{\text{oud}} = 0,47 \times 10.174.167 = \mathbf{4.781.858\ mm^4}$

- Maatgevend: **knik**
- Profiel met minimaal Inodig: **SHS 120 × 120 × 5 mm**

Controle met SHS 120 × 120 × 5 mm:

- Buitenmaat: b = **120 mm**
- Wanddikte: t = **5 mm**
- Binnenmaat: bi = $120 - 2 \times 5 = \mathbf{110\ mm}$
- Doorsnede: $A = 120^2 - 110^2 = \mathbf{2.300\ mm^2}$
- Kwadratisch oppervlaktemoment: $I = (120^4 - 110^4) / 12 = \mathbf{5.079.167\ mm^4}$
- Eigen gewicht kolom: $G_{k,kolom} = 0,002300 \times 3,50 \times 78,5 = \mathbf{0,63\ kN}$
- Totale permanente belasting: $\Sigma G_k = 57,24 + 0,63 = \mathbf{57,87\ kN}$
- UGT kolombelasting: $F_{c,d} = 1,2 \times 57,87 + 1,5 \times 54,00 + 1,5 \times 7,56 = \mathbf{161,8\ kN}$
- Drukspanning: $\sigma_{c,d} = F_{c,d} / A = 161,8 \times 10^3 / 2.300 = \mathbf{70,3\ N/mm^2}$

- Unity Check UGT druksterkte: $U.C. = 70,3 / 235 = \mathbf{0,30 < 1,0} \rightarrow \mathbf{voldoet}$
- Kritische knikkracht: $F_{cr} = \pi^2 \times 210.000 \times 5.079.167 / 3500^2 = \mathbf{859.400\ N} = \mathbf{859,4\ kN}$
- Knikgetal: $n = F_{cr} / F_{c,d} = 859,4 / 161,8 = \mathbf{5,3}$
- Toetsing knikgetal: $n \geq 5$ geeft **5,3 ≥ 5 → voldoet**
- Unity Check knik: $U.C. = 5 \times F_{c,d} / F_{cr} = 5 \times 161,8 / 859,4 = \mathbf{0,94 < 1,0} \rightarrow \mathbf{voldoet\ net}$

Conclusie: SHS 120 × 120 × 5 mm voldoet volgens de globale Vademecum-berekening, maar zit op knik vrij dicht bij de grens. SHS 150 × 150 × 5 mm is logischer als ontwerpmaat.

SHS 150 x 150 x 5 mm

CONSTRUCTION

CALCULATIONS - STEEL BEAM

Berekening Ligger (Staal)

Berekening globale dimensionering stalen ligger onder toegankelijk groen dak, L = 6,0 m + 2 × 1,5 m uitkraging:

- Liggertype: **stalen I-profiel, ligger onder betonnen dakplaat**
- Steunafstand: L = **6,0m**
- Uitkraging: a = **1,5m** aan beide zijden
- Totale liggerlengte: 1,5 + 6,0 + 1,5 = **9,0m**
- H.o.h. liggers / kolommen: s = **2,4m**
- Dakplaat: 150 mm gewapend beton (25 kN/m³) + Bee Pasture verzadigd: **1,55 kN/m²**
- Staalkwaliteit: **S235**
- Rekenwaarde vloeigrens S235: fy,d = **235 N/mm²**
- Elasticiteitsmodulus staal: E = **210.000 N/mm²**
- Volumieke massa staal: ρ = 7850 kg/m³ ≈ **78,5 kN/m³**
- Dakbelasting wel toegankelijk → Categorie C3: **5,0 kN/m²**
- Sneeuw NL: sk = **0,7 kN/m²**
- Gevolgklasse CC2: γG = **1,2**, γQ = **1,5**

- Vuistregel stalen hoofdligger: h = l/20 à l/30 = 9000/20 à 9000/30 = **450 à 300 mm**
- Geschat profiel: **IPE 300**

IPE 300:

- Profielhoogte: h = **300 mm**
- Profielbreedte: b = **150 mm**
- Lijfdikte: tw = **7,1 mm**
- Flensdikte: tf = **10,7 mm**
- Doorsnede: A = **5.381 mm²**
- Kwadratisch oppervlaktemoment: I = **83.560.000 mm⁴**
- Weerstandsmoment: W = **557.000 mm³**
- Eigen gewicht ligger: gk,ligger = 42,2 kg/m = **0,331 kN/m**

- Eigen gewicht dakplaat: 0,15 × 25 = **3,75 kN/m²**
- Permanente dakbelasting: Gk,dak = 3,75 + 1,55 = **5,30 kN/m²**
- Permanente dakbelasting op ligger: Gk,dak,ligger = 5,30 × 2,4 = **12,72 kN/m**
- Totale permanente lijnbelasting: Gk = 12,72 + 0,331 = **13,05 kN/m**
- Veranderlijke dakbelasting op ligger: Qk = 5,0 × 2,4 = **12,00 kN/m**
- Sneeuwbelasting op ligger: Sk = 0,7 × 2,4 = **1,68 kN/m**

- UGT lijnbelasting: qd = 1,2 × 13,05 + 1,5 × 12,00 + 1,5 × 1,68 = **36,18 kN/m**
- Steunmoment door uitkraging: MEd,steun = qd × a² / 2 = 36,18 × 1,5² / 2 = **40,7 kNm**
- Veldmoment in L = 6,0m: MEd,veld = qd × (L²/8 – a²/2) = 36,18 × (6,0²/8 – 1,5²/2) = **122,1 kNm**
- Totale belasting op ligger: qd × 9,0 = 36,18 × 9,0 = **325,6 kN**
- Reactie per steunpunt: R = 325,6 / 2 = **162,8 kN**
- Dwarskracht direct naast steunpunt: VEd = R – qd × 1,5 = 162,8 – 36,18 × 1,5 = **108,5 kN**
- UGT buigspanning veld: σm,d = MEd,veld / W = 122,1 × 10⁶ / 557.000 = **219,2 N/mm²**
- Unity Check UGT veldmoment: U.C. = σm,d / fy,d = 219,2 / 235 = **0,93 < 1,0 → voldoet**

- Benodigd weerstandsmoment: Wnodig = U.C. × Woud = 0,93 × 557.000 = **518.000 mm³**
- Profiel met minimaal Wnodig: **IPE 300**

- Controle dwarskracht:
- Av ≈ (h – 2tf) × tw = (300 – 2 × 10,7) × 7,1 = **1.978 mm²**
- τd = VEd / Av = 108,5 × 10³ / 1.978 = **54,9 N/mm²**
- τRd = fy,d / √3 = 235 / √3 = **135,7 N/mm²**
- Unity Check UGT dwarskracht: U.C. = τd / τRd = 54,9 / 135,7 = **0,40 < 1,0 → voldoet**

- BGT lijnbelasting:
- q = Gk + Qk + Sk = 13,05 + 12,00 + 1,68 = **26,73 kN/m**
- Doorbuiging: w = q / EI × (5L⁴/384 – a²L²/16) = 26,73 / (210.000 × 83.560.000) × ((5 × 6000⁴ / 384) – (1500² × 6000² / 16)) = **18,0 mm**
- Toetsing: w ≤ 0,004L geeft wmax = 0,004 × 6000 = **24 mm**
- Unity Check BGT doorbuiging: U.C. = w / wmax = 18,0 / 24 = **0,75 < 1,0 → voldoet**

Conclusie: **IPE 300 voldoet volgens de globale Vademecum-berekening.**

CONSTRUCTION

CURTAIN WALL SYSTEM

