

F o r m F o l l o w s F i n d

F r o m b r i d g e t o b u i l d i n g



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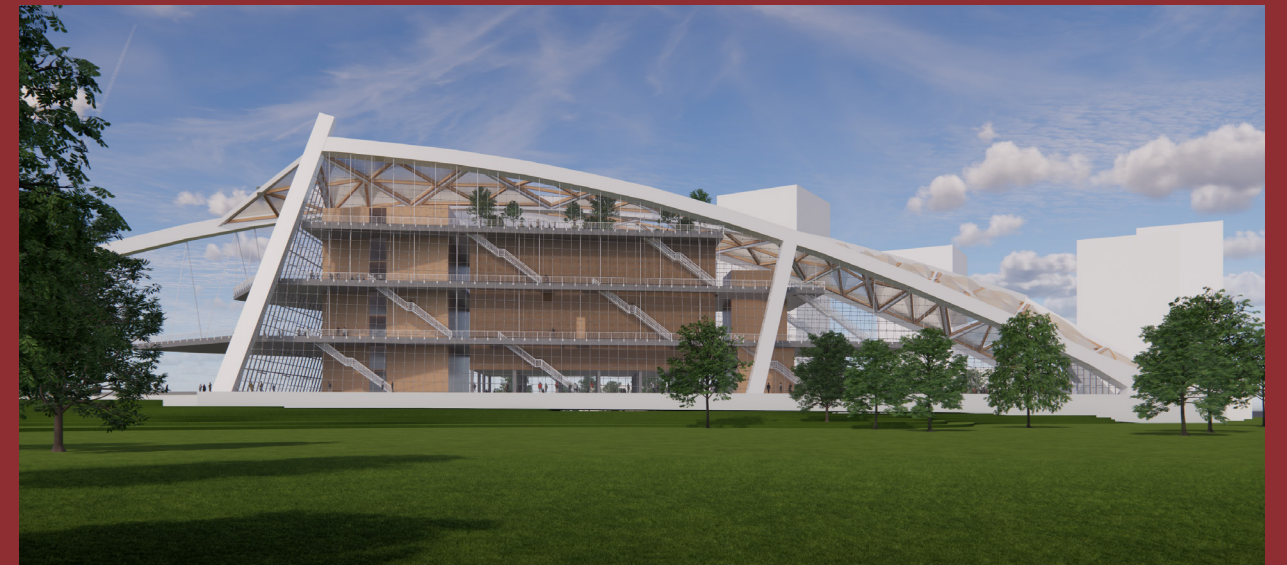
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A b s t r a c t

This master's thesis researches how industrial steel reuse from bridges can be reframed as an architectural driver rather than a technical constraint. Thereby, responding to the construction industry's high CO₂ emissions, the study develops a reuse-driven design framework: Form follows Find, integrating material availability, structural logic, and cultural value. The methodology research-by-design is used to combine mapping, prototyping, and case study analysis across regional, building, and human scales. The framework uses a test case, a cultural centre in Eindhoven's De Kade area, to investigate general design principles that present how industrial donor steel can enable circular and socially accepted architectural projects.



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Part .

Introduction

Part 1. Introduction

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1.1 Problem statement

The construction industry has a central role in the transition towards Net Zero and needs to shift from a linear to a circular economy (Figure 1), while it is responsible for 11% of global CO₂ emissions and 36% of the European Union’s energy consumption (Karakosta, C. et al, 2025).

The circular economy framework (CE) aims to maximise the value of materials and products and minimise waste streams throughout their life cycle. These circular design strategies serve as a guide towards achieving Net Zero Ambitions; the gR framework provides a structured hierarchy of these strategies, including recycling and reuse (Kirchherr et al., 2017).

Within this transition, steel is especially relevant. Steel is one of the most widely used construction materials, and building and infrastructure account for more than half of global steel use. At the same time, the production of new steel remains highly energy- and carbon-intensive.

Although steel is often described as circular because it can be recycled, recycling still requires substantial energy input and industrial reprocessing. Reuse performs significantly better because it preserves the material’s embedded energy and carbon, reducing 97% CO₂ in comparison to newly produced steel (Table 1) (World Steel Association, 2025; Alaux et al., 2024).

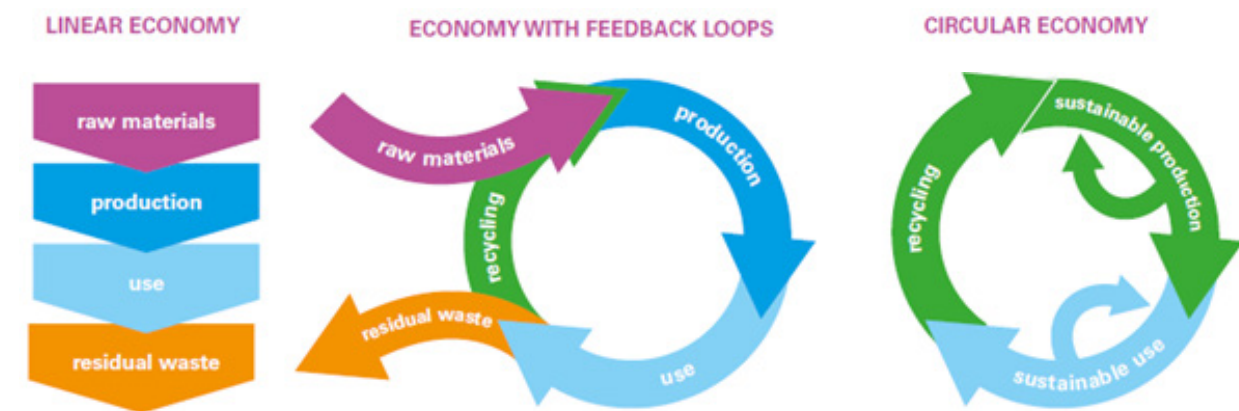


Figure 1: ‘Linear economy’, ‘Economy with feedback loops’ and ‘Circular economy’ (van Buren et al, 2016)

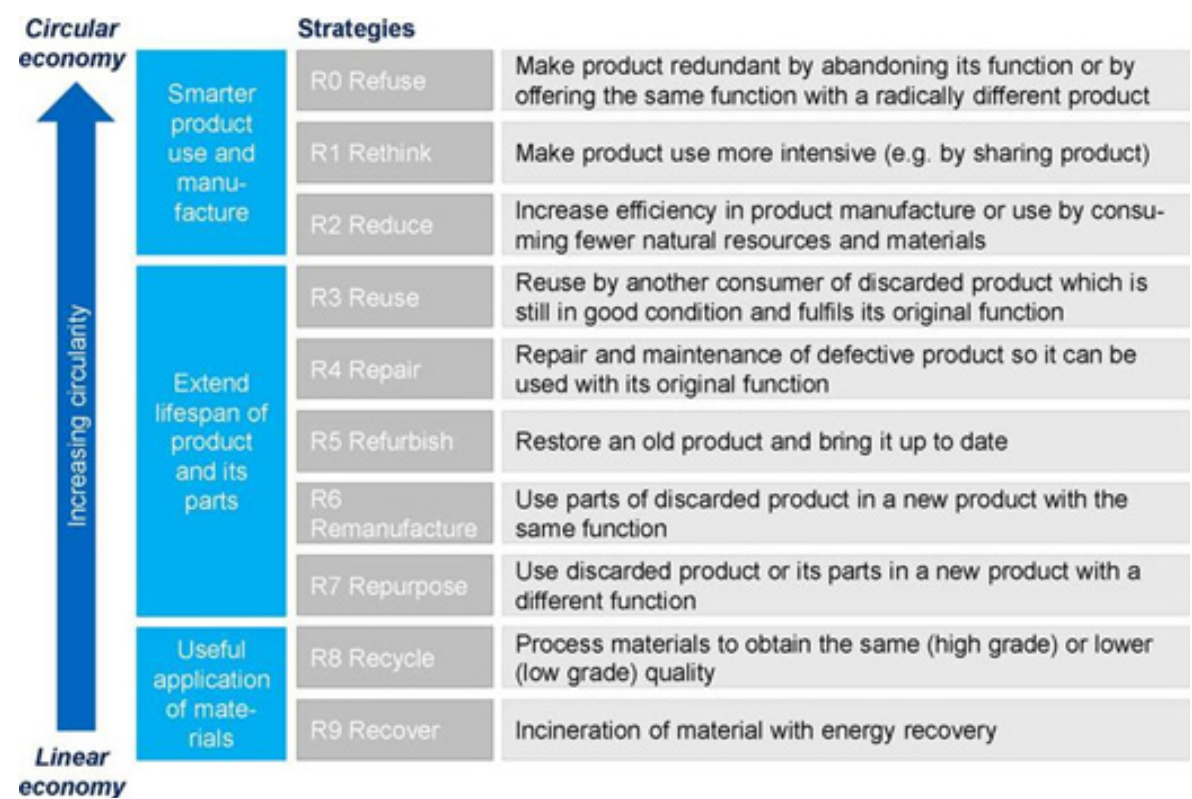


Figure 2: The circular economy framework, with the 9Rs (Kirchherr, J. et al, 2017).

Production route	CO ₂ -emission per ton of steel
Steel scrap in an electrical oven (EAF) with grey electricity	500-750 kg CO ₂ /ton steel
Steel scrap in an electrical oven (EAF) with green electricity	350-400 kg CO ₂ /ton steel
Reused steel; donor steel	100 kg CO ₂ /ton steel

Table 1: CO₂ emissions of recycled steel and reused steel (based on Commissie Verduurzaming Bouwketen Staal, 2025).

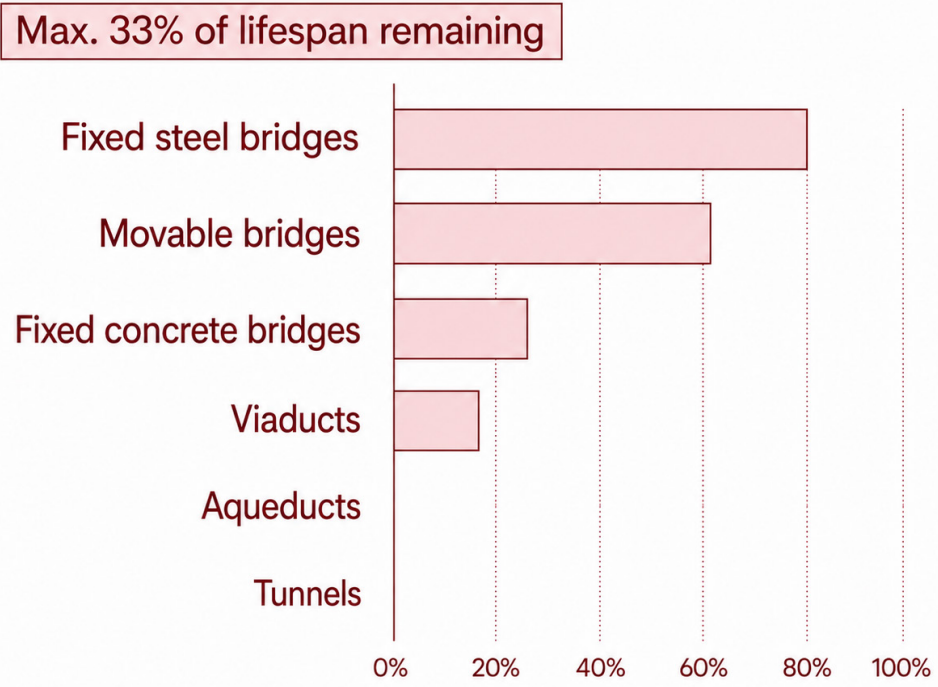
This issue becomes particularly urgent in the Dutch context, where many bridges and other civil assets are approaching the end of their technical service life. TNO identifies this replacement-and-renewal task as a major national challenge. A concrete and timely example is the Van Brienenoordbrug Oostboog in Rotterdam. Rijkswaterstaat’s current planning indicates that the renewal of the Van Brienenoordbrug is being carried out in phases, with the Oostboog scheduled for removal and replacement in 2032/2033. (TNO, 2021; Rijkswaterstaat, 2024).

At the same time, the Nationale Bruggenbank lists the Van Brienenoordbrug as a reusable steel superstructure and promotes bridge reuse as an alternative to demolition to support circular and climate goals. Making the bridge relevant as a case study because it is both current and lacks a defined architectural reuse destination (Nationale Bruggenbank, n.d.).

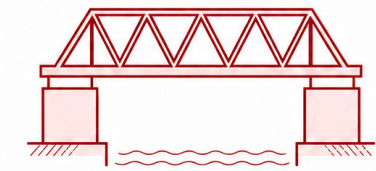
However, direct bridge-to-bridge reuse is often difficult. Steel bridges are subjected to repeated traffic-induced and cyclic loading, which can cause fatigue damage over time. Fatigue is therefore a key issue in assessing whether existing bridge components remain suitable for continued use in another dynamically loaded infrastructure application. Buildings, by contrast, are generally governed by self-weight and imposed loads associated with occupancy and use. This creates a specific architectural opportunity: steel elements from end-of-life bridges may be less suitable for renewed bridge use, yet still offer considerable structural, spatial, and architectural potential in a building context (Yu et al., 2021; CEN, 2002).

Therefore, this thesis addresses two issues. First, the construction sector urgently needs circular, high-impact carbon-saving strategies, especially for materials such as steel. Second, although bridges such as the Van Brienenoordbrug Oostbrug are becoming available as donor structures, their potential for architectural reuse remains largely untapped. Exploring the gap by investigating how a bridge’s steel structure can be translated into a meaningful building.

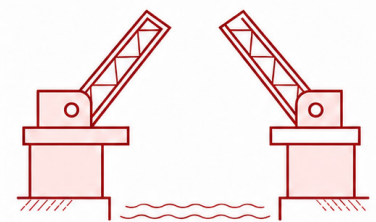
Large share of bridges and locks in need of maintenance



STEEL BRIDGES TO BE REPLACED



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1.2 Relevance

The relevance of this thesis is the intersection of circular construction, infrastructure renewal, and architectural transformation. In the Netherlands, an increasing number of bridges are being renewed or replaced, and the question of how to retain their structural value is becoming more urgent. Reuse offers an alternative to demolition, aligning with broader ambitions for resource-efficient and climate-conscious construction (TNO, 2021; Nationale Bruggenbank, n.d.).

Additionally, this research reframes reuse as an architectural design question rather than solely as a technical or environmental one. Much of the current discourse on reclaimed steel focuses on environmental performance, certification, availability, and regulation, while fewer studies address how existing infrastructural structures can become meaningful architecture. By using the Van Brienenoordbrug Oostboog as a live case, this thesis connects broader circular ambitions to a concrete and current Dutch bridge-renewal situation (Tingley et al., 2017).

Furthermore, the structural distinction between bridges and buildings makes this thesis feasible. Bridge elements are often limited by fatigue-related concerns under repeated dynamic loading; a building programme may offer a more suitable context for selected components and structural principles. This makes the bridge-to-building transformation a promising strategy for extending the life of ageing steel infrastructure in a technically realistic and architecturally productive way (Yu et al., 2021).

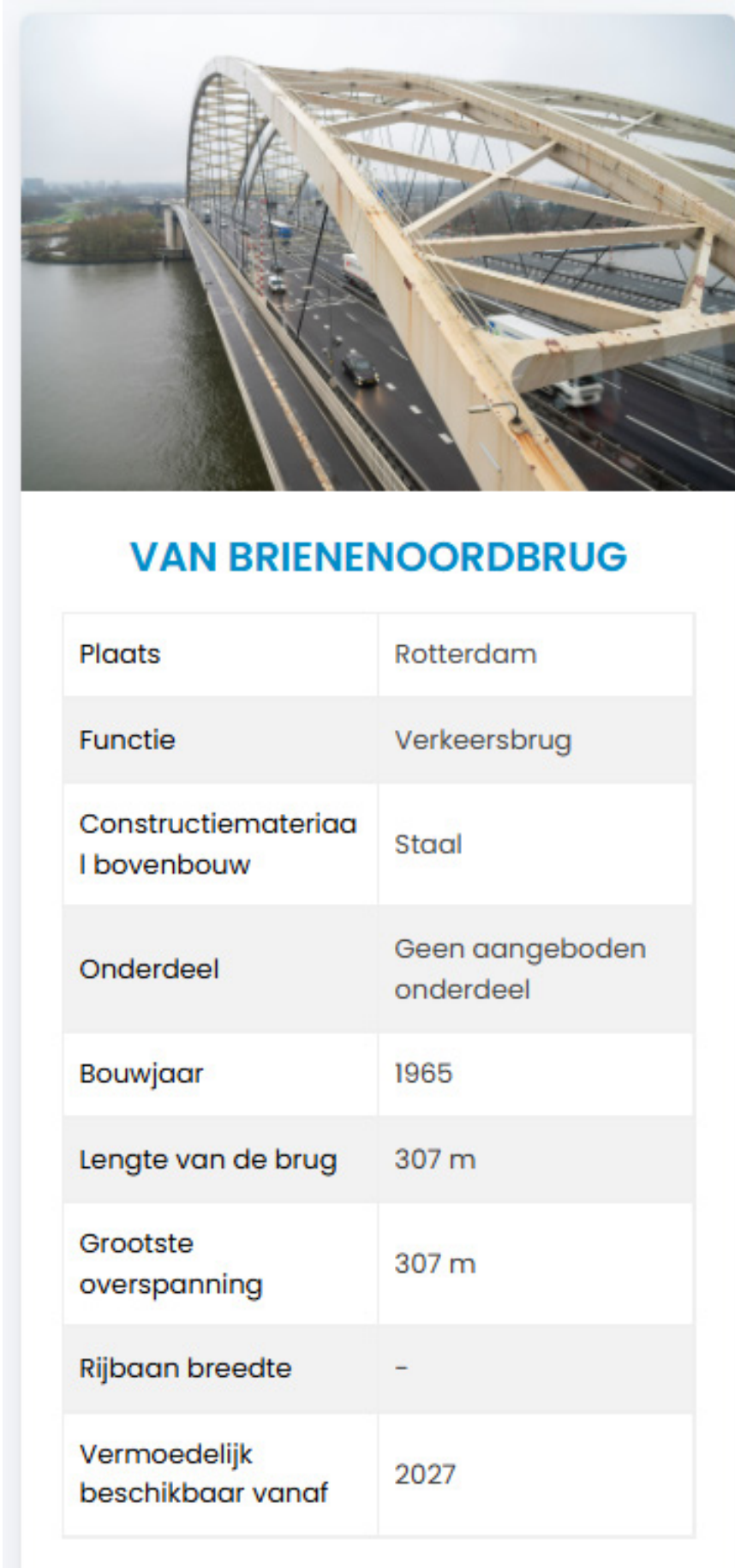


Figure 3: Van Brienenoord bridge East information on the Nationale Bruggenbank (Nationale bruggenbank, n.d.)

1.3 Objective & Motivation

The objective of this thesis is to investigate how the steel structure of an existing bridge can be translated into a new architectural building, resulting in a meaningful and buildable cultural centre on De Kade in Eindhoven. Rather than approaching the bridge merely as a source of reusable material, this thesis positions it as a spatial, structural, and architectural starting point for design. The project, therefore, explores how a bridge can become a building.

This research aims to develop an architectural framework that integrates structural logic, spatial organisation, and contextual integration through design. The bridge is studied not only in terms of its material components but also as a system of spans, hierarchies, rhythms, and connections that can inform a new architectural proposal. In this way, the thesis investigates through one specific case study: the Van Brienenoordbrug Oostboog in Rotterdam, how the transformation from infrastructure to architecture can produce a public building that is technically feasible and has architectural meaning.

The motivation for this research lies in the growing urgency of circular construction and in the architectural potential of ageing steel infrastructure. Bridges are often understood as highly efficient infrastructural objects, yet they also contain strong formal, structural, and cultural qualities. This thesis explores whether those qualities can be translated into architecture, and more specifically into a public cultural building. By doing so, the project contributes to broader discussions on circular construction, adaptive reuse, and the design potential of existing steel structures.

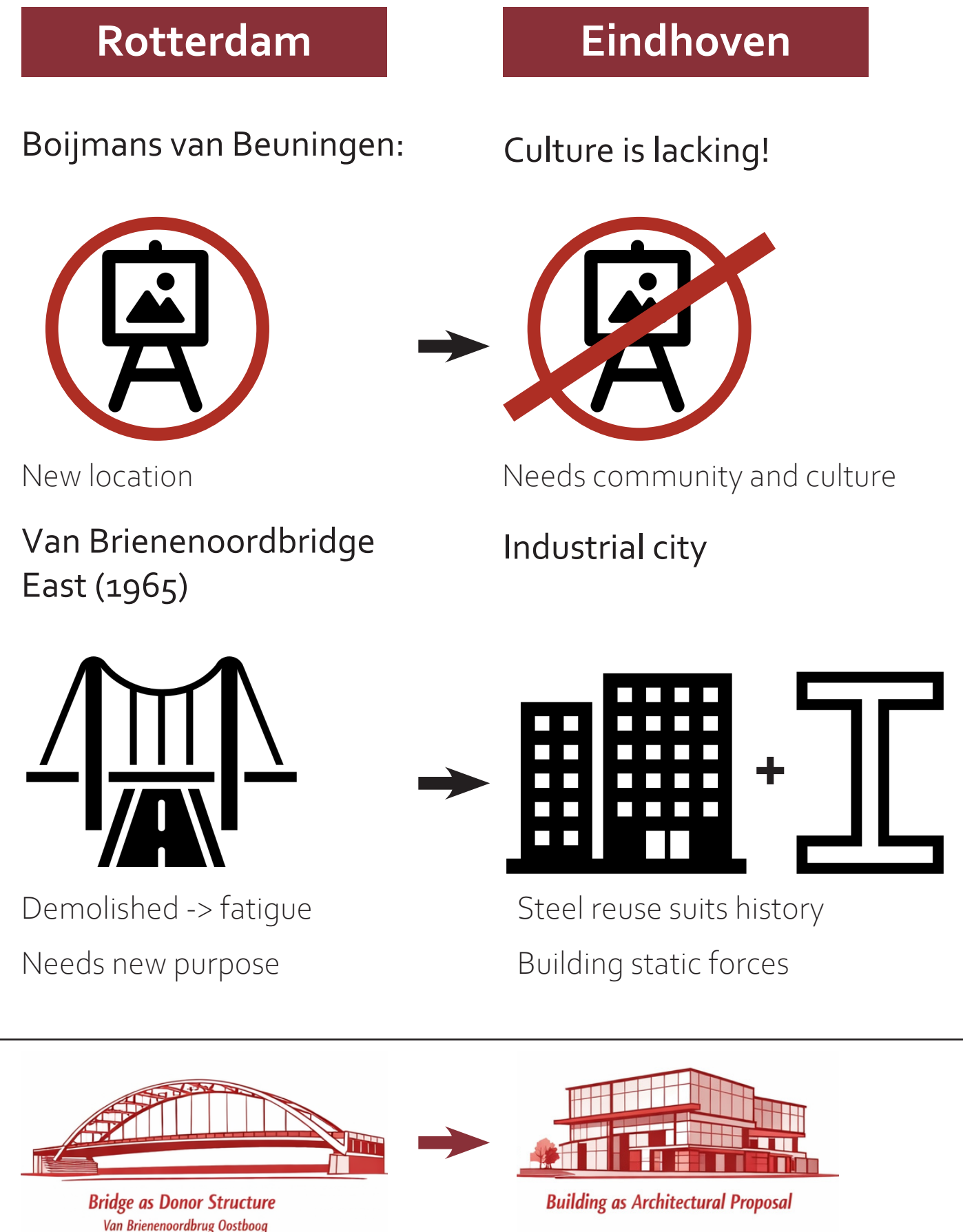


Figure 6: Schematic diagram of the objective and suitability of the bridge with Eindhoven.

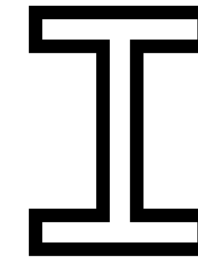
1.4 Research & Design questions

The main research question of this thesis will be the following:

"How can the steel structure of the Van Brienenoord Bridge East (1965) be translated into a buildable and meaningful culture centre on De Kade in Eindhoven?"

1. Which components of the Van Brienenoord Bridge East (1965) can be reused and structured in a harvest list with clear categories?
-> **harvest list**
2. How can the bridge's structural logic be translated into a building system that fits the constraints of the De Kade site in Eindhoven?
-> **bridge & building system**
3. How can the functions of the culture centre be organised spatially so that logistics and climate requirements are met, while the bridge structure remains the main design driver?
-> **program & spatial organisation**
4. How can the resulting culture centre be meaningfully integrated into the urban and historical context of De Kade and the old Campina district in Eindhoven?
-> **context & history**
5. How can physical prototyping generate design rules and design variants that can be evaluated for buildability, circularity, and spatial quality?
-> **generic architecture rules**

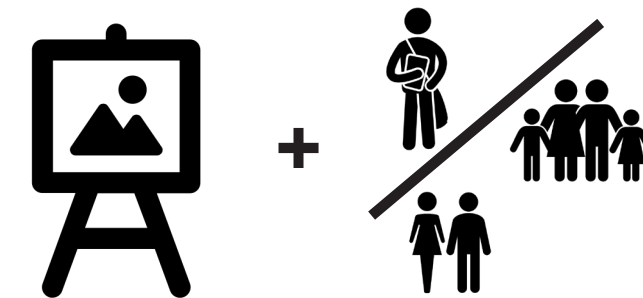
SQ1: Harvest list



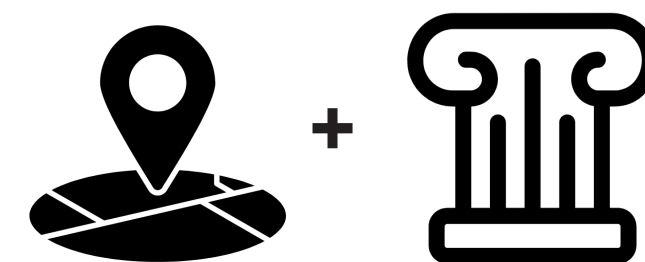
SQ2: Bridge & Building system



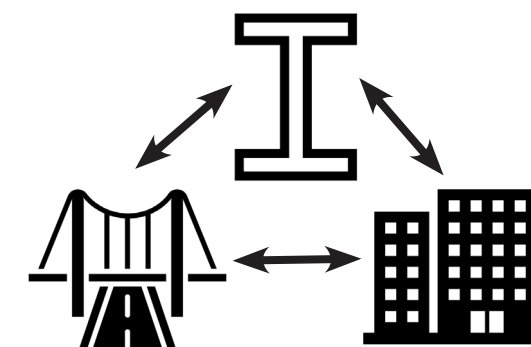
SQ3: Programm & spatial organisation



SQ4: Context & History



SQ5: Generic architecture rules



1.5 Scope

This thesis is situated in Eindhoven, a city characterised by industrial heritage, ongoing urban transformation, and a growing ambition for innovative public architecture. The project is located at De Kade, a developing area that offers the opportunity to introduce a new cultural landmark with a strong public function.

The program of the culture centre includes a combination of public and cultural functions, such as exhibition spaces, workshops, performance areas, meeting spaces, and supporting facilities. These functions require a range of spatial conditions, from large-span collective spaces to smaller and more intimate rooms. This makes the culture centre a suitable program for testing how the structural qualities of a bridge can be reinterpreted architecturally.

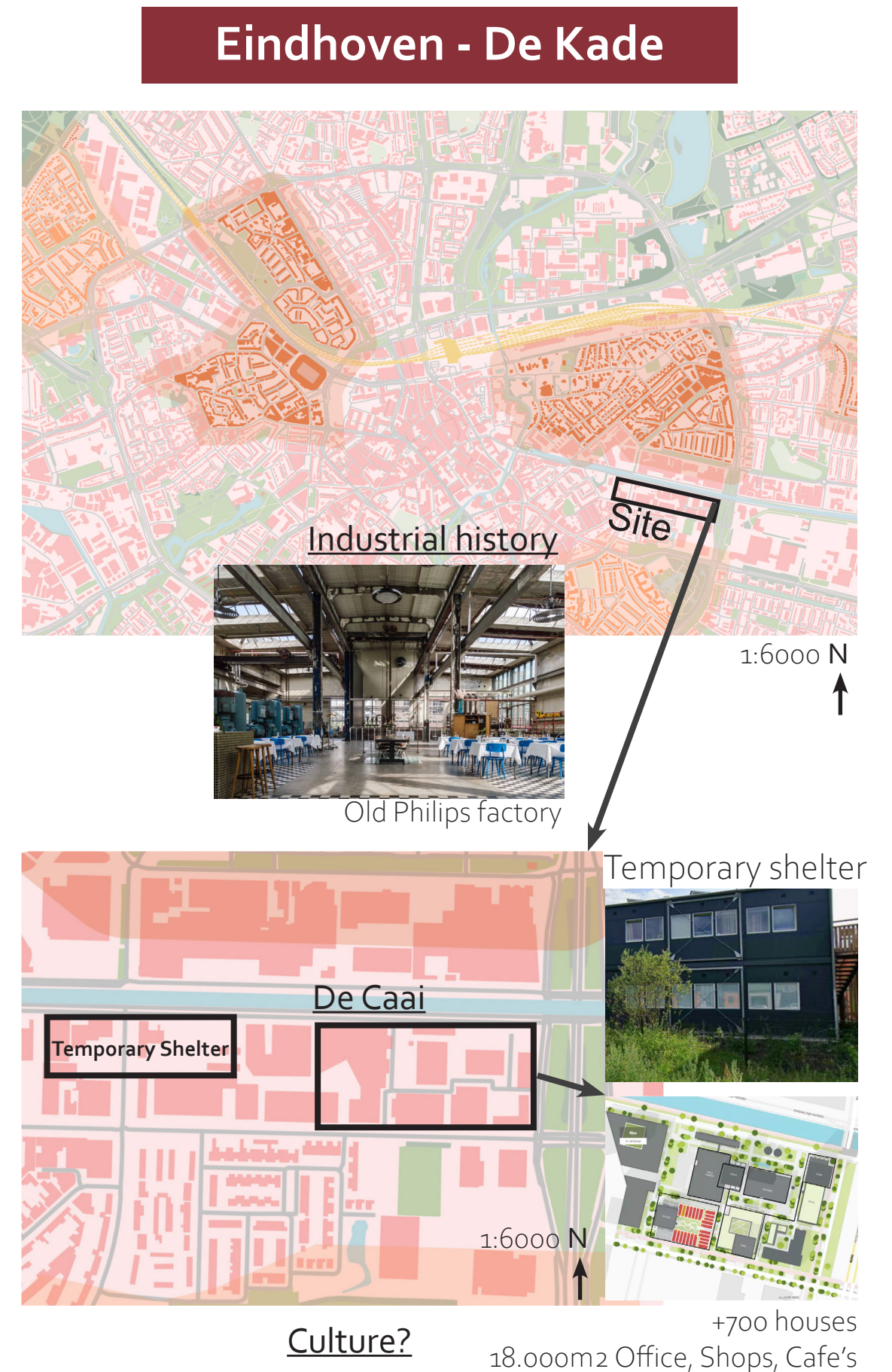


Figure 7: Site analysis Eindhoven and De Kade.

Van Brienenoordburg

The bridge's steel structure will form the starting point for this new building. The bridge is not only approached as a technical object, consisting of a collection of steel elements, but also as a spatial and structural system, with its own form language, structural logic, hierarchy, and architectural potential. The research focuses on translating the bridge structure into building form, specifically how this translation can result in a meaningful and buildable cultural centre.

Furthermore this thesis is organised through three lenses: Technology, Program, and Context.

- **Technology:** focuses on the bridge as a material and structural system.
- **Program:** examines how the functions of a culture centre can be organised spatially.
- **Context:** addresses De Kade's urban and historical context and the building's integration

Together, these lenses define the boundaries of the research and guide the project from bridge analysis to architectural translation. Additionally, through the design of a culture centre in Eindhoven, the research seeks to generate broader insights into the relationship between infrastructure, architecture, and adaptive transformation.

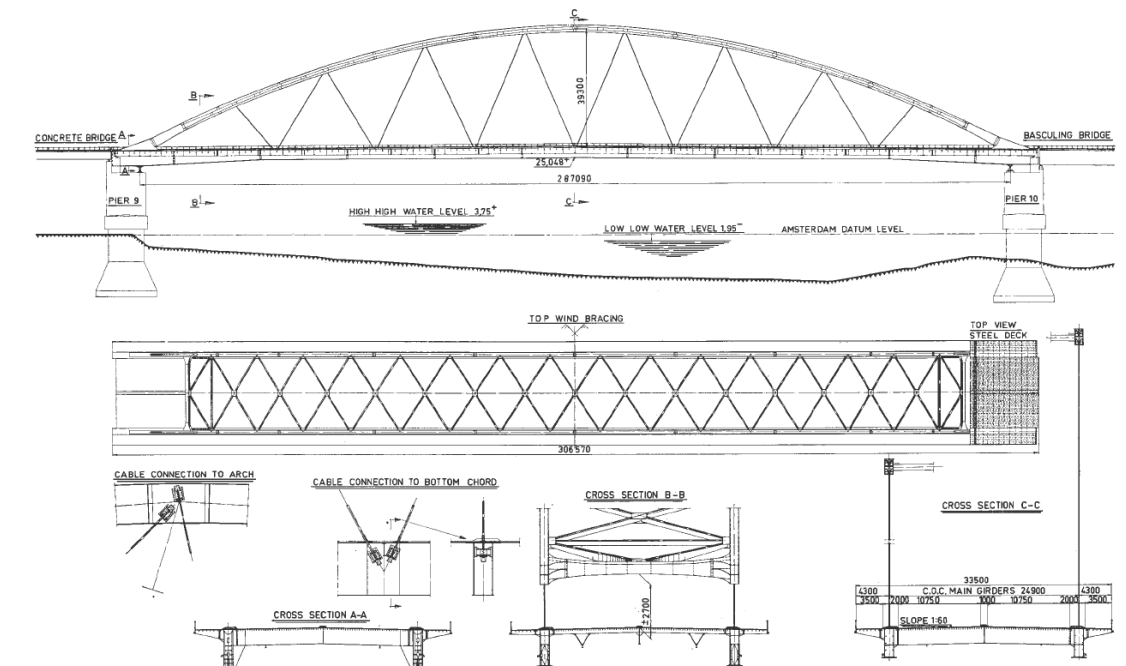


Figure 6. Scheme of the final design.

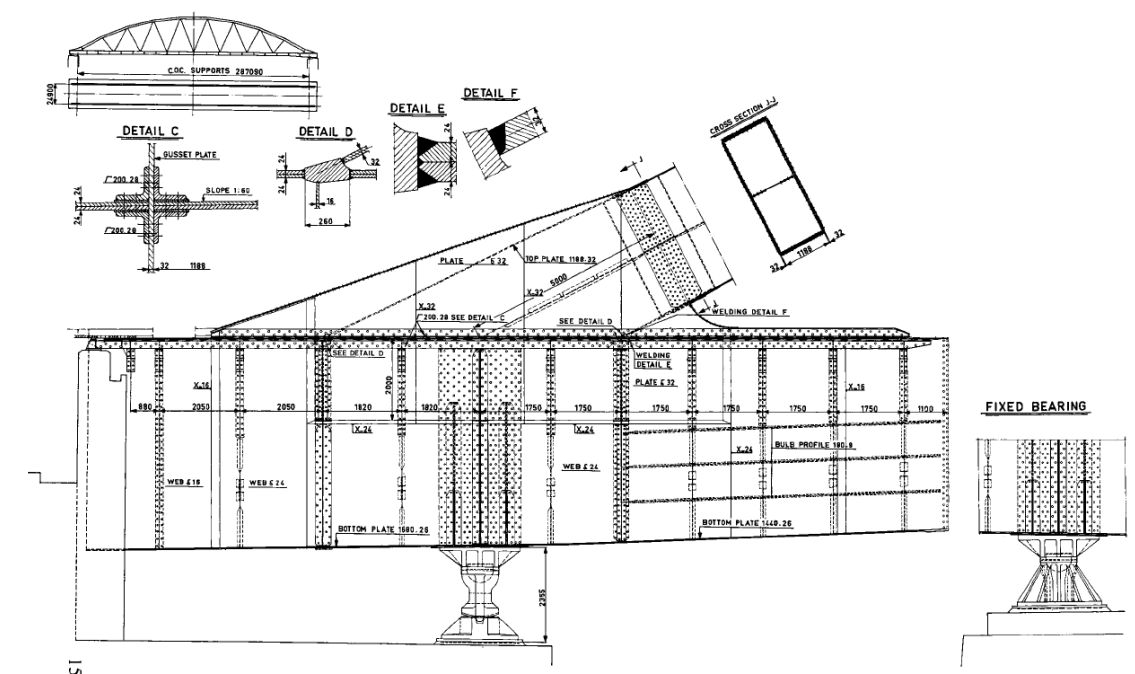


Figure 9. Connection arch to bottom chord with supports.

Figure 8 & 9: Technical drawings of the Van Brienenoordbrug East 1965 (van der Eb et al., 1968).

1.6 Double degree

This thesis forms the second part of a Double Degree programme combining the MSc Architecture, Urbanism and Building Sciences (MSc Architecture) and the MSc Construction Management and Engineering (MSc CME). It fulfils the graduation requirements for the MSc in Architecture and builds on the MSc CME thesis (Appendix B).

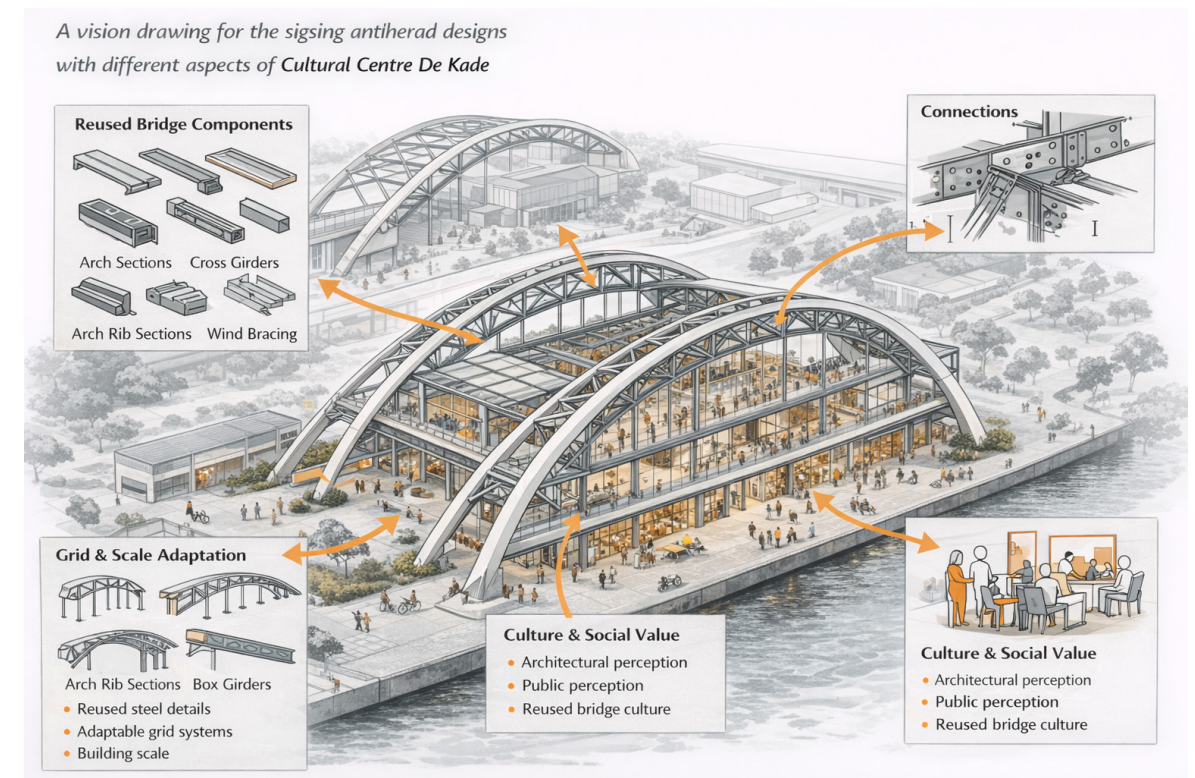


Figure 10: Vision drawing of the Cultural Centre De Kade, all suggestive, not final design.(made with AI)

Part .

Approach

Part 2. Approach

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2.1 Methods

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2.1.1 Research and design

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2.2.2 Programme layer: Cultural use as enable

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2.2.3 Context layer: Eindhoven and De Kade as test case

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2.1 Methods

This thesis uses a research-by-design methodology, in which design is both the subject of investigation and the primary method of inquiry. The project integrates research and design into an iterative process in which analytical research informs the design, and design explorations generate new insights. The approach is appropriate for the subject, as it simultaneously assesses material availability, structural logic, spatial quality, and cultural perception.

The methodology is structured through three lenses that guide the transformation from bridge to building across different scales and aspects of the design.

2.1.1 Research & Design

The research-by-design process is structured around the lenses, each addressed with a specific research technique for the sub-questions (see Figure 11).

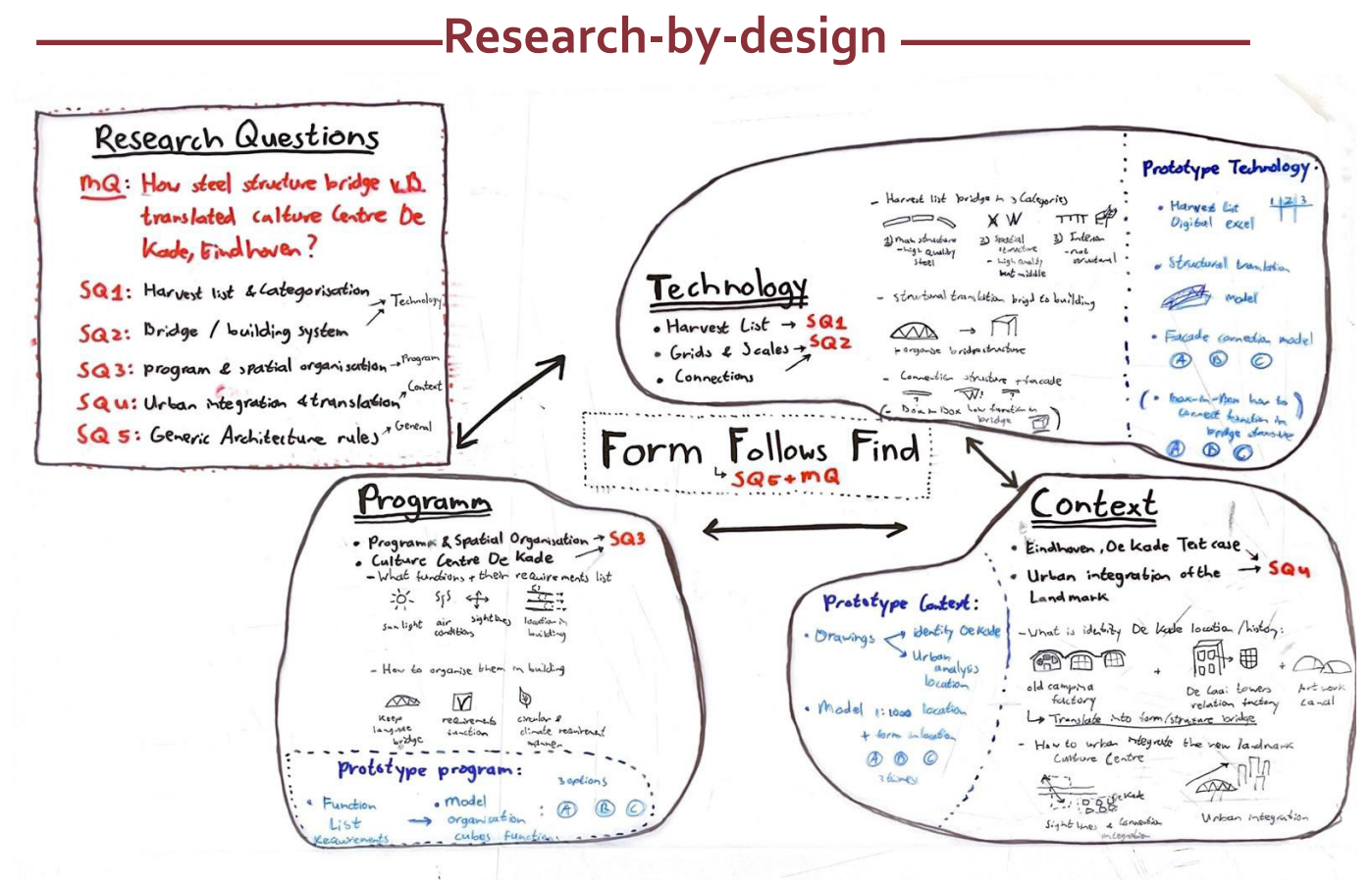


Figure 11: Research-by-design approach for 'Form Follows Find', with the layers: Technology, Program, and Context, and their associated research questions.

Technology

The technology lens addresses **SQ1** and **SQ2** and focuses on the bridge as a structural and material system.

SQ1: The research investigates how the bridge can be documented and categorised in a harvest list. This includes analysing the bridge components, dimensions, typologies, and possible categories of steel elements. The method consists of harvest-list making, categorisation, drawing analysis, and digital documentation. The outcome is a structured overview of bridge elements that can be used as design input.

SQ2: The research investigates how the bridge's structural logic can be translated into a building system. This concerns questions of span, rhythm, grid, hierarchy, load-bearing logic, and the relationship between large infrastructural elements and architectural space. The method consists of structural translation studies, analytical drawings, scale studies, and model-based exploration. Through these studies, the bridge is not copied literally, but transformed into a system that can support a new building.

Within this lens, prototyping is also used to test structural translation and façade or connection principles. This helps examine how bridge components or bridge logic can operate at the scale of the architecture, and how new interfaces among structure and skin can be designed.

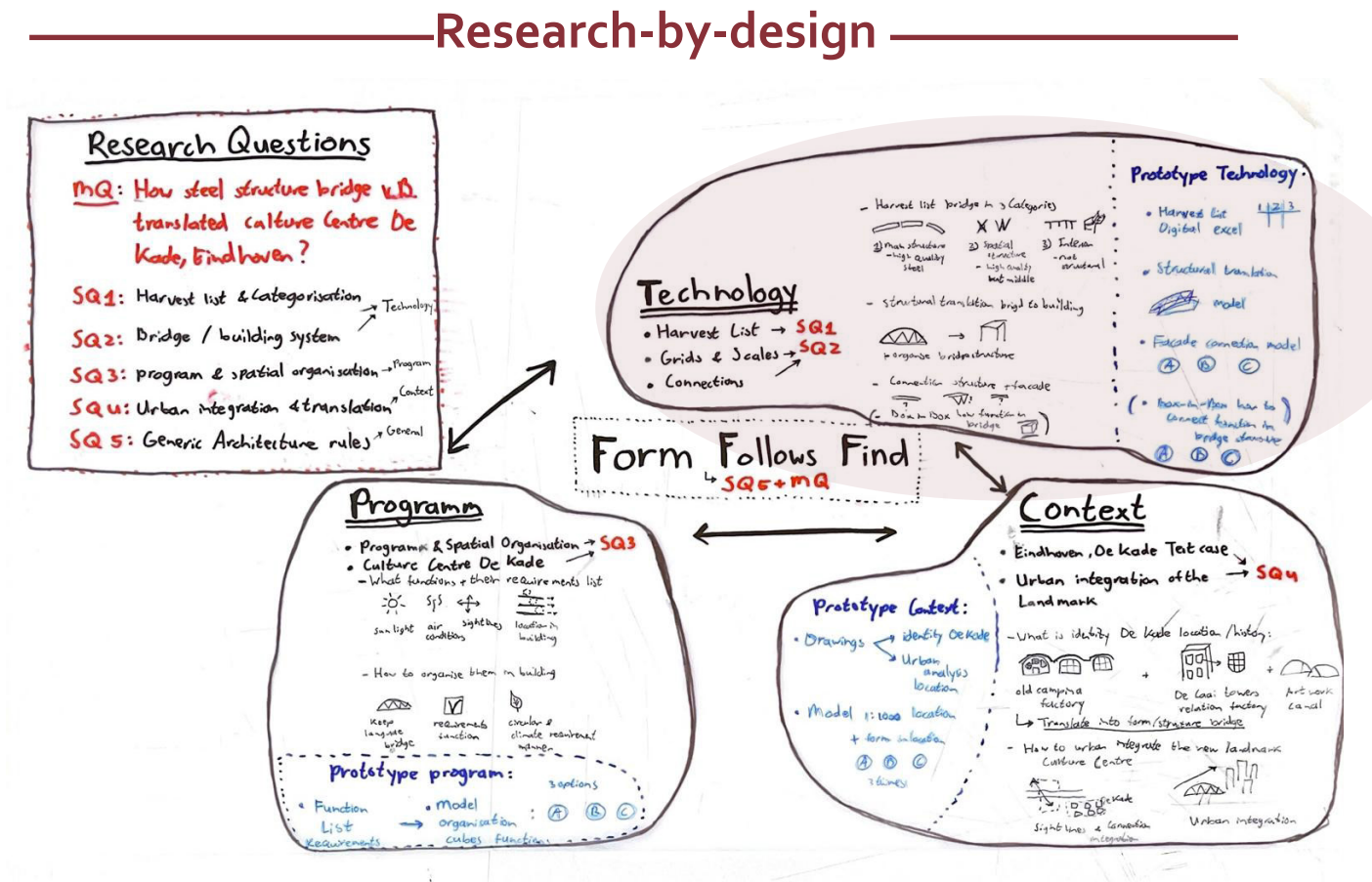


Figure 11: Research-by-design approach for 'Form Follows Find', with the layers: Technology, Program, and Context, and their associated research questions.

Program

The program lens addresses **SQ3** and focuses on the relationship between the translated bridge structure and the culture centre's internal organisation.

This part of the research investigates which functions belong to the culture centre, what their spatial and environmental requirements are, and how these can be organised within a building that emerges from the bridge logic. The method consists of programme analysis, functional requirement mapping, adjacency studies, organisational diagrams, and spatial models.

The purpose of this lens is to understand how the culture centre can be spatially composed in a way that both respects the logic of the bridge and creates a functional and meaningful public building. Rather than fitting a standard programme into a neutral structure, this thesis explores how the programme itself can be shaped by the bridge-derived building system.

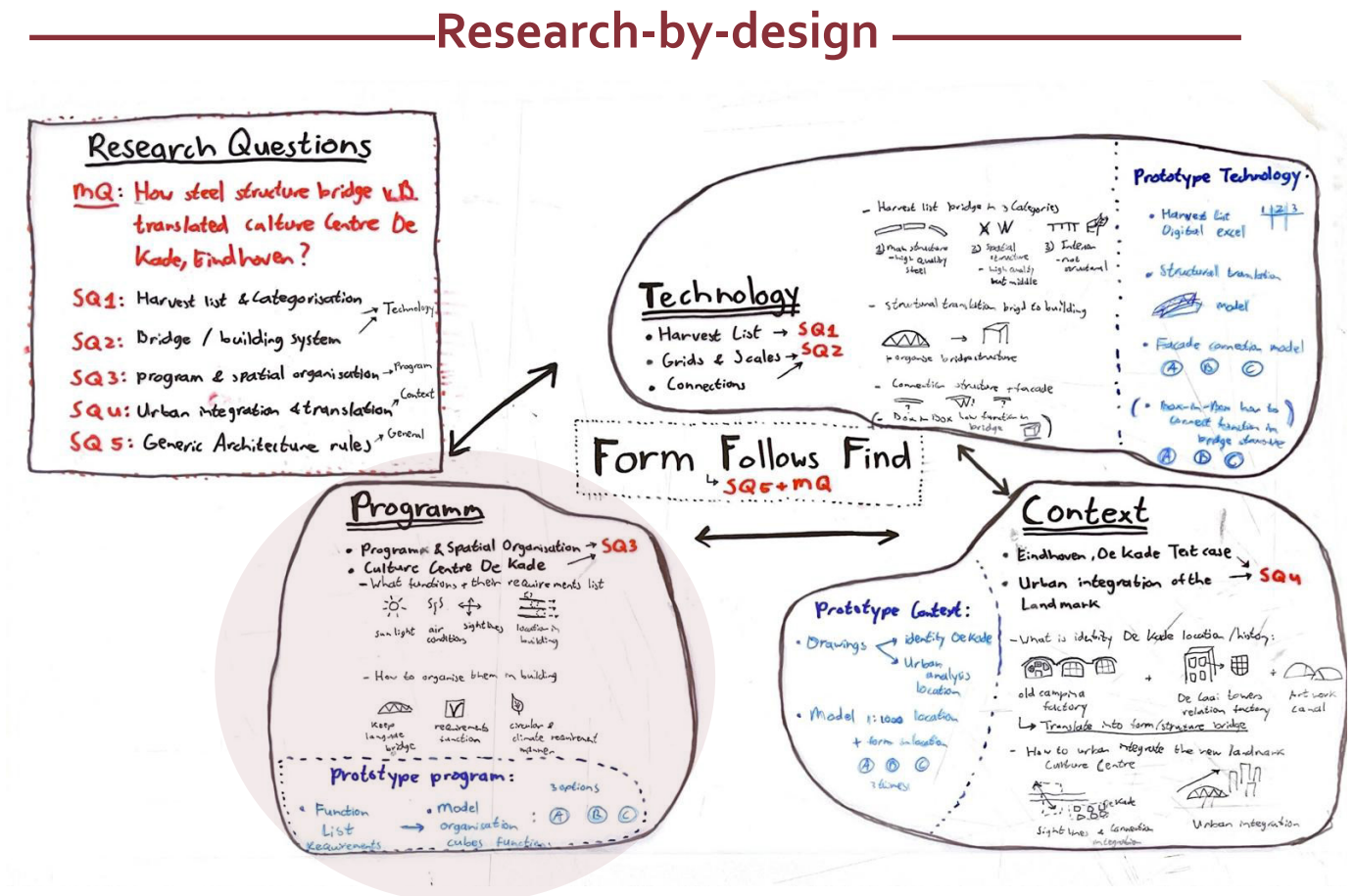


Figure 10: Research-by-design approach for 'Form Follows Find', with the layers: Technology, Program, and Context, and their associated research questions.

Context

The context lens addresses **SO₄** and focuses on the proposal's urban, historical, and architectural integration within De Kade in Eindhoven.

This part of the research investigates the site's identity, the area's historical background, the urban morphology, and the relationship between the future culture centre and its surroundings. Special attention is given to the area's former industrial character and to how a new landmark building can connect to that identity. The method consists of site analysis, urban analysis, historical research, mapping, drawings, and contextual models.

The purpose of this lens is to ensure that the transformed bridge does not become an isolated object but an architectural intervention embedded in the city. The bridge-to-building translation is therefore not only a structural operation, but also an urban and cultural one.

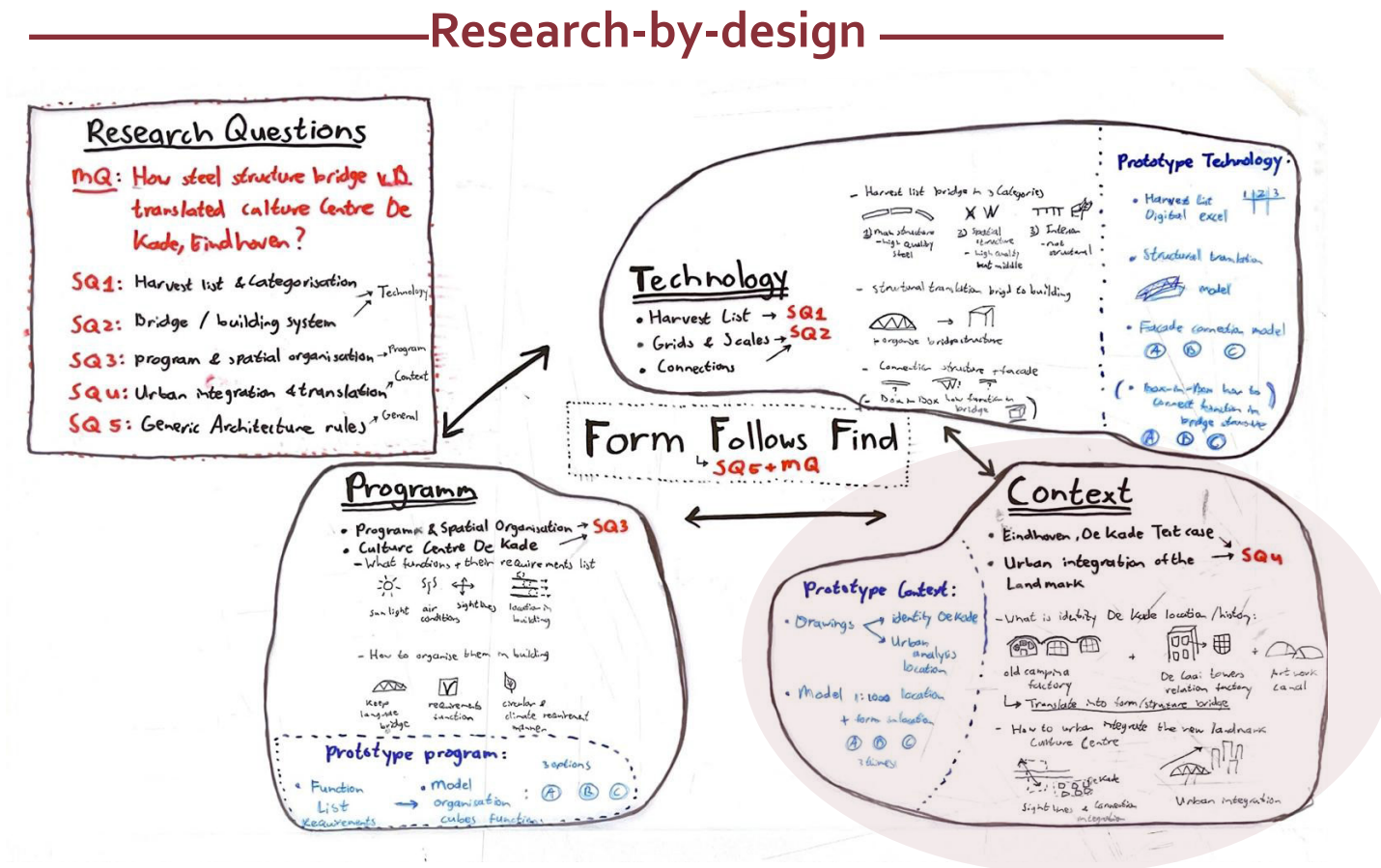


Figure 11: Research-by-design approach for 'Form Follows Find', with the layers: Technology, Program, and Context, and their associated research questions.

2.1.2 Thesis planning

The thesis planning follows a research-by-design approach in which analysis, design exploration, and evaluation are developed in parallel. The project investigates how the steel structure of the Van Brienoordbrug Oostboog can be translated into a culture centre on De Kade in Eindhoven.

Phase 1 (A1/A2) focuses on documentation and analytical groundwork. The Van Brienoordbrug Oostboog is studied as the donor structure through historical, technical, and structural analysis, drawings, and a harvest list. At the same time, De Kade is analysed as the design location, including its urban, historical, and programmatic conditions.

Phase 2 (A2) explores how the bridge can be translated into a building system. Through drawings, models, and prototyping, bridge characteristics such as span, hierarchy, rhythm, and connection logic are investigated as potential architectural principles.

Phase 3 (A2/A3) develops these findings into a design proposal. In this phase, the bridge-derived structure is integrated with the culture centre programme and the site conditions of De Kade, addressing spatial organisation, public use, and urban fit.

Phase 4 (A3/A4) consists of synthesis and reflection. The design outcomes are evaluated in relation to the research questions, resulting in both a site-specific proposal and broader principles for bridge-to-building transformation.

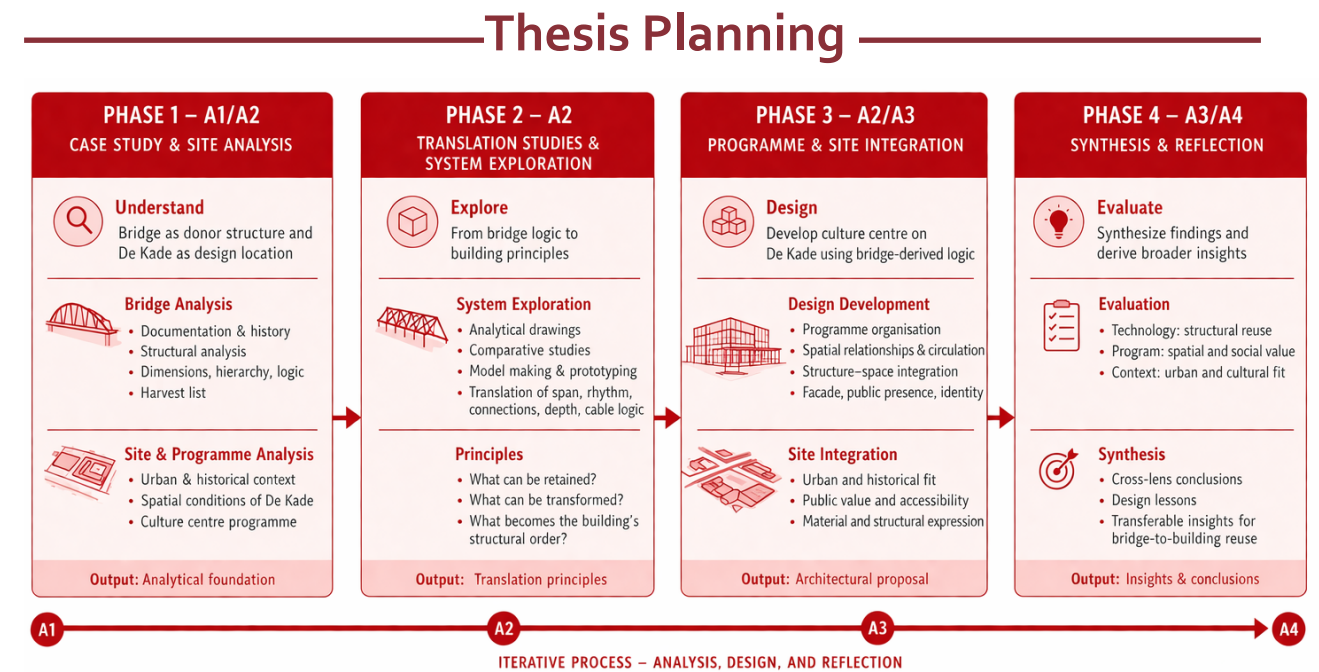


Figure 12: Thesis planning and structure following the research-by-design method.

2.2 Theoretical framework

The theoretical framework builds on the circular potential of steel reuse and the Dutch replacement and renewal challenge, as discussed in § 1.1. Additionally, the CME thesis demonstrated that steel reuse is hindered by early-stage barriers, presented in Table 2 (see Appendix A for more information).

Empirical research identified the following dominant obstacles:

- (1) cost and economic uncertainty
- (2) lack of collaboration and transparency
- (3) supply and demand inconsistencies, certification, and design standardisation.

(van Rooij, 2026)

Within this context, the Van Brieneoordbrug Oostboog is positioned as a timely case study, since it is part of an active renewal process and listed by the Nationale Bruggenbank as a reusable steel superstructure (Nationale Bruggenbank, n.d.; Rijkswaterstaat, 2024).

The framework approaches the bridge not only as a source of reusable steel, but as a spatial, structural, and cultural system with architectural potential. It revolves around **Form Follows Find**, in which “find” refers not only to found material, but also to found structure, order, and logic. In this way, the bridge is understood as a found structure that can be translated into a new public building.

The framework integrates three interrelated layers: technology, program, and context, which together structure the research-by-design approach.

Steel reuse obstacles

Obstacles	Explanation	Category
Supply and demand	- Material properties - Availability	➔ <i>Technical</i> ➔ <i>Organizational</i>
Certification and design standards	- Assessing structural safety	➔ <i>Technical</i>
Absence of legal frameworks	- EU regulations	➔ <i>Regulatory</i>
Cost and economic uncertainty	- Cost	➔ <i>Economic</i>
Collaboration and transparency	- Attitudes and perceptions	➔ <i>Behavioral/Organizational</i>

Table 2: Summary of the identified obstacles in the existing literature (van Rooij, K., 2026).

Theoretical Framework

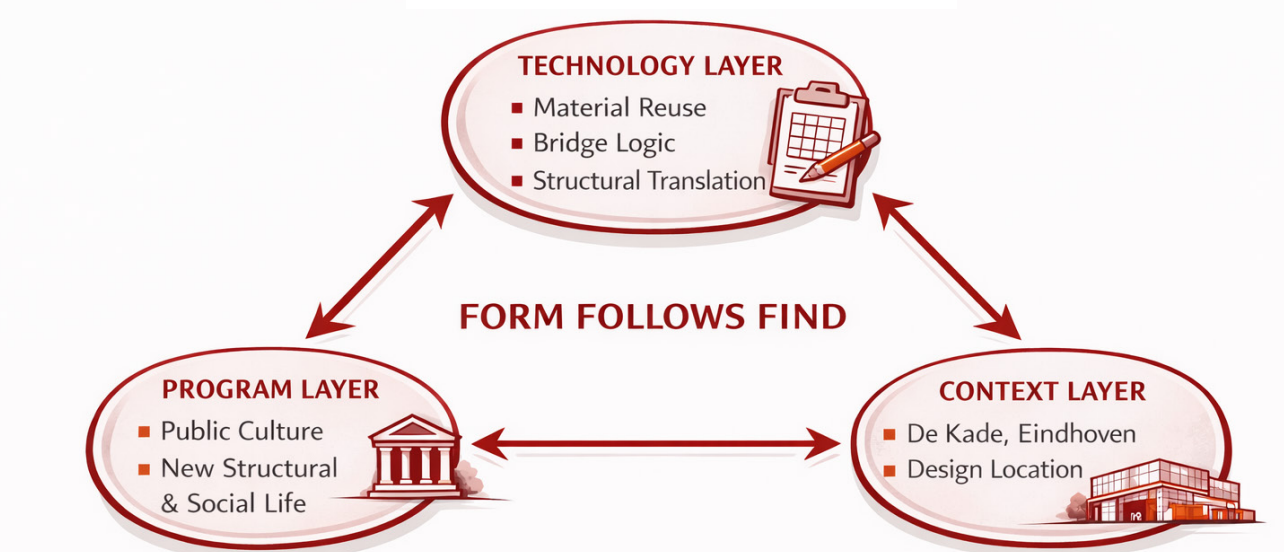


Figure 13: The theoretical framework revolving around 'Form follows Find' and the three interrelated layers.

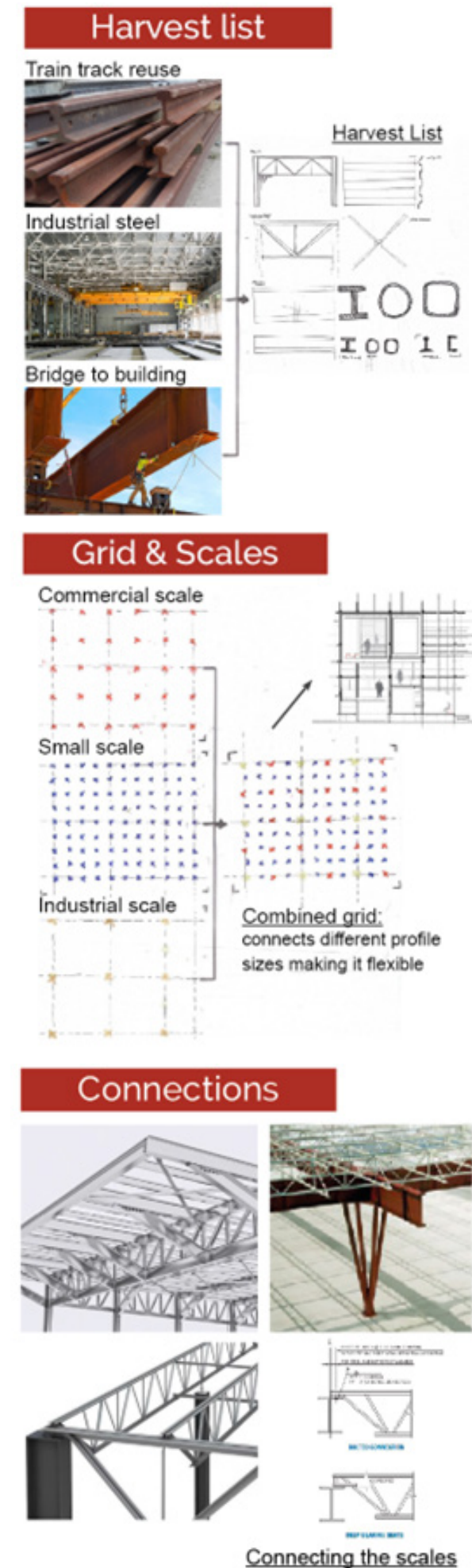
2.2.1 Technology layer

The **Technology layer** focuses on the bridge as a material and structural system. It is grounded in the understanding that reuse is one of the most valuable circular strategies for steel, since it preserves embodied energy and carbon more directly than recycling (Kirchherr et al., 2017; Alaux et al., 2024; Bartsch, 2025).

At the same time, the thesis recognises that bridge reuse is not straightforward. Existing research points to barriers such as traceability, certification, fragmented supply chains, and mismatches between available steel and new demand (Bartsch, 2025; Densley Tingley et al., 2017).

For bridges, fatigue is an additional issue, because bridge structures are exposed to repeated traffic-induced and cyclic loading, which limits their suitability for reuse in another dynamically loaded infrastructure application (Yu et al., 2021). Buildings, by contrast, are generally governed by self-weight and imposed loads associated with use (CEN, 2002). This distinction forms an important basis for the thesis: a building can provide a more suitable structural context for selected bridge elements and principles.

Within this layer, the Van Brienoordbrug Oostboog is studied as a system of parts, relations, and hierarchies. Its original design shows a carefully composed structure of arches, bottom chords, diagonal suspension members, wind bracing, orthotropic deck systems, and connection details (Van der Eb & Ypey, 1968). The harvest list, component analysis, and translation studies therefore function as both analytical and design instruments, revealing which structural principles can be retained, transformed, or reassigned in a new architectural context.



C M E

Supply & Demand
inconsistencies

Certification and
design
standardization

Cost and
economic
uncertainty.

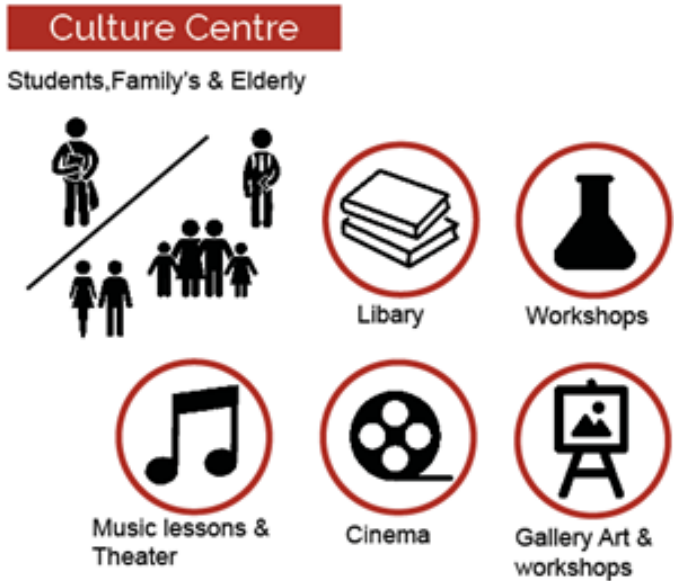
Figure 14: Technology layer explained and connected to the MSc CME thesis results.

2.2.2 Program layer

The **Program layer** investigates how a bridge-derived structure can support a new public function. In this thesis, programme is not treated as something inserted afterwards, but as an active part of the translation process.

The choice for a culture centre is important because it combines collective, flexible, representative, and more intimate spaces. This makes it suitable for testing the architectural possibilities of bridge structure.

This layer concerns the transformation of infrastructural logic into public architectural space. Bridges are designed for movement, span, efficiency, and force transfer; buildings must also support occupation, use, social interaction, and atmosphere. The programme therefore acts as a mediator between structural order and lived experience, extending the life of steel infrastructure not only materially, but also socially.



CME

Lack of
collaboration and
transparency.

Figure 15: Program layer explained and connected to the MSc CME thesis results.

2.2.3 Context layer

The **Context layer** frames the project through the relation between the donor bridge and the design site. The Van Brienoordbrug Oostboog in Rotterdam functions as the case study bridge and structural source, while De Kade in Eindhoven is the location where its translation into architecture is tested.

This layer therefore has a double meaning: it includes the infrastructural and historical context of the bridge, as well as the urban and spatial context of De Kade. Eindhoven is a relevant setting because of its industrial history and ongoing transformation. De Kade provides an opportunity to test whether bridge-derived architecture can contribute to a place marked by production, transition, and new public use.

In this way, the bridge-to-building transformation is understood not as a purely technical exercise, but as an architectural act of relocation, reinterpretation, and new meaning.

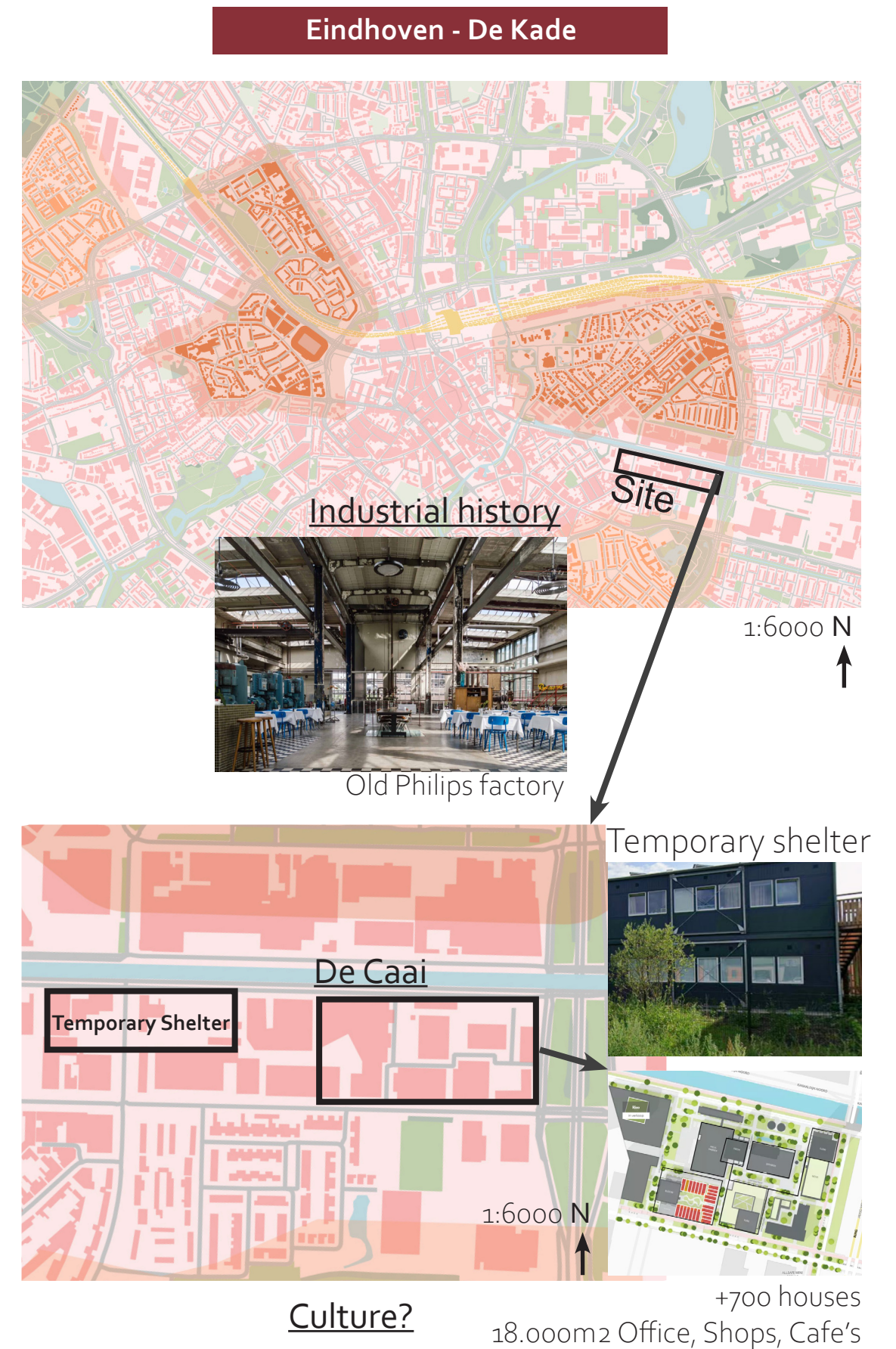


Figure 16: Context layer explained and connected to the MSc CME thesis results.

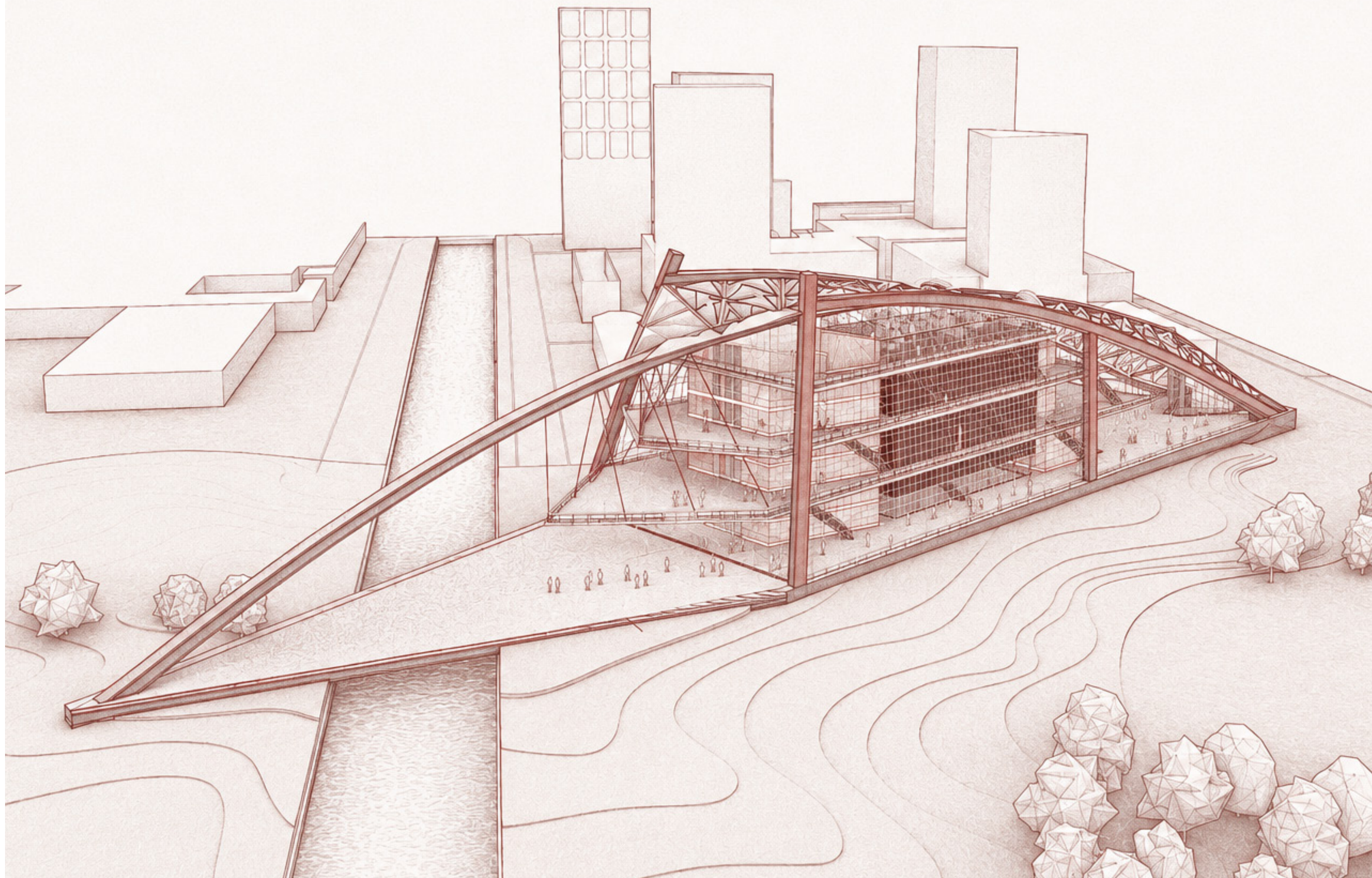
Part .

Results



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Teaser Final design



3.1 Research results

During the A2 & A3 period, the research and design were developed through the three previously defined layers: Technology, Context, and Program.

The research results will be explained per layer and there sub-theme's (see Figure 19). The layers were explored in parallel with the design choices, rather than sequentially, as indicated in the report.

Before starting the detailed research, three guiding criteria were formulated that continuously informed the design choices throughout the process.

These criteria functioned as a reference framework against which different options were evaluated:

1. Form language of the bridge and steel quality.
2. Connection to location and history (De Caai).
3. Landmark, culture, and social centre of Eindhoven.

These criteria were used to compare and select between different design directions and architectural options. Figure 21 shows the POM (Product Ontwikkel Methode) of the complete A2 design phase, including the different explored options.

Research layers overview

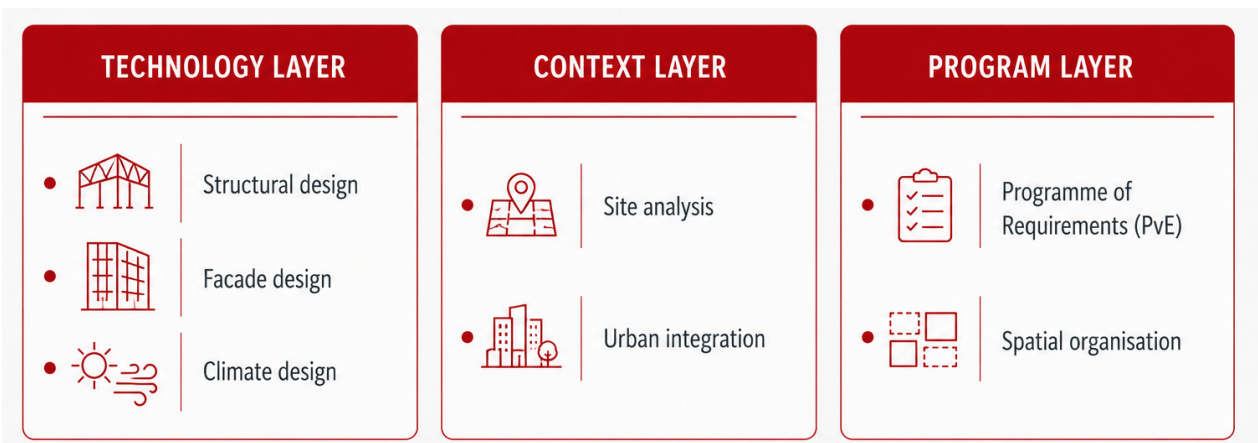
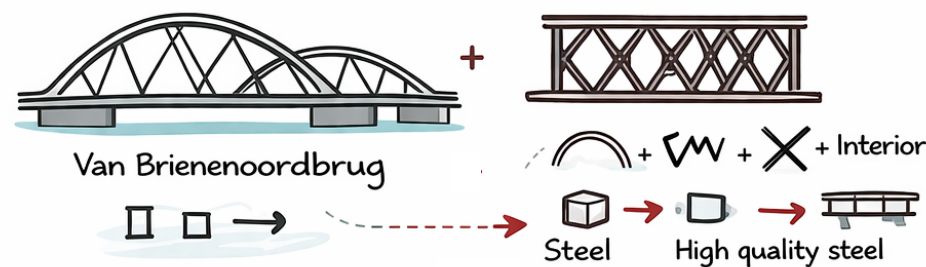


Figure 19: Research results structured per layer and their sub-theme's.

Design guidelines

1. Form language bridge & steel quality



2. Connection location & history



3. Landmark, culture centre Eindhoven



Figure 20: The three design guidelines use to make design choices.

POM: Product Ontwikkel Methode

Design aspects Criteria	Technology				Context		Program	
	Structural translation	Façade	DC system	Floors/Decks	Urban integration	Routing	Spatial organisation	Functions
1. Form language bridge & steel quality 2. Connection location & history 3. Landmark, Culture & social centre of Eindhoven								

Chosen designs options to continue with in the A3 period.

Figure 21: POM (Product Ontwikkel Methode) for all the design choices during A2 for all the three layers: Technology, Context & Program.

3.1.1 Technology research

Structural design ~ SQ1 Harvest list

The Technology layer started from the steel structure of the bridge as the main design input. The Van Brienenoordbrug Oostboog (1965) was studied carefully as a structural and architectural source.

The starting point was the development of a harvest list, in which the most useful and reusable steel elements of the bridge were identified. These elements were then categorised into three groups of steel quality, function, and scale (Figure 22):

- 1. Structural main
- 2. Spatial structure
- 3. Interior

In addition, criteria were established for the form language of the bridge: which structural and formal characteristics are essential for recognising and honouring the identity of the bridge, while allowing it to be reinterpreted in a new architectural way (see Figure 20).

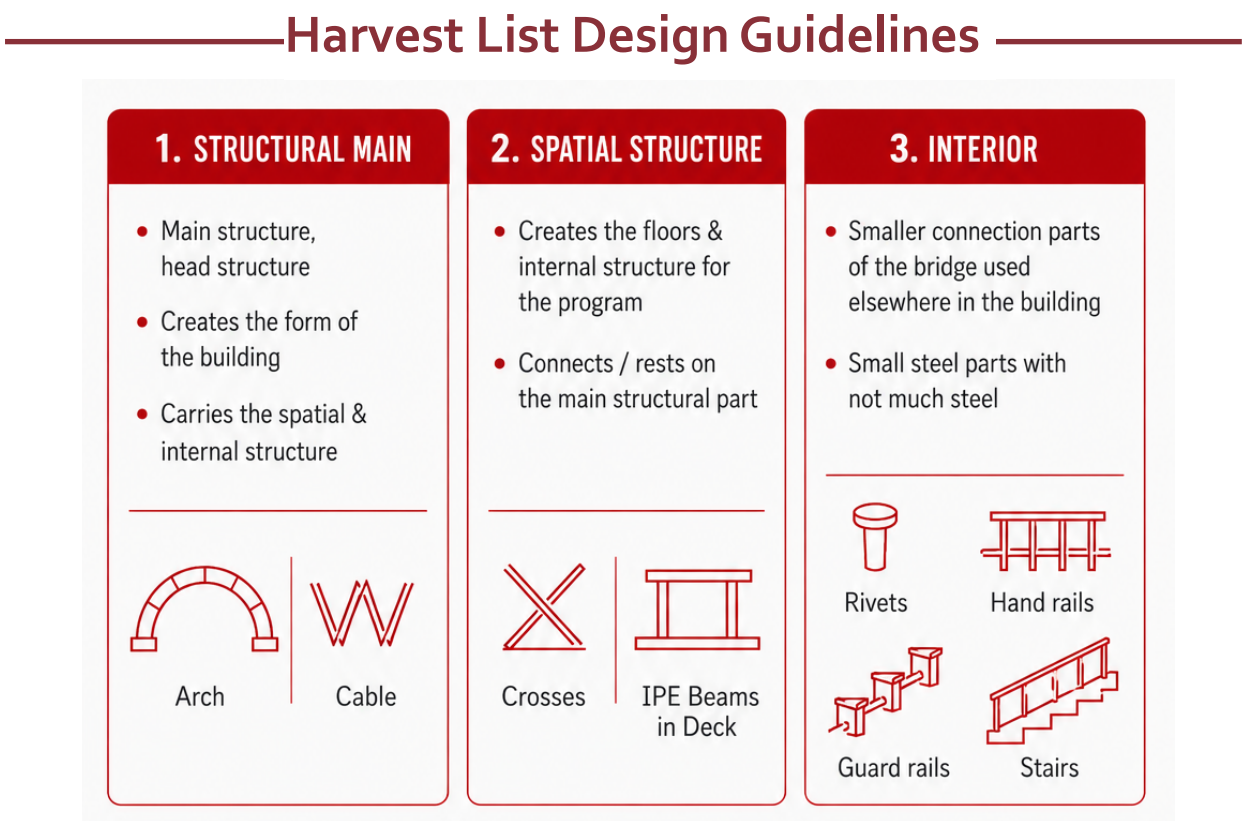


Figure 22: Harvest list design guidelines, categorizing the steel bridge element into 3 groups based on function and scale.

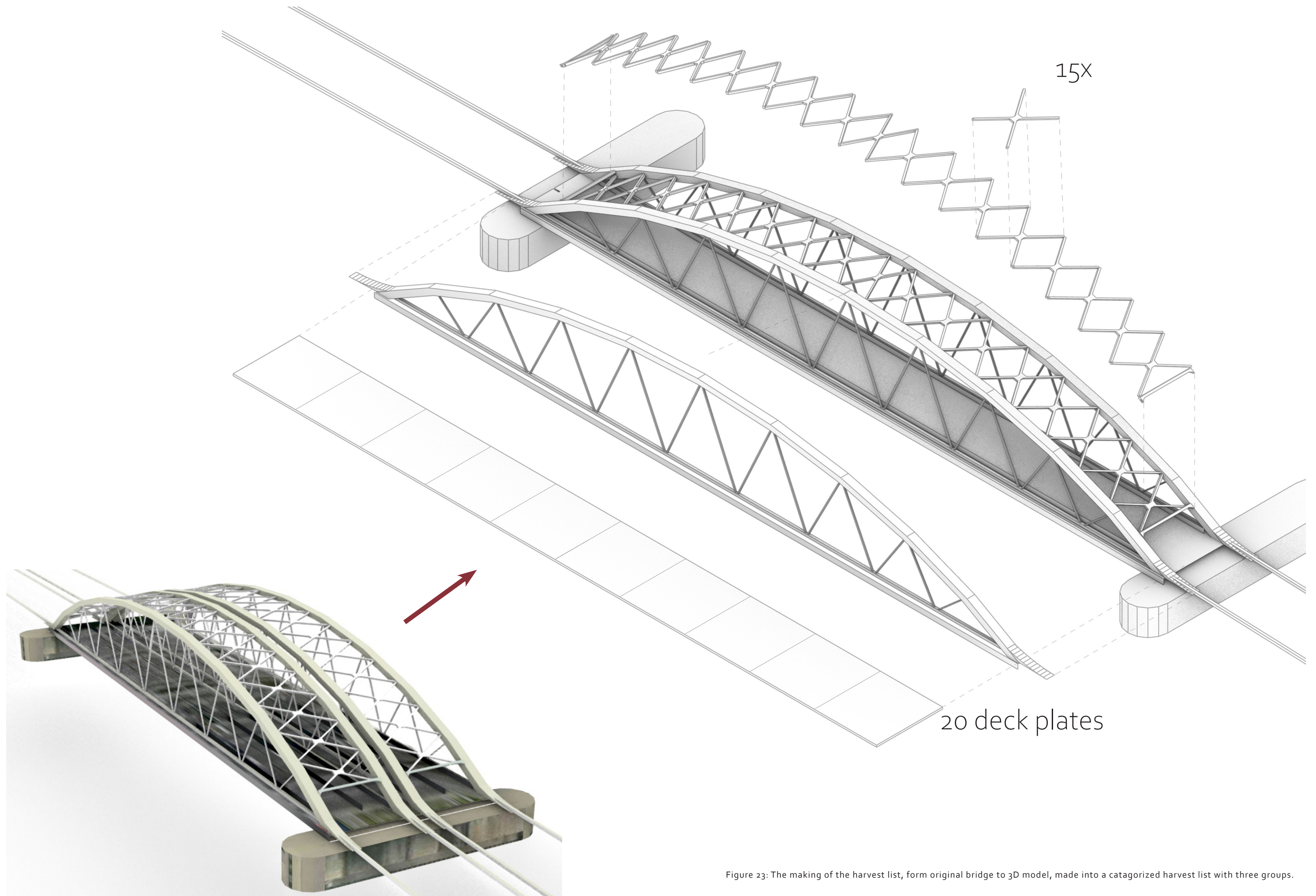
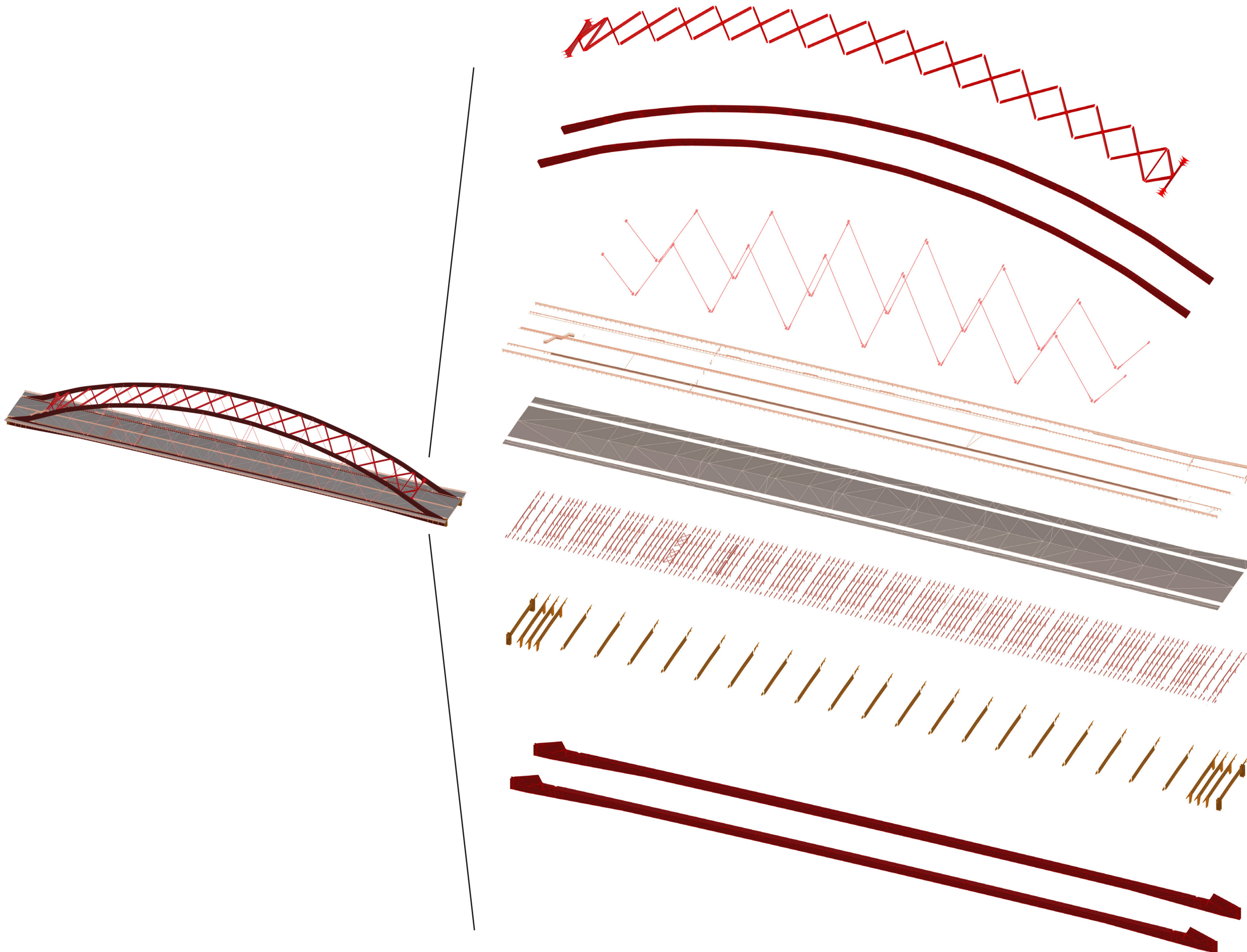


Figure 23: The making of the harvest list, form original bridge to 3D model, made into a catagorized harvest list with three groups.

Harvest List



Wind braces:

- Diagonal member near end portal
- Diagonal/ vertical members
- Portal cross beam

Arches:

- 10 parts per arch , 3 different profiles

Cables

- D= 110 mm

Handrails, Stairs, Guard rails

Deckplate & Bulb-profiles 180.8

Cross grinder

- INP-22 deck

Main grinders:

- INP-30 deck

Bottom chords

- 10 parts chord, 3 different profiles

POM: structural translation

Based on this harvest list, prototyping started first through drawings (Figure 24) and later through physical model studies at a scale of 1:200 (Figure 25). These studies tested different ways in which the bridge structure could be translated into a building system.

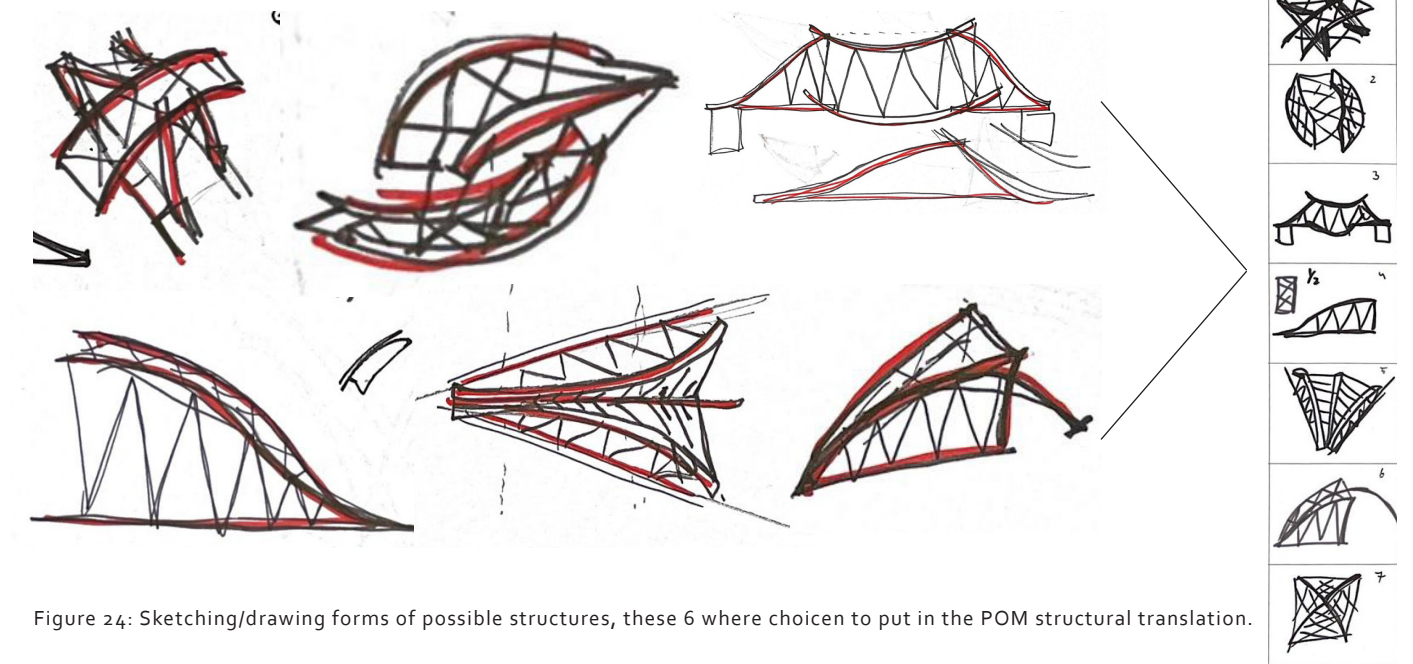


Figure 24: Sketching/drawing forms of possible structures, these 6 where choicion to put in the POM structural translation.

Model making

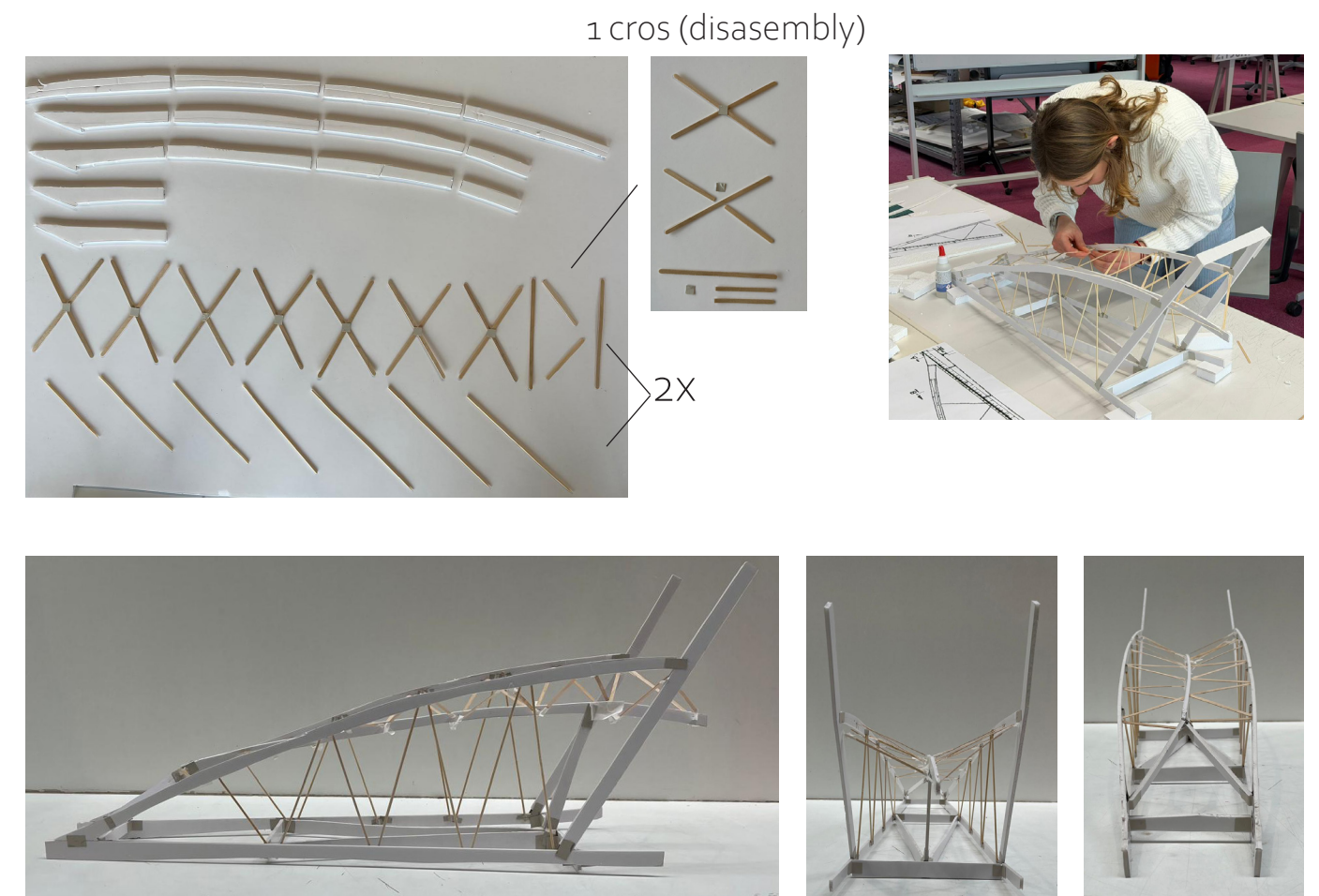
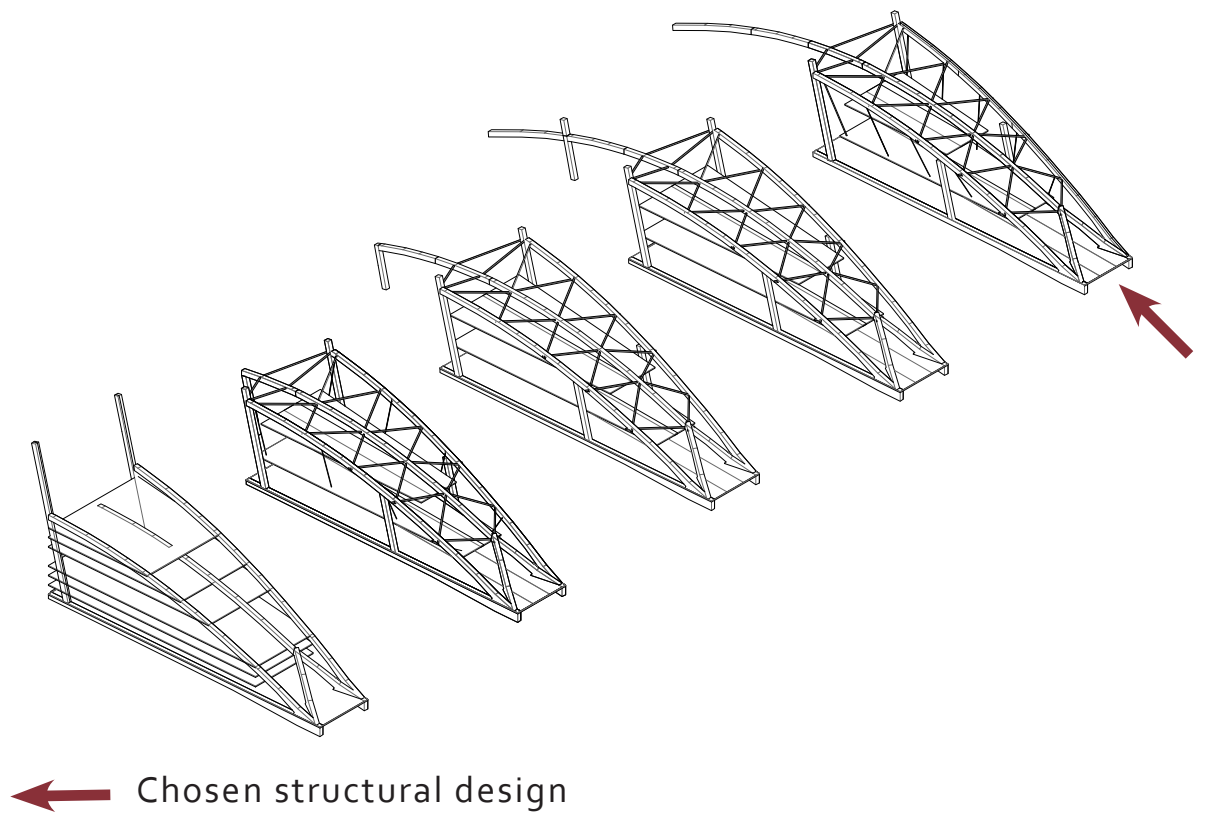


Figure 25: prototyping model studies of making the harvest list into a main structure of the building.

Digital prototyping structure

After the model making of the main structure, the model was developed further in Rhino to create a more detailed 3D study. In this digital model, more specific structural variations were explored in combination with the context analysis (see Section 3.1.2). Once the main structure had been defined, the next step was to investigate how floors and a façade could be inserted into this structural system.

The results showed that using half the length of the bridge and designing within the logic of the original structural form worked best (see Figure 26). This approach created a strong superstructure that preserved the bridge language while also responding to the historical and spatial context of the site (see Context, Section 3.1.2).



Form development

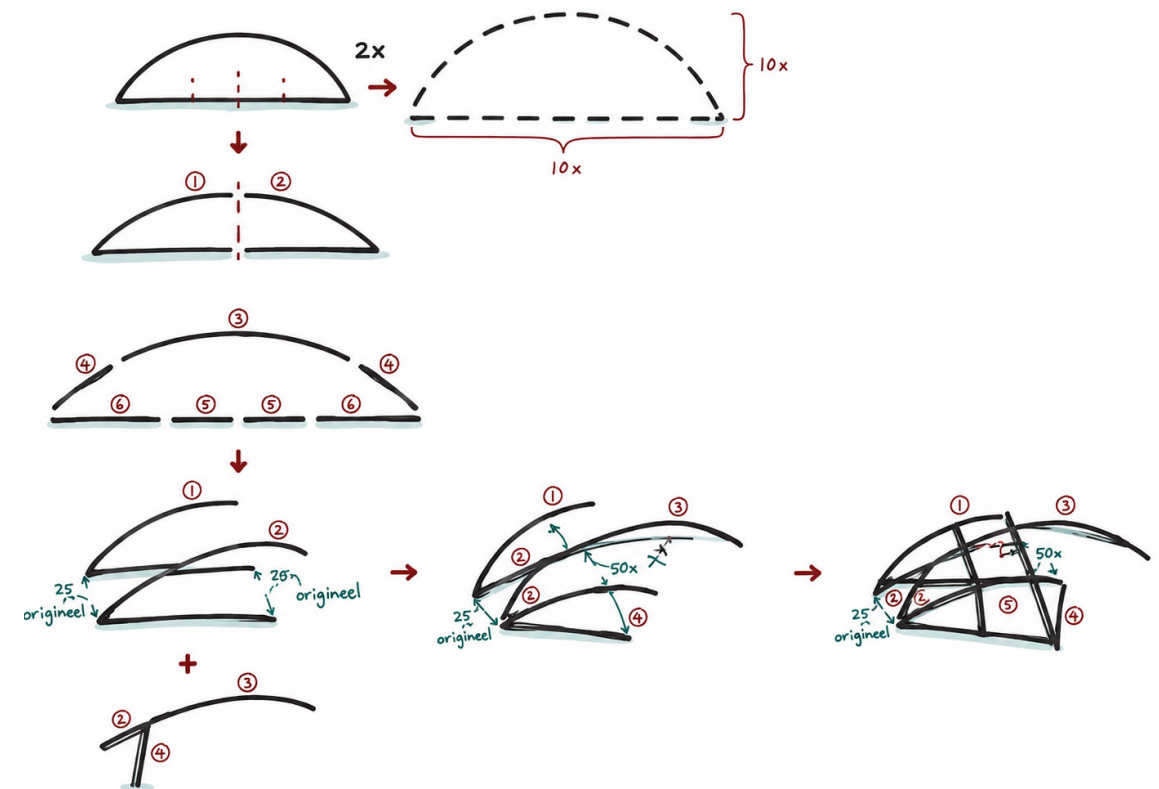


Figure 26: Digital prototyping structural elements & explanation form development.

Floor & Deck systems

For the floor strategy, different methods were studied (Figure 27). This resulted in three systems:

- **Decks:** using a core and floors suspended with cables from the main structure.
- **Indoor structure:** a routing system comparable to the MAS in Antwerp, in which functions are organised as boxes with their own constructive elements.
- **Hanging structure:** functions or boxes suspended openly in the large space created by the main structure.

The conclusion of this research was that the main structure should be used as much as possible because of its strength and its capacity to carry very high loads. As a result, the deck and hanging structure options is the most suitable (see Figure 27).

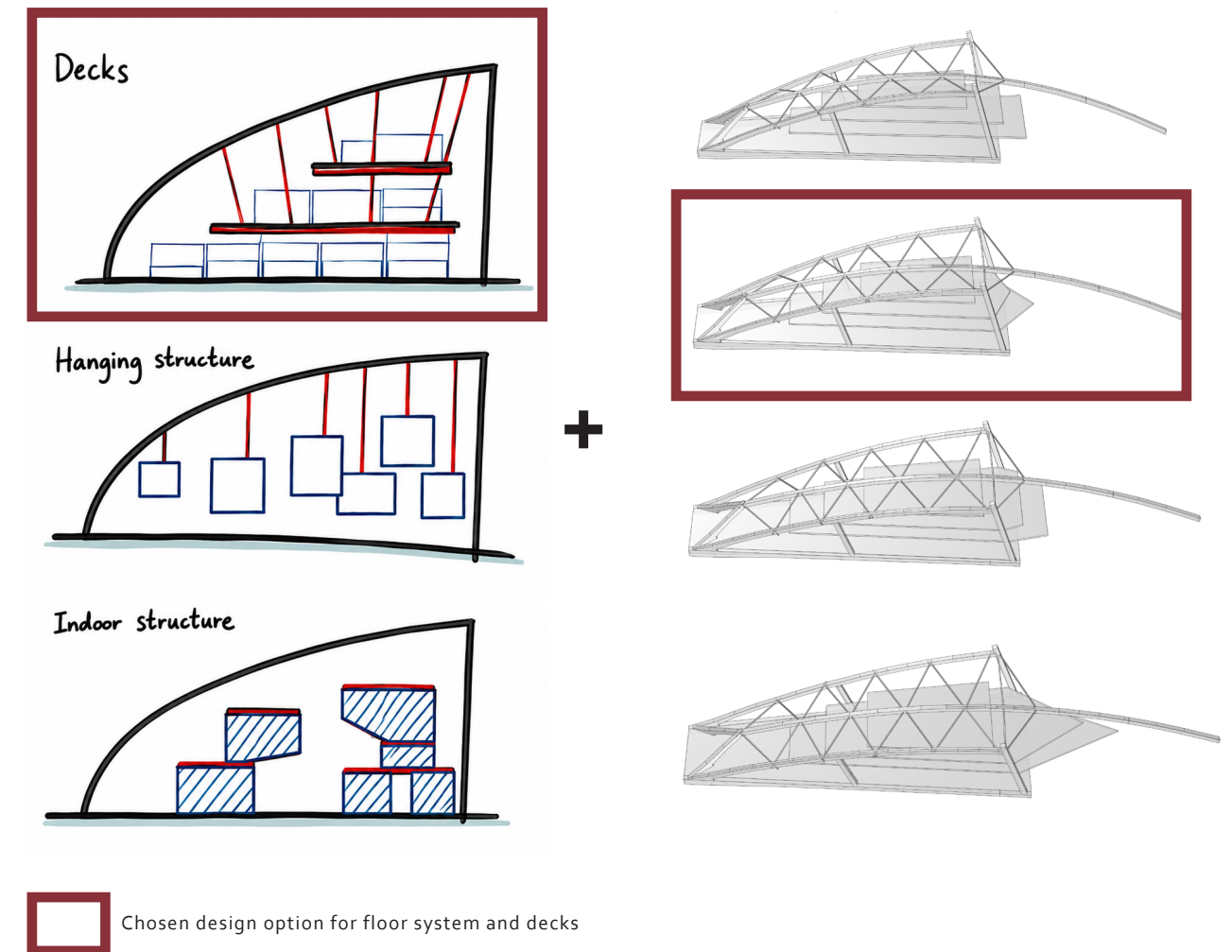


Figure 27: POM floor system, drawings of possible options to create floors/decks and insert functions⁷

Cable options

In combination with the prototyping of different cable options (Figure 28) resulted in the following structural design (see Figure 29).

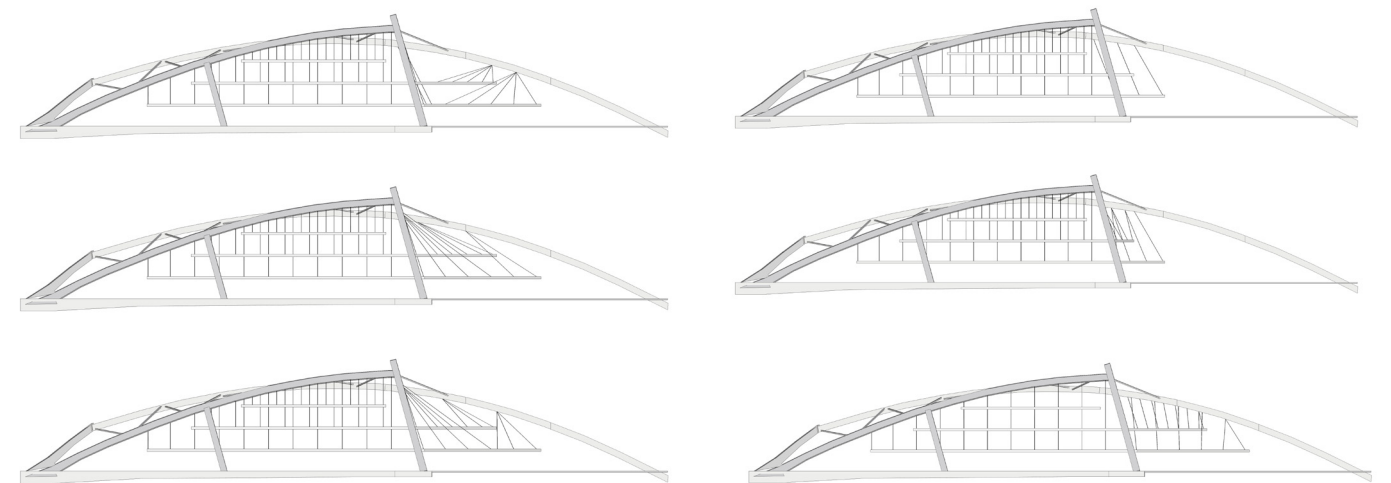


Figure 28: Prototyping cable options for the chosen floor and deck systems.

Conclusion structural design

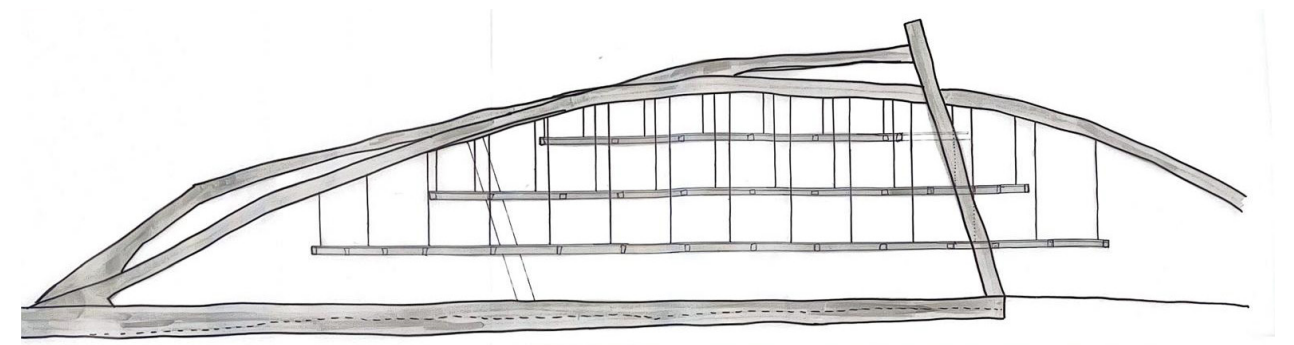


Figure 29: Conclusion structural design research and chosen final structural design.

Double skin facade

Facade design ~ SQ2 Building system

In order to create a building, a façade also had to be introduced between the arcs of the main structure. This led to a double skin facade principle, in which a semi-conditioned intermediate space emerges, comparable to the Markthal in Rotterdam. This space is slightly warmer inside, but naturally ventilated rather than fully heated, while the programme boxes themselves are fully climatized (Figure 30).

The façade had to meet several criteria. It had to be as transparent as possible, so that during the day the cultural programme inside would be visible and attract people.

In addition, the façade had to be non-load-bearing and remain subordinate to the form language of the main structure and the bridge. Figure 31 shows the wide range of façade systems that were explored.

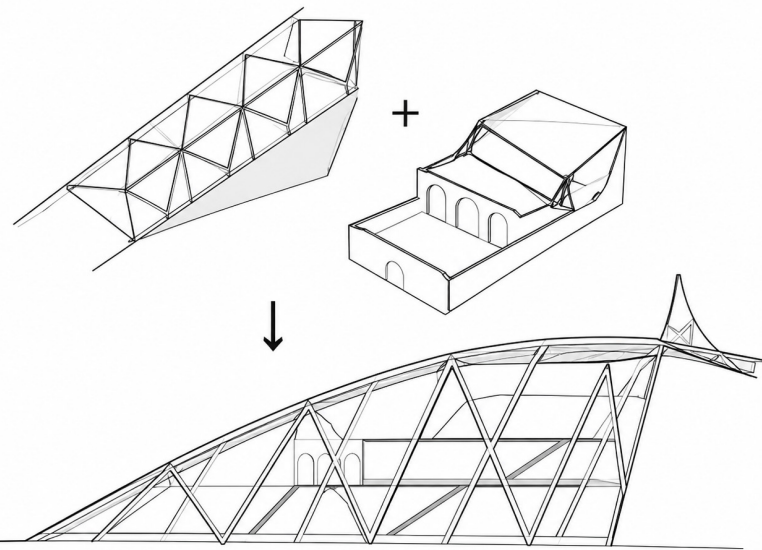


Figure 30: Double skin facade principle explained, the first facade is the bridge/building with the second facade in this structure climatised for the different functions.

Facade principles

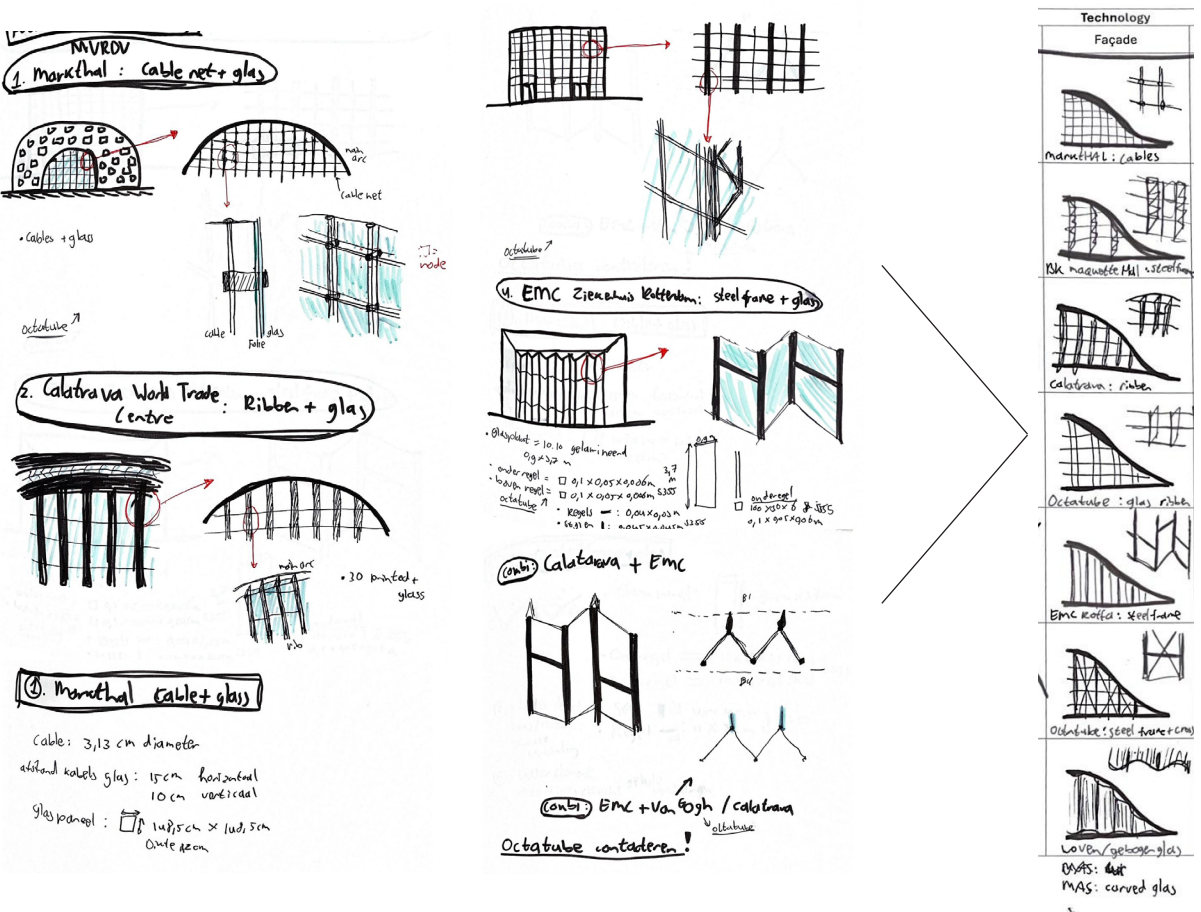


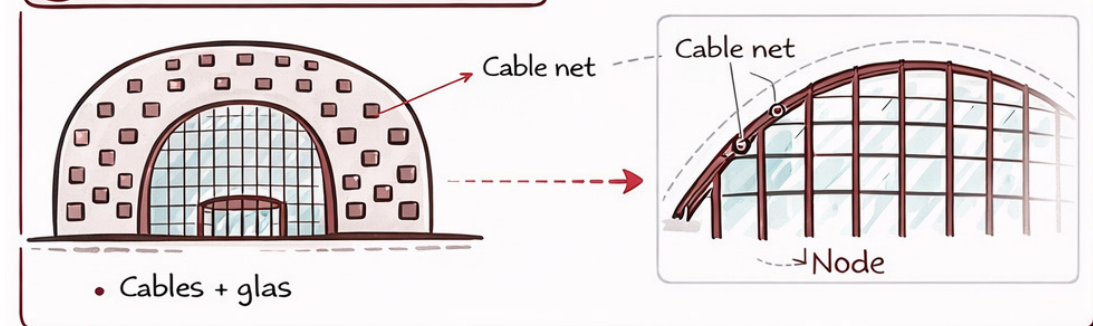
Figure 31: POM facade, researching the possible ways to make a transparent facade in the main archs.

From these, three options were selected and prototyped in model form:

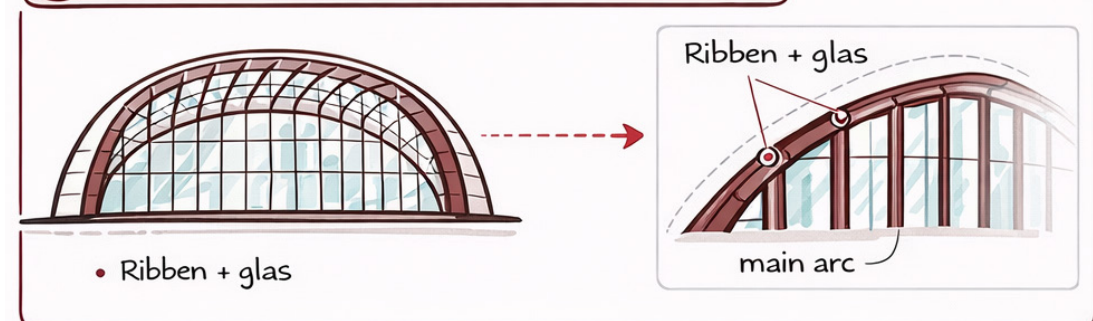
1. Markthal Rotterdam: cables and glass.
2. Calatrava World Trade Center: ribs with glass.
3. EMC Rotterdam: mullions with glass placed at a 45-degree angle.

Facade principles

1. Markthal : cable net + glas



2. Calatrava World Trade Centre : Ribben + glas



3. EMC Ziekenhuis Rotterdam : steel frame + glas

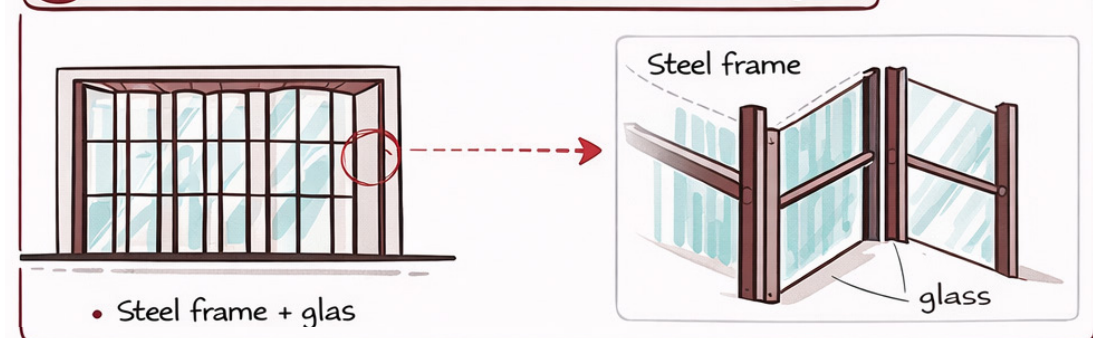
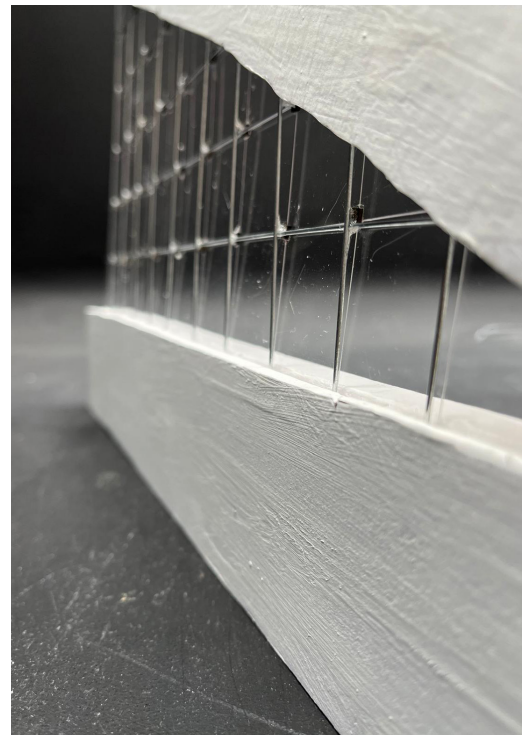
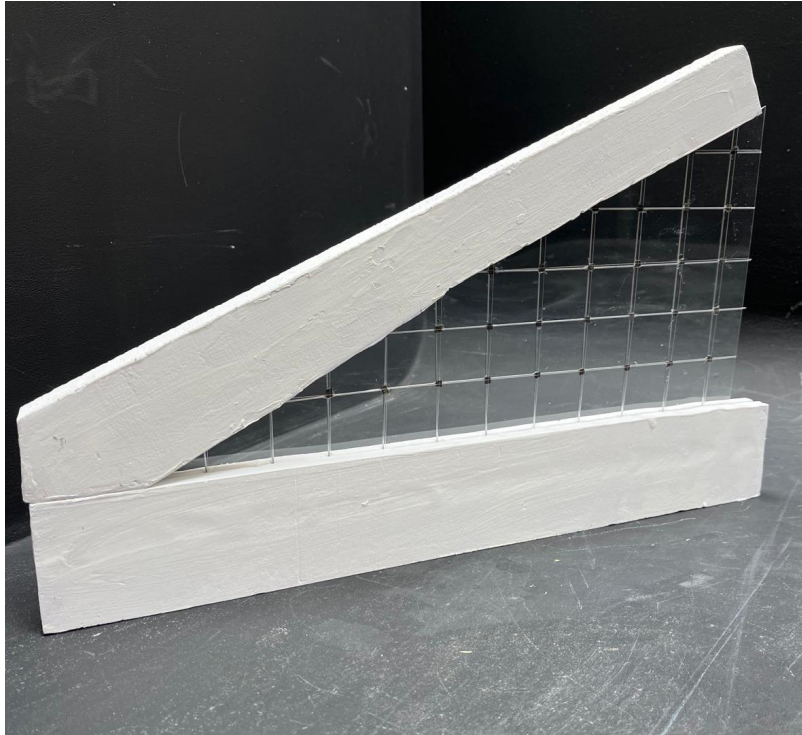


Figure 31: Selected facade principles for fysical modelmaking/prototyping.

Conclusion Facade Design

1. Markthal Rotterdam, MVRDV ←



2. World trade centre, Calatrava



3. EMC Rotterdam, Octocube ←



← Chosen facade principle between the arches: **1) Markthal**

- ✓ Maximal transparency
- ✓ Light structure and lacks structural expression
- ✓ Flexible design principle

← Chosen facade principle entrances: **3) EMC Rotterdam**

- ✓ Some transparency
- ✓ Light structure and lacks structural expression
- ✓ Interesting playfull facade to attract visitors

Figure 32: Fysical prototyping/ model making facade principles 1, 2, and 3.

Roof design

Moreover the roof also had to meet the same criteria, therefor it will consist of a three-layer ETFE system supported by a timber structure, distinguishing the new timber roof from the bridge's original donor steel structure.

The ETFE cushions include double shading elements for maximum solar protection from all directions, with flexible PV panels integrated at the centre to generate renewable electricity. The diagram alongside shows all components integrated into the design and original steel structure.

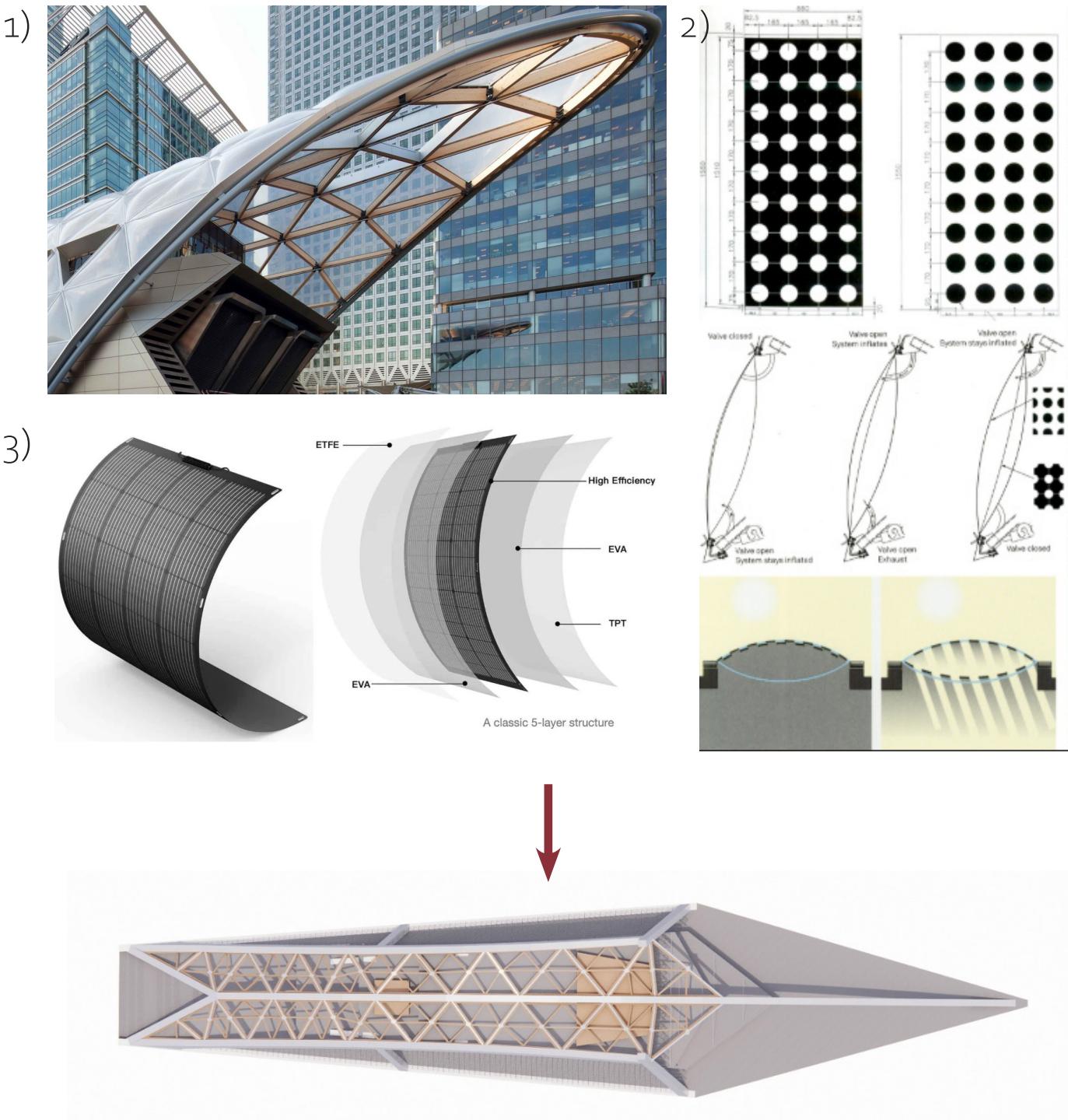


Figure 33: Roof design research: 1) Reference picture canary wharf station (Canary wharf station, n.d.)
2) EFTE 3 layers shading system (Saló, J. 2019)
3) PV panel in ETFE (Saló, J. 2019)

Climate design ~ SQ2 Building system

In parallel, the climate design (CD) was developed to define the main climate-related functions and systems of the culture centre. This scheme shows that the building will combine natural ventilation, an ETFE roof with PV and shading functions, a glass façade with solar control foil, and systems such as a heat pump.

In this way, the technological studies not only addressed the structural translation of the bridge, but also began to define the environmental and climatic performance of the future building.

Conclusion climate design

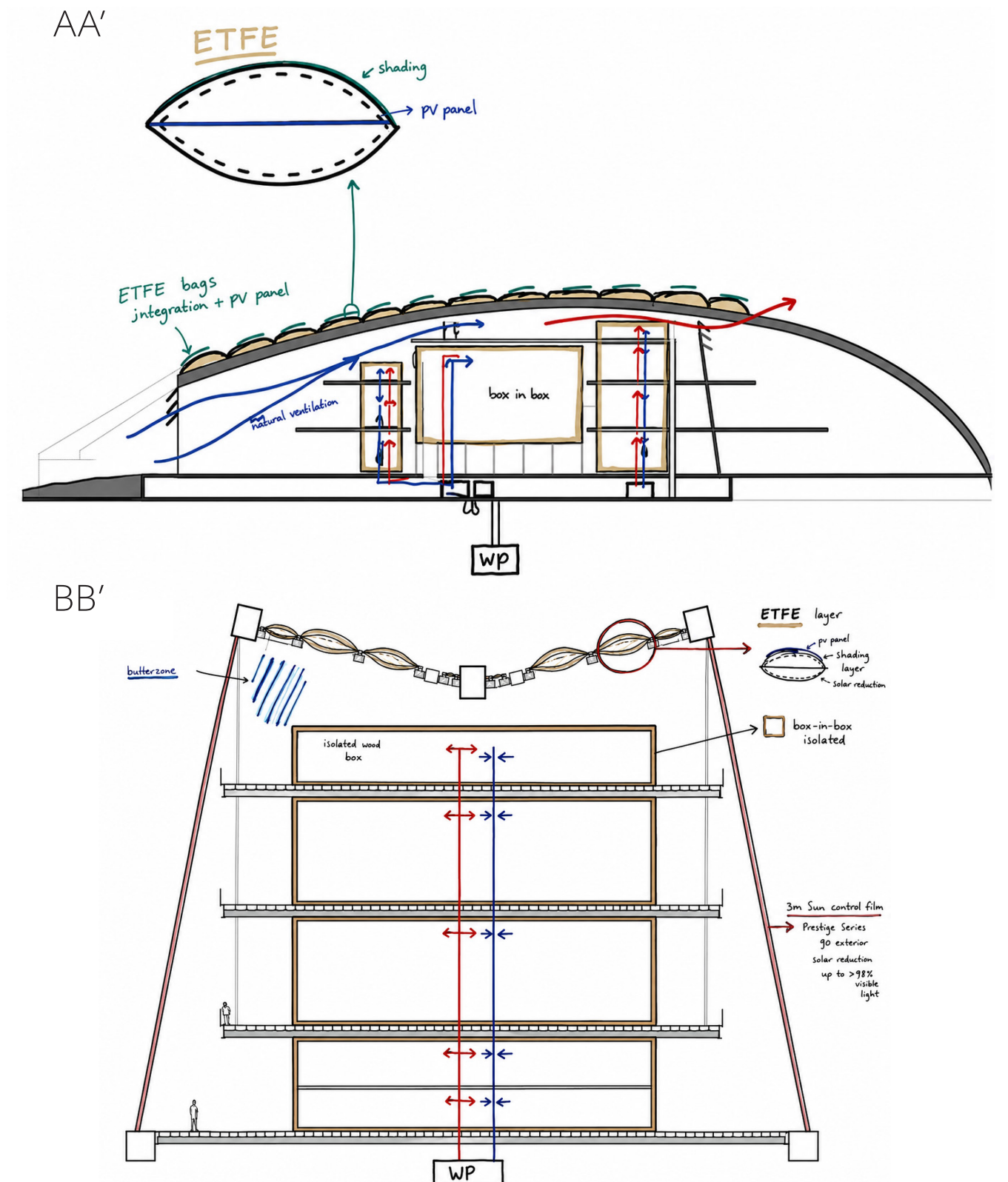


Figure 34: Climate design research in section AA' and BB'.

3.1.2 Context Research

Site analysis ~ SQ4 context & history

As outlined in the scope, the project is situated in Eindhoven because of its strong industrial character and the relative lack of a clearly defined cultural centre within the city. More specifically, the project is located at De Caai / De Kade, an area that is currently undergoing major transformation (Figure 35).

The municipality of Eindhoven has developed a broader urban vision and several spatial plans for this area, aimed at transforming it into a new lively urban district along the canal (Figure 36).

These plans show an ambition for a more car-free environment, increased green space, and the creation of a new vibrant urban centre with a new bridge over the canal. Since a large number of new housing developments are being realised in De Caai, while space for culture remains limited, the introduction of a culture centre fits well within this broader urban narrative.

In addition, the insertion of a bridge-based building on this site could strengthen the cycling route towards the station by creating a more direct connection.

Eindhoven, De Kade location

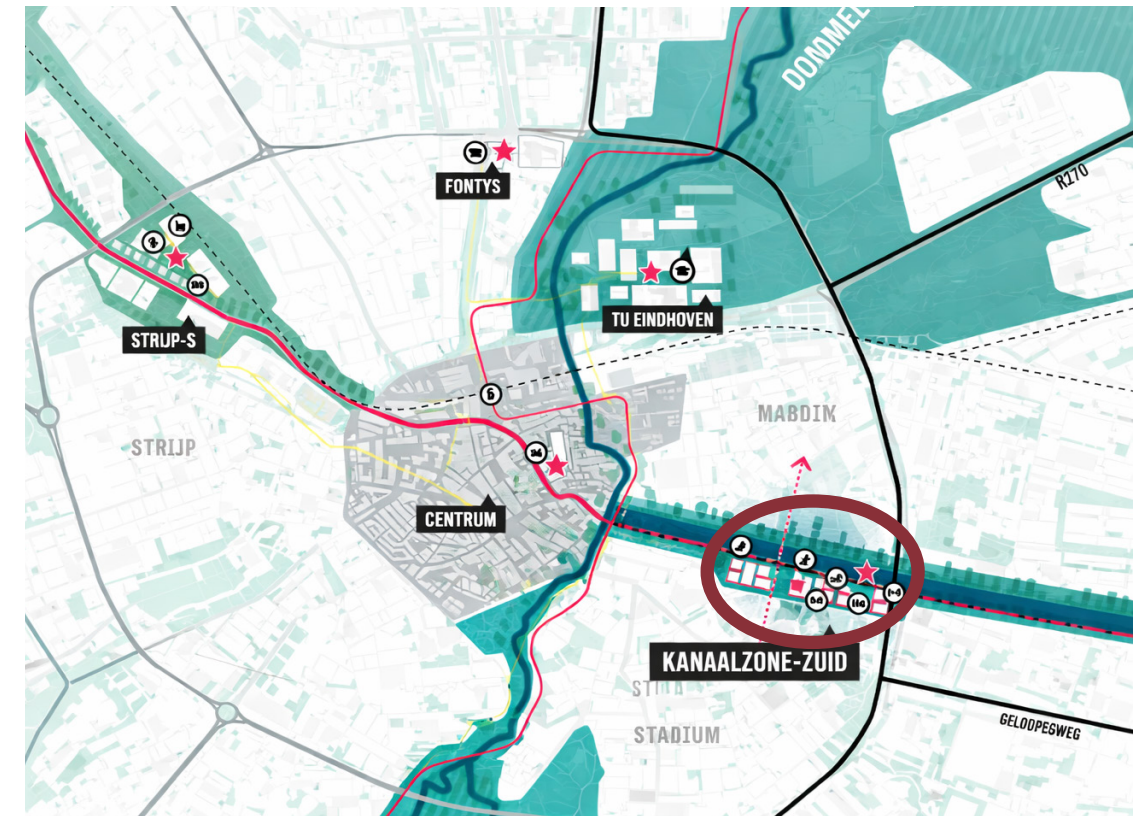


Figure 35: Urban plan and vision municipality of Eindhoven with focus on the Kade district (Gemeente Eindhoven, 2024/2025).

De Kade master plan

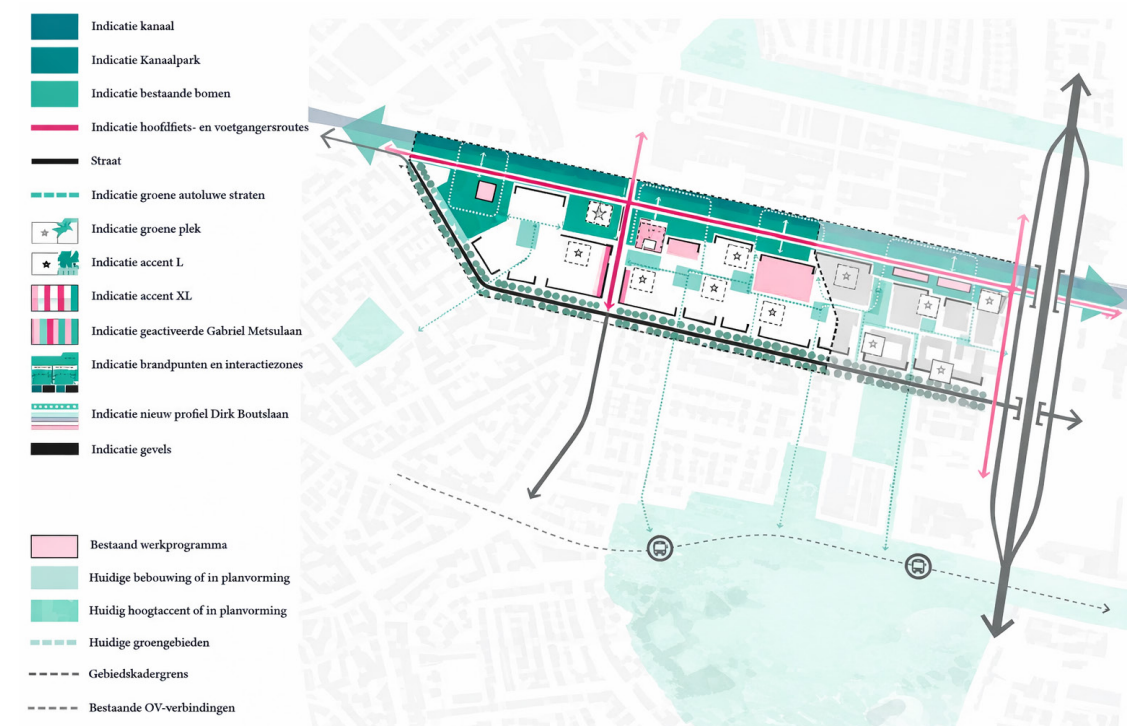
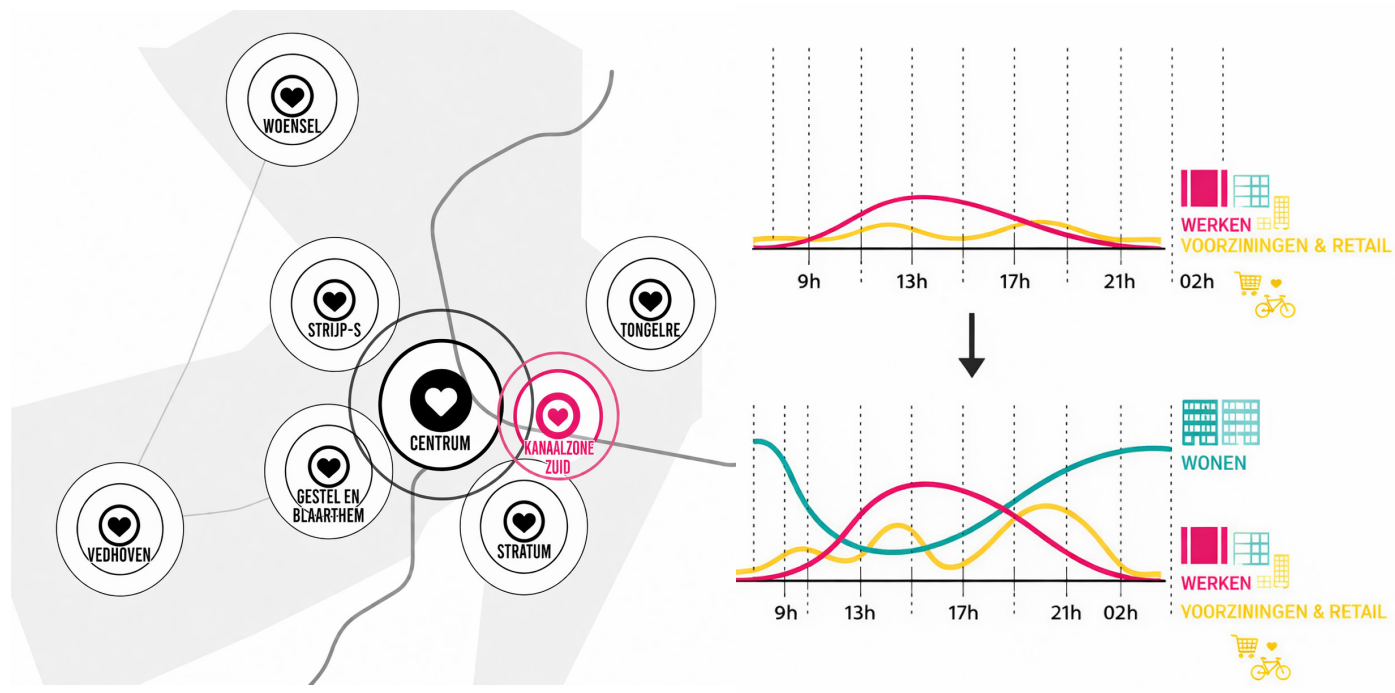
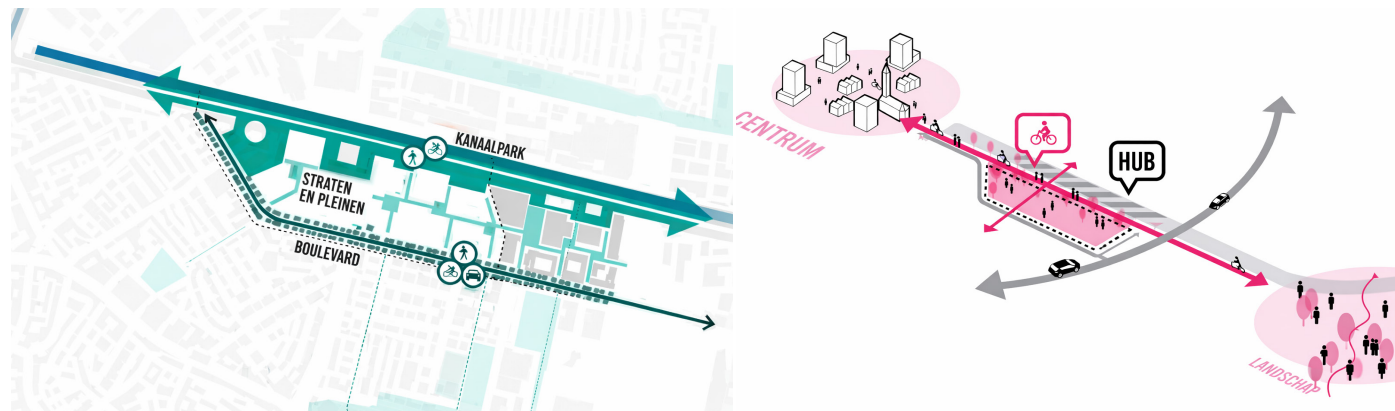


Figure 36: Final vision drawing of De Kade district (Gemeente Eindhoven, 2024/2025).

Analysing De Kade



New active centre -> active program



Car free zone, more green & new HUB

Figure 37: Master plan schematic diagrams of De Kade district (Gemeente Eindhoven, 2024/2025).

Location excursion

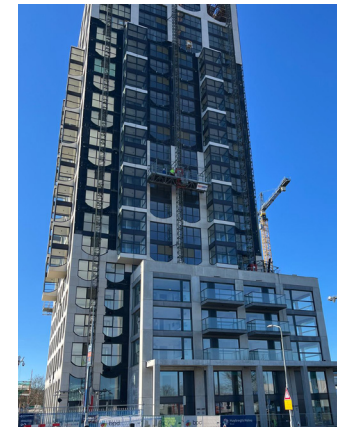


Figure 38: Pictures made of important elements of De Kade during the location excursion in Eindhoven (made by K.M van Rooij)

Form language De Kade/ old Campina factory

During this analysis, several contextual qualities stood out. Most importantly, the arch forms and the rhythmic repetition of the former industrial halls of the Campina factory were identified as essential spatial characteristics of the site and its history. These qualities were implemented in the structural design in order to create a stronger connection with the location and its industrial past.

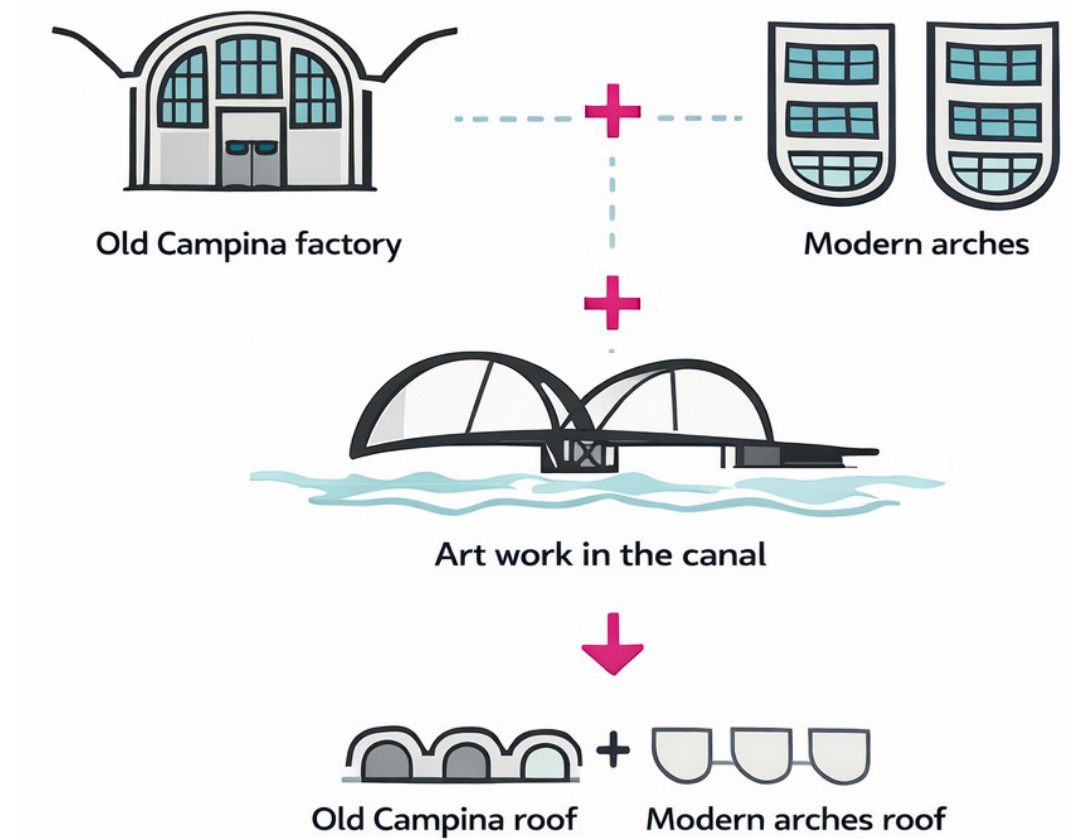


Figure 39: Important form language principles of De kade and Old campina factory.

Conclusion site analysis

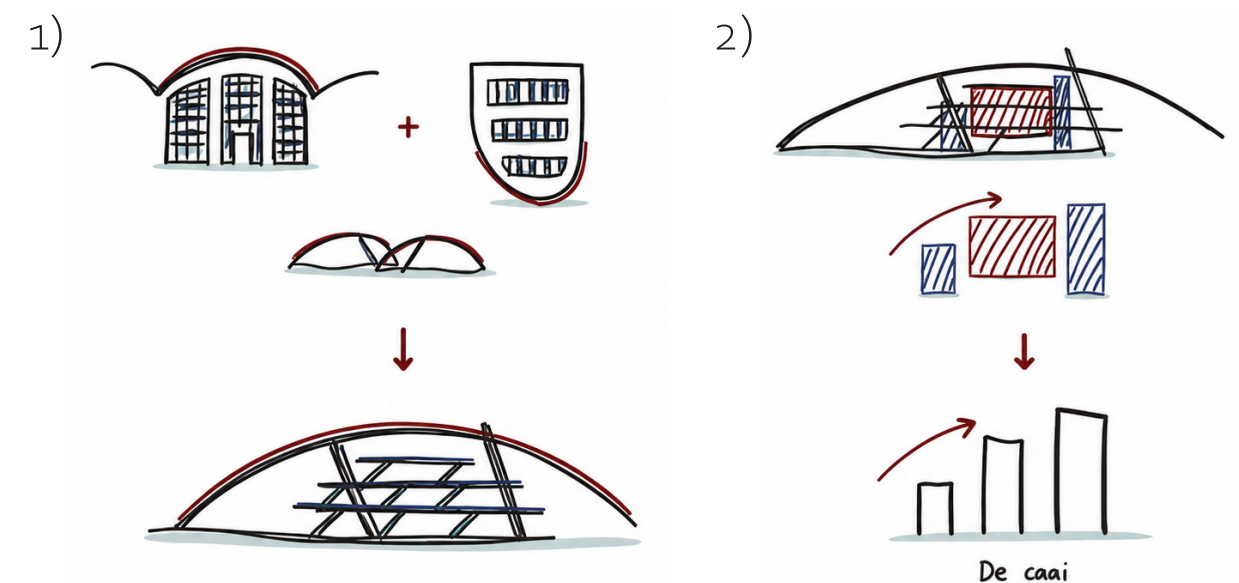


Figure 40: Conclusion site analysis:
1) Form language location implemente in structural design
2) De Caai's rising heights are reflected in the stepped interior of the design

Urban integration ~ SQ4 context & history

The location excursion and site analysis made it clear that the initial placement of the building needed to be reconsidered in order to establish a stronger relationship between the bridge, De Caai, and the route towards the station.



Figure 41: Switch in location of the culture centre after the excursion.

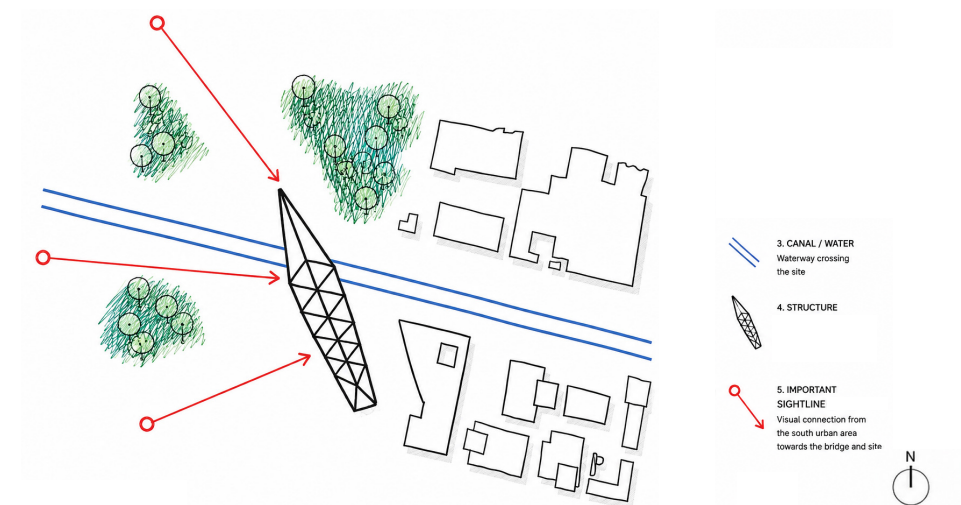


Figure 42: Sightlines analysis of the culture centre in De Kade.

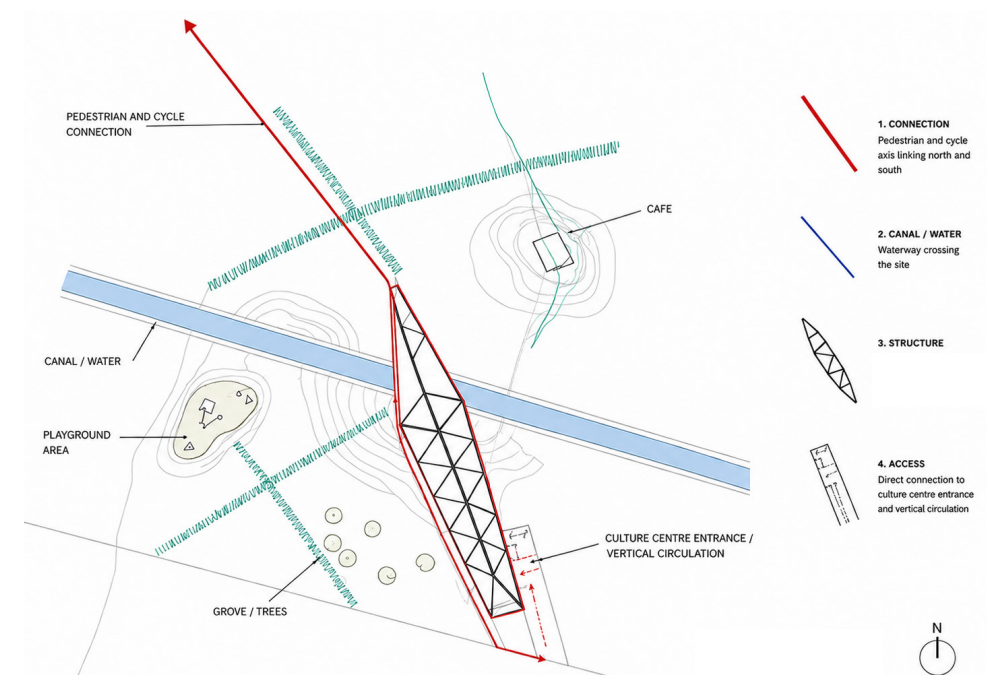


Figure 43: First set up urban integration and design of the culture centre in De Kade area.

Key findings urban integration

The final placement of the building was therefore determined in such a way that it creates a direct spatial connection between the station and De Caai. At the same time, the architectural language of the design was adjusted to better relate to the existing context through the use of the arch and an emphasis on rhythm.

In its final composition, the bridge also establishes a stepped relationship with De Caai (see Figure 44 1.): while the bridge structure reaches a height of approximately 40 metres, the adjacent tower volumes rise gradually from 45 metres to 75 metres. This stepped height transition contributes to a more careful integration of the landmark within the surrounding urban context, while maintaining the visibility and significance of the culture centre as both a public building and a landmark in its own right.

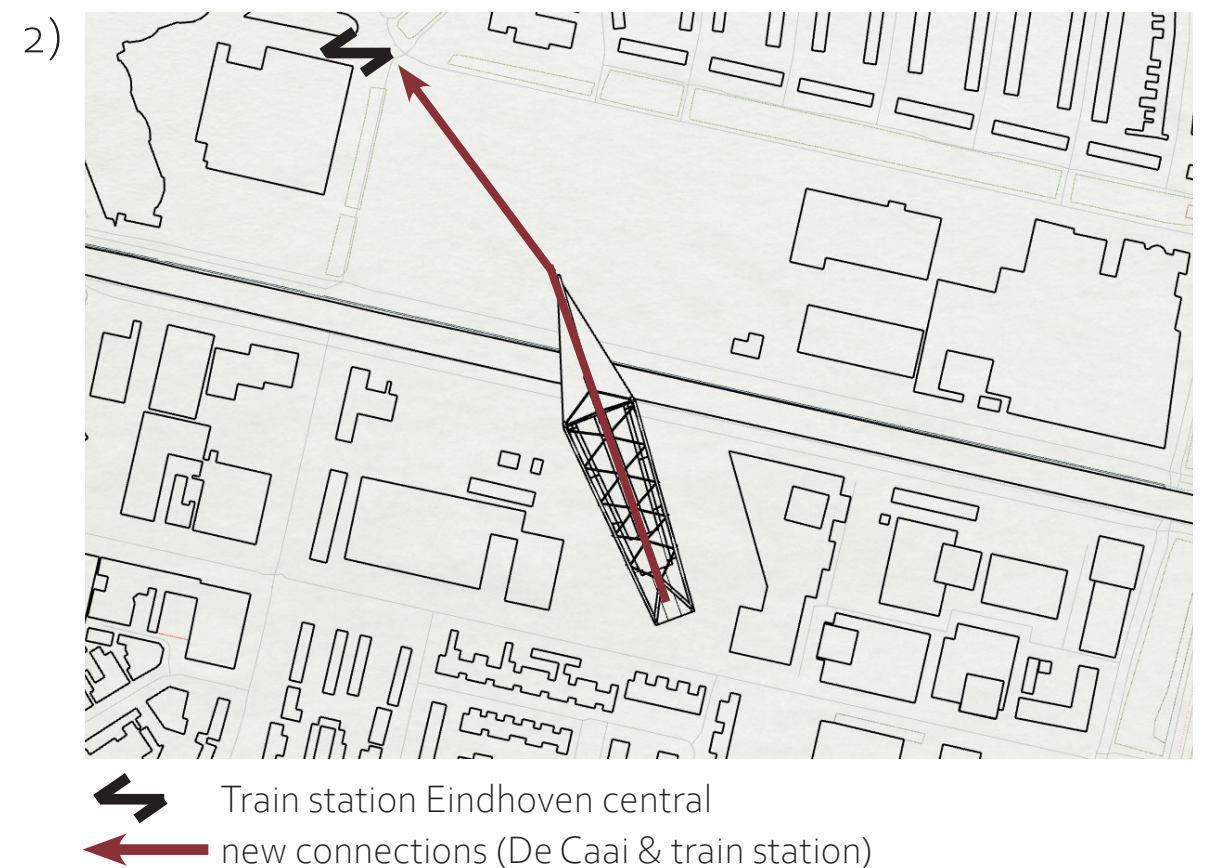
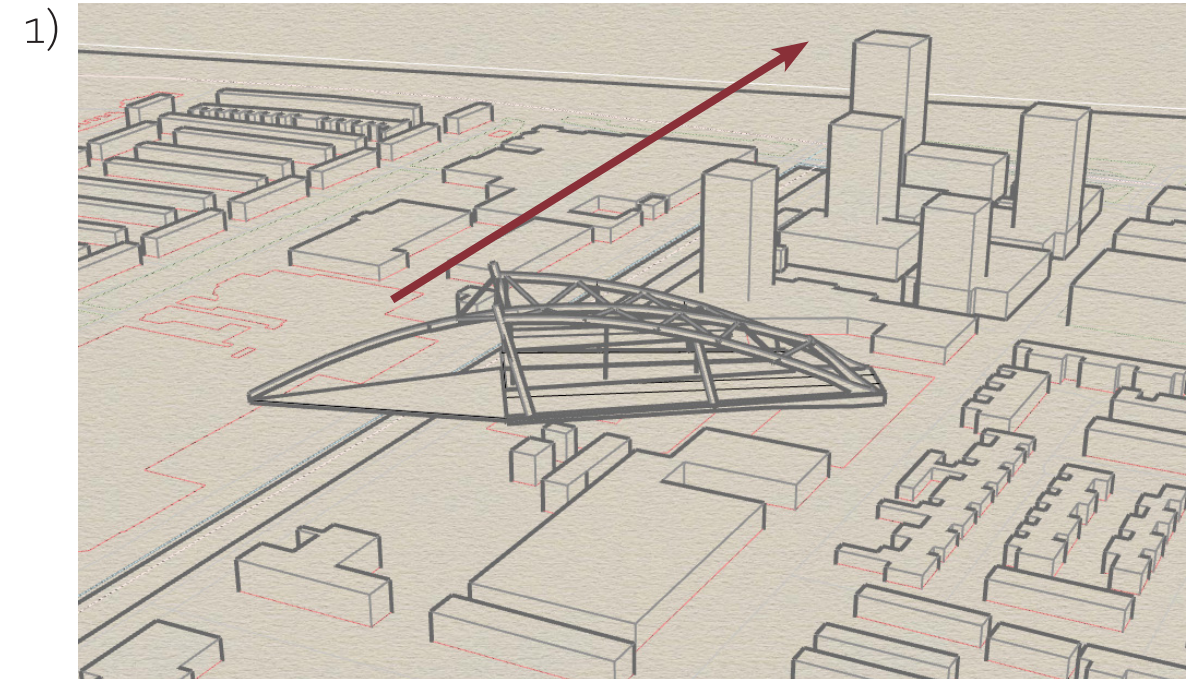


Figure 44: Conclusion urban integration:

- 1) Relationship De Caai and culture centre in heights by stepping transition
- 2) Relation culture centre with the train station by forming a route over the canal



Figure 45: Conclusion urban integration with the master plan for the park around the culture centre.

3.1.3 Program research

Programm of requirement (PvE) ~ SQ3 Programm & spatial organisation

As defined in the scope, the starting point for the Program layer was the development of a culture centre for De Kade. From this broader ambition, the programme was gradually specified in more detail. The first step was to study reference projects as the A-factory in Amster dam in order to understand the approximate floor areas, spatial requirements, and functional relationships of comparable cultural buildings. Based on this research, the programme was organised into the following main clusters:

- Theatre / stage and performing arts
- Museum
- Music school
- Hospitality
- General foyer
- Technical spaces and offices
- Restaurant / event venue

For each of these clusters, the required spaces, performance criteria, and desired qualities were studied in detail. This resulted in a more general Programme of Requirements (PvE) in which all clusters and functions were defined and structured. This overview clarified not only the quantitative requirements of the programme, but also the spatial and functional conditions necessary for the different parts of the culture centre.

Inventarization PvE

Hoofdfunctie	Subfunctie	Oppervlakte (m² BVO)	Opmerkingen
Publieke entreezone	Entreehal / ontvangst	800	Hoofdoriëntatiepunt van het gebouw
	Ticketing / infobalie	100	Nabij entree
	Garderobe / lockers	150	Voor museum en zaal
	Algemene foyer / verblijfsruimte	900	Centrale ontmoetingsruimte
	Museumshop / designshop	250	In relatie tot entree en museum
	Publiek sanitair	200	Verspreid of centraal
	Verticale circulatie / verkeersruimte	600	Liften, trappen, routing
Subtotaal		3.000	
Horeca	Café / restaurant	700	Ook zelfstandig te gebruiken
	Bar / uitgifte	100	Aan foyer gekoppeld
	Keuken	250	Professionele horeca-opzet
	Opslag / koeling	120	Back-of-house
	Afwas / spoelkeuken	80	Logistiek gescheiden
	Personeelsruimte horeca	50	
	Interne verkeersruimte	200	
Subtotaal		1.500	
Museum en expositie	Permanente expositie	3.000	Flexibel indeelbaar
	Tijdelijke expositie	2.500	Wisselende tentoonstellingen
	Projectruimte / experimentele expo	800	Voor hedendaagse installaties
	Multimedia / immersive room	400	Zwarte doos
	Introductieruimte	250	Begin bezoekersroute
	Educatieve expositieruimte	300	Voor scholen / workshops
	Ondersteunende opslag / techniek / beveiliging	750	Achter de schermen
Subtotaal		8.000	
Theather grote concertaal	Grote zaal / publieksruimte	2.000	ca. 1.200–1.800 bezoekers, afhankelijk van opzet
	Podium	500	Groot podium met flexibele inzet
	Backstage / artiesten	300	Inclusief artiestenverblijf
	Kleedkamers	200	Groepen + solisten
	Techniek / regie	250	Licht, geluid, AV
	Instrumenten / opslag	250	Tijdelijke opslag
	Laden en lossen	250	Directe logistieke aansluiting
	Foyer voor concertaal	500	Voor pauzes en ontvangst
	Sanitair / verkeersruimte	250	
Subtotaal		4.500 m²	
Podiumkunsten	Grote theater-/concertzaal	1.600	Ca. 600–900 zitplaatsen
	Podium + zijtoneel	700	Voor flexibele programmering
	Backstage / laden en lossen	500	Direct gekoppeld aan podium
	Kleedkamers	250	Artiesten
	Green room / artiestenverblijf	150	
	Regie / techniek	250	Licht, geluid, controle
	Decor- en instrumentopslag	400	
	Zaalfoyer	700	Voor pauzes en publieksontvangst
	Sanitair / verkeersruimte	450	
Subtotaal		5.000	
Muziekruimtes	Kleine oefenruimtes	350	10 stuks à ca. 35 m²
	Middelgrote oefenruimtes	360	6 stuks à ca. 60 m²
	Grote ensemble ruimtes	360	3 stuks à ca. 120 m²
	Opramestudio / control room	180	
	Instrumentenopslag	150	
	Docenten / begeleiding	120	
	Informeel verblijf	180	Ontmoeting / wachten
	Verkeersruimte / buffers / techniek	800	Akoestische tussenlaag
Subtotaal		2.500	
Kunstworkshops	Grote workshopruimtes	600	4 stuks à ca. 150 m²
	Middelgrote ateliers	360	4 stuks à ca. 90 m²
	Specialistische maakruimtes	300	Keramiek, textiel, grafiek
	Materiaalopslag	150	
	Docenten / voorbereiding	100	
	Presentatie / critique ruimte	140	
	Verkeersruimte / spoelzones / techniek	350	
Subtotaal		2.000	
Educatie / community	Lesruimtes	320	4 stuks
	Seminar rooms	240	4 stuks
	Kleine lezingzaal	300	Voor debat, film, college
	Community rooms / buurtkamers	250	Publieke gebruiksfunctie
	Opslag / pantry / verkeersruimte	390	
Subtotaal		1.500	
Kantoren en organisatie	Open werkplekken	800	Museum, productie, staf
	Vergaderruimtes	250	
	Directie / overleg	150	
	Pantry / personeel	150	
	Ondersteunende kantoorfuncties	200	Print, archief, administratie
	Beveiliging / control room	250	Centrale monitoring
Subtotaal		1.800	
Techniek en ondersteuning	Installatieruimtes	1.600	Klimaat, lucht, elektra
	Algemene opslag	500	
	Schoonmaak / facility	150	
	Afval / logistiek	200	
	Technische werkruimtes	250	
Subtotaal		2.700	
Restaurant/ Event location	Restaurant zitgedeelte	500	Zelfstandig exploitabel
	Bar / ontvangst	100	
	Keuken	250	Volwaardige horecakeuken
	Opslag / koeling	120	
	Afwas / back of house	80	
	Personeelsruimte	50	
	Verkeersruimte / sanitair	100	
Subtotaal		1.200 m²	

Categorie	Totaal (m² BVO)	Natuurlijk daglicht	Plek	zichtlijnen/ uitzicht
Publieke entreezone	3.000	Ja	BG	Ja
Horeca	1.500	Ja	BG	Half
Museum en expositie	8.000	Nee	BG/ 1	Nee
Podiumkunsten kleine zaal	5.000	Nee	1 of 2	Nee
Podiumkunsten grote zaal	4.500	Nee	1 of 2	Nee
Muziekruimtes	2.500	Ja	-	Half
Kunstworkshops	2.000	Ja	-	Half
Educatie / community	1.500	Half	-	Nee
Kantoren	1.800	Half	-	Half
Techniek / ondersteuning	2.700	Nee	kelder dak	Nee
Restaurant/ event locatie	1200	Ja		Ja
Totaal	33.700 m²			
Functioncluster	Moet direct naast	Liefst dichtbij	Liever gescheiden van	
Publieke plint	Entree; foyer; ticketing; garderobe; café; restaurant; museumshop	Museum; community; parkeren	Laad- en loszone; backstage; afval	
Museum & expositie	Permanente expo; tijdelijke expo; intro; educatieve expo	Foyer; workshops; filmzaal	Muziek; concertaal; loading	
Podium	Theater; concertaal; podium; backstage; kleedkamers; opslag	Restaurant; parkeren; techniek	Museumzalen; stille leerplekken	
Muziek	Oefenruimtes; studio; instrumentenopslag	Podium; educatie	Museum; restaurant	
Workshops & educatie	Workshops; ateliers; lesruimtes; seminar rooms	Expo; foyer; community	Backstage; zware logistiek	
Kantoren & support	Werkplekken; vergader; directie; pantry	Beveiliging; servicekern	Drukke foyer; oefenruimtes	
Mobiliteit	Parkeren; fietsparkeren; kiss & ride	Entree; avondentree	Expositie; logistieke achterzijde	

Figure 46: Inventariation Programm of requirements of each function

Spatial organisation~ SQ3 Programm & spatial organisation

Following this analytical phase, the programme was further explored through physical prototyping and model making.

The first step in this process focused on the theatre hall, since this function was considered the most spatially determinant for the organisation of the other programme components. Four different theatre typologies were therefore developed and tested. These options are shown alongside the design study and formed the basis for the next phase of programme exploration.

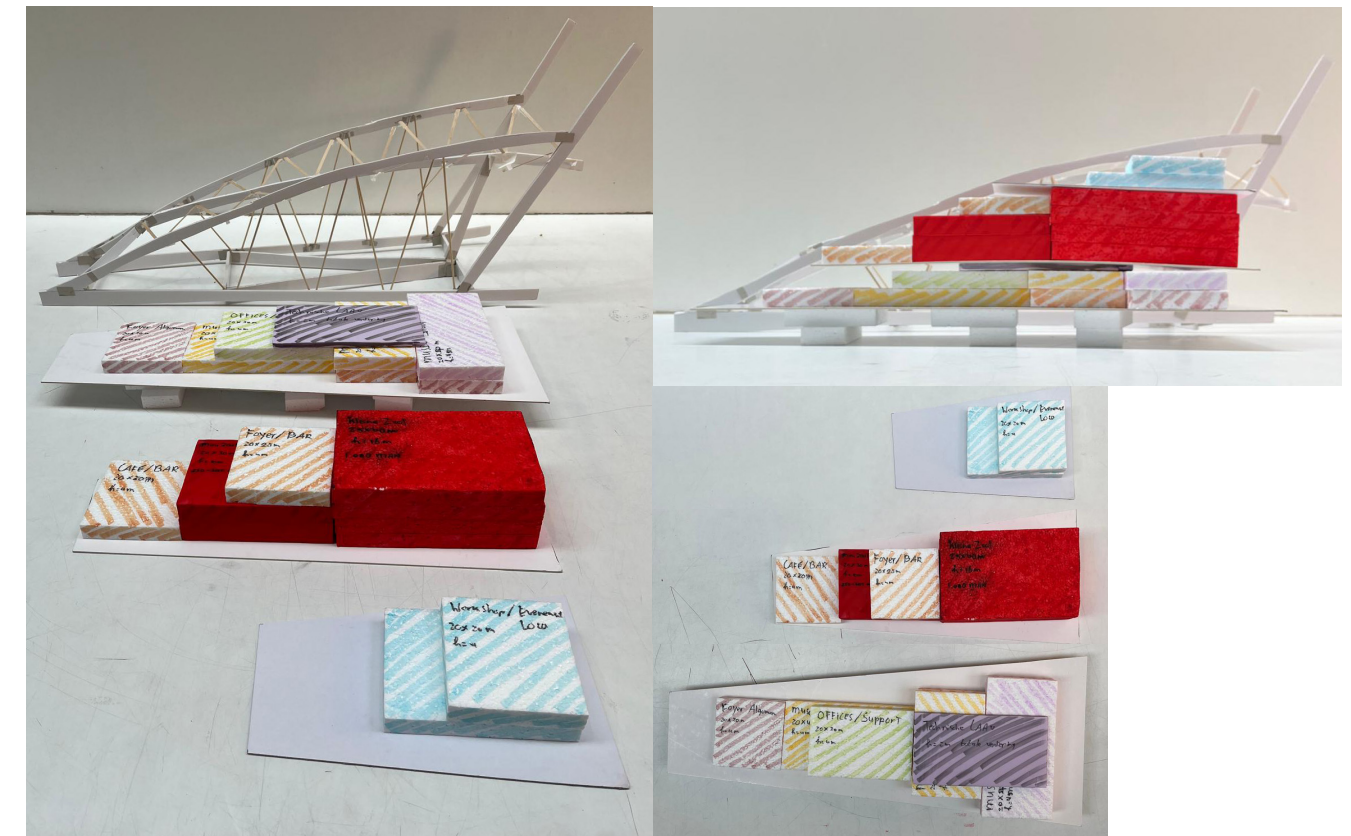
Subsequently, the different clusters and functions were tested in relation to the deck system of the bridge-derived structure. Through this process, multiple spatial configurations were explored to determine how the programme could be organised within the architectural and structural logic of the bridge.

This resulted in five different configuration options, each with its own advantages and disadvantages. These were evaluated in relation to the bridge form, the structural system, and the internal organisation of the building.

Options 1, 2, and 3 are characterised by the presence of central decks, as illustrated in the design studies. In these configurations, the primary circulation is organised around the decks, positioned along the façade. This spatial arrangement allows for visual connections towards the roof, enabling users to experience the main structural system of the building from within.

In contrast, options 4 and 5 are based on a central street typology, where circulation is located in the middle of the building. This organisation results in two side decks distributed across different levels. The main advantages of this configuration is the strong vertical visual connection to the roof, which enhances the presence of natural light within the interior. However, this layout also leads to relatively narrow deck widths, which makes it more challenging to accommodate larger programme elements, such as the theatre halls.

Option 1:



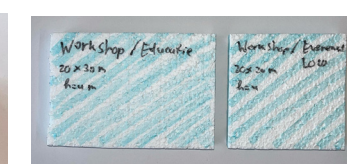
BG



1ste



2de



BG: public layer
1ste: Theater layer (private)
2de: public-private

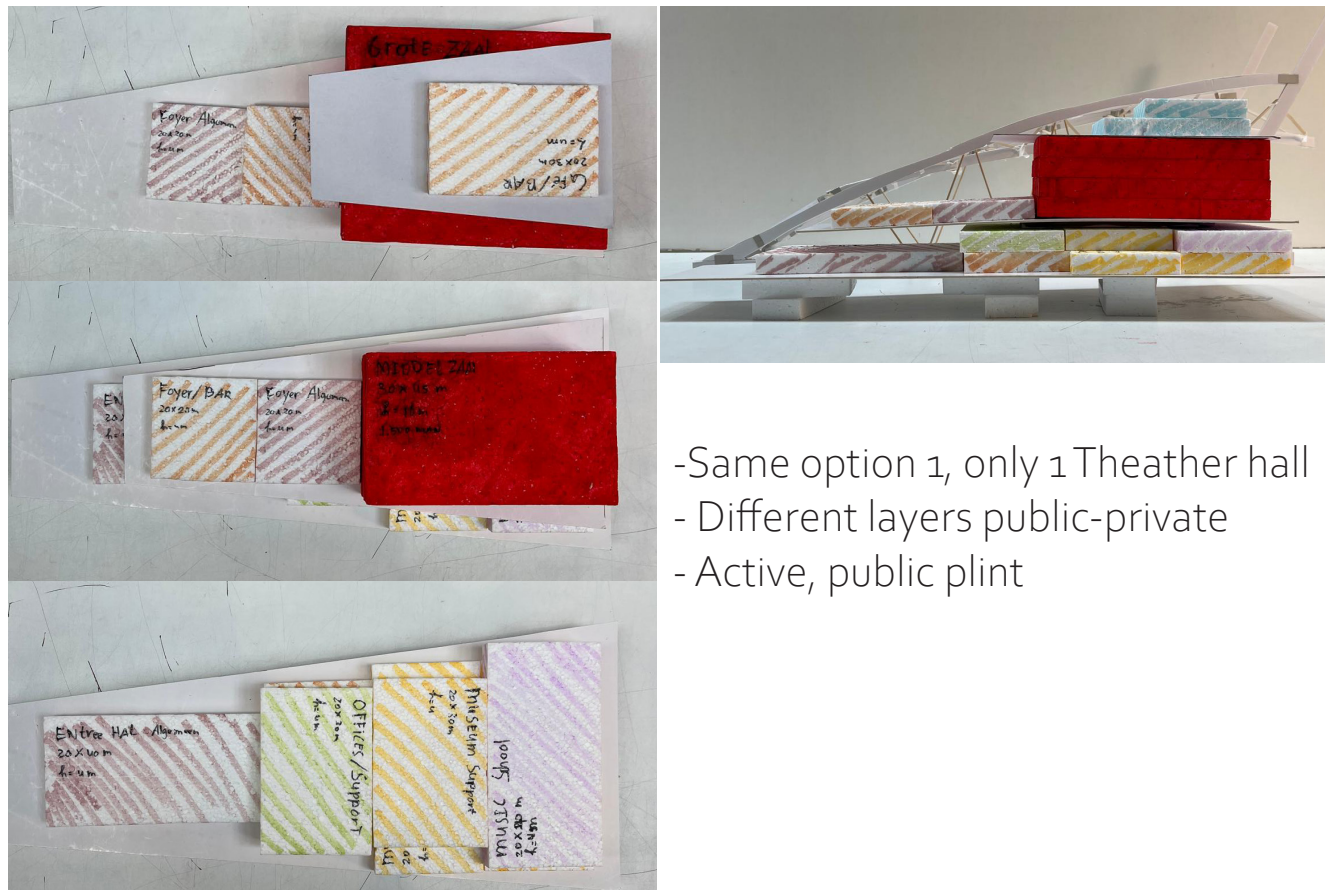
- Workst good with the form of the bridge
- Different layers public-private
- Active public plint with routing

Prototyping Spatial organisation

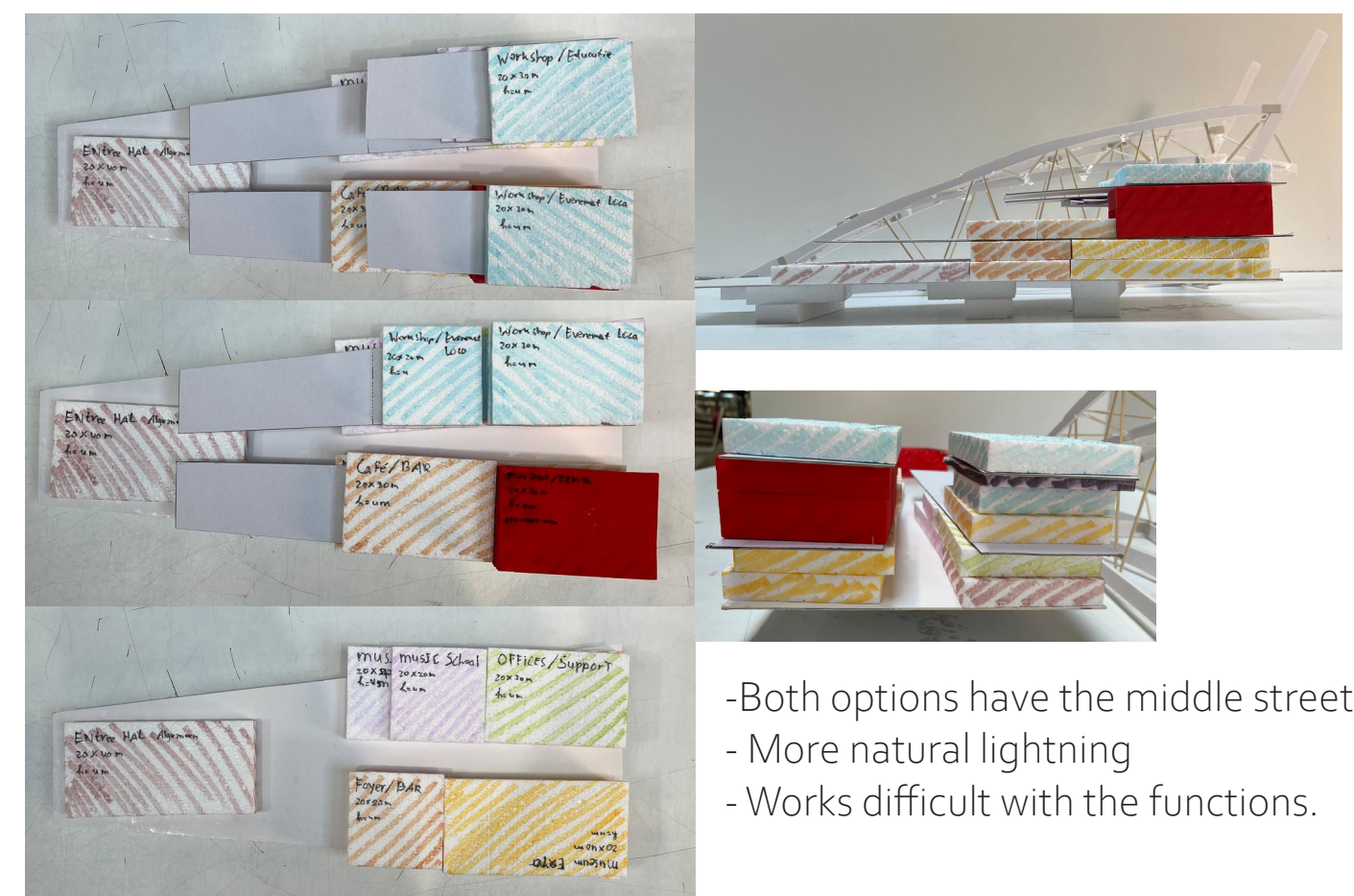
Option 2:



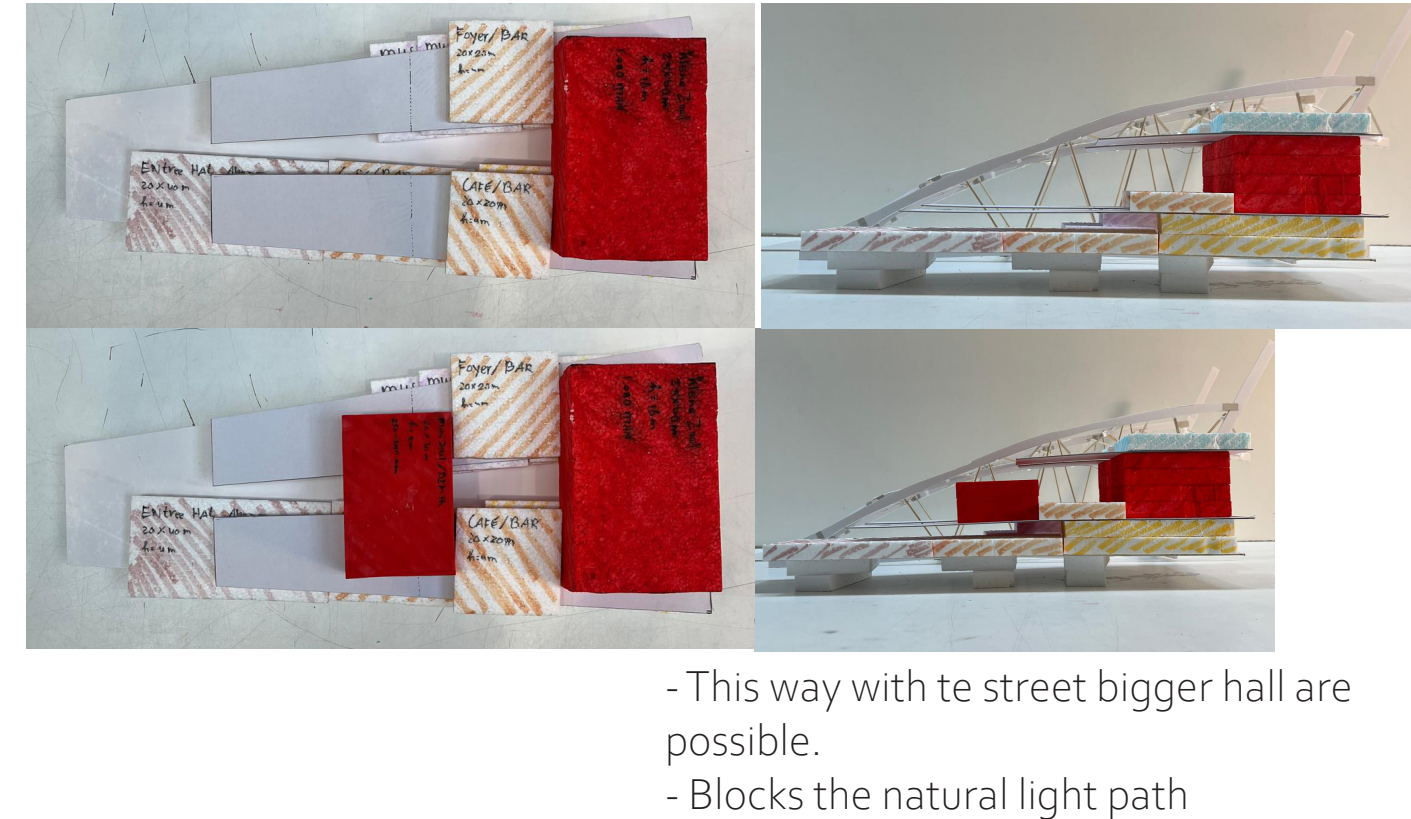
Option 3:



Option 4:



Option 5:



Conclusion Spatial organisation

From this comparison, several options proved more successful than others. Finally, an combination between Option 1,2 and 3 emerged as the strongest solutions, as it worked best in relation to the form of the bridge and its structural logic.

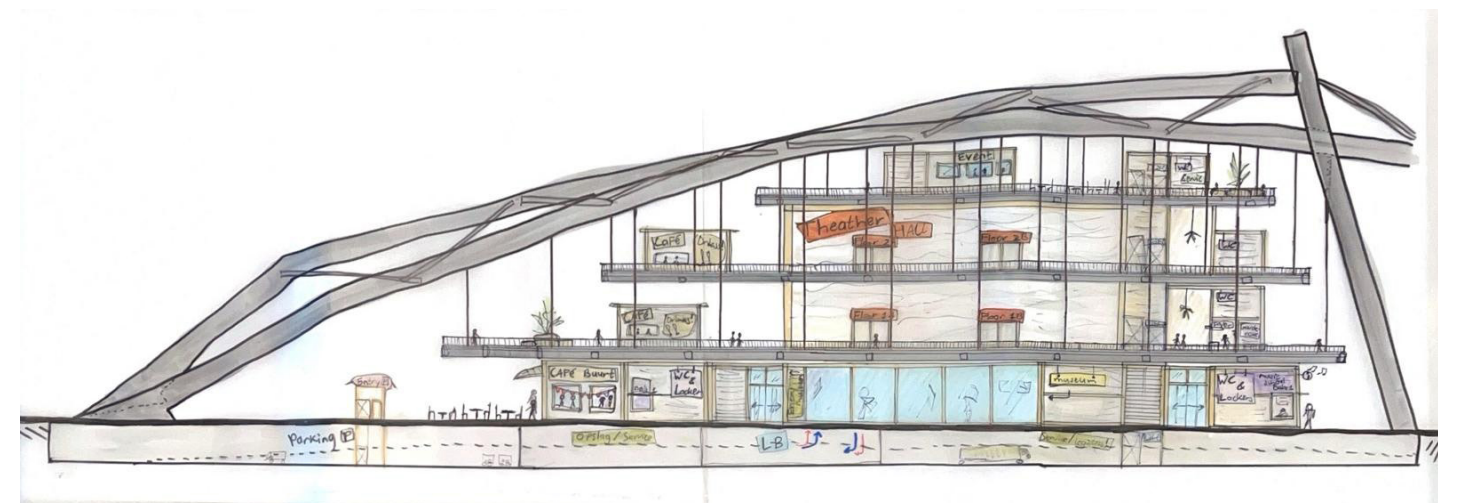
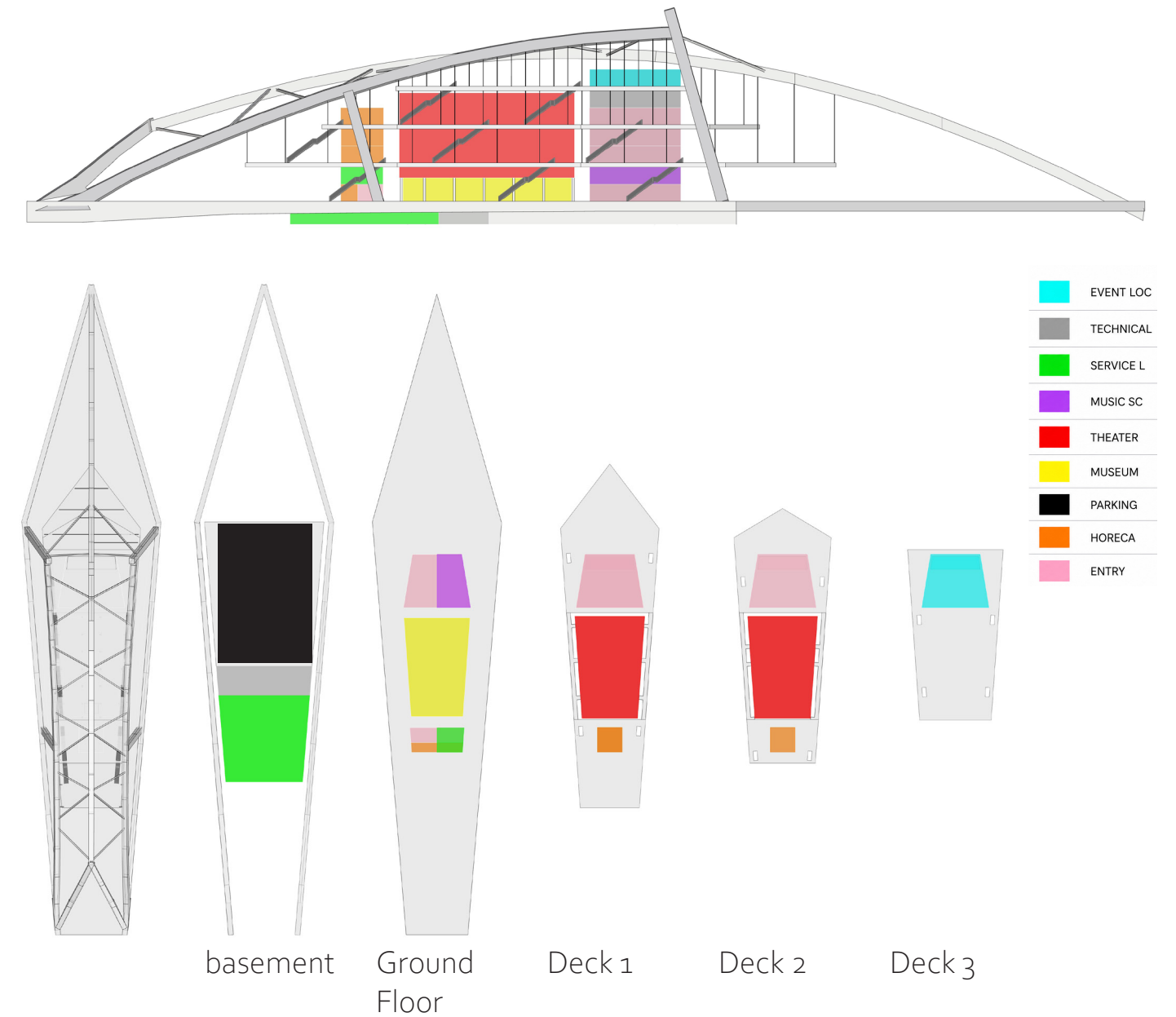


Figure 47: Conclusion spatial organisation of all the functions in the programm of requirements.

3.1 Design results (Final Design)

Urban scale ~ Site model

The final placement creates a direct spatial link between the station and De Caai. By using the arch and its rhythm, the design connects to the surrounding context. Its height also steps up from the 40 m bridge structure to towers of 45–75 m, integrating the landmark into the urban setting while keeping the culture centre visible and recognisable.

The surrounding park adds green space, seating areas and biodiversity, forming a museum park for De Caai and its neighbourhood. The canal is also integrated into the plan, becoming a connector between both banks instead of a barrier.

In addition, through the landscape height differences, the building appears embedded in its surroundings, further integrating the reused Van Brienoord Bridge elements into the park (see Figure 49).

Urban site model

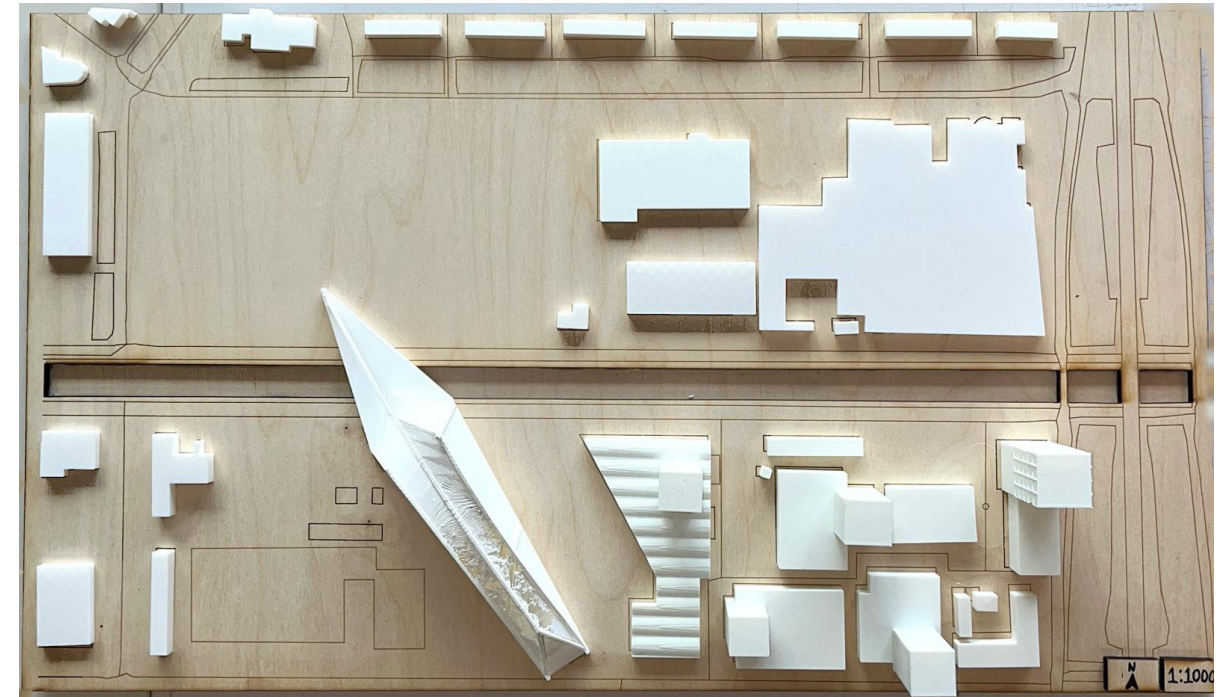
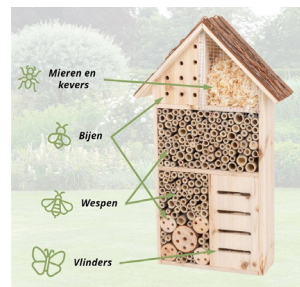


Figure 48: Urban site model 1:1000 De kade area and the integrated culture centre. (not yet done)

Situation map

Insect hotels



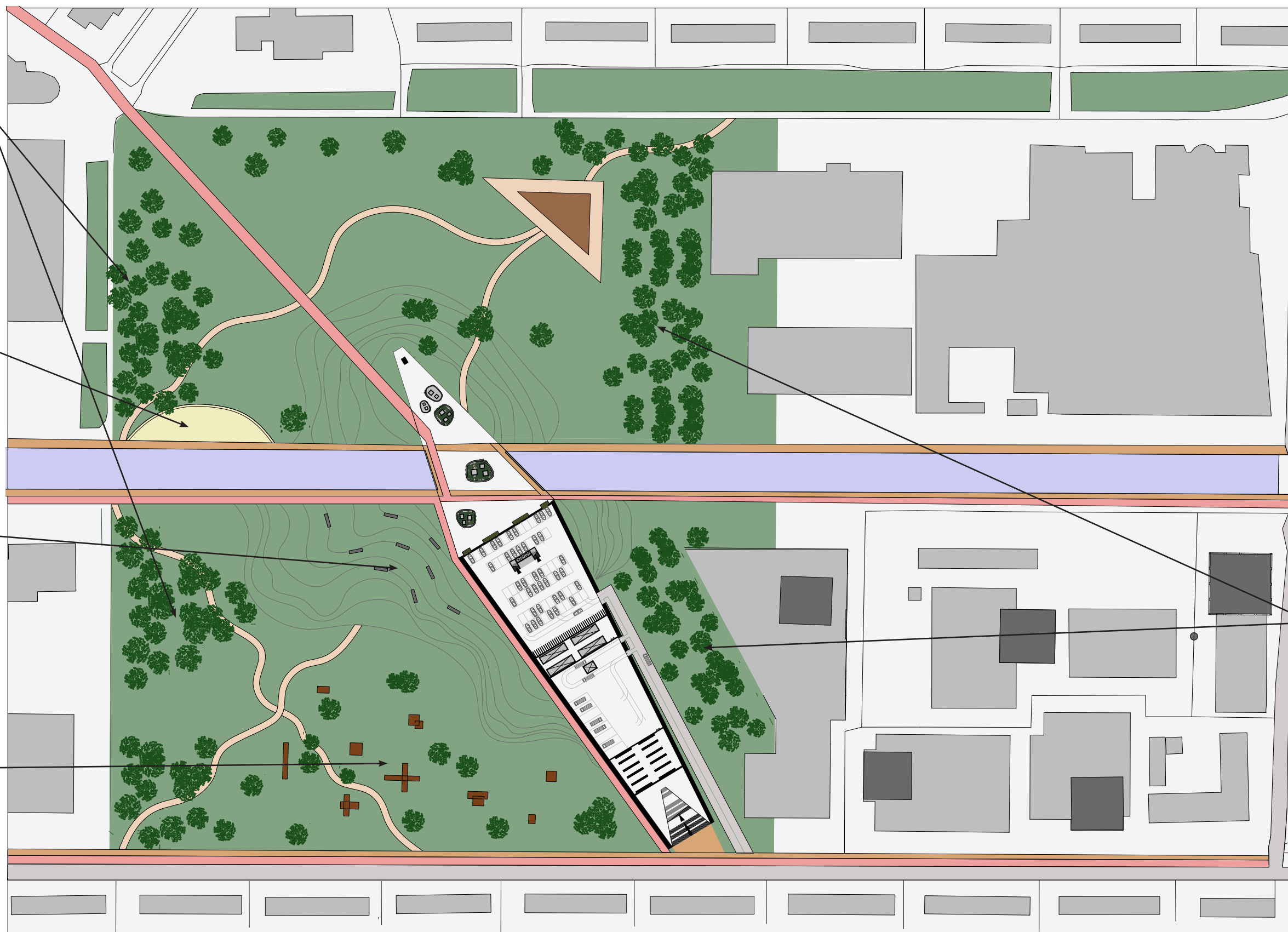
Beach place



Hill with benches



Museum park



locatie map

- gras
- gebouwen
- straat
- heuvel
- water
- cafe
- torens

hoofd voetgangers

- voetgangers
- bomen
- fiets
- kunst park
- strand

Wadi's

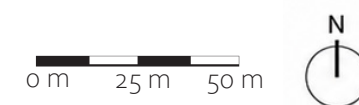
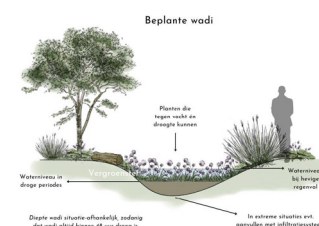


Figure 49: Situation map of the Culture centre in Eindhoven de Kade 1:1000.

Structural design

Building scale ~ Structural design

The structural design is developed in six steps (Figure 50), as illustrated alongside and explained in more detail on the following page. The final design retains the bridge's structural logic and form language by using half of the original bridge length. This approach creates a strong superstructure while preserving the identity of the bridge and responding to the historical and spatial context of the site.

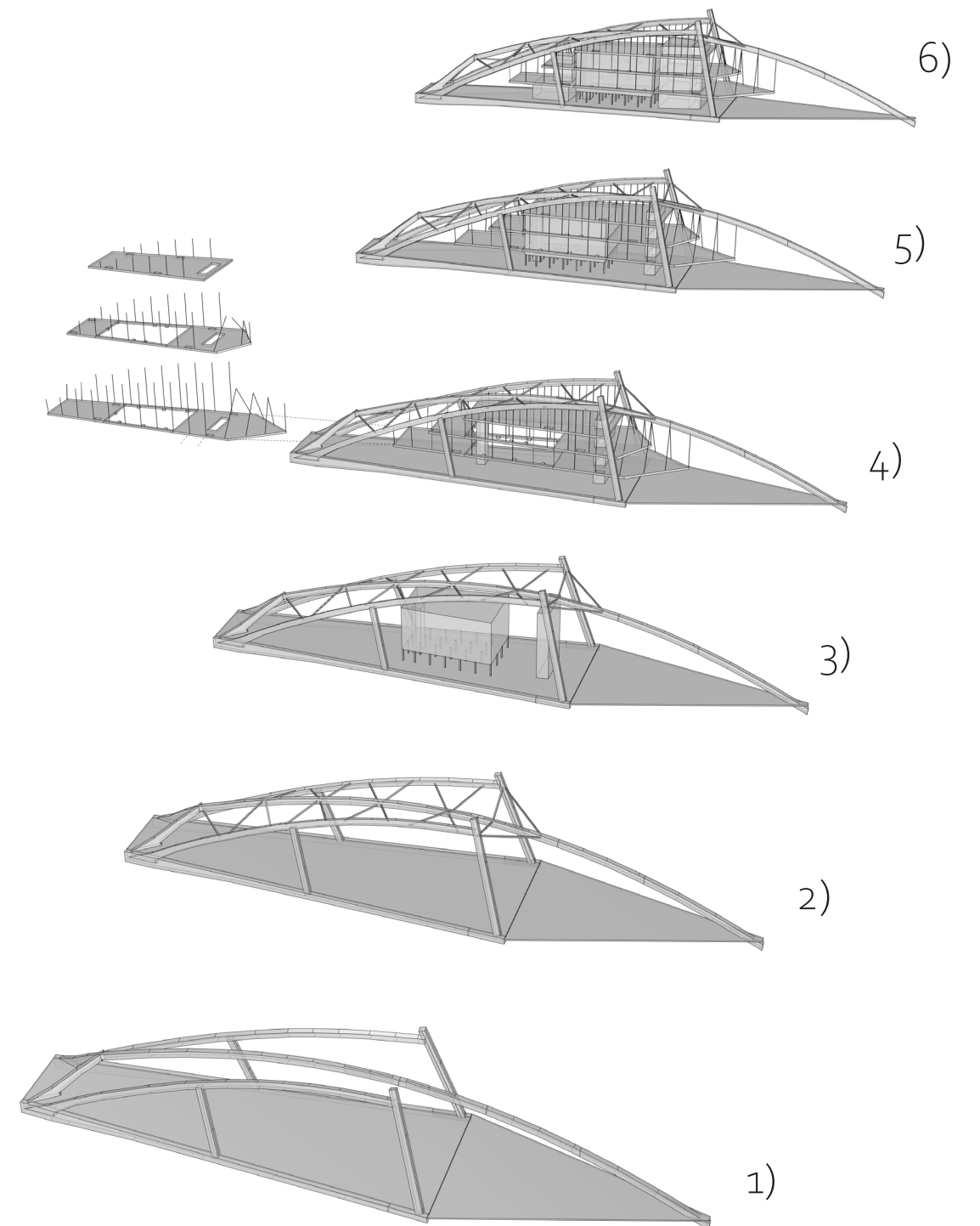
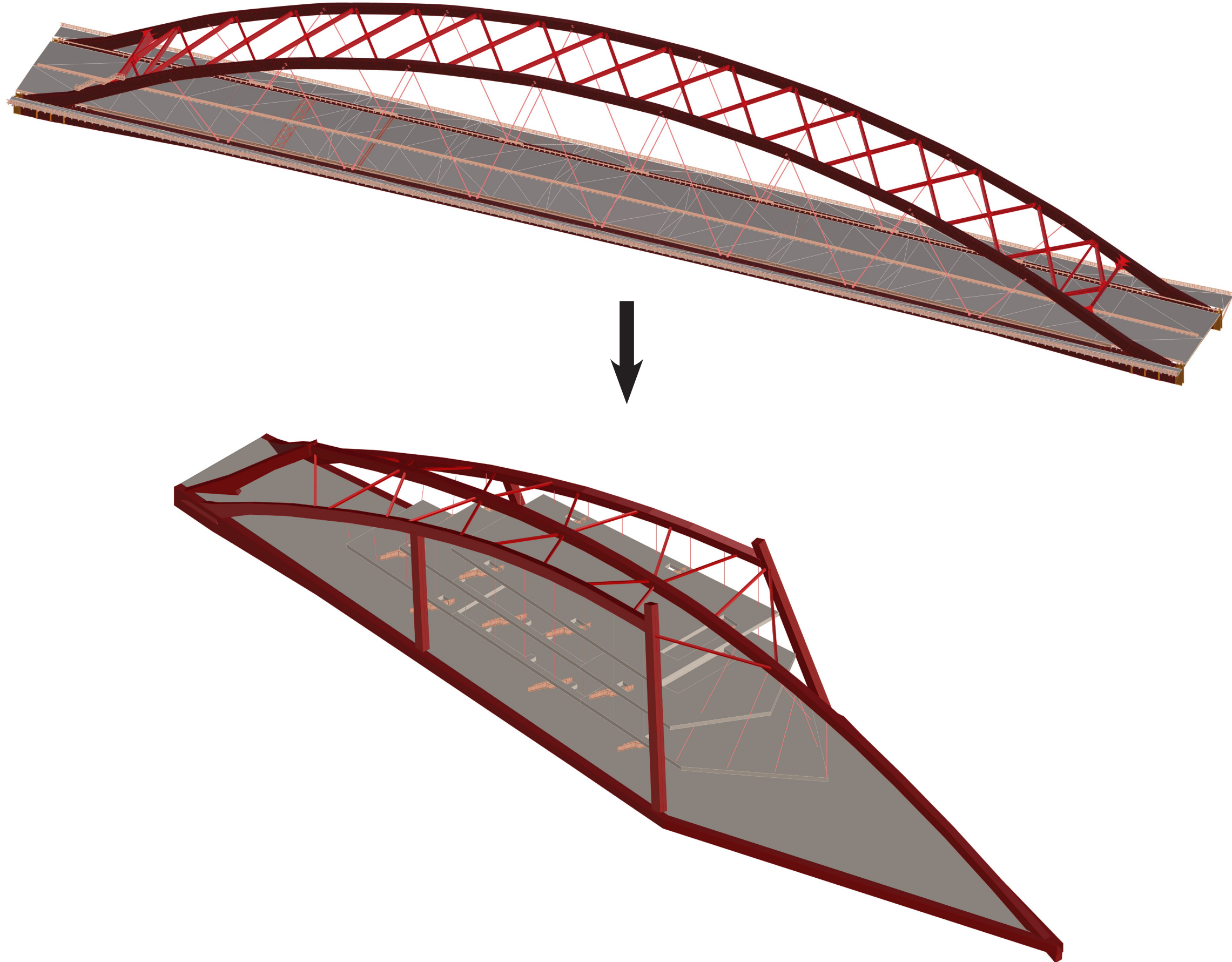
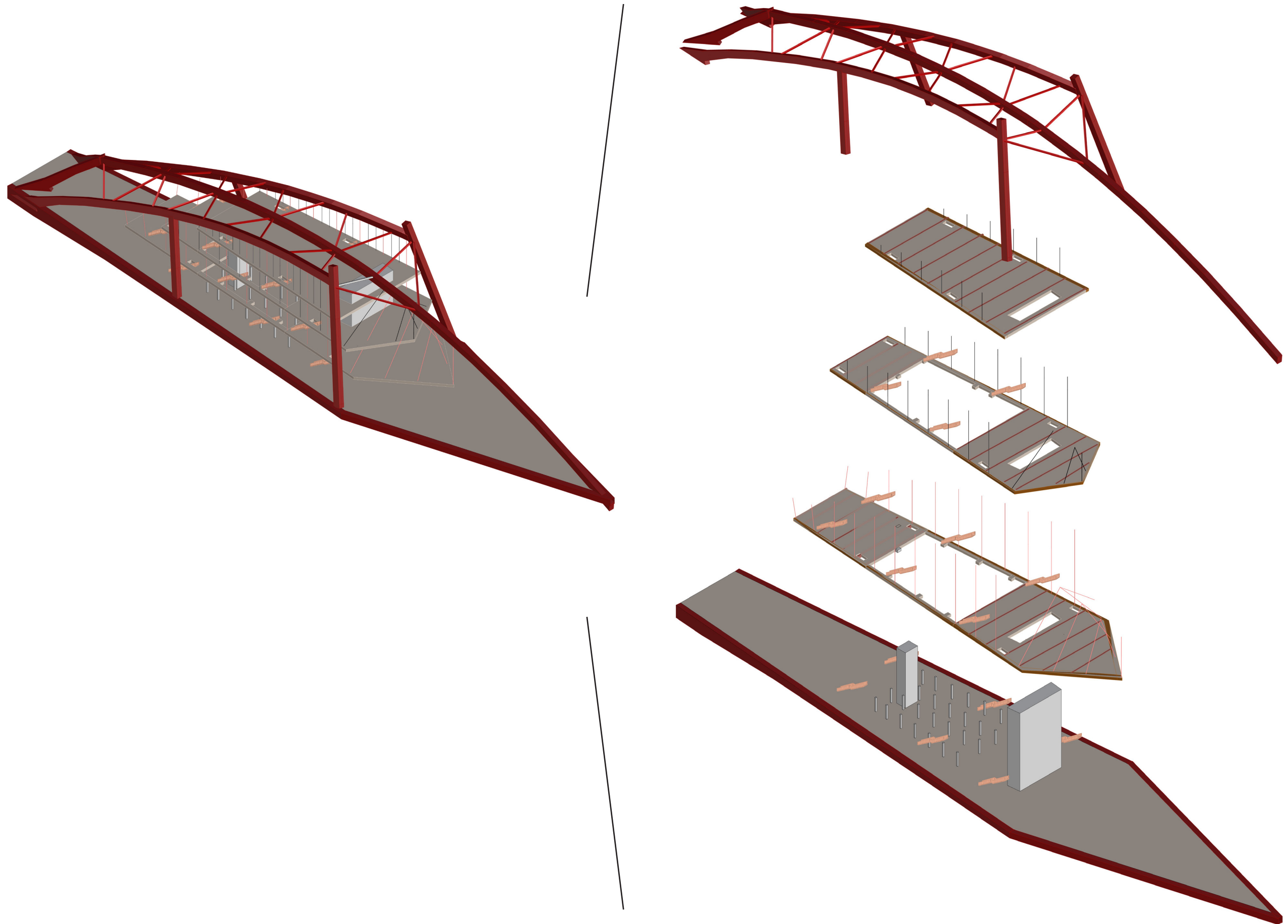


Figure 50: Final structural design explanation.

Structural Design

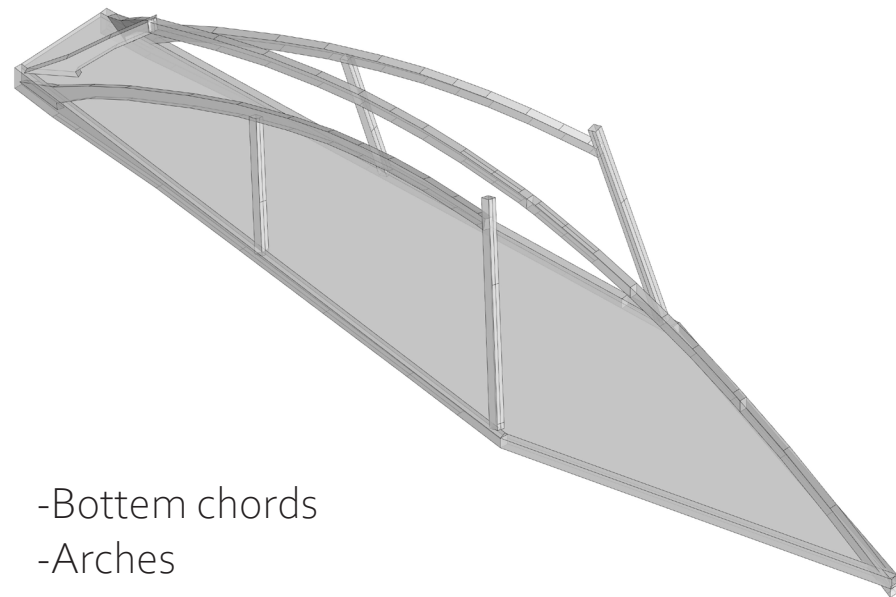


Structural Design

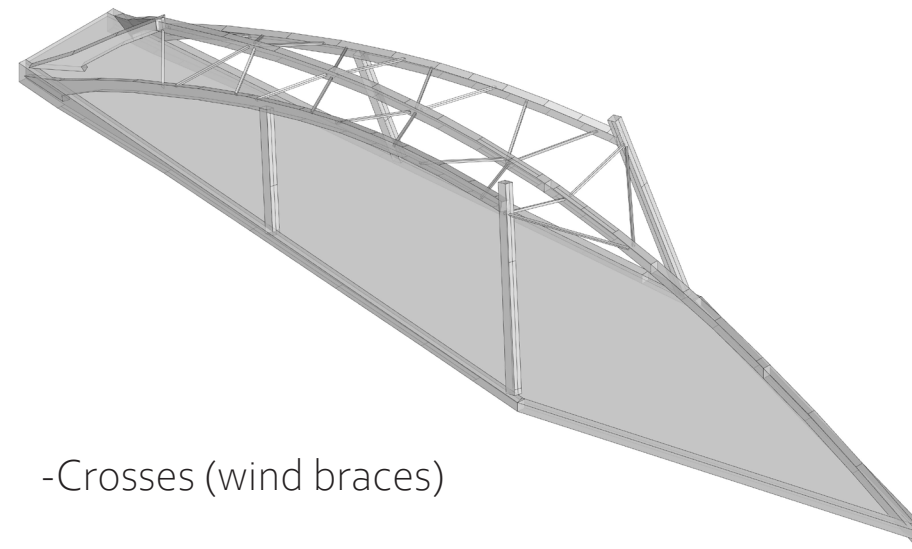


Structural design principle

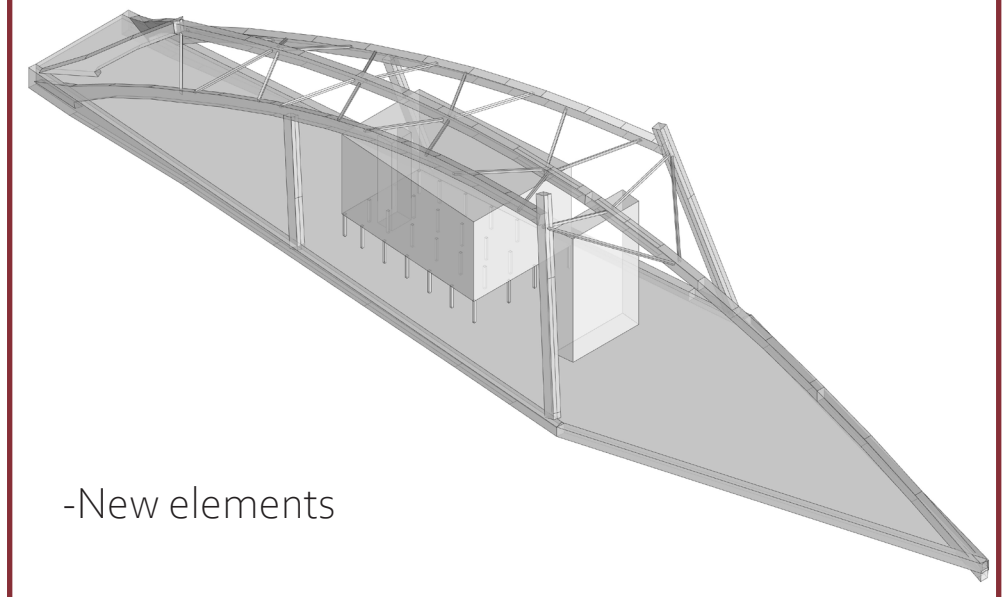
1) Main structural form



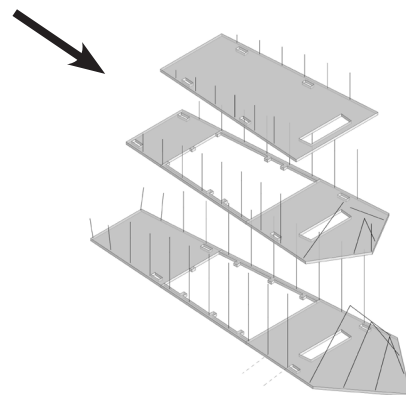
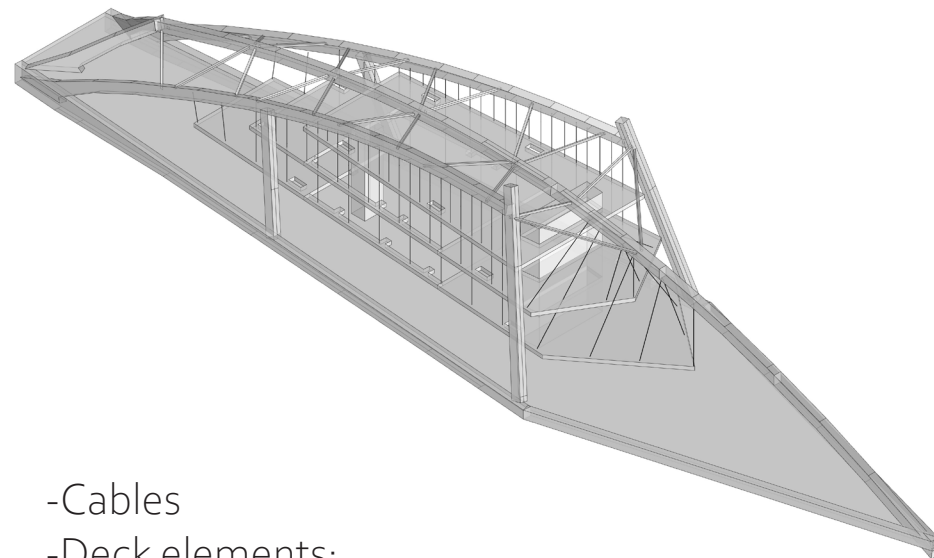
2) Creating stability



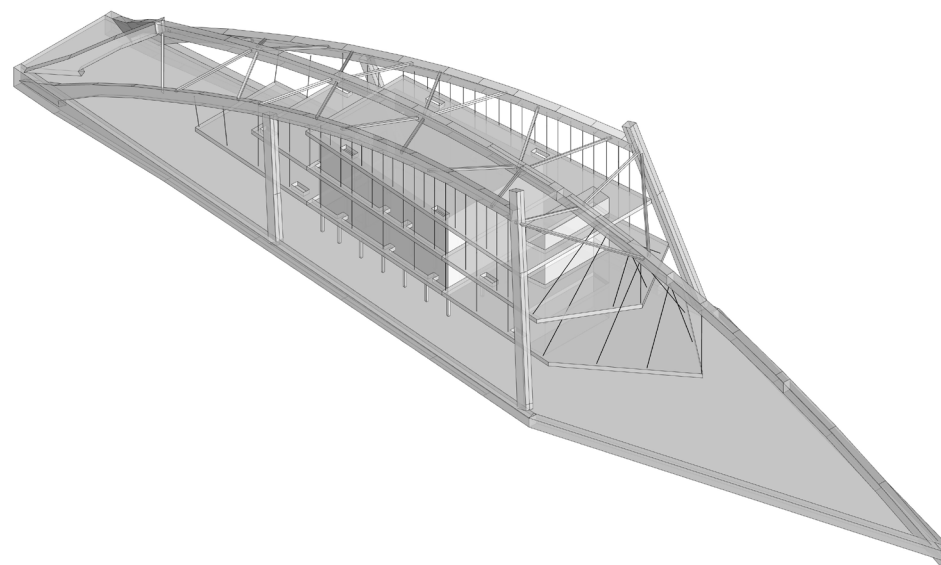
3) Cores & theather



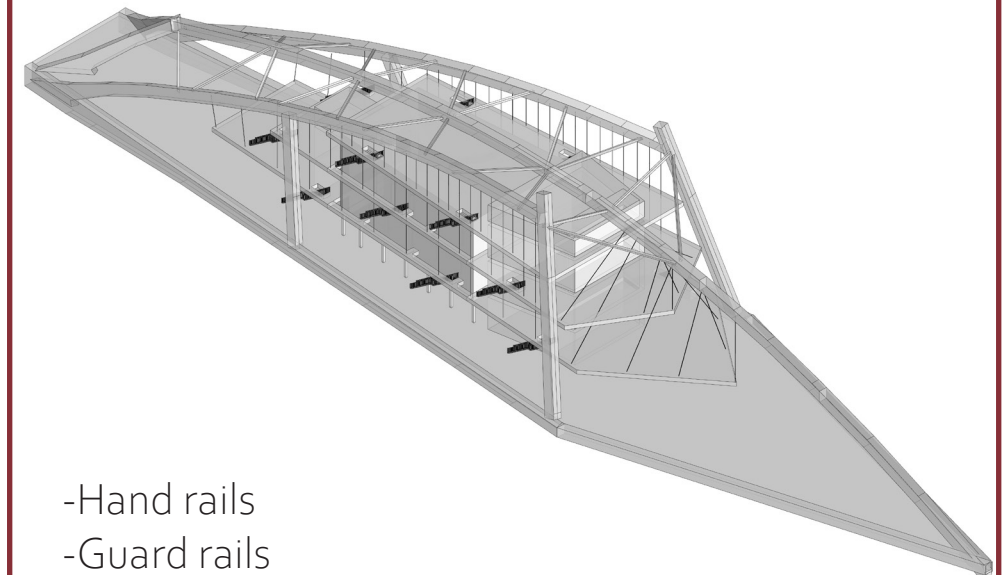
4) Creating spatial structure



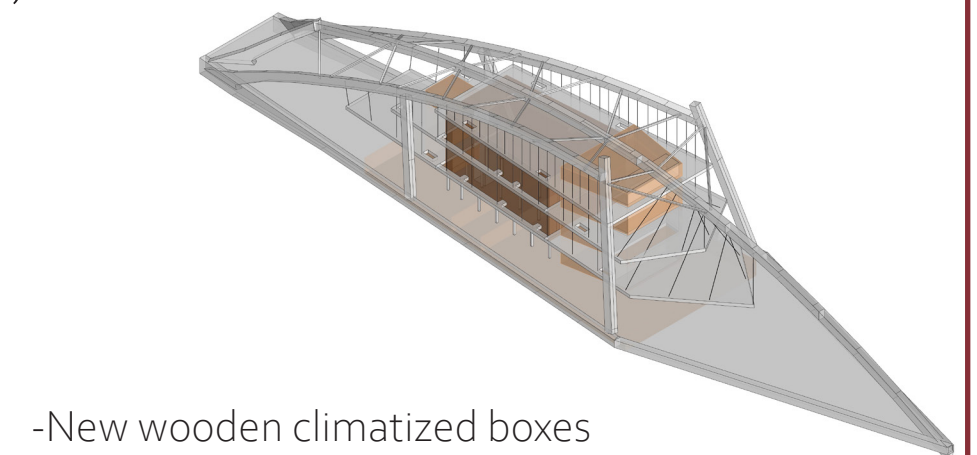
5) Complete main and spatial structure



6) Using interior steel category



7) Non-constructive interior structure



Building scale ~ Structural design

In the first version, the arches were positioned vertically, causing the cables to run diagonally from the decks to the arch. This created internal forces within the decks, requiring them to be very stiff and shape-stable. By rotating the arches inward, the cables can run vertically and act as fixed rods. As a result, internal forces in the decks are reduced, making the deck system more stable.

A force calculation was then made for the load-bearing cables, as shown on the next page. These cables are placed every 10 metres and are reused from the original Van Brienenoord Bridge hangers. The additional cables are newly added, non-load-bearing elements. They can therefore remain light and mainly create a visual rhythm that relates to De Caai. Together, the original 10 m cable rhythm and the new intermediate cables create a $\frac{1}{3}$ rhythm. The calculation shows that the reused bridge cables alone are sufficient to carry all decks and functions.

Structural force flow

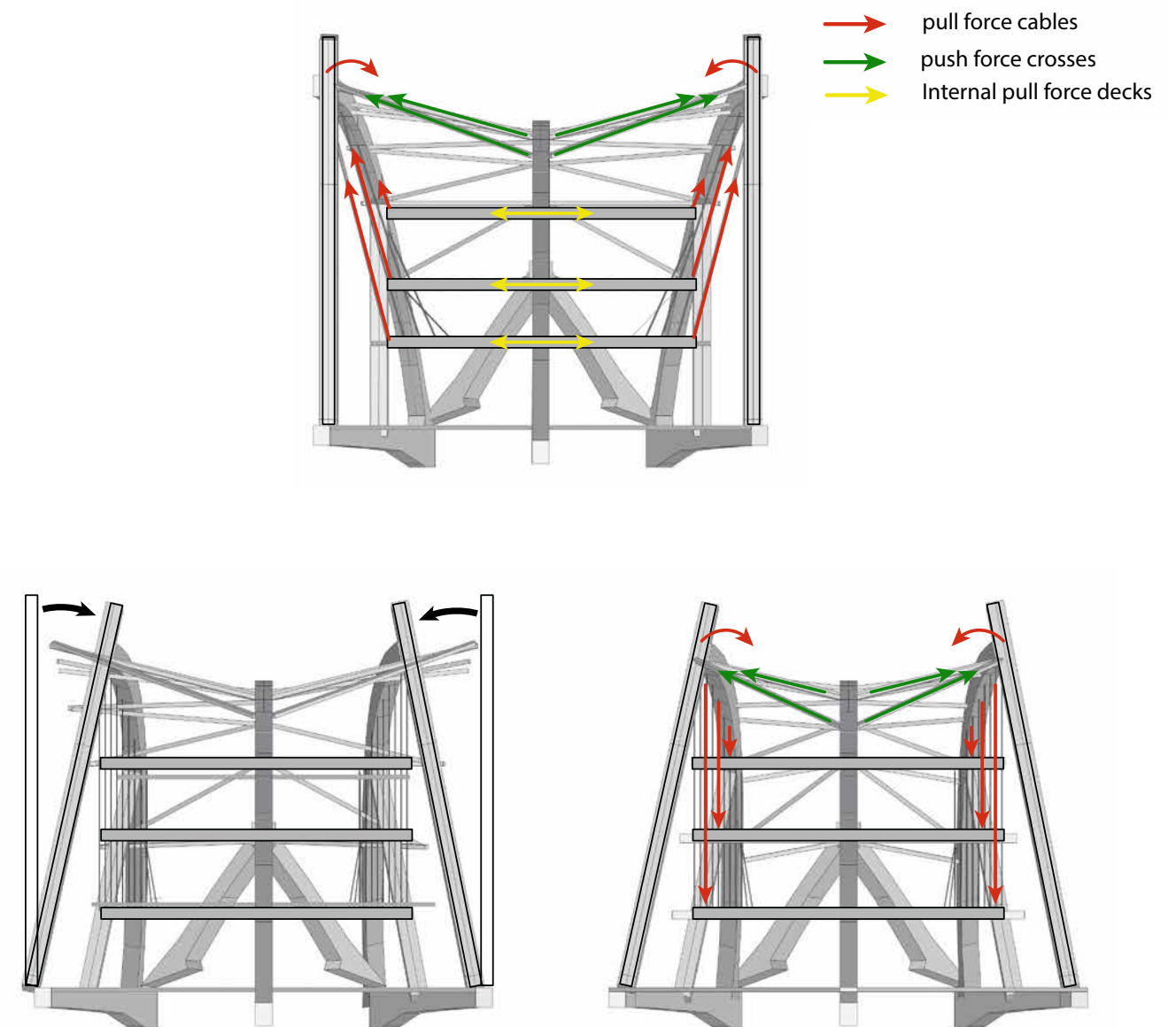
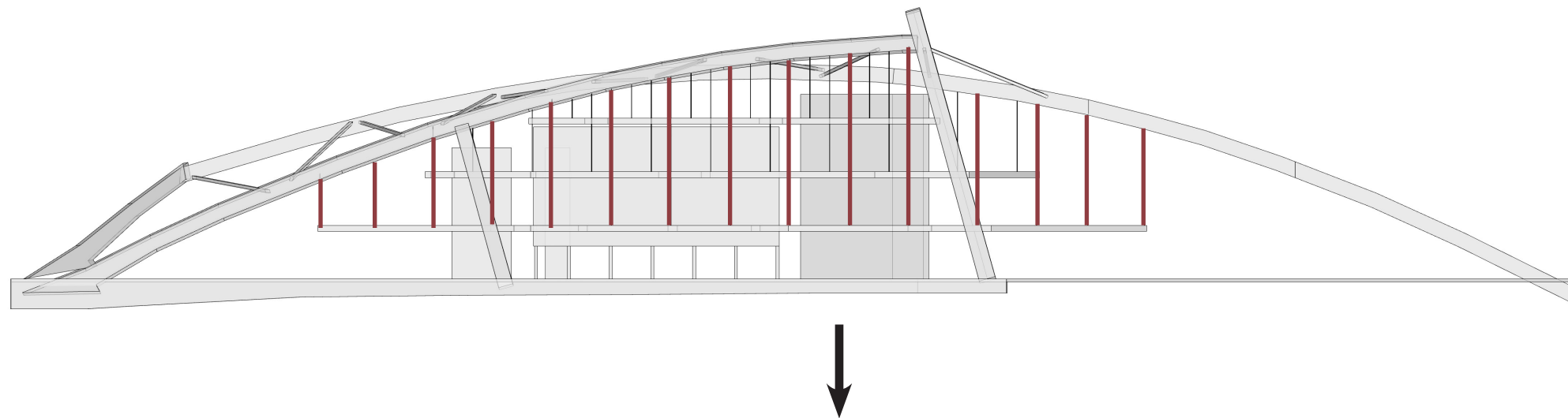


Figure 51: Structural flow explanation to stabilize the forces in the decks.

Structural diagram

— Loadbearing cables for calculations



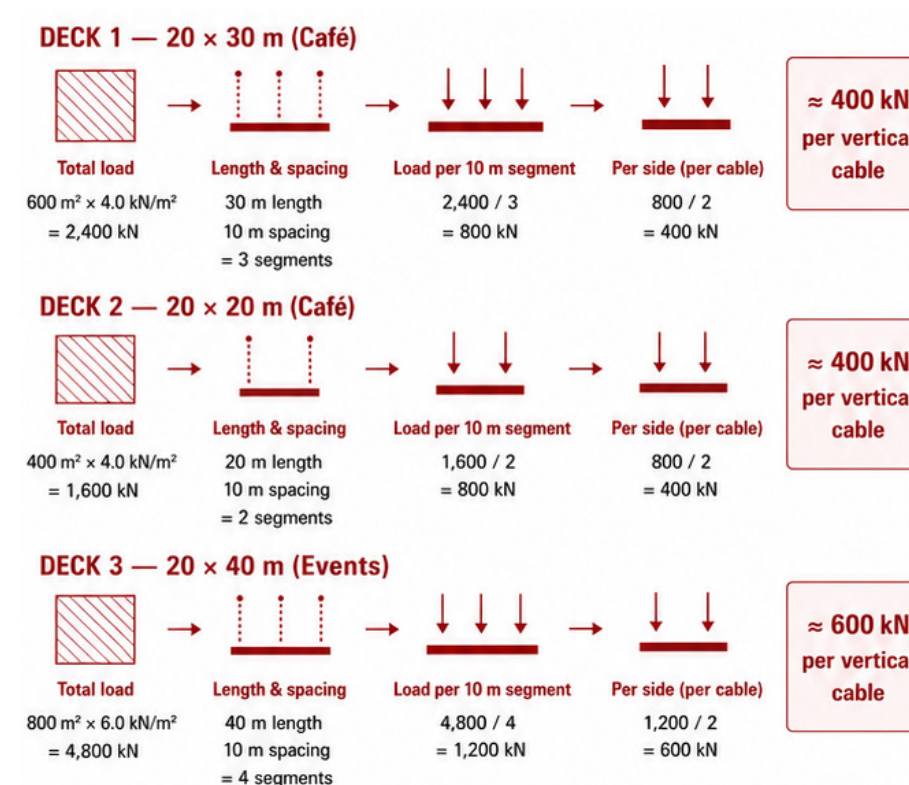
Step 1)

Calculating total vertical load per deck

Deck	Use	Surface area (m²)	Load (kN/m²)	Total vertical load (kN)	Truck equivalent (≈ 490 kN per truck)
Deck 1	Café	600	4.0	2,400	4.9 trucks
Deck 2	Café	400	4.0	1,600	3.3 trucks
Deck 3	Events	800	6.0	4,800	9.8 trucks
TOTAL		1,800	—	8,800	17.9 trucks

Step 2)

Calculating vertical cable force per deck



Step 3)

Comparing the original cables

The Rijkswaterstaat document states that the original diagonal cables had a diameter of 110 mm and cable loads varying from approximately 70 to 320 ton.

70 ton	≈	687 kN
320 ton	≈	3,139 kN

Comparison of estimated vertical hanger forces with original cable loads:

Deck	Estimated force per vertical hanger (kN)	Comparison with original cable load
Deck 1 – Café	≈ 400 kN	Lower than 70 ton / 687 kN
Deck 2 – Café	≈ 400 kN	Lower than 70 ton / 687 kN
Deck 3 – Events	≈ 600 kN	Slightly lower than 70 ton / 687 kN

Figure 52: Structural force calculations for the cables per deck.

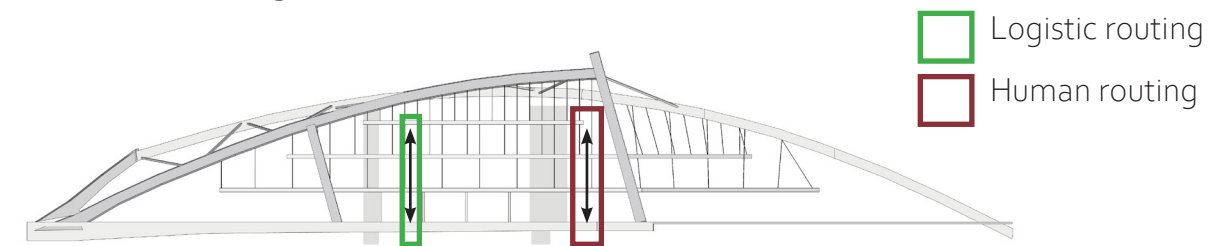
Building scale ~ Spatial organisation

The diagrams alongside illustrate the spatial organisation of the building, explaining:

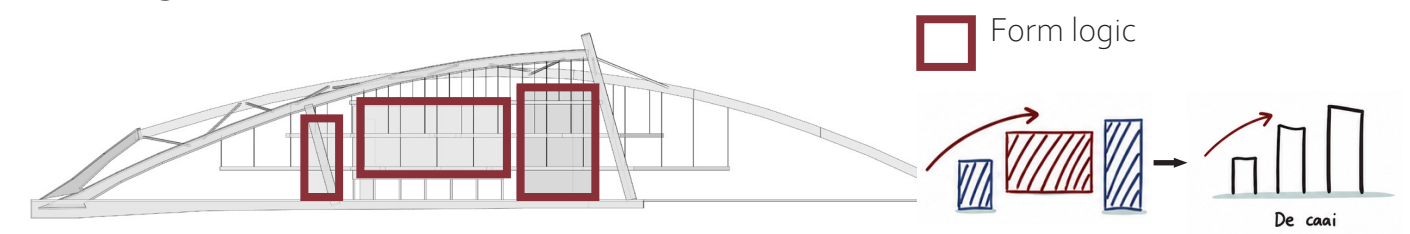
- The vertical routing
- Form logic and connection to site
- Materialisation indoor boxes
- Organisation of the functions
- Cable and stairs rhythm (connected to the site and old Campina factory halls)

Program organisation diagrams

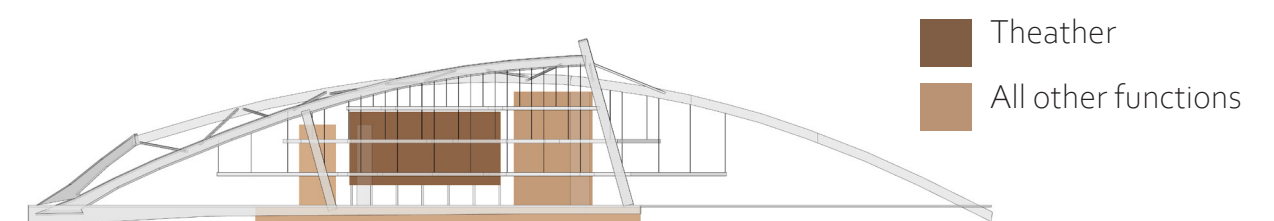
Vertical routing (elevators)



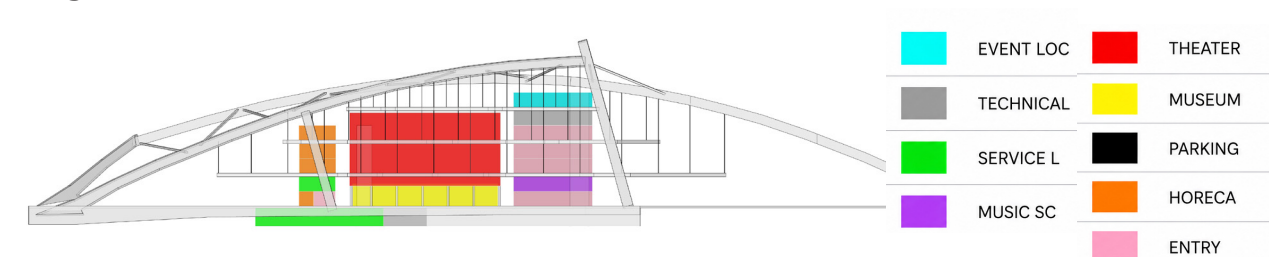
Form logic connected to site



Materialisation indoor boxes



Organisation of the functions



Cable & Stairs rhythm

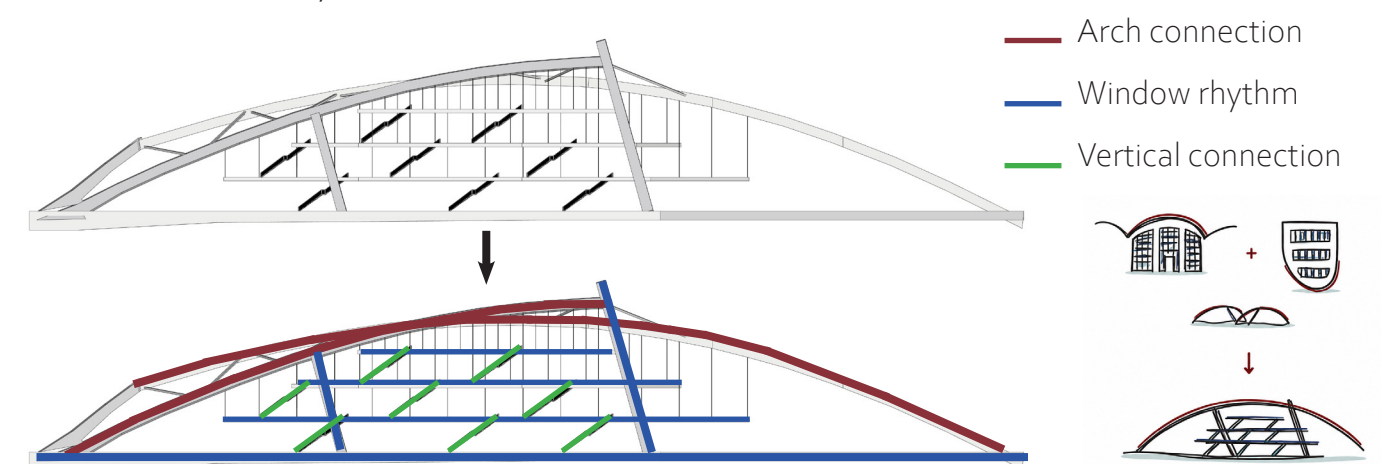


Figure 53: Spatial organisation diagrams of the building.

Organisation of the functions

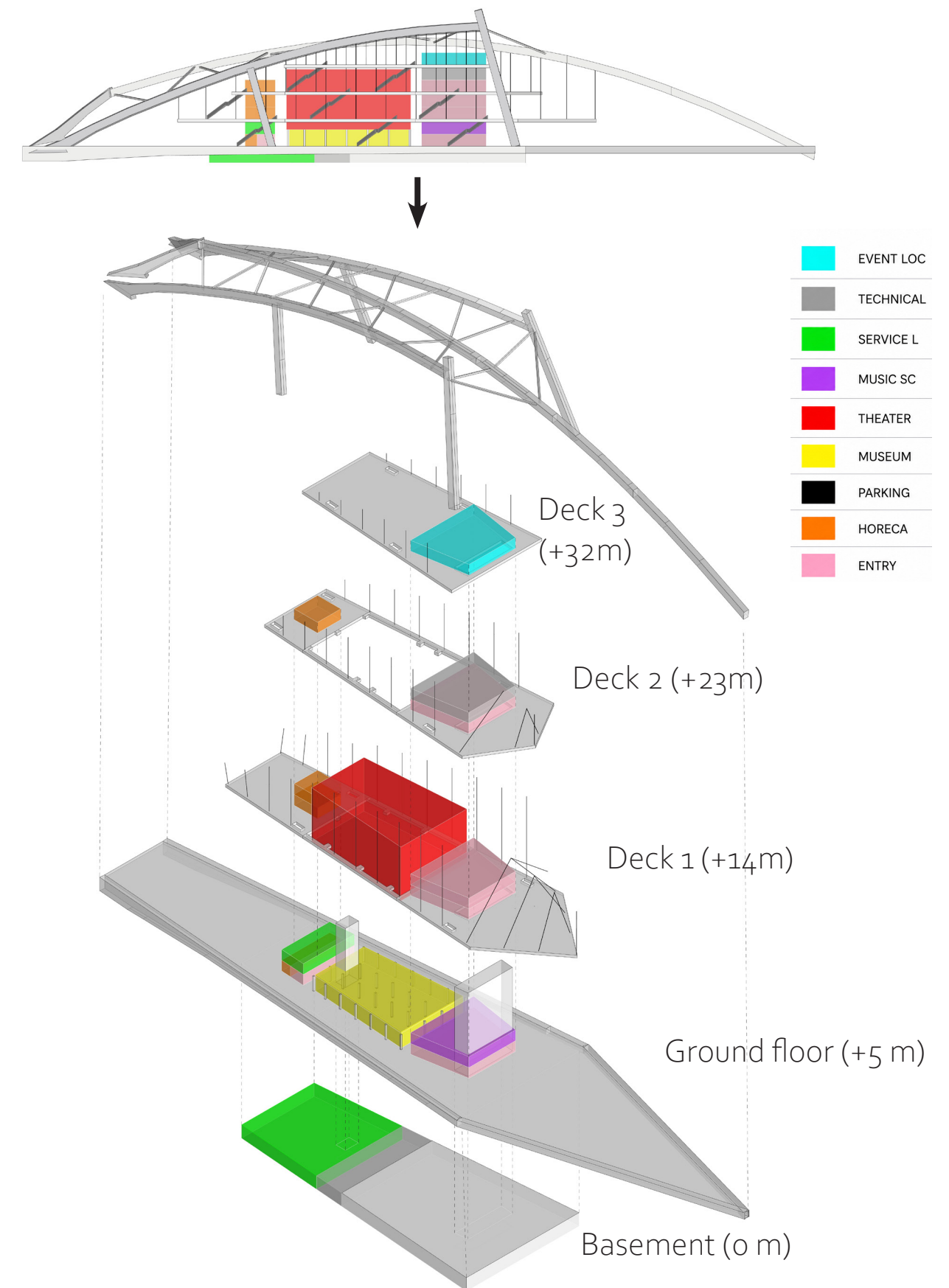


Figure 54: Spatial organisation of the programme and functions.

Building scale ~ Spatial organisation

The functions are organised across the decks according to their public, technical and logistical requirements. At 0 m, the basement is located between the two bottom chords and therefore appears partly embedded. This level mainly contains logistical functions, such as parking, climate rooms, technical installations, service routing and storage for the theatre and other building functions.

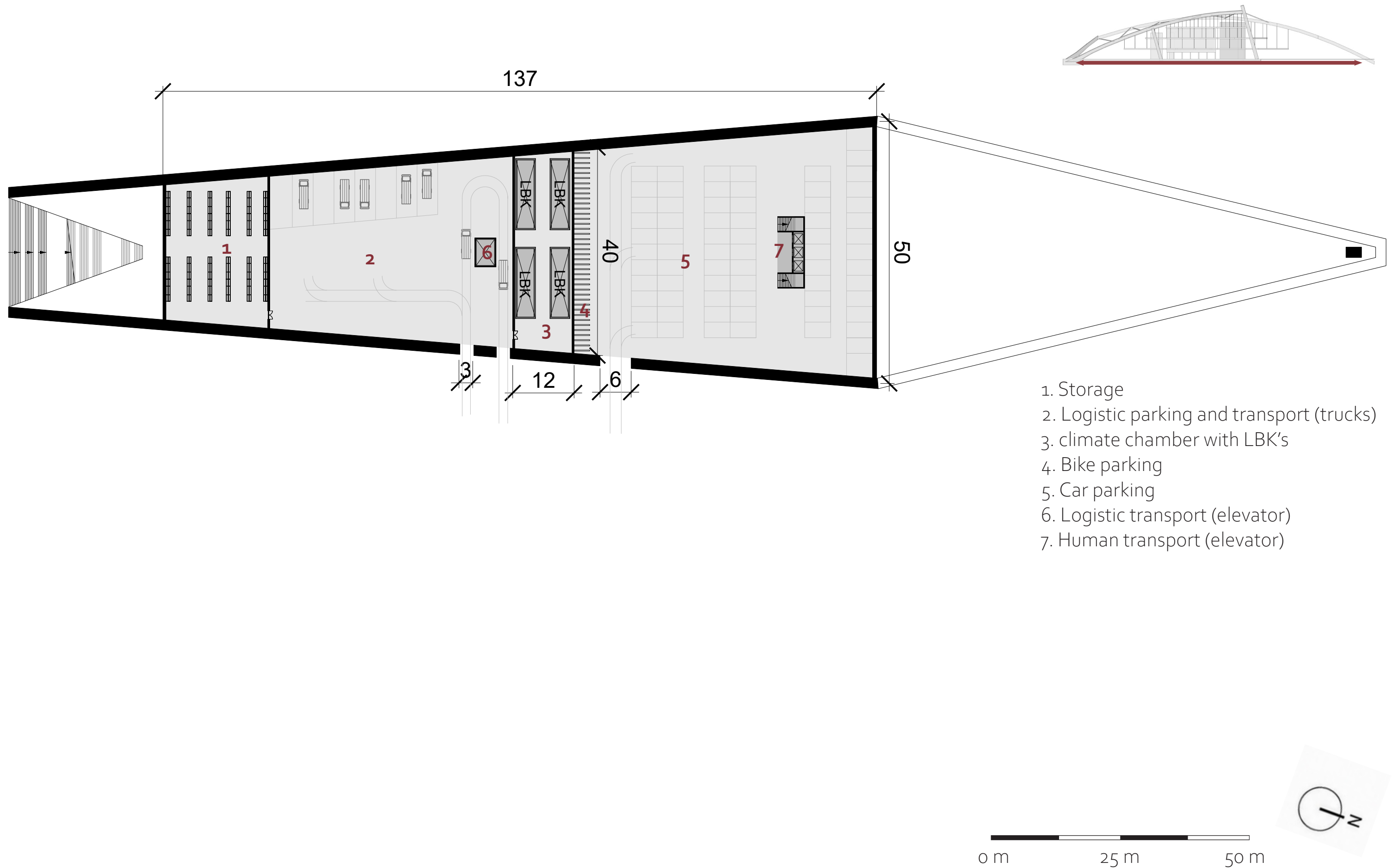
The ground floor deck (+5 m) forms the main public level. It includes the Boijmans van Beuningen museum, general foyers, toilets, wardrobes information desks, a café/restaurant and the music school. Large open green areas allow temporary activities such as exhibitions, events, an open-air cinema or a skatepark.

Decks 1 and 2 are publicly accessible through the stair system, but mainly serve the theatre hall, which can accommodate around 1,000 visitors. Space around the theatre creates vertical connections between the decks, allowing views up and down through the building. These levels also include supporting theatre functions such as storage, foyers, toilets, cloakrooms and cafés.

Finally, Deck 3 is a semi-public event deck that can be rented out, but is public accessible if this is not the case. It provides space for larger gatherings within the green roof garden.

Building scale ~ Plans 1:200

The following pages present the detailed floor plans of all decks and intermediate levels. These drawings illustrate the open character of the ground-floor deck, where large unobstructed spaces direct attention towards the form language and spatial presence of the theatre hall. This openness strengthens the visual impact of the central volume while maintaining clear sightlines and flexibility for public activities.

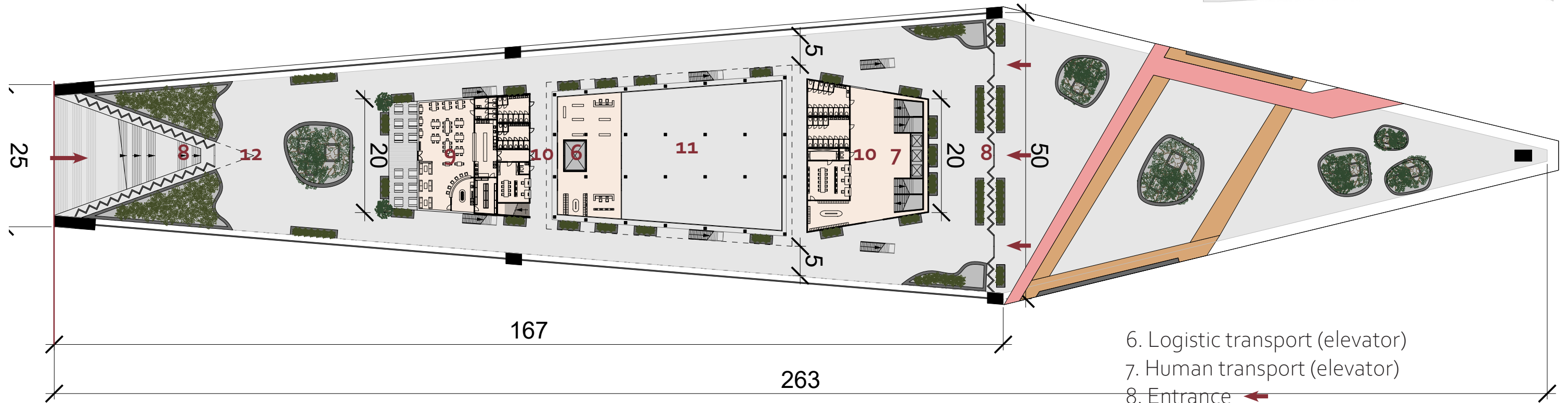


1. Storage
2. Logistic parking and transport (trucks)
3. climate chamber with LBK's
4. Bike parking
5. Car parking
6. Logistic transport (elevator)
7. Human transport (elevator)

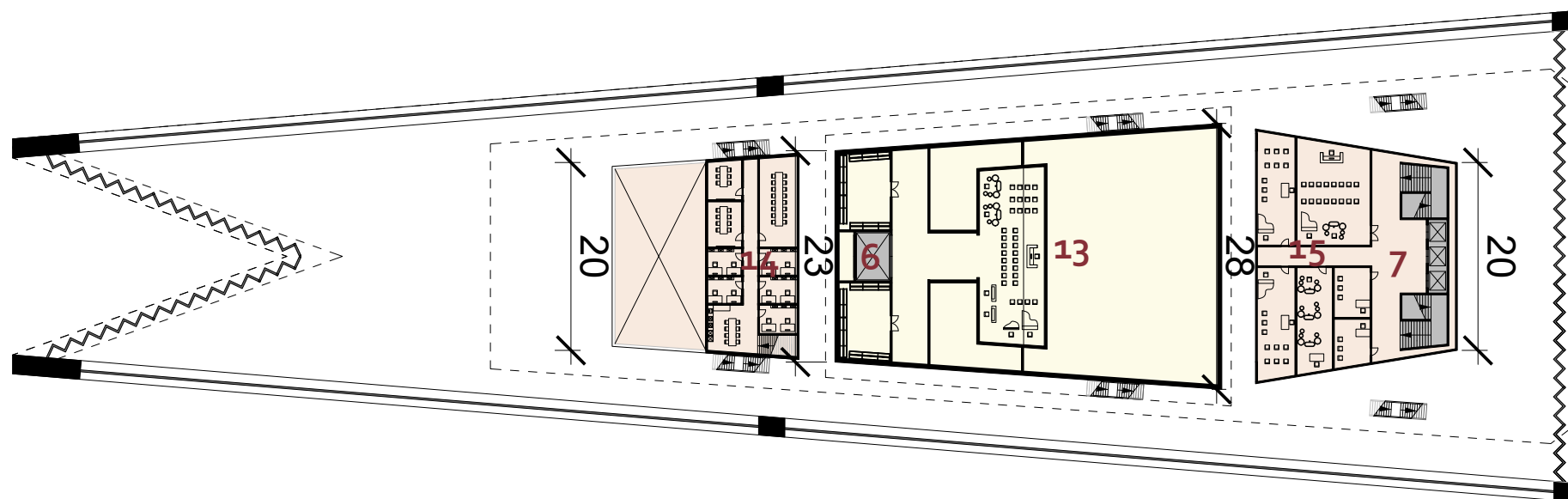
Figure 56: Plan Basement ~ 1:200

Plan: Ground floor ~ 1:200

Ground floor A (+5 m)



Ground floor B (+9 m)



- 6. Logistic transport (elevator)
- 7. Human transport (elevator)
- 8. Entrance
- 9. Café / Restaurant
- 10. General foyer (information place, WC & wardrobe)
- 11. Boijmans van Beuningen museum
- 12. Open public space for activities
- 13. Theater
- 14. Offices & Support
- 15. Music school

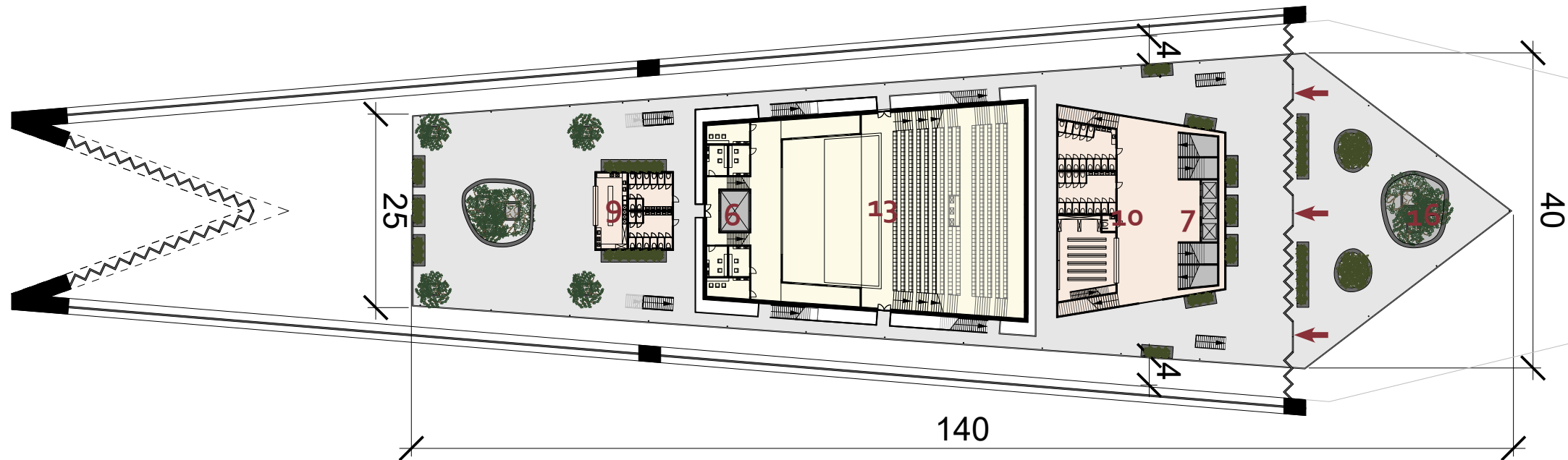
0 m 25 m 50 m



Figure 57: Plan Ground floor A & B 1:200

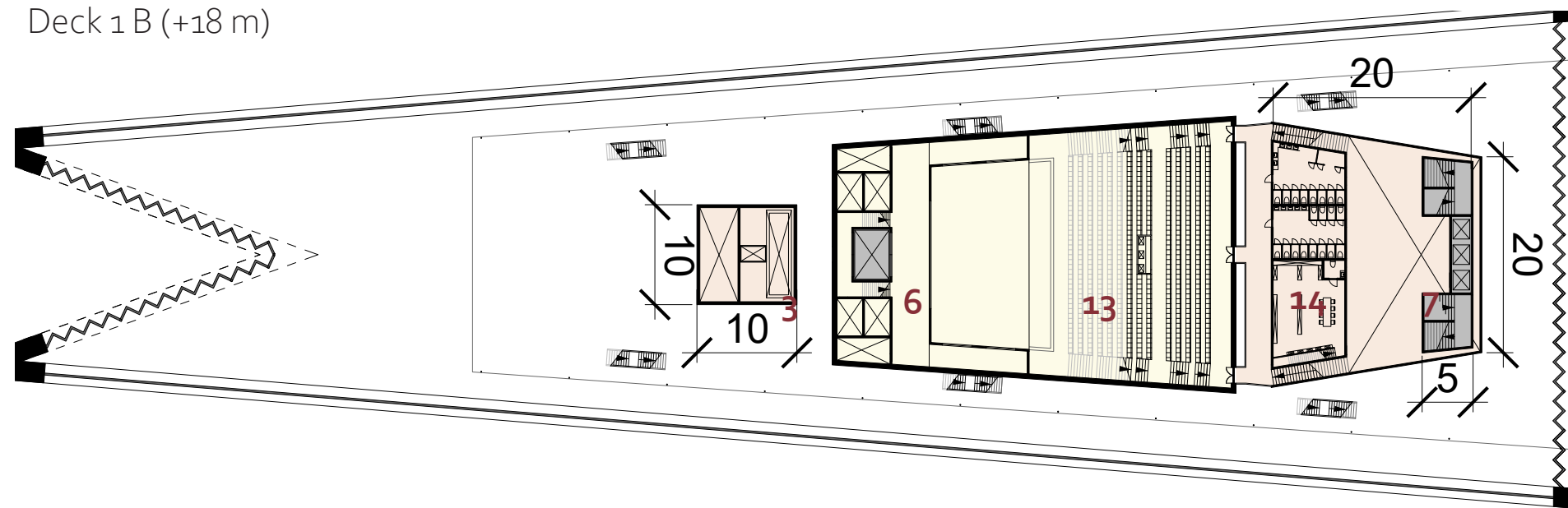
Plan: Deck 1 A & B ~ 1:200

Deck 1 A (+14 m)



- 3. climate chamber with LBK's
- 6. Logistic transport (elevator)
- 7. Human transport (elevator)
- 9. Café / Restaurant
- 10. Theater foyer (information place, WC & wardrobe)
- 13. Theater
- 14. Offices & Support
- 16. Outside public deck (with green)

Deck 1 B (+18 m)



0 m 25 m 50 m

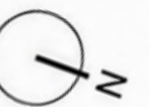
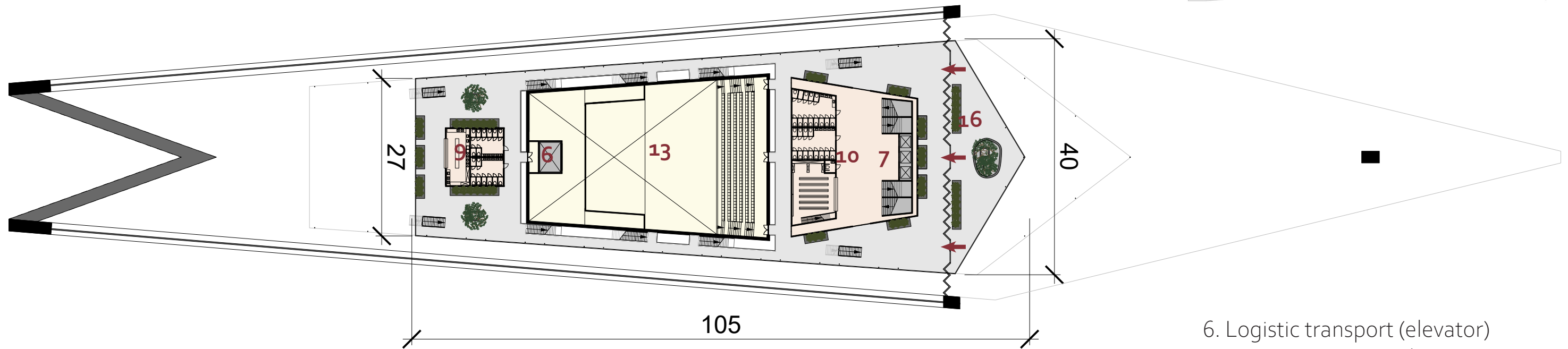


Figure 58: Plan Deck 1 A & B 1:200

Plan: Deck 2 A & B ~1:200

Deck 2 A (+23 m)



- 6. Logistic transport (elevator)
- 7. Human transport (elevator)
- 9. Café / Restaurant
- 10. Theater foyer (information place, WC & wardrobe)
- 13. Theater
- 14. Offices & Support
- 16. Outside public deck (with green)

Deck 2 B (+27 m)

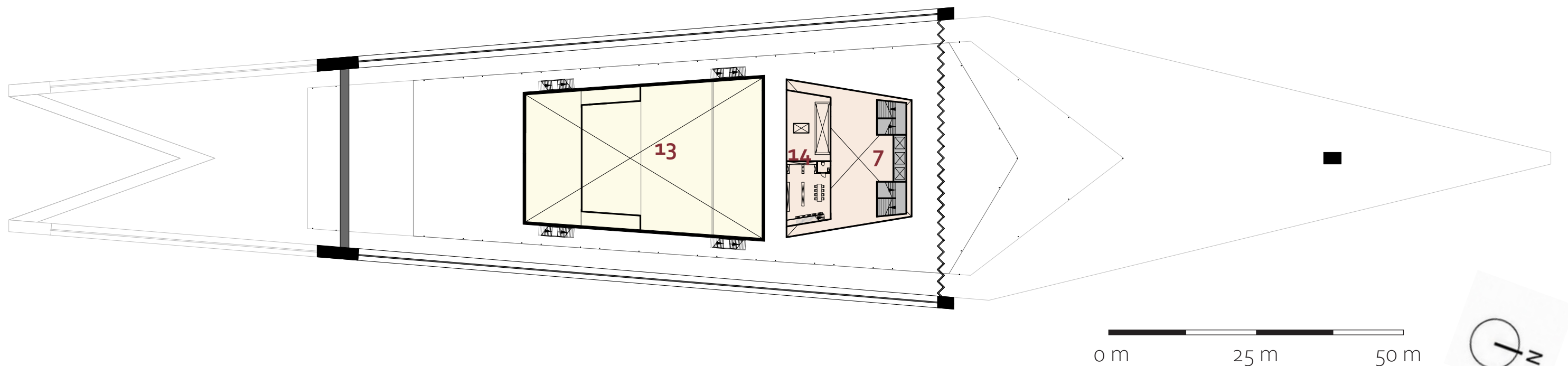
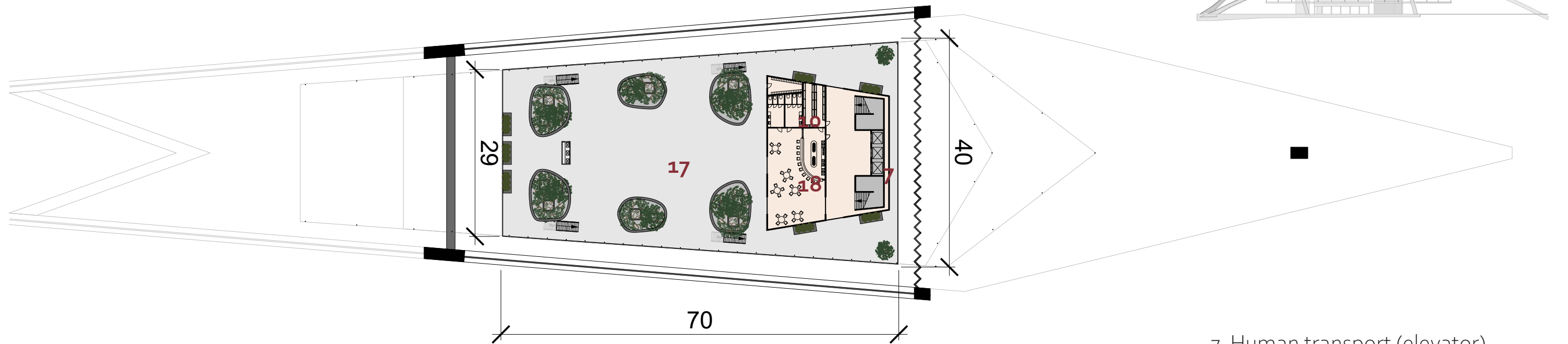


Figure 59: Plan Deck 2 A & B ~ 1:200

Plan: Deck 3 ~1:200

Deck 3 (+32 m)



- 7. Human transport (elevator)
- 9. Café / Restaurant
- 10. General foyer (information place, WC & wardrobe)
- 17. Roof terras with green
- 18. Event location

0 m 25 m 50 m

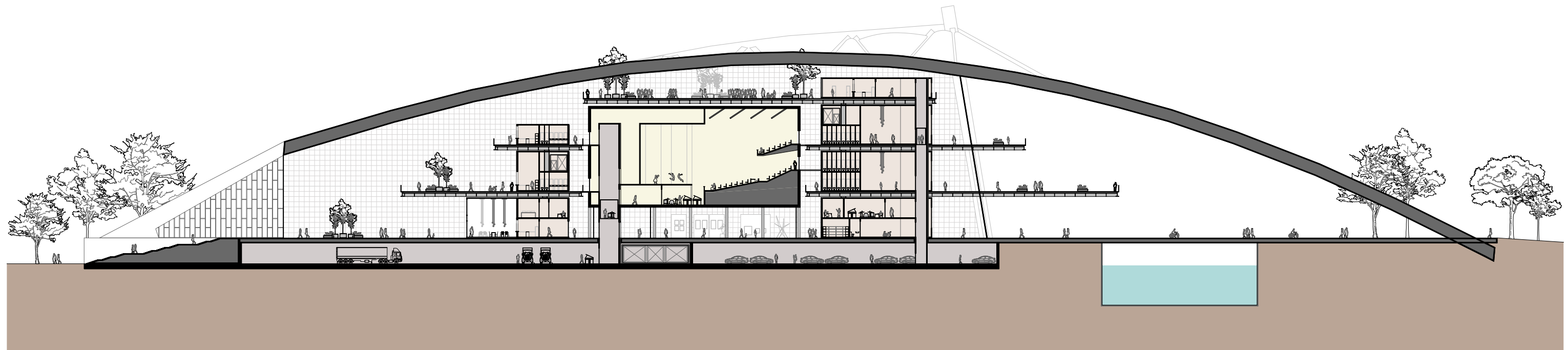
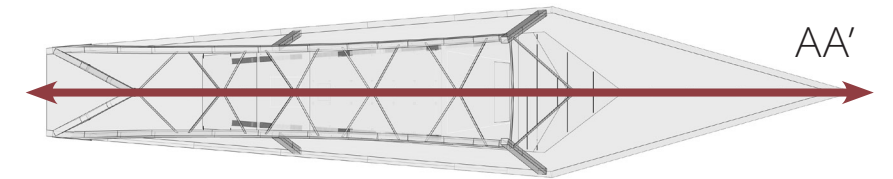


Figure 60: Plan Deck 3 ~ 1:200

Section: AA' ~ 1:100

Building scale ~ Sections 1:100

Section AA clearly illustrates the activity and interaction within the building. The theatre hall forms the central element and is directly connected to the music school, creating opportunities for collaboration and shared use. The projecting public decks extend beyond the enclosed building and can be used as terraces and gathering spaces for the cafés. These outdoor decks also reinforce the connection to the original function of the structure as a bridge, as the bridge form remains clearly visible where no enclosed functions are placed.



0 m 25 m 50 m

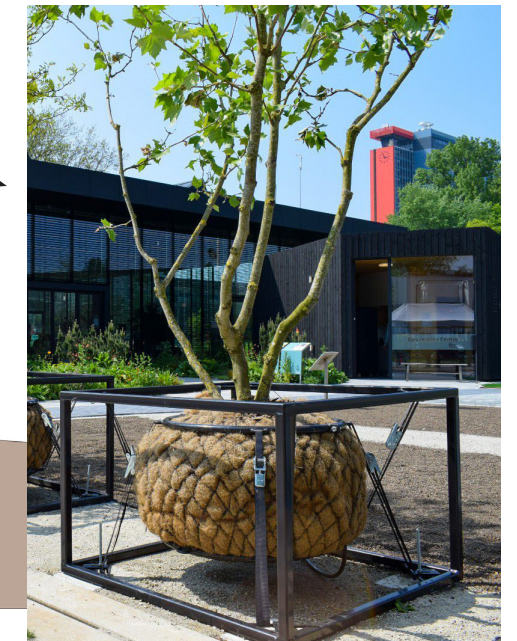
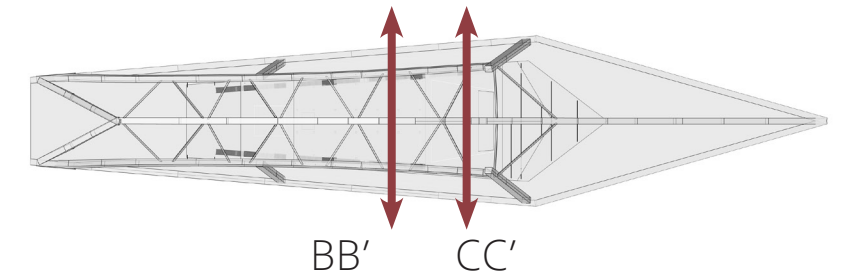
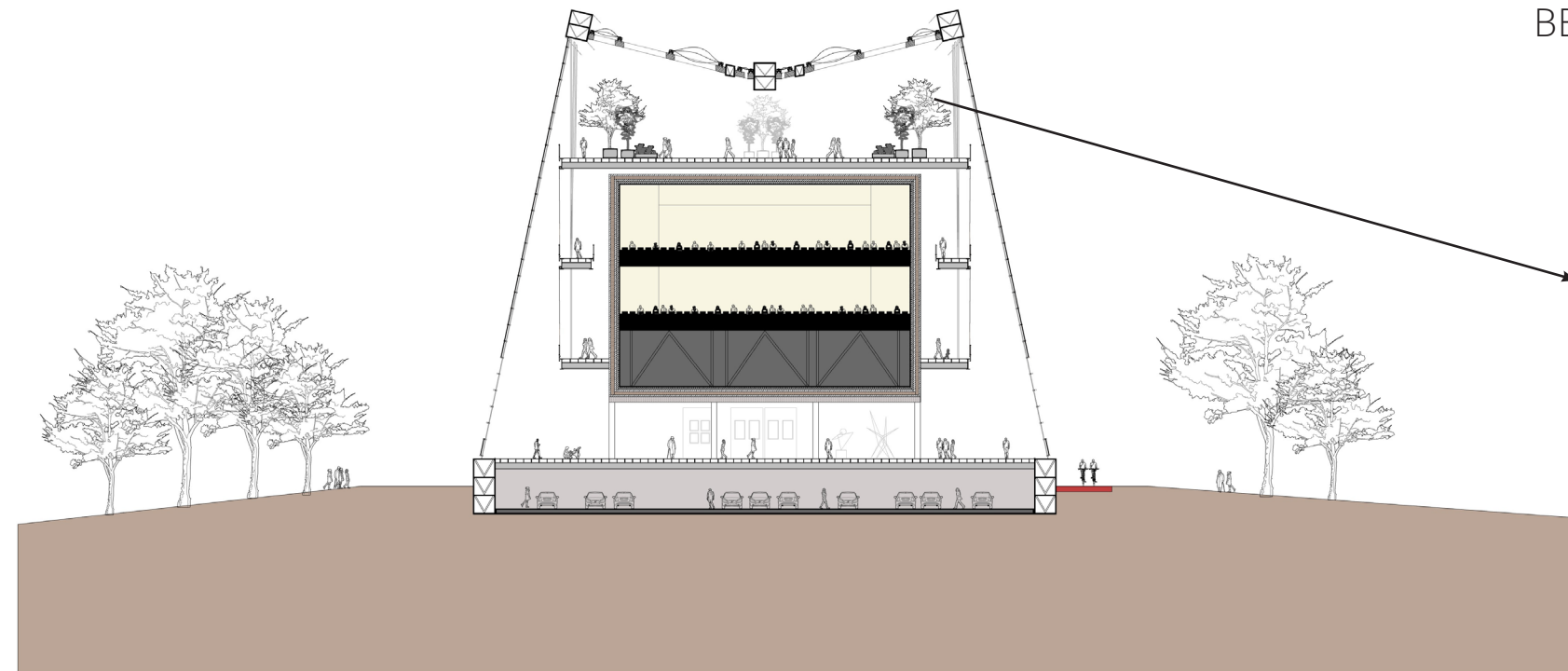
Figure 61: Section AA' 1:100

Section: BB' & CC' ~ 1:100

Section BB'

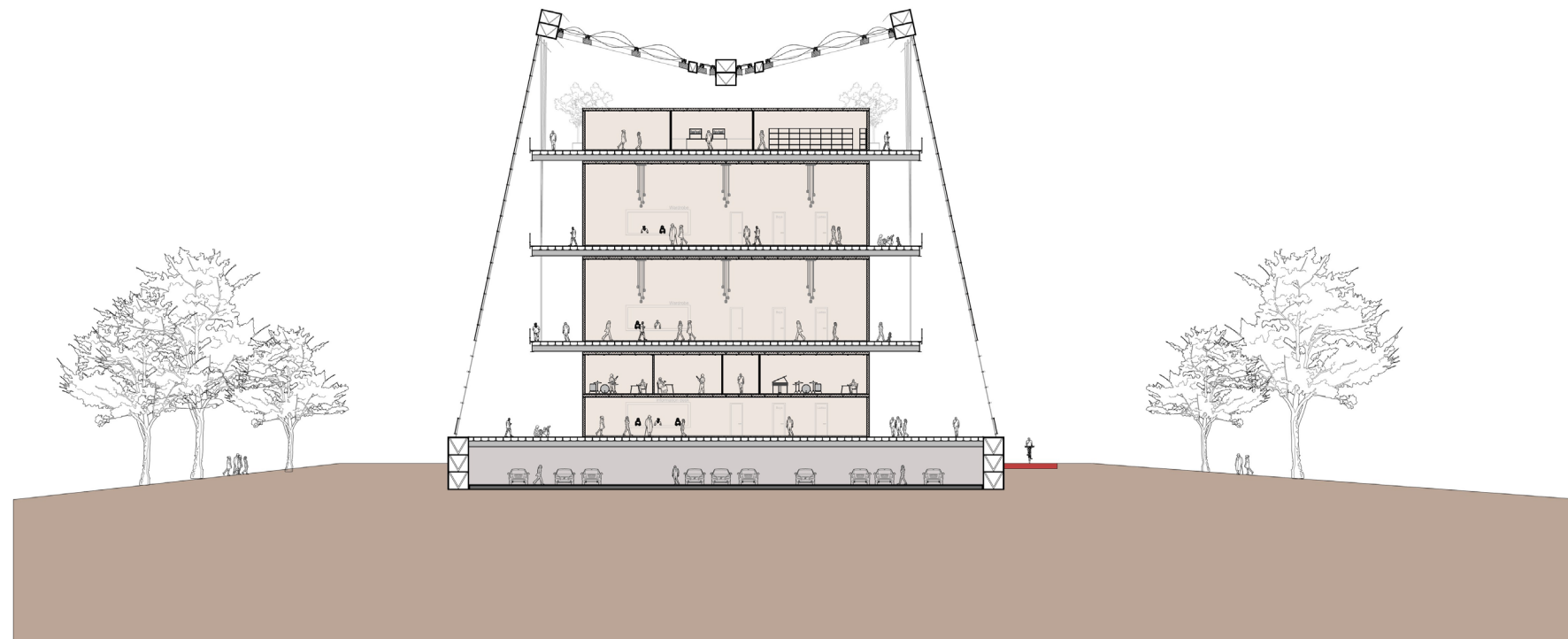
Section BB clearly demonstrates how the open space beneath the theatre hall, together with the concrete column structure of the museum, creates a unique spatial experience. The section emphasises the strong vertical connection alongside the theatre hall, linking the lower levels to the decks above.

It also illustrates how the roof garden contributes to the building without requiring significant structural depth or weight. Research conducted at The Green Village shows that vegetation, including small trees, can grow in relatively shallow planting beds, reducing both soil volume and structural load while still providing a green and biodiverse environment.



Section CC'

Section CC shows how the timber climatized boxes are used to house the different functions. They create enclosed, controlled spaces within the larger bridge structure, allowing each programme to meet its own comfort, acoustic and climate requirements.

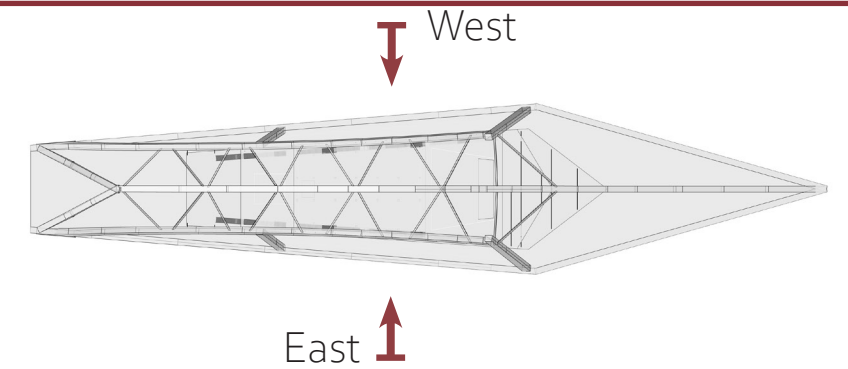


0 m 25 m 50 m

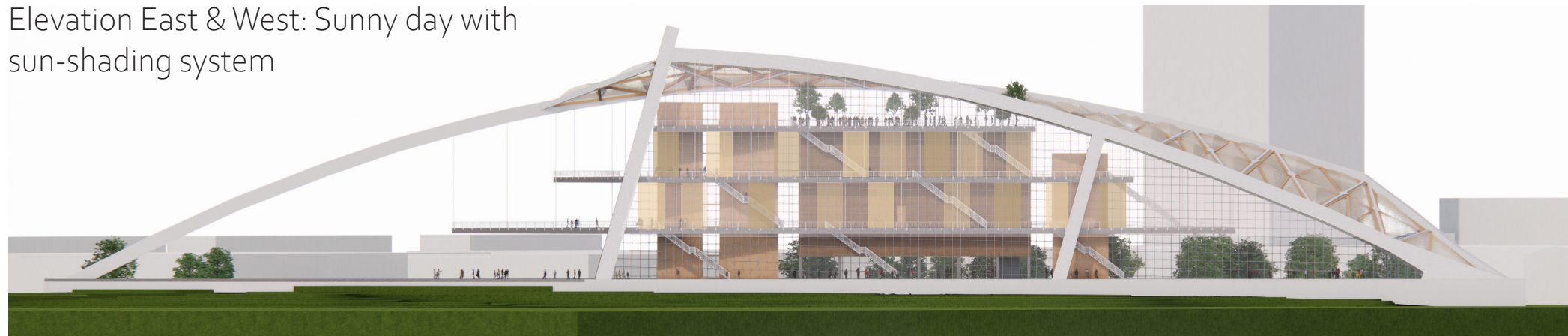
Figure 62: Section BB' & CC' 1:100

Building scale ~ Elevations 1:100

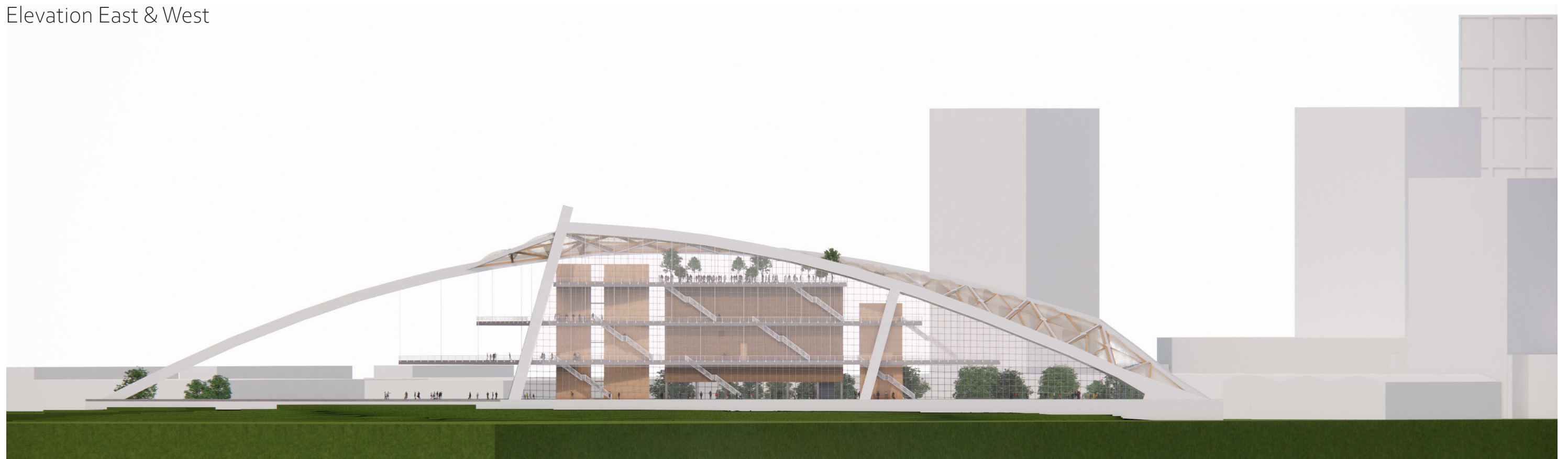
The east and west elevations are the same and clearly show the connection in form language with De Caai. The original bridge steel remains central, both structurally and visually. The decks, cables and stairs create a rhythm that relates to the surroundings and the old Campina factory. Together with the light ETFE cushion roof, these elements form one coherent building. In addition, the internal sun-shading system introduces movement to the façade, creating a dynamic rhythm and changing pattern across the building envelope.



Elevation East & West: Sunny day with sun-shading system



Elevation East & West



0 m 25 m 50 m

Figure 63: Ellevation East & West 1:100

Ellevation North & South~ 1:100

Ellevation North

The north and south elevations form the two entrances of the building. The south façade becomes the main entrance, oriented towards the important street of De Kade, the access route to the district and the Eindhoven ring road.

Unlike the east and west elevations, these façades use an angled glass pattern, inspired by the EMC in Rotterdam (Octatube, n.d.). This creates a more expressive façade that attracts attention and clearly indicates where the entrance and activity of the building are located.



Ellevation South

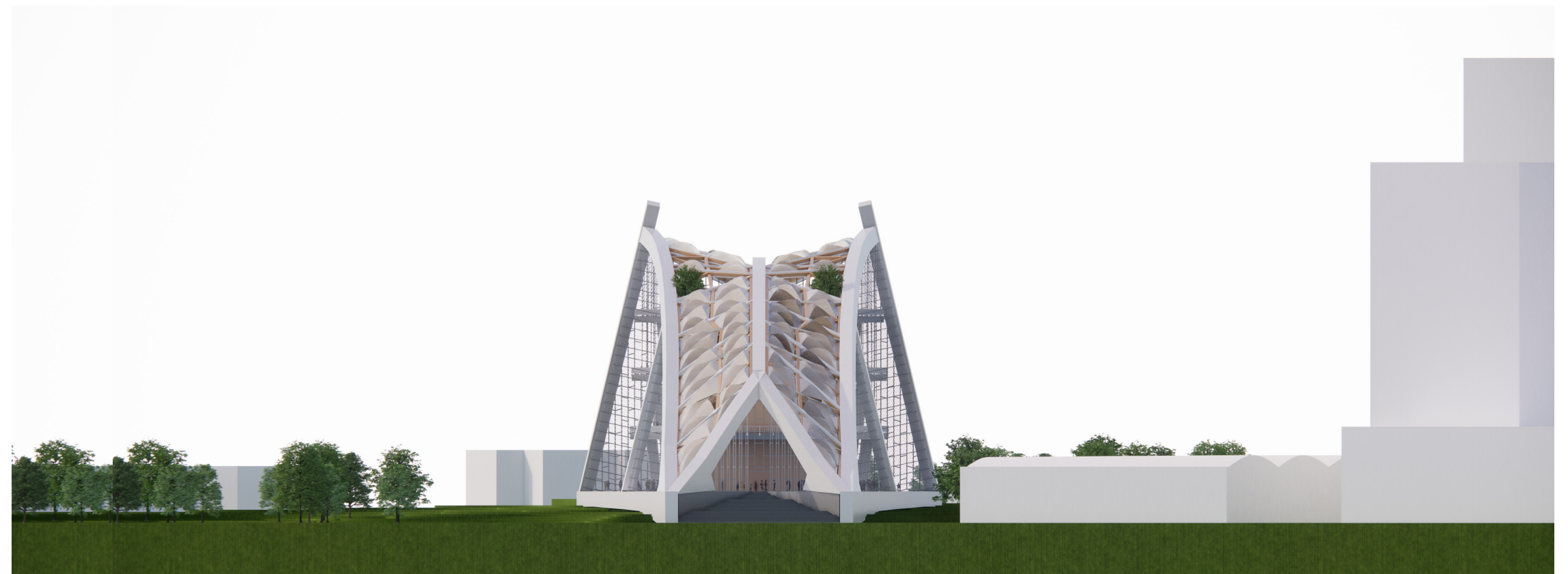


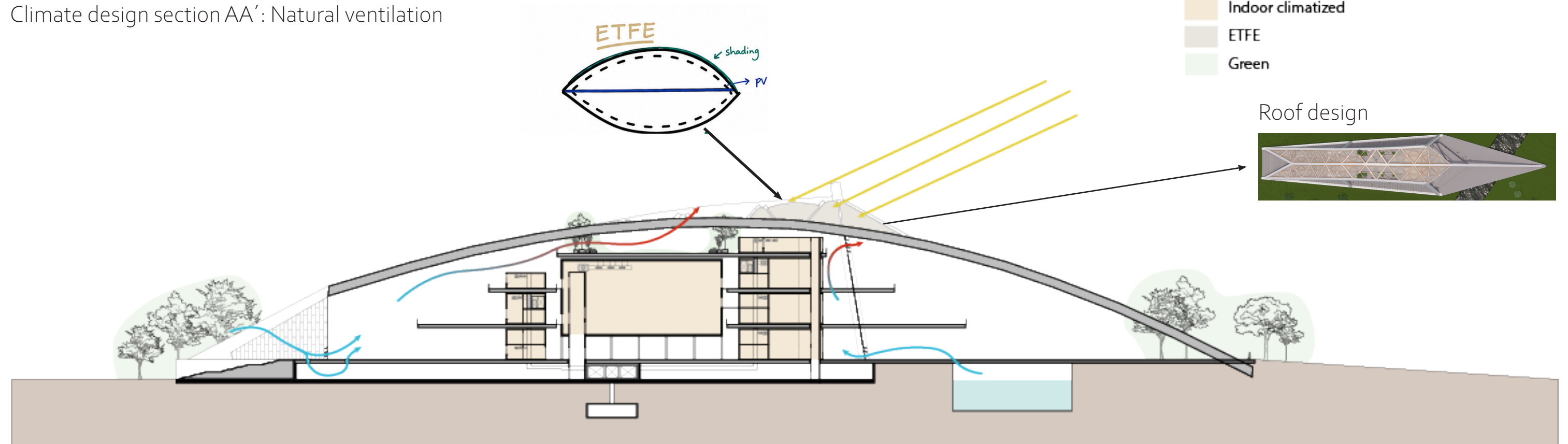
Figure 64: Ellevation North & South 1:100

0 m 25 m 50 m

Building scale ~ Climate design

Section AA shows the climate system, combining natural ventilation with mechanical ventilation in the timber boxes. These boxes are supported by a heat pump, powered by PV panels integrated into the ETFE roof. Natural ventilation is created through openable façade windows and basement vents: warm air rises and escapes through roof openings where no ETFE cushions are placed, which can be closed in winter. The remaining ETFE cushions include two shading layers to reduce solar gain. In addition, the canal and surrounding greenery provide natural cooling.

Climate design section AA': Natural ventilation



Climate design section AA': Mechanical ventilation

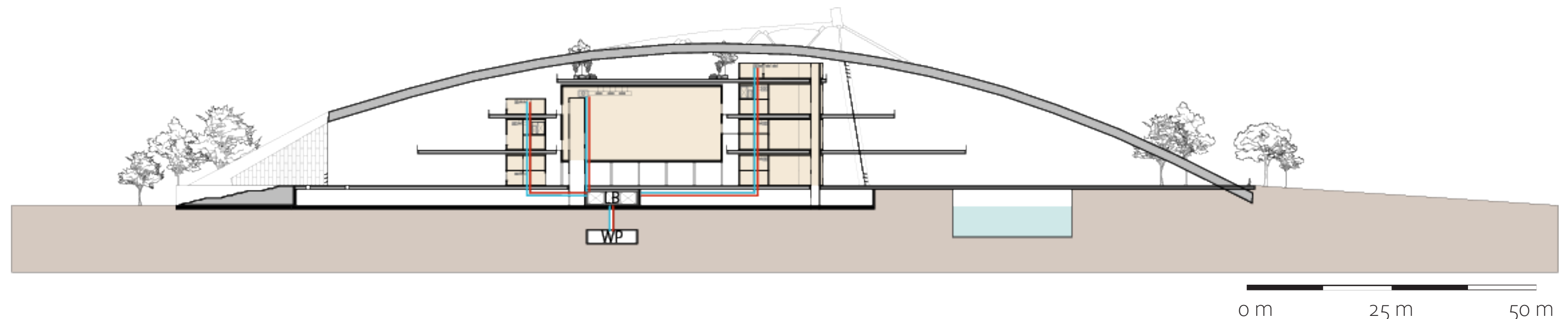


Figure 65: Climate design section AA' natural & mechanical ventilation

Climate design Section BB'

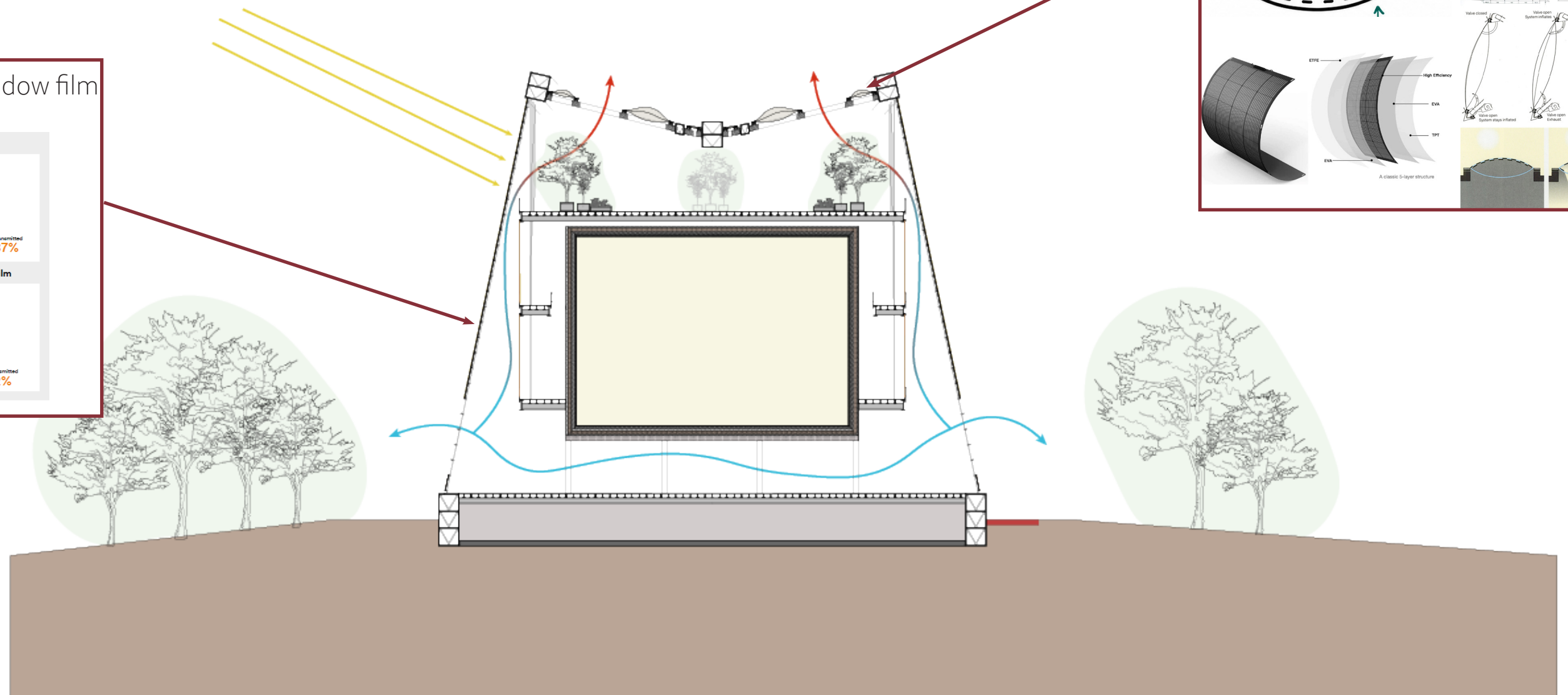
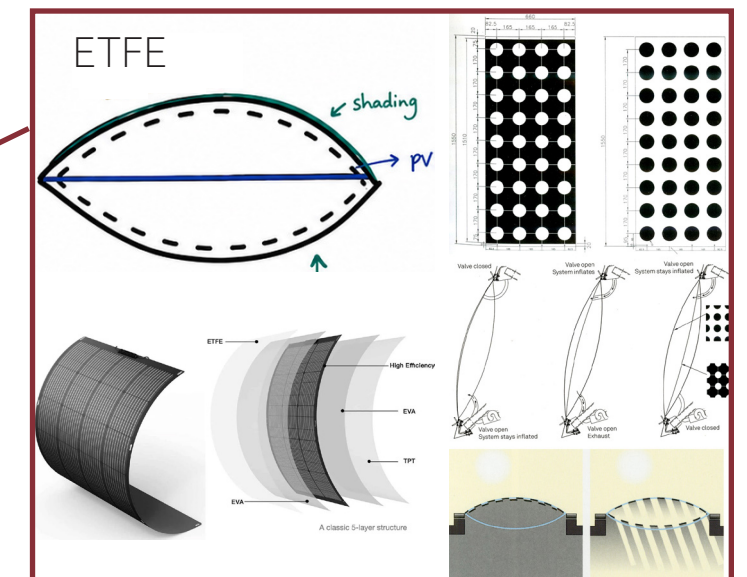
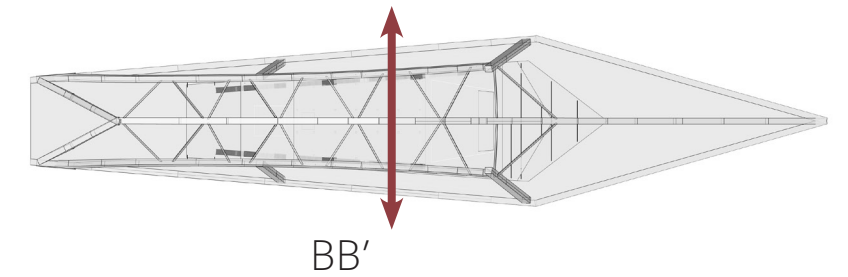
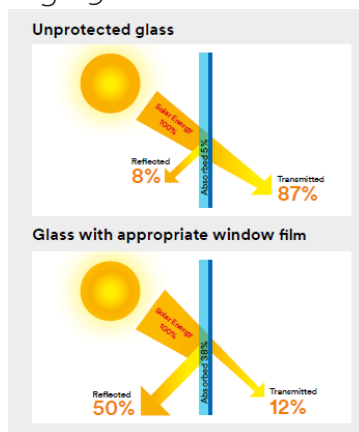
Section BB shows how removing the ground-floor glass panels up to the height of the first deck allows cool air to flow beneath the theatre hall and through the building, supporting additional natural ventilation. The remaining glass façade panels are fitted with 3M Sun Control Window Film, reducing solar heat gain by approximately 50%.

Climate design section BB'

Legenda

- Indoor climatized
- ETFE
- Green
- 3M sun control window film
- Interior sun shading

3M Sun control window film
Prestige 90 exterior



0 m

25 m

50 m

Figure 65: Climate design section CC' with explained principles.

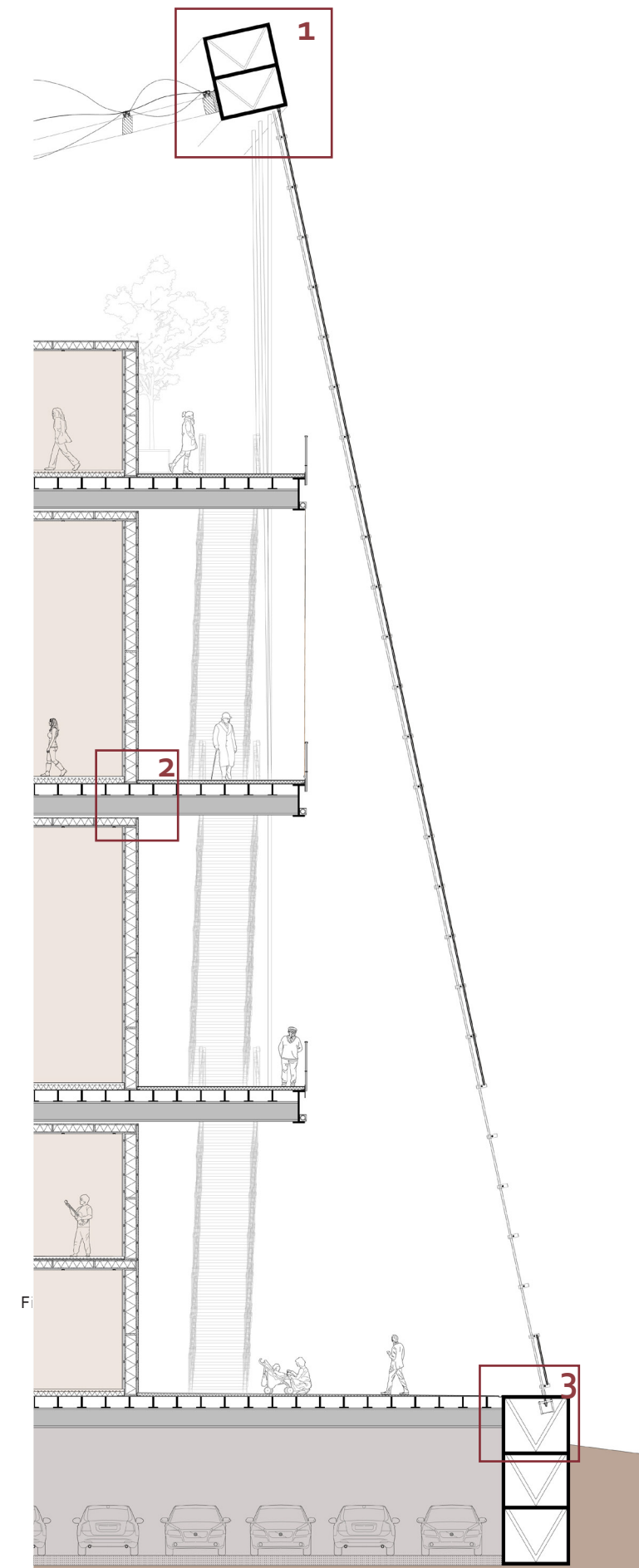
Human scale ~ Facade fragment

The façade fragment on the following page brings together the main constructive and climatic principles of the building: the reused bridge elements, such as the bottom chords and arches, the climate design strategy, and the overall architectural expression. Three key connection points are indicated and further developed as 1:5 details.

Detail 1 shows the connection between the steel arch element and the ETFE roof, together with the cable-glass façade principle by Octatube. The cable-net façade requires approximately 70 cm movement space in both directions, which has been integrated into the design.

Detail 2 shows the climatized timber boxes with Accoya timber finishing and Kerto-Ripa floor elements. These boxes have their own independent structure, making them structurally separate from the main bridge structure. Their light timber expression avoids competing with the reused steel. The decks are made from reused bridge elements, onto which the timber boxes can be placed. This makes the design flexible and future-proof; only the vertical cores remain fixed.

Detail 3 explains the open ground-floor façade. The ground-floor deck slopes 1% towards the façade, where a drainage gutter collects water and directs it towards the ground and canal, keeping the timber boxes dry. The original steel bridge elements are already weather-resistant. The façade cables are anchored to the bottom chords at the same positions as the original bridge cables.



Facade fragment ~ 1:20

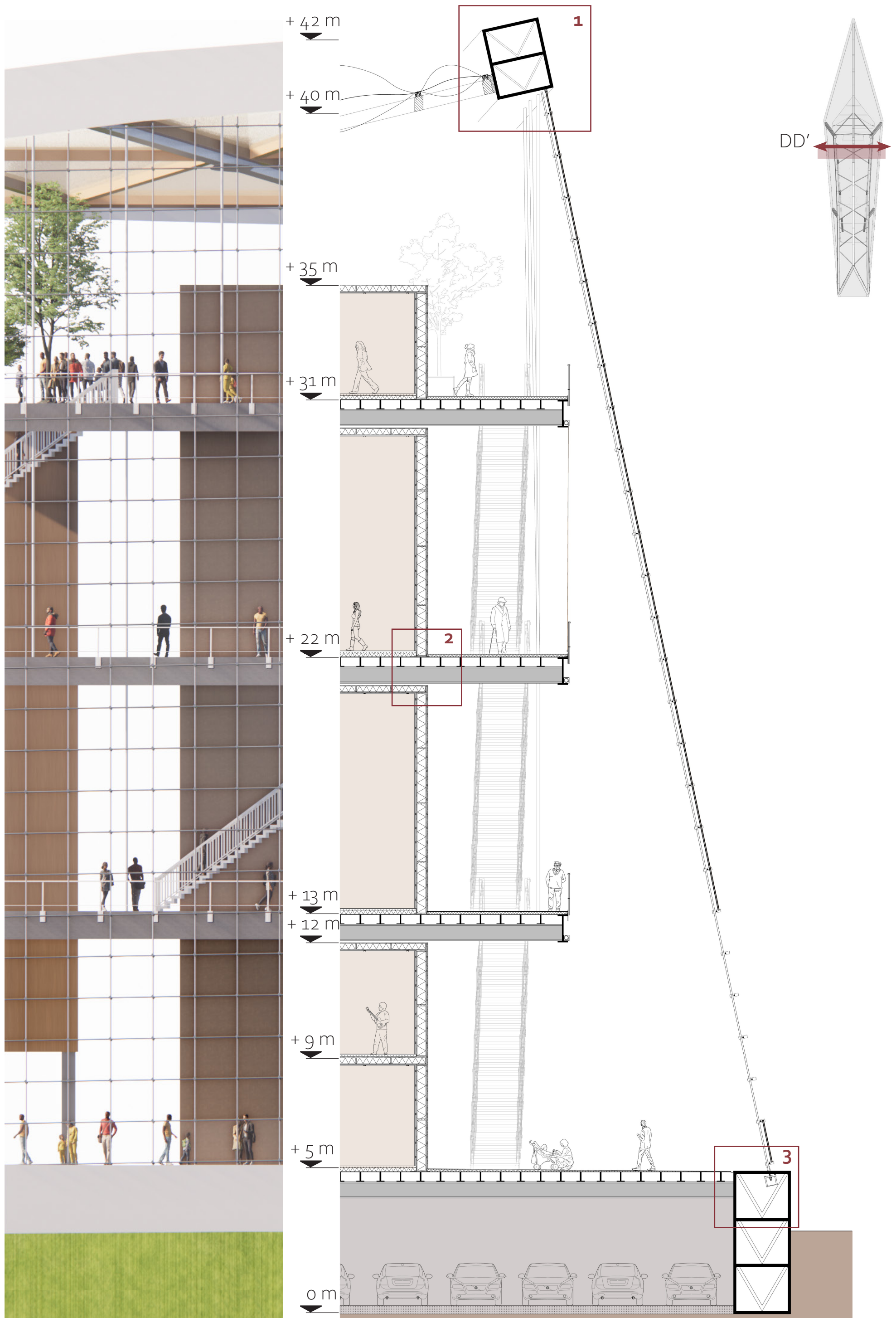
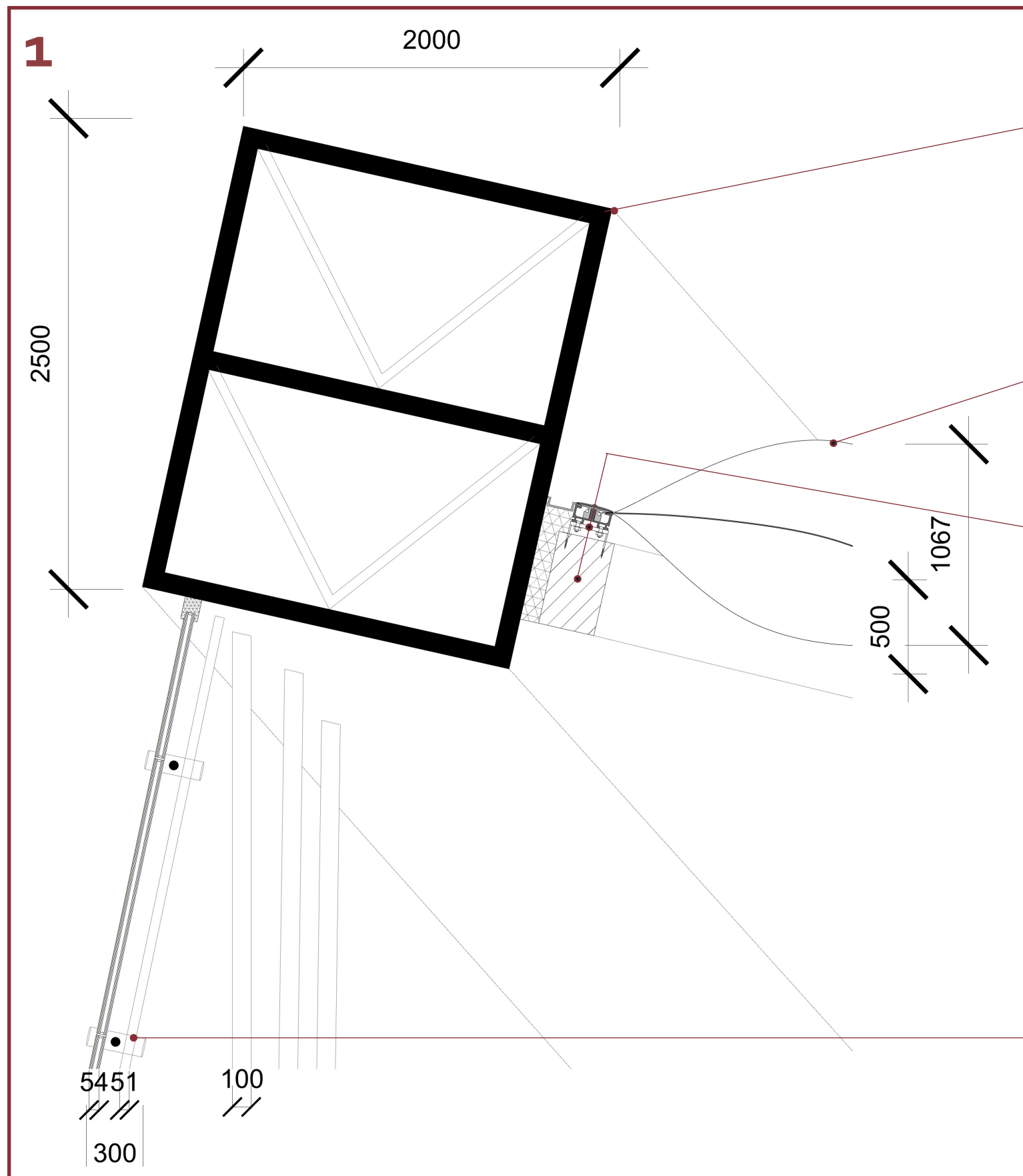


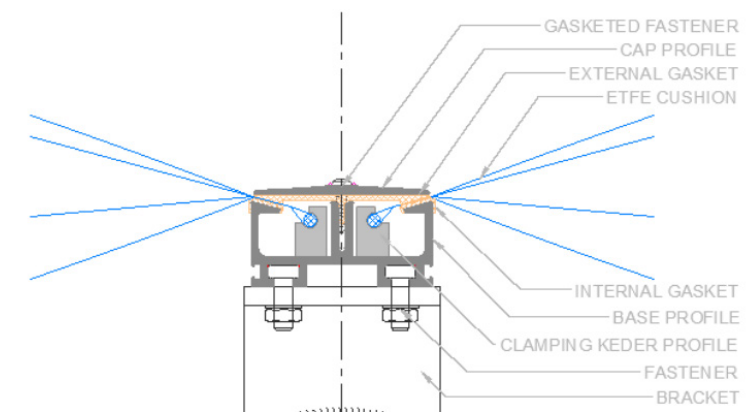
Figure 66: Facade fragment and section 1:20.



Arch: Stiffening Girder K-Type 80 x 8

3 Layer ETFE Foil Cushion
U Value = 1.8w/m²K

- Timber diagrid
- ETFE alluminium construction detail:



- Cable & glass facade octatube

1. Vertical cable, d: 31,3 mm, 884 KN
2. Horizontal cable, d: 31,3 mm, 884 KN
3. Steel casting knob
4. Laminated glass panels, 1485 x 1485 mm
5. Round clamping discs

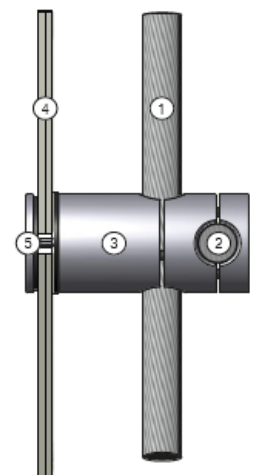
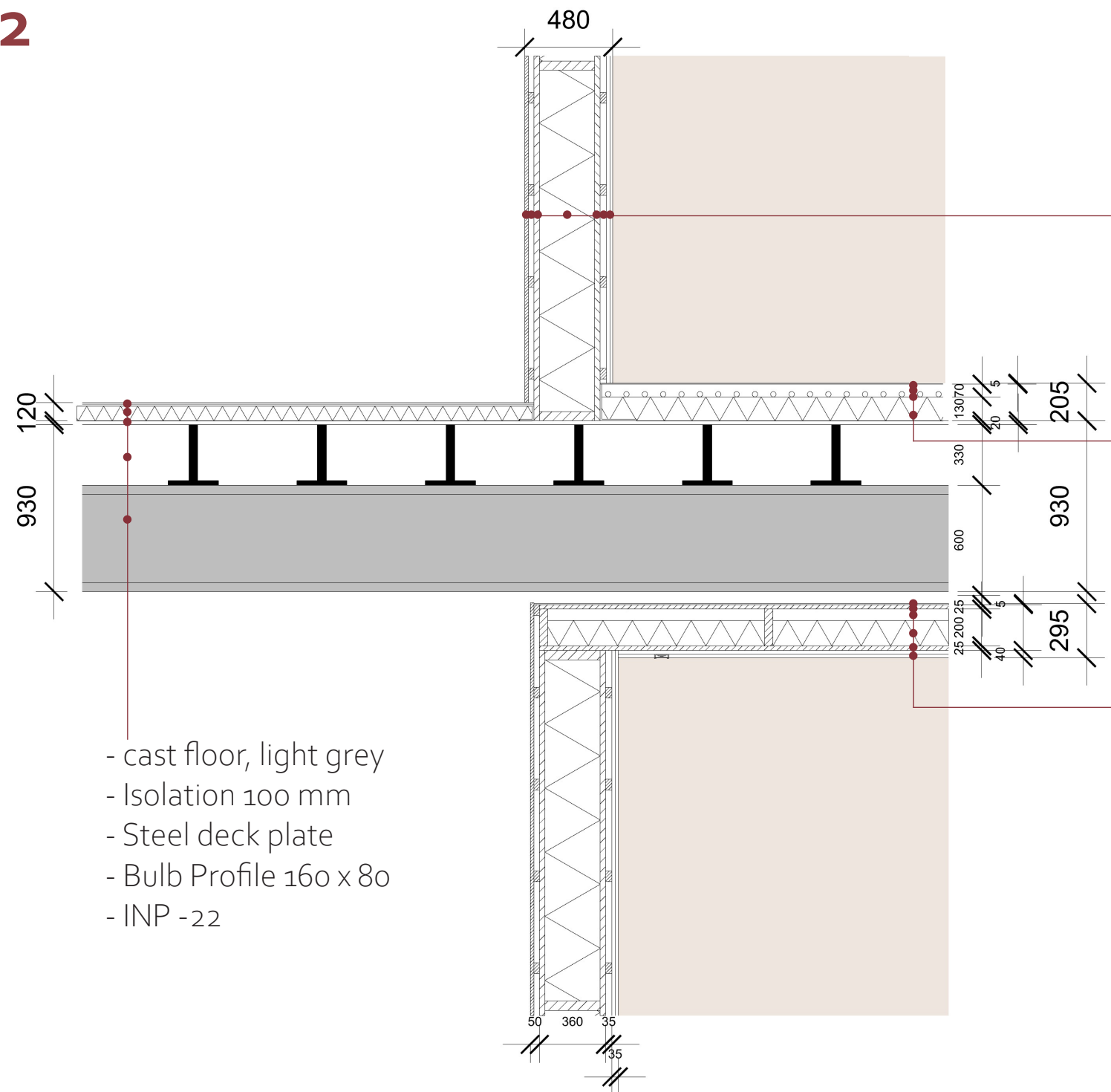


Figure 67: Detail 1 connection steel arch to glass facade and ETFE roof. (Saló, J. (2019) & (Octatube, n.d.)

2

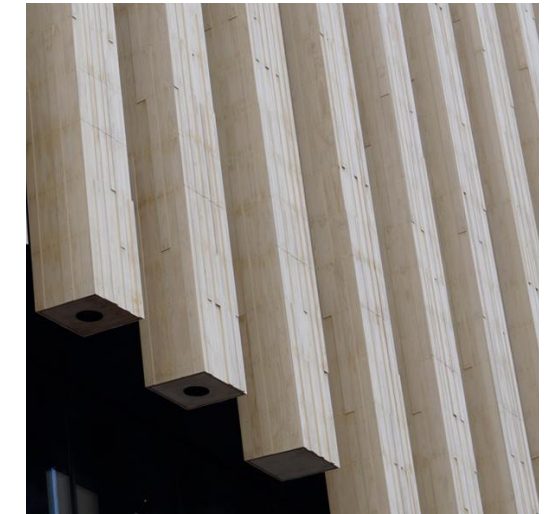


- cast floor, light grey
- Isolation 100 mm
- Steel deck plate
- Bulb Profile 160 x 80
- INP -22

- Accoya wood 20 mm
- Water resistant breather foil
- Timber stud framing
- CLT 30 mm
- Insulation 300 mm
- CLT 30 mm
- Timber stud framing
- Plasterboard 2x

- Cast floor, light grey
- Fermacell, dry leveling granules
- Floorheating & cooling,
- Isolation 130 mm (pressure proof)

- Cap sheet
- Water resistant breather foil
- Prefab Kerto Ripa roof
- Insulation 200 mm
- Plasterboard 2x



Kerto-Ripa Box

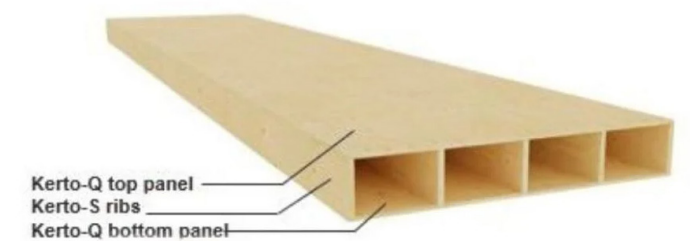
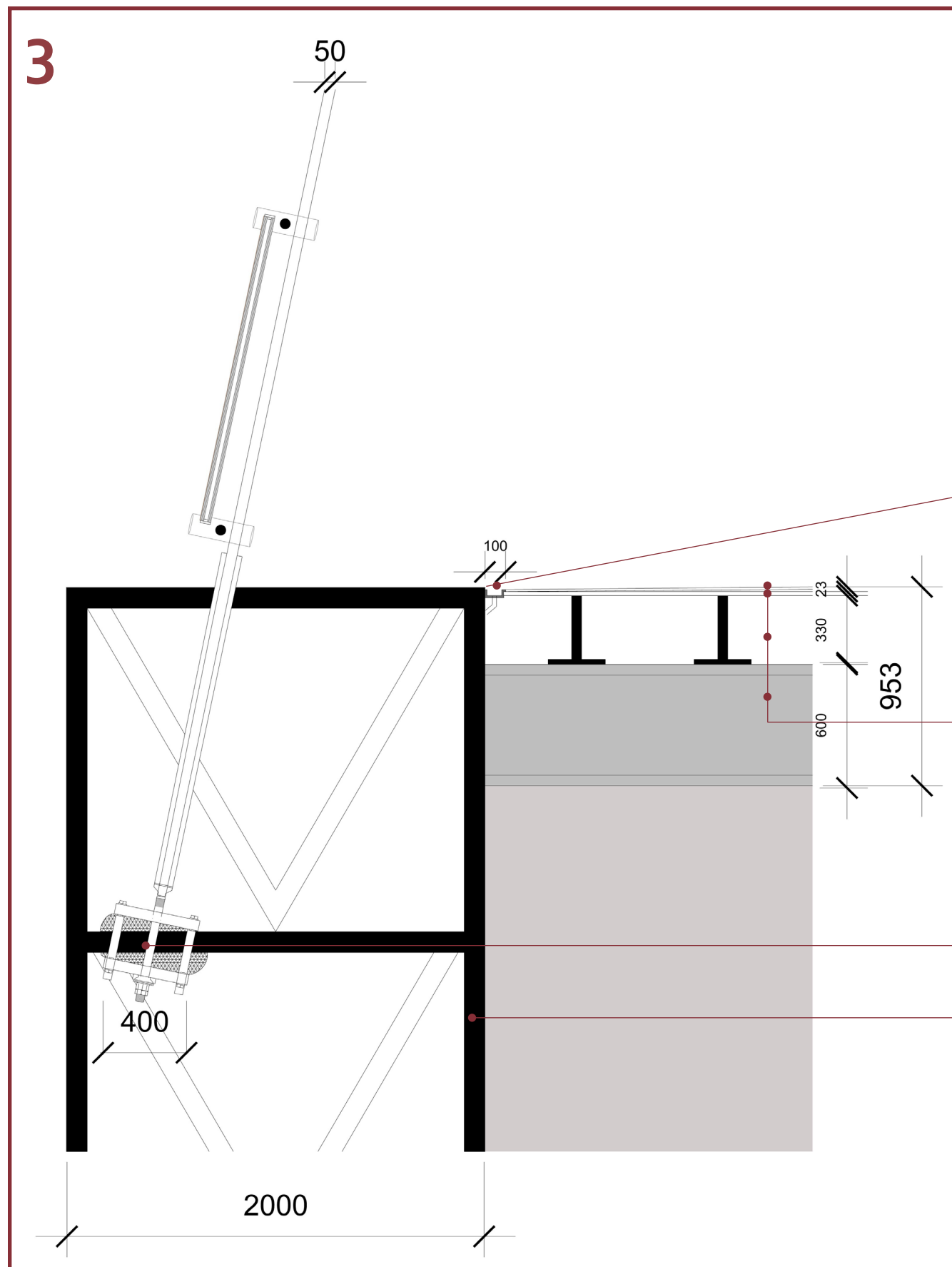


Figure 68: Detail 2 of Interior boxes and deck construction.



Water drainage

- Cast floor, light grey
- Steel deck plate (with water sloop)
- Bulb Profile 160 x 80
- INP -22

Steel nesting boxes (Octatube connection)

Bottom chord

Cable system facade (octatube, n.d.)

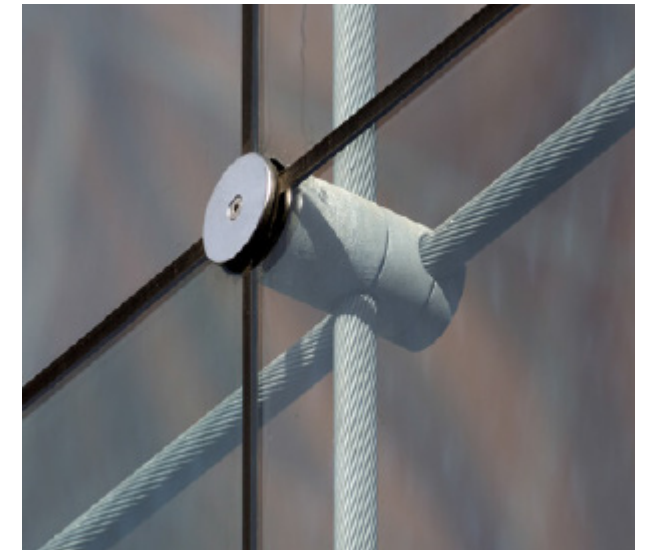


Figure 69: Detail 3 Connection bottom chord with deck and steel cables from the facade.

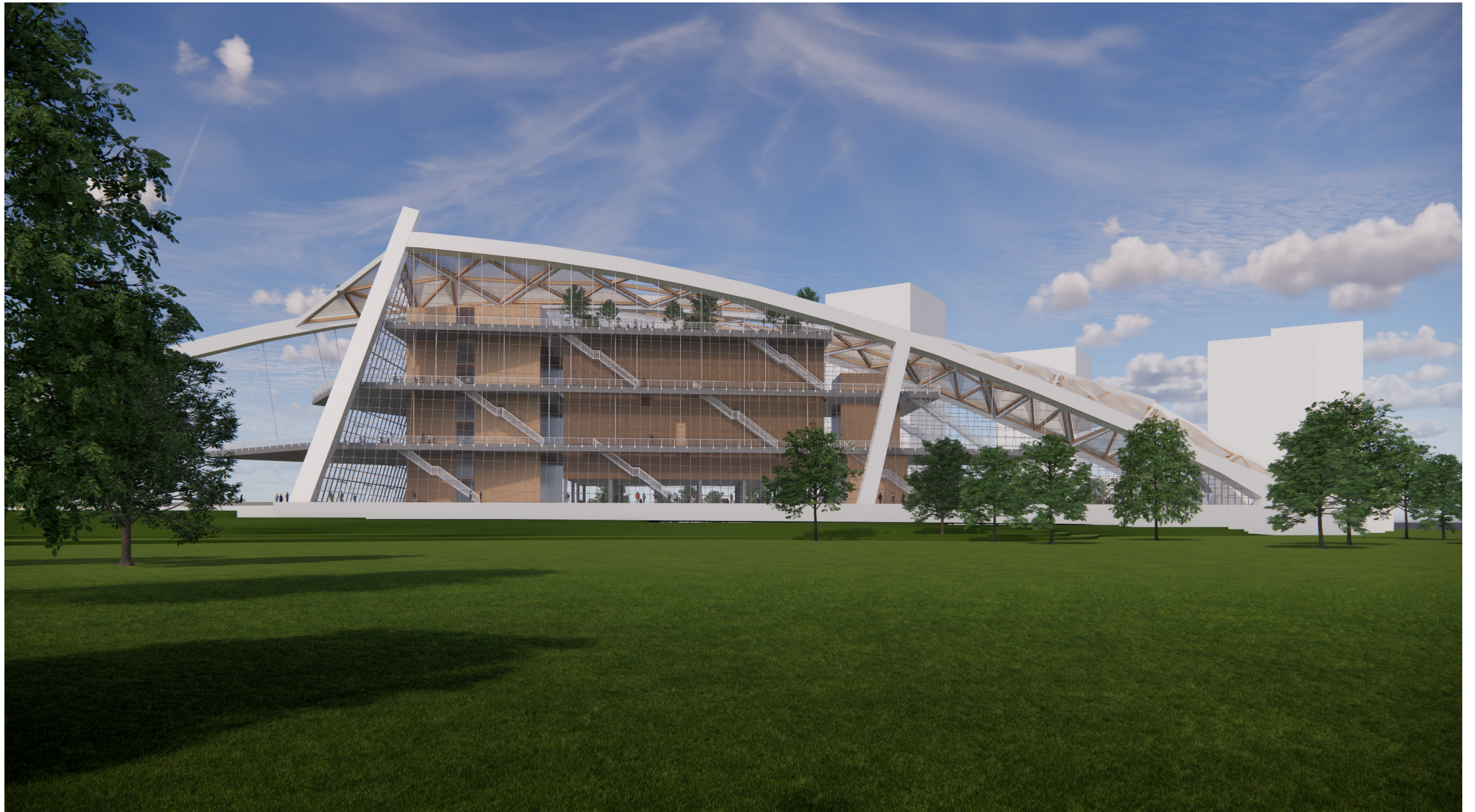


Figure 70: Visualisation render outsit to the culture centre. (not finished)



Figure 71: Visualisation render indoor interior ground floor deck. (not finished)



Figure 72: Visualisation render indoor interior third deck event location and public green. (not finished)



Figure 71: Visualisation render indoor interior ground floor deck, next to museum. (not finished)



Figure 71: Visualisation render outdoor culture centre, main entrance. (not finished)



Figure 71: Visualisation render outdoor culture centre, Water entrance (not finished)

Part 4

Part .
Consluction & Discussion

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3.1 Conclusion

Conclusion ~ Main research question

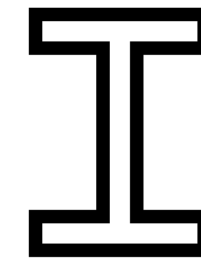
"How can the steel structure of the Van Brienenoord Bridge East (1965) be translated into a buildable and meaningful culture centre on De Kade in Eindhoven?"

The aim of this thesis was to investigate how the steel structure of the Van Brienenoord Bridge East (1965) could be translated into a buildable and meaningful culture centre on De Kade in Eindhoven. Rather than treating the bridge as a source of reusable material alone, the research approached it as a spatial, structural, and architectural system capable of generating a new public building.

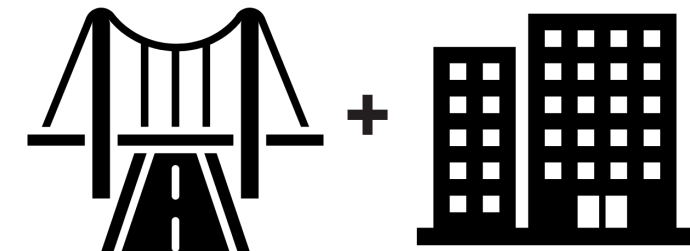
By answering sub-questions 1 to 5, the main research question can be addressed step by step. Together, these sub-questions explain how the bridge was analysed, categorised, structurally translated, spatially organised, contextually integrated, and tested through prototyping.

The results demonstrate that industrial donor steel can function as the primary architectural driver of a project when reuse is approached through the framework Form Follows Find. The final design shows that the bridge's structural logic, material hierarchy, and formal language can be transformed into a contemporary cultural centre while maintaining both technical feasibility and architectural identity.

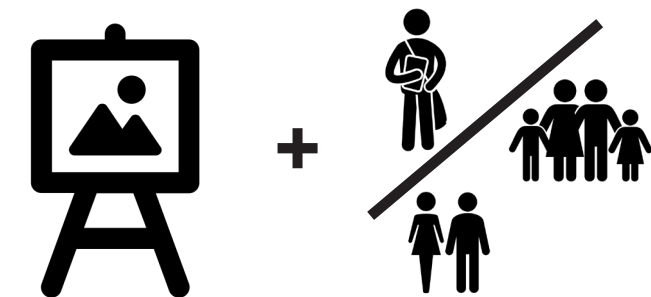
SQ1: Harvest list



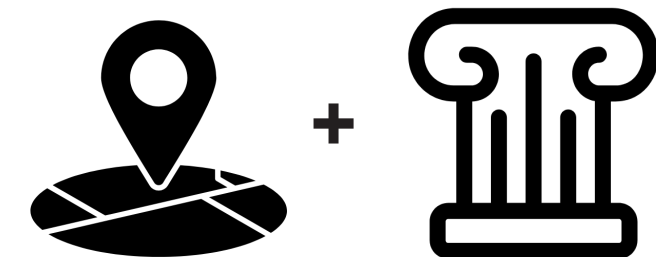
SQ2: Bridge & Building system



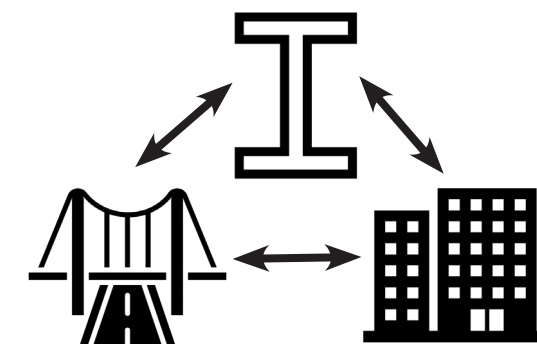
SQ3: Programm & spatial organisation



SQ4: Context & History



SQ5: Generic architecture rules



Conclusion ~ Sub-question 1 Harvest list

1. Which components of the Van Brienenoord Bridge East (1965) can be reused and structured in a harvest list with clear categories?
-> harvest list

The first research question focused on identifying which bridge components could be reused through a harvest list. This harvest list was based on archival research into the Van Brienenoord Bridge East (1965), using archive material received from Rijkswaterstaat. In addition, a 3D model of the bridge was provided, which strongly supported the analysis and categorisation of the bridge components.

All bridge elements were categorised into three groups based on their function and scale (see Figure 22):

1. Structural main
2. Spatial structure
3. Interior

These categories directly informed the structural design process. The design first positioned the structural main elements to create a strong primary structure, after which the spatial and interior components were integrated step by step. By grouping the harvest list according to each element's specific qualities, the project ensures that every steel component is used as effectively as possible and retains its structural, spatial, or architectural value.

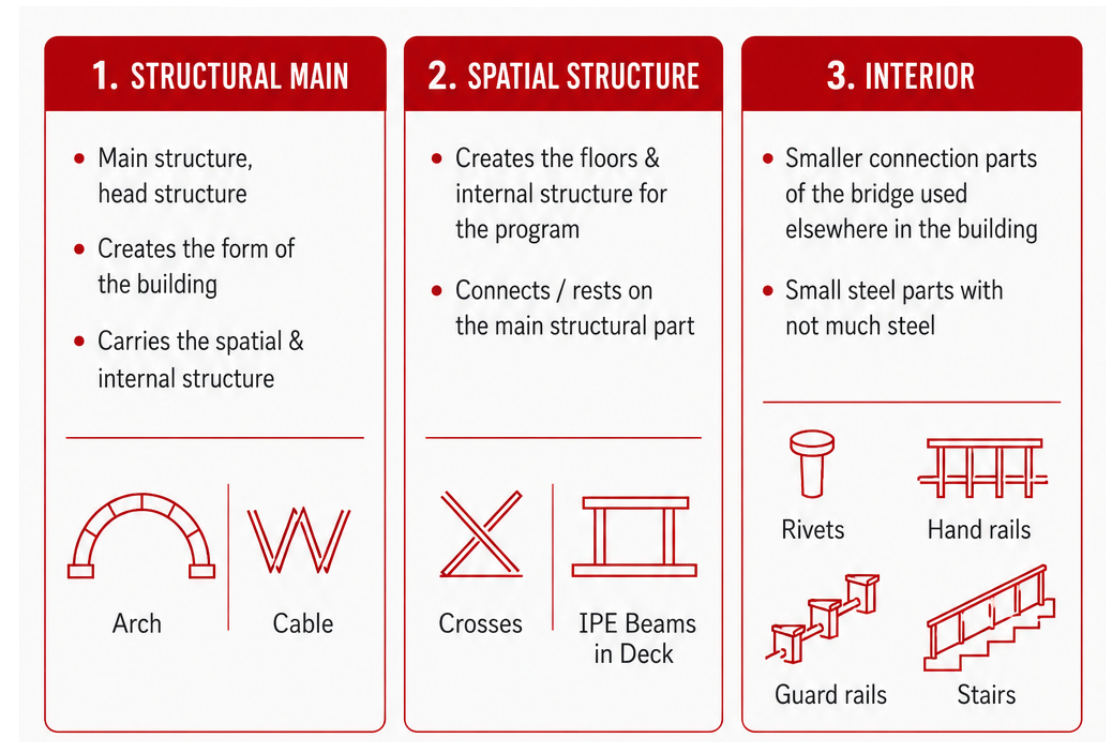


Figure 22: Harvest list design guidelines, categorizing the steel bridge element into 3 groups based on function and scale.

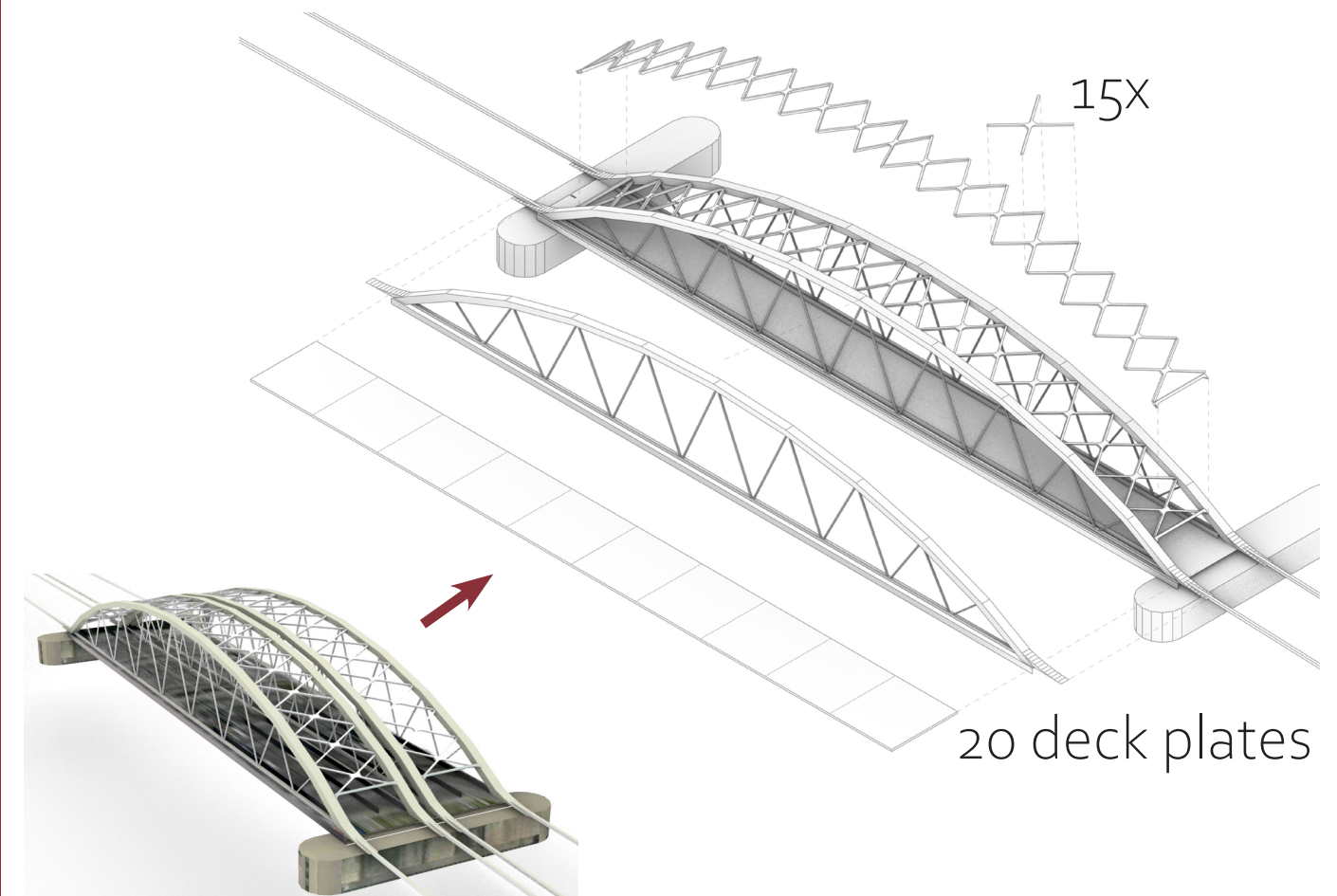


Figure 23: The making of the harvest list, from original bridge to 3D model, made into a categorized harvest list with three groups.

Form development

Conclusion ~ Sub-question 2 bridge & building system

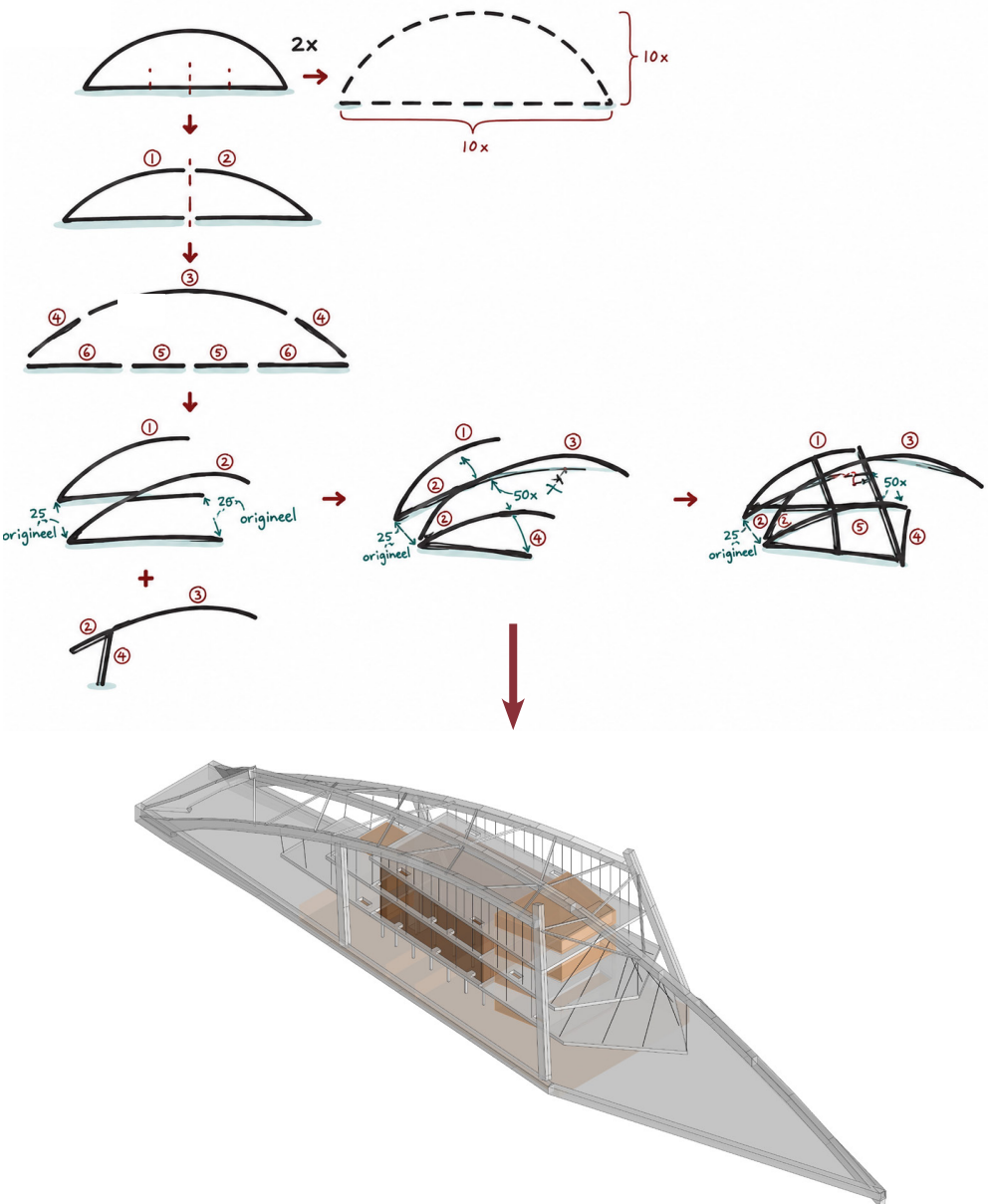
2. *How can the bridge's structural logic be translated into a building system that fits the constraints of the De Kade site in Eindhoven?*
-> bridge & building system

The second research question investigated how the bridge's structural logic could be translated into a building system. Through prototyping, model making, digital studies, and structural calculations, it became evident that using approximately half of the original bridge length while preserving the original arch logic produced the strongest architectural and structural result.

The final structure reuses the bridge's arches, bottom chords, cables, and deck principles to create a superstructure capable of supporting the cultural programme (see Figure 50 structural design for step-by-step explanation) .

In addition to the load-bearing structure, the double-skin façade system plays a crucial role in transforming the reconfigured bridge into a building. Together with the suspended deck system, it introduces a façade, building envelope, and floor structure, allowing the original bridge elements to function as a complete architectural environment rather than as a structural frame alone.

The structural design therefore demonstrates that the original engineering logic of the bridge can successfully be adapted to a building context.



Double skin facade

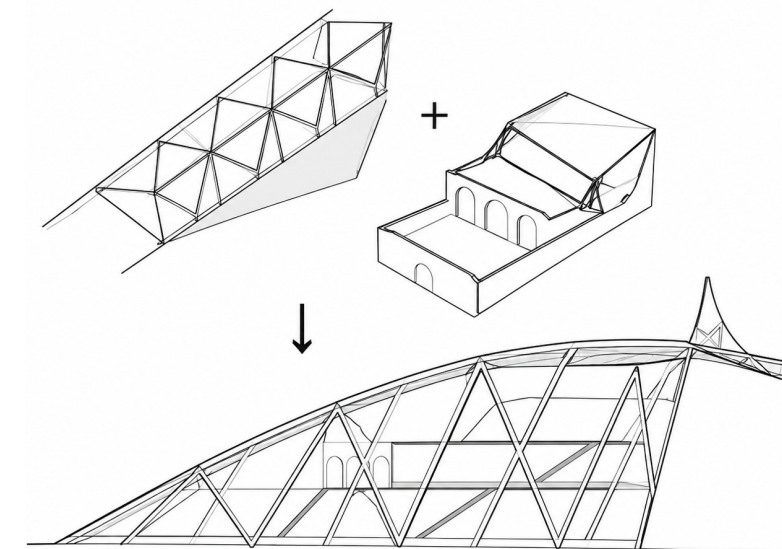


Figure 30: Double skin facade principle explained, the first facade is the bridge/building with the second facade in this structure climatised for the different functions.

Organisation of the functions

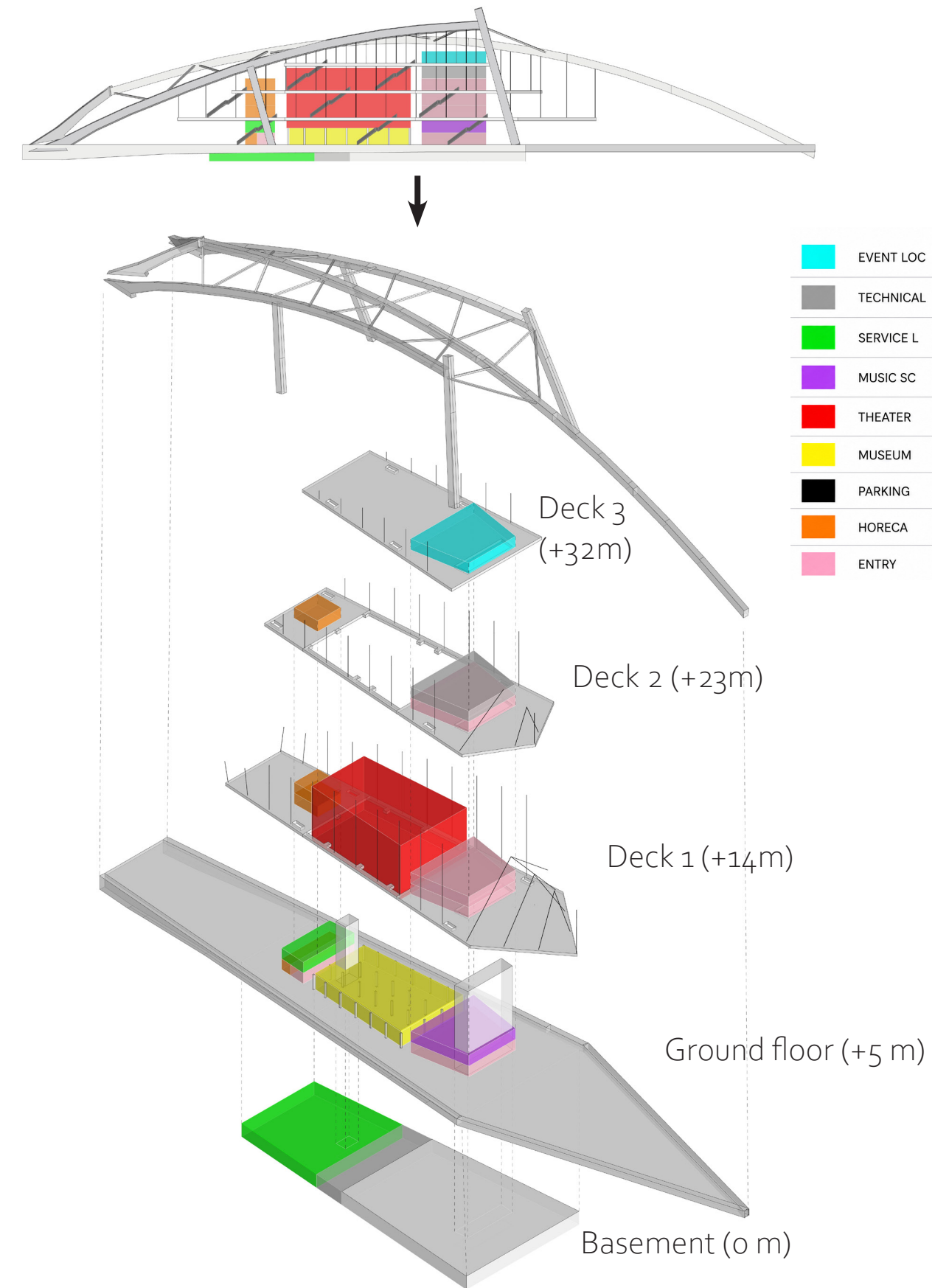


Figure 54: Spatial organisation of the programme and functions.

Conclusion ~ Sub-question 3 program & spatial organisation

3. *How can the functions of the culture centre be organised spatially so that logistics and climate requirements are met, while the bridge structure remains the main design driver?*
 -> program & spatial organisation

The third research question addressed the spatial organisation of the cultural programme. The results show that the bridge structure can effectively organise a complex public programme through a layered deck system.

The final proposal combines museum functions, a music school, hospitality spaces, public event areas, and a 1,000-seat theatre within a coherent spatial framework. The deck and suspension system also make the internal organisation flexible, allowing functions to change over time. Public and logistical flows can coexist while maintaining visual connections throughout the building.

Moreover, the cultural programme creates continuous movement across the decks, referring to the original function of the bridge as a structure of constant movement and crossing. As a result, the bridge structure does not constrain the programme but actively shapes and enriches it.

Conclusion ~ Sub-question 4 context & history

4. How can the resulting culture centre be meaningfully integrated into the urban and historical context of De Kade and the old Campina district in Eindhoven?

-> context & history

The fourth research question explored how the building could be integrated into the urban and historical context of De Kade. The site analysis revealed strong contextual characteristics, particularly the industrial rhythm of the former Campina factory and the importance of connecting De Caai with the station area.

These findings directly informed the final urban strategy. The culture centre acts as a bridge across the canal for pedestrians and cyclists, creating a more direct and accessible connection between De Caai and the station. This transforms the waterway from a barrier into a connector.

Simultaneously, the building establishes a formal relationship with the industrial heritage of the site through rhythm, arches, and stepped height transitions. The characteristic rhythm of the surrounding context is also reflected in the structure, façade, cables, stairs, and spatial organisation of the building. The surrounding museum park further strengthens biodiversity, public use, and urban integration.

Form language De Kade/ old Campina factory

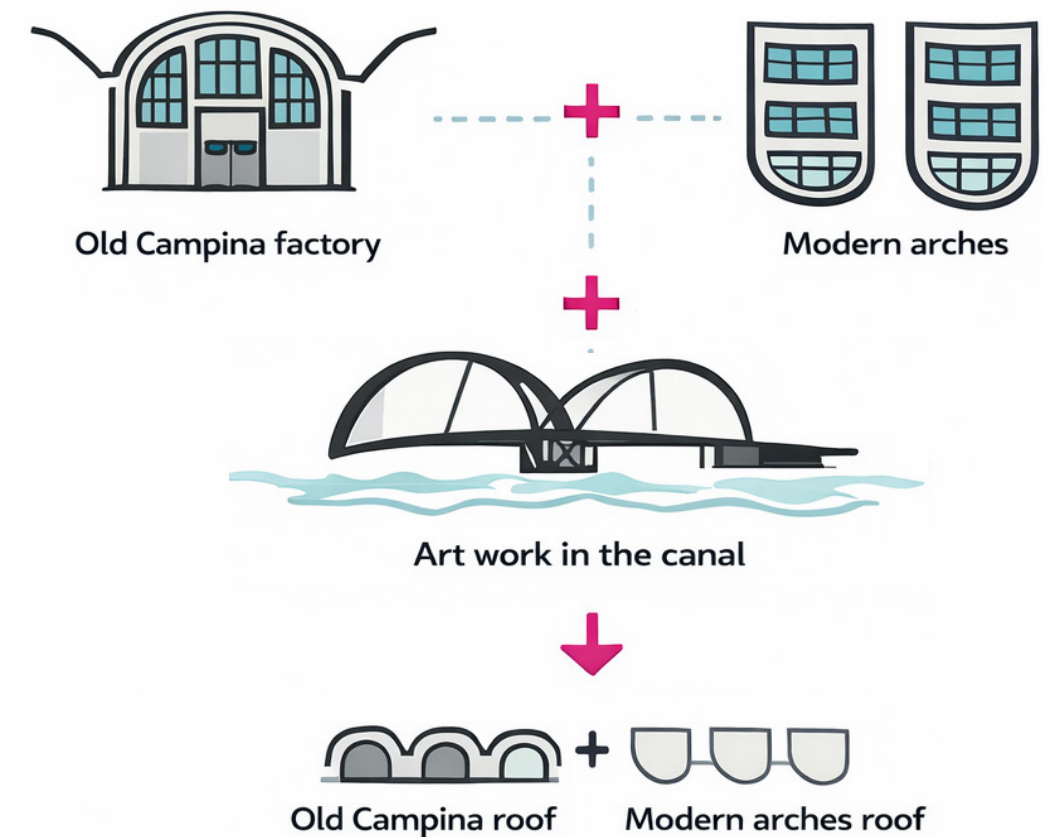
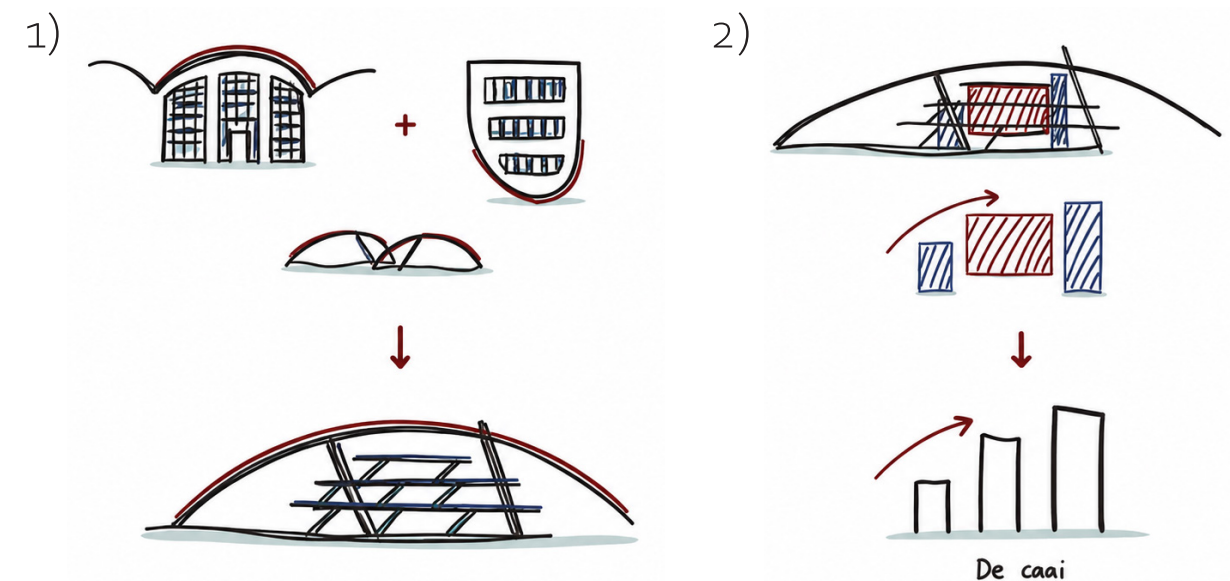


Figure 39: Important form language principles of De kade and Old campina factory.

Conclusion site analysis



Conclusion ~ Sub-question 4 generic architectural rules

5. *How can physical prototyping generate design rules and design variants that can be evaluated for buildability, circularity, and spatial quality?*
 -> generic architecture rules

The fifth research question investigated how prototyping could generate broader architectural design principles. The iterative process of sketching, physical model making, digital prototyping, structural testing, and comparative design studies proved essential in translating infrastructure into architecture.

The research showed that successful bridge-to-building transformation depends on preserving the underlying structural logic rather than literally copying the original form.

The project therefore generated a set of transferable principles:

- 1) Work within the original structural hierarchy.
↓
- 2) Maintain the rhythm and identity of the donor structure.
↓
- 2) Let the program shape the internal structure.
↓
- 3) Integrate the transformed structure within its new context.

GENERIC ARCHITECTURAL RULES (Form Follows Find)

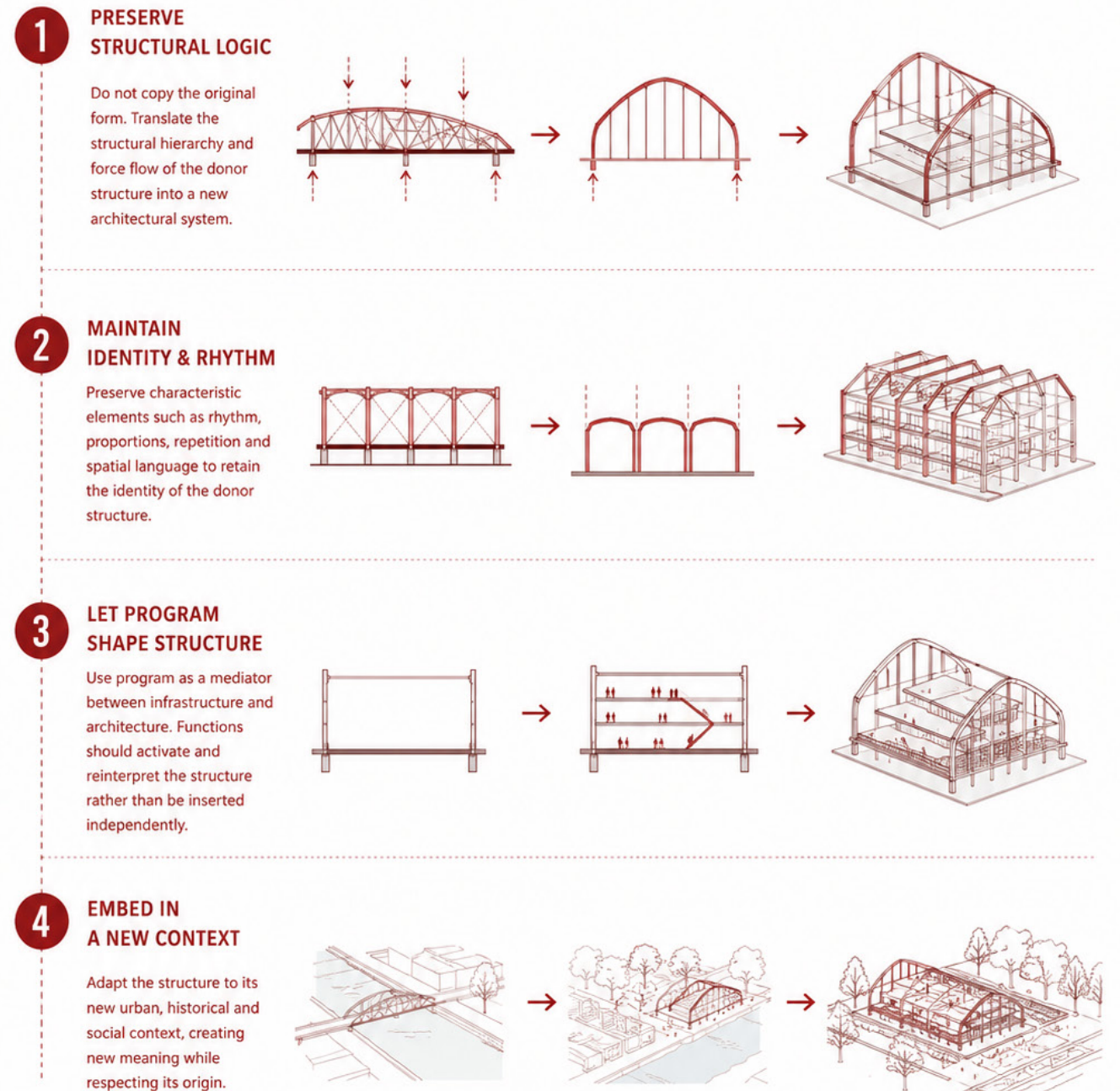


Figure 72: Generic architecture rules for other bridg-to-building project (made with help of AI)

Conclusion ~ Main research question

In relation to the ambitions formulated in the introduction, the final design demonstrates that circular construction can move beyond technical material reuse and become a meaningful architectural strategy.

The project extends the life of an existing steel bridge while creating a new cultural landmark for Eindhoven. By integrating structural reuse, cultural programming, climate-responsive design, and urban activation into a single proposal, the thesis shows how ageing infrastructure can gain a second life as architecture. The bridge therefore becomes more than a donor structure; it becomes the generator of form, space, identity, and public value.

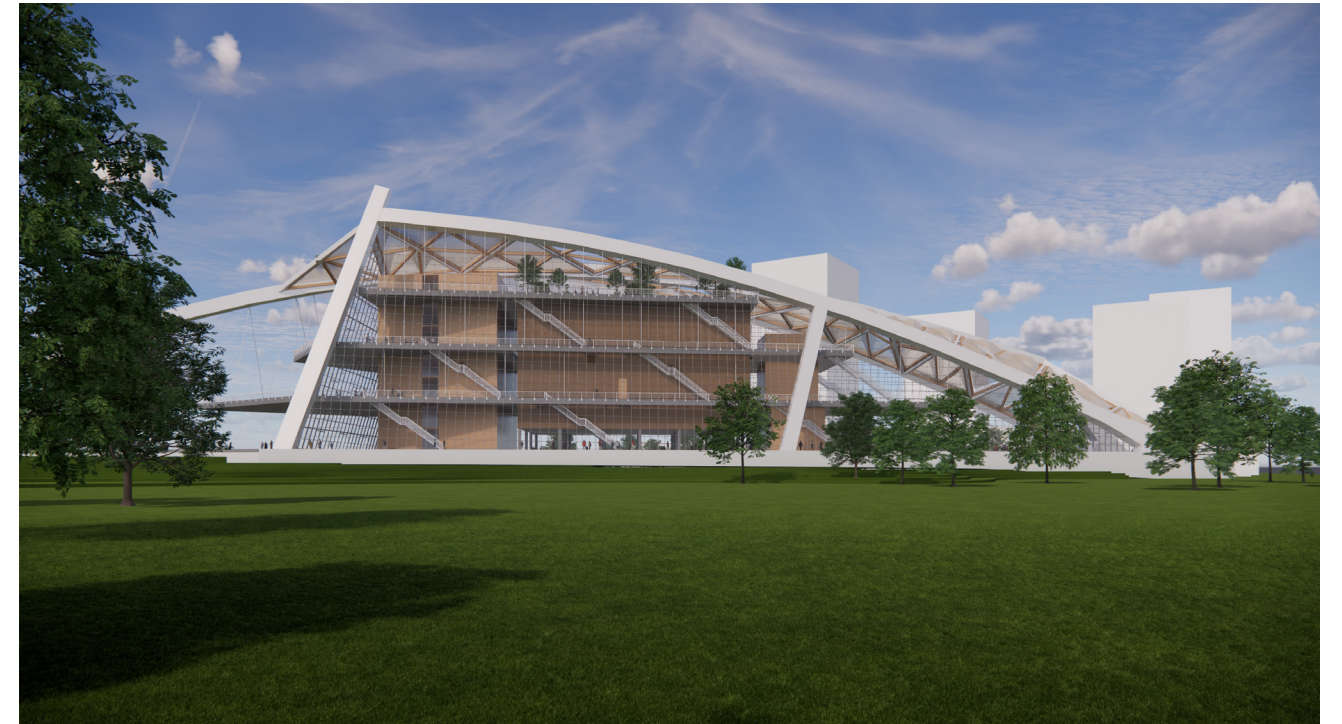


Figure 70: Visualisation render outsit to the culture centre. (not finished)

4.2 Implications & Recommendations

This thesis contributes to the architectural profession by proposing a shift in how donor structures are perceived. Current discussions on steel reuse often focus on technical feasibility, certification, environmental performance, and material availability. While these aspects remain essential, the results suggest that architecture can play a much larger role in unlocking the potential of reuse.

The project demonstrates that existing structures should not only be evaluated as material inventories but also as repositories of spatial logic, structural intelligence, and cultural meaning. The concept of Form Follows Find proposes an alternative design approach in which found structures become active generators of architectural form. This creates opportunities to develop distinctive buildings that simultaneously reduce embodied carbon and strengthen local identity.

For practice, the research recommends integrating donor structures into the design process from the earliest stages of project development. Early design decisions have the greatest influence on the feasibility of reuse, particularly regarding programme, structural strategy, and urban integration. Architects should therefore collaborate closely with engineers, clients, contractors, and material suppliers from the beginning of the design process.

Furthermore, the project suggests that large-scale infrastructural elements such as bridges, viaducts, and industrial structures represent an underexplored resource for future architectural projects. As increasing numbers of Dutch bridges approach replacement, opportunities emerge to transform these structures into public buildings, cultural facilities, and urban landmarks rather than treating them solely as demolition waste.

Finally, future research could investigate the economic feasibility, life-cycle performance, and real-world implementation of bridge-to-building transformations. While this thesis demonstrates architectural and technical feasibility, further work is required to understand procurement processes, stakeholder collaboration, and regulatory frameworks for large-scale infrastructural reuse.



Figure 71: Visualisation render indoor interior ground floor deck, next to museum. (not finished)

Figure 72: Visualisation render indoor interior ground floor deck. (not finished)

4.3 Reflection

This thesis employed a research-by-design methodology in which research and design continuously informed one another. The combination of analytical research, physical prototyping, digital modelling, and architectural design proved effective for addressing the complexity of bridge reuse. Rather than separating research and design into distinct phases, both developed simultaneously through the three layers of technology, programme, and context.

One of the strongest aspects of the process was the extensive use of prototyping. Physical models, sketches, structural studies, and digital modelling allowed design decisions to be tested and compared throughout the project. This iterative approach made it possible to evaluate architectural quality, structural feasibility, and contextual integration simultaneously. Several important design decisions, such as the structural configuration, deck organisation, façade system, and urban placement, emerged directly from this process.

Another strength was the integration of findings from the MSc CME thesis. The obstacles identified in the CME research provided a broader understanding of donor steel reuse and ensured that the architectural proposal remained connected to current challenges within the construction sector. The Architecture thesis therefore complements the CME research by demonstrating how these challenges can be translated into an architectural design response.

At the same time, several limitations should be acknowledged. Due to the scale and complexity of the project, it was not possible to fully calculate the entire building structure within the scope of this graduation project. Although structural principles, climate strategies, and detail studies were developed, a complete engineering validation would require further research. I would also have liked to develop the final architectural design in more detail. In particular, the public ground-floor deck could be elaborated further to make the use of the open deck spaces more explicit. The surrounding landscape and museum park could also be developed in greater detail to strengthen the spatial relationship between the building, the park, and the wider context.

Reflecting on the final outcome, the project successfully demonstrates how a bridge can become a building while preserving its structural identity and cultural significance. The final design achieves the ambition of creating a landmark culture centre that simultaneously addresses circular construction, urban activation, and architectural quality.

Most importantly, the research shows that reuse can become a source of architectural innovation rather than a limitation. Through the transformation of the Van Brienenoord Bridge into a cultural centre for Eindhoven, the thesis illustrates how existing structures can generate new forms of architecture, new public spaces, and new meanings for the future.

So that Form Follows Find: Transforming infrastructure into architecture for a circular future!

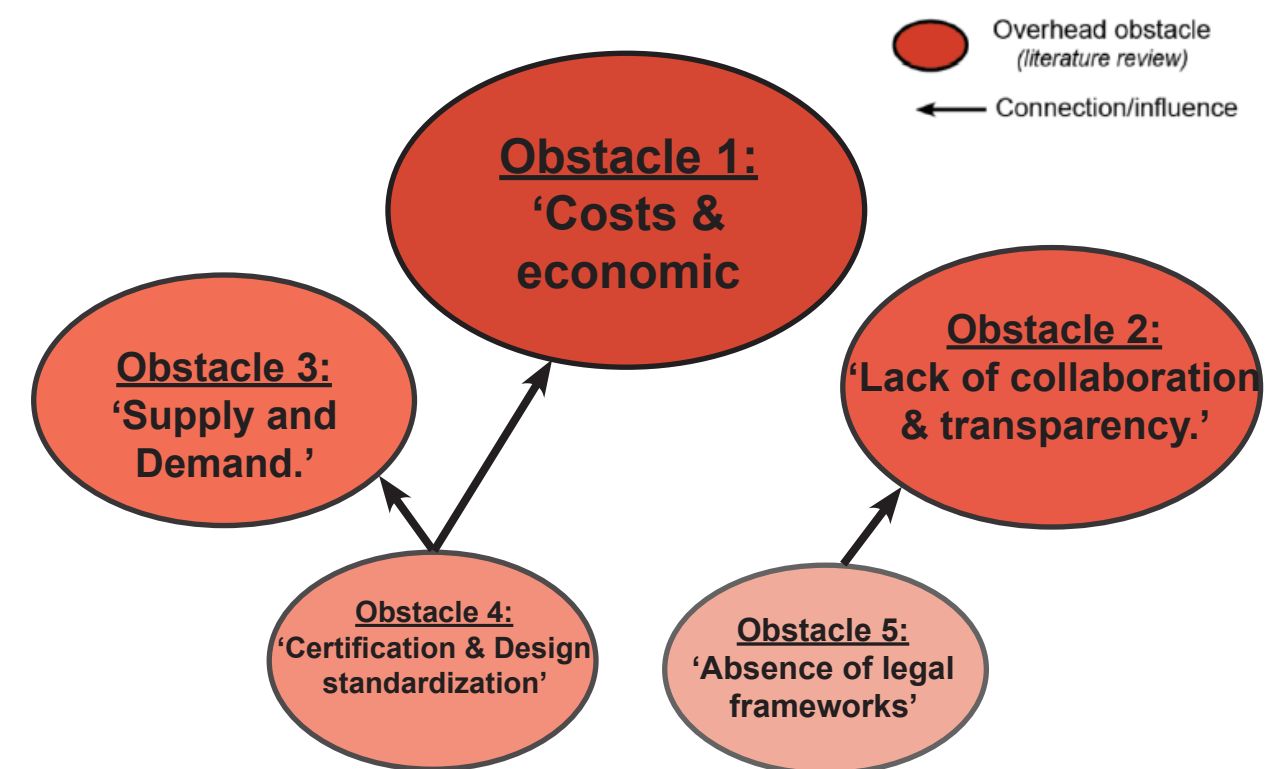


Figure 18: Overview of the overhead obstacles (oval) and their interrelations, results from the empirical research (K.M. van Rooij, 2026).



Appendice .

M S ' c C M E T h e s i s

Appendice A. Summary MS’c CME thesis	7
A.1 Executive summary CME thesis	7
A.2 Summary of the identified obstacles	9
A.3 Summary opportunities innovations & technologies	9

A.1 Summary CME thesis

The construction sector must reduce its material use and environmental impact because of its significant CO₂ emissions and energy consumption. Structural steel plays an important role in this challenge, as it has high embodied carbon while many existing buildings and structures still contain steel components with substantial remaining value. Steel reuse, or donor steel, involves harvesting steel elements from existing structures for use in new projects and therefore offers clear circular potential. However, despite growing sustainability ambitions and the availability of digital innovations and technologies, donor steel is still not widely applied in practice.

This thesis investigated how early-stage decision-making can support the integration of donor steel in circular construction projects. The main research question was: How can applications of digital solutions and conditions for collaboration in the early design stages help to address the identified key obstacles to integrate donor steel in circular construction projects?

To answer this question, the research combined an exploratory approach with a case study approach. Literature review, exploratory interviews with construction stakeholders, and multiple case studies were compared. The literature identified five main obstacles: supply and demand mismatch, certification and design standardization, absence of legal frameworks, cost and economic uncertainty, and lack of collaboration and transparency. Together, these obstacles show that the integration of donor steel is hindered not only by technical issues, but also by financial, regulatory, and organizational factors.

The interviews across the construction supply chain confirmed that lack of collaboration and transparency, cost uncertainty, and donor steel availability were the most dominant barriers in practice. Regulation appeared less decisive than suggested in the literature, while additional obstacles emerged, especially around client decision-making and timing. The case studies further showed that the main enablers were early-stage decision-making, strong collaboration with stakeholder engagement, and client sustainability ambitions. Digital solutions such as BIM, MP's, and material testing can support donor steel application, but only when implemented early.

Based on these findings, the thesis developed an emerging framework to support early decision-making. A 10-question decision tree helps project teams assess whether a project is suitable for donor steel in the early design phase, while a 7-step manual provides structured guidance for implementation in line with NTA 8713. Together, these tools translate abstract obstacles into concrete decision points and practical steps.

In conclusion, donor steel integration is constrained mainly by early-stage organizational and economic conditions rather than by technical limitations or the absence of digital tools.

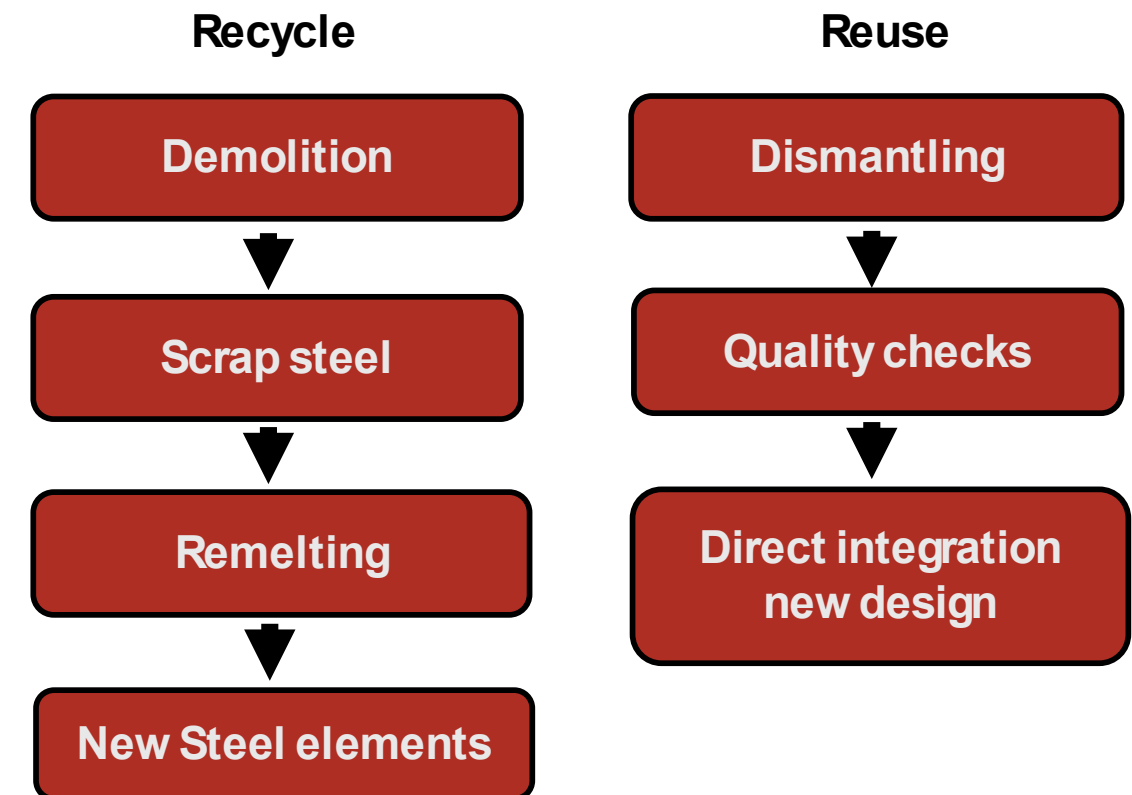


Figure 17: Simplified diagram of the different steps in both strategies: recycle and reuse (based on Dunant et al, 2017)

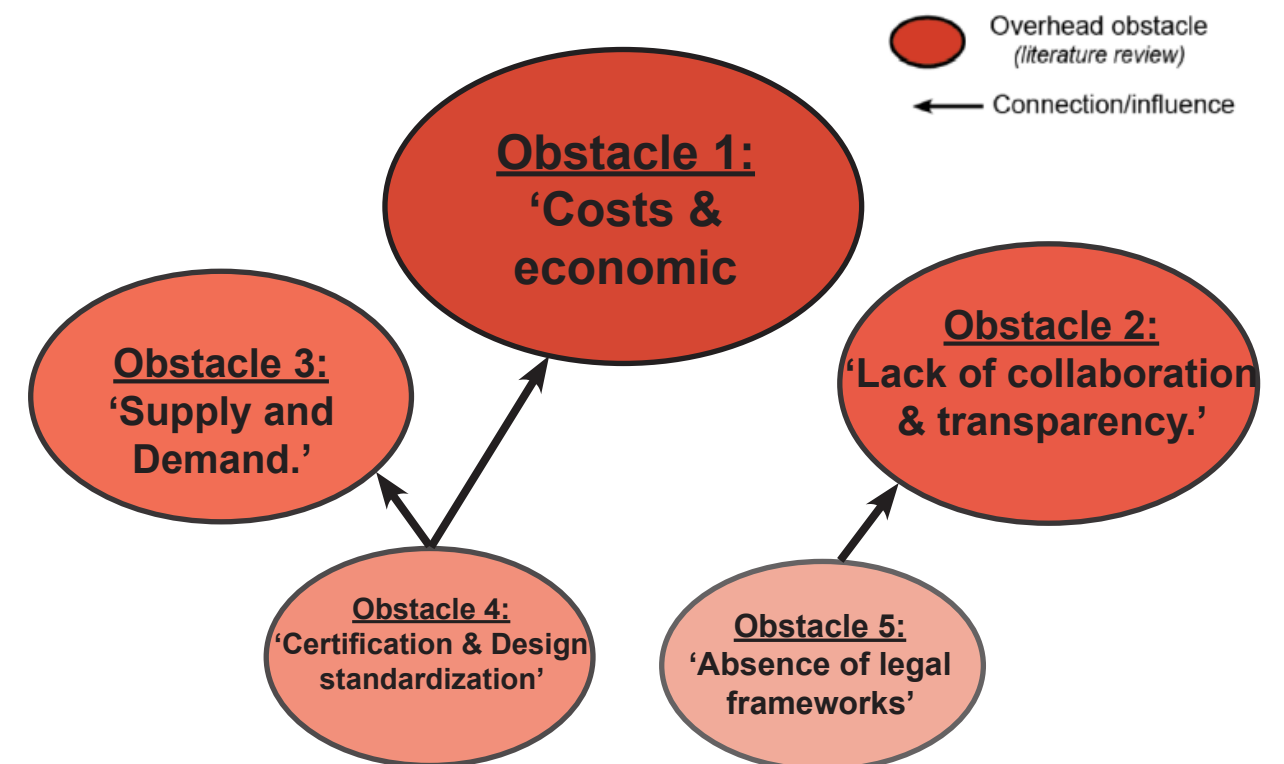


Figure 18: Overview of the overhead obstacles (oval) and their interrelations, results from the empirical research (K.M. van Rooij, 2026).

A.2 Summary opportunities innovations and technologies

In summary, innovations and technologies can help overcome the obstacles outlined in A.1. Table 2.3 summarizes the added value of each technology for each obstacle.

Obstacle (§ 2.1)	Added value of:			
	MP's	3D scanning	BIM model	Digital Twins
Supply & Demand	- Overview of supply - Support digital environment	-Accurate geometrical documentation	-Integrates inventories -Provides early reuse matching	-Continuous tracking with IoT & sensors -Dynamic inventory
Certification & Design standardization	-Link test & CE data to component (according to NEN/NTA)	-Detailed dimensional data -Supports safety assessments	-All data in one model (MP, testing, 3D, ECI) -Ensuring traceable quality control	-Real-time monitoring for recertification standards
Absence of legal frameworks	-Shared data governance -Standardized platform (CB'23)	-Measurable records -Legal documents for certification	-Open data standards -Providing transparent governance data	-Transparent, traceable digital thread -Linking physical to digital
Costs & Economic uncertainty	-Document environmental values (e.g., ECI, CO ₂) -Strengthening CE business	-Reducing redesign & surveying costs	-Real-time lifecycle & cost simulations (5D BIM/ LCA) -visualizing financial & environmental benefits	-Reducing replacement cost by predictive forecasting
Collaboration & transparency	-Creates digital language -Allowing cross-case reuse & lifecycle management	-Facilitating data exchange (Scan-to-BIM model) -Improving workflow coordination	-Shared visual data platform for actors -Improving coordination & decision-making	-Shared accessibility to live data -Providing trust and coordinated decision-making

Table 2.3: Summary of the added value for each technology for each obstacle in § 2.1. (K.M. van Rooij, 2026).

A.2 Summary opportunities innovations and technologies

Both contracting and procurement models have distinct features and can be compared based on the following collaborative conditions and responsibilities, as shown in Table 2.4. These collaborative conditions all have an important role in enabling donor steel integration..

Collaborative conditions:	Traditional model	IPD model
	Regie & RAW-Bestel	Collaborative & Integrated
Intensive collaboration	X	V
Shared risk allocation	X	V
Early stakeholder engagement	Possible	V
Transparency	Minimal	High
Joint problem-solving	X	Possible
Long-term cooperation	X	Possible
Responsibilities:		
Design	Client	Contractor/ Together
Realisation	Contractor	Contractor
Maintenance period	Client	Contractor/Client

Table 2.4: Comparison between the different contracting models and donor steel enablers (Based on CROW, 2000/2005/2025; de Ridder H.A.J., 2009)

(K.M. van Rooij, 2026).

Appendice.

Data management checklist

Appendice b. Data management checklist

Section A. General considerations	yes	no
1. Is the graduation project conducted as part of an internship (at a company), or as part of a research project at TU Delft? If a student's graduation project is conducted at a company or as part of a research project at the university, questions of data ownership and intellectual property rights need to be addressed in a written graduation or internship agreement before the project begins. Student and supervisor should consult the Intellectual Property Rights of Students webpage. Additional information can also be found in the Extended Personal Research Data Workflow. If applicable, complete the Confidentiality Agreement.		X
2. Does the project involve conducting (part of) the research outside the Netherlands? Students who intend to travel abroad (even to other EU countries) for study, exchange, research, internship, or graduation project purposes need to follow the Travel Safety Protocol. This includes attending a mandatory Travel Safety Training Session: see the Disclaimer.		X
3. Will the research involve processing data from humans, such as running a survey, conducting interviews or workshops, collecting data through social media or internet forums, or re-using existing datasets about humans provided by a third party? (If 'yes', see follow-up questions 4 to 13 in Checklist B.) Students who work with data from human participants must complete the next section and apply for and receive ethical approval from the Human Research Ethics Committee (HREC) before conducting the research.		X

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A I s t a t e m e n t

Artificial Intelligence (AI) was used as a supporting tool throughout this graduation project. AI was primarily used to translate text written by the author from Dutch into English and to improve the clarity and readability of written content. In addition, AI-assisted image generation and enhancement tools were used to refine a limited number of visualisations, such as improving the realism of architectural renders and enhancing diagram presentations. All design decisions, research findings, analyses, drawings, calculations, and conclusions were developed and verified by the author. AI was used solely as a supportive tool and not as a substitute for independent design or research work.

