HARBOUR CREATIVE EXCHANGE

MASTER THESIS
AALBORG UNIVERSITY

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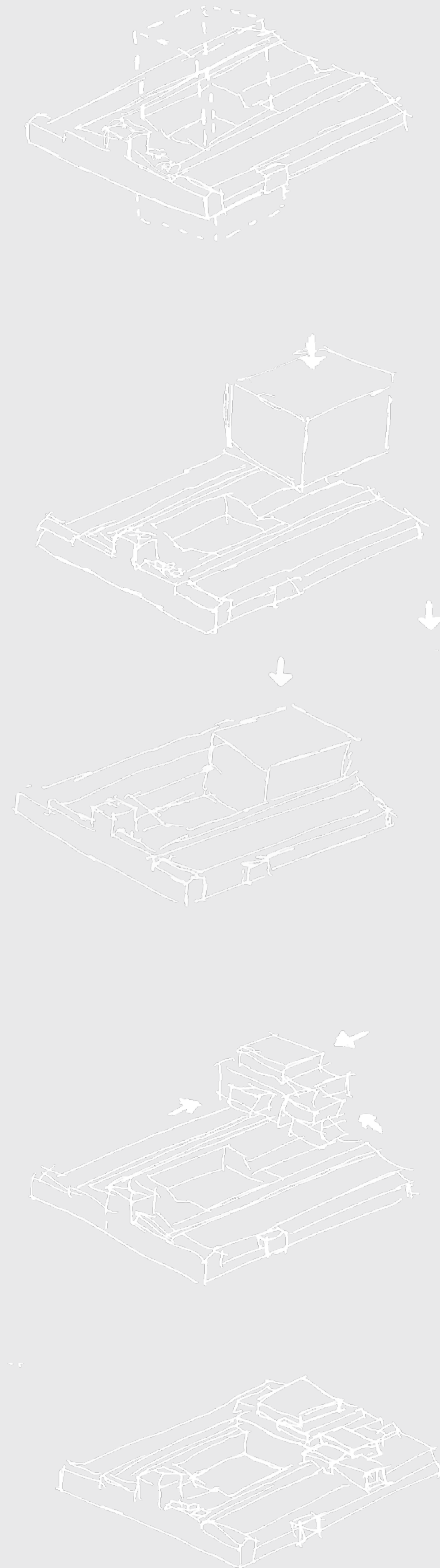

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_01_ ACKNOWLEDGEMENT

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READING GUIDE

_02_ READING GUIDE

This master thesis report showcases a comprehensive compilation and presentation of the methods, theoretical studies, analysis, and relevant research, that collectively form the framework of the project and define its focus. Selected materials from the design process are included to provide insight into the project's evolution, starting from initial ideas and culminating in the final design. Each chapter in this report is offering readers a preview of the content and allowing for reflection at the end of the document. All external literature and illustrations used in this report are appropriately cited and referenced following the Harvard reference method. The sources utilized are categorized into reference, literature, and illustration lists, which can be found in the Epilogue section. Please note that illustrations produced by the group are not specifically mentioned in these lists. Maps and illustrations featuring a north arrow are labeled with an arrow symbol alongside the illustration number and accompanying text. To enhance the reader's understanding, this report references the design through three scales introduced in the program, interventions, and design drivers. The scales provide an overview of the scales employed and developed throughout the project, contributing to a broader comprehension of the presented material. Additionally, the design drivers indicate significant subjects that are recurrently referenced throughout the project.

ABSTRACT

_03_ ABSTRACT

Many cities face the issue of buildings in industrial areas getting abandoned and left to deteriorate. At the same time the need for space is rising, and many central areas, such as harbor fronts, are being modernized. With most of the plots being transformed to new developments, the historical industrial architecture is often doomed for demolition, even though it presents a lot of material and historical value in its structure. Despite the approach of adaptive reuse becoming more widespread in the recent years, the unique aspects of adapting industrial harbour buildings has not been explored enough to establish it as a common practice. This master thesis proposes an adaptive reuse design embracing the industrial heritage of a harbour building, while utilizing Building Information Modelling (BIM) tools. Together with a documented design process, it provides an overview of the beneficial practices and challenges of industrial heritage adaptation projects. The object of the adaptation is a warehouse at Havnegade 16 in the Odense harbor, historically used as a granary. While the city is planning to reactivate its old harbor with a new master plan for the area, many of the old industrial buildings still remain there with no repurposing plan, with the old granary being one of them. The design developed in this thesis transforms the granary into a multifunctional public building with a focus on creative and cultural functions. The adaptation embraces the industrial heritage of the site, while orientating its design towards the new vision for the harbour area. The transformation design of the building takes into account appropriate renovation methods to preserve the character and unique features of its industrial history, while adding an extension accommodating new functions. It also utilizes BIM technology to create a precise model of the existing building, which will become valuable for the maintenance and its end of life phase. The final design proposes an approach for adapting existing harbour buildings, which can be utilized in other industrial heritage adaptation projects and research.

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INTRODUCTION

_04_ INTRODUCTION

The practice of adaptive reuse is becoming a prominent topic in the discussion on sustainable development possibilities. Transformations of existing buildings activate abandoned areas and create new facilities with much smaller CO_2 footprint than new constructions. In the context of architectural heritage, adaptations allow for preservation and ensure maintenance of historical buildings. These factors are just a few of the reasons for this practice gaining popularity in recent years. However, the understanding of historical heritage is often limited to very characteristic, architecturally detailed, old buildings. Industrial architecture has only recently been recognized as a highly valuable asset to this heritage and started developing as a method with its own strategies and preservation requirements. In particular, the harbour architecture of European port cities, which has its unique characteristics, is a fairly unexplored area despite its great potential.

To close this research gap, this thesis aims to propose a reuse adaptation design of an industrial warehouse in the harbour of Odense in Denmark. The building was chosen due to its architecture, which stands out with the techniques of industrial construction of the beginning of 20th century as well as its simplicity. There are many other abandoned industrial buildings in European harbours of similar form and proportions. Therefore, this thesis can be utilized as an example in the transformation of other harbour areas. Furthermore, the chosen building is in the city's prime location, with surrounding new developments and a new city masterplan aiming to activate the area. The adaptation of the warehouse will respond to the new city vision for the harbour and the needs of local communities.

Transformation design of the building will take the appropriate renovation methods into account to preserve the character and unique features of its industrial heritage. It will also utilize currently available technology such as Building Information Modelling (BIM) to create a precise model of the existing building which after transformation, will allow the creation of a Digital Twin, which can be utilized for the maintenance and reuse of its elements.

The overarching goal is to propose a transformation for an industrial heritage building, displaying that with the use of BIM tools and critical renovation methods, abandoned industrial areas can become valuable features of the urban landscape.

01. ODENSE HARBOUR TODAY

RENOVATION TO ADAPTATION

_05_ BACKGROUND

The following chapter looks into the available literature and history on the topic of renovation, adaptive reuse of industrial heritage and BIM technology in such projects.

_05_01_ RENOVATION TO ADAPTATION

The practice of renovation and retrofitting of existing buildings was present for a long time before first theories emerged. For example, according to Koenraad Van Cleempoel and Bie Plevoets (Van Cleempoel and Plevoets, 2013), in the Renaissance period classical buildings were transformed and given new functions. However, the purpose of these practices was not the preservation of cultural heritage. They were renovated to maintain the structural integrity of the building and adapted for functional and financial reasons (Powell, 1999). The first records of renovation theory date back to the 19th century. It is worth mentioning that these records discussed the principles of traditional renovations, whereas retrofitting theories have only recently emerged as a distinct method. Nevertheless, renovation theories can be applied in retrofitting methods. Eugène Emmanuel Viollet-le-Duc (1814–1879) was one of the first major contributors to the renovation method theory and a leader of the restoration movement. He argued for the stylistic restoration which preserved the historical elements and recreated the style in added architecture (Viollet-le-Duc, 1875).

"In such circumstances, the best plan is to suppose one's self in the position of the original architect, and to imagine what he would do if he came back to the world and had the programme with which we have to deal laid before him. "

Despite this statement's noble objective, in practice, replicating the work of an architect from another historical would require use of materials and techniques often not accessible for the restorer. Viollet-le-Duc also believed that the best way to preserve a building is to find use for it (Viollet-le-Duc, 1990) and worked on multiple adaptation projects.

The discussion on interference in the architectural heritage in the 19th century specified a theory in opposition of restoration. John Ruskin (1819-1900) critiqued Viollet-le-Duc's theory, pointing out the risks of unsuccessful restoration and the loss of authenticity. He became the leader of the conservation (or anti-restoration) movement which stood for the heritage preservation through regular maintenance of the buildings (Ruskin, 1849).

"Do not let us talk then of restoration. The thing is a Lie from beginning to end.. . .Take proper care of your monuments, and you will not need to restore them."

According to Ruskin architectural heritage buildings should be protected rather than refurbished and stylized to hide any signs of decay. His protégé, William Morris, reflected on the restoration as an impossible act, as it was trying to recreate the original architect's approach. As a founder of the Society for Protection of Ancient Buildings (SPAB) in England he actively worked towards wide protection and conservation of historical buildings. In SPAB's "Manifesto" he expressed his believes on the preservation of historical values and their importance for future generations (Morris, 1877). Another key contributor to renovation theory was the general conservator of the Central Commission of Austria, Alois Riegl (1858–1905). His theories separated building values into different types (Riegl, 1903) and grouped them into "memorial values" and "present-day values". The former consisted of the age value, historical value, and intended memorial values, where the historical value stood against the restoration movement principles, while the age value supported them. The latter included the use value, art value, relative art value and newness value. Riegl renovation theory was based on systematic analysis and distinguishing values and needs of the building depending on its historical period (cite). He also prioritized conservation and presented restoration as a necessary step, that should include very little intervention. His systematic approach to building assessment and renovation shaped the methods used in modern times.

Influenced by the destruction the First World War brought, the International Museum Office organized

02. RENOVATION TO ADAPTATION

the Athens Charter (1931). It discussed seven solutions which could be implemented in restoration, preservation, and protection of architectural heritage, and introduced the first international preservation policies (Tomaszewski, 2008) (Jokilehto, 2017). The Athens Charter indirectly discussed theories regarding adaptive reuse, as it emphasized the importance of conservation and discouraged stylistic restoration as practiced by Villet-le-Duc. Furthermore, it discussed the importance of preserving the heritage buildings even if they were in decay by supporting the existing structure. The added materials, however, were supposed to indicate the difference between the old and the new (Mehr, 2019). A similar opinion was expressed by Cesare Brandi (1906–1988) who introduced practical rules and methods of conservation and restoration (Schädler-Saub, 2008). Brandi emphasized the respect for original building and its architect and critiqued style imitation. According to him the decayed elements of the building showcased its real age and should not be restored (Barassi, 2010). His theories had a major influence on modern renovation methods and the development of related policies.

After the Second World War the Athens Charter was revised in the Venice Charter (1964). It addressed the modern restoration-conservation theories and introduced adaptive reuse as a form of conservation for the first time. In 1979 the Burra Charter extended the theories from the previous document with a new system for heritage assessment (Wong, 2016). Since then, the renovation theories have been continuously reviewed along the rising consciousness of the values regarding historical buildings of various periods.

Since the Venice Charter, the adaptive reuse became an intentional method in architectural practice and in the second half of the 20th century many retrofit projects have been developed and adaptive reuse has become one of key the topics in the scholarly literature in the architectural environment (Van Cleempoel and Plevoets, 2013). "New Uses for Old Buildings" by Sherban Cantacuzino in 1975 was one of the first publications on the topic of adaptive reuse (Cantacuzino, 1975). In his works Cantacuzino emphasized the significance of building adaptation and preservation in the context of social perception of belonging to a particular urban context (Cantacuzino, 1989). Stewart Brand discussed the modern practice of adaptive reuse not only in the context of architectural heritage, but also new technological advancements (Brand, 1994), and De Arce argued for adaptive reuse in regard to sustainable urban development (de Arce, 2014).

Modern works on the topic of adaptive reuse are often based on case studies. Koenraad Van Cleempoel and Bie Plevoets recognized three different approaches to in these works: typological, technical, and strategic (Van Cleempoel and Plevoets, 2011). They differentiate the methods used to establish buildings heritage value and possibilities of adaptive transformation (Douglas, 2006).

Discussed theories have shaped the methods currently used in the renovation practices and are still relevant. The discussion on architectural heritage preservation over the years has resulted not only in preservation policies but also high consciousness on the topic among the public and professionals. Adaptive reuse is still an unexplored area of the preservation subject. However, the theories on restoration and conservation can be a guideline on how a successful and respectful building transformation should look like.

INDUSTRIAL HERITAGE

_1_01_ INDUSTRIAL HERITAGE

For nearly two centuries, industrial progress has given countries in Europe and the West in general the opportunity to rise from being agricultural to industrial countries. The standard of living rose drastically, and the wealth of the population increased. Progress has consisted in moving natural raw materials through trade, and the invention of the steam engine allowed the processing of these raw materials into products that could again be sold. This act brought great progress in the West, which was driven by capitalism (Douet, 2013).

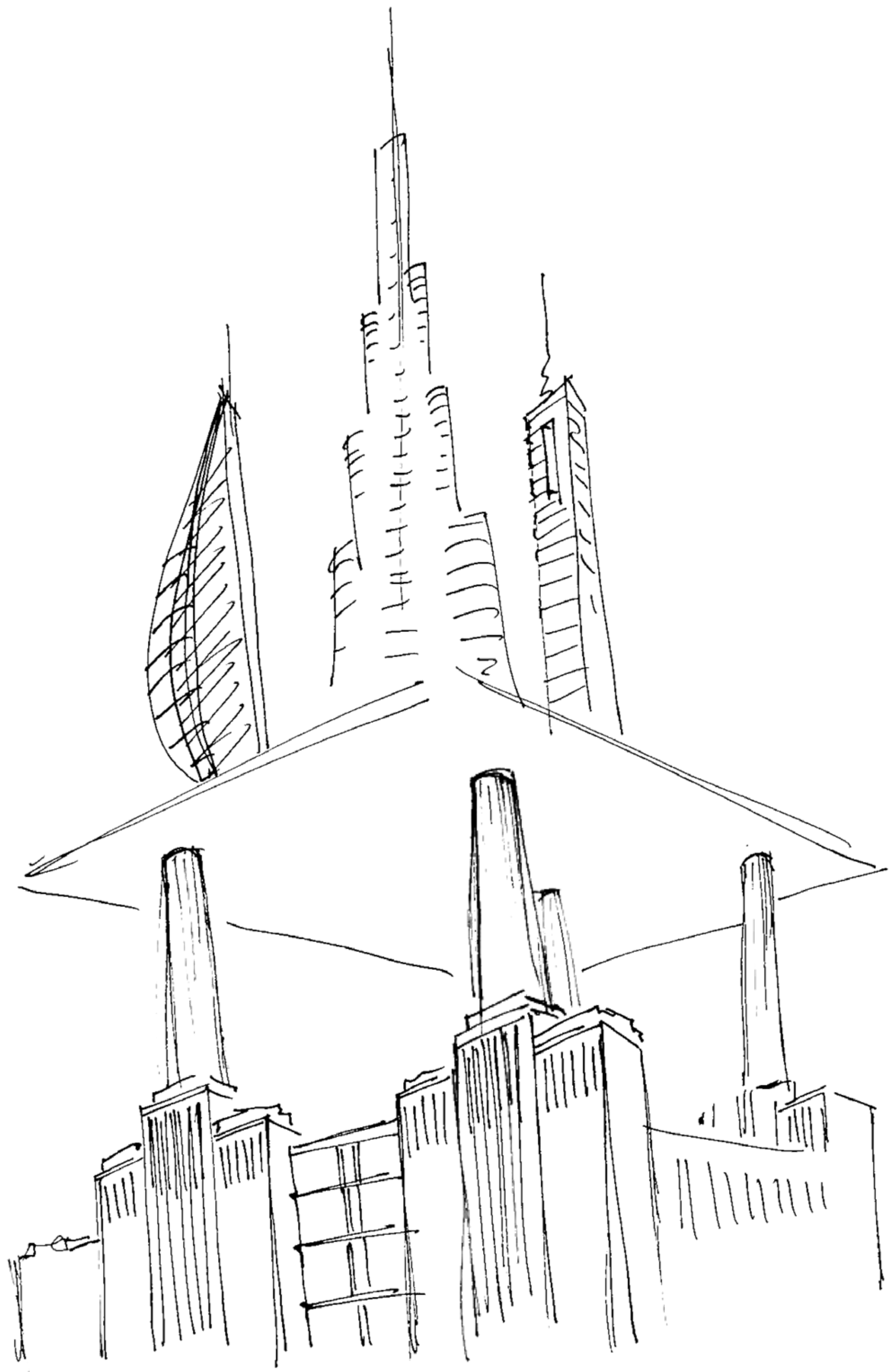
After the Industrial Revolution, world order shifted. The economic focal point, which used to be Europe, has moved. Factories and warehouses of the late 19th and early 20th century could not adapt to new technologies and many cities started facing abandoned industrial areas in prime urban locations. United Kingdom was one of the pioneers if it comes to renovation and reuse of warehouses and factories (Stratton, 2003). Unfortunately, today the remaining industrial buildings stand as a reminder of a bygone era, often abandoned and slowly falling into decay. Industrial heritage is proof of the prosperity, with factories and industrial halls as its monuments. These industrial areas are also connected to the local community's identity as they used to be the heartbeat of the city. Apart from their economic and social impact, the industrial heritage presents a high architectural value as emphasized by Banham (Banham, 1986). The industrial buildings represent the architectural canon of their time as they were a vital element of its development. Furthermore, their large scale and function requirements challenged the AEC professionals, which resulted in a lot of experimentation when it comes to building design. The warehouses and factories display the innovations of industry in their large span structures and monumental interiors.

In 1973 the First International Conference for the Conservation of Industrial Heritage was held in England, and it resulted in the foundation of The International Committee for the Conservation of the Industrial Heritage (TICCIH). It aimed to expand the understanding of the architectural heritage beyond the classical monuments. The "Recommendations on the protection and conservation of industrial, technological and Civil Engineering Heritage" (1990) of the European Council has further emphasized the importance of preservation of the industrial heritage, as it represents the knowledge and established building techniques of past generations (Grecchi, 2022). In the 21st century the development of theories regarding industrial heritage continues with works such as the Seville Charter of Industrial Heritage of 2019. It discussed the different approaches affecting industrial heritage, challenges of its preservation and strategies that could be implemented to respond to them (Sobrino Simal and Sanz Carlos, 2018). The preservation and possible adaptation of industrial heritage is also being explored by the scientific community with Blagojević and Tufegdžić exploring the main objectives of industrial building renewal in the era of new technology and sustainable approach (Blagojević and Tufegdžić, 2016).

> *"Criteria for the industrial heritage authenticity valorization must include both, tangible and intangible, characteristics of the monument; goal of the industrial heritage reuse must be preservation of its specific, socially recognized, values in a way which allows its contemporary use; indicator of success of the industrial heritage conservation and presentation is the level of project sustainability and the degree of community development."*

Vardopoulos analyzed most principal factors in industrial adaptive reuse projects and emphasized, that with an optimal strategy, these projects can have an impact, not only related to heritage preservation (Vardopoulos, 2019). Energy saving, promoting sustainable approach, great return on investment and urban revitalization can be achieved with a correct approach.

Just as the industrial areas had a significant impact on the city in the previous centuries, if reactivated now, they can influence the whole urban environment (Kağan Günçe and Damla Mısırlısoy, 2015). If given access to, industrial heritage buildings can educate the public on the important part of the local history and if adapted thoughtfully, reflect on the genius loci of the place (Moshaver, 2011).



03. INDUSTRAL HERITAGE

BIM IN RENOVATION

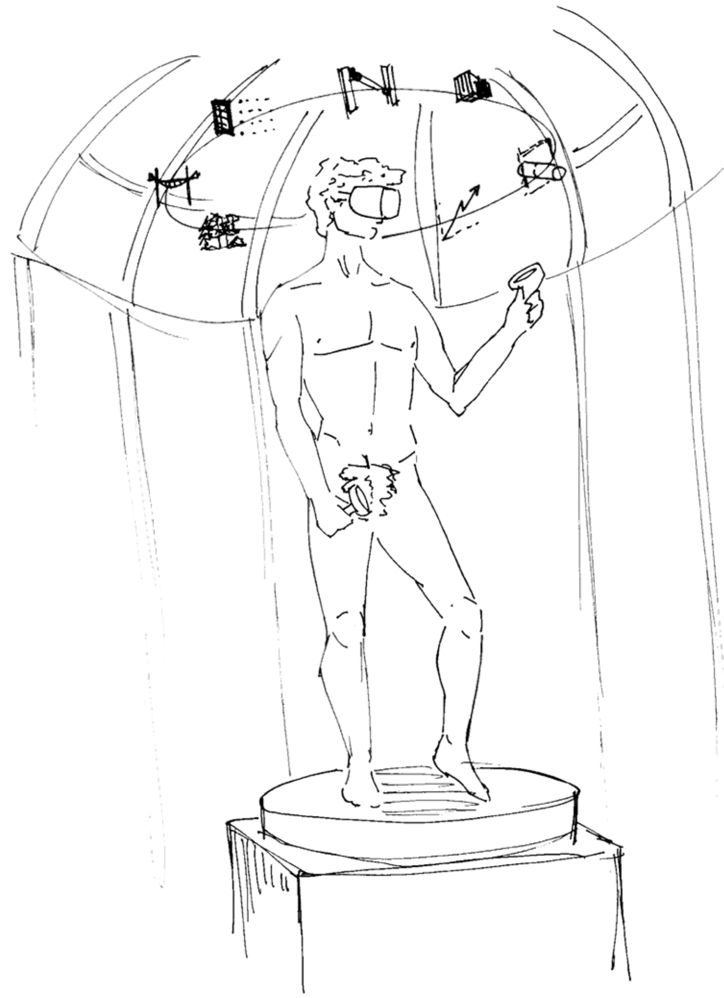
_05_02_ BIM IN RENOVATION

BIM plays a key role in the architecture, engineering, and construction (AEC) industry as it influences the whole life cycle of the building. The use of BIM can reduce the total documentation and enable efficient management of building elements. BIM is currently used primarily in the projects of new buildings and the are few examples of methodologies and case studies involving BIM implementation in renovations and adaptations and even less related to industrial heritage (Pavlovskis et al., 2019; Sánchez et al., 2019).

Rebekka Volk, Julian Stengel, and Frank Schultmann reviewed the literature on BIM adaptation in existing buildings in the whole life- cycle of the building. They concluded many benefits of this method including reviewing multiple design alternatives, optimization, risk mitigation deconstruction measures, as well as sustainability properties (Volk, Stengel and Schultmann, 2014). They also pointed out the challenges related to the implementation of BIM in existing buildings such as creation of a model without modern digital documentation. 3D photogrammetric recording equipment, that enables a very precise survey, can be a solution to these issues as it showcases the building with all the changes since its construction and documentation (Rocha et al., 2020). With the adaptive reuse often depending on transformation and relocation of elements the flexibility of a BIM modelling offers easy changes during the design BIM enables management of the materials and elements flow. In the context of adaptive reuse Heritage Building Information Modeling (HBIM) could be applied, to consider the historical data on the condition, maintenance, and transformation options. It is therefore crucial that the model is created in the early concept phase as the element data can influence the design (Helander and Singh, 2016). However, it does not sufficiently support the disassembly and product recovery management and simulation related to adaptive reuse and therefore the model depends on the information attached to the model elements (Sanchez et al., 2020). Despite the BIM software still lacking tools to accommodate all data necessary in renovation and transformation projects, it can enable better balancing between the efficiency and preservation of historical heritage (Brahmi et al., 2021).

Another technology which can be utilized in renovation and reuse projects is the Digital Twin. A digital twin of a building is supposed to be its digital representation with all the properties of the physical elements registered in the model. In its premise a digital twin should be created along with the initial design and develop, transform throughout the building's life cycle. However, in the case of a project on an existing building with 3D documentation the role of the digital twin changes. If precise, data of a building can be collected and transformed into a model and the digital twin can be an object for simulation and assessment for necessary transformation (Kaewunruen and Xu, 2018). Going further a digital twin can become a base for a transformation and later a library of the building elements. Such a library can be used for building maintenance, but also for any interventions along the building's life cycle. This way, the building elements can be reused after the building itself is demolished.

Discussed technologies present enormous potential if applied in an adaptive reuse project. Even though BIM software is still adapting to accommodate existing building transformations, its current possibilities enable for creation of building's digital twin. 3D scanning tools make it possible to register the historical details of heritage buildings that later can be entered in the BIM model together with all necessary data. These technologies not only make the design and construction process more efficient but can also extend building's life and therefore protect the historical heritage it represents.



04. VR BIM TECHNOLOGIES

Conclusion

Renovation theory has been developing since the 19th century with different movements arguing for the factors that should be considered in the practice. The general objective of renovation shifted over the years from replicating the original style and removing any signs of decay to prioritizing maintenance and avoiding any unnecessary interventions in the original structure. Despite the practice of adaptive reuse almost always requiring some changes to the historical building, theories, such as Brandi's, can be a guide in the design process. Furthermore, in building evaluation Riegl's value types are still valid factors, weighing on preservation decisions. If adapted to the transformation of industrial buildings, these theories can support the preservation of that valuable part of AEC heritage. The unique building techniques used in these buildings, as well as the special connection they have to local communities, deserve special attention in the transformation design. Abandoned industrial buildings also present an exciting potential if reactivated. Large, flexible spaces, often in central locations can become dynamic city hubs, pushing the changes in urban development of the area. The materials and elements used in the construction of industrial buildings give them additional value, as they are often not possible to source sustainably in the current environment. Therefore, they are a great object for reuse and recycling. BIM strategies and technology can support that process, as they enable easy elements management and store historical data of the building for its whole life cycle. The currently available technology can not only make the design and construction process more efficient and sustainable, but it also supports the preservation of valuable building elements and strategic adaptive design. Utilizing the appropriate renovation methods in a BIM process gives a potential of achieving optimal balance between the targets of sustainable development and heritage preservation.

PROBLEM STATEMENT

_06_ PROBLEM STATEMENT

Looking at the harbour building, which is the object of this thesis, through the theory discussed in section _05_ prompts to explore the topic of industrial heritage adaptive reuse and address the current gaps in the strategies of the practice.

The following questions reflect the objectives of this thesis:

What is the methodology that should be used for analysis and assessment of existing industrial buildings?

How can the building's transformation balance the original architectural heritage with the added elements?

How to preserve the industrial heritage and the *zeitgeist* of the warehouse throughout the transformation process?

How can a warehouse space propose functions which are attractive for the urban structure and activate the harbour while aligning with the city masterplan?

What is the data necessary for buildings maintenance and reuse, and how to incorporate it in a digital model?

These questions lead to the main problem statement:

HOW TO REUSE AN INDUSTRIAL HERITAGE HARBOUR BUILDING AND TRANSFORM IT INTO A PROMINENT FEATURE THAT WILL BENEFIT THE AREA, WHILE USING NEW BIM TECHNOLOGY?

METHODOLOGY

_07_ METHODOLOGY

In this section the methodology of the thesis design process as well as the building survey is explained to provide a base for further research and design.

_07_01_ GENERAL DESIGN METHODOLOGIES

The design work in this report is based on the combination of two main methodological approaches, which together support designing a transformation scheme by steering the design workflow on its technical, functional, and aesthetic aspects. The methods are the integrated design process (IDP) by Mary-Ann Knudstrup(Knudstrup, 2004) and Transformation of Architecture – five methods by Nikolai Bo Andersen. (Andersen,2015)

IDP

The "Integrated Design Process (IDP)" is divided into five phases. The transitioning between these phases is not linear but instead an integrated approach is encouraged. The main objective of using the IDP is to integrate engineering and architectural aspects seamlessly during the design phase.

FIVE METHODS

Methodology of "Transformation of architecture – five methods" by Nikolai Bo Andersen advances an approach to the transformation of cultural heritage using five methods.

In the context of this thesis, this methodology was used to gather and develop knowledge that helps us to transform and renovate in the sketching phase of IDP. The methodology is based on the studying of the building's materials, the architectural history and the structural architecture to identify the buildings architectural elements worthy of preservation.

SAVE SURVEY

Despite not being a methodology, but a method, the SAVE survey is critical in supporting the analysis phase of the IDP and five methods. Therefore, the method will be introduced at this stage.

A method that has been used in the evaluation of the warehouse in Odense is the SAVE assessment (Stenak et al. 2011). The method was developed by The Ministry of Culture of Denmark to assess whether a building is worth preserving or elements within the building is worth preserving.

A SAVE survey of buildings can be carried out as an independent procedure, where one registers and assesses the conservation values of buildings. The basis of the assessment is the designation of the conservation values, which are qualified through the registration of the character-giving building parts and the building's location in the context. The conservation assessment in SAVE is based on the building's exterior, i.e., the external appearance and its interaction with the surroundings. The assessment does not deal with the interior of the building.

The SAVE assessment evaluates buildings using a scale from 1 – 9. The score of a building is based on five parameters which relate to various aspects of the building. If a building is given the score 1, it results in the building being listed and cannot be demolished or changed, as it presents a huge worth of preservation. If a building is given the score 9, it means that it has a low worth of preservation and can be demolished or changed.

The five parameters of the SAVE assessment are:

Architectural value

The architectural value is based on proportions harmony, facade rhythm, the degree of architectural processing and the interaction between form, material effect and function.

Cultural-historical value

Cultural-historical value is the manifestation of the local and vernacular building technologies in the building It could show a particular architectural style or a specific craftsmanship or construction tradition and technology.

Surrounding value

The surrounding assessment looks at the building's importance for an area and investigates whether the building provides a specific value to the area and the neighboring buildings.

Originality

The assessment of originality looks at the extent to which the building's original expression has been preserved, or whether the overall impression that has been sought to be created in the event of a major renovation appears original.

Condition

The condition assessment examines whether the building is properly maintained, including the general condition of the construction. Additionally, this point observes if the building appears healthy.

Furthermore, the SAVE assessment allows for a systematic approach where elements in the building can be registered through pictures and described through text the condition. This allows for an overview when the value of the five parameters is determined.

_07_02_ GENERAL METHODOLOGICAL APPROACH

The methodology is combined as follows: The main structure aligns with IDP methodology under the phases: Problem, analysis, sketching, synthesis, and presentation.

Under each phase, one of the five methods by Nikolai Bo Larsen is used to support the renovation aspect of the project and better understand the existing building. Furthermore, the SAVE method is used during the analysis phase to establish preservable elements in the building.

Problem: The overall problem of the task

Technology: register, analyze, and find the technical figures for the existing building.

History: Describe an exciting story and the connection to cultural history.

Phenomenon: Register, analyze and evaluate the building and its volumes

Analysis: Analysis of the building, the street, and the surrounding context.

The approach is about scale, it is crucial to assess the building on different scales. The larger one that relates the surroundings, the medium scale which is the surround buildings and the small scale on details in the building.

Landscape: Describe the relationship of the site and the surrounding area, focusing on a larger scale.

Still life: The connection between buildings and their relationships, focusing on proportions in the urban space.

Portrait: Specific character traits and details of the building- tectonic and collections

* SAVE survey: Evaluate the building on five parameters and assign a numerical value to determine level of preservation. (Detail in previous section _07_01_)

Sketching: the problem and the knowledge gathered are used to develop a continuous design

Skin: Facade that separates interior and exterior, the first impression of the building. The elevation

Meat: The spatiality and division of internal spaces, the organizational plan

Bone: The construction, the structure, and the framework of the building- the section.

Synthesis: Gather all information from earlier and evaluate the design

Look: see and analyze the building

Throw: the collected knowledge is put aside for a while, to develop other aspects of the project.

Project: The knowledge from look and throw is gathered to develop a design for the project.

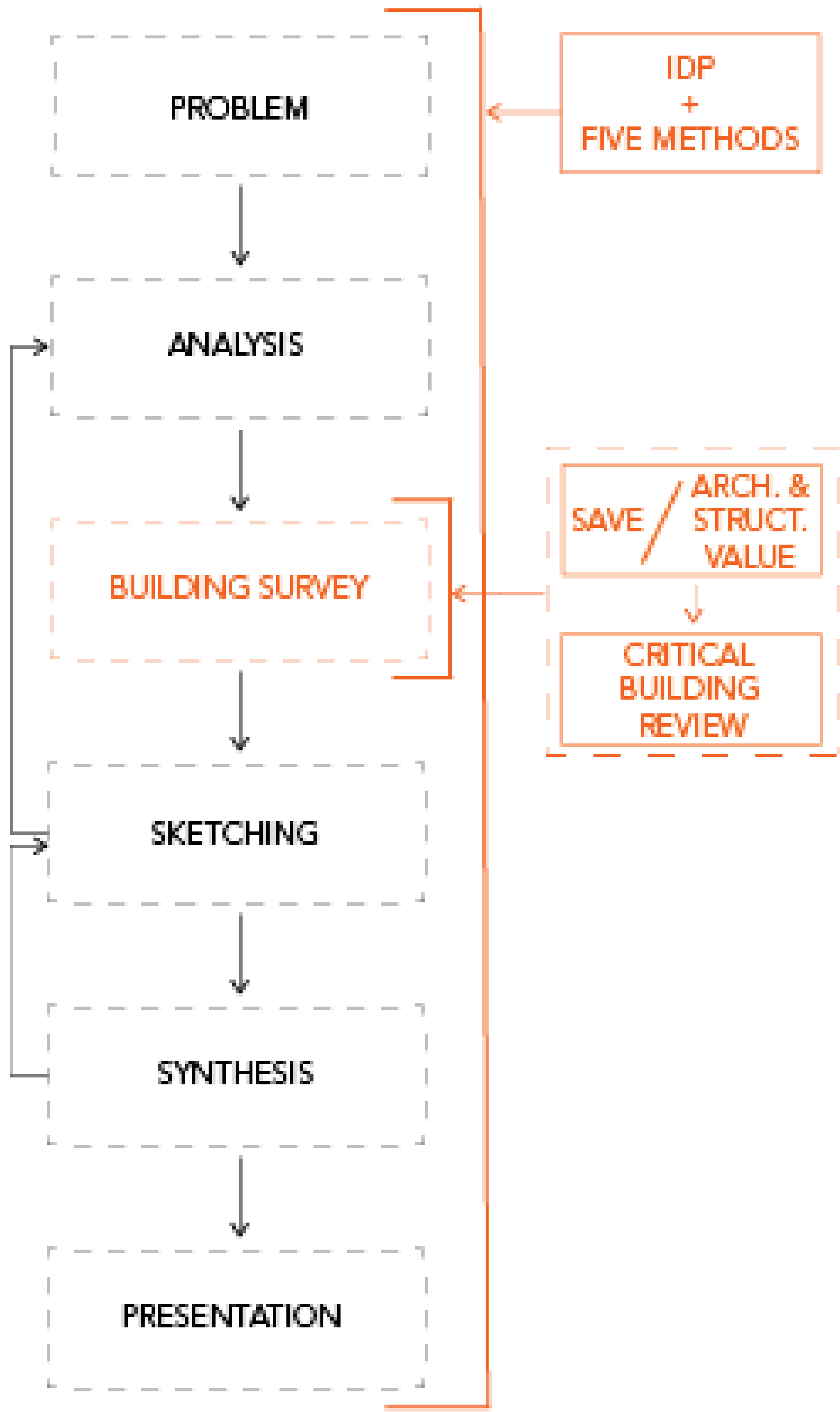
Presentation: Combine the design and the process into a presentation of the final product.

Present the project through the aspects of:

Subtraction - Reconstruction - Repair - Rephrasing – Addition

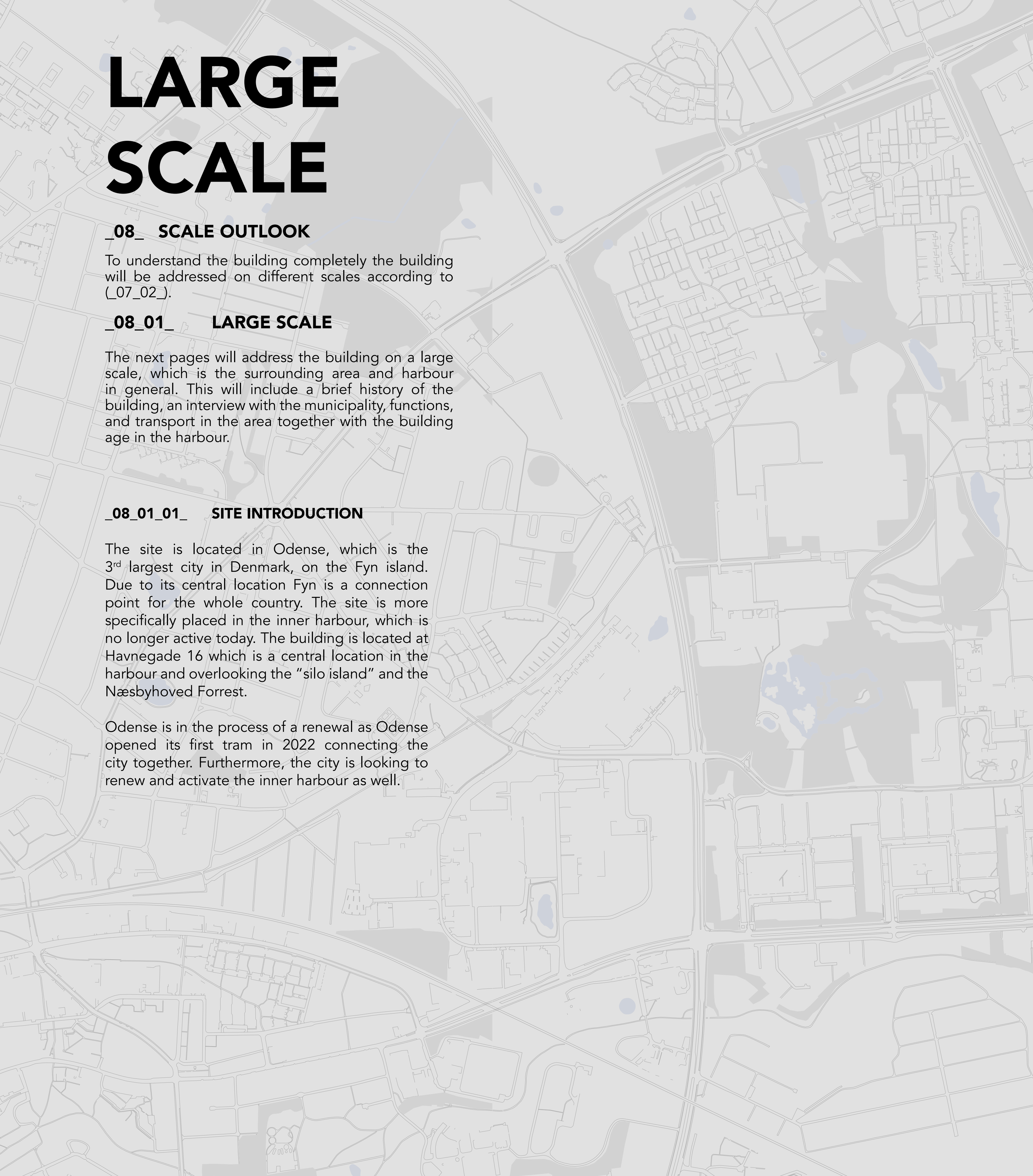
_07_03_ DELIMITATION

The thesis will focus on the conscious renovation of industrial heritage and adaptation design balancing the old and new building elements. The evaluation of building elements will be performed to indicate preservation opportunities. It will be based on the subjective opinion of the authors and data collected in the survey. Furthermore, a design will be developed with a focus of the tectonics and performance of the added structure. The digital model will be created with the use of Revit (Autodesk) in the analysis phase and later developed to registered structural elements.



05. METHODOLOGY


ODENSE
Havnegade 16



LARGE SCALE

_08_ SCALE OUTLOOK

To understand the building completely the building will be addressed on different scales according to (_07_02_).

_08_01_ LARGE SCALE

The next pages will address the building on a large scale, which is the surrounding area and harbour in general. This will include a brief history of the building, an interview with the municipality, functions, and transport in the area together with the building age in the harbour.

_08_01_01_ SITE INTRODUCTION

The site is located in Odense, which is the 3rd largest city in Denmark, on the Fyn island. Due to its central location Fyn is a connection point for the whole country. The site is more specifically placed in the inner harbour, which is no longer active today. The building is located at Havnegade 16 which is a central location in the harbour and overlooking the "silo island" and the Næsbyhoved Forrest.

Odense is in the process of a renewal as Odense opened its first tram in 2022 connecting the city together. Furthermore, the city is looking to renew and activate the inner harbour as well.

HISTORY

06. **ARIAL PHOTO OF ODENSE HARBOUR 1950**

_08_01_02_ HISTORY

HARBOUR

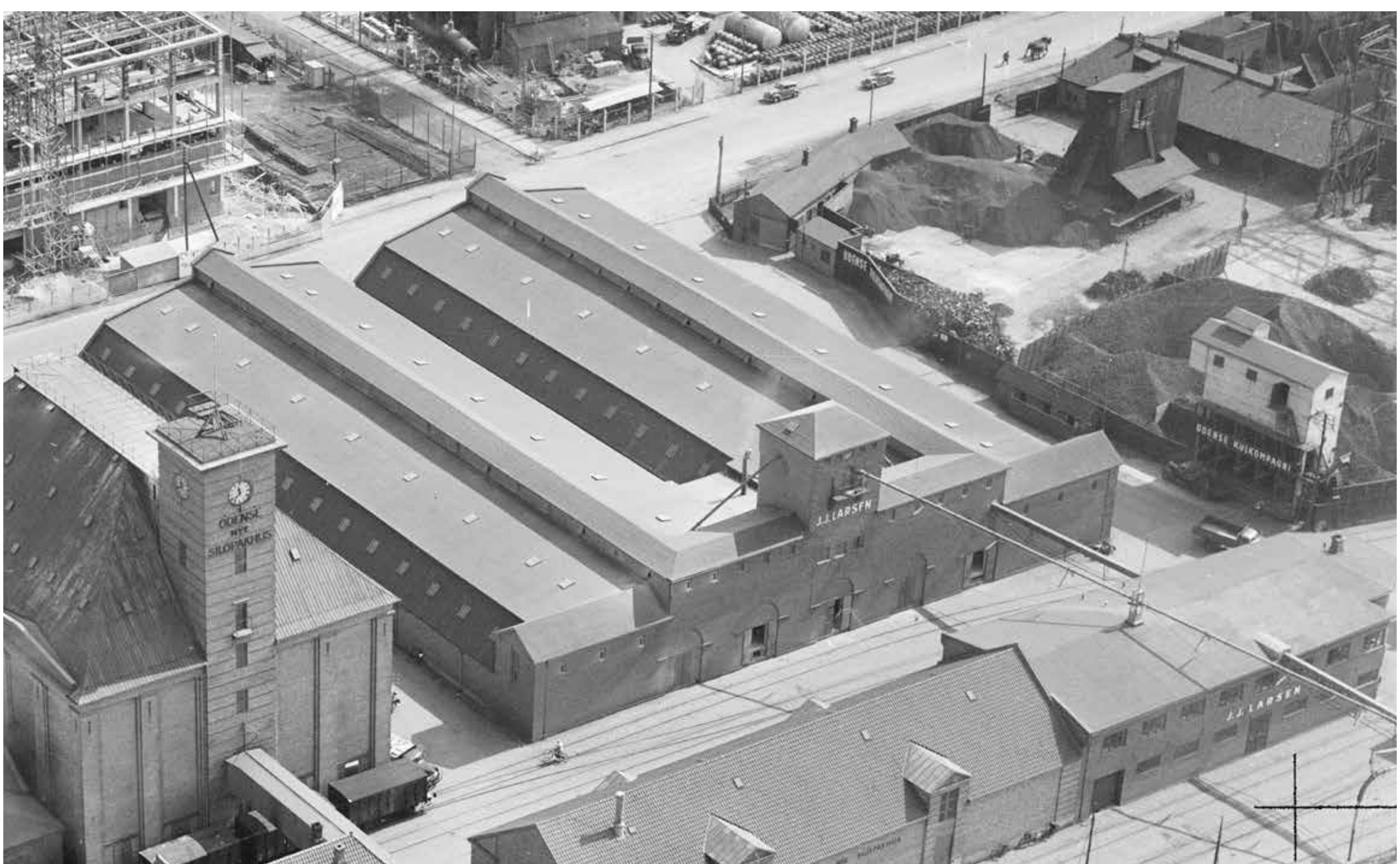
Odense originally was not a harbor city, but the city lay on the fjord and Odense "turned its back to the sea". It was not until 1803 that a canal was dug to the city which enabled ships to come to the city. The port was mainly an import harbour, where sea transport was the only realistic form of transport when it came to heavy goods and large quantities. Here it was luxury goods from Copenhagen and Lübeck, from Norway it was iron ore and timber. From Odense, several agricultural goods were shipped, the sale of grain and fodder from the surrounding arable land (Harnow, 2003). The ships became larger over time and the water depth was dredged further in 1876, which allowed steamships to access the harbour. Odense is a regional hub for the railway, which strengthened the harbour for greater exports. The first large warehouse was built in 1884, with more warehouses to follow. Companies were established at the harbour and Odense lime works together with N.F. Hansen's Odense Shipyard were the prominent companies of the time. Lots of goods came into the port, coal, roofing slate and machinery from Newcastle - cement, timber, sand, and petroleum from North America. (Harnow, 2003). Fixed passenger transport links to Copenhagen, Newcastle, Hamburg were established. Exports in the port were still in agricultural goods, which became even larger in line with the cooperative movement. The port of Odense had a renaissance through the 1960s and 70s, with the expansion of its businesses, and the remains of that expansion such as the concrete silos are still present today in the harbour area.

J.J LARSENS GRAIN AND FODDER COMPANY

In 1860, Jørgen Joachim Larsen (1829-1888) established that he had established himself in host Rasmussen's farm with a "commission expedition & collection business, which includes the purchase and sale of grain products and the country's other products". The company developed into a large and recognized company with most of Funen as a customer base. J.J Larsen died in 1888 and after Larsen's death, the company was carried on by his sons Emil Magnus Larsen and Jacob Marius Larsen. The sons were both educated and proposed moving the grain and feed department to Odense and the same year, a new warehouse was built at the port. Here, wholesale trade in domestic grain and import of foreign feedstuffs was built up to a large extent. (Benny Boysen, 2014) The grain and fodder company J. J. Larsen's warehouse was built in wood in 1907, but after a large harbour fire in 1925, the building burned down. The granary was resurrected again in 1926, this time built in brick.

The granary stands out from other similar warehouses in the harbour. The oldest warehouse in the harbour dates from 1884 and was built by grain merchant and wholesaler Elias B. Muus, this was Denmark's first six-story automatic silo warehouse. J. J. Larsen, on the other hand, was a one-story warehouse, where grain was transported from the surrounding arable fields to the warehouse on train cars. Then the grain was stored lying loose on the floor before it had to be loaded onto ships (Pil Lindgreen, 2020). In step with the industrial revolution, J.J Larsen had the warehouse modernized to have a vacuum pump, which could suck up the grain from the silo and through a pipe through the tower and over to the harbour edge. This also helped the process of relieving train cars where the grain could be vacuumed up and through the grain aisle in the attic, and conveyor belts were used to distribute the grain throughout the warehouse. The warehouse at Havnegade 16 is the only building left in Odense harbour that was owned by J.J. Larsen

07. ARIAL PHOTO OF J.J.LARSEN WAREHOUSE 1960



FUTURE PLANS

_08_01_03_ FUTURE PLANS

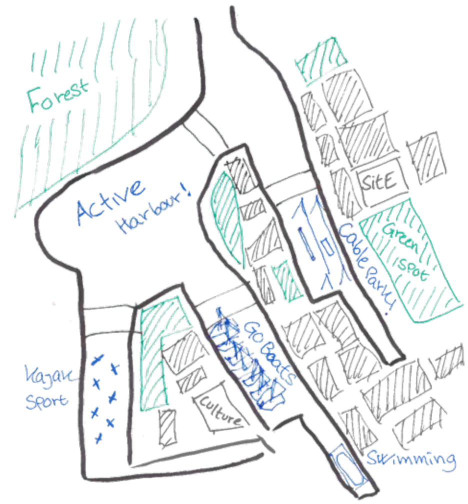
"Odense is today entering a new era. The inner harbour has played its role as the home of industry, storage, and heavy traffic on land and at sea. The city's large, industrial workplaces have instead largely moved outside the city. The harbour is being transformed into a new district. The port's location between water, forests, older city quarters and the city center, the large building scale combined with the relatively small and intimate port and the special identity and cultural history constitute a great potential for urban development"

(Odense municipality, 2022)

Odense municipality is looking for a new master plan for Odense Inner Harbour. In this connection, Odense municipality. The vision sets the direction for the development of the harbour it will be used as a guideline, after which an architectural competition for the area will be held. In connection with the competition and the vision for the Odense Inner Harbour, an interview was conducted with Pia Damkjær Pedersen, who is an urban planner at Odense Municipality. The interview was conducted to understand the needs of the area and wishes from the municipality regarding the future. The interview was held as an open interview.

The first urban transformation plan for Odense's inner harbour was adopted in 2003, and it was replaced in 2016 by Urban Transformation Plan 2.0. Where a total of 1,350 homes as well as offices and commercial buildings have been built. (Odense municipality, 2022)

Can you tell us a little bit about the harbour today?

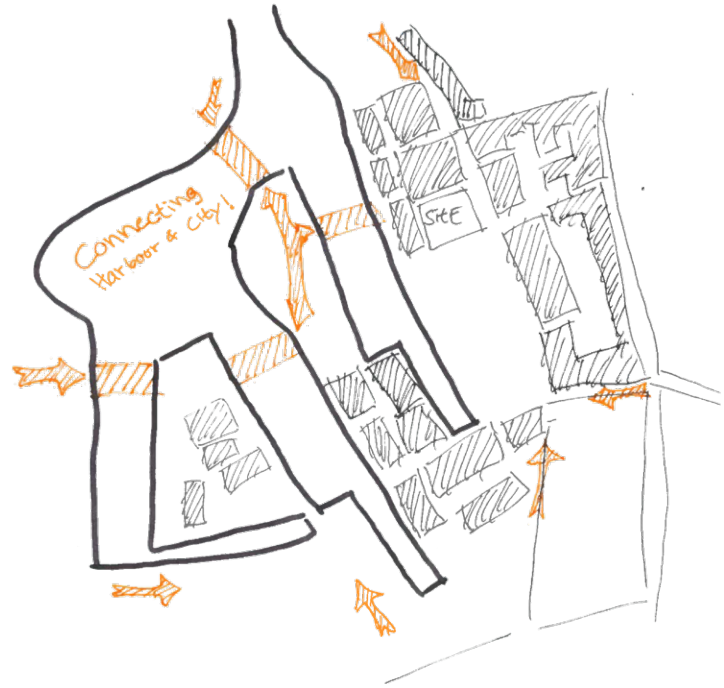


08. ACTIVE HARBOUR

"The transformation of the harbour has been going on for 20 years or something like that. So, it is in this transformation from an industrial harbour into a residential harbour more or less. But there are also areas where you have a lot of, cultural functions, especially on – "byens Ø", there is a lot of, culture, but also outdoor activities. So that is a big cluster of that. Then there are also of course Office buildings, but it's mainly residential use right now."

"The harbour is also a little disconnected from the city as it is now. You have this big road called Toldbodgade and the area from the harbour to the city called Nørrebro is also under development. So, you kind of have a harbour that is a little detached from the rest of the city."

As part of the vision for the inner harbour, it was the goal of a coherent city and district. The harbour must be an attractive district and a destination worth visiting. The district must offer something to look for, something that leads the public on its way. Odense municipality, 2022)



What is the need for this new master plan, and what is the city looking for?

"I think the edition that we have now, no. 2. was made in collaboration with a more or less Odense harbour, meaning it was the harbour that had to sell some areas which resulted in a plan. The municipality developed a local plan for the area but with this master plan it became clear to us that the quality was not as high as requested by our politicians and the general public" -

"The private investor, I think I could ask them for yourself, but in my words, they're interested in doing business in the areas. The Municipality are also interested in making it into a high-quality area and maybe getting some other functions into the harbour."

"We are developing a plan with a developer and in this coming process we will also work on finding some of these cultural actors and clarify if the municipality has some functions to place in the harbour, but that is some of these things we are looking into right now."

09. CONNECTED HARBOUR

As part of the vision, the inner harbour must be a district with a particularly creative pulse and life all year round. Cafés, restaurants, bars, and specialist shops create city life in obvious places, while there are spaces where there is room for calm and contemplation. (Odense municipality, 2022)

Furthermore, provide the boundaries for urban companies, small businesses, and entrepreneurs.

The vision for the harbour stated that it should be the greenest harbour, can you explain that? The greenest harbour is that in terms of adding greenery to the hardware you think or is it mostly the sustainability aspect?

"It's actually the greenery that is. So, we have in Odense we have this we called bio-factor I think other municipalities have this, but we have this calculation of bio-factor when we are developing new areas."

10. Green harbour

"In terms of greenery and of course there have also been works with the sustainability but in some way, I think it's more on the private investor's side of the project because they would like to have these markings you can get on the sustainability."

The vision for the port is that the port grows urban nature in new ways together with the urban, maritime, and industrial environment in a "green metropolitan jungle". The harbour must provide the opportunity to stay in green urban spaces for both users and residents in the form of small parks. The greenery is intertwined with the port's identity so that the port is experienced as an urban green district, where people think green in new ways, e.g., green facades, wild green edge zones, trees, and a focus on biodiversity. (Odense municipality, 2022)

Conclusion

The warehouse has a substantial part in the history of the harbour. The economic cycle of the harbour regarding export of grain gives the warehouse a historic value. The main import of the harbour was coal which is placed right next to the building. The municipality is keen on activating it by moving functions and cultural elements to the area. The new masterplan provides a vision which should guide the development of the harbour and create a more connected harbour. Transformation of the warehouse should align with the vision while respecting the historical importance of the building.

FUNCTIONS

_08_01_04_ FUNCTION ANALYSIS

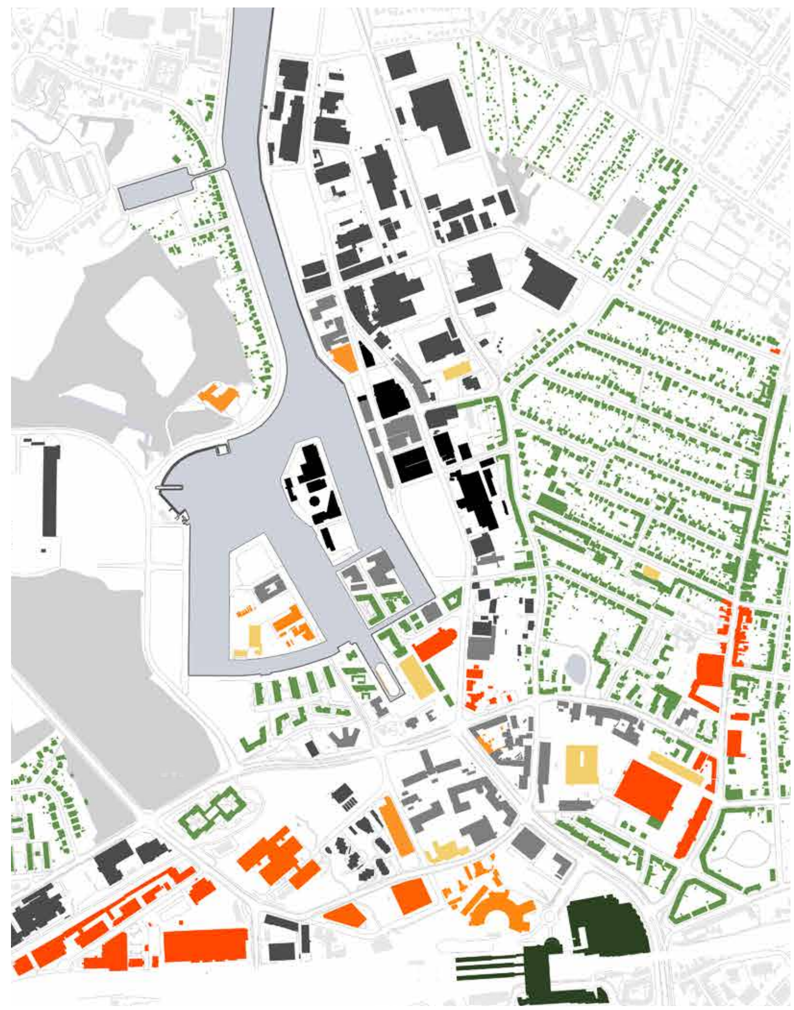
In order to create an understanding of the area and which existing functions are around the site, a building application for the area around the inner harbor has been made.

From illustration 11, it can be seen that the current buildings around the warehouse are used for office, business or stand empty. The warehouse is located in the middle of the harbour, where there is a smaller business district north of the warehouse. East of the warehouse there is a residential area with detached houses. New apartments have been built in the southern part of the harbor, as well as a number of offices, schools, and a supermarket. West of the warehouse is the Silo island, which is currently empty. The backdrop to the west is Næsbyhoved forest. At present, there are several apartments and offices around the warehouse, and in the vision for the inner harbor of multiple functions, the warehouse will be ideal for retail and culture. In the inner harbor there is the "Byens Ø", which lies west of the warehouse, which contains the North Atlantic House as a community house for North Atlantic countries, the building contains a bit of art and public rooms. In addition, there is also Dynamo which is a circus with presentation art. The harbour only has one restaurant, and the closest one to the harbour is 1 km away. The location of the warehouse in the center of the harbor offers good opportunities for a restaurant, retail market, art exhibition and small start-up offices.

Conclusion

After reviewing the functions in the harbour and in the area around the harbour. It is clear to see the harbour is developing, which new apartments are being added in the harbour, but the lack of diversity in the harbour is lacking. Restaurants, leisure, and culture in the harbour is lacking.

ODENSE CITY 1 : 15000



11. BUILDING FUNCTIONS

ABANDONED	RETAIL
HOUSING	SCHOOL
OFFICE	CULTURE
INDUSTRY	GASTRONOMY
TRANSPORT	SPORT

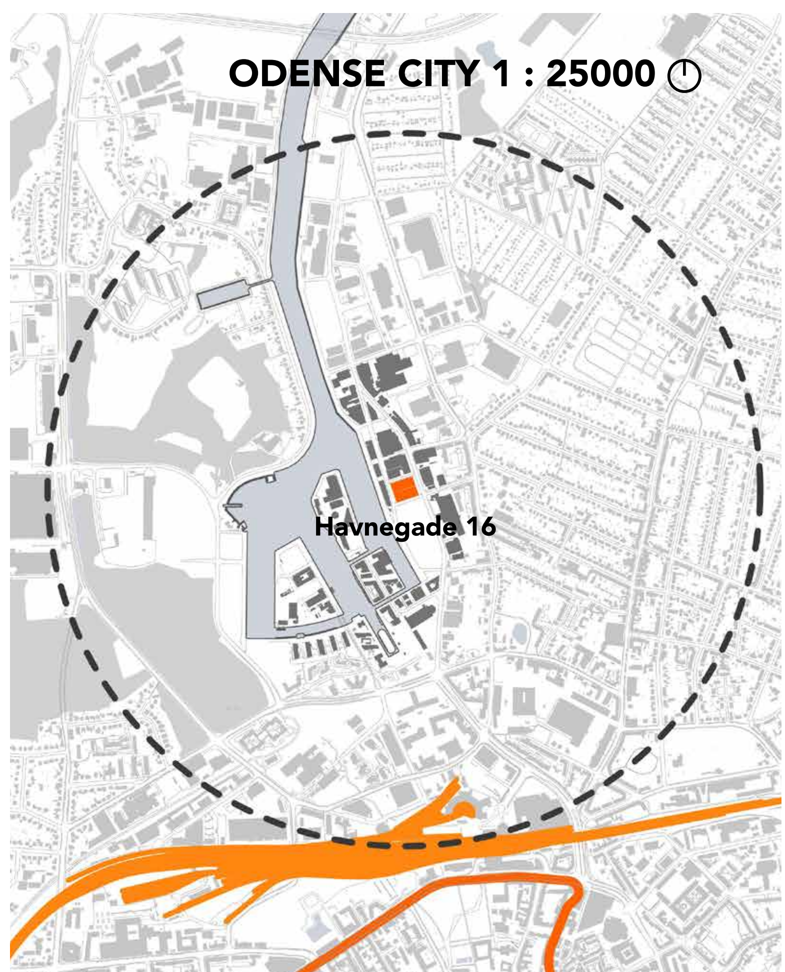
TRANSPORT

12. TRANSPORT IN ODENSE

DOMESTIC TRAIN

ODENSE TRAM

1 KM



_08_01_05_ TRANSPORT ANALYSIS

Connection routes in Odense's inner harbor are limited, and there is no public transport inside the harbour. The location of the warehouse gives direct access to the city through Havnegade and Thomas B. Thriges Gade. The Harbour is located north of Odense railway station, which has domestic trains to the rest of the country. In 2022, Odense got its own tram, which is connected to the railway station, this tram extended the public transport network. The main traffic for the site will be mainly pedestrians and bicycles.

Conclusion

After reviewing the public transport in the harbour and surrounding area. It is clear that the area is not well integrated with Odense,1 kilometer south of the harbour there is a train station, which is the largest transport hub in Odense. From the station arrives domestic trains and the local train from Fyn. Furthermore, there are connections with the tram to the rest of Odense.

BUILDING AGE

_08_01_06_ BUILDING AGE ANALYSIS

Odense Inner Harbor has a large age variation between the buildings in the harbor. The oldest building in the harbor is the old harbor customs building, which dates from 1848.

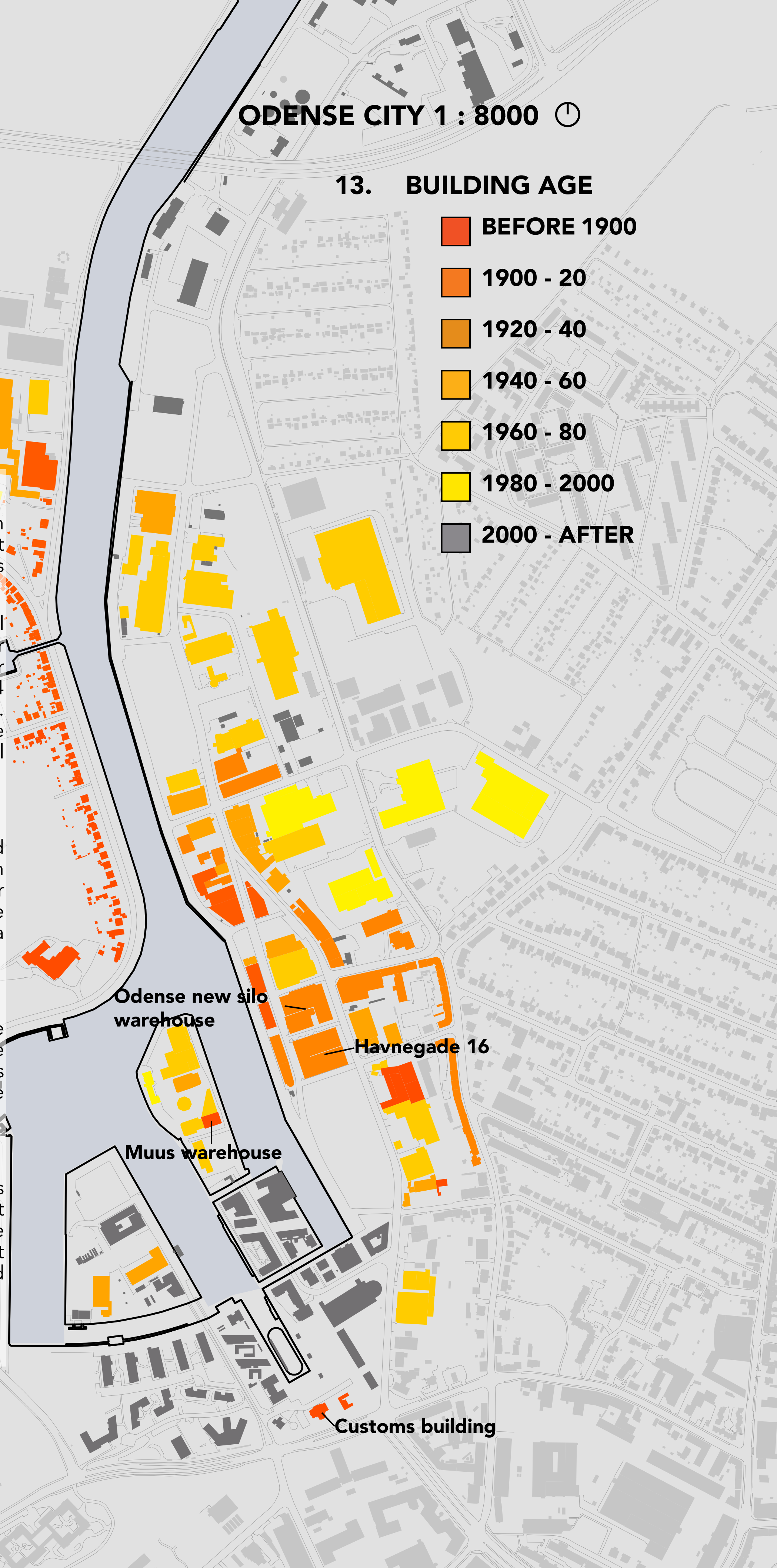
The harbor has seen a lot of development and several buildings have been demolished to make way for new apartments. Notable buildings left in the harbor are Muus warehouse on the silo island from 1884 and JJ. Larsens Pakhus from 1925 on Havnegade 16. Other buildings that are still standing, but which have received a notable renovation, are Odense steam mill – Victoria and Odense nye Silopakhus

Odense experienced a renaissance in the 1960s and 1970s, when a number of concrete silos were built in the harbour. In 2003 came the first master plan for the harbor which resulted in new apartments in the harbour. This has made the harbour into a diver's area with many different building topologies.

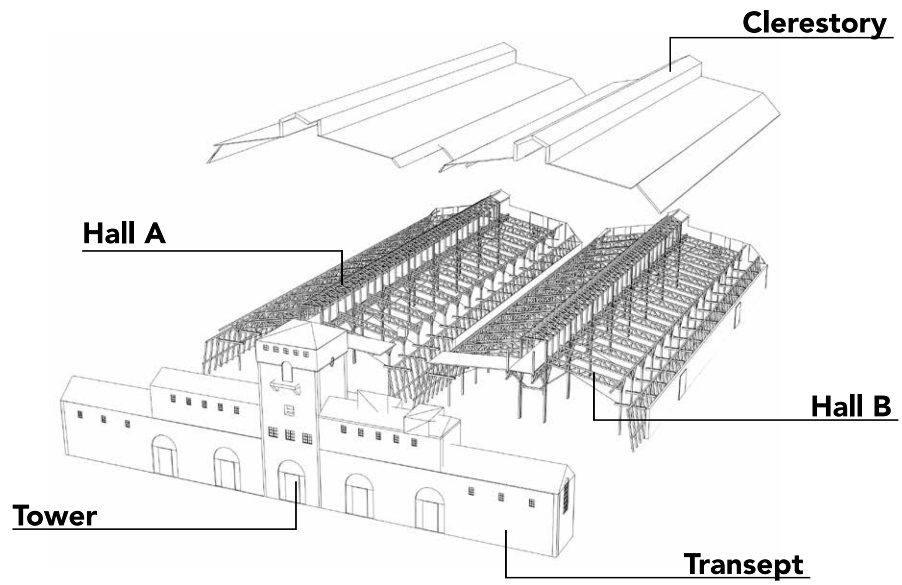
JJ. Larsens Pakhus at Havnegade 16 is one of the only two remaining warehouses that still stand in the warehouse style of the time. The warehouse contains the unique architecture and spirit of place that the harbor once had.

Conclusion

After reviewing the age of the surrounding buildings in the harbour. It is clear that the warehouse at Havnegade 16 is one of the oldest buildings in the harbour, with the costumes building being the oldest one. This gives a historic value to the warehouse and gives character to the harbour.



CURRENT STATE



14. OVERVIEW OF GRANARY

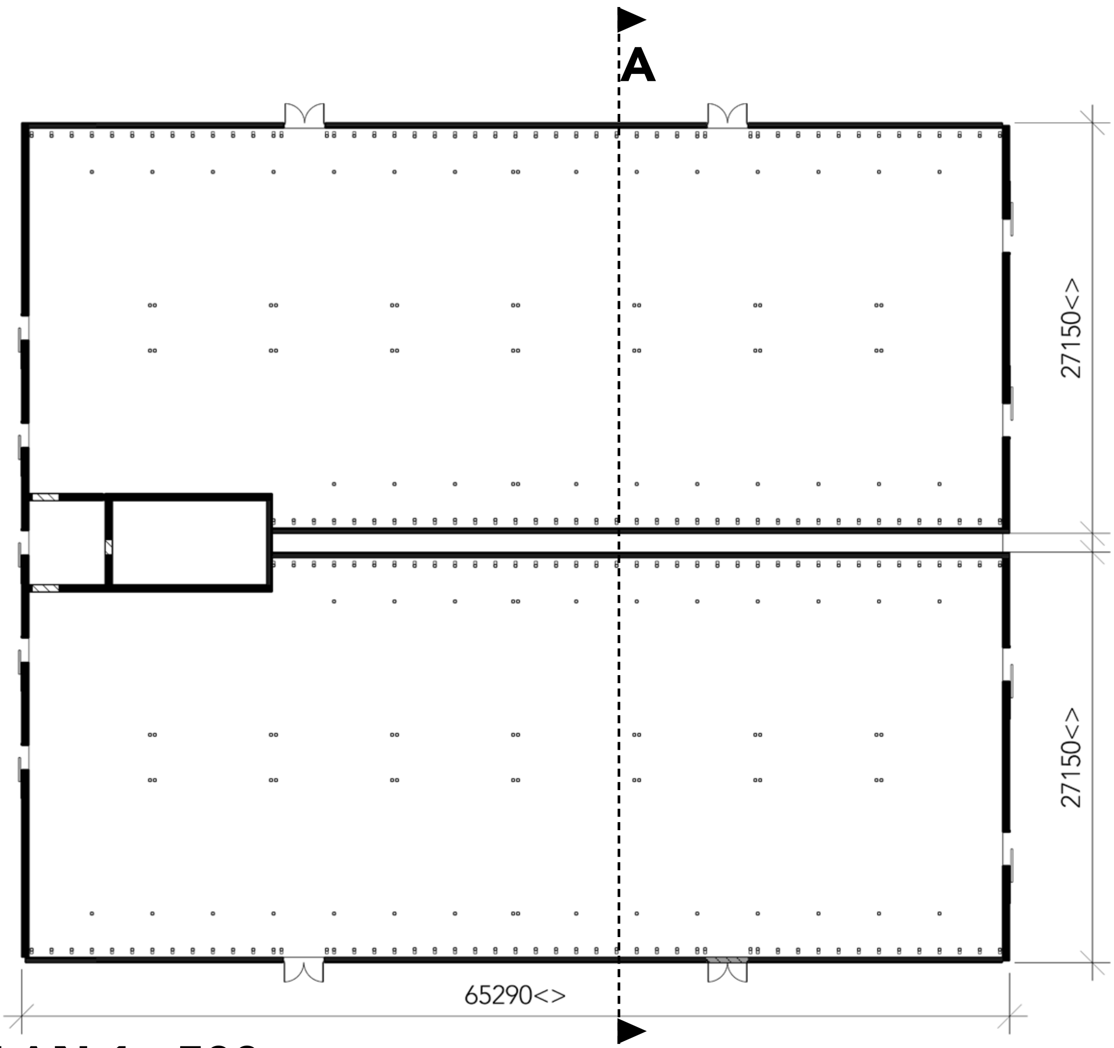
_08_02_ MEDIUM SCALE

According to (07_02), the building will be comprehensively examined on various scales. The Medium Scale analysis will concentrate on the site, including the buildings and the urban spaces. The objective of this analysis is to comprehend the proportions and connections between the building and its surroundings, as well as the micro-climate of the area.

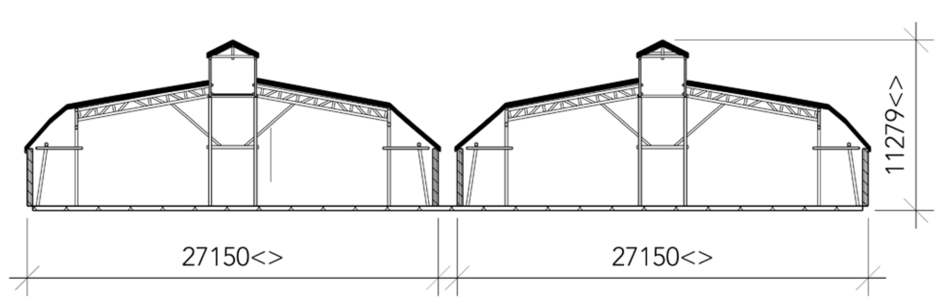
_08_02_01_ CURRENT STATE

Olav de Linde purchased the warehouse almost 20 years ago with the purpose of renovating it, but as there was no development in the harbor, the building was utilized as a storage facility by the company. As time went by, the building was not adequately maintained, while the company awaited the development of a new master plan for the area. Nevertheless, in 2022, the renovation of the warehouse began, and it is scheduled to be finished by September 2023.

15. CURRENT STATE



FLOORPLAN 1 : 500



SECTION A - AA 1 : 500

STREET SECTION

_08_02_02_ STREET SECTION

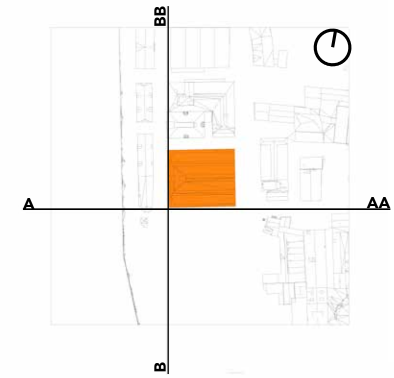
In order to gain a comprehensive understanding of the building and its surroundings, a section analysis is conducted. This analysis focuses on examining the relationships between the buildings and the placement of the granary within the site.

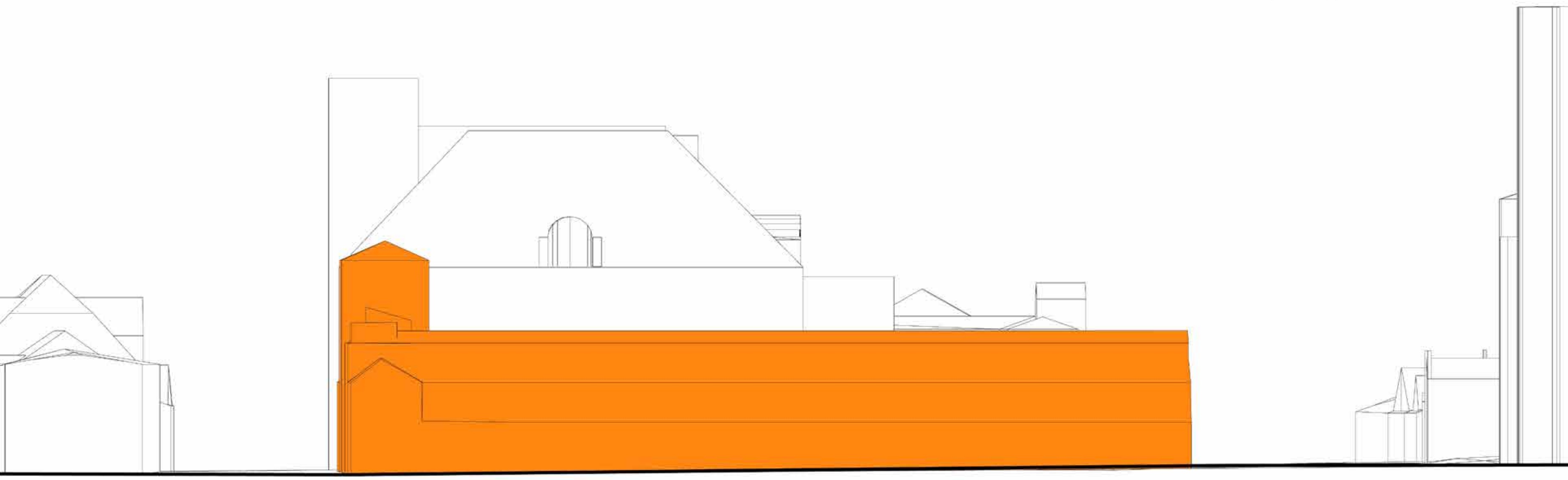
Looking at the site from an east-west perspective, there is a 2-story office building situated in front of the west façade and blocking the connection with the harbour front. This building was originally used as office space for the warehouse. On the east façade, there is a road with medium traffic flow and a towering granary with a 20-meter-high silo. (16)

Examining the site from a north-south perspective, the Odense "new" warehouse towering 17 meters-high is situated to the north of the granary. A small road runs between these two buildings. To the south of the granary lies a vast open field that used to be the coal storage area, but now remains unoccupied. (16)

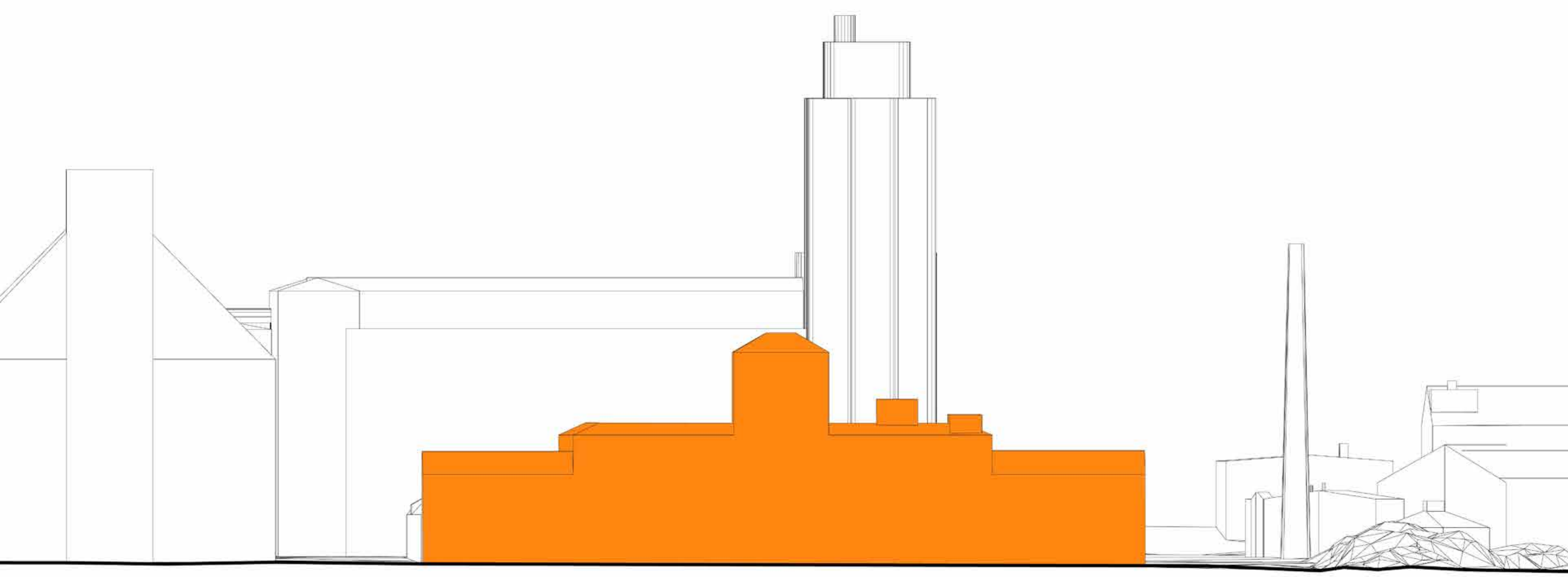
Conclusion

The granary is enclosed from multiple directions but has a large undeveloped area at the south of the building, which can be utilized for development. The road east of the building is the main access to the building in terms of delivery.





EAST - WEST SECTION 1 : 500



NORTH - SOUTH SECTION 1 : 500

16. STREET SECTION

MICROCLIMATE

_08_02_03_ MICROCLIMATE

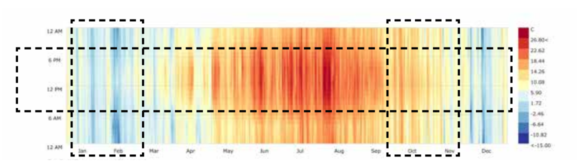
Microclimate is important in understanding to initiate the design principles. The site is enclosed by the large warehouse to the north and northeast of the building, but to the south of the building is a large open plot.

Air temperature

The air temperature mainly ranges between 2°C and

30°C during the year. It reaches up to 30 °C in the summer, and decreases until

-6 °C in the winter.

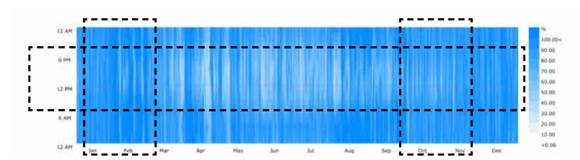


Humidity

The relative humidity is over 60% that is out of the

comfort zone. It increases in the morning during summer and winter.

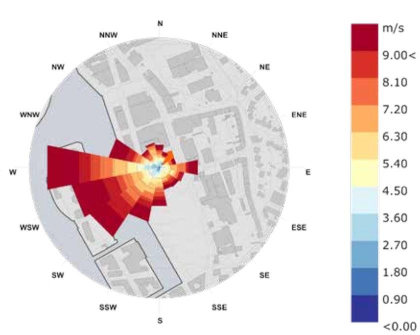
however, it drops to 18% in the afternoon.



Wind

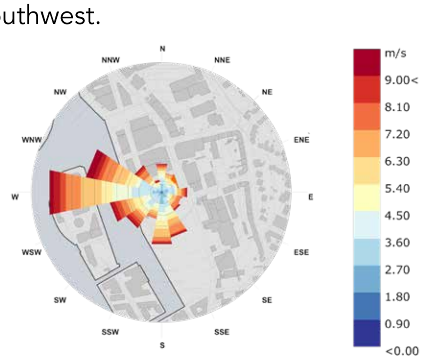
Winter

The wintertime, the dominant wind is coming from West and northwest.



Summer

The summertime, the direction shifts to the west and southwest.



Daylight

A daylight hour analysis of the site has been made to understand how the surrounding buildings shade on site. The area south of the site is currently empty, but to interpretate future buildings a fictive 15-meter-high building is placed to cast showdowns on site.

Summer

The daylight situation is optimal with no building casting shadows on the site.

Equinox

The daylight situation is again optimal with no building casting shadows on site.

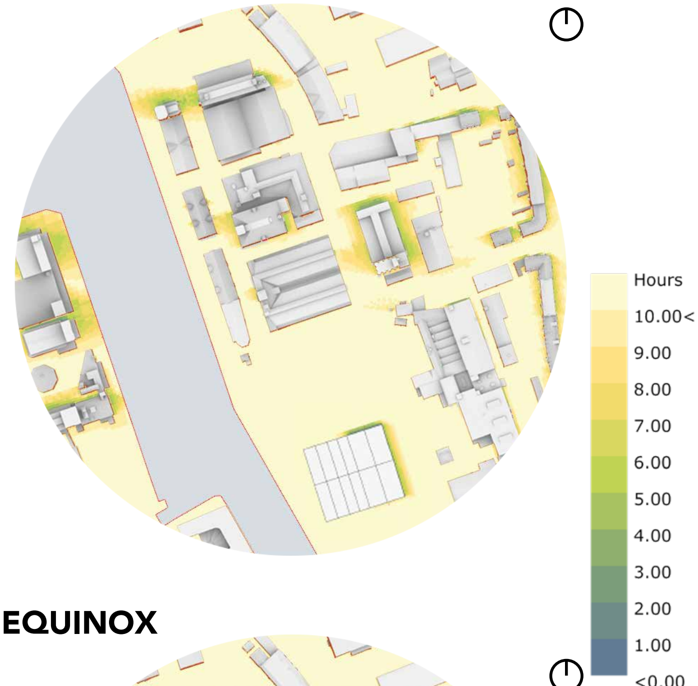
Winter

The daylight situation in the winter has large shadows cast from the surrounding buildings in the south, but the site still has areas that are optimal for sun in the winter months.

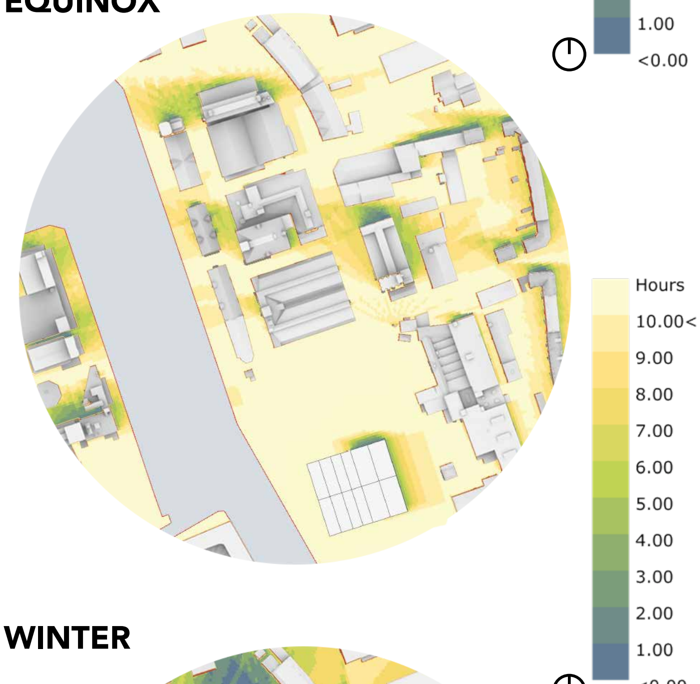
Conclusion

The site has particularly good daylight with almost no shading all year. Wind is coming from the west during summer and southwest in the winter, since the site is very exposed to wind cover would be required.

SUMMER



EQUINOX



WINTER

SAVE SURVEY

_08_02_04_ SAVE SURVEY

Upon visiting the site in Odense, a SAVE survey was conducted to understand the building and review which parts of the building are worthy of preservation a SAVE survey has been done. The SAVE Survey is explained in methodology _07_01_ and the detailed SAVE survey from can be found in appendix x. The building was assessed as followed:

ARCHITECTURAL VALUE: 4

The warehouse is a single standing building consisting of a two halls connected by a transept with a tower. The halls are crowned by clerestories running along them and meeting in the transept wings.

The granary has a central location in the harbour and is one of the oldest buildings in the harbour.

The granary is symmetrical over the east-west axis. The granary is clearly a place of storage as the building is spacious and robust.

CULTURE-HISTORICAL VALUE: 3

The granary is the only one of its kind resembling a different type of granary that has to be operated by hand. The wood structure resembles the craftsmanship and materials of the time. The granary was drawn by an engineer, J. Christensen.

SORRUNDINGS VALUE: 2

The granary stands as one of two buildings untouched in the harbour, which resemble the previous industry in the harbour. The granary´s tower brings a lot of history to the harbour.

ORIGINALITY: 3

The warehouse is almost in its original condition, with the roof collapsed in some areas. The original roof from 1925 has been changed at some point into roofing tiles, but besides the roof the building stands untouched.

Furthermore, a door has been shifted out with a revolving door for forklift to enter the warehouse.

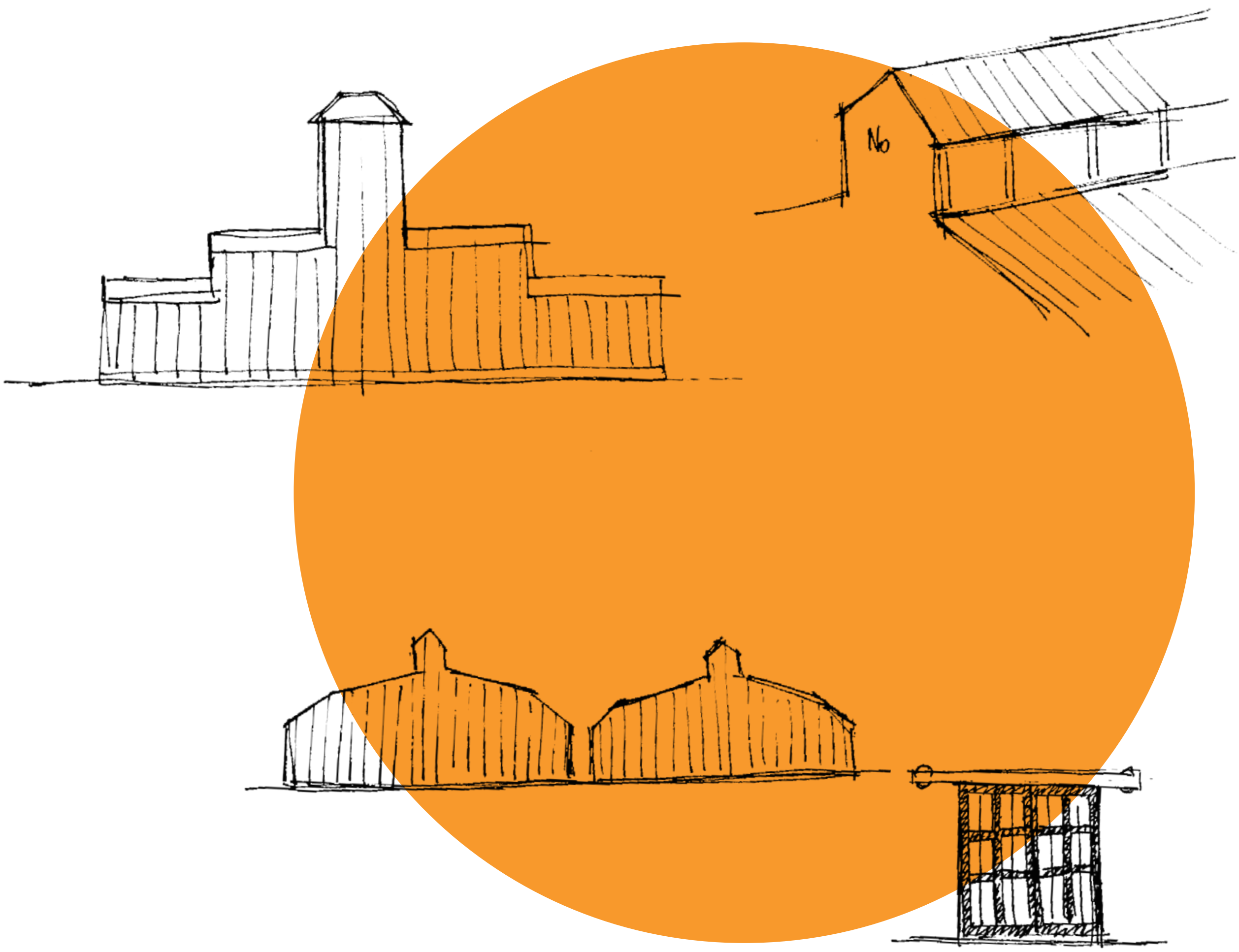
CONDITION: 5

Due to the lack of maintenance over the years the roof has been in poor condition resulting in collapse in some places. The moisture has passed into the wall thus resulting in cracks in the brickwork.

OVERALL SAVE ASSESSMENT: 3

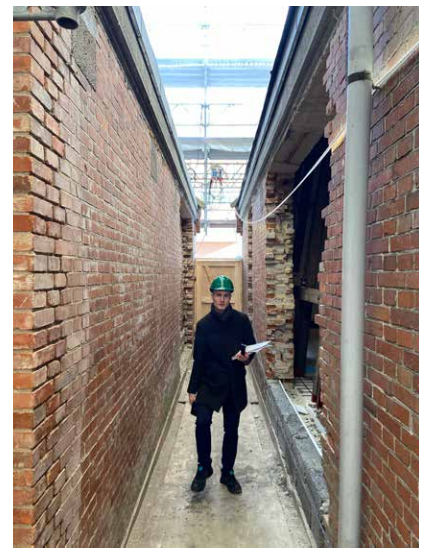
After reviewing the five parameters, the overall assessment of the granary is 3.

This is based on the unique granary which is one of the last original buildings on the harbour that has not been demolished or refurbished. The architectural value is unique with its tower and two halls combined with clerestory´s on top, the symmetry of the building and the icon blue doors. The west façade consisting of the tower and transepts are iconic for the building and is a key feature of the granary. The warehouse ooze of the harbour environment where grain and coal were exchanged. The originality is still high as this building has not seen notable change, nevertheless, the lack of maintenance and renovation of the warehouse is noticeable, with many walls being cracked and the roof collapsing in some places.



17. SAVE SURVEY

SITE SURVEY



_08_03_ SMALL SCALE

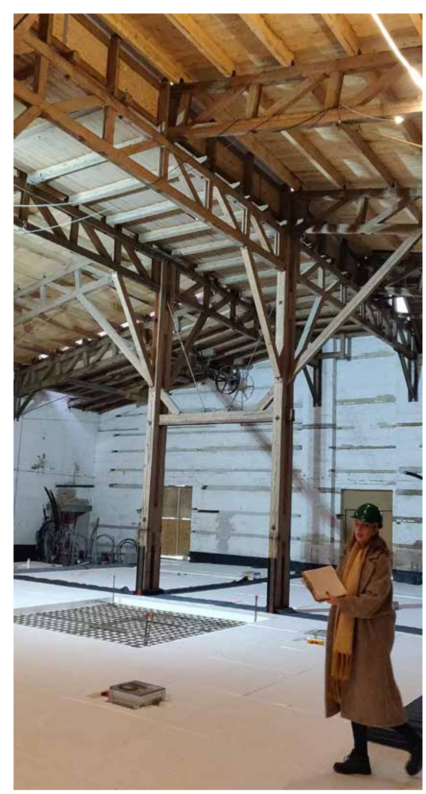
The small scale section will present the survey and a review of the building. It will start with evaluating building's condition to understand the architectural value and structural integrity of its elements. Later, data of the building element survey will be gathered and presented in the critical building review to understand the potential and limitations for transformation.

_08_03_01_ BUILDING SITE SURVEY

This section focuses on the analysis of the existing building, assessment of the architectural value and structural integrity of building areas. The assessment is based on the site visit, existing documentation and a 3D scan shared by the owner of the building- Olav de Linde. The areas of the building will be assessed it two categories:

STRUCTURAL INTEGRITY- condition of the element's material composition, enabling it to be structurally intact and bear any weight it was originally intended to.

ARCHITECTURAL VALUE- importance of the element to the overall architectural expression of the building in its original style, uniqueness of the element within the building and within the use of its construction technique or material



18. SITE SURVEY

GENERAL CONDITION

During a site visit, a meeting with the representants of Olav de Linde was held, which provided an insight into the condition and challenges of the building. The warehouse at Havnegade 16 is in mediocre condition. It has been used as a storage for almost 20 years without any maintenance, and it had its impact on the building. The old wooden ceiling, which was covered with roofing felt, has collapsed in a few places. The brickwork has long cracks in many places, where walls have shifted due to expanding iron plates inside them, what also applies for the tower. The concrete floor in the main halls has sunk in several places. The supporting wooden structure has been damaged by water and needs repair in several places. The old windows are broken with broken panes.

ROOF

STRUCTURAL INTEGRITY

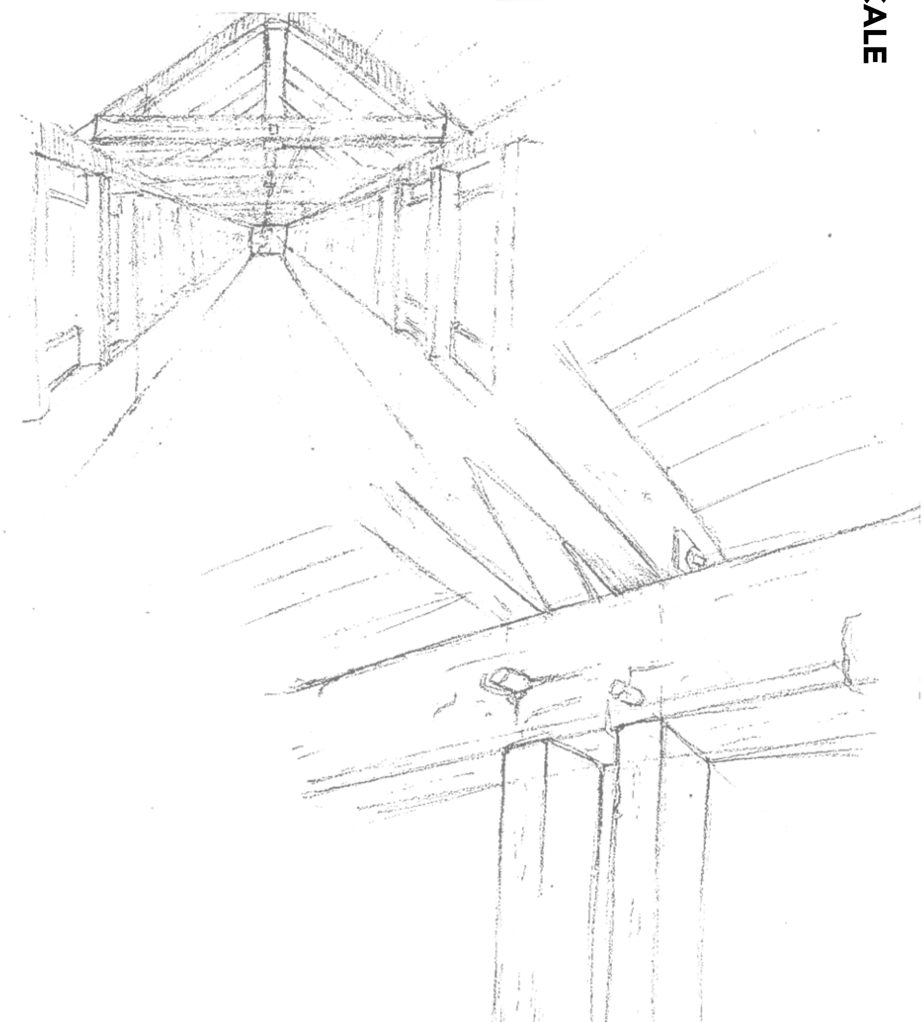
The general condition of the roof was poor, nevertheless there is some variation in the levels of roof decay. The roof above the main hall is in a bad condition, where the roofing felt has come off and water has seeped through to the battens, which has resulted in the battens being completely/partially rotten. The roof has therefore collapsed in some places. The roof perpendicular to the main halls is in the requires renovation, however, it can be restored. The roof of the tower is in a poor condition and needs replacement.

ARCHITECTURAL VALUE

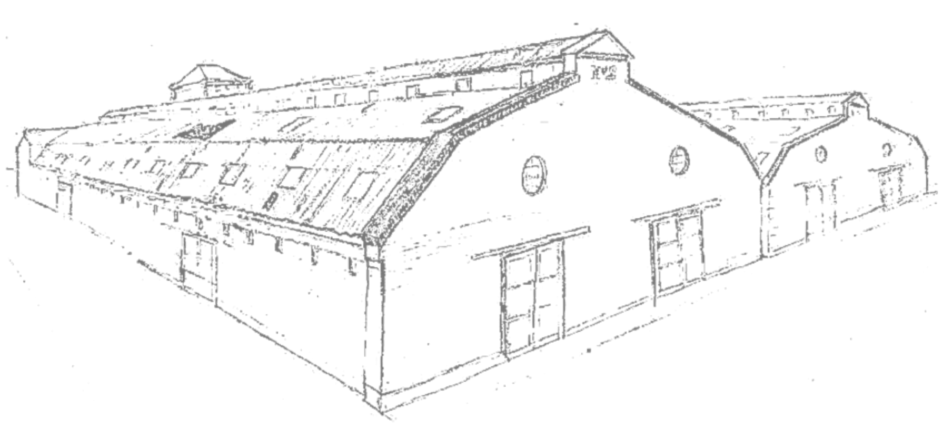
It can be assumed that the original roof has been replaced somewhere since the original construction as the material does not match the original documentation of the building. Nevertheless, the shape of the roof was preserved and remains a prominent future of the building.

The roofs of the two halls are gambrel roofs with clerestories along the middle covered by a gable roof. In the south-west gable there is a tower with a roof perpendicular to the halls on each side. The roof of the entire warehouse is the only one of its kind in the port.

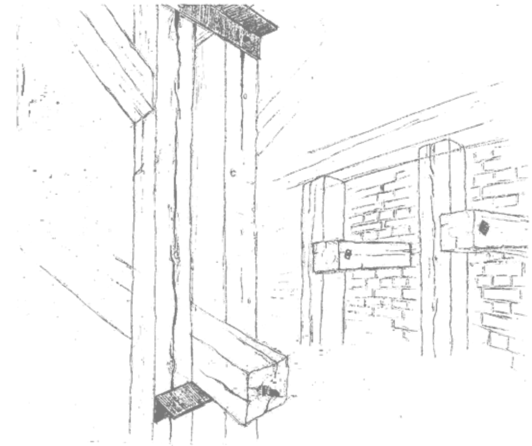
The roof shape is unique for this building and the roof type is the only one within the harbour, therefore, it holds a unique architectural value.



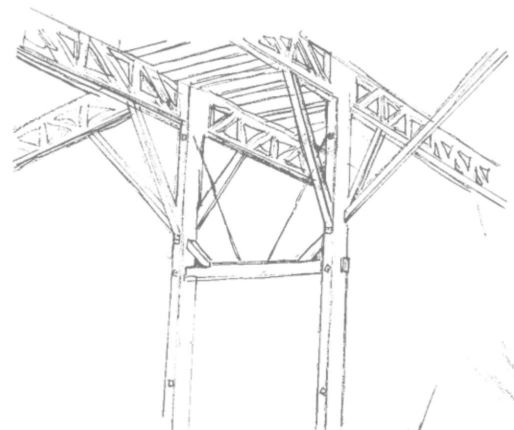
19. CLERESTORY SKETCH



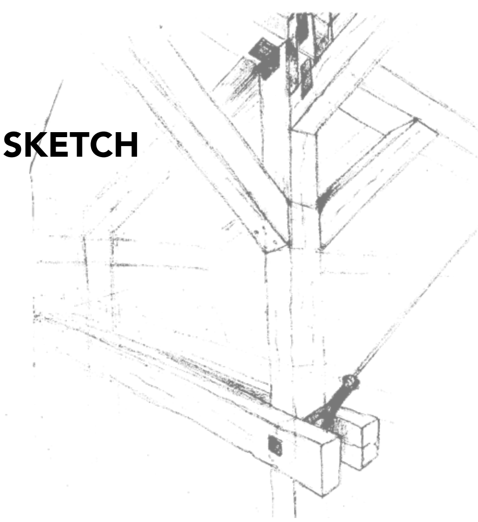
20. ROOF SKETCH



21. STRUCTURE SKETCH



22. MAIN COLUMNS SKETCH



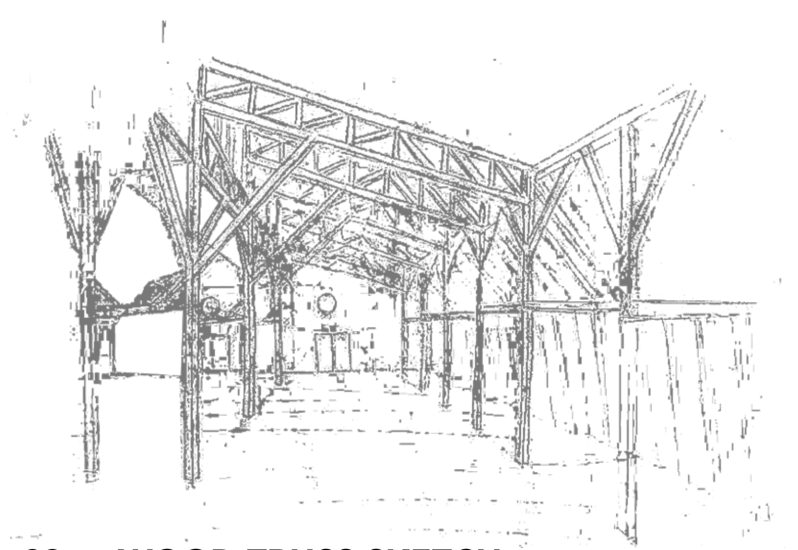
MAIN HALLS – STRUCTURE

STRUCTURAL INTEGRITY

Hall A´s wooden structure consists of three wings: a central one with load-bearing columns, which support the clerestory, and two support structures on the sides, which support the roof with wood trusses across. Some of the wood trusses have been damaged by water from the leaky roof which resulted in several truss sections rotting. Almost all the columns in both entire halls have absorbed moisture from the ground, which has resulted in the footing of the column rotting. Despite the structure being intact the rotting sections require additional support if preserved.

ARCHITECTURAL VALUE

The main hall's wooden structure is the most striking element in the whole warehouse. The central wooden columns support the wood trusses with wood struts and tension rod cables stabilizing the structure. The clerestory at the roof is assembled with special wood joints which is characteristic for the construction at the time. The wood trusses and columns are unique elements especially as a total structural frame is repeated along the hall interiors. The interior wood structure reflects the historical techniques used in industrial buildings of its time, and therefore has a high architectural value.



23. WOOD TRUSS SKETCH

MAIN HALL – WALLS

STRUCTURAL INTEGRITY

The walls of the warehouse are in a mediocre condition. The brick walls have been made with iron ribbons inside the mortar, which strengthened the wall when grain was pushed against it. Over the years the iron has started to corrode and expand which results in the brick walls cracking. The condition of the bricks and walls is okay but in in the areas close to the western façade the cracks are so big that the wall will require renovation.

Hall A and B are divided by an external corridor that leads up to the tower section. The walls that form the corridor are in poor condition and will require renovation. The biggest cracks are found in hall B.

ARCHITECTURAL VALUE

The warehouse walls consist of red brick walls which are untreated. The brickwork is characteristic for the time of construction and there are unique details around the window and door openings. The red brick walls were at the time (1925) the most common construction material, but currently the building's brickwork is one of the last remainders of that time in the harbour area. Therefore, the red brickwork has a high architectural value.

The corridor between hall A and B is a peculiar feature of the building. Nevertheless, it is a very narrow space with no architectural detailing, and it does not add to the building's architectural value.

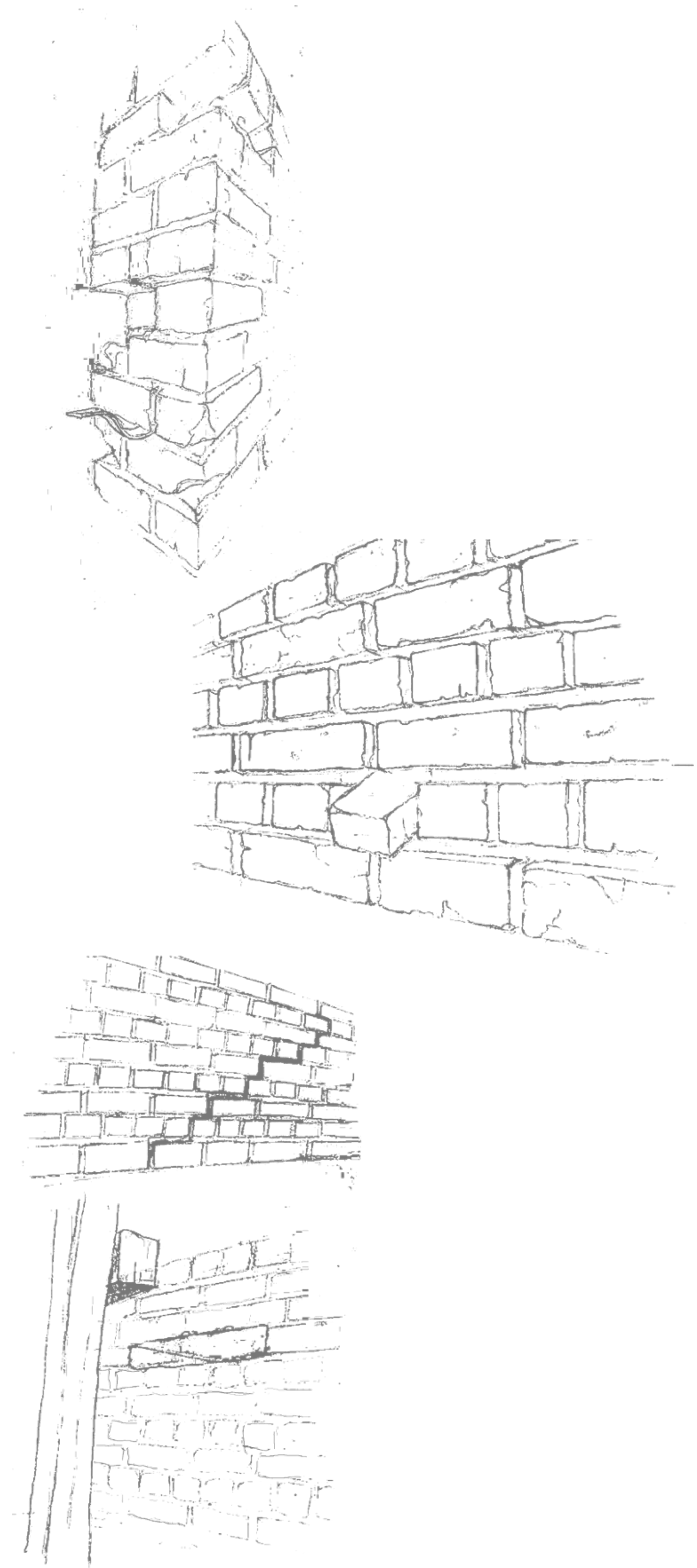
MAIN HALL – FLOOR

STRUCTURAL INTEGRITY

The floor of the warehouse is an in-situ concrete layer. The concrete floor in the main halls has sunk in several places and has been repaired over time by adding more concrete on top. This has resulted in a slab of 400 mm of concrete which is not levelled. Hall A is in a better condition and Hall B requires levelling of the sunken areas of the ground slab.

ARCHITECTURAL VALUE

The current concrete floor does not reflect the historical style of the building. Therefore, it does not present an excellent value which needs to be preserved.



24. BRICK WALL SKETCH

TOWER

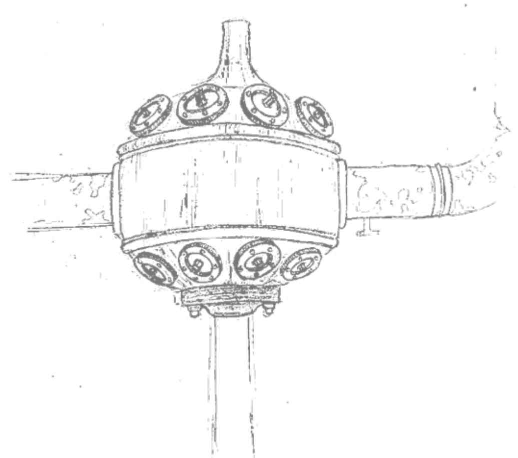
STRUCTURAL INTEGRITY

The tower is constructed in brick and has a staircase inside as well as a mechanical room. The stairs have decayed to the point where they are not structurally sound and need to be replaced. The tower was used to suck grain from the warehouse up and across to the harbour edge. The walls have been reinforced with iron ribbons, and the corrosion and expansions of these ribbons has resulted in large cracks in the brickwork and made the whole wall shift 2 cm horizontally. The tower has an exterior balcony, which has possibly been damaged when the walls shifted. It might require support if preserved.

ARCHITECTURAL VALUE

The tower is the most visible and unique element of the warehouse exterior. The tower distinguishes this building from the other warehouses in the harbour and gives the building a unique expression. The warehouse is one of two buildings with a tower within the harbour, and the only tower with a balcony. This element with all its windows and detailing presents a high architectural value.

The corridor between Hall A and B leads to the back of the tower, where a mechanical room with its original installations can be found. The original pump is preserved and holds a high historical value.



25. ENGINE SKETCH

WINDOWS AND DOORS

STRUCTURAL INTEGRITY

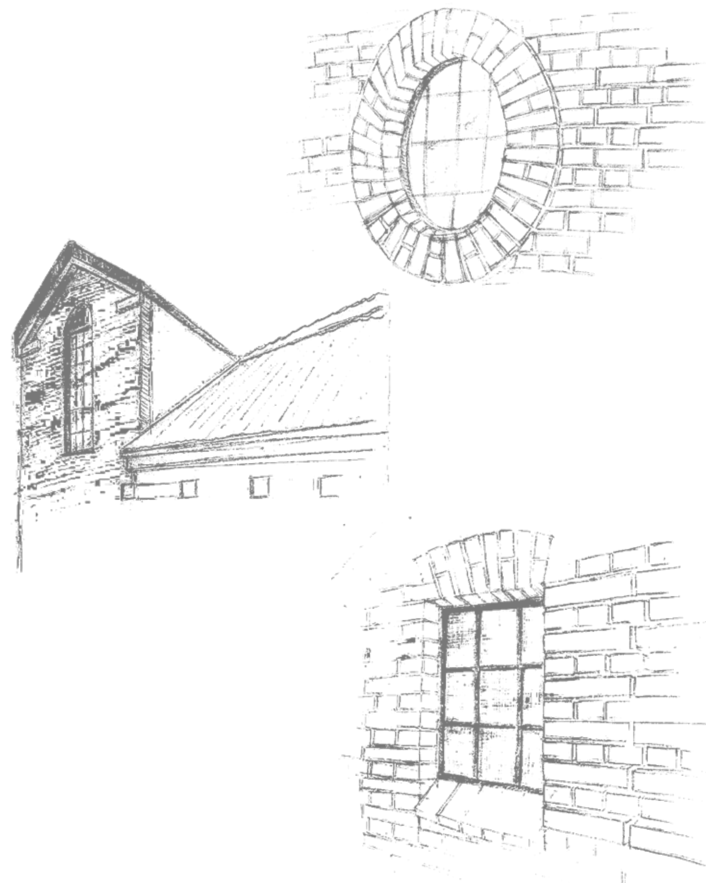
The windows and doors are in a poor condition. The blue sliding doors were originally made from wood covered with metal sheets and painted blue. The metal has corroded, and the exposed wood is rotten. On the exterior a few of the doors were covered in spray paint. Some of the blue doors have been replaced, but a few remain and are in need of restoration if preserved.

The windows are single pane with iron mullions and frames. In most cases the glazing sections have decayed over the years and have many holes. The large rectangular windows on the sides of the western façade are in much worse condition than the others, as some of the smaller windows remained intact.

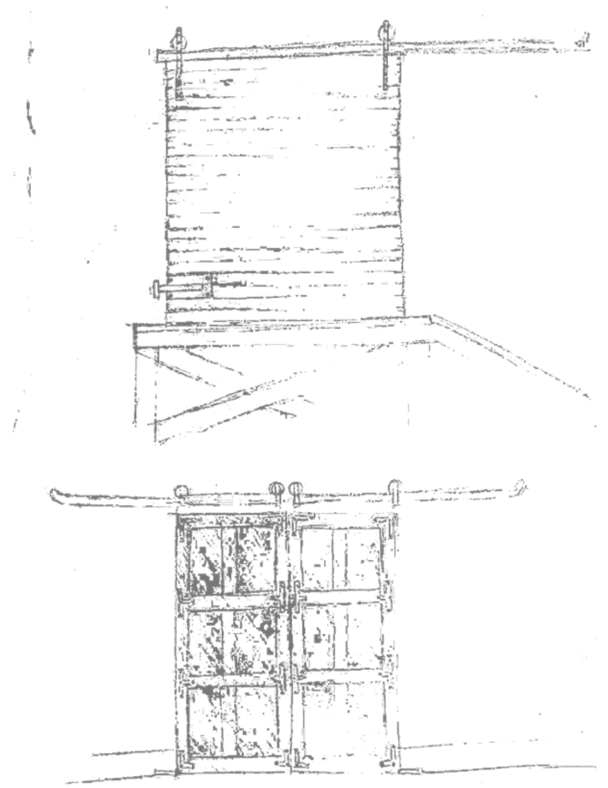
ARCHITECTURAL VALUE

The blue doors are unique for the buildings and industrial buildings in the area. They are also the main entrances to the building. When grain was stored in this warehouse it was delivered through these blue doors. Therefore, they possess a high architectural value.

The windows come in different shapes varying within the building. The large circular windows in the gable are a prominent feature for this building and hold a high architectural value. The large rectangular windows positioned on the side gables of the western façade emphasize the perpendicular roof and are an important element both from the perspective of exterior and interior. The smaller windows placed along the facades, tower, roof, and clerestory add to the repetitive expression in the building but by themselves do not present a high architectural value.

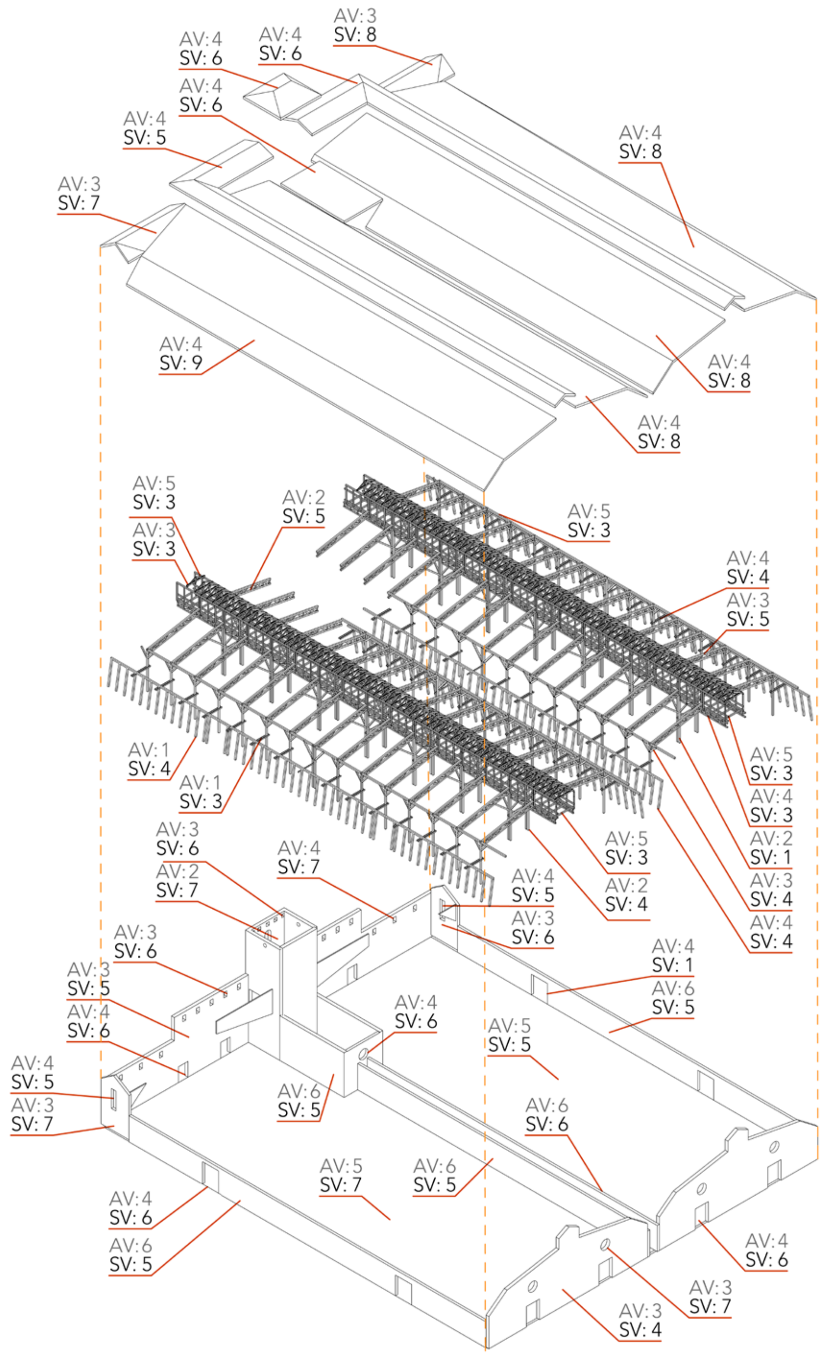


26. WINDOWS SKETCH



27. BLUE DOORS SKETCH

CRITICAL BUILDING REVIEW



28. CRITICAL BUILDING REVIEW

_08_03_02_ CRITICAL BUILDING REVIEW

This section summarizes the assessment of buildings elements in their architectural value and structural integrity. The summary, particularly the architectural value assessment, take into the account the SAVE method review and the building features it emphasized (0). The scale of the assessment is based on the SAVE method, with 1 being the highest value and 9 the lowest. The showcased values are generalized for elements placed on each façade and inside each hall for the general review (e.g. west façade doors, hall A floor). The numerical scale values are assessed on the basis described below.

ARCHITECTURAL VALUE

1- Very high heritage value, unique detailing and architecture, indispensable for the expression of the building

2-Very high heritage value, unique architecture, important for the expression of the building

3-High heritage value, unique architecture

4-High heritage value, valuable features

5-Average heritage value, no significant detailing

6-Average heritage value, no valuable features

7-Low heritage value, not valuable for the buildings expression

8-Low heritage value, not a historically specific element

9-Very low heritage value, features not adding to the overall architectural expression or damaging the historical value of the building

STRUCTURAL INTEGRITY

1- Very good condition, no visible damage to the element's material

2-Very good condition, some deterioration signs not impacting the integrity of the material

3-Good condition, some maintenance work required to prevent further deterioration

4-Good condition, repairment of the whole element required to prevent further deterioration

5-Average condition, visible deterioration on the whole element requiring repairment

6-Average condition, deterioration has disrupted the structural integrity of the material, in need of repairment or additional support

7-Bad condition, a risk of material collapse requires serious repairment to maintain intact

8-Bad condition, large areas of the element in need of replacement, advanced repairment needed

9-Very bad condition, the material is not intact and has collapsed, in need of major repairment and replacement

Conclusion

Various building elements have deteriorated over time due to the lack of maintenance and local environment. Architectural and structural integrity values together with SAVE method assessment suggest, which elements of the building should be preserved, restored, reused, or demolished. The roof is generally in a poor condition, which has resulted in collapsing in some areas. However, the architectural value of the roof lays in its shape and therefore if replaced the general form should be replicated. A review of the roof elements has determined that 30 % of them can be reused if the whole structure gets demolished.

The interior wooden structure of the warehouse is incredibly unique for this warehouse and has a high architectural value, which needs to be preserved. The condition of wood structure is good, but some of the wood trusses have started to rot, which needs to be reinforced or replaced. Furthermore, the footing of all the columns have absorbed moisture from the floor, which has resulted that the bottom part starting to rot. Support for the columns will be needed if preserved.

The walls of the warehouse have multiple large cracks, which has resulted in the walls in some places have shifted. The iron ribbons inside the wall need to be removed so the remaining walls condition will be preserved.

Some of the walls are in such a poor condition that the walls have to be demolished. A review of the bricks has determined that 90 % of the bricks can be reused.

The tower of the warehouse was in a poor condition. The wall has shifted 2 cm horizontally and will need to be reinforced in preserved. The roof of the tower was in poor condition, with most of the wood ceiling being rotten. The roof structure will therefore have to be replaced.

The architectural value of the tower is unique for this building and is the first of two towers in the harbour.

CASE STUDIES

29. **KUNSTHAUS GRAZ**

_09_ CASE STUDIES

A number of case studies were chosen to display practices in adaptive reuse that are related to the building, which is the objective of this study. The projects focus on the reuse and preservation of industrial heritage and highlight various designs adding and transforming existing structures.

_09_01_ KUNSTHAUS GRAZ

Location: Graz, Austria

Architect: Peter Cook

Year: 2003

Located in Graz, Austria, Kunsthaus Graz is a contemporary art museum that was built in 2003 as part of the European Capital of Culture celebrations. Designed by British architects Peter Cook and Colin Fournier, who won an international competition, the museum is a stunning example of contemporary design that reflects the city's modern and dynamic character. It was built as a renovation of the first cast-iron building in Europe, with a unique shape resembling a giant blue bubble or amoeba. This design was chosen to reflect the fluid, organic nature of contemporary art and to create a sense of movement and energy. Inside, the museum is arranged over several levels, featuring a central atrium that allows natural light to flood into the building. The exhibition spaces are flexible and can be adapted to suit different types of art, while the building also includes a café, a shop, and an auditorium for performances and events. Kunsthaus Graz is committed to displaying innovative and cutting-edge art, making it a must-visit destination for contemporary art enthusiasts. (museum-joanneum, 2023)

30. HANZAS PERONS CULTURAL CENTER

_09_02_ HANZAS PERONS CULTURAL CENTER

Location: Rīga, Latvia

Architects: Reinis Liepins, Sudraba Arhitektūra

Year: 2019

Hanzas Perons is a project in the center of Riga, a city with a long industrial history. The transformed building was constructed at the beginning of the 20th century and used to be a cargo rail station. The warehouse was the only building which has survived with many historical elements still intact. The architects have utilized the large open space of the warehouse and transformed it into an event and culture venue. As the original walls and roof were not able to provide sufficient support, the architects have designed a load-bearing structure wrapping around the building.

The design by Sudraba Arhitektūra and Reinis Liepins is a fitting example of a horizontal extension in an adaptive reuse project (ArchDaily, 2020). The added structure, apart from its supporting function, provides the building with additional spaces for lobbies and meeting areas. The envelope also made it possible for the optimal indoor climate to be reached. In its design the extensions follow the form of the original warehouse, but in a modern expression in steel and glass. Additionally, when the added areas are lit up, the illumination emphasizes the historical brick details of the warehouse walls. The interior details of sliding doors were also preserved further emphasizing the industrial heritage of the project. As the hall remained an uninterrupted open space it presented a good opportunity for the architects. With the added flexible walls, the hall can be divided into three separate venues depending on the need.

31. CANADIAN MUSEUM OF NATURE

_09_03_ CANADIAN MUSEUM OF NATURE

Located: Ottawa, Canada

Architect: KPMB

Year: 2010

The Canadian Museum of Nature, located in Ottawa, Ontario, is a natural history museum in Canada.

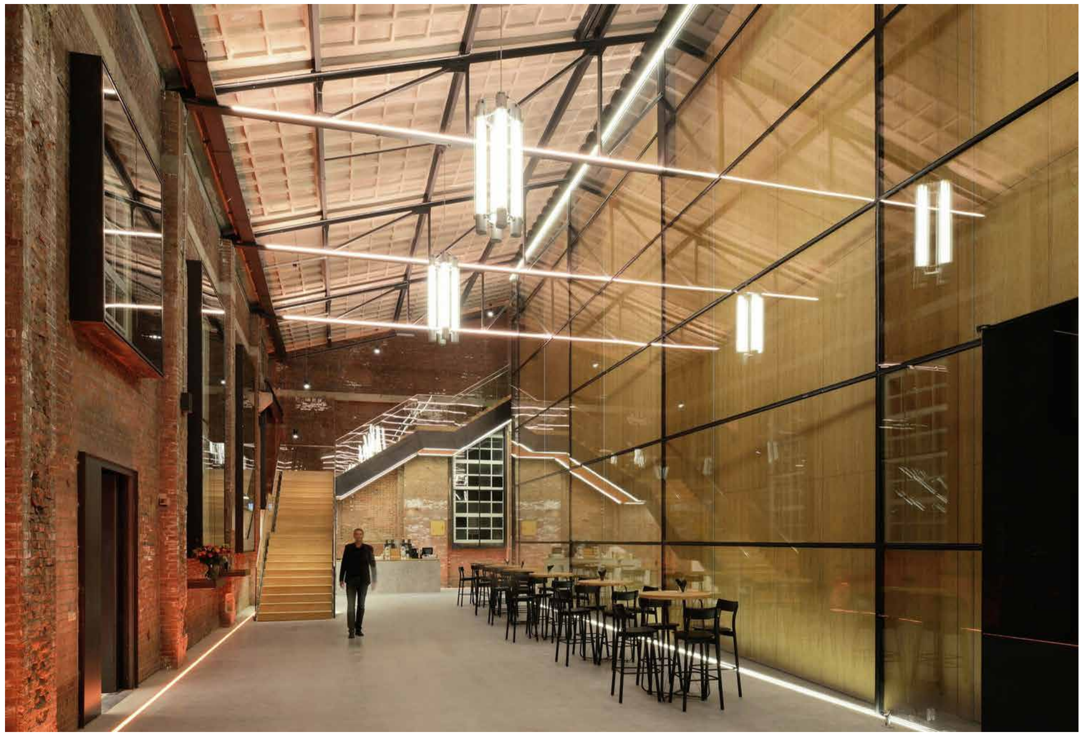
The original design of the museum was created by architect David Ewart in 1905. Ewart drew inspiration from European Gothic architecture, particularly the castles and cathedrals of France. Construction began in 1906, and the building was completed in 1912. (Canadian Museum of Nature, 2023)

Unwittingly built on a layer of Leda clay, the stone entrance of the tower started to sink into the ground.

In 2001 the museum underwent several renovations as the museum had to be truncated to de-load the structure. The design of KPMB architects is a notable example of renovation for historical buildings and an addition that focuses on the simultaneous awareness of time past and present.

The addition of the building, a contemporary wing designed to harmonize with the existing structure.

Most remarkable renovation of the building is the removal of the old tower and the new addition of the lantern tower, covered in glass. Inside the tower a butterfly Stair clarifies circulation. This is part of the new wing added to the museum, which is situated on the southern side of the building, resulting in the creation of a South Terrace. The South Terrace serves as a vibrant outdoor gathering space for the public, providing a platform from which visitors can appreciate the impressive sandstone walls and marvel at the craftsmanship.(KPMB Architects, 2023) The VMMB provides modern exhibition spaces and facilities while maintaining the architectural integrity of the original building.



32. THEATRE DE KAMPANJE

_09_04_ THEATRE DE KAMPANJE

Location: Den Helder, The Netherlands

Architect: van Dongen-Koschuch

Year: 2015

The interior seen in the photo above belongs to the concert hall in Den Helder. It is located in an old shipyard area of Willemsoord, and a result of a project involving a complex of maritime buildings, which the public had no access to for the past 170 years (ArchDaily, 2015). The project activates the area by bringing new cultural, office and gastronomy functions into the old warehouses. The architects have preserved as much as possible of the original buildings and the added elements emphasize the character of the area.

Theatre ‘The Kampanje’ stands as an inspiring example if it comes to the changes made inside the historical buildings. The architects have managed to maintain the feeling of a striking large open space while separating the halls to accommodate new functions. The utilization of glass separations, in the case of the concert hall, creates a transparent “box “ in the middle of the warehouse. Flexible separations can enclose the space completely if necessary, otherwise the open feeling of the space remains uninterrupted. This choice in the design of building interiors gives the visitors an insight into the original expression of the warehouse without compromising the new functions.

Conclusion

Presented case studies give an insight into possible transformations of industrial heritage. The extensions enable flexible design of the new functions inside the building. If done properly, they can emphasize the historical features of the original structure and show a balance between the old and the new. The composition of materials used in the added structures can have a great impact on the expression of the whole design, as they can purposefully connect or isolate the original and added elements. The interior is particularly important if it comes to expressing the history of the building in its new function. Therefore, the preservation of interior details and installations as well as the general feeling is a key in industrial heritage transformations. The historic warehouse buildings are usually not compliant with current energy standards and require additional energy renovation. External envelopes or internal isolated structures present a solution to this issue, as they allow for the preservation of the facades and roof in their original form. Industrial heritage buildings discussed in these case studies present a great potential, similarly to the object of this thesis, because of their location and open structure. This can result in a very versatile design of the interior spaces and the building being able to host multiple functions. The architects of the discussed buildings utilized this potential and activated these industrial spaces, making them available for the public and the cities.

NEW DESIGN

_10_ NEW DESIGN

This section outlines the development of a new design plan, delineating the vision for the revitalized inner harbor of Odense and highlighting the role of the new building at Havnegade 16 within the overarching masterplan. The conceptual foundation for this new design is premised upon a set of fundamental design principles, which have been formulated to meet various objectives. The overarching goals of the design are themselves derived from the design drivers that emerged from the initial analyses.

VISION

_10_01_ VISION

The restoration plan for granary is rooted in its historical significance, as the building was a pivotal component in the grain export industry of Fyn, and a key contributor to the prosperity of the surrounding area. The proposed transformation seeks to re-instate the building as a vital role in the harbor and its vicinity. The overall development aims to offer a space for relaxation and connection with the water, a public plaza is planned for the adjacent plot, with the granary building serving as a scenic backdrop that overlooks the harbor.

A new addition to the building introduces a new cultural venue to the harbour creating a cultural driver within the harbour that accommodates talks, art, and music. The building itself will provide office space for new start-up companies, thus creating the product and knowledge for future export ventures.

A restaurant provides a gastronomical destination in the harbour and to ensure activity throughout the day, a café that will add to the vibrant atmosphere of the area and provide space for small shops that showcase the work of local artists.

33. NEW ODENSE HARBOUR VISION

DESIGN DRIVERS

_10_02_ DESIGN DRIVERS

To guide the design of the building, three key drivers have been established based on an initial analysis. These drivers serve to steer the design process and translate the strategic direction into clear design goals. The three guiding principles consider the analysis of the building on three different scales, with each principle addressing a different scale. This ensures that the drivers are comprehensive and adaptable to various aspects of the building's design.

CONNECTED HARBOR

This principle comes from the upcoming masterplan and the vision from the municipality regarding the harbour. This is translated into connected harbor which is about the surrounding context and how functions and design will activate the harbor.

IMPORT/ EXPORT

The driver comes from the history of the site, where grain and coal were exchanged. This is translated into import/export which is about addition and subtraction on the site. This will help to develop the design of the building.

PAST+PRESENT+FUTURE

This principle comes from the preservation and transformation of the building. A wish to preserve the past, allow the present to enjoy the building and maintaining it for the future generations.

34. DESIGN DRIVERS

GOALS

_10_03_ GOALS

For this master's thesis, a series of design goals have been formulated with the purpose of guiding the design process and facilitating the transformation of the building. These goals serve as a compass in some situations and as a mandate in others, providing direction throughout the design process. It is important to note that these goals are not limited to a specific design driver, but rather represent an overarching objective for the design process.

Aligned with the new masterplan vision.

Connecting people in the harbour

Activities all day

Unique from the old city center

Connected to the water.

Bringing back the *zeitgeist* ***of the harbour***

Materiality of the transported goods

Functions reflecting the area's character.

Contrast between the old and the new

Greenery harbour

Preserve the wood structure.

Preserve the exterior building façade.

Insulate the interior of the building.

_10_04_ STRATEGY

To achieve the set goals a strategy will be followed to proceed with the design development. The design drivers and topics they focus on respond to the three scales of looking at the building discussed in the methodology: Connected Harbour- Large Scale, Import/Export- Medium Scale, Past+Present+Future- Small Scale. Therefore, the drivers will be working as guidelines in the concept exploration and decision making during the design development process.

DESIGN CRITERIA

_10_05_ DESIGN CRITERA

Based on the goals formulated in the previous section _11_03_, specific design criteria´s has been made for the new design to achieve. These design criteria´s are not related to the design drivers but rather represent an overarching objective for the design process. Design criteria´s is:

Achieve renovation class 1 in energy frame (53 kWH /m²)

Total transmission loss under 30 W/ m²

Use renewable energy sources in the energy frame.

Minimum 50% daylight on 50 % of the floor area.

Keep 75 % of the original wood columns.

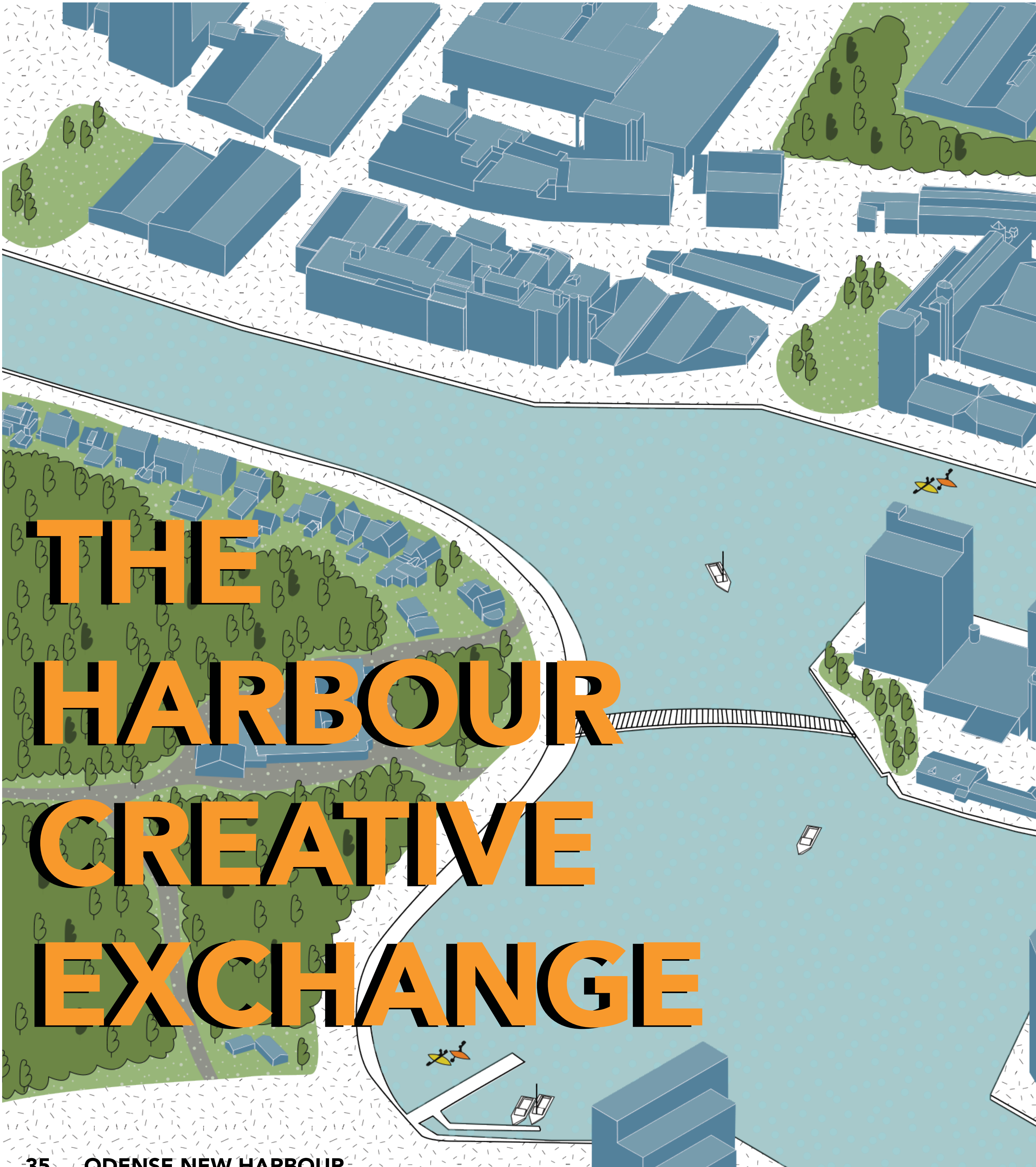
Keep 80 % of the original wood framing.

Keep 75 % of the original brick wall.

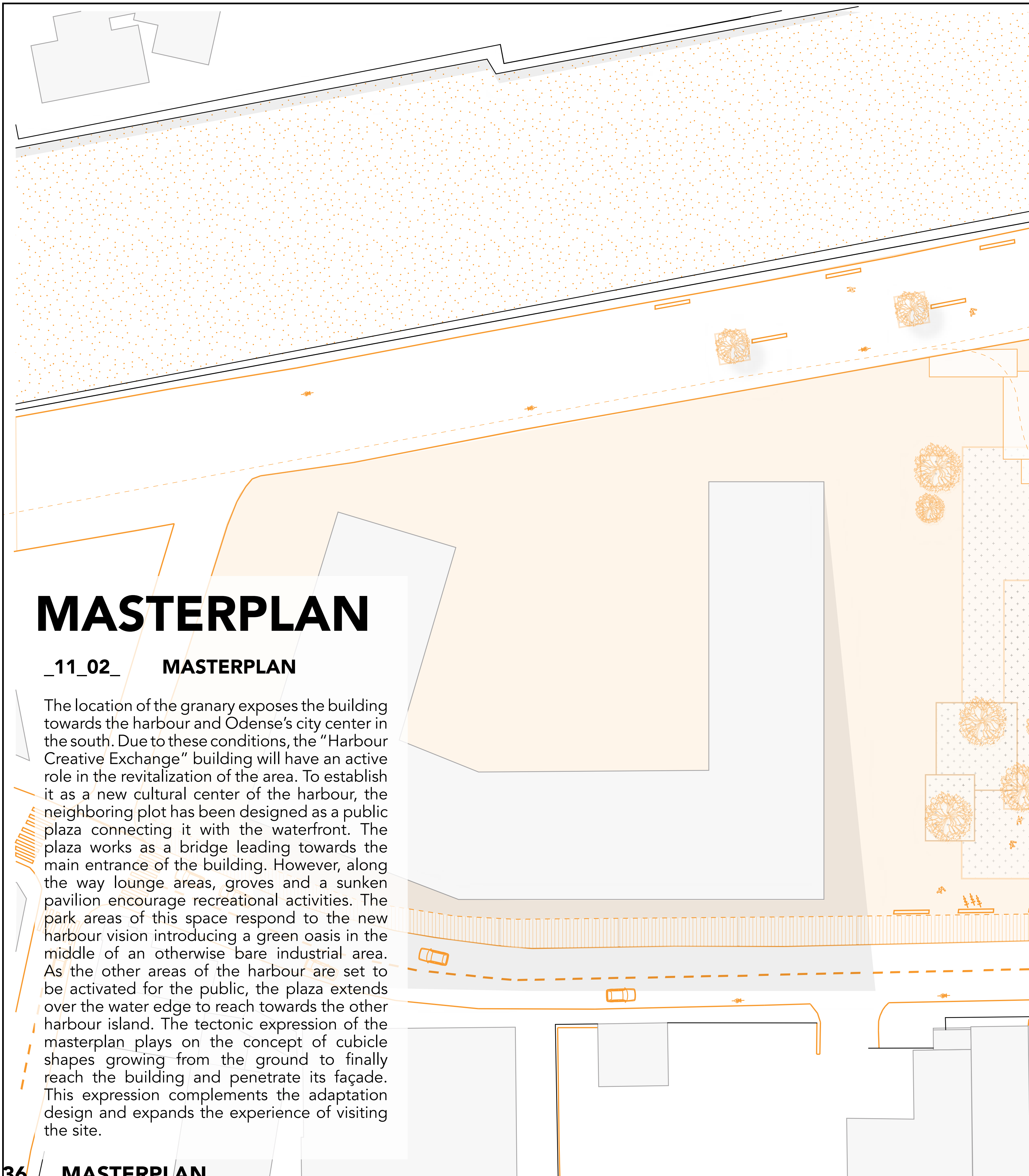
_10_06_ ARCHITECTURAL PROGRAM

	Amount	Approximated m² (brutto)	Total m²
Culture space			
Art expo	1	360	360
Concert hall	1	200	200
Foyer	1	100	100
Admin	1	130	130
Storage	1	50	50
Reception	1	50	50
Toilets	1	80	80
Restaurant			
Floor	1	300	300
Mezzanine floor	1	160	160
Kitchen	1	100	100
Toilets	1	20	20
Storage	1	150	150
Technical	1	50	50
Museum			
Museum floor	1	400	400
Office	1	50	50
Toilets	1	30	30
BOH	1	20	20
Café			
Open floor	1	350	350
Mezzanine floor	1	250	250
Coffee shop	1	50	50
Shared shop	1	200	200
Toilets	1	50	50
Technical	1	50	50
Office			
Office floor	1	650	650
Private office	4	50	200
Mezzanine floor	1	250	250
Lab	1	80	80
Tech lab	1	50	50
Wet lab	1	50	50
Kitchen	1	120	120
Toilets	1	30	30
Technical	1	50	50

THE HARBOUR CREATIVE EXCHANGE



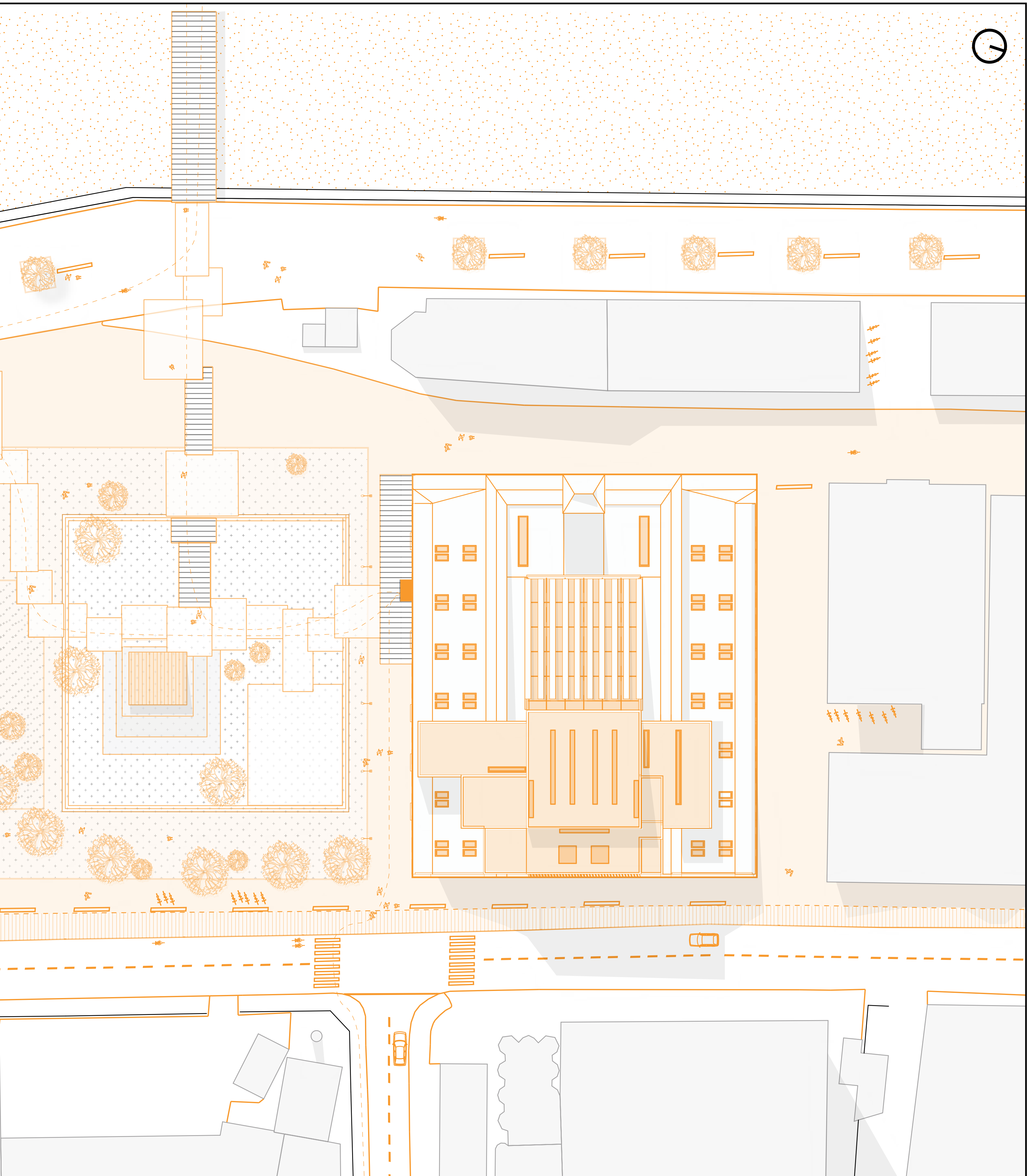
35. ODENSE NEW HARBOUR



MASTERPLAN

_11_02_ MASTERPLAN

The location of the granary exposes the building towards the harbour and Odense's city center in the south. Due to these conditions, the "Harbour Creative Exchange" building will have an active role in the revitalization of the area. To establish it as a new cultural center of the harbour, the neighboring plot has been designed as a public plaza connecting it with the waterfront. The plaza works as a bridge leading towards the main entrance of the building. However, along the way lounge areas, groves and a sunken pavilion encourage recreational activities. The park areas of this space respond to the new harbour vision introducing a green oasis in the middle of an otherwise bare industrial area. As the other areas of the harbour are set to be activated for the public, the plaza extends over the water edge to reach towards the other harbour island. The tectonic expression of the masterplan plays on the concept of cubicle shapes growing from the ground to finally reach the building and penetrate its façade. This expression complements the adaptation design and expands the experience of visiting the site.

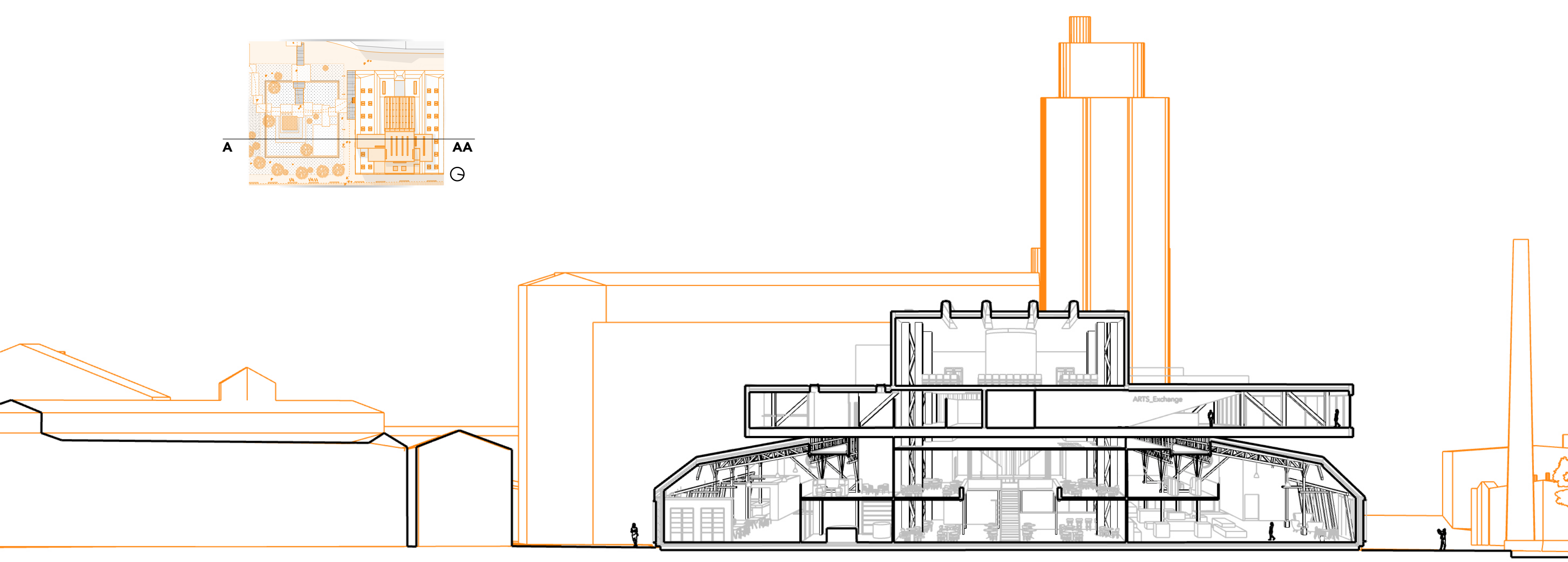


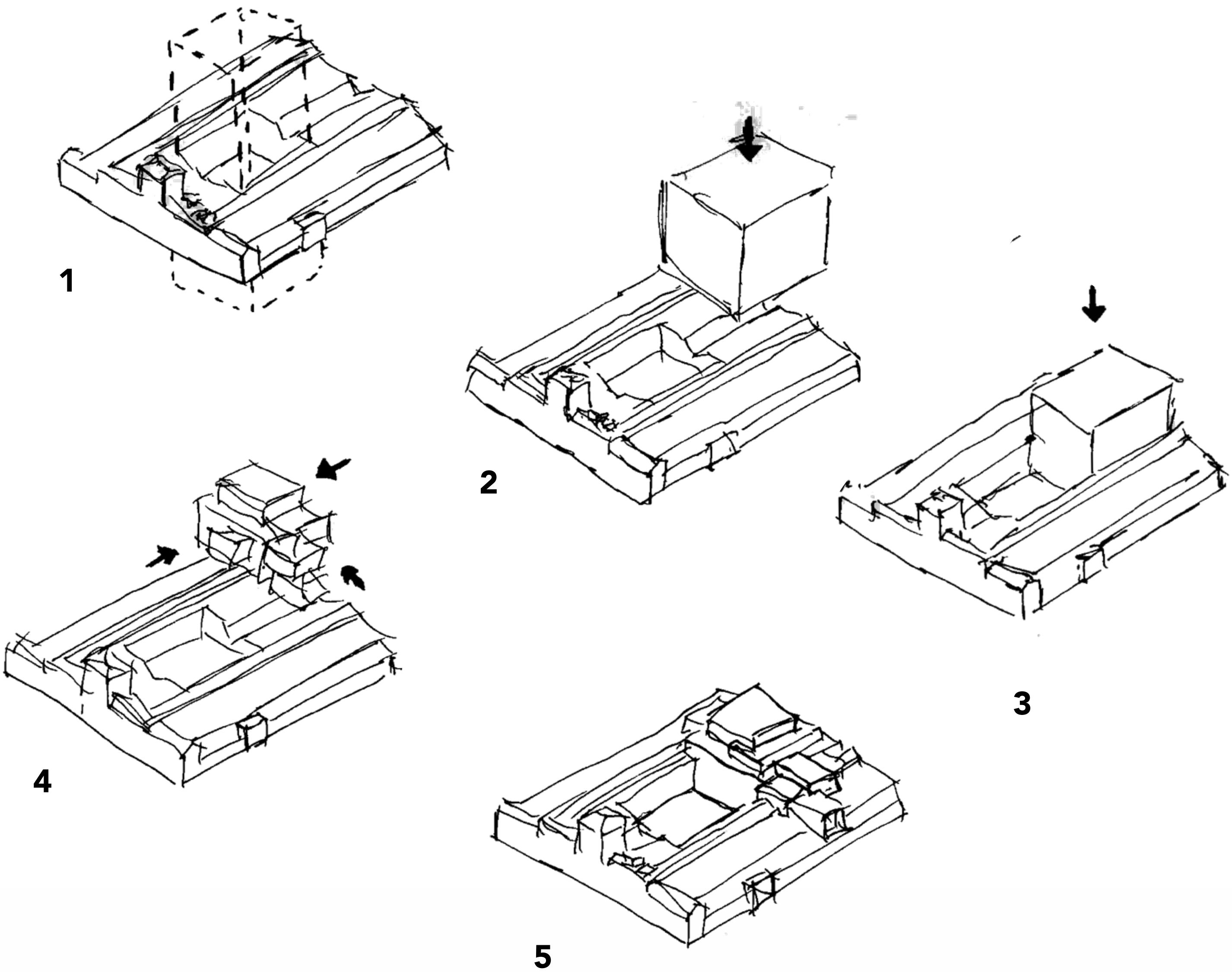
CONCEPT

_11_ THE HARBOUR CREATIVE EXCHANGE

_11_01_ CONCEPT

Design concept is based on the balance between addition and subtraction of the granary form. A void in the existing building creates a transition space and opens up deep building halls. The added building rests on top of the existing granary with a height balancing the existing tower. The form was fragmented to resemble a coal piece and therefore represents the other historical function of the site. To enable smooth transition from harbour, front the south façade is penetrated by an entrance void which connects the outside with inner courtyard. To bring an end to the journey through the building, the new structure protrudes over towards the harbour to expose the final destination for a visitor.





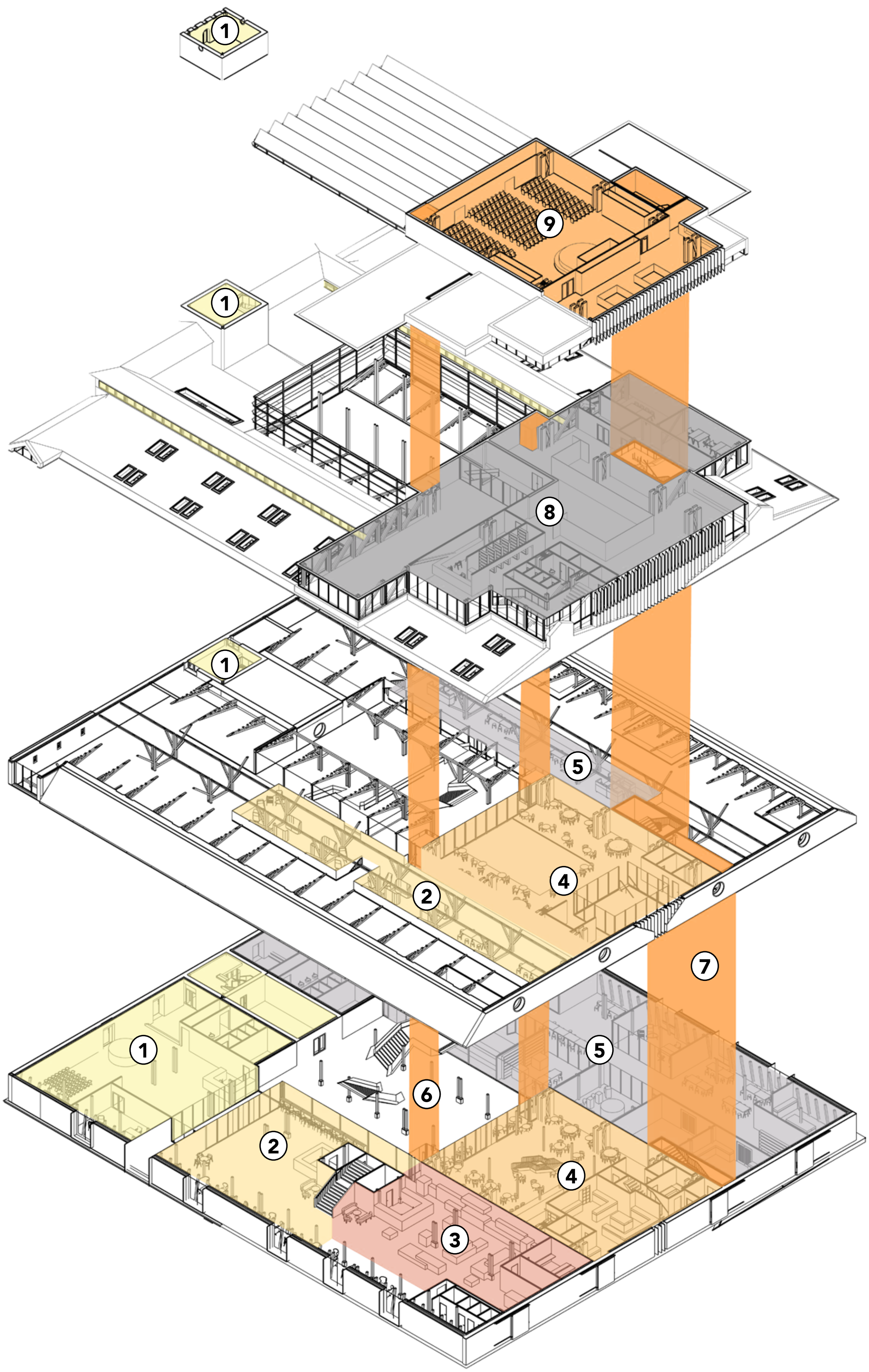
37. SITE MASTER SECTION

NEW FUNCTIONS

_11_03_ NEW FUNCTIONS

CONNECTED HARBOUR and IMPORT/EXPORT dictate the functions added to the building. Existing halls A and B represent the goods exchange heritage with separation between import and export. The southern hall is the “export ” area with a museum, café, and retail. These three functions are based on exporting the goods and knowledge characteristic for the harbour building. The northern hall represents the “import” by bringing different creative entrepreneurs together in a start-up space. The ground floor functions are connected by a courtyard and a restaurant placed in between the halls. Above the restaurant lays the “Art Exchange” cultural center with a viewing platform, an art gallery, and an event venue. The functions interact and together express a united vision: a hub supporting the collection and presentation of creative “goods” for the community of Odense. The four levels are connected by mezzanine stairs in each hall, courtyard stairs and escape staircase near the eastern façade of the building. Two elevators in the courtyard support vertical communication to upper levels.

1 Museum
2 Cafe
3 Retail
4 Resturant
5 Start-up hub
6 Elevators
7 Fire escape
8 Art Exchange
9 Event Venue



38. EXPLODED VIEW

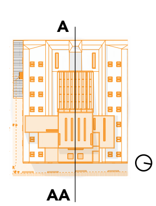
OLD/ NEW

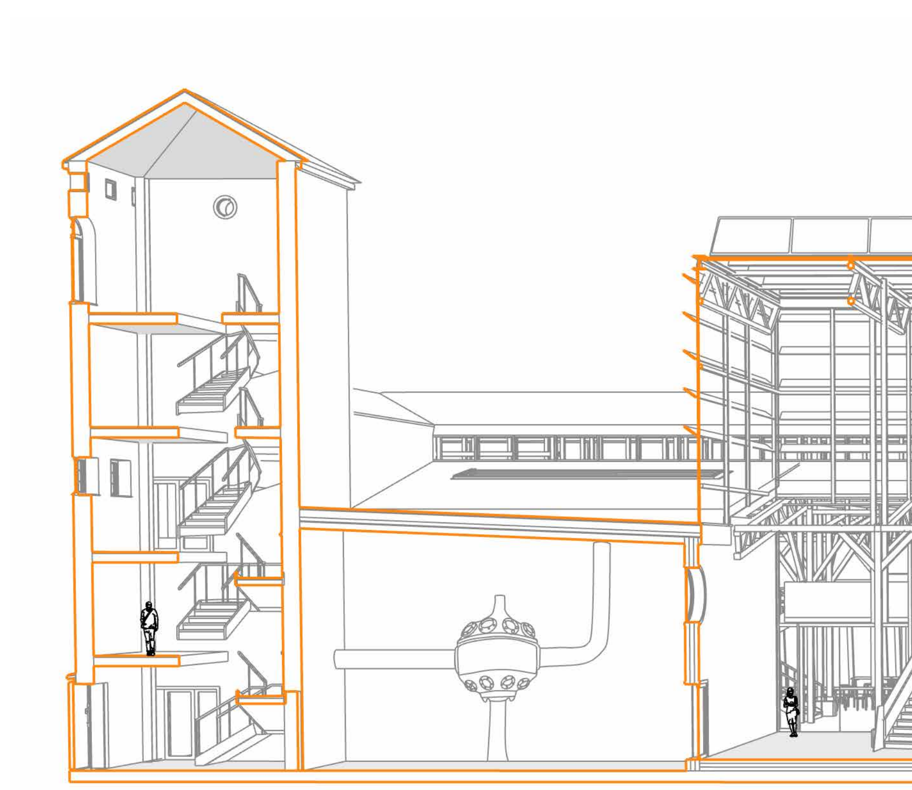
_11_04_ OLD/ NEW

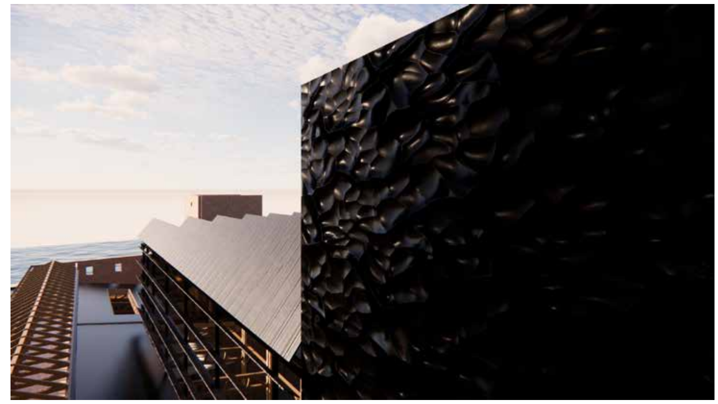
The adaptation design balances the preservation of the “old” and addition of “new” in the existing building. The existing building is penetrated by new forms in strategic locations to provide access from the southern piazza. The main entrance void is the biggest intrusion in the façade inviting the guests. In the opposite manner the cultural venue building was added to the existing form, hovering above the roof level, and balancing the tower on the opposite side of the granary. That form, symbolizing coal historically stored in the piazza area, references the past in a new form and unites the old granary and neighboring plot to embrace the various aspects of Odense’s industrial history. The play between addition and subtraction maintains the character of the existing building, while accommodating new functions and opening the enclosed structure to the harbour.

MATERIALS

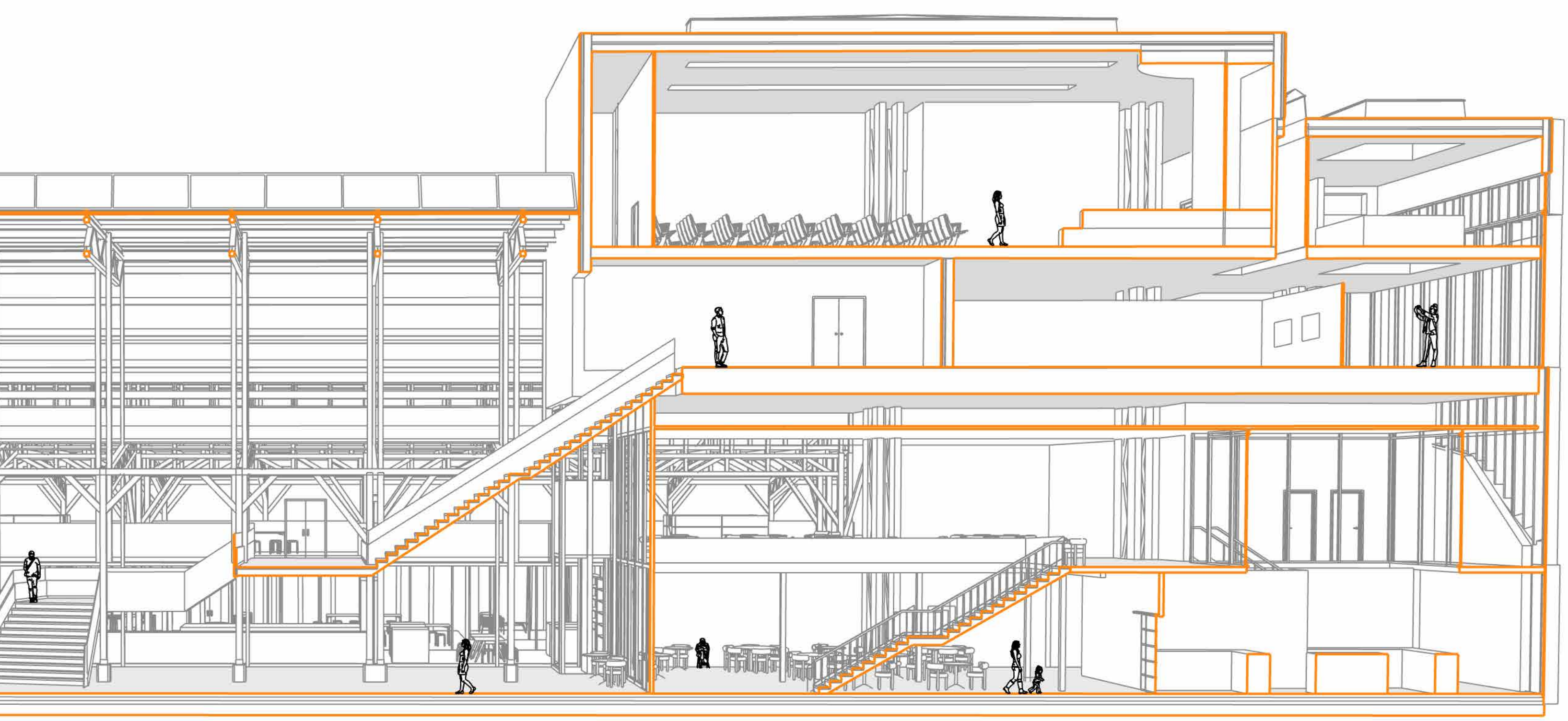
Materiality is a key factor in the expression of the final design. Aligning with the renovation approach, added structures and restoration elements are contrasting with existing materials. Simultaneously, the expression of new elements maintains the industrial character of the building, respecting its historical zeitgeist. Colours and materials used in the design are in a neutral palette giving the interior a warm and calming feeling, while highlighting the existing structure. Exterior expression embraces the contrast between the existing and new structures with black cladding cutting the old façade and wrapping the cubicles of the cultural venue.





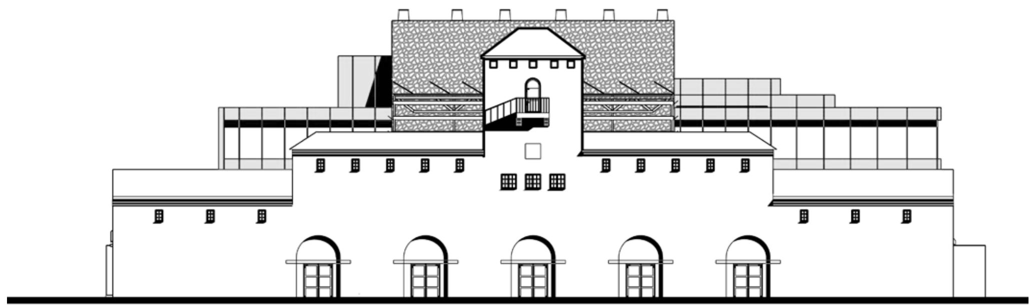


40. FINAL MATERIAL SELECTION



39. SECTION A- AA 1 :200

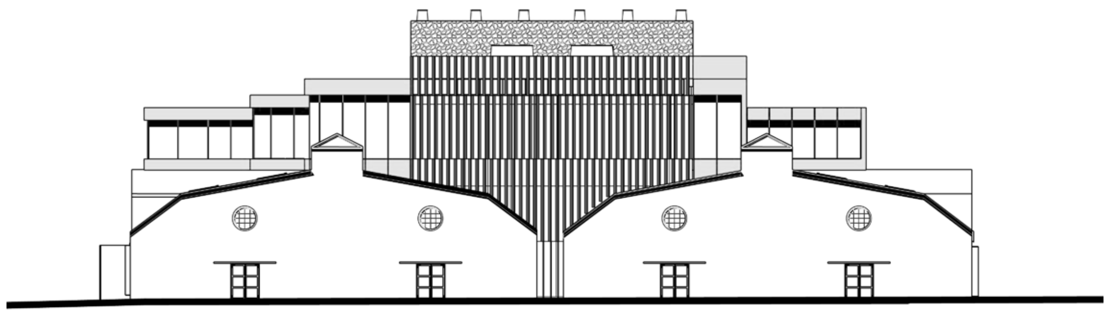
41. RENDER FROM HARBOUR FRONT



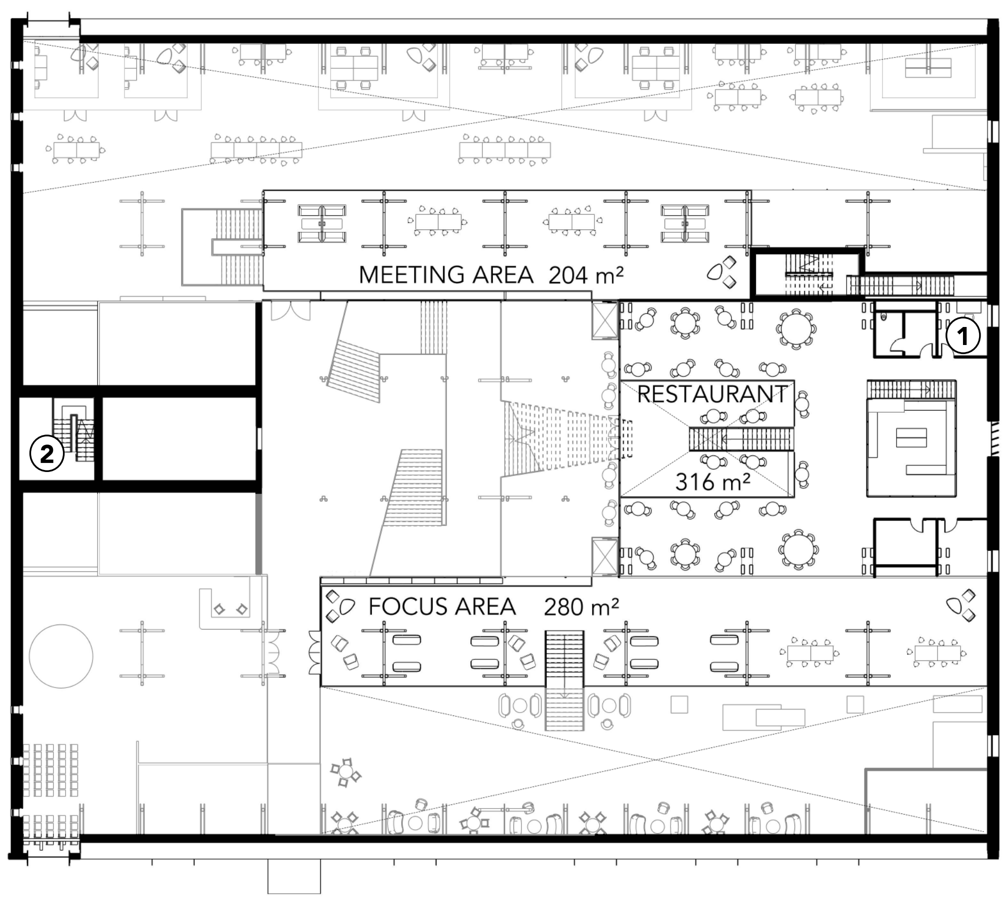
42. WEST ELEVATION 1 : 500

43. GROUNDFLOOR 1 : 500

1 Museum - office
2 Start-up labs
3 Storage
4 Kitchen

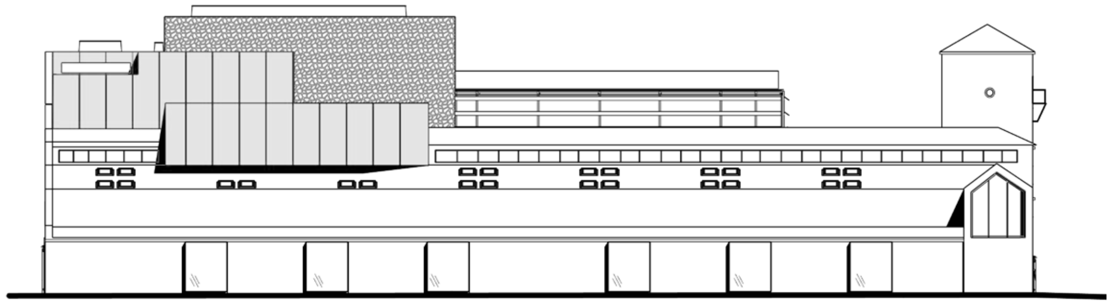


44. EAST ELEVATION 1 : 500



45. MEZZANINE 1 : 500

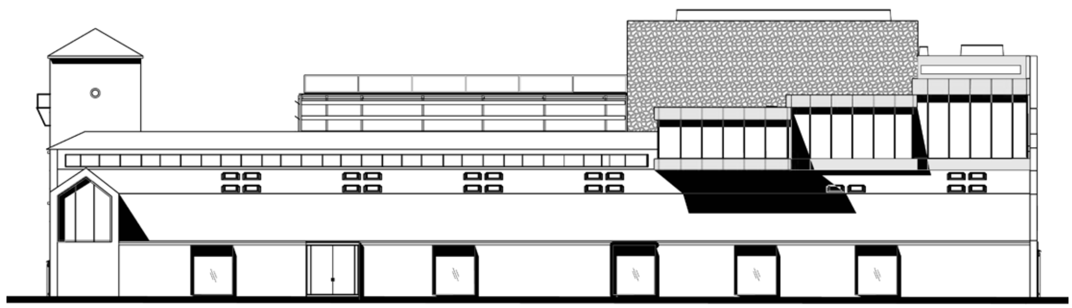
1 Dressing room
2 Museum tower



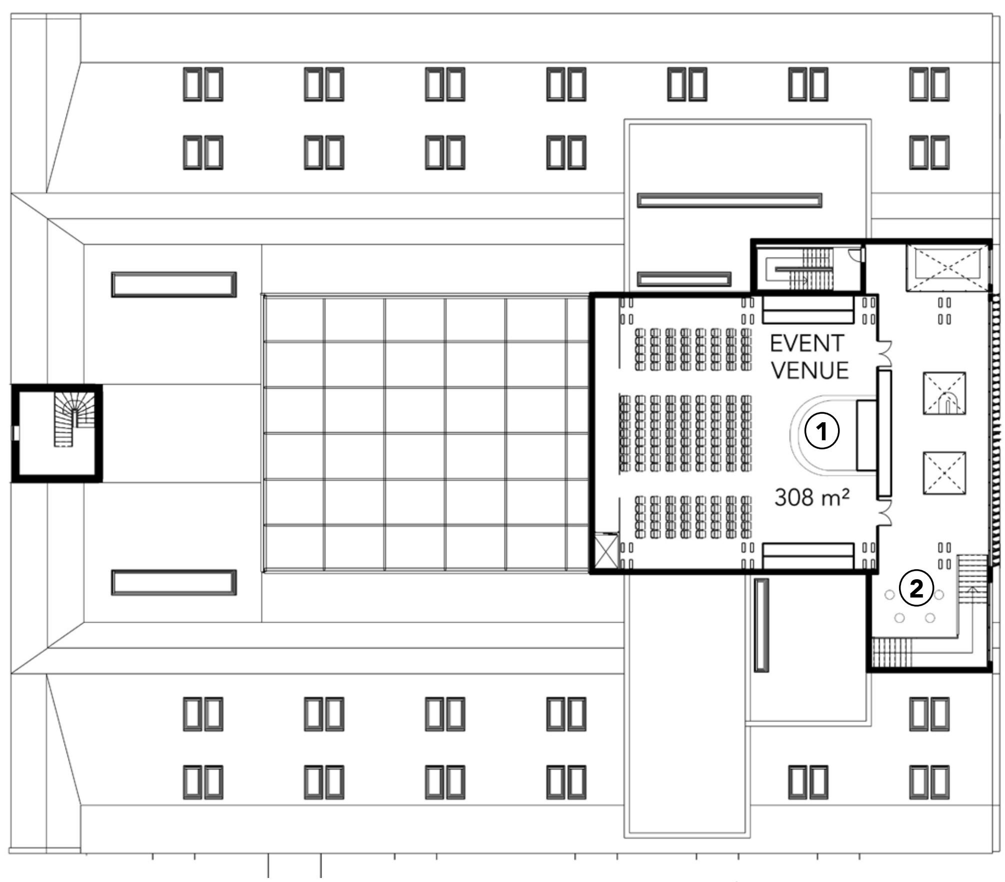
47. **NORTH ELEVATION 1 : 500**

46. **LEVEL 1 - 1 : 500**

1 Reception
2 Administration
3 Storage



48. SOUTH ELEVATION 1 : 500

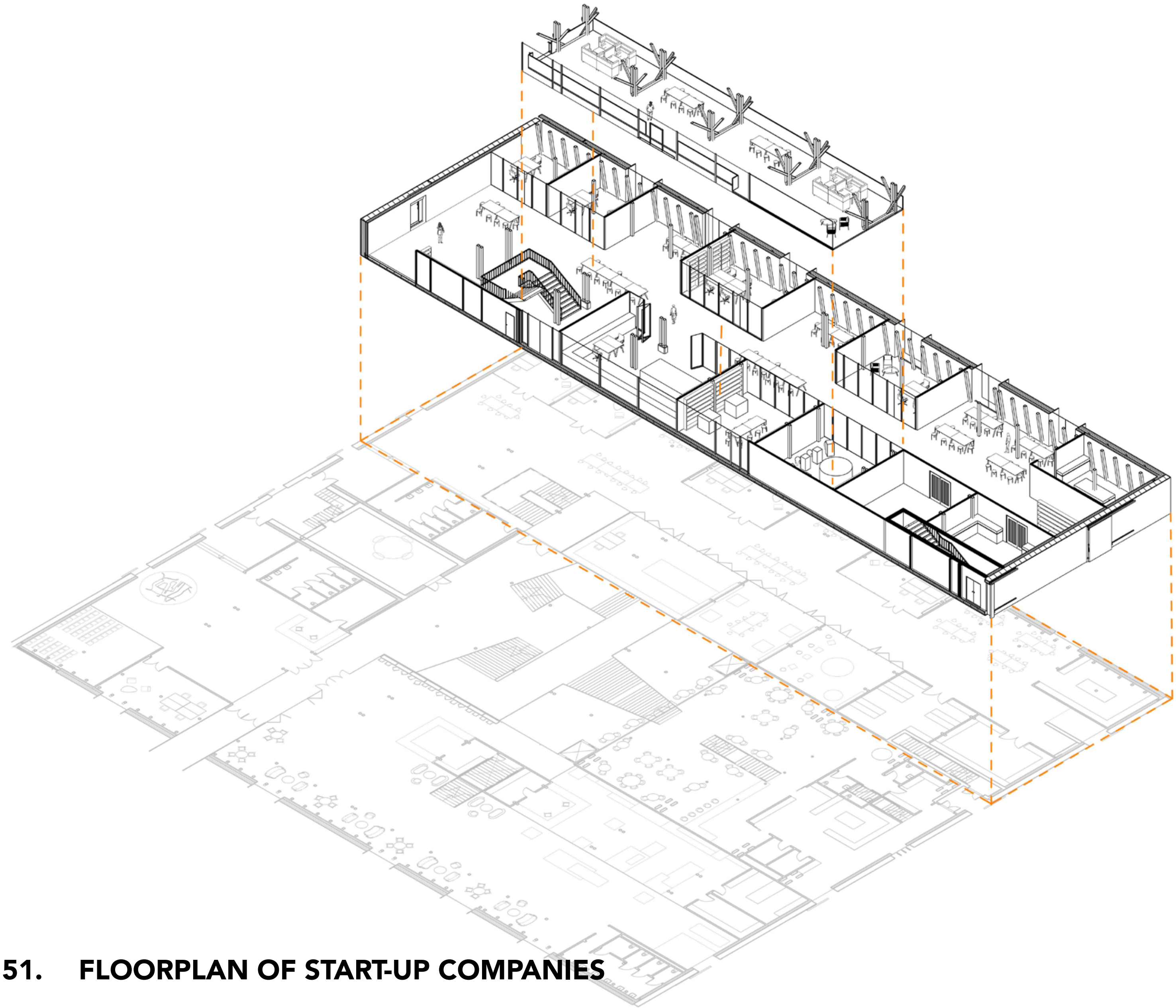


49. LEVEL 2 - 1 : 500

1 Event Venue
2 Lobby

EXPORT

50. RENDER OF START-UP COMPANIES



51. FLOORPLAN OF START-UP COMPANIES

_11_05_ EXPORT

The most public area is the “export” focused southern hall. Located by the main entrance this open hall showcases the original character of the granary by exposing all original structure. The grand space is broken by cubical forms that accommodate the functional rooms and create a mezzanine along the courtyard wall of the hall.

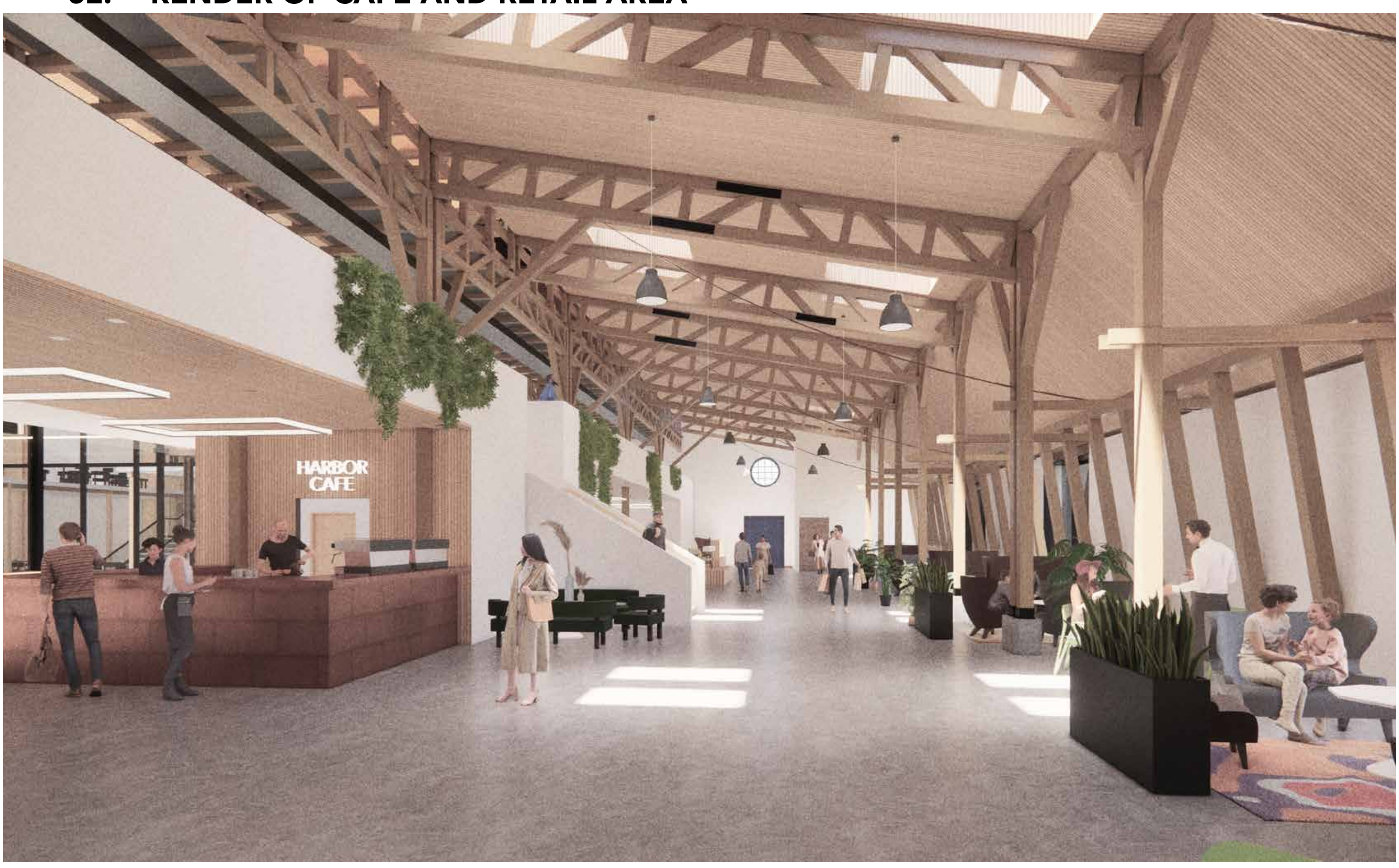
The museum is located close to the western façade and continues into the existing building’s tower and all the way up until the clerestories. The museum displays the history of Odense harbour and the granary building. The visitors are able to explore the most untouched part of the building with all its original mechanical equipment to experience the character of the industrial history of the city.

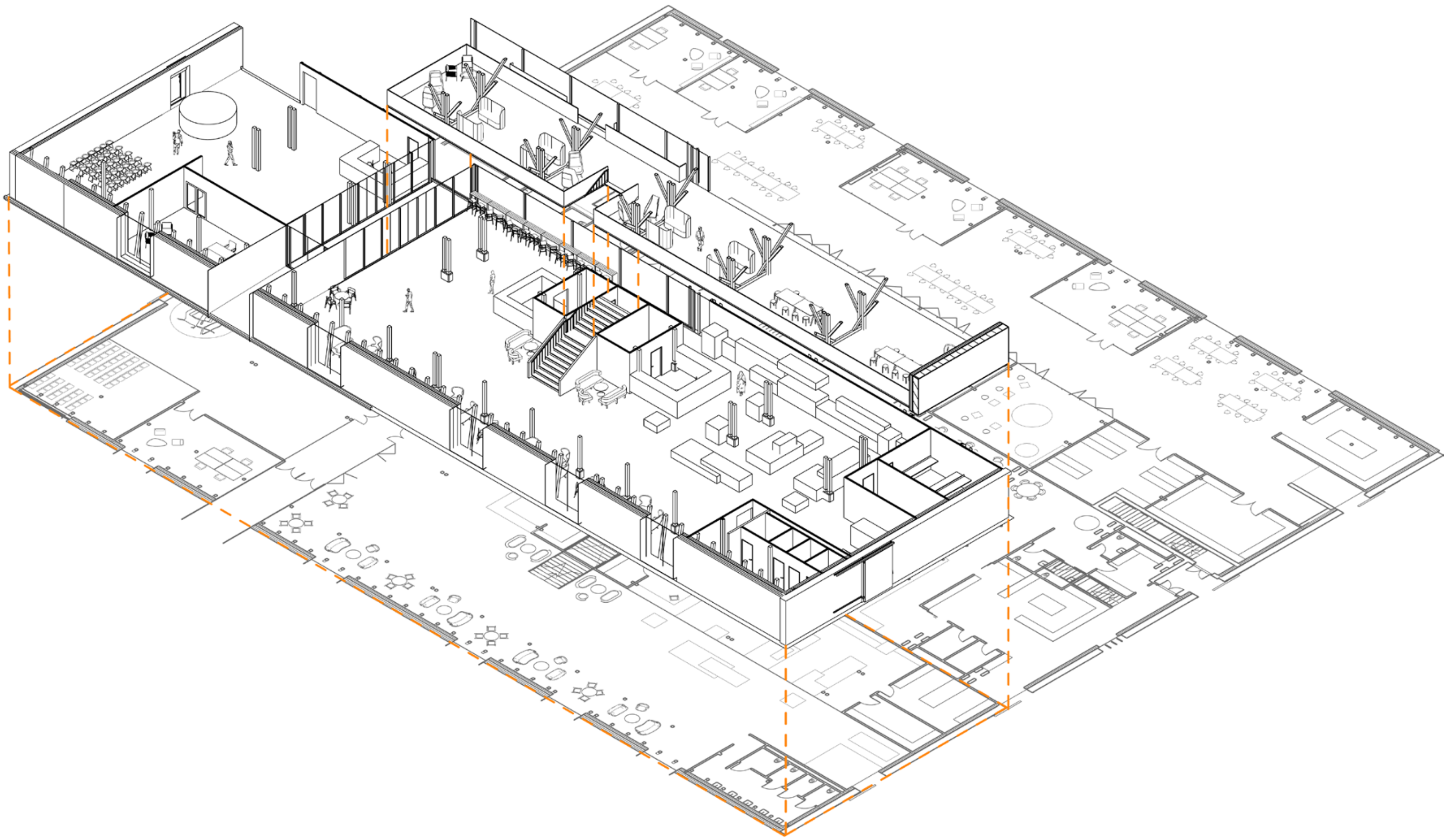
On the other side of the entrance a café invites visitors to sit and enjoy the ambience of the hall between its wooden columns and trusses. Sitting spaces continue along the southern façade, courtyard wall and on the mezzanine providing various levels of privacy, as well as diverse ways to experience the building and its structure.

Continuing along the café area the visitors reach the retail space. Its purpose is to present and sell products of start-up creatives from the other side of the building. The visitors have a chance to meet the local producers, learn about their products and purchase unique goods in a cozy atmosphere.

IMPORT

52. RENDER OF CAFE AND RETAIL AREA





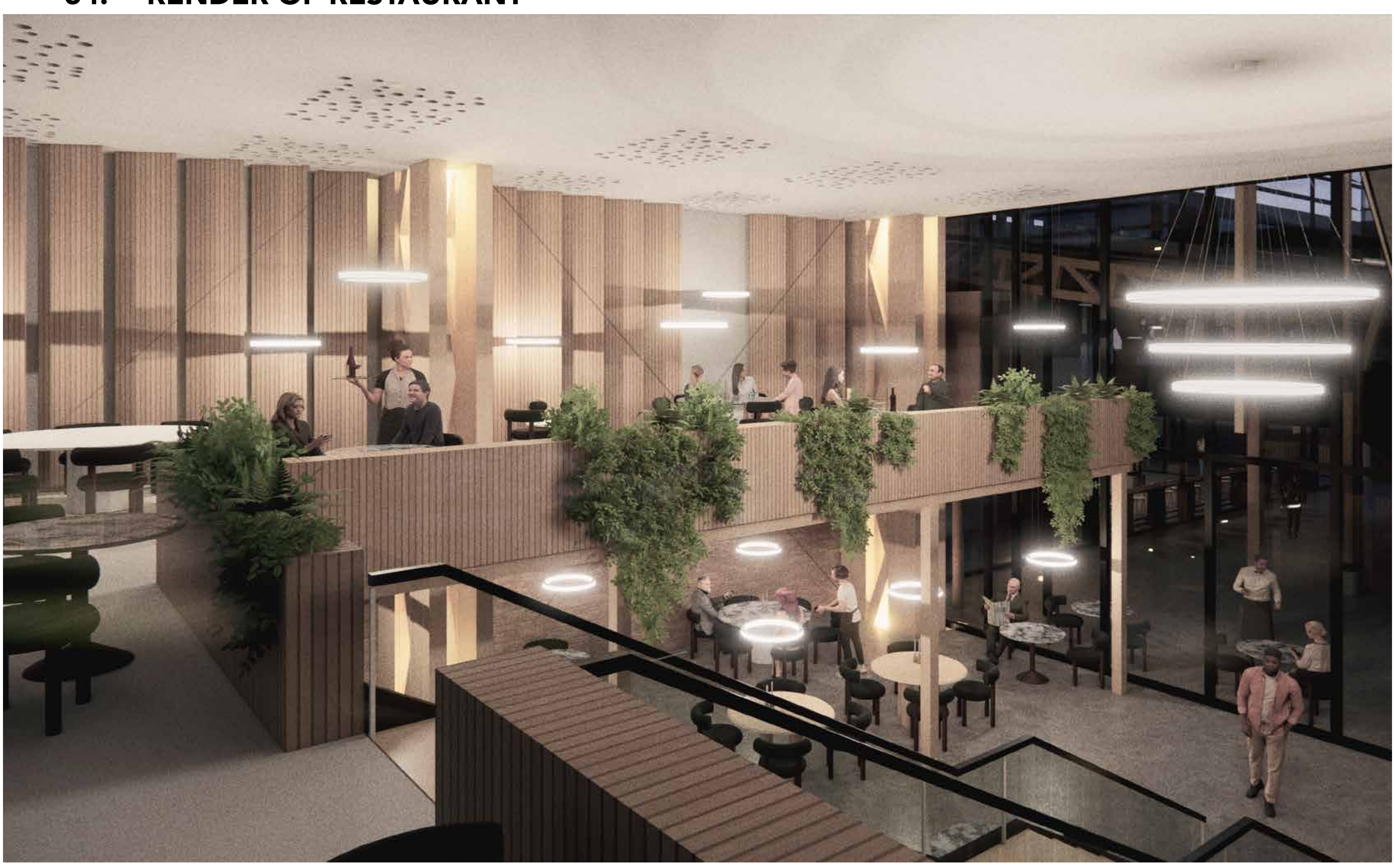
53. FLOORPLAN OF CAFE AND EXPORT HALL

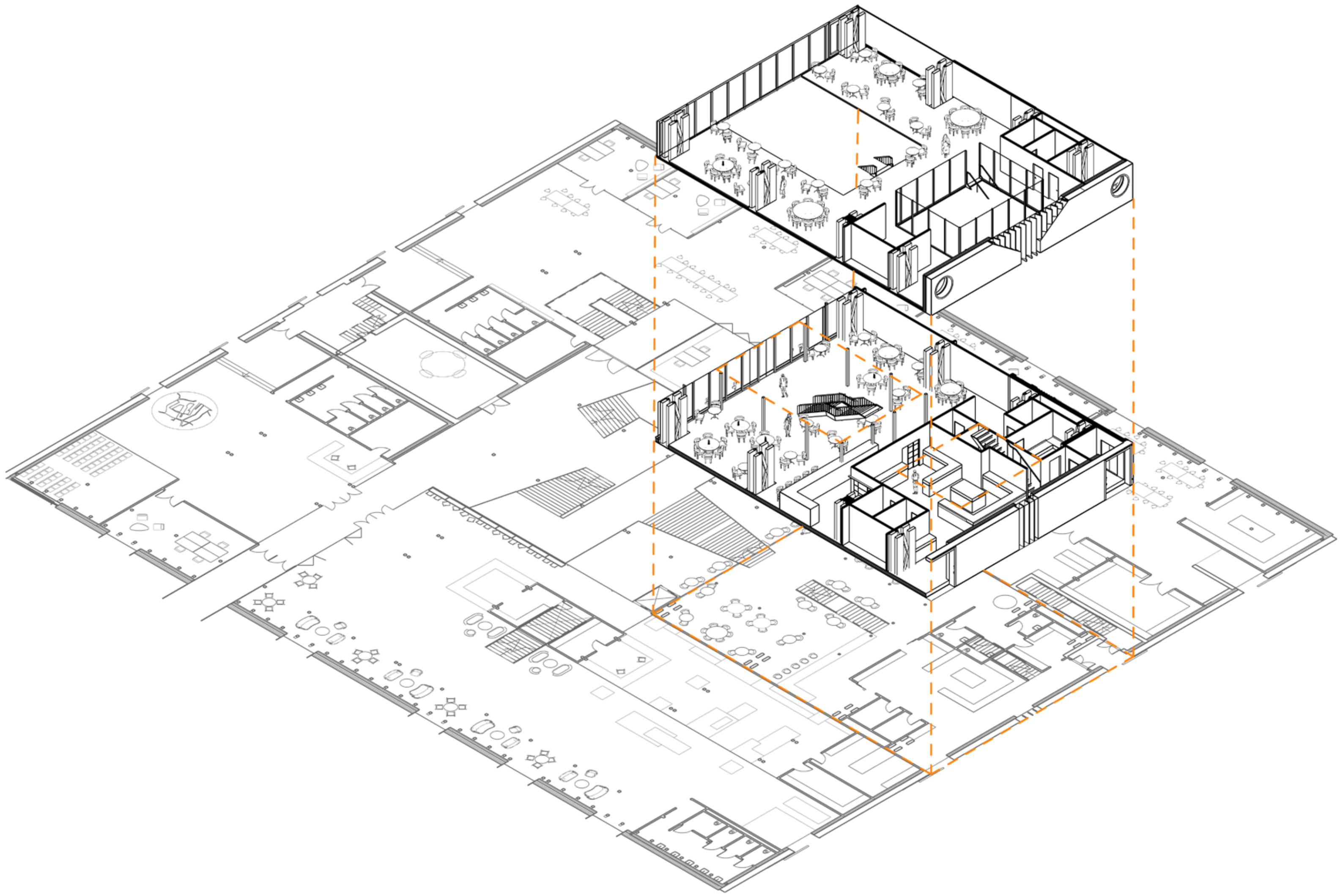
_11_06_ IMPORT

Across the courtyard the start-up office fills the northern hall. This co-working space is aimed for small and one-person creative companies. Three main workshops provide space and equipment necessary for prototypes and product creation often not feasible for start-ups. Similarly, to the southern hall, the open space is interrupted by cubical forms hosting workshop rooms with a mezzanine on top along the courtyard wall. Cubes along the northern façade are the offices for companies requiring an enclosed workspace. They are the only completely private areas of the hall, as the idea behind this "import" focused space is to encourage collaboration between different creators and entrepreneurs by bringing them into one space. The majority of the working stations and the workshops are shared by the users. Storage rooms and semi-enclosed meeting spaces on top of the mezzanine cater for companies based in the open space. Companies are able to exchange their knowledge and collaborate in an inspiring working environment.

CONNECT

54. RENDER OF RESTAURANT





55. FLOORPLAN OF RESTAURANT

_11_07_ CONNECT

In the middle area between the two halls, a restaurant works as a social connector between all functions. Opening towards the courtyard, the heart of the building, the restaurant invites visitors as well as people working in the building. The mezzanine spans around the restaurant creating intimate sitting for the guests while maintaining the impressive double-height entrance experience. Through the glazed façade, guests are able to observe the courtyard. The materiality of the restaurant reflects the transitional character of the space between the existing building and the new cultural form above it. The warm, wood-based interior together with monumental truss columns around the space and reused brick wall reflect the structural elements of the existing building in a modern form. The kitchen of the restaurant is based on two levels along the eastern façade of the building. This provides the working areas with necessary daylight and gives the guests a glimpse of the eastern façade as they walk up to the mezzanine.

_11_08_ TRANSITION

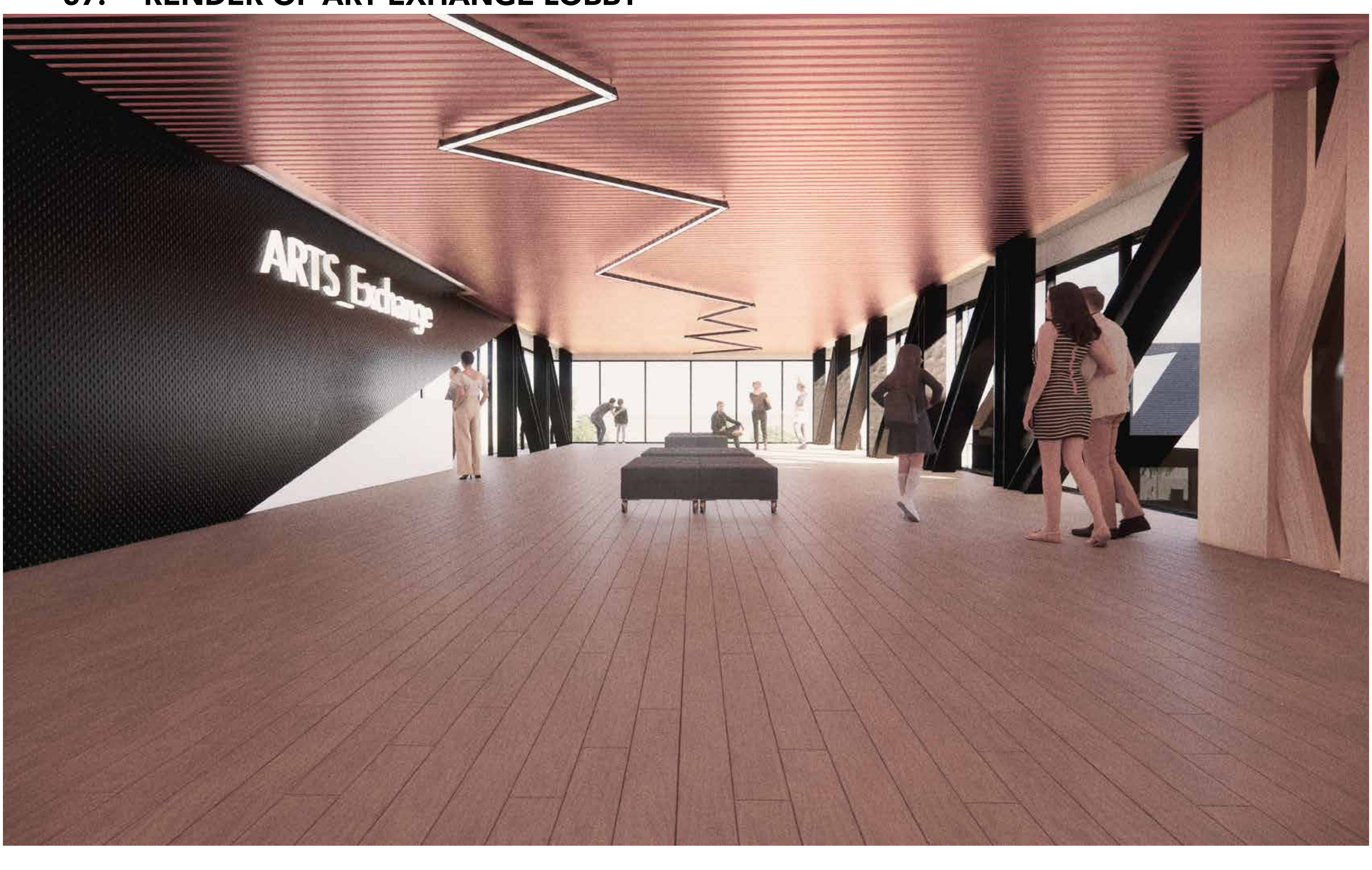
The courtyard is a key area in the main journey through the building as it connects the existing building with the added “Arts Exchange” cultural building laying on top if it. It does it with a sculptural staircase spreading through the courtyard. The stairs give the opportunity to experience the old building structure as a skeleton of the existing building. The landing in the middle connects the mezzanine levels of the two halls and provides an opportunity for easy

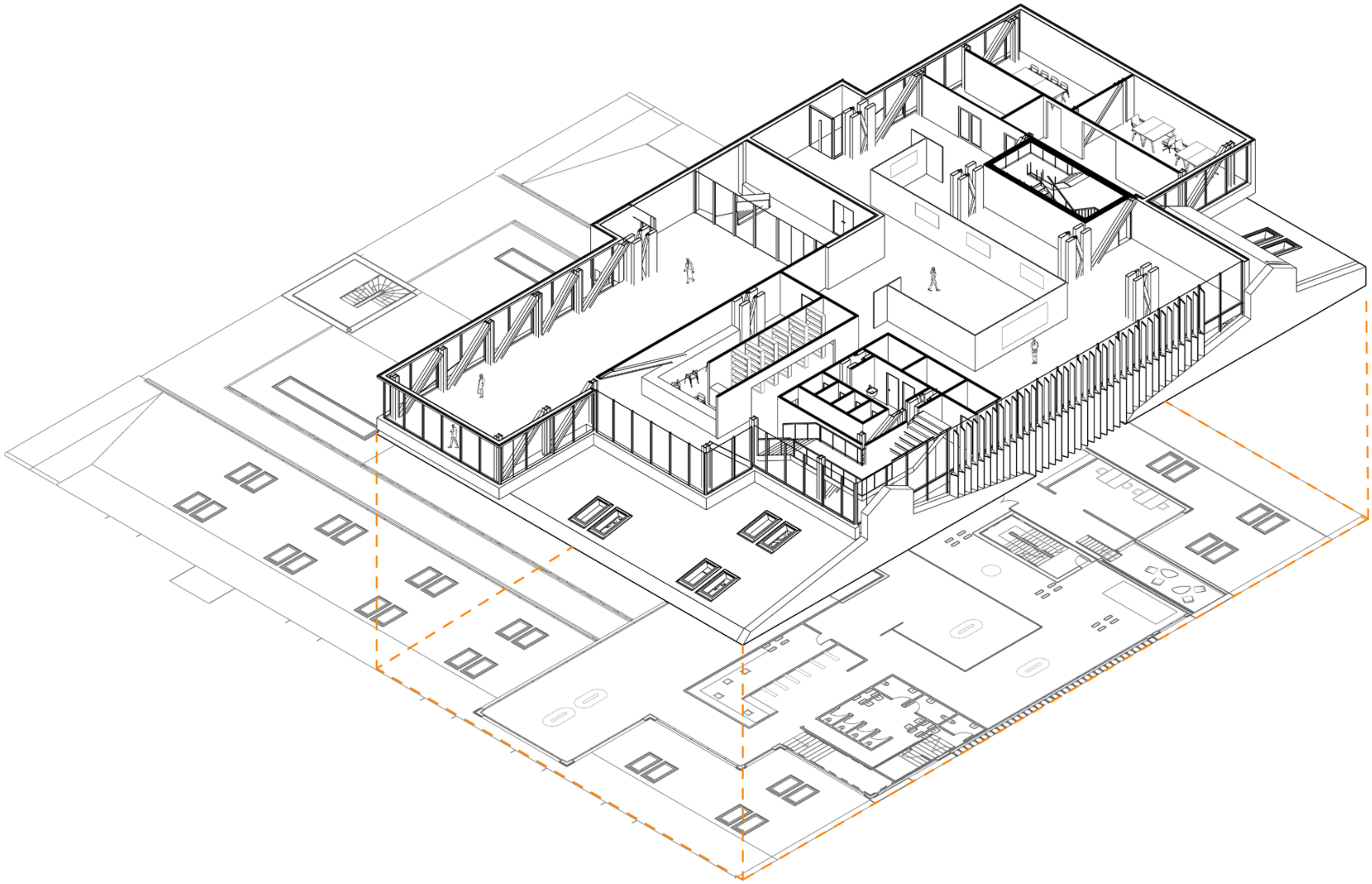
56. RENDER OF COURTYARD

transition between the working and lounge spaces of the two. In its last section the stair runs to reach a void in the cubical entrance to the added cultural building. The whole courtyard is covered by a glass roof supported by a structure rising from the columns of the existing building. The light coming through the roof is interrupted by lamellas resulting in beautiful patterns travelling through the courtyard space throughout the day.

ART EXPORT

57. RENDER OF ART EXHANGE LOBBY





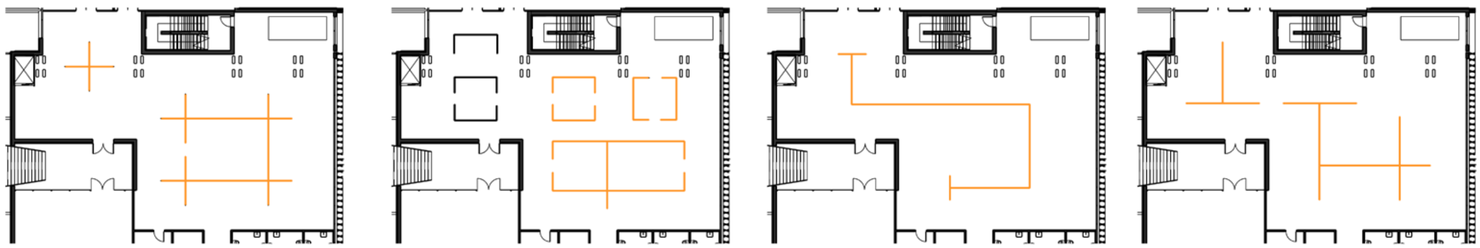
58. FLOORPLAN OF CULTURAL VENUE

_11_09_ ARTS EXPORT

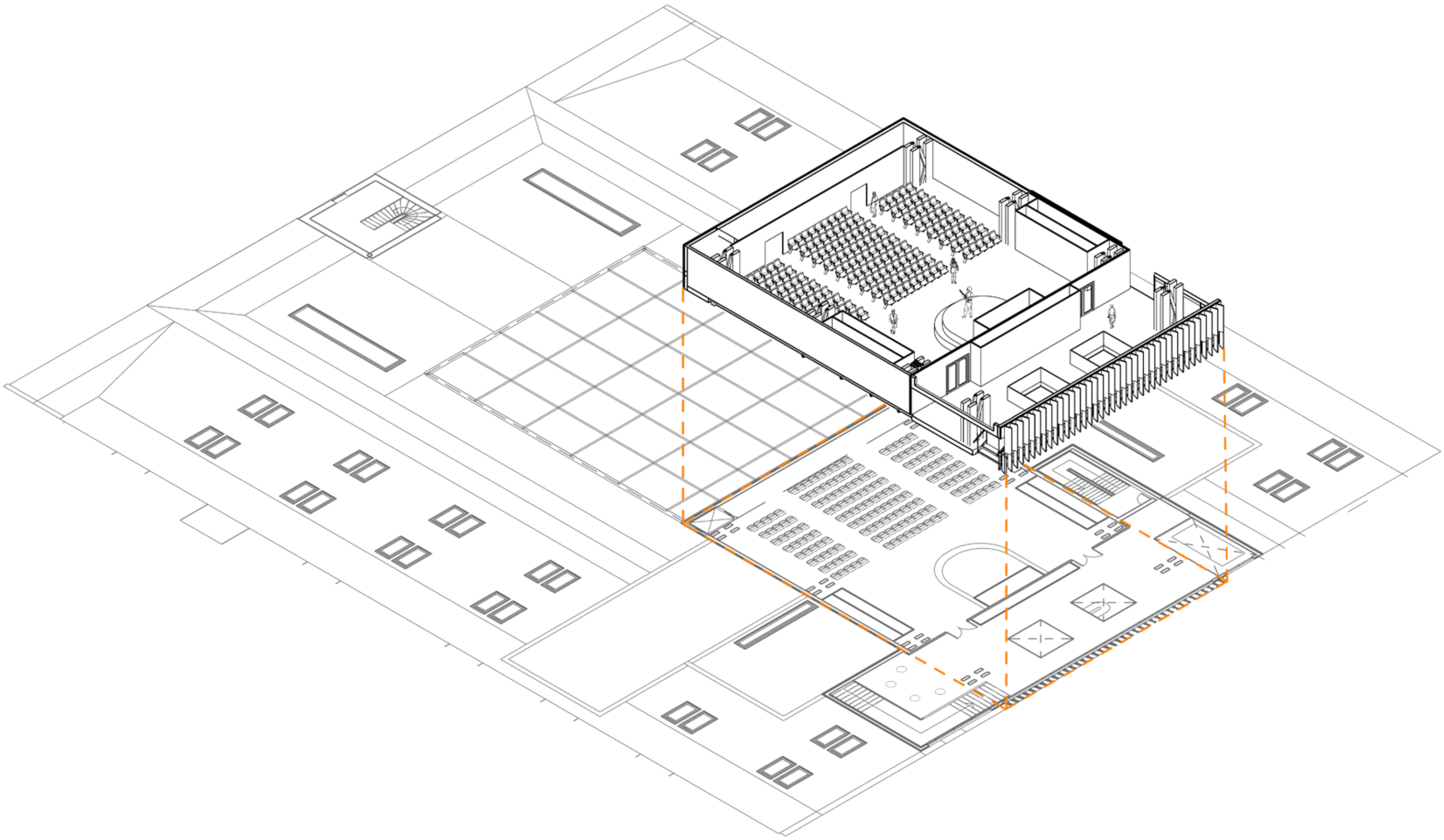
From the courtyard visitors can enter the new, culture focused building with its viewing platform. It is the end point of the journey through the building indicated by the features visible from the outside. The platform is placed as an extension of the lobby of the "Arts Exchange" cultural center and is accessible for all public without entering the exhibition and event area. It protrudes above the existing building towards the south providing guests with a view of the harbour. New structure exposed in this area indicates the new, added, form, while maintaining the industrial character in its materiality. The viewing area of the building is also the access point for the exhibition and the event space located above it.

The exhibition can be accessed by following the reception wall along the façade. The passage through the cloakroom area guides guests into the exhibition space. The open layout allows for various exhibition set-ups and accommodates larger art pieces in the locations where the ceiling is cut expanding the exhibition into the foyer above. The exhibition space spans along the eastern façade and ends at the courtyard façade where the administration and storage space are located.

ALTERATIONS OF THE EXHIBITION SPACE



59. RENDER OF ART EXHIBITION



60. FLOORPLAN OF THE EVENT VENUE

The final function hosted by the new form is an event space located in the very top section of the added building. It is accessed from the main lobby by a staircase going along the southern façade and turning to meet the foyer space on the top floor. The foyer is connected to the exhibition below by floor cutouts that give the guests a peak into the art pieces. From the foyer the guests can access the large event room. Its function can change depending on the needs of the event and it is to function independently of the exhibition area if the event is private.

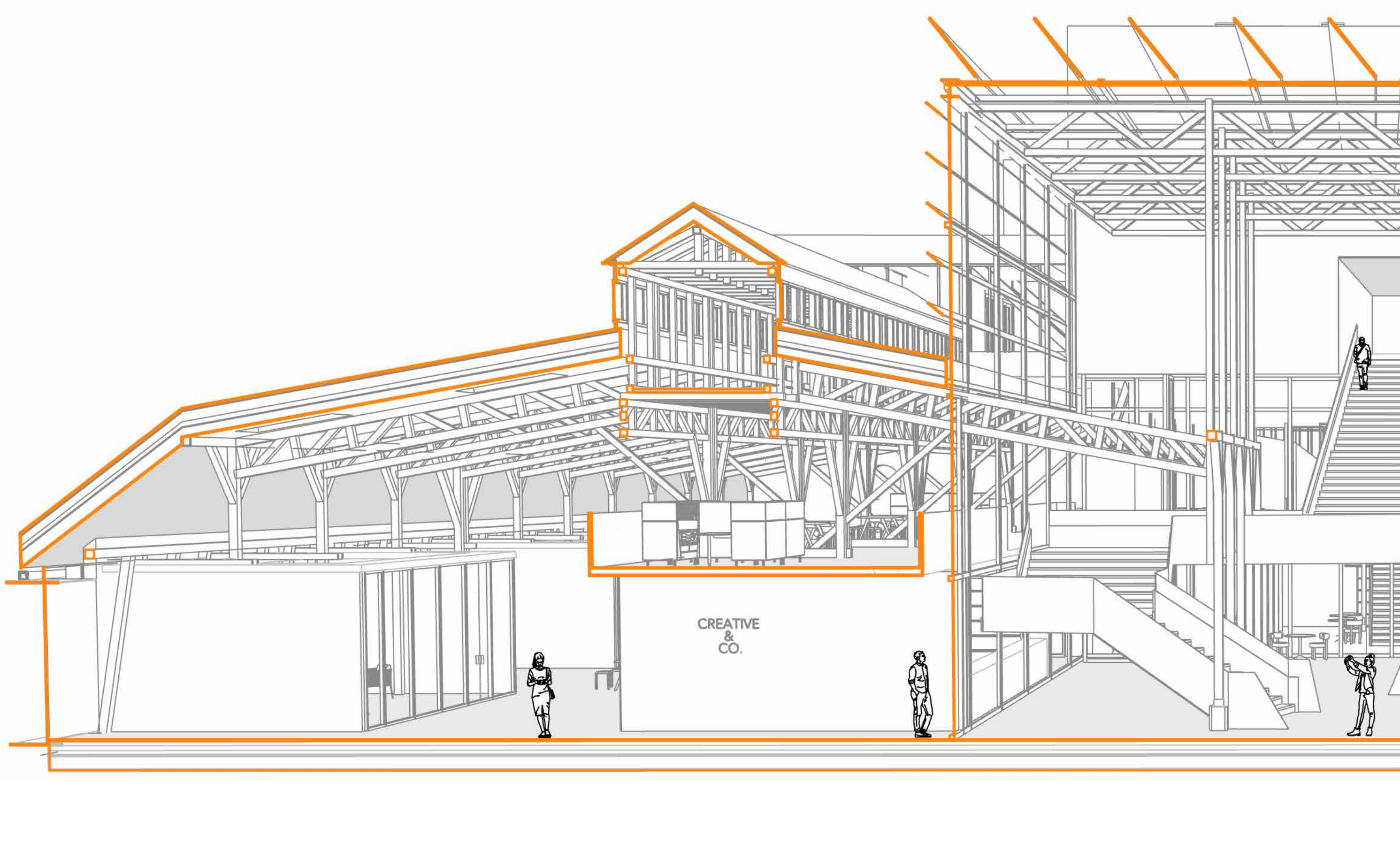
61. RENDER OF SITE AT NIGHT

HOW DID WE PRESERVE ?

_11_10_ THE PAST – PRESERVATION

The adaptive reuse design results in the majority of the original building being preserved and repaired, while respecting the strategy of contrasting old and added elements. Excluding the roof, which was in need of total replacement, 75 % of the exiting structure was preserved. Some of the materials, such as brick, are set to be reused for the added walls and in repairment of the existing brick walls. The doors and windows of the granary can be preserved with basic refurbished as a majority of the original façade openings remained unchanged. The key focus of the renovation was to preserve and highlight the timber structure of the granary. The new design achieves that goal by maintaining the open structure in both halls.

Despite subtractions from the existing volume in the middle of the building, the experience of the architectural heritage is enhanced as the exposed structure in the courtyard can be observed from different perspectives and accessing the mezzanine level exposes the structure of clerestory supports. These design elements enable for better understanding of the original character of the granary and showcase its unique features for the public to experience. The renovation of the halls is complemented by the preserved tower area. It accommodates the museum, allowing the visitors to become familiar with the history of the harbour through a journey around one of the most prominent historical features of the area. As the original machinery is located mostly in the tower, the museum is able to showcase the technology used in the 20th century by industrial buildings. (62)



62. SECTION B-BB 1 : 150

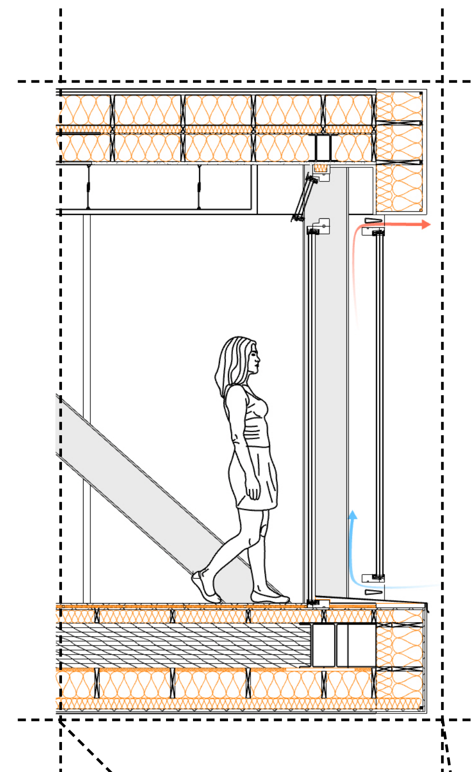
HOW DID WE ADD?

_11_11_ THE PRESENT – NEW STRUCTURE

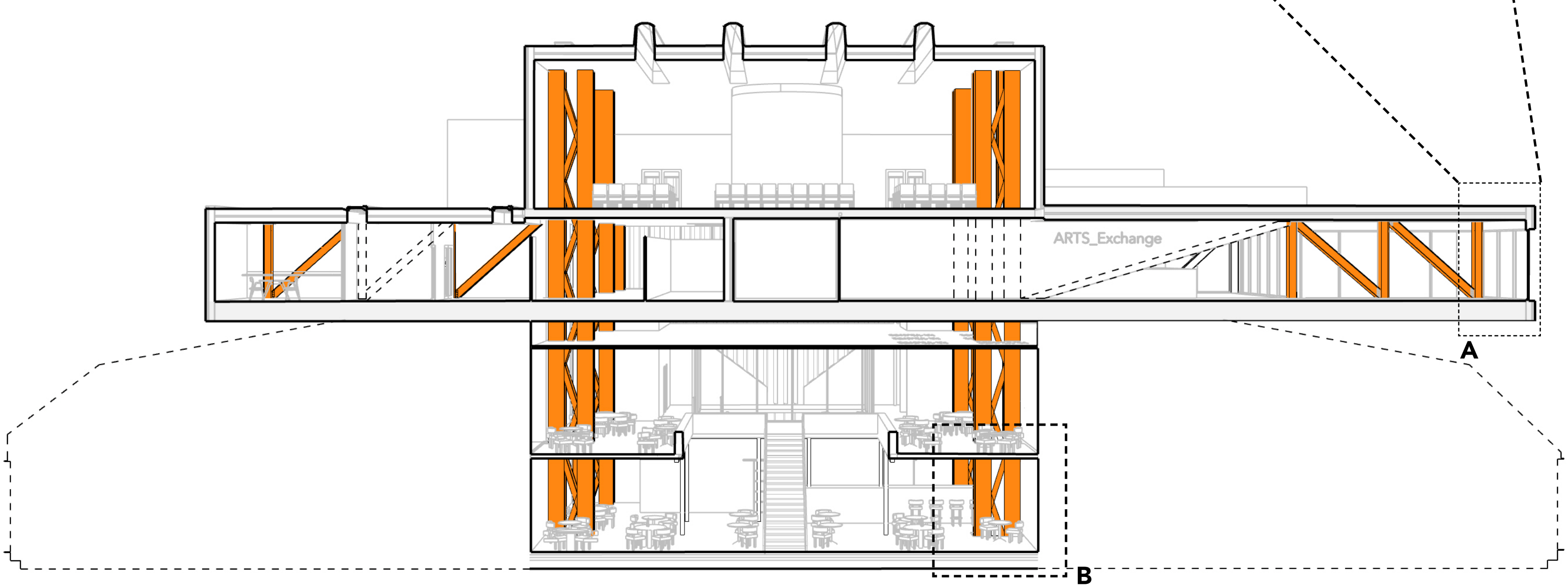
The integration of the new structural system within the historic granary holds significant importance in displaying the building's aesthetic expression. The restaurant acquires an architectural character due to the central column, which bears a resemblance to the traditional trusses found on the granary. (63)

These columns provide support to the cultural space situated above the granary, designed using a visible steel frame system that can be observed from the interior and the exterior. Additionally, the viewing platform boasts sturdy columns that serve as a showcase for the structural principles of the overhang. (64)

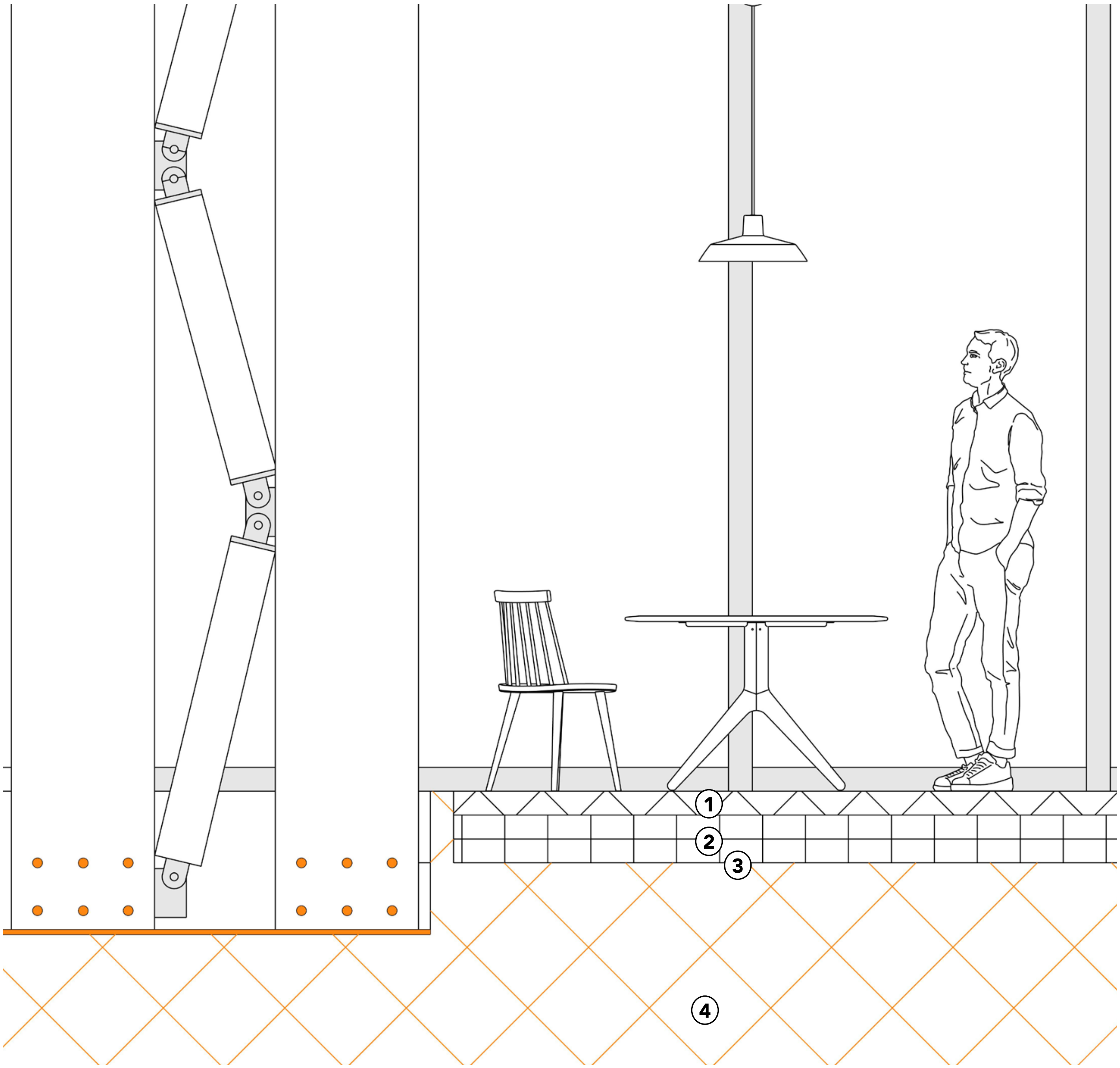
Due to the extensive glass façade in multiple orientations of the overhang, the exposure to sunlight results in overheating in order to avoid overheating in these areas a double skin façade is implemented. (63)



64. CALLOUT A



63. STRUCTURAL PRINCIPLE



65. CALLOUT B

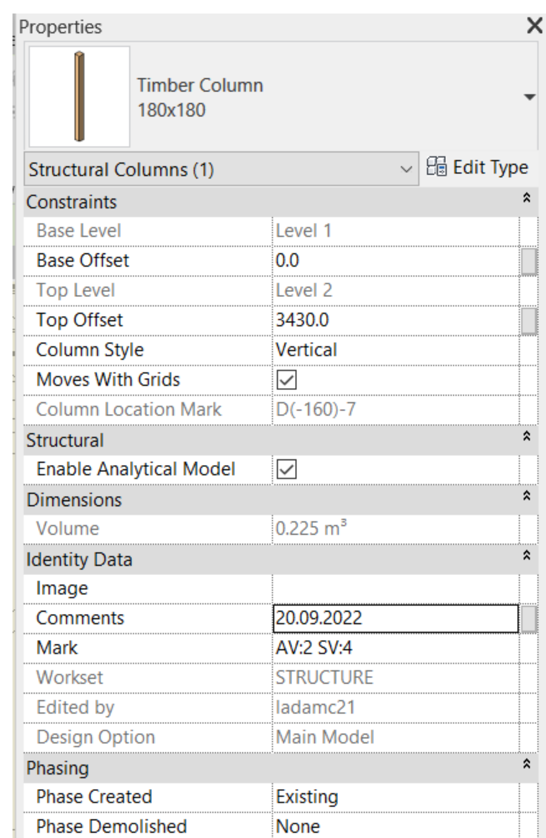
1. 50 mm cement spread
2. 200 mm Kingspan kooltherm
3. Breather membrane
4. Original concrete slab

HOW DO WE PREVENT?

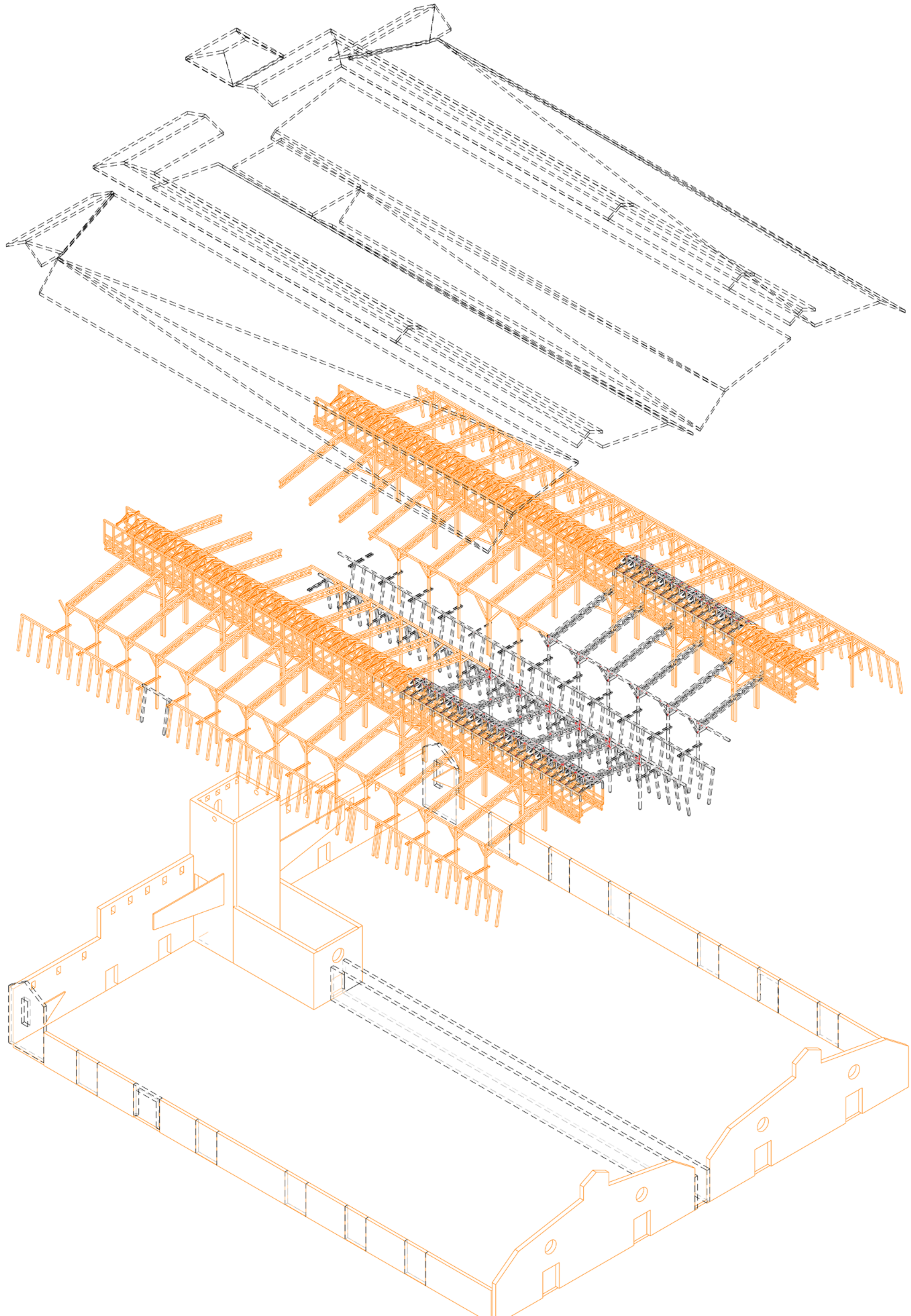
_11_12_ THE FUTURE- DIGITAL TWIN

Data gathered during the analysis phase and along the design development has been gathered in a detailed digital building model. In the process the use of BIM tools enabled better management of existing elements and helped to understand the existing structure. However, the most beneficial use for the digital twin and BIM related tools is in the further stages of building's life. (67)

Existing and added elements were registered with a unique assembly code and are able to be evaluated on their architectural value and structural integrity. Therefore, as the building is used over the years, data on its elements can be evaluated and used for efficient maintenance. Furthermore, in case of a need for aa change of use or demolition the element library can be the base for material rearrangement or reuse. (66)



66. FLOORPLAN OF CONCERT HALL



67. SUMMARY OF PRESERVED AND DEMOLISHED ELEMENTS

DESIGN DEVELOPMENT

APPROACH

_12_ DESIGN DEVELOPMENT

_12_01_ APPROACH AND INITIAL SKETCHING

The design development process started with establishing an approach regarding the initial design topics. It was based on the theoretical research, analysis, as well as methodology chosen for the project. Together with the design drivers, an approach chosen for each design topic guided the initial exploration of concepts.

_12_01_01_ SCALE OUTLOOK

Initial design exploration began with an analysis of the existing building and all its potential while experiencing it on different scales. This step highlighted a lot of possible focus points in the project as well as potential challenges and opportunities of the existing structure. It influenced the process until the final design, as looking at the design from different architectural scales corresponded with the three design drivers: "Connected Harbour" (large scale), "Import/Export" (medium scale) and "Past+Present+Future"(small scale).

LARGE SCALE DISCOVERIES

While looking at the granary from the perspective of the whole harbour it becomes apparent that it is a key feature of the area, especially with its large open space to the south and access to the harbour front. In comparison with the surrounding architecture, the granary has a very horizontal expression, and its form and materiality distinguish it from the rest of harbour.

The function analysis of the area, and the findings of the interview with municipality representant together with the large-scale outlook bring out the functions the building should accommodate to benefit the harbour area. Some of them are lacking in existing functions such as gastronomy, and cultural venues. Others come from the larger outlook on the harbour character and the design drivers. The goods exchange, historically present in the location, inspires a modern alternative aligning with current needs of the area. Facilities focused on gathering, producing, and exporting local ideas and products corresponded with the historical function of the building and together with the cultural and gastronomy functions present a possible new life for the old granary. Another important function that focuses on the historical aspect of the building is a museum, where the visitors can learn about the history of the Odense harbour and experience the industrial heritage first-hand.

The mix of functions also ensures that the building will be active at all times of the day and during the weekends.

The function of the new building was therefore decided to be:

- A new cultural venue that should display art and accommodate smaller gatherings like talks and intimate concerts.
- A new restaurant in the harbour that should accommodate 60 people.
- A new local museum of the harbour showcasing the industrial heritage.
- A new start up – office space for companies focused on industrial design.
- A new café for the harbour with study space.
- A retail area that offers a selection of locally sourced goods, including various products from start-up companies.

MEDIUM SCALE DISCOVERIES

Looking at the granary site provided great insight into how the building form influences human experience. When approaching from the main access route, the south, the building is placed sideways. Its enclosed façade is not inviting, and a tower placed on the western façade of the building dictates a different "main" entrée point. This counters the natural flow of approaching the building from the south. Moreover, a large empty area in the south is an opportunity for a public plaza and a natural entryway to the building. The southern access route was located along the harbour edge and therefore the plaza was an opportunity to connect the building with the waterfront. These discoveries emphasized a challenge for this project: to open the project to the people coming onto the site, the south side of the building had to become the main façade. To make the building more balanced from the southern perspective adding a new form counterweighting the tower became a considered design option. The matter of opening the southern façade also became an important aspect to be considered in the project.

SMALL SCALE DISCOVERIES

The critical building review helped to establish the state of the building elements and possible changes that had to be made in terms of structural integrity of the existing building. Moving on from these conclusions, an analysis of the building on the small scale suggests which areas of the building are valuable in terms of human experience and their potential for the future of the building. The roof's shape and the symmetry in the east-west direction are a prominent aspect of the building and give the visitor a unique special experience along with the exposed pattern of the wooden structure. This suggested the building areas' symmetry should be maintained with the open feeling of the roof support structure. Brick walls, apart from their characteristic shape in the east and west facades, contributed to the overall industrial feeling of the building's exterior. However, they were damaged in various areas, especially in the western façade gables. The walls separating the halls create an uncomfortable narrow corridor that did not contribute to the building's overall value. The tower is a unique element distinguishing itself from the open halls with its vertical expression and confined feeling inside. Despite it requiring restoration works, the tower as a beacon of the existing building and a representation of the original main façade is established as a crucial element to preserve together with the clerestories connected to it.

Conclusion

Considering the building in different scales provides a base necessary for the beginning of a sketching phase of the project. It outlines the general approach for the design and renovation and helps to establish the new function of the building.

RENOVATION

_12_01_02_ RENOVATION APPROACH

Reflecting on the theoretical research, building review and the scale outlook, an initial strategy for renovation could be outlined.

The renovation strategy was to follow principles close to those of the historical conservation movement and the theories of the Athens Charter. The elements of the historical value were to be restored for the future generations to experience, however all restorations using new elements were to be clearly visible to emphasize the contrast between the old and the new. At the same time by utilizing BIM technology, elements could be registered to enable easier maintenance and avoid the need for future drastic restoration. The same approach would be used for the adaptation phase of the design as all new elements should be visibly contrasting with the existing building and not try to imitate its historical style.

Design criteria outlined the desired energy renovation level, therefore an improvement of the general envelope had to be considered. The critical building review revealed the poor condition of the roof, and a decision was made to replace it, while respecting the original shape, as it brought excellent value to the building. The rest of the envelope required insulation and other improvements to achieve the energy goal. The goal was set to insulate the structure without changing the general expression of the building.

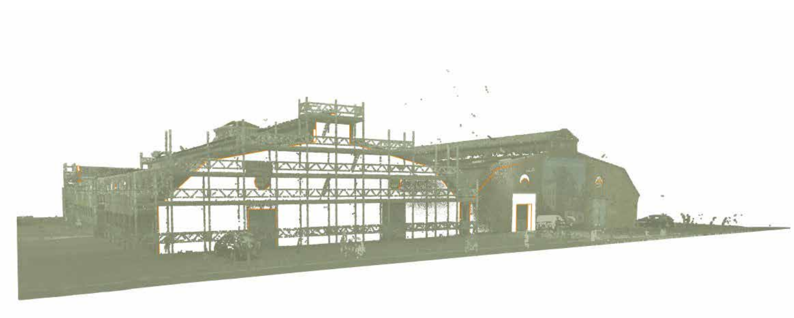
The structure was established as one of the key historical features of the granary, and therefore the aim was to preserve it as much as possible. Due to the deterioration certain structural elements had to be restored, keeping in mind the overall renovation strategy. The walls were not of similar preservation value; however, it was decided to aim for maintaining the integrity of the outer façade where possible. An area of exceptional historical value was the tower section, which despite its deterioration signs was crucial to the exterior expression of the granary. Therefore, it was set to be restored and supported to maintain its structural integrity.

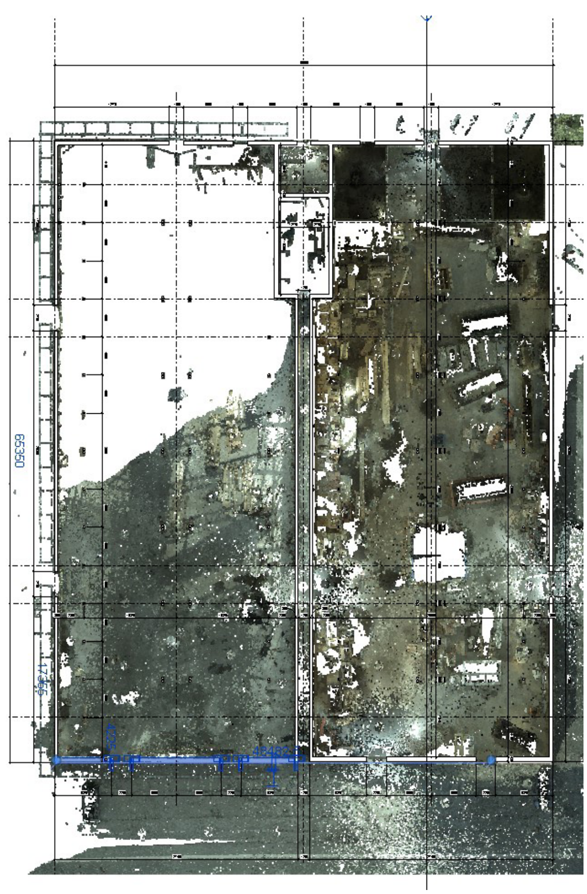
BIM APPROACH

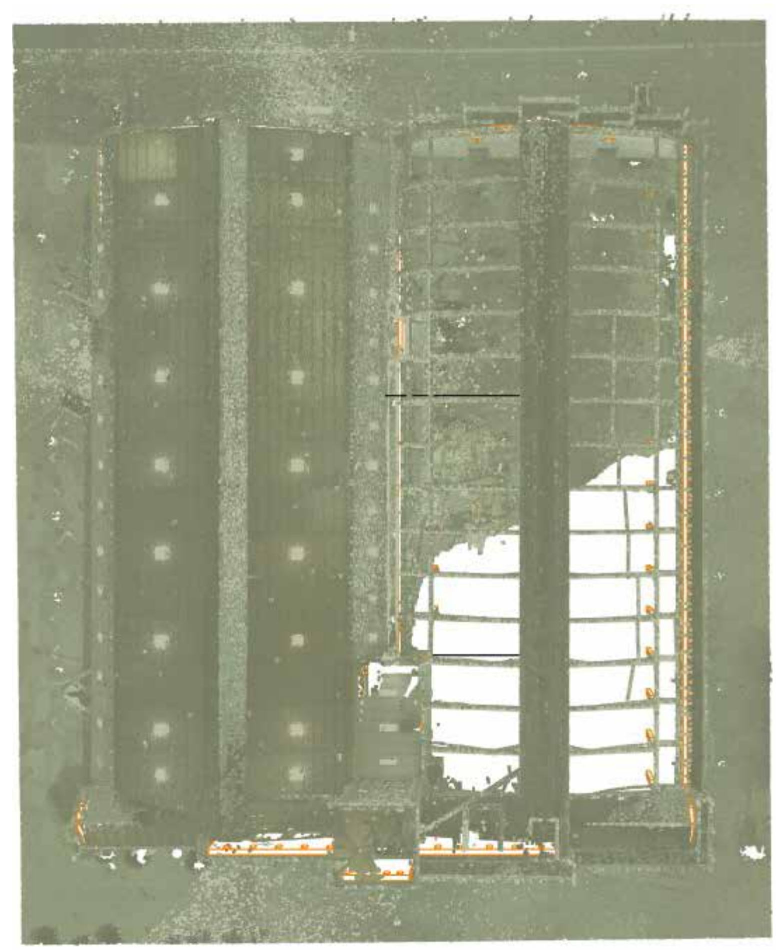
_12_01_03_ BIM

As BIM was a crucial element of the project's objective, an approach was chosen for the design process.

In the analysis phase, BIM tools were to be used for the survey of the building and understanding its architecture. The owner of the site, Olav de Linde, has provided a point cloud 3D scan of the existing building in its original state. (68) Together with the site survey data it was used to examine the building and create a precise digital model in Revit. It was set to be the base for the element library and register any transformations, demolition, and additions to the building. The model was also to be used for tracking the demolished material for possible reuse in the design. The final goal was to develop a precise model, which could be used as a database for the building and its old and new elements. Another BIM tool set to improve the design was Prospect by IrisVR. It was decided to use it in the synthesis phase to evaluate the design and notice any issues.







68. BIM APPROACH

SKIN - MEAT - BONE

_12_02_ UNDERSTANDING THE POTENTIAL

The design process of the granary was kick started with a workshop of the building assessing it through: Skin (façade), Meat (interior), bone (structure). It reflected on the conclusions of the scale outlook and set on finding a design responding to them. It was to be achieved through sketching and examining various aspects of the building.

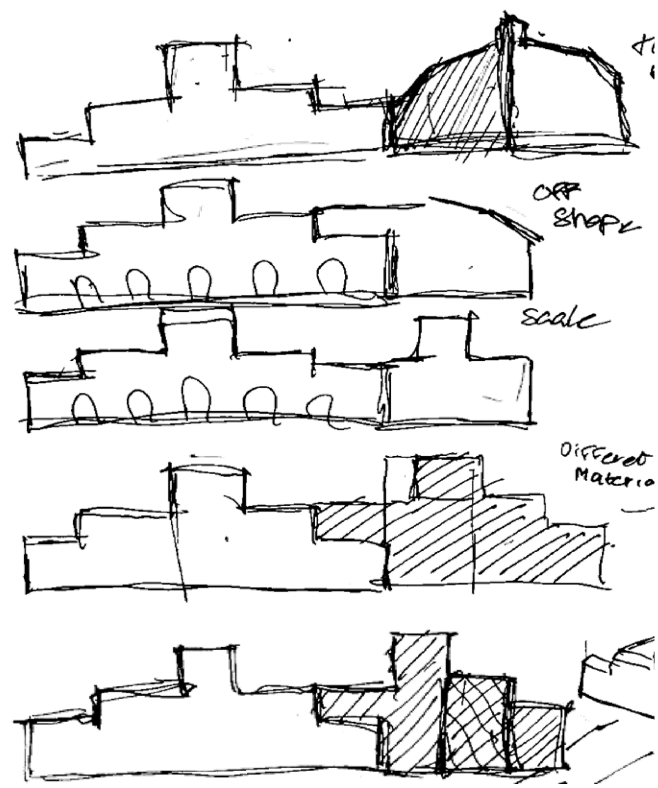
_12_02_01_ SKIN

The examination of the granary building involved studying photographs, sketches, and elevations. As already established by the scale outlook, the granary tower was considered the front facade of the building. The scale outlook suggested that to open the building to the public, opening the southern façade might be necessary together with an addition changing the main façade.

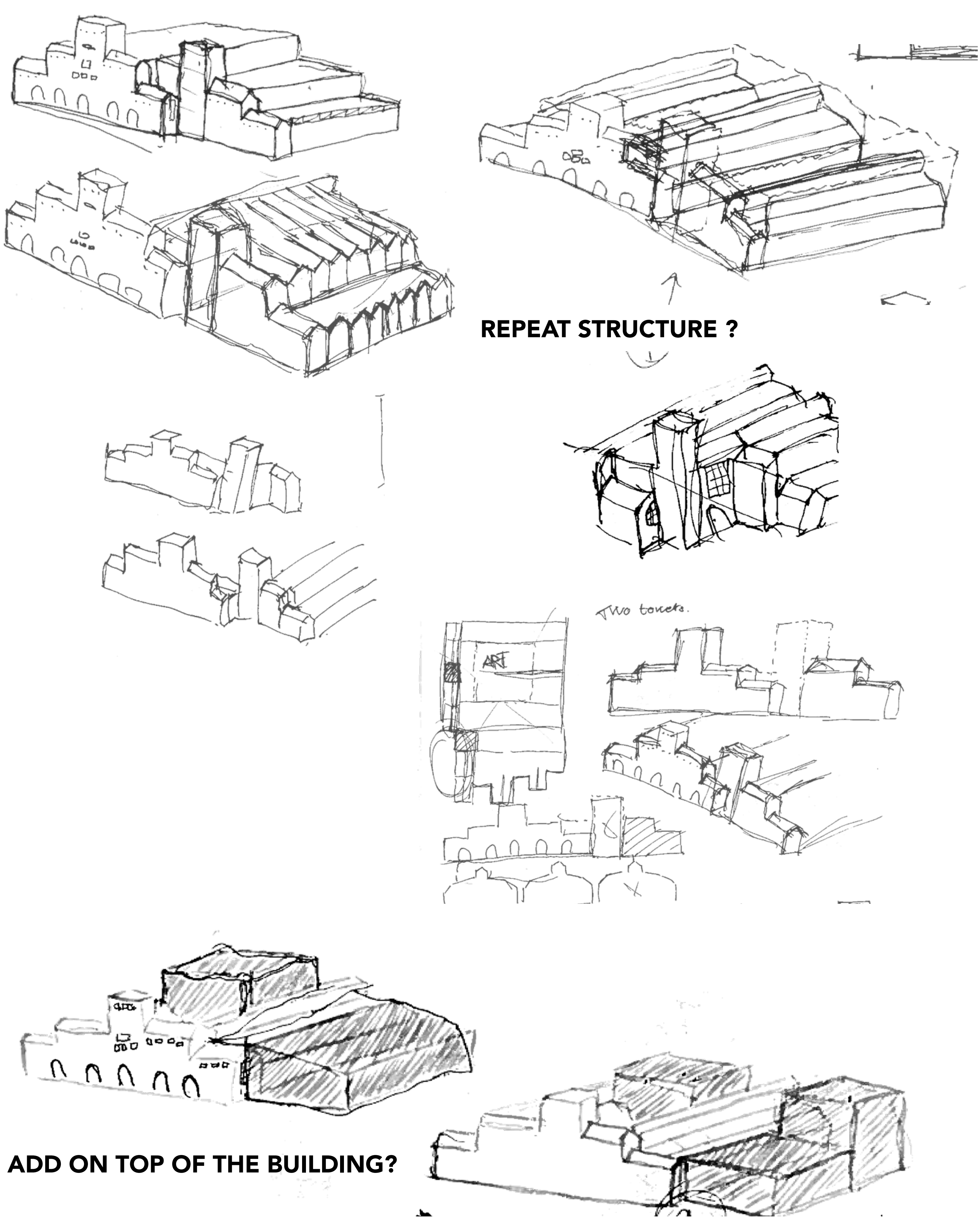
It was studied through sketching, and various iterations were tested to achieve a respectful transformation while preserving the building's proportions and duplicating elements.

However, it was confirmed that integrating the proportions and shapes of the building's facade in a new design would be challenging and the current shape of the building would not accommodate new functions.

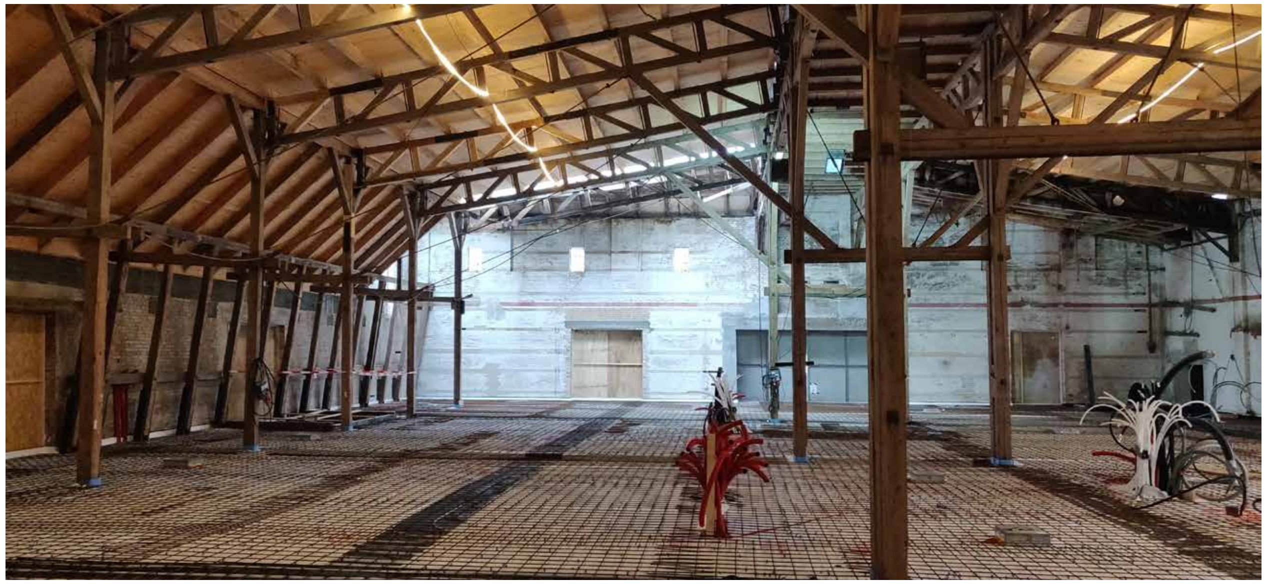
As a result, an approach was taken, preserving the tower facade as the most historical part of the building, while adding an extension to the roof of the building on the eastern side to balance the southern façade.



DUPLICATING VOLUMES ?



69. SKETCHING SESSION



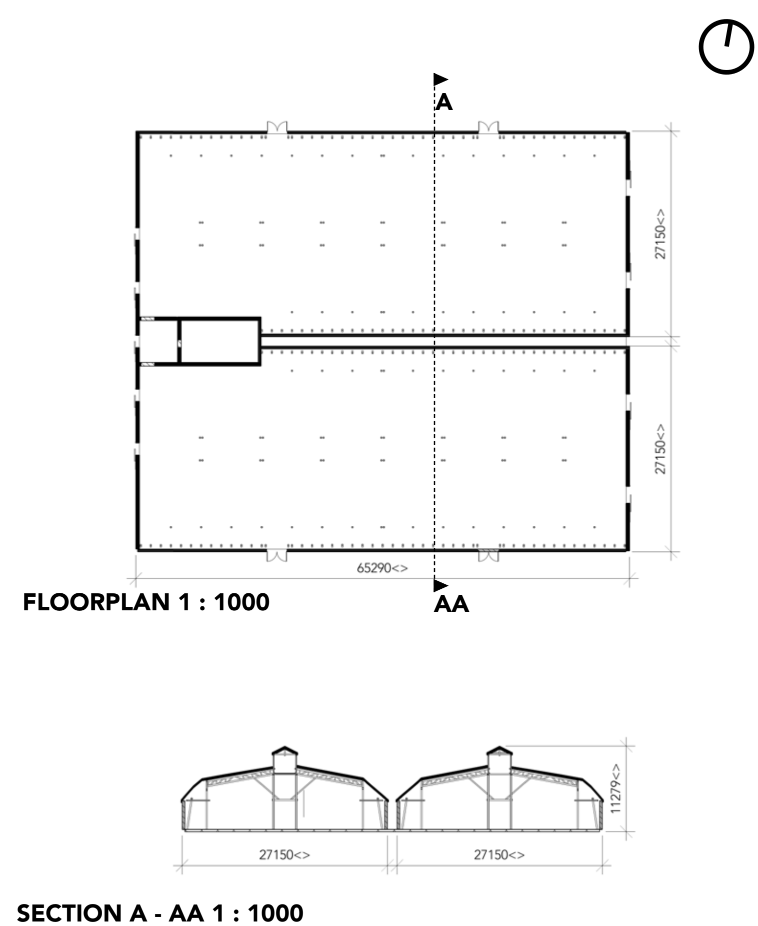
70. THE LARGE VOLUME OF THE HALL

_12_02_02_ MEAT

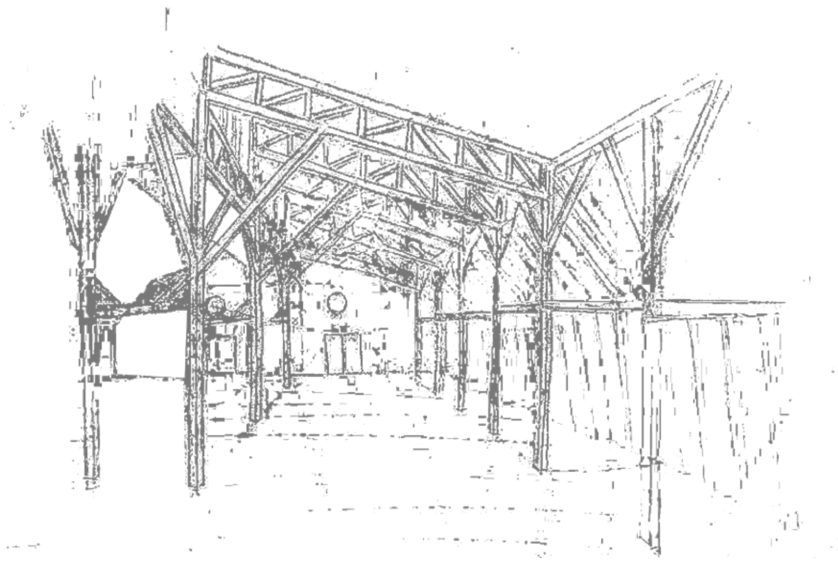
The granary's internal space was analyzed through photographs, floorplans, and sections to establish possible adaptation concept.

The halls' interior spaces were large and only the wooden structure interrupting the large volumes. To accommodate desired functions, they had to be divided and multiple strategies were considered to create smaller rooms. Separating the halls along their total height was rejected, as it interrupted the visual experience created by the repeating roof trusses and resulted in very tall and narrow spaces. To preserve the open volume of the halls, they were separated into two levels, where enclosed rooms were to be placed in the lower one and the space on top would create a mezzanine. Moreover, the spacing of the rooms was set to be aligned with the structure. This ensured that the open feeling of the halls is maintained, allowing the historic aspect of the granary to be visible.

To create a clear distinction between public and private areas, the design included a separation strategy within the building (illustrated). However, due to the large building mass and lack of natural light, the idea of opening up the building was considered to improve the interior lighting. This opening would also serve as a guideline for separating the interior volumes in the later stages of the design process. The opening will be covered as part of the design.



71. PLAN AND SECTION

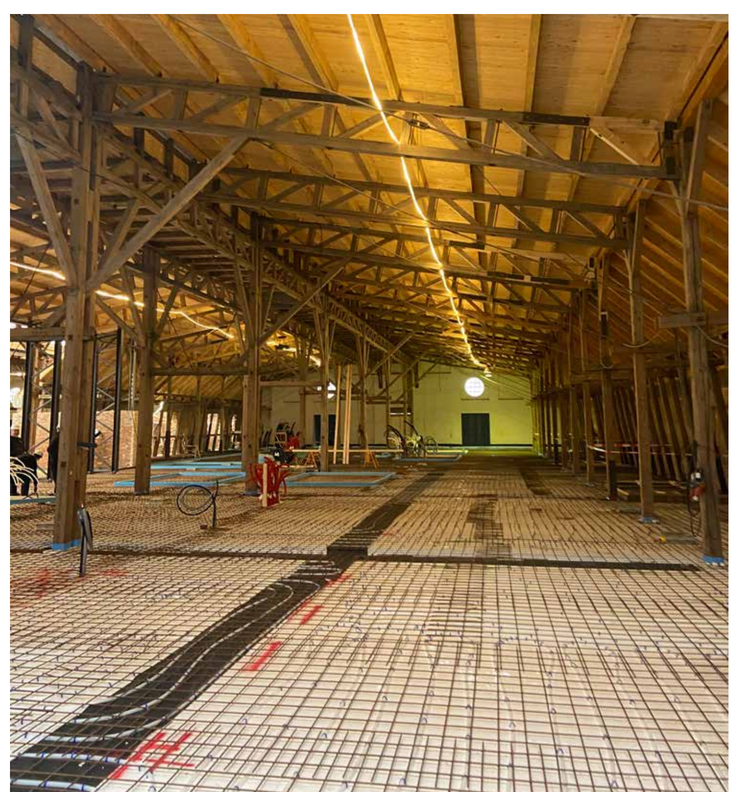


_12_02_03_ BONE

The granary structure was analyzed through photographs and sections. The structure was made of a timber frame that supports the roof and brick walls creating the façade. It was visible inside the halls and was an important aspect of the interior space. The structure was composed of repeating frames, each with three parts: the central one located under the clerestory, and two truss wings. Not only did the structure serve as a vital part of the building's interior, but it also represented the history of previous construction techniques.

Therefore, preserving the structure was crucial, and any damaged or worn-out elements needs to be repaired accordingly. However, the structure also posed limitations to the building's potential possibilities. Any changes in the building's volume would require either the removal of certain areas of the structure or the room configuration to adapt to it.

The new structure of the granary will be addressed later in the report.



72. THE REPEATING TRUSS

OLD STRUCTURE RENOVATION

_12_02_04_ OLD STRUCTURE

Various methods were reviewed to achieve renovation objectives of the adaptation, while considering the condition of building elements established by the critical review. The research divided the granary into crucial areas and elements to find common strategies for each type of issue. The envelope of the building has been improved with the new energy performance outlined in Appendix 2 and detailed comparison of the build-ups showcased in Appendix 3.

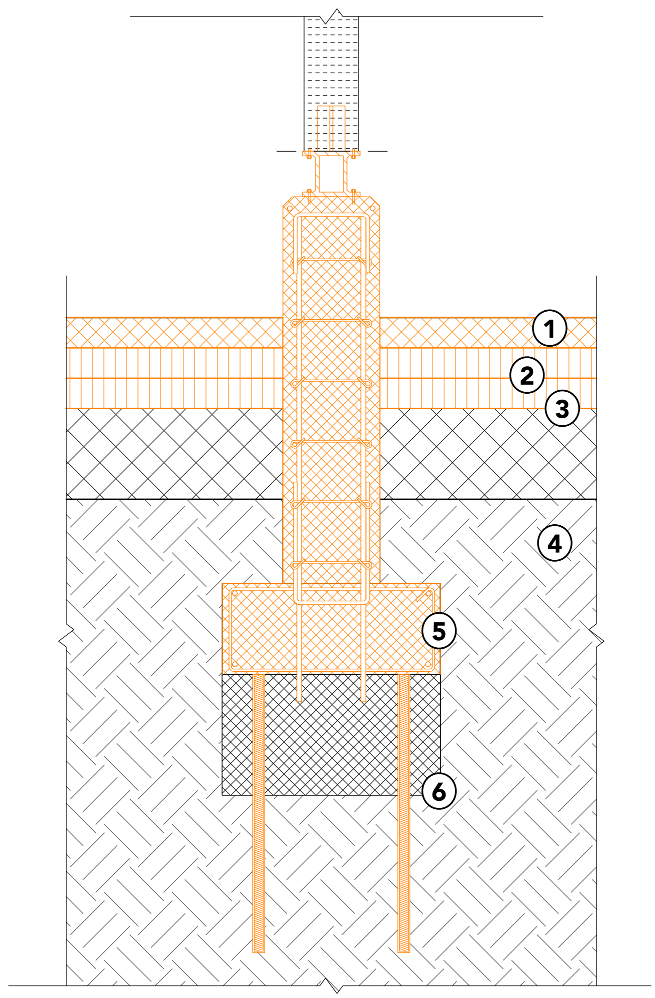
FLOOR

The was one of the more problematic areas of the granary as the floor has sunk in several areas and the amount of concrete added to fix it over time varied from hall to hall. Therefore, it had to be levelled and reinforced to stabilize the ground slab. To improve the building's envelope, 300 mm of insulation had to be added on top of it. Next, a screen with a possibility of installing floor heating was set to be followed by a floor finish option explored further in the design. This solution resulted in the floor level inside being raised and required stairs and ramps inside to enable access. However, it was necessary to improve the envelope of the building.

COLUMNS

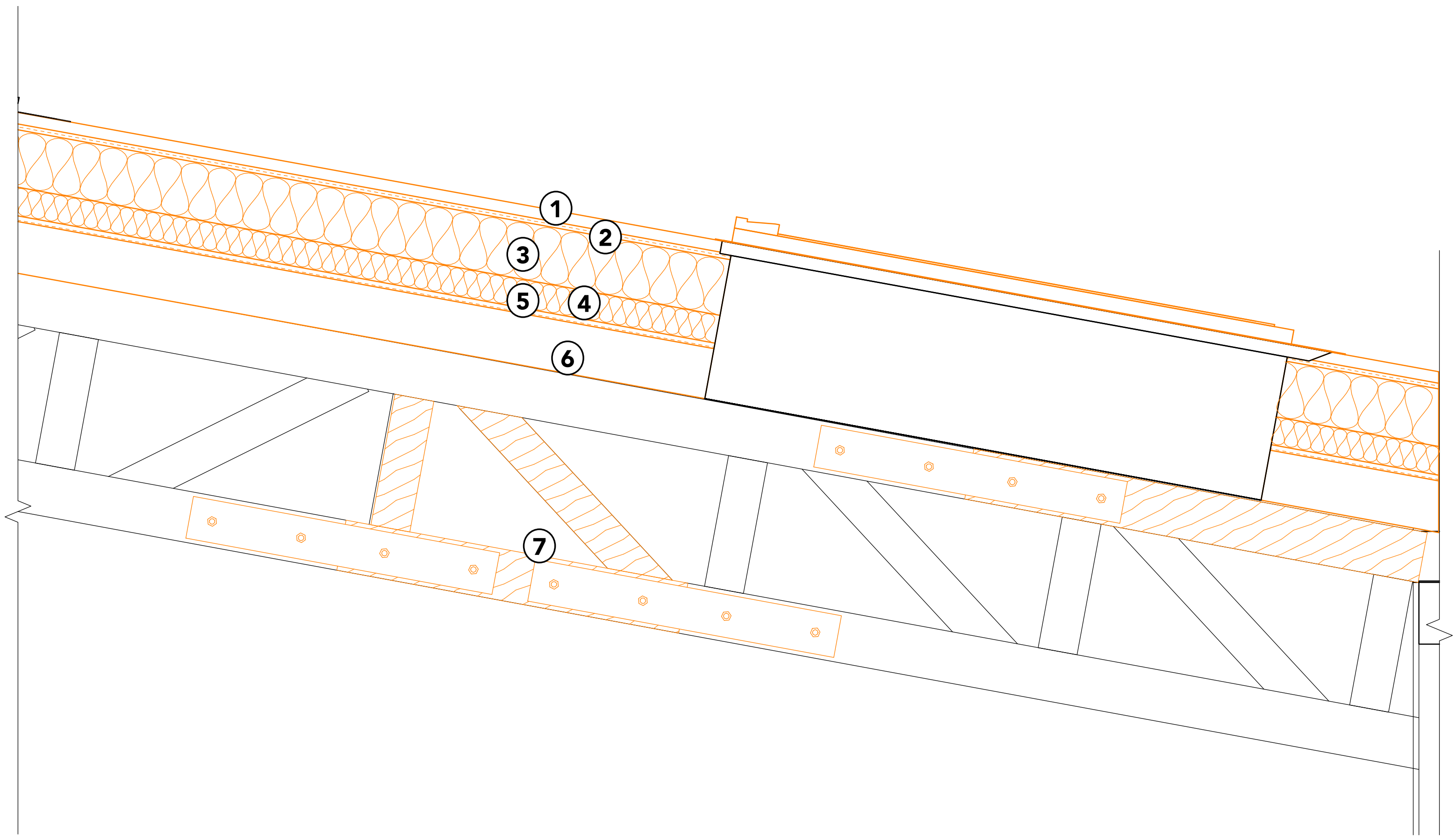
The columns were an element set to be preserved in the structure, therefore any issues regarding their structural integrity had to be resolved. Their timber structure had absorbed water from the soil below, and in time it could result in them collapsing. Cutting the bottom part of the column and connecting it with a reinforced footing with another element was a solution for this issue. The remaining question of the connecting element was explored with sketching and test renders to establish a solution fitting the space and materiality of the new design. The column foundations were to be reinforced with micropiles to prevent any skinning in the future.

After several alterations, a concrete footing was chosen, raising the column from the ground, and matching the floor material, giving the illusion of columns "growing" from the floor. The connection between the concrete base and original column was set to be made with a steel profile (73).



73. NEW COLUMN FOOTING

1. 50 mm cement spread
2. 200 mm Kingspan kooltherm
3. Breather membrane
4. Original concrete slab
5. Original column foundation
6. New additional concrete foundation



74. NEW TRUSS REPAIR

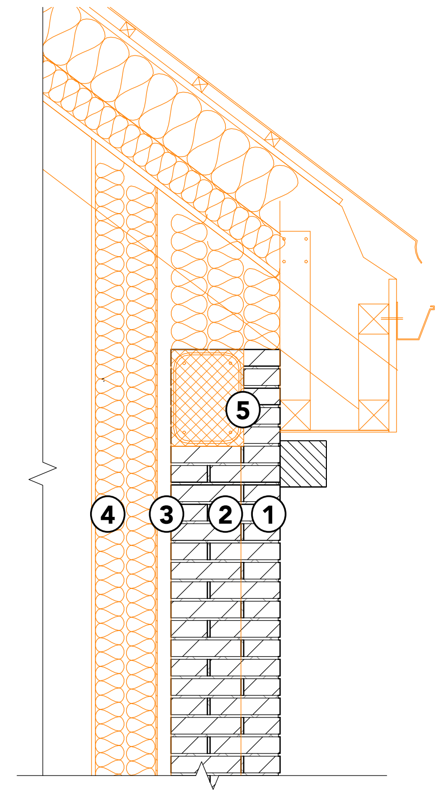
1. Roof slates
2. Pine battens
3. 200 mm insulation
4. Vapor barrier
5. 100 mm insulation
6. Pine rake
7. Truss improvements

WOOD TRUSS

The wooden structure in the building had great architectural value and the construction was still in good condition, however some of the trusses were affected by moisture leaks and had to be repaired. A method of replacing truss elements was chosen by marking the new timber fillings with contrasting bracing. This ensured structural stability, while aligning with the renovation strategy of contrasting the old and the new (74).

WALLS

The outer walls were in various condition and required overall repair as the metal bands running inside them had to be removed. The repair was set to be done from inside with the addition of a concrete beam running along the walls and stabilizing the structure. The choice of disrupting the wall face inside coincided with the need for added insulation. 200mm of insulation was added to the existing wall on the interior. This resulted in the exterior expression remaining unchanged, while improving the building 's envelope. The walls of the inner corridor between the halls as well as the wall elements presenting as gables of the western façade were in a condition that required demolition. The gable walls were decided to be an important historical element of the building and therefore set to be rebuilt from the brick reused from the demolition (75). The demolished walls are addressed in further design development.



75. NEW WALL RENOVATION

1. 360 mm brick wall
2. Ventilated air gap
3. 200 mm insulation
4. Vapor barrier
5. Gypsum board
6. New Concrete header

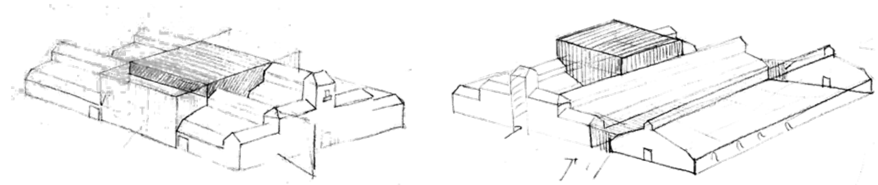
ROOF

The roof of the building was set to be demolished and rebuilt in its original shape. The old structure of the roof was in an extremely poor condition and could not be reused. The new roof was designed to consist of rafters that mimic the structure of the old roof, with added 300 mm of stone wool insulation to enhance the energy frame. The cladding will be roof felt.

TOWER AND CLERESTORIES

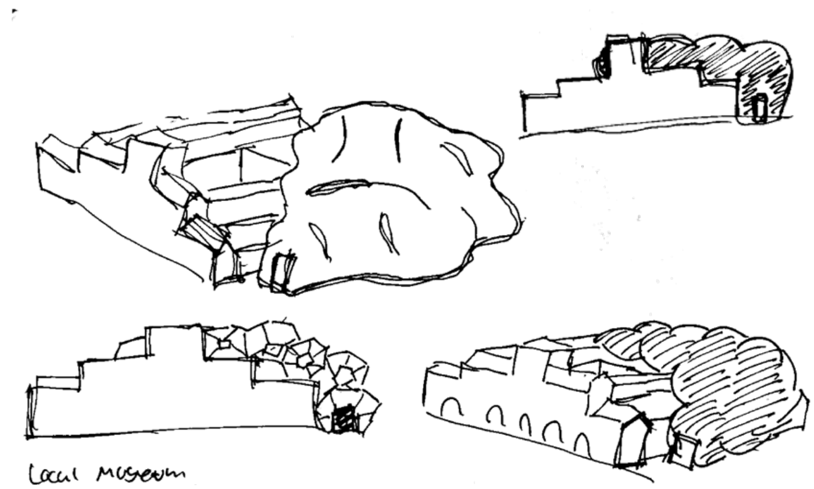
The architectural value of the tower was remarkably high and to avoid interfering too much with its exterior expression, the new support would have to be introduced internally. The main issue was the shift at a certain level, where the wall was moved 2cm horizontally towards the exterior. An old staircase inside the tower had to be removed and a new steel structure with stairs would be placed inside to stabilize the walls. The clerestories connected to the tower were another element of a very high architectural and historical value. Due to their structure being in a particularly good state, the only renovation set as necessary was an improvement of their envelope, and therefore the roof and walls were replaced to maintain the open character of this area.

ADDITION



_12_03_ WELCOMING THE NEW

With the understanding of the existing granary, its challenges, and potentials, as well as renovation solutions, the design concept moved into the adaptation phase. The process had exposed the need for bringing the attention of the building to the southern façade with possible additions making the design appealing from the perspective of people walking along the harbour. The sketching process of accommodating the new functions and designing for the desired impact of the project has been based on the concept of balancing addition and subtraction.



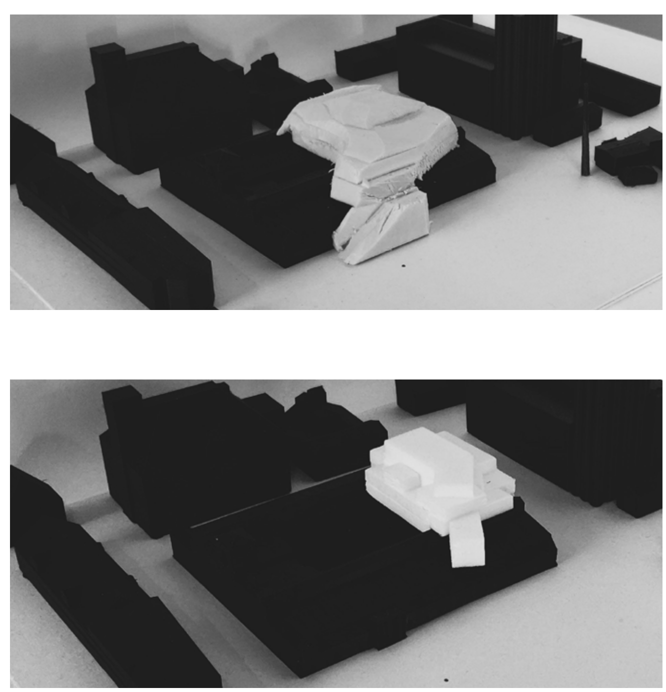
76. ORGANIC APPROACH

_12_03_01_ ADDITION

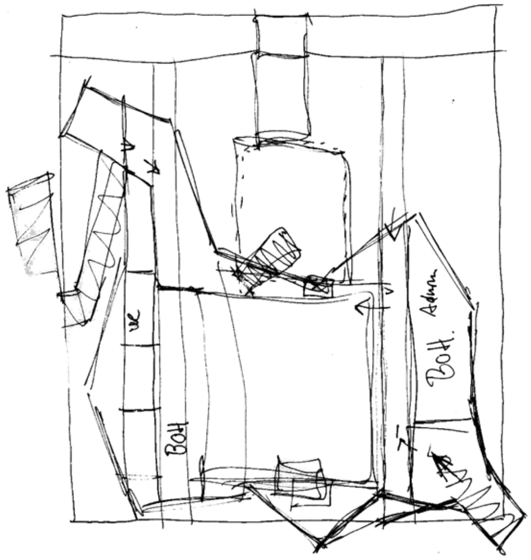
The design for the addition to the granary building aimed to pay homage to the site's history. As coal was once added to the nearby coal plot as an addition to the harbor, the architectural addition to the building was set to resemble the presence of coal. This design approach aligns with the import/export design driver.

The proposed placement of the "coal" addition is on top of the building, as previously described in the report. The primary function of this addition will be a cultural space, as discussed earlier. This function requires a high ceiling thus a taller design.

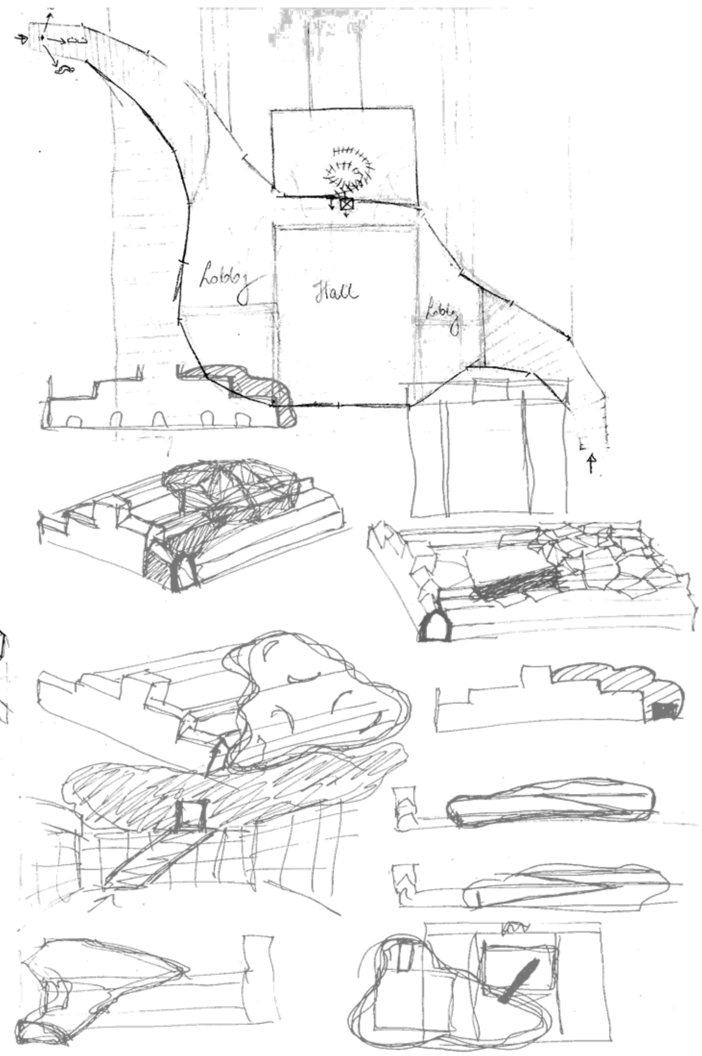
During the design exploration phase, various iterations of the addition's shape were examined through sketching and modeling. Two main approaches were considered: an organic approach and a geometric approach. The organic approach offered a more artistic expression but posed challenges in terms of planning. On the other hand, the geometric approach established a clear connection to coal and proved to be more feasible to execute. Thus, the decision was made to pursue the geometric approach, as it harmonizes better with the existing granary.

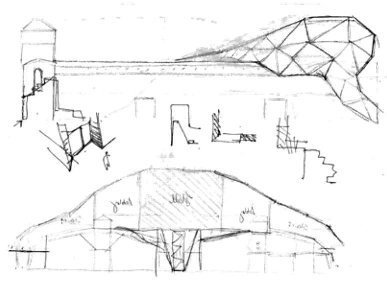


77. MODEL TEST



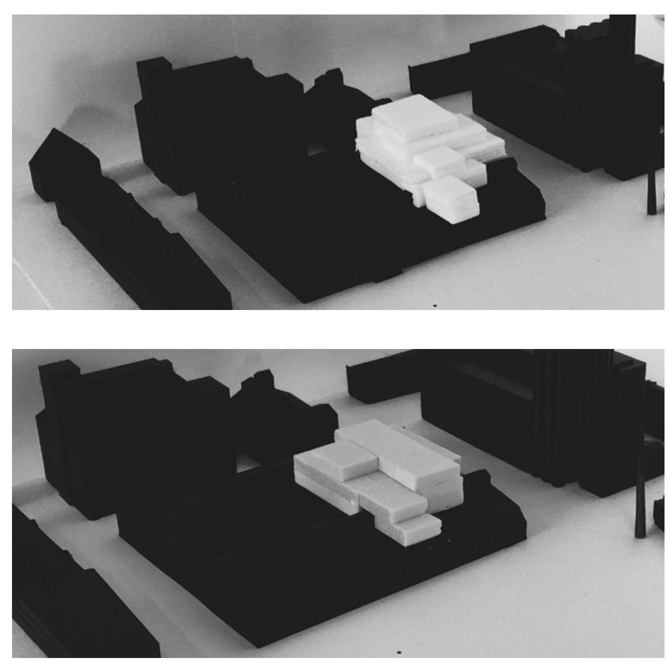
79. ORGANIC APPROACH





The design concept revolves around placing "the coal" on top of the building, serving as an extraordinary element that contrasts with the old structure. This juxtaposition creates a link between the old and new, while also attracting people to the building through its cultural function. Moreover, "the coal" addition should become a desired destination in the harbor area and establish a connection to the harbor itself. To achieve this, a viewing platform will be incorporated into the design, allowing for a visual connection over the surrounding area. The platform will be accessible to the public, in line with the connected harbor design driver.

To respect the architectural value of the original building, the addition will be positioned at the back (east), on top of the two main halls, avoiding the front façade and tower. This approach ensures that the original building's significant architectural features remain.



78. GEOMETRICAL MODEL TEST

SUBSTRACTION

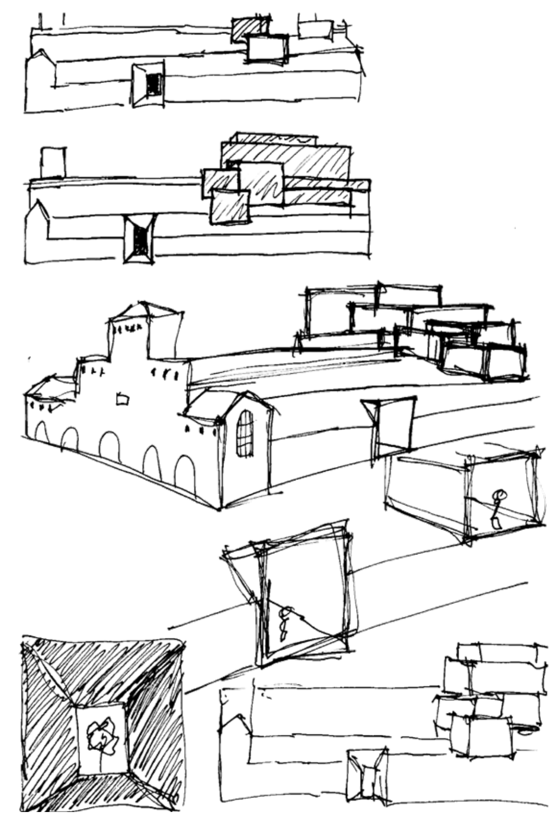
_12_03_02_ SUBSTRACTION

Just as coal played a significant role in the site's history, grain was also shipped from the harbor, and the granary building itself stands as a symbol of that export. Following the addition to the building, a subtraction will now take place as well, aligning with the import/export design driver.

Considering that coal was previously stored at the coal plot south of the building, the concept emerged to add a representation of "coal" on top of the granary. Simultaneously, the old coal plot will be transformed into a public plaza, serving as a vibrant gathering area within the harbor. This approach reflects the connected harbor design driver.

The original orientation of the granary faced the harbor. However, with the addition of the new plaza, the orientation of the granary will be turned. The idea emerged to create a subtraction from the granary, serving as the new entrance to the building. Various iterations of this subtraction were explored through sketching and design iterations. (80) An intriguing notion emerged, suggesting that the entrance and subtraction of the building should establish a relationship with the addition, particularly the viewing platform. Multiple sketches were developed to explore this connection, ultimately leading to the formulation of a narrative: Upon entering the building, the ultimate destination would be the viewing platform.

To realize this concept, a void was created within the building to frame the entrance. This void takes the form of a tunnel that penetrates the building, acting as a distinct and novel architectural element. Additionally, the tunnel leads to a void within the granary, enhancing the openness of the structure. To further enhance the openness, an interior courtyard was introduced, serving as the centerpiece of the building, and framing the entrance to the addition on top of the granary. The old structure will be preserved within the courtyard, as an aesthetic element.



80. PLAN AND SECTION

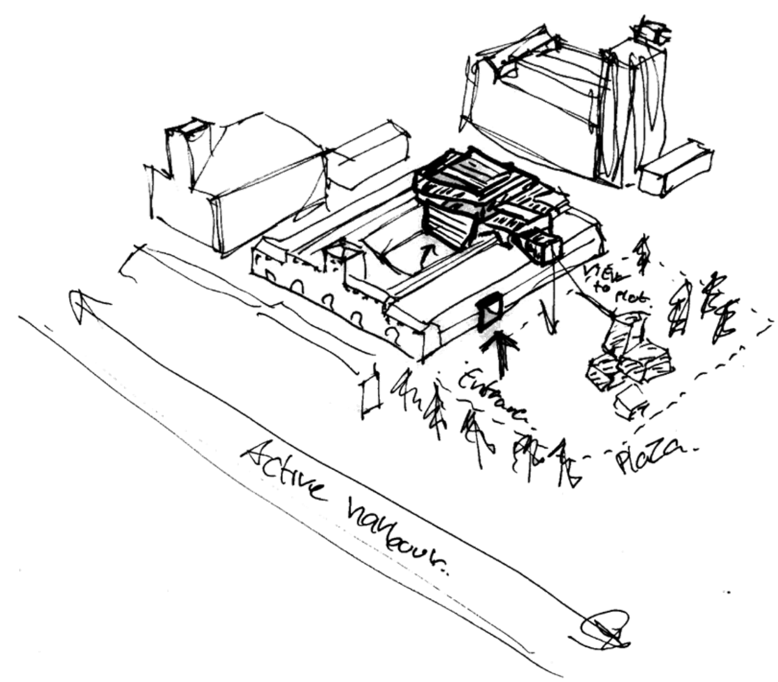
BALANCE

_12_03_03_ BALANCE IN THE DESIGN

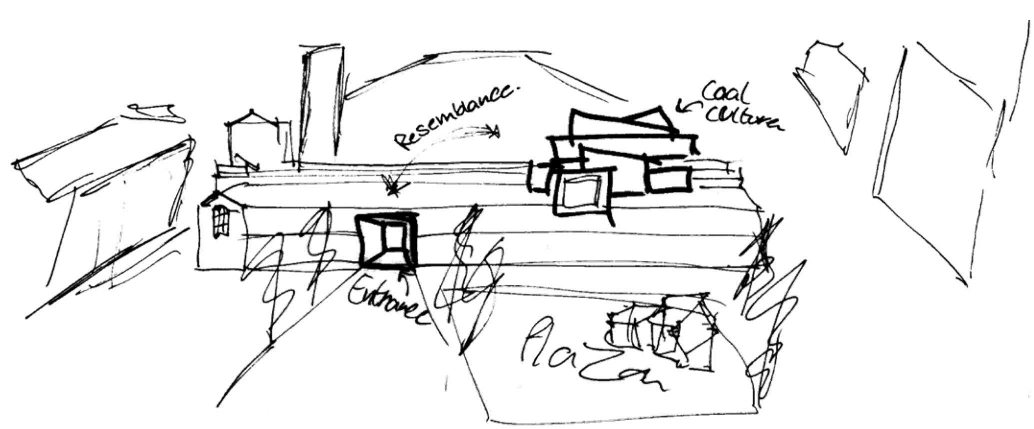
As additions and subtractions have been implemented in the design, a balance between interior functions and exterior expression is essential. The volume of the cultural space on top of the granary needs to be carefully adjusted to meet its functional requirements. The inclusion of a concert hall, art exhibition space, administration and viewing platform necessitated an iterative process of refining the volume and floorplan. Different exterior expressions of the cultural hall were explored through sketching, aiming to find the most suitable design. (81-82)

Various options were considered, based on the geometrical approach, characterized by arrangement of geometric boxes that corresponded to the interior functions. The central volume was dedicated to the concert hall and art exhibition, while a rectangular overhang projected outward, offering panoramic views of the harbor. The administration area extended towards the north, effectively balancing the overhang.

To add visual interest and dynamic interplay to the façade, the geometric boxes were designed to vary in height, creating a captivating composition. This approach not only addressed the functional requirements of the cultural space but also brought an intriguing architectural aesthetic to the building's exterior.

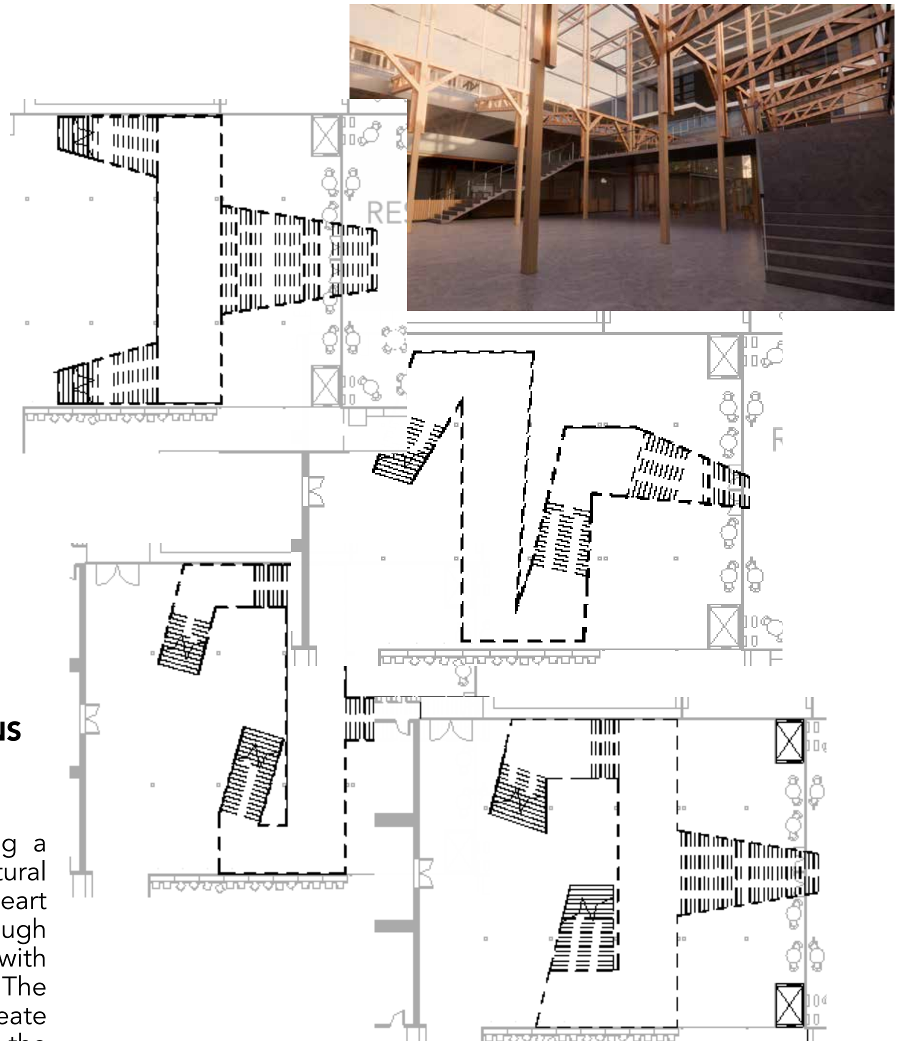


81. CONCEPT SKETCH



82. RESEMBLANCE SKETCH

COURTYARD STAIR



83. COURTYARD ITERATIONS

_12_03_04_ COURTYARD STAIR ITERATIONS

The courtyard plays a vital role in establishing a connection between the ground level and the cultural space located atop the building. It serves as the heart of the entire structure, with visitors passing through this central space. In order to link the courtyard with the cultural hall, a staircase will be incorporated. The stairway must obey the existing structure and create a grand entrance. Various design options for the courtyard stairway were explored through sketches.

The initial iteration involved a single straight stairway, which exuded a monumental presence . The second iteration featured a symmetrical stairway that would pass beneath the old structure and converge at the center, leading to the cultural venue. This concept was further visualized through renders to better comprehend the approach from the tunnel (83).

However, the length of the stairway presented some challenges, particularly the cramped landing area near the tunnel. As a result, the landings were modified to face inwards and towards each other. Although this adjustment resulted in a subdued expression, an alternative design approach was daringly explored. The landing areas were displaced in front of each other, allowing for a more audacious expression and creating a grand entrance for the cultural venue. This design also provided a captivating view and a pathway leading to the restaurant (84).

84. FINAL COURTYARD

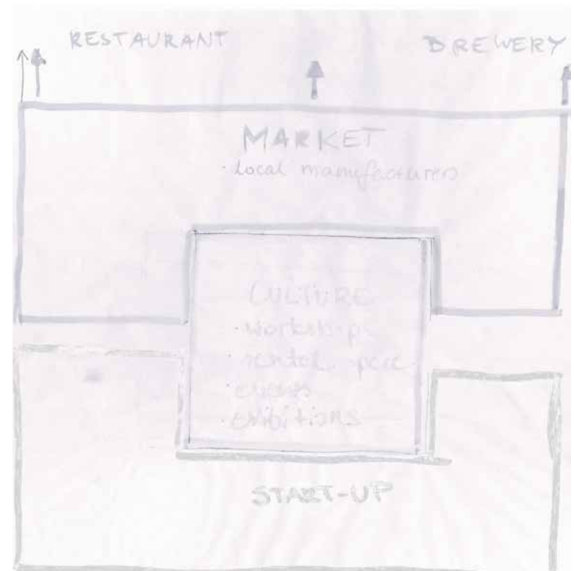
FLOORPLANS

_12_03_05_ FLOORPLANS

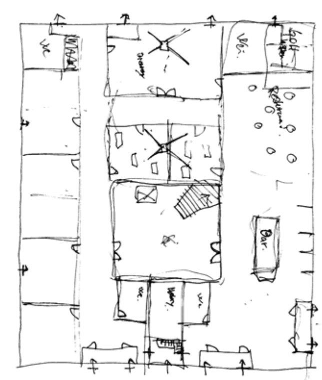
The transformation of the granary from one function to another posed challenges in reconfiguring the interior layout. The new rooms and functions required different proportions than the previous layout. However, it was important to preserve the essence of the old function and allow it to influence the future functions. One approach was to maintain the openness of the halls by not connecting walls to the ceiling, thereby displaying the existing structure. Initially, the floorplan aimed to separate public and private areas, with the public spaces directed towards the open plaza in the south and the private spaces situated in the north, along with the implementation of a central courtyard to delineate the functions (85).

To draw people to the site and make it a focal point in the harbor, it was decided that the cultural venue would be placed within the addition of the granary. Through an interactive process of sketching, the floorplan layout was developed. The first plan emphasized placing specific functions in designated areas. The office spaces were positioned in the northern section, consisting of multiple small offices and a large open floorplan. The restaurant and café were situated in the southern section, in relation to the public plaza. Initially, there were considerations for a microbrewery, but it was later discarded. The overall concept revolved around promoting openness between functions (86).

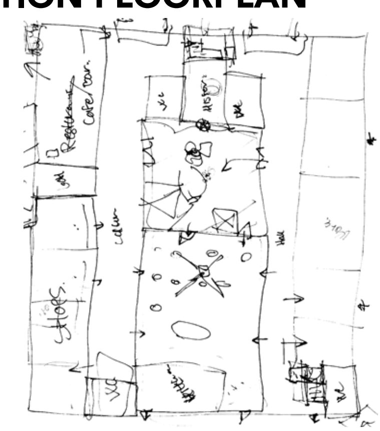
In the second iteration, the void tunnel was introduced to lead people into the café and shops area. The restaurant was relocated to the middle of the building, aligned with the courtyard. This allowed the restaurant to cater to both the public and the start-up companies while highlighting the new structure above as a central element of the restaurant. This plan facilitated connectivity between functions (87).



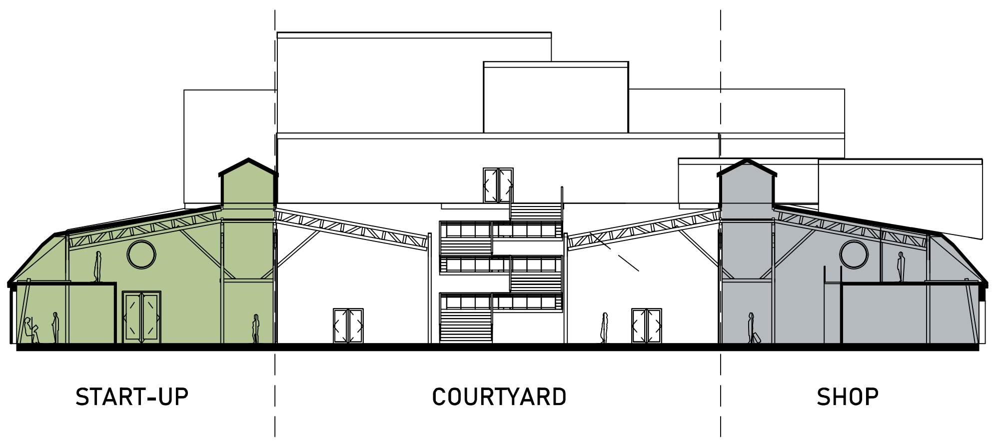
85. INITIAL FLOORPLAN ZONING



86. 1 ITERATION FLOORPLAN



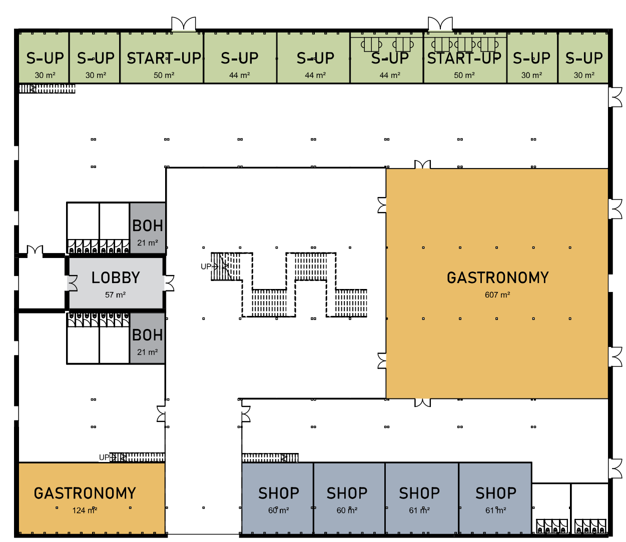
87. 2 ITERATION FLOORPLAN



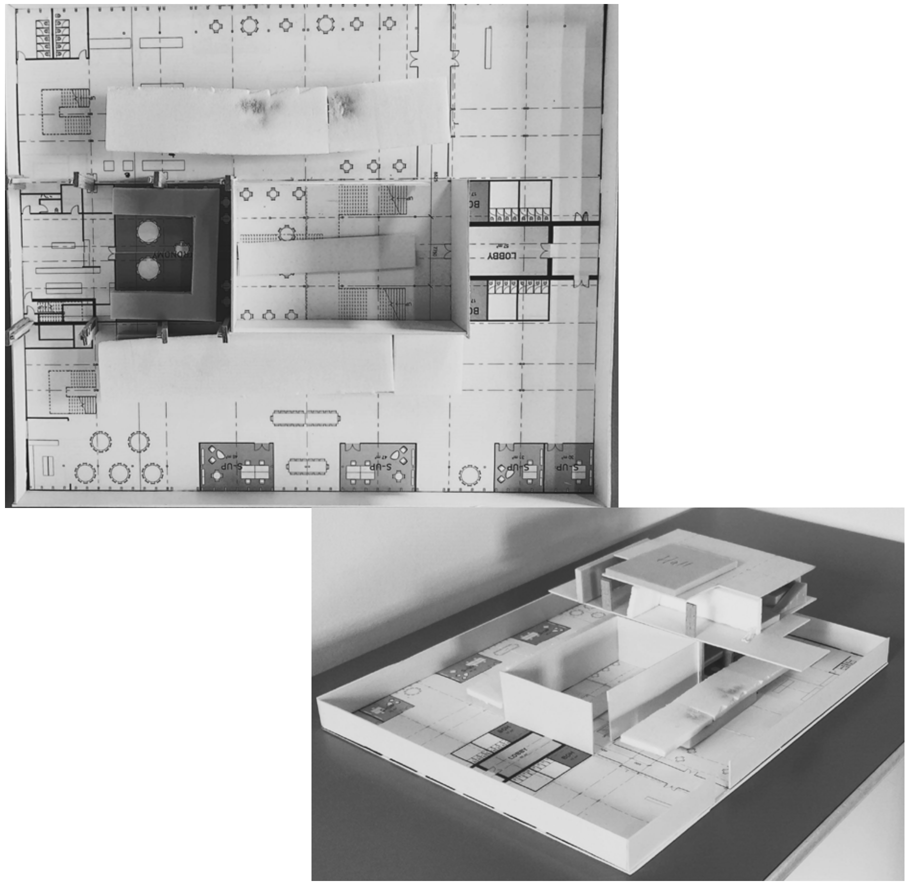
88. MEZZANINE SECTION

The third iteration involved a stricter separation, pushing all functions towards the façade to preserve the integrity of the old structure. The tunnel now led into the courtyard, which functioned as a divider between the shops and café (85). The lofty ceiling of the granary created a sense of grandeur within the interior space and allowed for the incorporation of a mezzanine level. However, the challenge was to integrate a mezzanine without compromising the continuous spaciousness of the hall. Initially, mezzanine levels were planned along the north and south façades but had to be discarded due to limitations imposed by the ceiling and trusses (88).

After the midway seminar, the ground floor began to take shape with the introduction of a museum and the merging of the café with the shops. The museum was designed to relate to the old tower of the building and the clerestories above. The number of private offices was minimized to encourage collaboration among start-up companies. Small workshops were introduced to enable the production of various models. The restaurant was downsized, along with the courtyard, to achieve better proportions, aligning with the existing blue doors to utilize them instead of creating new openings in the façade.

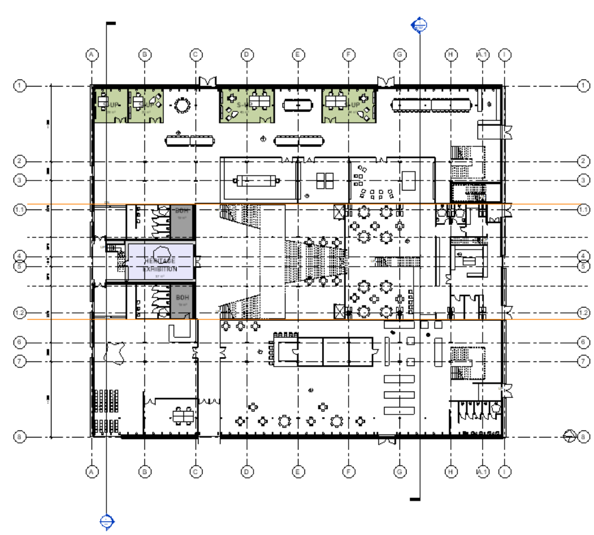


89. 3 ITERATION FLOORPLAN

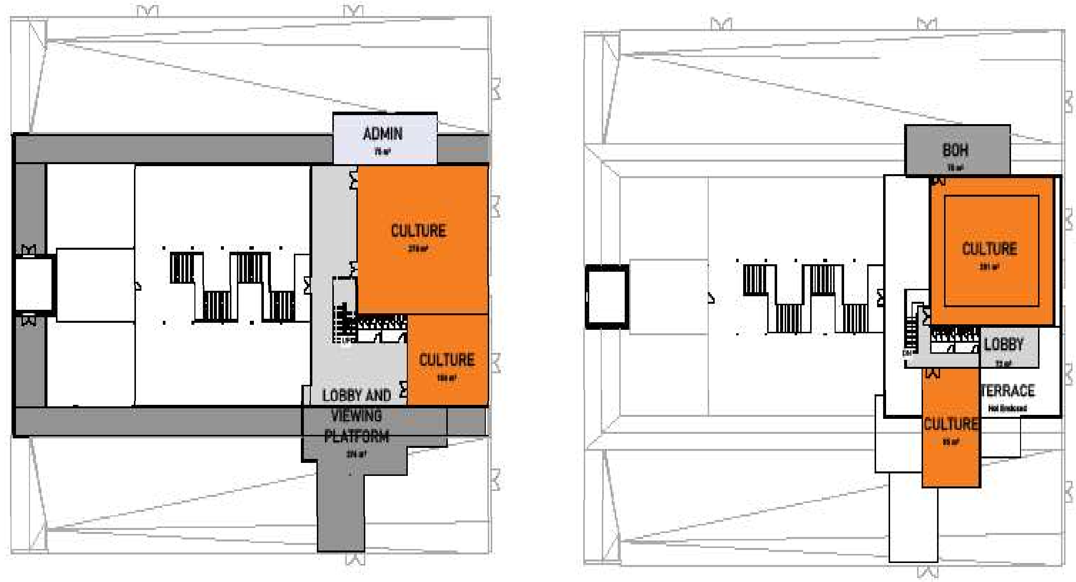


91. PLATFORM MODEL

The café and shop area were combined to benefit from each other, and the operational staff could be minimized. The mezzanine level was reintroduced to provide study spaces for the café and to be utilized by the start-up companies. It was repositioned to align with the courtyard, allowing the structure to remain visible. The final floor plan underwent some minor adjustments, such as incorporating additional storage and technical spaces, as well as improvements to the the kitchen, restaurant, and café/shop areas (90-91).



90. 4 ITERATION FLOORPLAN

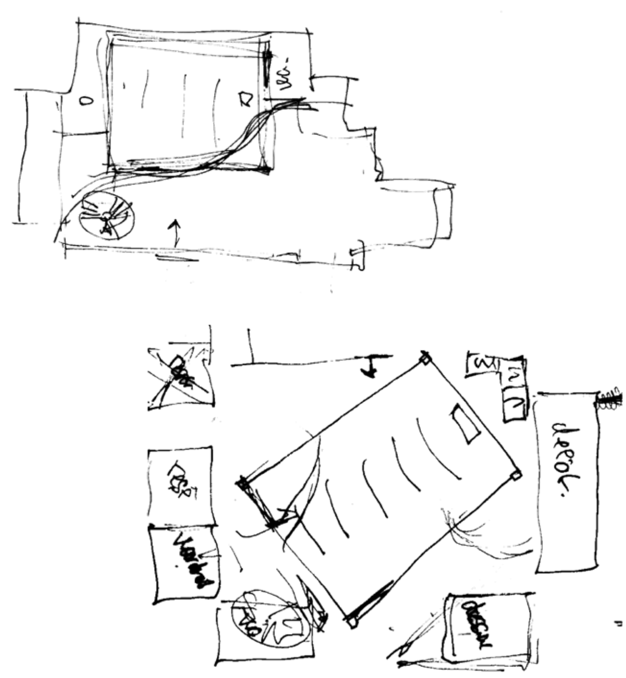


93. INITIAL CULTURAL FLOORPLAN

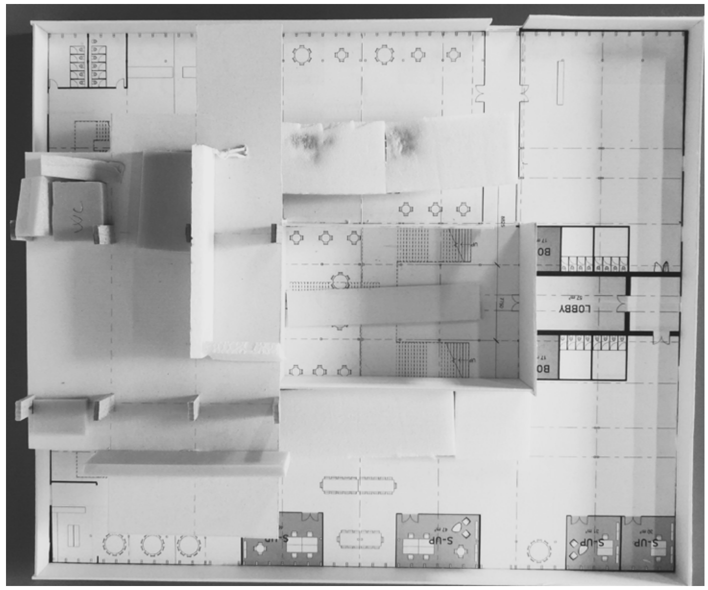
_12_03_06_ CULTURAL FLOORPLAN

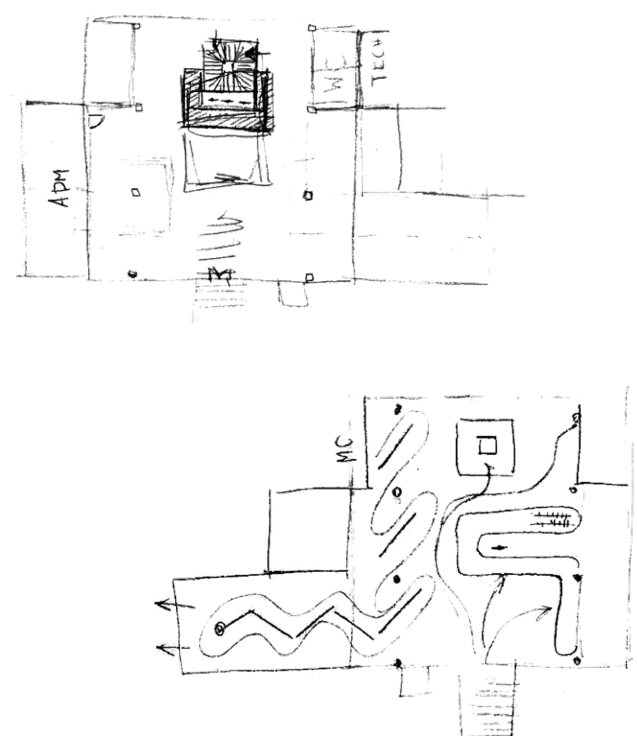
The initial floorplan for the cultural venue included a viewing platform, multiple halls with various functions, administration areas, and bathrooms. An interactive process of sketching was undertaken to design the layout of the cultural venue. The placement of the viewing platform was determined to be in the south, as the space itself was designed to accommodate this feature. The height of the rooms was carefully considered during the iterative process to ensure alignment between the interior and exterior design.

In the first iteration of the floorplan, the focus was on combining the lobby with the viewing platform. Four halls were planned on multiple levels. However, this design resulted in a tall structure that required high ceilings in multiple rooms. Additionally, the entrance lacked a grand feeling. It became evident that accommodating multiple halls within the volume without excessively tall proportions would be challenging. Consequently, a decision was made to have a single, central hall on one level that would be flexible and capable of accommodating both music and art events.



92. 1 ITERATION FLOORPLAN





The second iteration introduced the incorporation of a fire escape as a necessary element (92). The concept of multiple halls was abandoned due to difficulties in planning adjacent rooms. The halls were separated into distinct spaces for art and music. The entrance of the cultural venue became the focal point, positioned centrally within the courtyard. The second level was reintroduced, with the music hall located above and the art exhibition space below. All adjacent rooms were situated below, with the reception area being the first point of entry.

The art exhibition area was designed with an open floorplan to allow for versatile uses. Further exploration of this floorplan was conducted, and a platform model was created to examine the spatial flow. The stairway to the concert hall proposed a challenge as the stair frame the entrance to the hall. A central stair would create problems and minimize the hall. A spiral staircase was tested, but the solution became a stair that followed the south façade, and the spatial flow.

94. 2 ITERATION FLOORPLAN

NEW STRUCTURE

_12_03_07_ NEW STRUCTURE

In this section the new structure will be covered on how the new cultural space is supported. This is documented through tectonic sketch, physical models, and FEM analysis in ROBOT. The calculation on the final structure can be found in Appendix 4.

_12_04_ SUPPORT

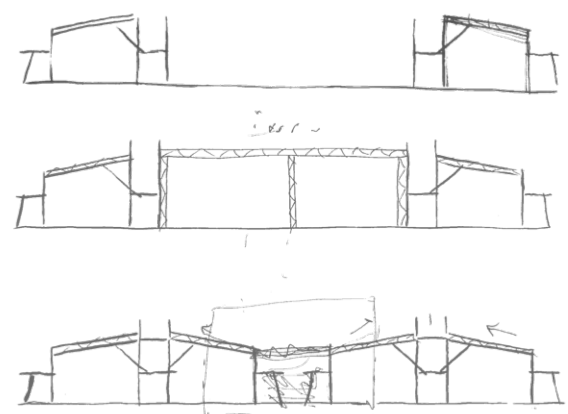
Given that the new cultural space is situated above the existing granary building, the design must account for a new structure to support this additional space. The challenge lies in supporting a new building within the confines of an existing structure, while preserving its integrity.

It was determined early on that the old structure could not support the new building, and a new structure was required to be added for this purpose. To minimize the impact of the new columns on the existing structure and prevent them from interfering with the original trusses, it was decided to limit their number and location. The designated area for the new columns was between the two clerestories, directly beneath the cultural space, to ensure that the span between the columns remained within manageable limits. Eventually, this created an overhang with the viewing platform that has to be handled structurally. (95)

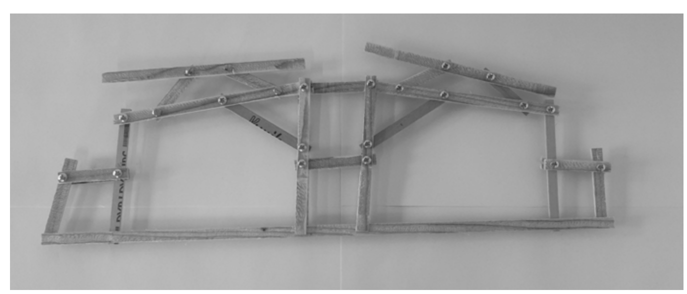
The question then arose whether the old structure should be removed to make room for the new one. To assess the structural principles involved and the potential impact of removing structural elements, a frame model was created. (96) This model revealed that the structure would remain stable even if the trusses and columns were removed.

The decision was made to create a new structure that emerged from the ground and penetrated the old granary building, removing the old structure to make way for the new. This approach allowed for a new tectonic expression that did not detract from the old, creating a harmonious balance between the old and new.

To ensure continuity, the spacing between the new columns would follow the original spacing of the old columns, which were 8 meters apart along the building.



95. ORIGINAL STRUCTURE



96. FRAME MODEL

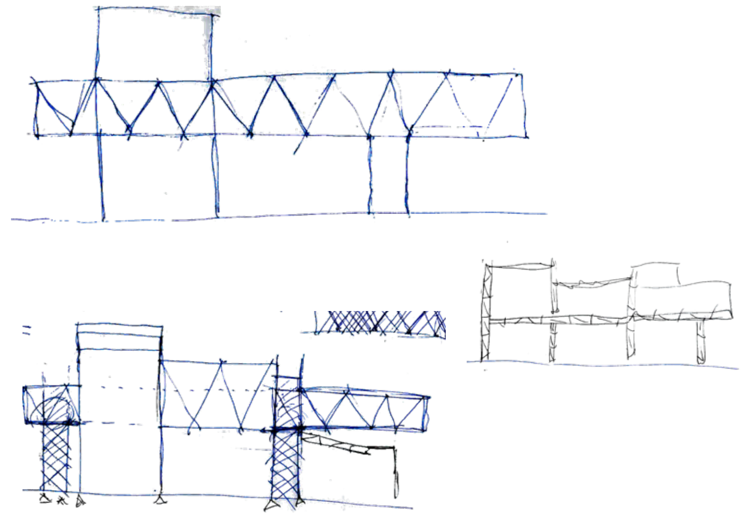
_12_04_01_ NEW STRUCTURE EMERGES

The cultural space above is categorized as a "meeting hall – no seating" with a load of 5 kN/m² (DS/EN 1991-1-1). Based on a rough estimate, the cultural space is about 1200 m², which translates to 6000 kN. However, the real challenge for the structure was not the load of the cultural space, but rather the moment created by the overhang of the viewing platform.

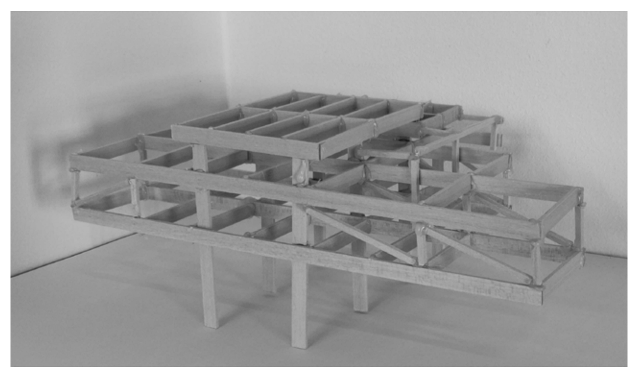
This overhang had to be accounted for in the structure. Various iterations were sketched to determine the best way to support the overhang and address the moment in the structure (93). Different structural principles involving elements working in compression and tension were tested.

The chosen solution was a truss system consisting of columns and slanted columns that reinforced the structure to withstand the moment within it. This system was advantageous in terms of floor height, as a taller truss would be more efficient. The direction of the slanted columns and the type of joints within the truss system will be addressed later in the report.

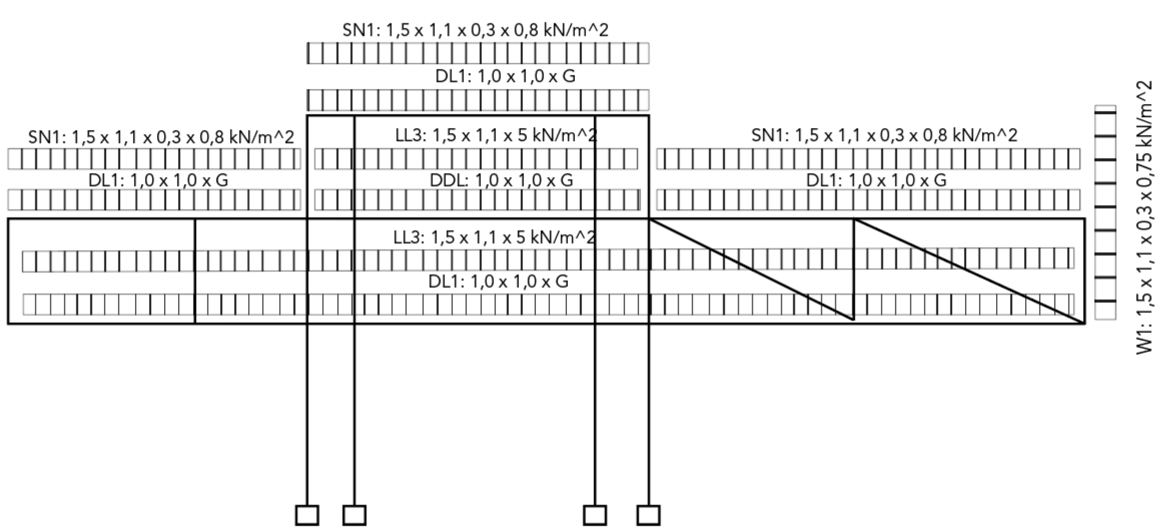
Early initial body diagram, with all fixed connections. (99)



97. SUPPORT ITERATIONS



98. STUDY MODEL



99. INITIAL BODY DIAGRAM

_12_04_02_ NEW COLUMNS

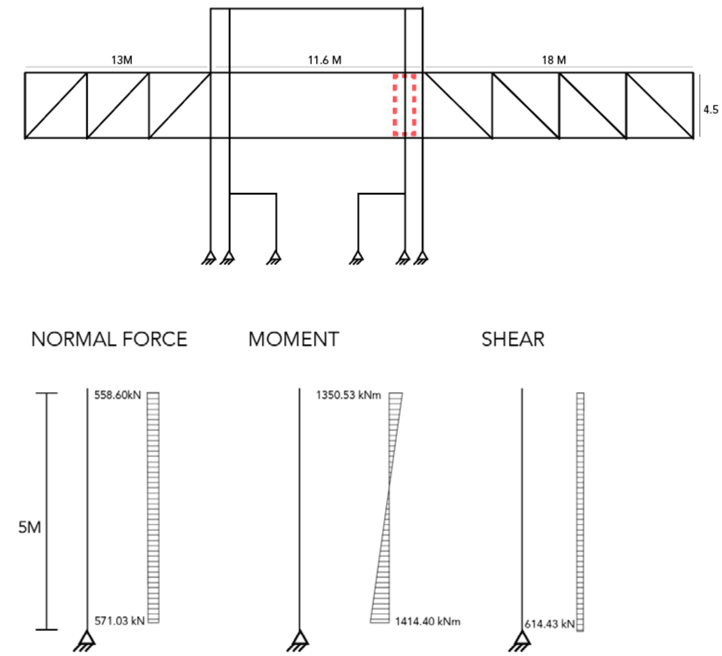
In the beginning, a row of four columns was placed 8 meters apart, and different numbers of columns were tested across the building span, including 2, 3, and 4 columns. (102)

Since the room beneath the cultural space would be a restaurant with a large open space, the columns would be a crucial element in framing the size of the room and creating a tectonic presence. However, there would also be a concert hall above the restaurant, which meant that central columns could not be used. To maintain symmetry, four columns were chosen with the exterior columns aligning with the interior courtyard and the interior columns placed 1.5 meters inward. This resulted in an 18-meter overhang to the south, an 11-meter overhang to the north, and an interior span of 11.6 meters. (100)

Having overhangs on both sides was beneficial as they are balancing each other out. However, it required a column that could withstand a moment of 1414.40 kN * m. (according to FEM Analysis) The column's massive momentum of resistance depended on its profile's moment of inertia and material, whether it was steel, wood, or concrete.

Based on the Import / export design driver, it was necessary for the cultural space to have a distinct contrast with the granary building. Thus, various column designs were explored, including steel and concrete columns, which did not provide an elegant appearance. However, glulam wooden columns were found to offer a connection to the old structure. (103) Several wooden column profiles were tested, and the double rectangular profile was found to be more elegant as the column was divided into two parts. By dividing the column into two profiles, it allowed for a secure connection to the beam above. However, determining the appropriate size required calculations of the momentum of resistance and moment of inertia. Eventually, a 2 x 800 x 400 profile was calculated. (101)

It was evident that the 2 x 800 x 400 column profile was insufficient, necessitating a different approach to manage the moment in the structure without resulting in bulky columns. Therefore, instead of the structure bearing the moment, it was proposed that the connections should handle it.



100. COLUMN ANALYSIS

$$I = b * h^3 / 12 = 400 * 800^3 / 12 * 2 = 34133 * 10^6 \; mm^4$$

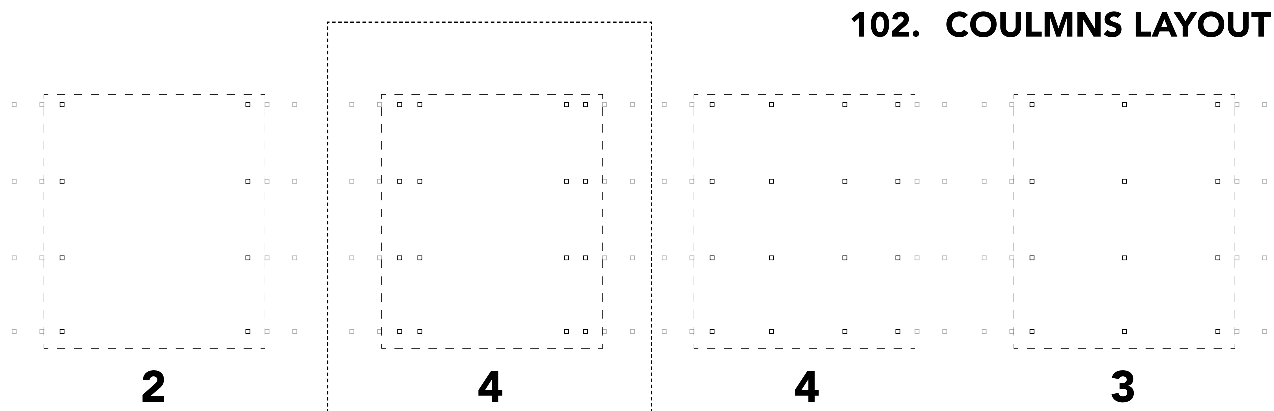
$$W = \frac{I}{e} \; mm^3 = \frac{34133 * 10^6 \; mm^4}{400 \; mm} = 85333333 \; mm^3$$

$$\sigma m,y,d = applied\ moment\ (1414{,}40) / first\ moment\ of\ area\ (\ 85333333\ mm^3) = 16{,}58\ MPa$$

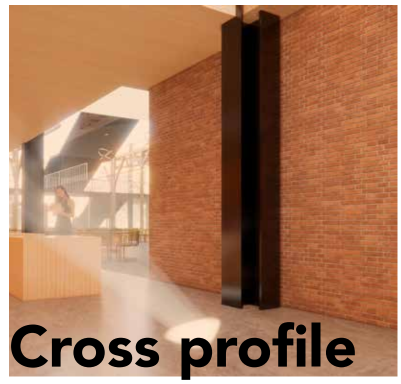
$$\frac{\sigma m,y,d}{fm,y,d} = \frac{16{,}58}{15.36} = 1{,}28 > 1$$

101. PROFILE CALCULATION

102. COULMNS LAYOUT



103. RENDER OF COLUMN EXPRESSION


Cross profile

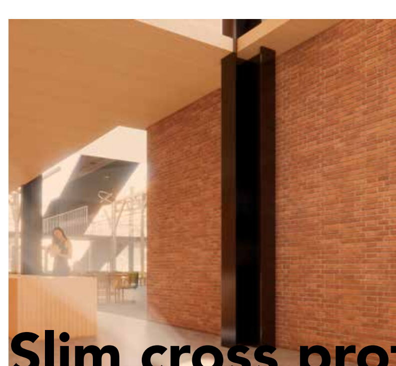

2 x 800x 400


4x Square


Square


4x Angle profile


Concrete profile

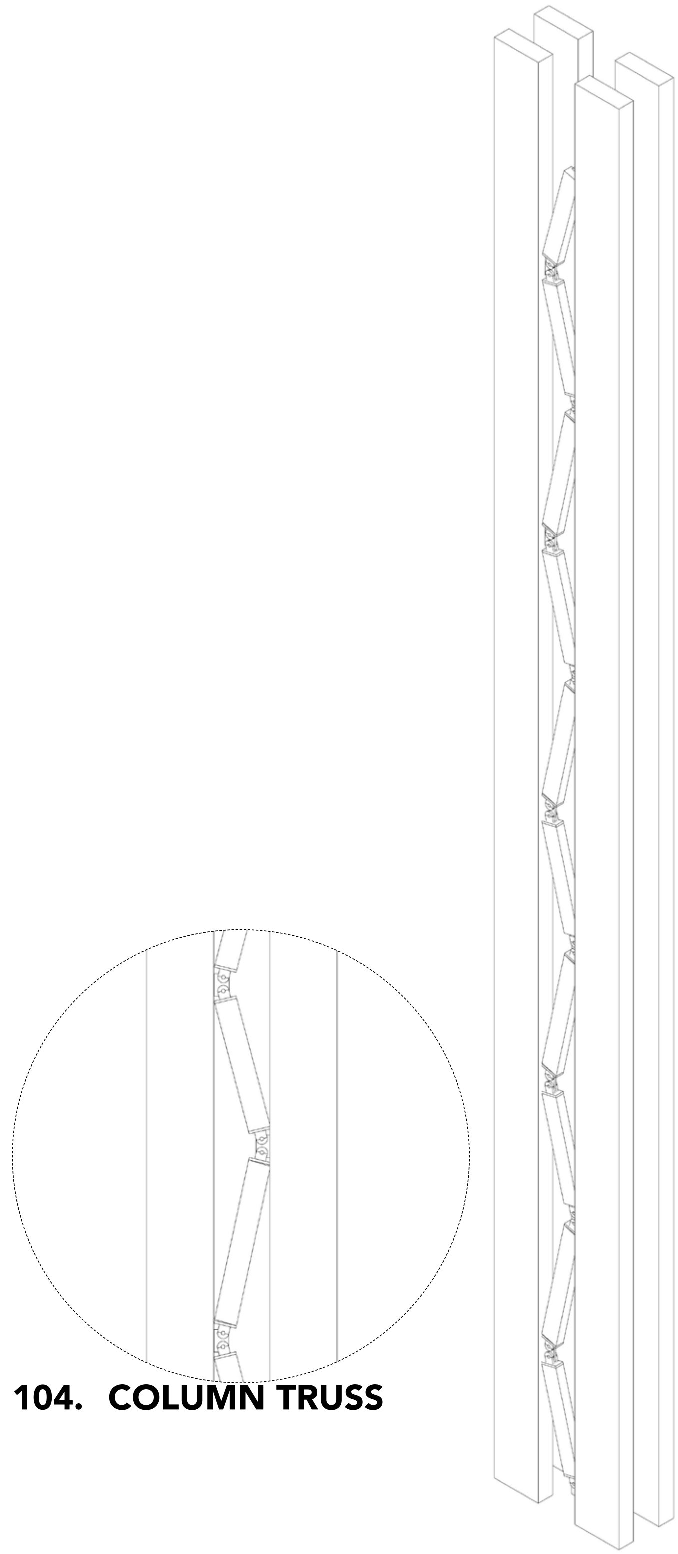

Slim cross profile


2 x 600 x 200

This led to the idea of optimizing the timber columns to avoid the columns handling the moment, but rather let the connections handle it. The idea was inspired by the old structure and wood trusses in the ceiling. The space between the exterior and interior column was narrowed down to 0,5 meters and connected to create a "column truss" making the connections inside the column handle the moment. (104)

The concept was tested, and it allowed for smaller profiles of columns to be examined. Through FEM analysis in ROBOT, the moment in the column truss was calculated, reducing it to 158.97 kN * m. This was a significant improvement, allowing for smaller profiles to be tested, including 2 x 700 x 300, 2 x 600 x 200, 2 x 500 x 200, and 2 x 400 x 200. (106)

Ultimately, the decision became a design decision based on the tectonic expression. The interior expression was tested through renders, and the final decision was made on 2 x 600 x 200. (104)



104. COLUMN TRUSS

105. PROFILE CALCULATIONS

$$I = b * h^3 / 12 = 300 * 700^3 / 12 * 2 = 17150 * 10^6\, mm^4$$

$$W = \frac{I}{e}\, mm^3 = \frac{17150 * 10^6\, mm^4}{350\, mm} = 49000000\, mm^3$$

$$\sigma m,y,d = applied\ moment\ (158{,}97) / first\ moment\ of\ area\ (49000000\, mm^3) = 3{,}24\, MPa$$

$$\frac{\sigma m,y,d}{fm,y,d} = \frac{3{,}24}{15.36} = 0{,}21 < 1$$

$$I = b * h^3 / 12 = 200 * 600^3 / 12 * 2 = 7200 * 10^6\, mm^4$$

$$W = \frac{I}{e}\, mm^3 = \frac{7200 * 10^6\, mm^4}{300\, mm} = 24000000\, mm^3$$

$$\sigma m,y,d = applied\ moment\ (158{,}97) / first\ moment\ of\ area\ (24000000\, mm^3) = 6{,}62\, MPa$$

$$\frac{\sigma m,y,d}{fm,y,d} = \frac{6{,}62}{15.36} = 0{,}43 < 1$$

$$I = b * h^3 / 12 = 200 * 500^3 / 12 * 2 = 4166 * 10^6\, mm^4$$

$$W = \frac{I}{e}\, mm^3 = \frac{4166 * 10^6\, mm^4}{250\, mm} = 16664000\, mm^3$$

$$\sigma m,y,d = applied\ moment\ (158{,}97) / first\ moment\ of\ area\ (16664000\, mm^3) = 9{,}53\, MPa$$

$$\frac{\sigma m,y,d}{fm,y,d} = \frac{9{,}53}{15.36} = 0{,}62 < 1$$

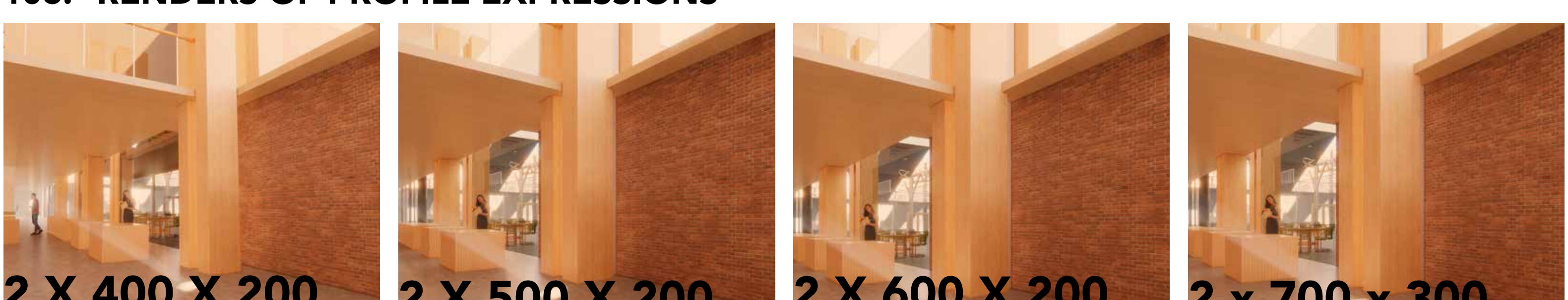
$$I = b * h^3 / 12 = 200 * 400^3 / 12 * 2 = 1066 * 10^6\, mm^4$$

$$W = \frac{I}{e}\, mm^3 = \frac{2132 * 10^6\, mm^4}{200\, mm} = 10660000\, mm^3$$

$$\sigma m,y,d = applied\ moment\ (158{,}97) / first\ moment\ of\ area\ (10660000\, mm^3) = 14{,}91\, MPa$$

$$\frac{\sigma m,y,d}{fm,y,d} = \frac{14{,}91}{15.36} = 0{,}97 < 1$$

106. RENDERS OF PROFILE EXPRESSIONS

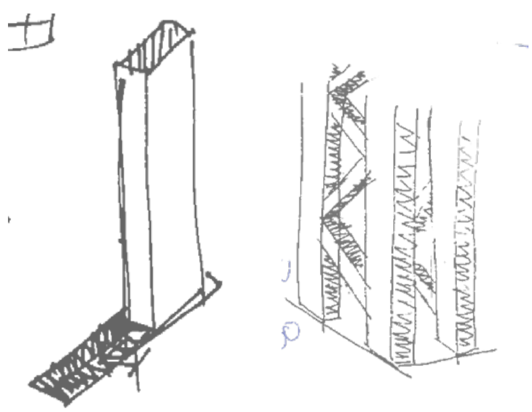


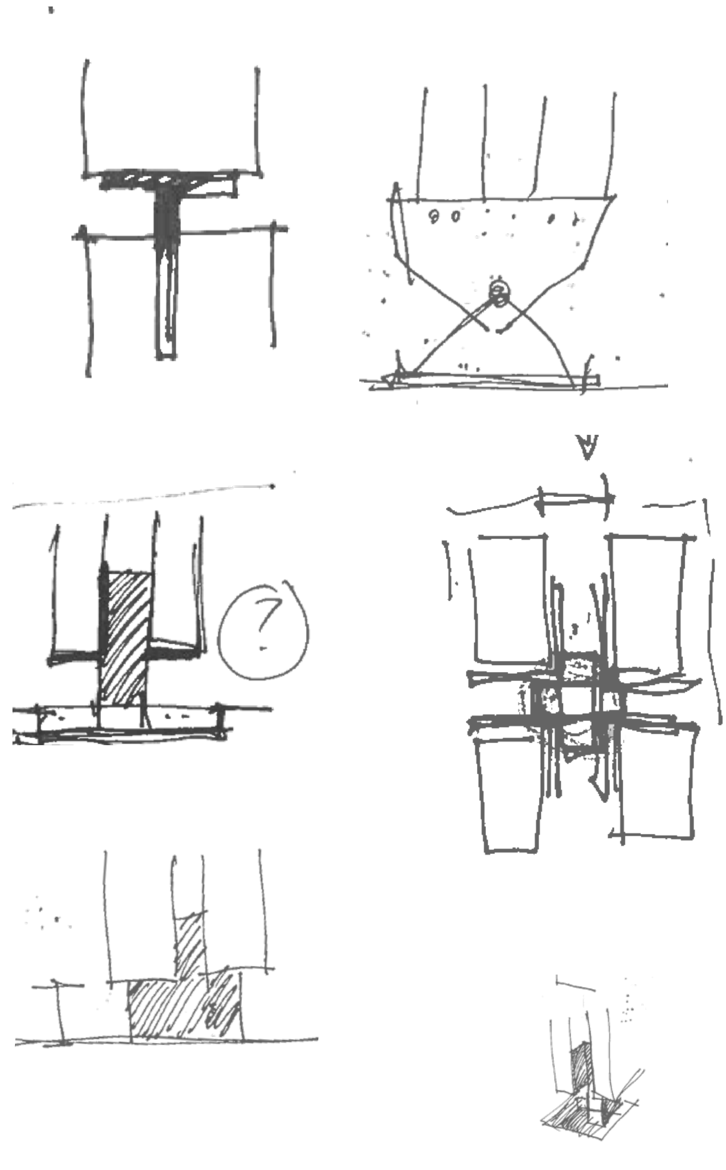
_12_04_03_ COLUMN FOOTINGS

The column holds a significant tectonic role in the overall design of the restaurant, and its connection with the floor is crucial for its expression. Different variations of footings have been explored through sketches, aiming to find the perfect match. (107)

One of the sketched proposals suggests terminating the column footing into a spike, creating an elegant appearance, and giving the impression of lightness. However, it is important to acknowledge that the column possesses a certain volume that symbolizes strength and would not harmonize with the column.

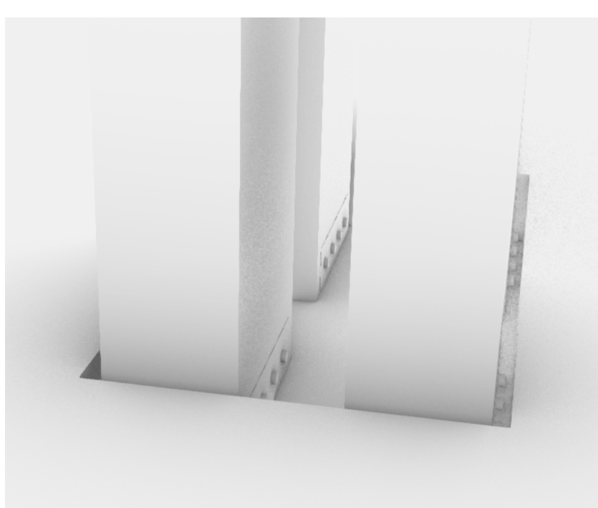
Renovating the old columns, a new footing has been introduced, involving the addition of a concrete base. The new column will mirror the footing, by having a deducted base. This approach allows artificial light to illuminate the new columns from below, enhancing their visual impact. (108)



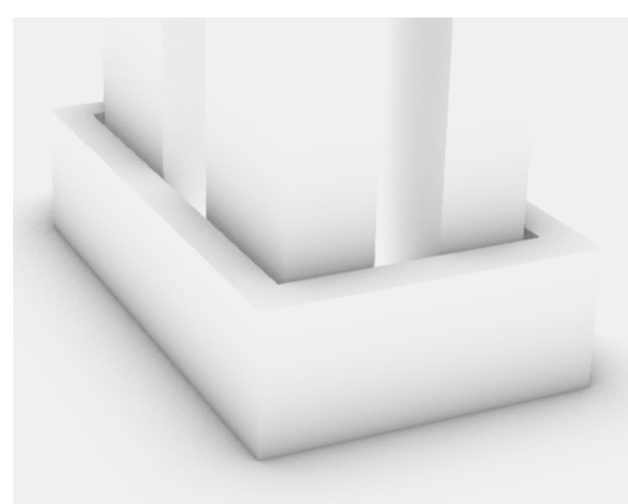


107. FOOTING SKETCHES

108. FOOTING SOLUTIONS



SUBSTRACTION



ADDITION

_12_04_04_ CONNECTING THE OVERHANG OF THE BUILDING

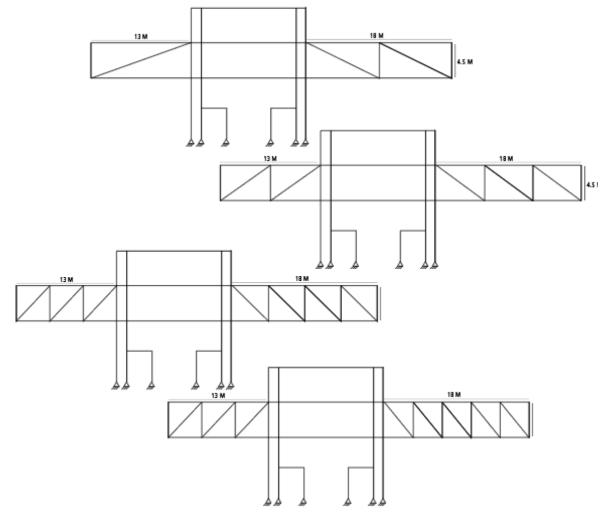
As the cultural space is located on top of the building, a new structural material was needed for the space that differed from the old granary.

Steel (S235) was chosen to reflect the new element being added to the old granary. The truss system had to be developed to determine the number of slanted columns (system) needed within the truss. An analysis in ROBOT with 2, 3, 4, and 5 systems showed that adding more systems improved the structure, leading to a design decision of using 5 systems. (109)

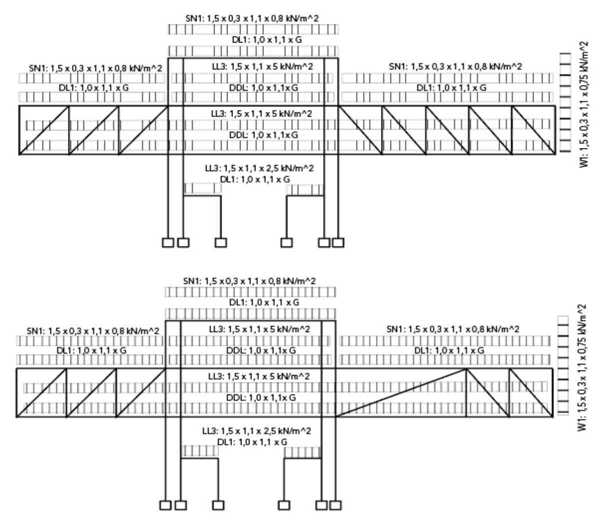
The slanted columns within the system were to be directed downwards from the main column to work in tension. However, an opening was required for the art space, which necessitated a larger upwards slanting column to replace the systems. This was the only area where the slanted column was in compression instead of tension. Ideally, the structure should only work in tension to avoid buckling and the need for a larger profile. (110)

Initially, the truss system was fixed in the connections, creating a huge moment within the structure as the members had to handle the moment. To handle the moment within the structure, the connections were designed to handle it.

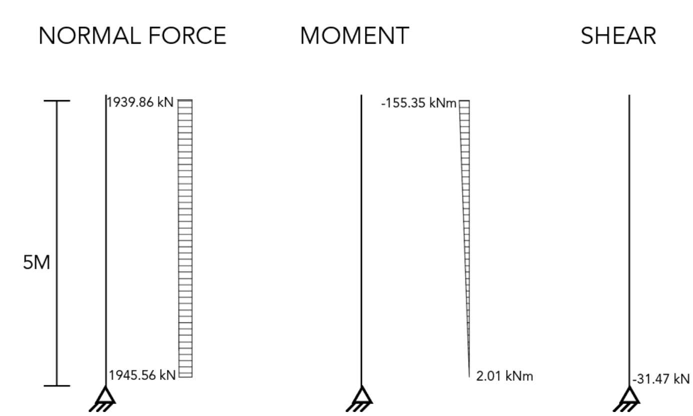
Pinning the connections of the slanted columns in a truss system allowed the column to rotate, moving the moment in the element to the connection. An iterative process of testing connections and combinations resulted in a more optimal structure, allowing the size of the elements to be minimized. The final body diagram (113)



109. TEST OF SYSTEMS IN A FRAME

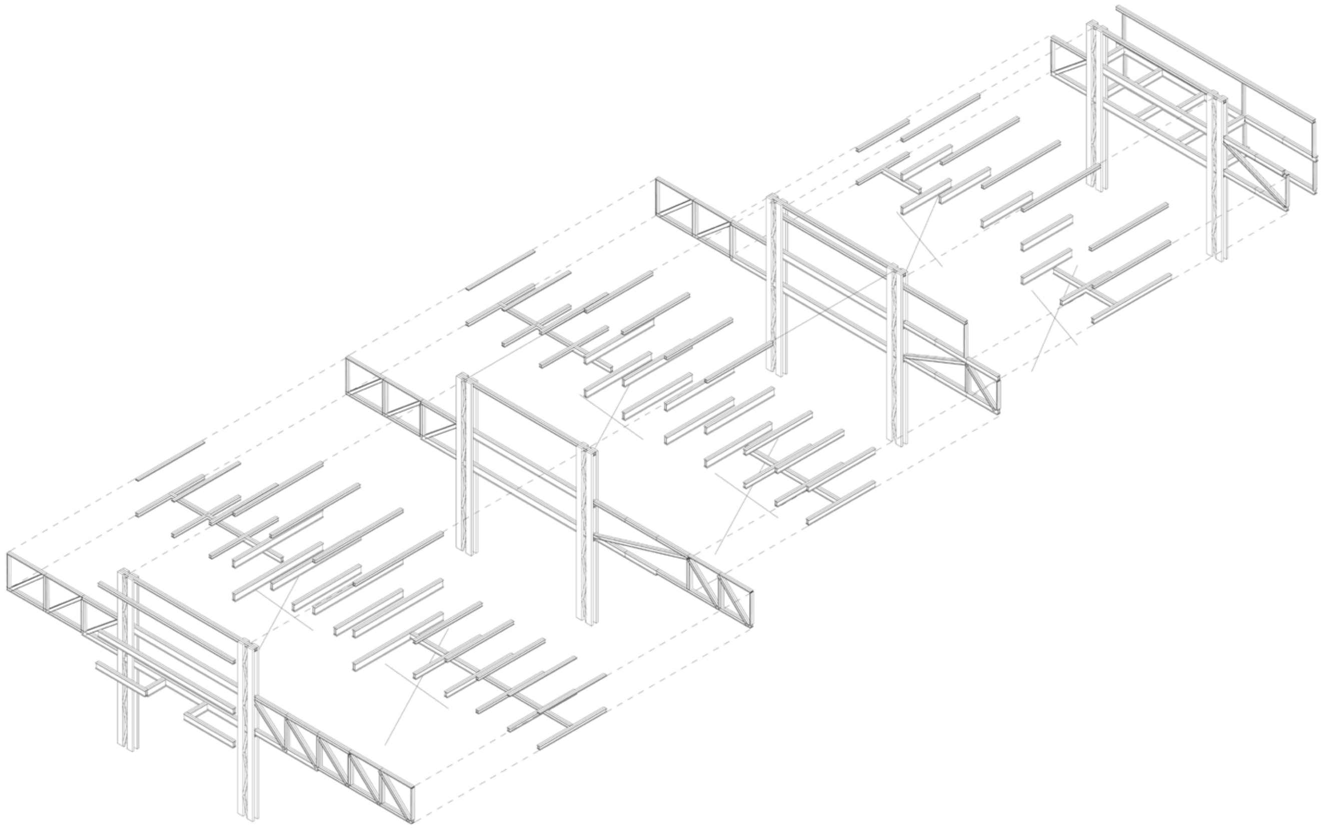


110. SECOND ITERATION BODY DIAGRAM

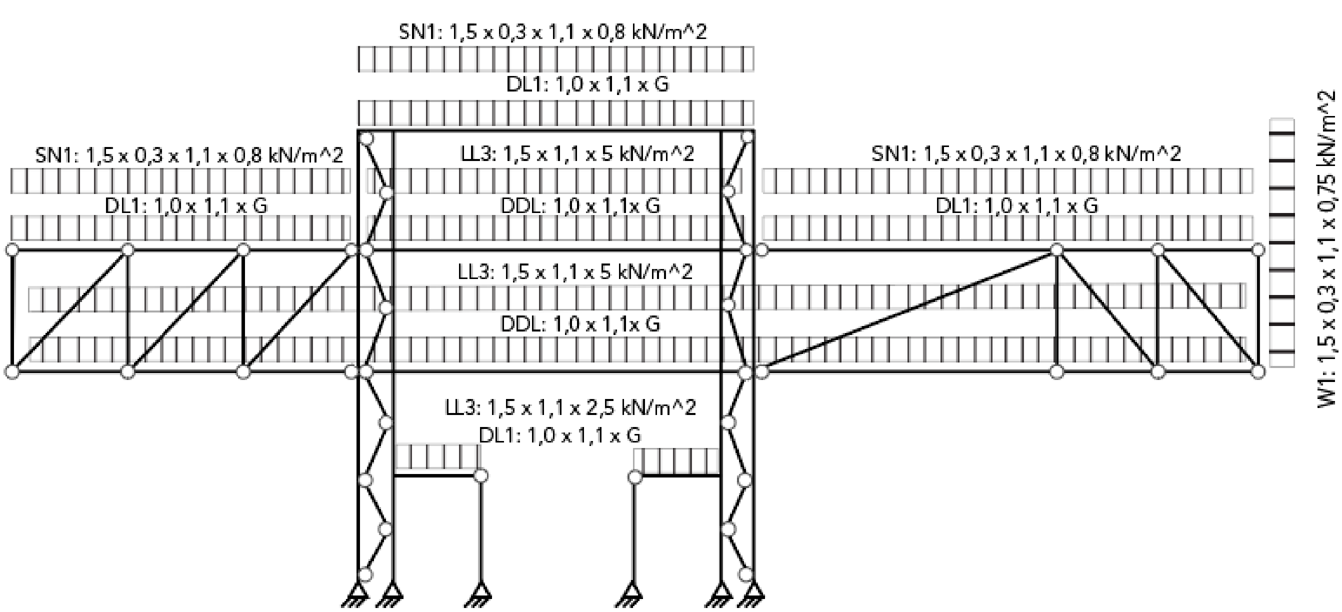


111. NEW FORCE A THE COLUMN

112. EXPLODED STRUCTURE



113. FINAL BODY DIAGRAM



_12_04_05_ FEM ANALYSIS

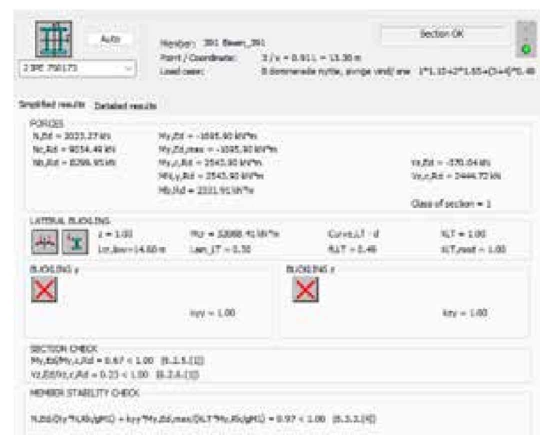
The FEM program ROBOT structural analysis was utilized to compute the profiles of the structure, which is part of the BIM approach as the structure can be analyzed as part of the central file.

Although the cultural space would be constructed of steel, the sizing of the profiles still needed to be determined. Load combinations, with live load being the dominant load and wind and snow as secondary loads, were calculated. As previously mentioned, the load of the cultural space was defined as 5 kN/m², and with the spacing between the columns being 8 meters, the carrying area of the beam was 4 meters on each side. This load, calculated into a line load, amounted to 40 kN/m and in a load combination with dominant live load, it added up to 66 kN/m.

The most critical beam was the interior span of 14.6 meters, with a moment of 1766.81 kN*m and a normal force of 2072.93 kN. The calculation was performed on various IPE profiles, as the profiles were robust in load and moment. A calculation on a 750 x 222 profile was performed, and the result revealed that the beam needed to be double the size to bear the load. (114)

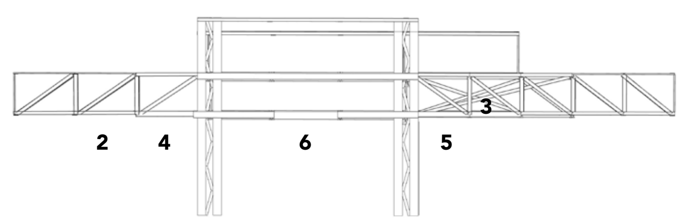
However, this would create problems with the beam colliding with the clerestory floor, where the overhang is overlapping. Therefore, additional columns needed to be added to carry the load or the load area had to be minimized. The 8-meter spacing of the columns was maintained, but the solution was to use a doublet profile beam, thus reducing the load area to 4 meters. A calculation on a 2 x 750 x 173 profile was performed. (115) The final usage ratio of the beam was 0.97. The used profiles and the usage ratio of the beams are illustrated in the diagram below.

750 x 222



2 x 750 x 173

114. FEM ANALYSIS IN ROBOT



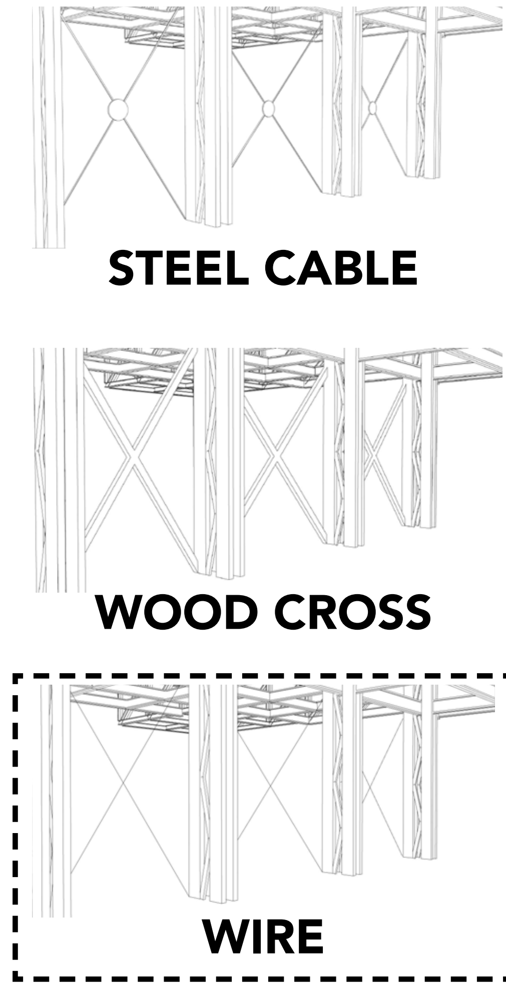
115. OVERVIEW OF MEMBER USAGE

	PROFILE	STEEL TYPE	USAGE RATIO	CRITICAL FORCE
1	2 IPE 100	S235	0.54	Tension force
2	2 IPE 300	S235	0.98	Compression
3	2 IPE 400	S235	0.96	Compression
4	2 IPE 500	S235	0.60	Moment
5	2 IPE 600	S235	0.78	Compression
6	2 IPE 750 173	S225	0.97	Compression

_12_04_06_ STRUCTURAL STABILITY

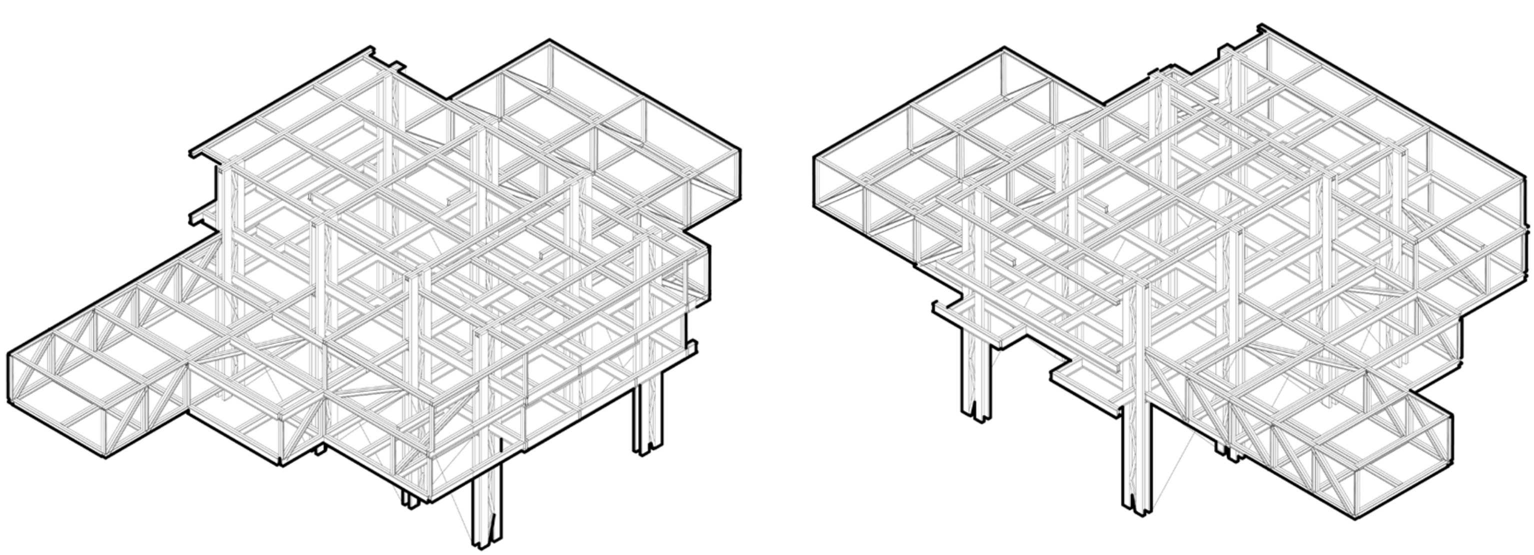
The structural stability of the building was a crucial consideration, both longitudinally and latitudinally. While the former was addressed through internal systems, the latter needed a different approach. Several options were sketched to achieve the desired latitude stability, with the best solution being to use the height of the 9-meter restaurant space to create stability along the axis. Various options were tested, including wires, wooden crosses, and metal framing, but the final solution was cables. (116)

This option was not only subtle but also had a connection to the old structure, and it was easy to incorporate into the kitchen and restaurant floorplan.



116. DIFFERENT STABILITY OPTIONS

117. FINAL STRUCTURE



COURTYARD STRUCTURE

_13_ INTERIOR COURTYARD STRUCTURE

The subtraction of the granary resulted in an interior void, which was utilized to create an interior courtyard. The intention was to cover the courtyard so that it could function as a buffer zone and not be considered a part of the façade.

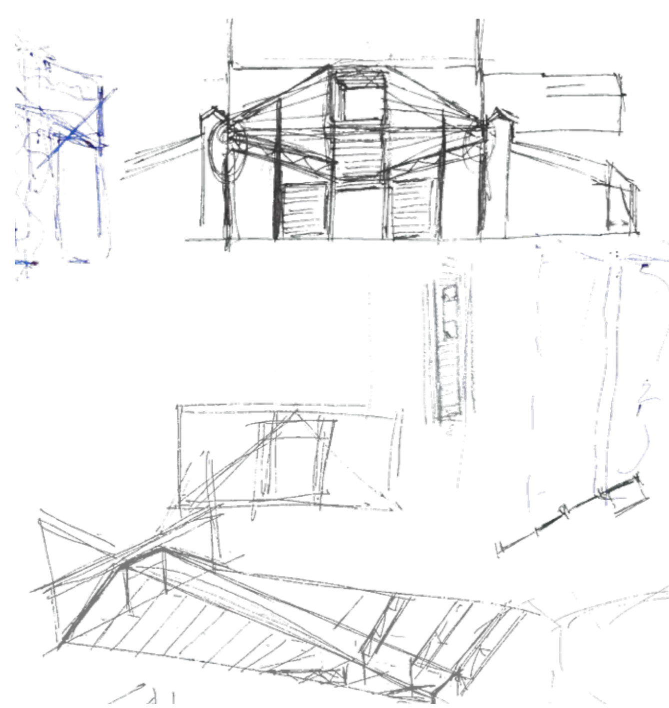
Additionally, the courtyard cover was intended to frame the entrance of the cultural hall and provide a grand entrance feel. Designing the courtyard cover proved to be a challenge as the old structure was to be preserved and a new structure had to be added. Initially, the idea was to follow the interior glass façade for the supports of the courtyard cover, but it was decided to use the old structure as it was still in good condition. Unique design options for the courtyard cover were explored through sketches, and two options were evaluated - one traditional and one more daring to frame the entrance.

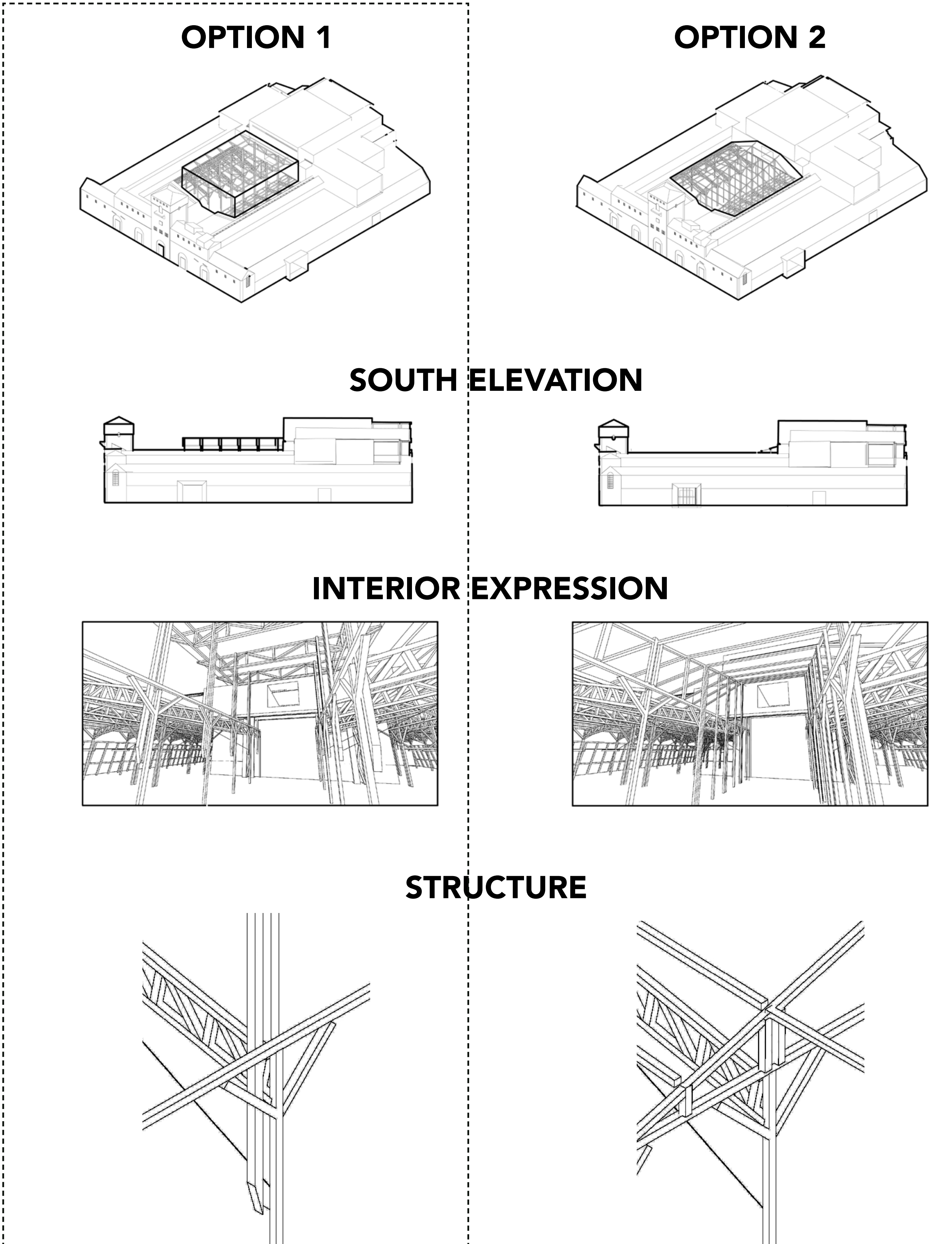
Option 1 was a modern truss frame flat square, resembling the black box shape of the cultural space and in contrast with the old structure in the courtyard. (119)

Option 2 was a tilted plane that flattened into the roof, offering a continuous shape that transferred into the cultural space. (120)

Both options were assessed from a constructive, elevation, and interior expression point of view. The square option was chosen as it was more subtle and offered a continuous expression of the cubes.

118. COURTYARD STRUCTURE SKETCH





119. OPTION 1 FOR COURTYARD

120. OPTION 2 FOR COURTYARD

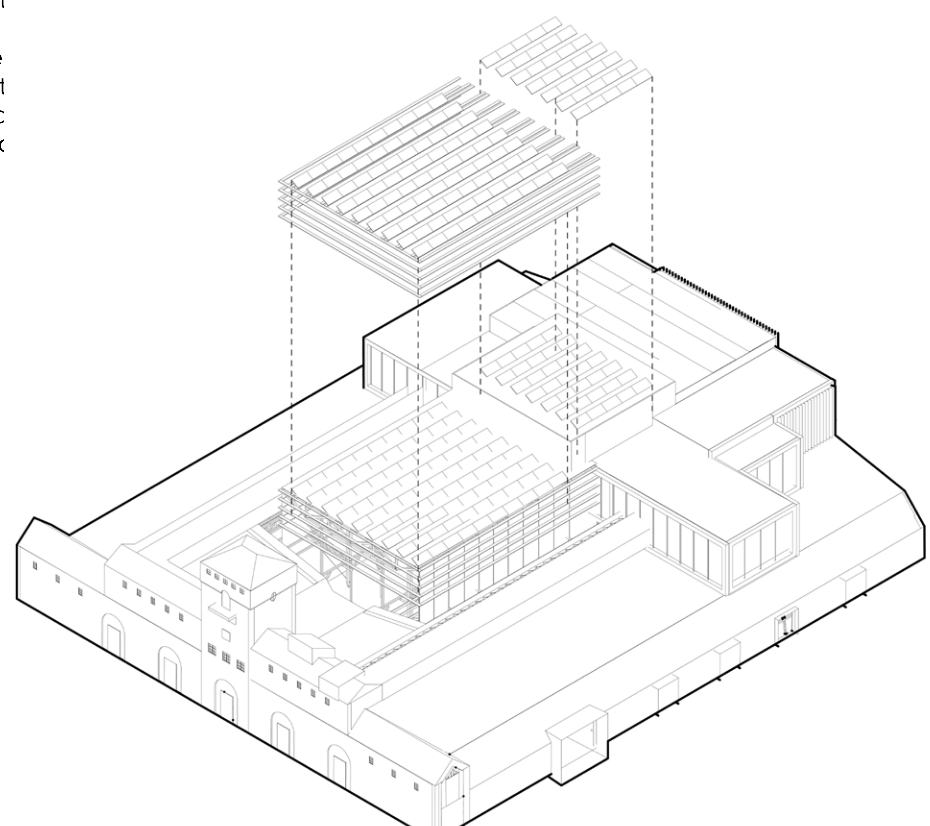
PASSIVE STRATEGIES - RENEWABLE TECH

_13_04_01_ PASSIVE STRATEGIES AND RENEWABLE TECHNOLOGIES

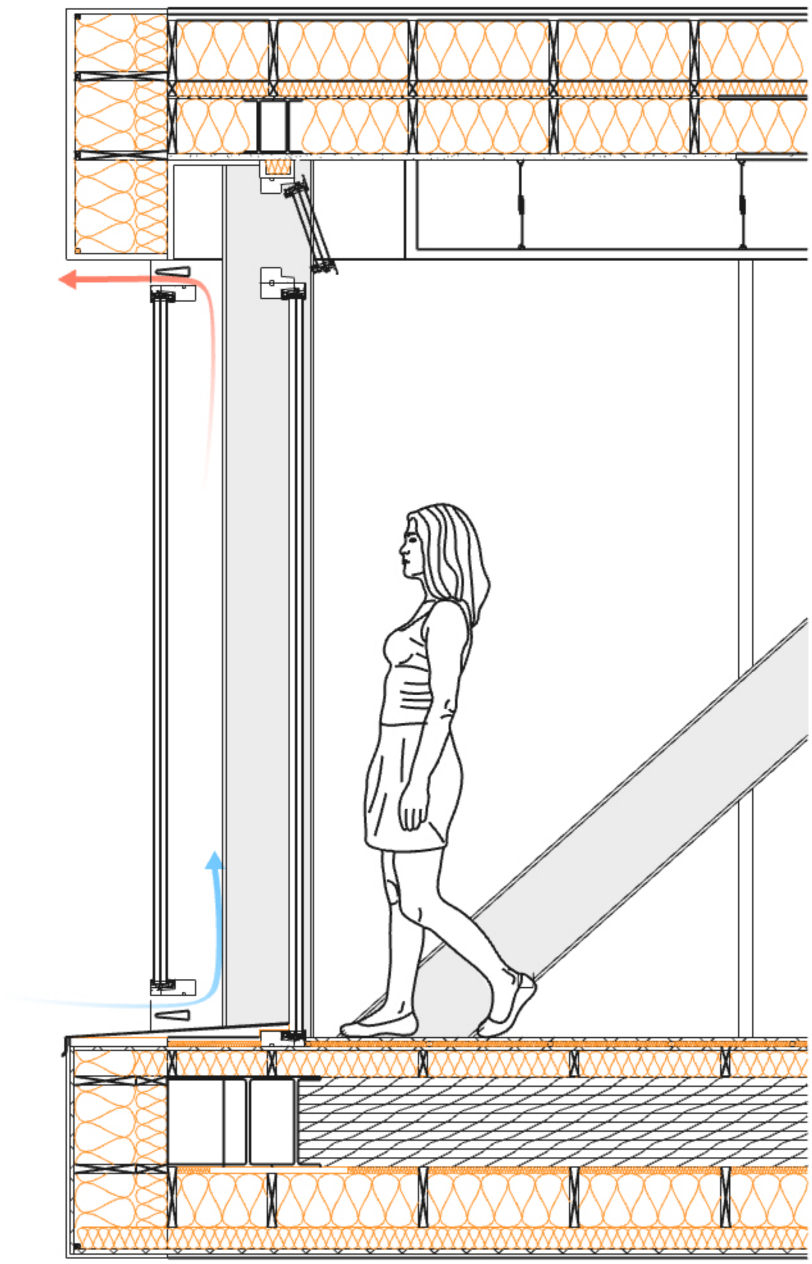
Passive strategies have been integrated into the design to address the large amount of glass façade facing south, while renewable strategies have been implemented to assist with the energy frame. To prevent overheating in specific areas with high sun exposure, passive strategies were employed.

Exterior shading was required for the courtyard, and various iterations were tested to create shading. The solution was to combine shading with the placement of PV panels. The shading had to reflect the continuous lines in the façade, creating horizontal ribbons across it. The roof of the courtyard was partially covered with PV panels. (121)

For the overhang of the cultural space, exterior shading was avoided to maintain the exterior expression. Instead, the passive strategy had to be added internally. The idea of interior shutters was tested, but they still allowed heat to transfer int the building. The solution for the overhang was double skin façade that allowed for internal shutte to be installed without allowing heat to transfer int the building. The buffer zone between the façac could then be naturally ventilated through the stac ventilation principle. (122)

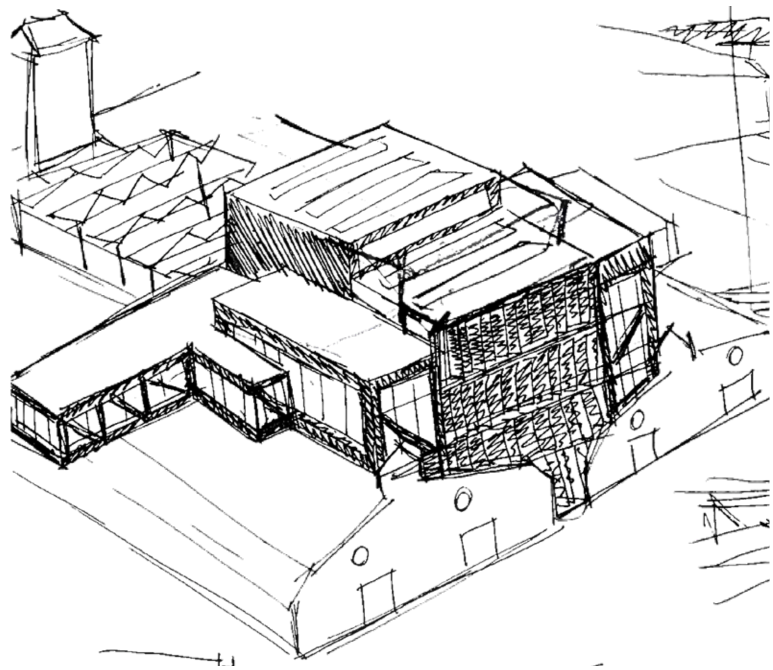


121. PASSIVE STRATEGIES



122. PRINCIPLE OF DOUBLE SKIN FACADE

MATERIALITY



123. INITIAL SKETCH FACADE

_13_04_02_ MATERIALITY AND FACADE

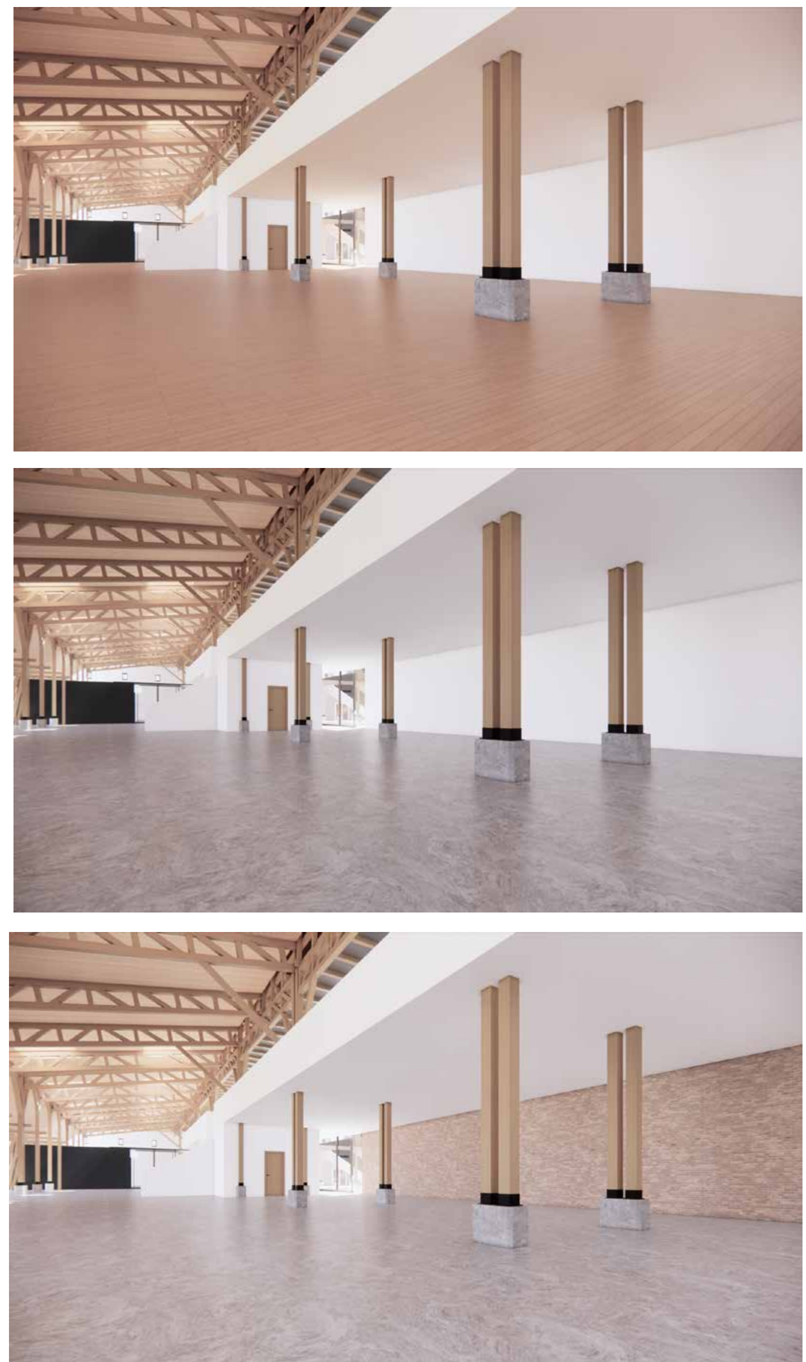
The materials used in the repaired and added elements of the design had to reflect the expression intended by the new function of the building as well as the renovation objective set for the project. The material compositions had to change along the building to reflect the character of its different areas.

In the two main halls the existing structure was the element intended to draw the most attention. To achieve that the added rooms and mezzanine were made in materials aligning with the warm tones of the existing elements and not overwhelm it.

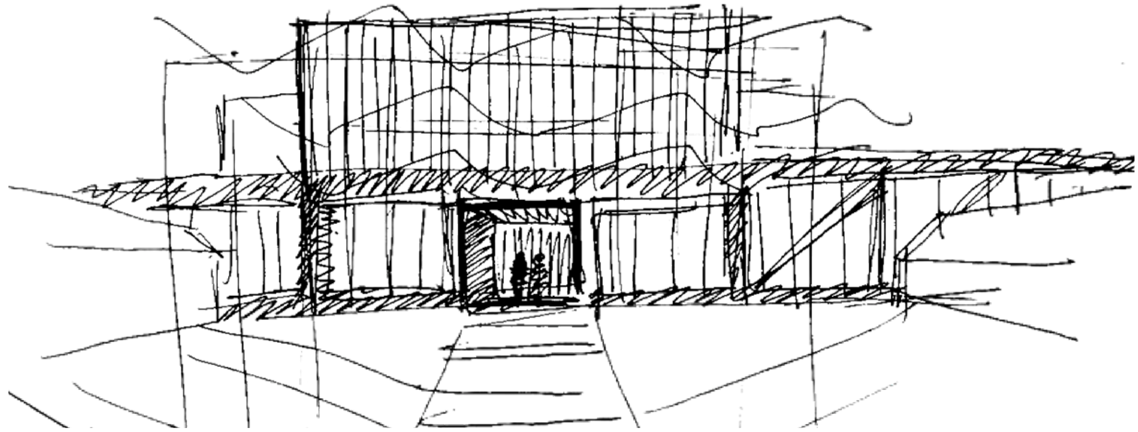
The form added to the existing building was also to follow the adaptation strategy established at the beginning of design development. Therefore, the used materials were not to imitate the existing, but contrast and indicate a new addition. The spaces considered as additions included the restaurant, courtyard roof and the cultural venue above the existing building.

The restaurant was considered a transitional space, as even though it was located within the area of the existing building, the original structure was removed and the new, large timber columns were indicating the added form rising from the ground. Therefore, the materiality of the restaurant interior and mezzanine structure was decided to maintain the warm, wood-focused atmosphere of the existing building but in a modern form (124). This provided the restaurant with a pleasant ambience and complemented the new structure exhibited in the dining area.

124. RESTAURANT INTERIOR



125. INTERIOR MATERIAL TEST RENDERS



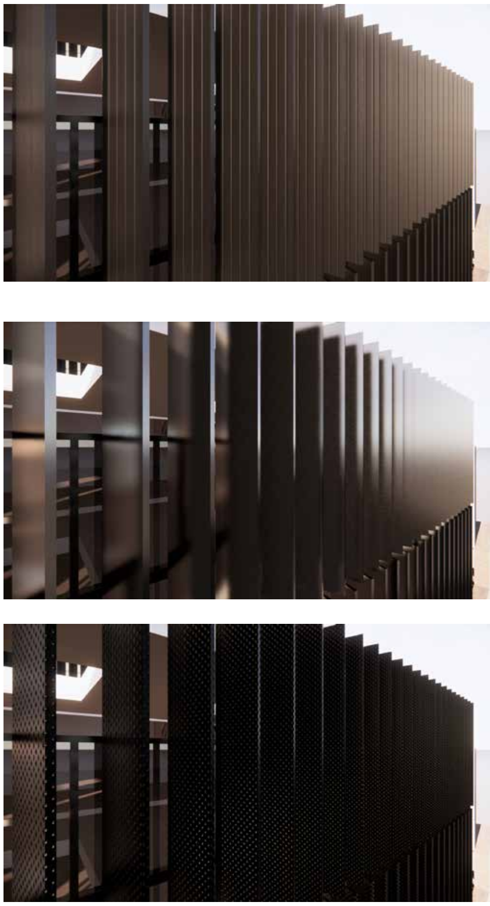
126. CULTURAL VENUE FACADE SKETCH

The cultural venue above the restaurant was considered the symbol of the new. As the from growing form the existing granary had to contrast with the warm materiality of the existing building and symbolize a piece of coal, an idea of a black box came forward as a base for the material choices.

The new addition consisted of cubical forms with the tallest one in the center of the structure. The concept of a viewing platform in the southern façade resulted in a glazed façade, opening the form towards harbour views (123). Apart from the large glazing, cubical forms were to have a dark, opaque cladding matching the steel structure exposed in the openings. Various expressions of steel cladding were tested in sketching, resulting in a choice for vertically connected dark zinc paneling (127).

The chosen cladding aligned with the desired expression of the smaller cubes. However, the largest one accommodating the main cultural facilities and the main entrance lacked in its texture. A number of different materials were tested in renders to find one that would establish the large middle form as a monumental coal representant, balancing the tower placed on the opposite façade(126). Finally, the design was concluded with glass fiber reinforced concrete panels resembling the irregular texture of coal (128).

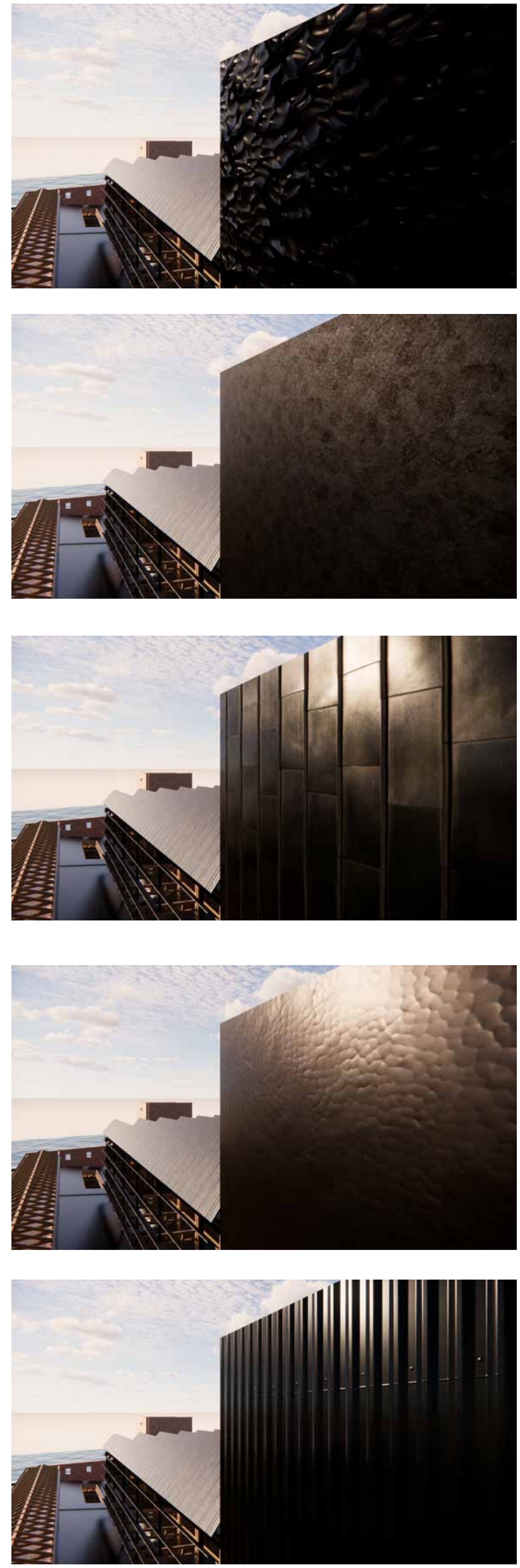
The roof over the courtyard had to be supported by the existing structure, however, it was also the extension of the added culture venue, and therefore the column material was chosen to be wood and the roof supporting frames, steel. This combination provided the vertical structure with the story of transition of existing columns into new addition and reflected the composition of structural materials



127. LAMELLAS TEST RENDERS

in the cultural building. The stairs leading from the courtyard up to the culture venue entrance have been chosen to have a black balustrade to connect them with the materiality of the large cube.

The external expression of the building is based on the existing façade contrasting with black additions indication new structure. The use of black frames in the window openings and an extended framed tunnel forming the main entrance is a key factor in showcasing, where there has been a subtraction from the original building. Simultaneously, the extended entrance tunnel together with the overhang creates the experience of possible beginning and end of a journey through the building.



128. CUBE FACADE TEST RENDERS

DAYLIGHT

_13_04_03_ DAYLIGHT

In order to ensure adequate levels of natural lighting within the building, new windows will be installed. The design of the windows must be such that it is respectful of the preexisting structure of the granary, while simultaneously facilitating an optimal level of daylight penetration. The building regulations' requirements for daylight (§379-381) state: the requirement to achieve 300 lux in at least half of the room (the relevant floor area) for at least half of the daylight hours is demonstrated by calculating the illuminance from daylight in all nodes of the calculation network for all daylight hours in the year.

ClimateStudio is a software used to analyze and evaluate buildings' environmental performance. ClimateStudio measures Spatial Daylight Autonomy (sDA), which is the percentage of regularly occupied floor area that meets the target illuminance level of 300 lux using daylight alone for at least 50% of occupied hours. This means that the area is considered 50% daylight autonomous. The aim for daylight is to have a minimum of 50% sDA in the building. Additionally, to prevent areas from being overly lit, an analysis called Annual Sunlight Exposure (ASE) is used. ASE looks at locations that receive direct sunlight (>1000 Lux directly from the sun) for more than 250 occupied hours. Here the aim for daylight is to have under 8 % in the building. ASE Is acceptable in areas which are considered hallways and not assigned work areas.

Ensuring the optimal daylight was an interactive process that required a lot of design options. Apart from the daylight simulation results, the possibility of overheating, chosen renovation approach and façade expression were taken into consideration.

Window north/ south

The initial windows strategy is to respect the façade and size of the exterior blue door, therefore the windows in the north and south façade have the same proportions as the doors. Due to the orientation in the façade the north requires more openings to bring more light into the building. Therefore, the north has by default an additional window. To determine the number of windows, multiple daylight simulations were conducted, testing 3 – 4 – 5. (129)

129. FACADE WINDOWS

The results represent the total sDA as they consider consecutive windows addition alterations.

The sDA result for 3 was 37,5 % sDA.

The sDA result for 4 was 39,5 % sDA.

The sDA result for 5 was 41,5 % sDA.

The analysis revealed that the configuration with five or six windows produced the optimal outcome, which is a logical conclusion given the greater number of windows. Additionally, the spacing between the windows was aesthetically pleasing, and this played a pivotal role in the design decision-making process. (129)

Skylights

The interior courtyard is a vital component in providing daylight throughout the building, and incorporating windows towards the courtyard facilitates the distribution of light. However, the challenge lies in lighting the high-ceilinged and deep hall, particularly the office area located in the north section of the building. In order to address this issue, skylights were a suitable solution, and various sizes were evaluated, including 1m / 1,5 m, and 1 x 2 meters. Skylights are then put together in clusters of four. The spacing between the window inside the cluster has then been tested for additionally.(130)

The amount of skylight is seven which match the spaces between the trusses in the ceiling. The overhang of the cultural space obstructed a portion of the roof which resulted in only six skylights in the southern roof.

The final solution was 1 x 2 meter window, in cluster with windows 2 meter apart. The difference in sDA was 52,2 to 55,5.

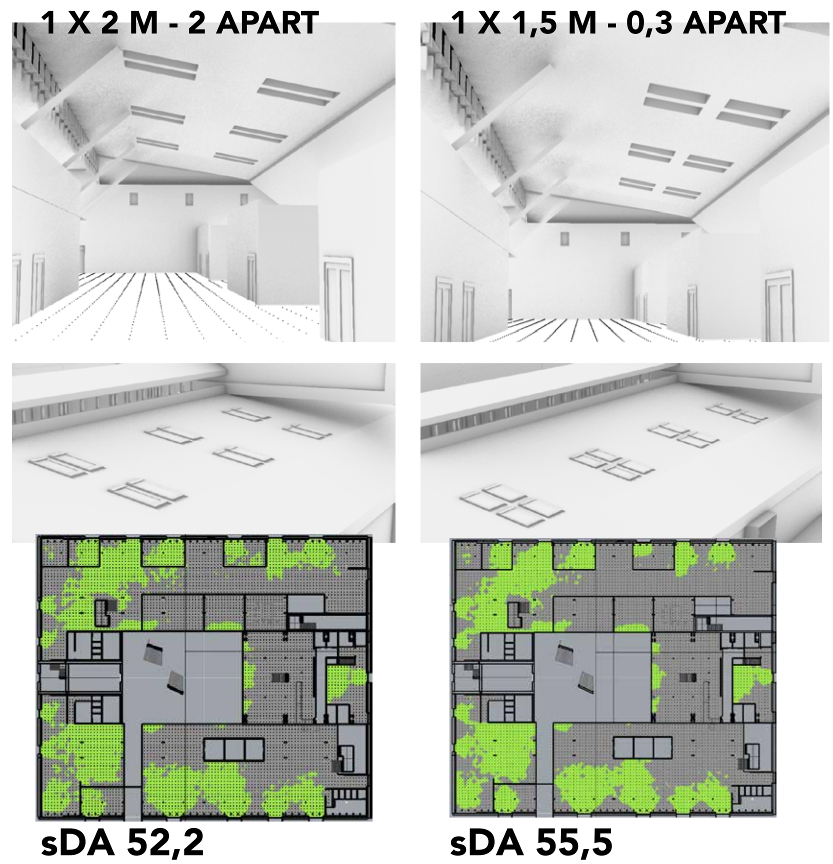
Cultural space

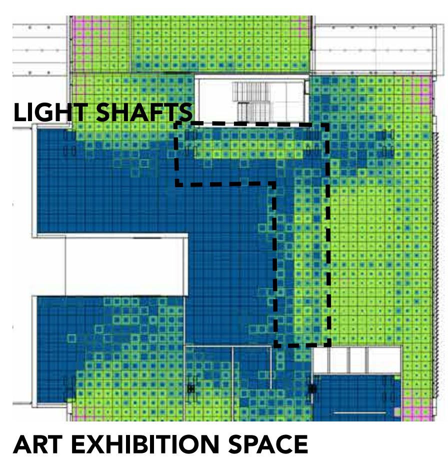
The illumination of the art exhibition space posed a challenge in terms of natural lighting. A lamella façade was incorporated into the east façade, but direct sunlight had to be avoided. The solution included light shafts that run from the roof to the art exhibition space via the concert hall. After testing, the optimal size for the light shafts was determined to be 6 m x 0.7 meters. However, the space failed to meet the requirements for sDA, which refers to the percentage of the daylight hours during which a specified minimum illuminance level is met. The Useful Daylight Illuminance (UDI) metric was used to assess the amount of usable light available to the occupants. The typical UDI values range from 100 to 300 lux, with values outside of this range being either too dim or too bright for most activities.

The UDI metric is divided into four categories, namely, Falling (less than 100 LUX), Supplemental (between 100 and 300 LUX), Autonomous (between 300 and 300 LUX), and Excessive (more than 3000 LUX). The incorporation of light shafts provided more supplemental light, which is beneficial for art spaces that do not require direct sunlight. (131) Furthermore, space in the exhibition is left dark intentionally so the exhibition can accommodate light sensitive pieces.

The final daylight result can be found in Appendix 5.

130. SKYLIGHTS





131. SKYLIGHTS IN ART EXHIBITION

BIM AND DIGITAL TWIN

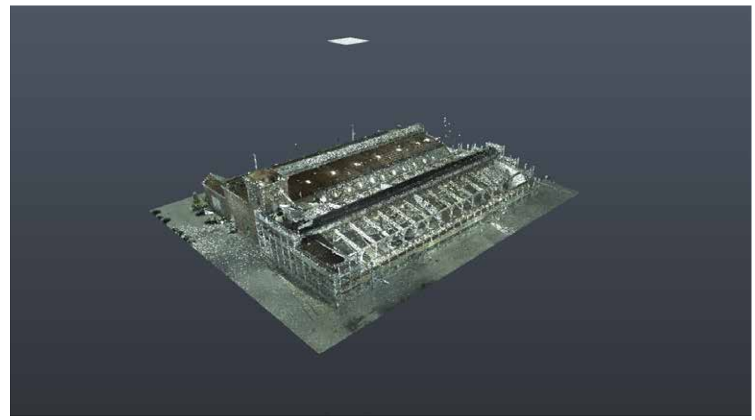
_13_04_04_ BIM AND THE DIGITAL TWIN

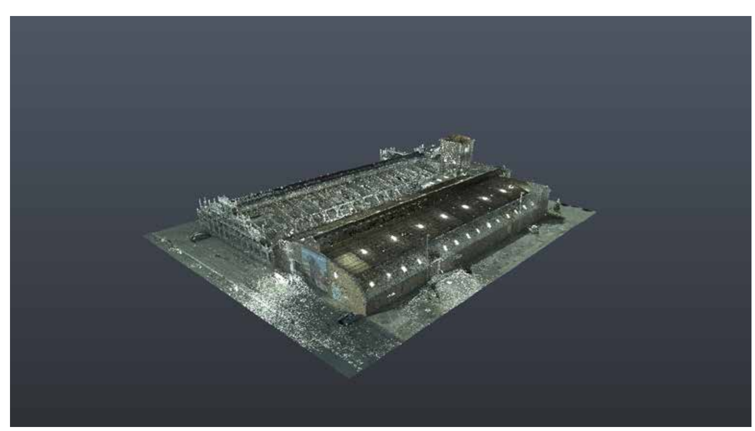
The process of utilizing BIM tools began in the analysis phase. Data gathered during the site visit and existing documentation helped with the creation of an initial model. Further, the point cloud scan of the granary shared by the site owner allowed for detailing the model and adjusting for any changes caused by deterioration (132). This resulted in a library of existing building elements. The elements registered in the model were: walls, columns, timber framing, doors, windows, and roof structure and can be seen in the schedule examples in Appendix 6. As the used software allows for assigning elements properties, mentioned structure was assigned assembly codes for identification and marked with the SAVE method values as indications of the current condition and architectural value. The phasing of the design model allowed for the management of the existing structure.

As design progressed, the model was updated, with elements requiring replacement being marked as demolished and evaluated for possible reuse. With the poor state of most of the damaged timber fragments most of the wooden structure was set not to be reused in the adaptation. However, the brick from removed walls had a potential of reuse due to the demolished volume and repairments required in the façade.

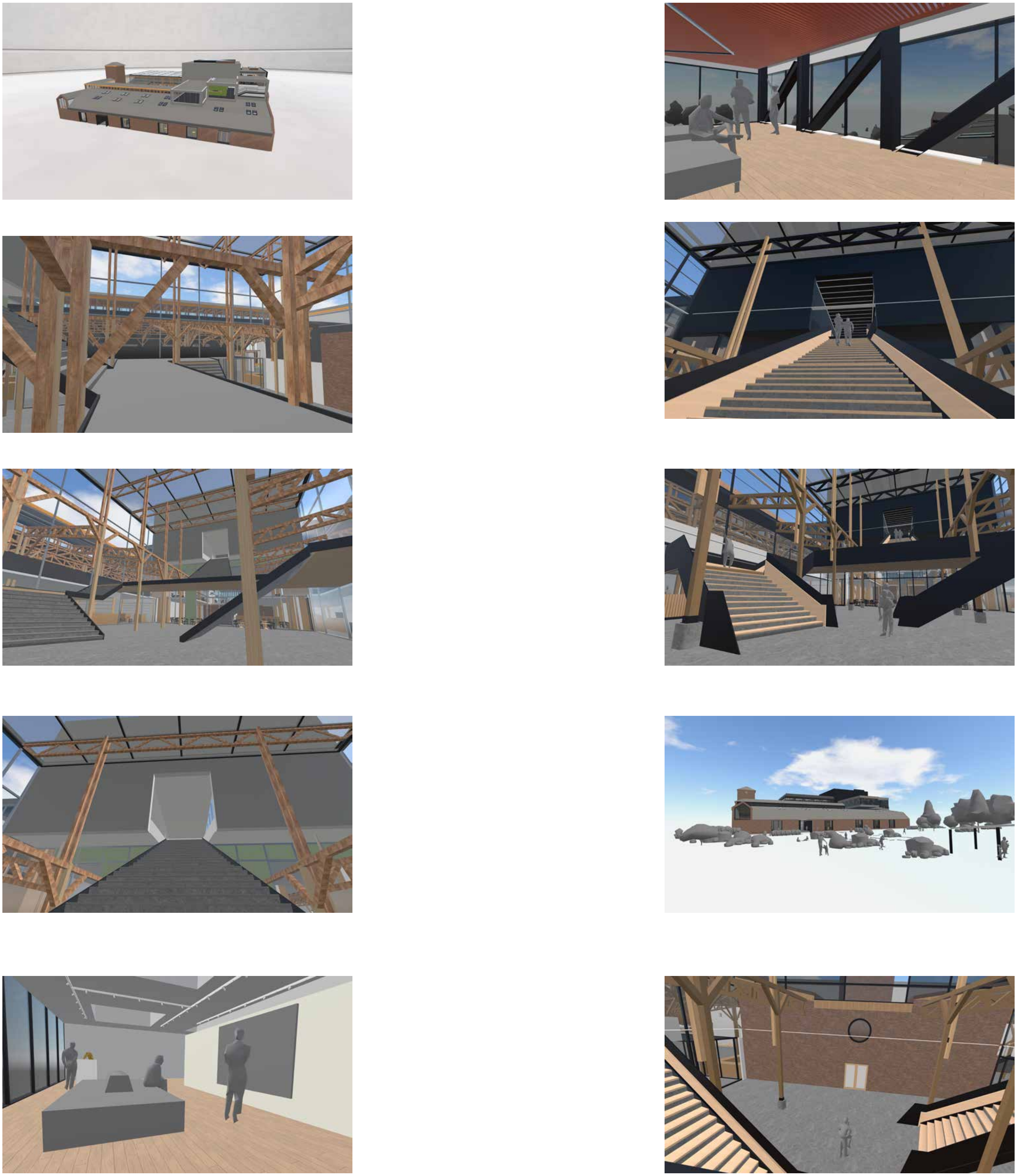
A detailed building model together with a virtual reality BIM tool, Prospect by IrisVR, allowed for evaluation of the design and its alterations (133). The courtyard staircase design was tested in a virtual reality model to achieve the desired user experience when walking through the building. The life-like experience of the building exposed the strong features as well as challenges of the design, that would not be noticed otherwise.

Finally, as the design came to a conclusion, schedules containing all modelled elements could be created. Together with assigned element properties, a complete model library displayed the balance between the added and existing elements and presented a potential for use in the building's future life stages.





132. INITIAL 3D SCAN



133. VR PERSPECTIVE TESTS

EPILOGUE

_14_ EPILOGUE

This final section of the report will conclude on the design and its development in relation to the set problem question, and further reflect on the process and the final design. The epilog draws a connection to the initial program and its goals to encapsulate the achievements and challenges of the design process.

CONCLUSION

_14_01_ CONCLUSION

The adaptive reuse design transformed the old granary into a creative hub, interacting with the community of Odense in various ways, thanks to its multifunctional character. Adaptation follows three main design drivers focusing on different scales in the project to achieve the objective of the thesis. Each driver has been developed through a critical alteration process to ensure a holistic transformation design. In the large scale "Harbour Creative Exchange" building responds to the needs of a harbour vision, while embracing the history of the building. The granary, once closed off from the waterfront and old city, is now inviting the public with its open plaza and intriguing added design. Furthermore, while looking at the project in the medium scale, the historical *zeitgeist* translates to the functions inside the granary. Halls focused on import and export of the goods and ideas encapsulate the character of building's heritage. In the added volumes cultural facilities complement the functions in the granary halls and establish the building as a cultural center of the harbour. Added functions are hosted by the new adaptation design, balancing the concepts of addition and subtraction in the forms of the building. The contrasting materials respect the historical architecture and help the guests to better understand the building. Achieved balance forms a path through the building, which showcases all aspects of the design. Visible from the plaza, the extruded entrance leads the visitors inside the building and guides them through the courtyard and finally to the viewing platform. As the beginning and ending point of the journey is visible from the perspective of the harbour front, the building invites all the public to experience and look over the harbour's landscape becoming a destination point for the visitors of Odense. In the small scale, the history of the building is exposed by the renovation. Its industrial heritage has been respected and preserved in its finest elements. Open halls of the building, with their beautiful structure can be experienced in their original form in the outer hall wings, and exposed in the courtyard. The tower remains as a historical pinnacle, emphasizing the architectural value of the existing building from the outside and showcasing the past in its museum inside.

The main technical objective of this report is to develop the transformation design with the utilization BIM tools. The design development has exposed these tools as particularly beneficial in a project of an existing building. The digital twin of the existing structure enabled for better understanding of the granary and throughout the design process has proven to be a great support in element management as well as design decisions. The final data gathered in the building element library not only provides an overview of the design, but also supports the challenges of heritage projects. If maintained, this database works towards elongation of building's life cycle.

Presented design responds to the challenges of industrial harbour architecture adaptation, balancing the "old" and the "new" elements of the building. However, the main principal behind adaptive reuse is giving an unused building a new life. To achieve that, the design, as well as the functions, have to activate the location for years to come. The "Harbour Creative Exchange" responds to that need with its wholesome design outlook and technical database enabling for the building to reinvent itself depending on the needs of the Odense's harbour.

REFLECTION

_14_02_ REFLECTION

The development of the adaptation design has been a process requiring a particular structure due to its unique nature. Evaluation of the industrial heritage in the architecture of the granary has proven to be a long process, requiring advanced expertise and equipment. The used SAVE survey method provided an outline for the evaluation, but due to its subjective character it could not be established as the main decisive tool for the renovation phase. Existing building, hosting the new design, provided inspiration and guidance in the search for the concept. However, it has also restricted the interior layout and form of the design. It was also caused by the taken adaptation approach of respecting and showcasing the valuable architectural elements of the granary. This resulted in a need for a significant amount of design alterations to enable for a new function while embracing the existing building. The industrial character of the harbour building has also required special attention during the design development. Façade and overall detailing, usually prominent in architectural heritage buildings, were not elements that could stand as the main exciting features of the public-focused design. Therefore, the adaptation had to embrace the overall unique from of the granary and add a volume that made it stand out in the harbour's architectural landscape.

The placement and design of the cultural venue above the existing halls has also resulted in various challenges that, could have been averted by a different concept approach. The support of a massive weight of a public venue, constricted within the existing clerestories resulted in a large added structure. If the restaurant, placed underneath the cultural venue, was to be the function placed in the added structure, as a lighter function it would not require as big of a supporting structure. The demolition of the existing timber framing under the cultural venue was a necessary step to allow for the new structure growing from the existing building. However, if the preservation of the valuable historical elements was the main priority of the thesis, the structure could have been preserved with an alternative concept of the cultural venue.

Adaptation projects require the design relating to a variety of specialized building disciplines. Because of the nature of this thesis, focus areas had to be specified, which resulted in some of the design aspects remaining unexplored. Indoor climate and life cycle assessment would have been topics detailed next if the thesis topic was to be developed further. The areas of focus have also limited the detail level of the digital twin. The structure being the topic explored in renovation and adaptation design allowed for a creation of an element library. However, to utilize it as intended, as a maintenance and material reuse base, other elements such as ventilation systems should be included and controlled within the digital twin model.

Despite challenges presented by the adaptative reuse process, the goal of transforming an old industrial harbour building into an active feature of the city was achieved, and the new design maintains a good balance between the existing granary and added volumes. The process also exposed the opportunities in the use of BIM tools in existing building projects, which could be further explored in future research.

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_15_ BIBLIOGRAPHY

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ILLUSTRATION LIST

APPENDIX

INDEX

Appendix: SAVE SURVEY

Building – Odense, Havnegade 16, bygning 1

BBR-oplysninger

BBR-number: 461 – 153127 – 1
Municipality: Odense
Address: Havnegade 16, 5000 Odense
Building number : 1
Property number: 153127
Building type: building
Number of floors: 1
Developed area: 3640
Total building area: 3640
BBR-building history:

- Construction year: 1926

Application: office, trade, storage, admin
Area source: by owner
Roof deck: roofing felt
Exterior wall: Brick (tile, sandstone, cement tile)
Material source: by owner

BBR-Ændringer

Tagdækningsændring: skifer, asbestcement

SAVE-undersøgelse

ARCHITECTURAL VALUE: 4

The warehouse is single standing building consisting of a double hall with a tower and two transepts. The two transepts continues on the halls to form clerestory's.

The granary is has a central location in the harbour, and is one of the oldest building in the harbour.

The granary is symmetrical over the east-west axis. The granary is clearly a place of storage as the building is spacious and robust.

CULTURE-HISTORICAL VALUE: 3

The granary is the only one of its kind resembling a different type of granary that has to be operated by hand. The wood structure resembles the craftsmanship and materials of the time. The granary was drawn by the engineer J. Christensen.

SORRUNDINGS VALUE: 2

The granary stands as one of two buildings untouched in the harbour, which resemble the previous industry in the harbour. The granary´s tower bring a lot of history to the harbour.

ORIGINALITY: 3

The warehouse is almost in its original condition, with the roof collapsed in some area. The original roof from 1925 has been changed at some point into roofing tiles, but besides the roof the building stands untouched.

Furthermore, a door has been shifted out with a revolving door for forklift to enter the warehouse.

CONDITION: 5

Due to the lack of maintenance over the years the roof has been in poor condition resulting in collapse in some places. The moisture has passed into the wall thus resulting in crack in the brickwork.

OVERALL SAVE ASSEMSNT: 3

After reviewing the five parameters, the overall assessment of the granary is 3.

This is based on the unique granary which is one of the last original buildings on the harbour that hasn't been demolish or refurbished. The architectural value is unique with its tower and two halls combined with clerestory´s on top, the symmetry of the building and the icon blue doors. The west façade consisting of the tower and transepts are iconic for the building and is a key feature of the granary. The warehouse ooze of the harbour environment where grain and coal were exchanged. The originality is still high as this building hasn't seen significant change, nevertheless, the lack of maintenance and renovation of the warehouse is noticeable, with many walls being cracked and the roof collapsing some places.

Building construction
Building part: tower, Spire, ridge turret
Building part: Balcony
Door/gate: hinged door
Original function: granary
Gable construction: foundation wall gable
Cornice: Masonry cornice
Main plan: Single-jointed building

Base: marked, plaster
Style: historicism
Roof construction: pitched roof/ full roof - hipped roof
Decoration: details in natural stone, plaster, cement or metal
Window: rectangular - round arched
Outer wall: untreated surface
Building surroundings:
Built-up area: Industrial area, Harbour
Surroundings: Plant, harbor quay

Photograph:

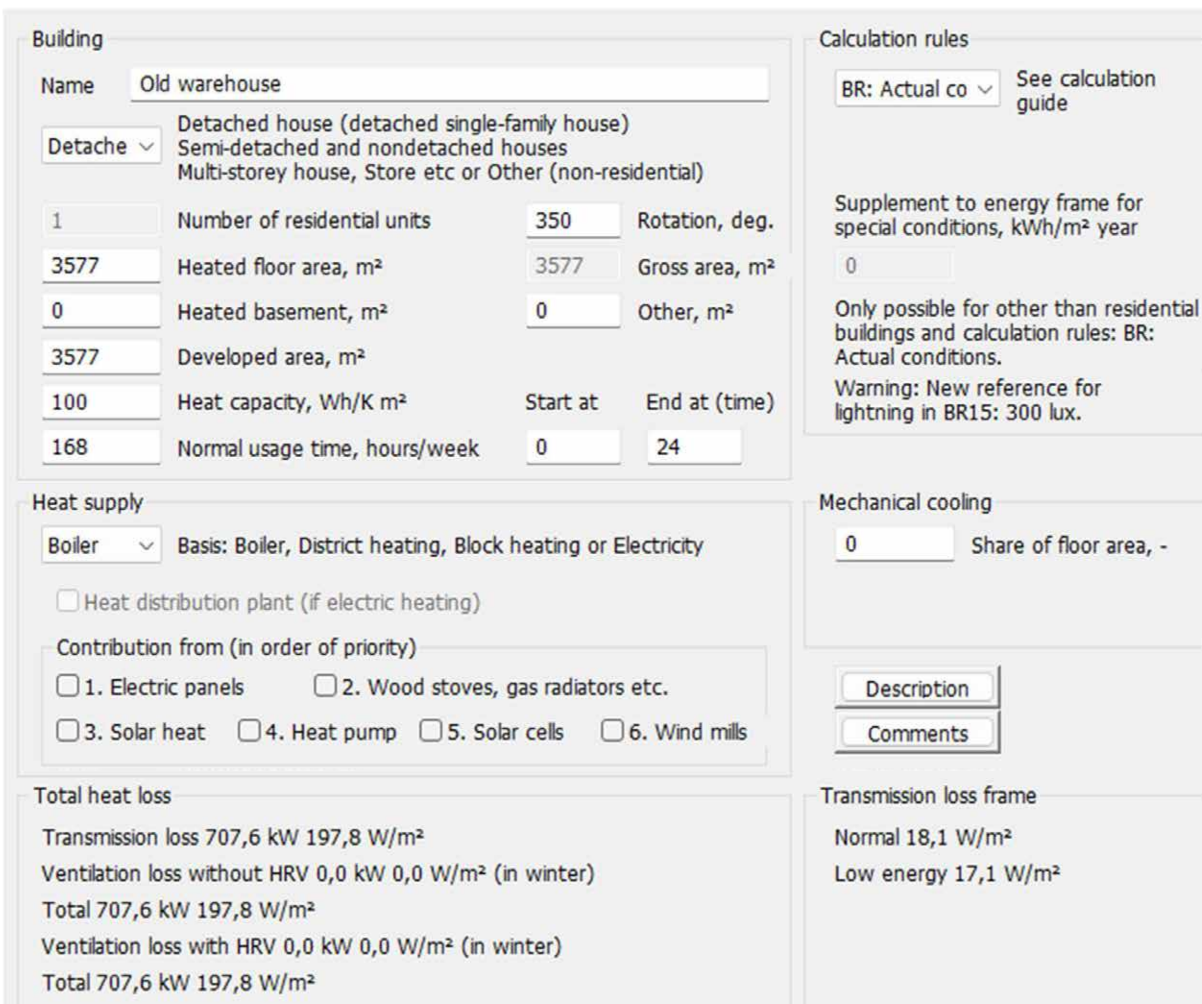
APPENDIX 2 - ENERGY PERFORMANCE

Appendix: Energy performance: BE18

In order to understand the thermal properties of the existing building a calculation of the energy frame has been made. The calculation will create the basis for improvement of the building and highlight opportunities for improvements in the building. To calculate the energy frame of the building the program "BE18" has been used.

The building

The building has a heated floor area of 3577 sq. meter and is constructed in brick walls and wood roof structure. The heat capacity is assumed to be 100 Wh/km2. The heating will in the future be connected the the district heating system with photovoltaics on the roof as a renewable energy source.



Climate envelope

Exterior walls, floor and roof

The existing building is consisting of two types of walls. A 360 mm brick wall and a 480 mm brick wall. These walls has big potential for improvement since the walls are solid and has a poor energy performance. The same goes for the roof and floor which has a huge potential for improvement.

	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Insid	Dim.Outsi	Loss (W)
		9616,9		CtrlClick	19748,8			699300
+1	South facade360mm	202	1,398	1,00	282,396			9036,67
2	southfacade 480mm	33	1,114	1,00	36,762			1176,38
3	east facade1	177,5	1,114	1,00	197,735			6327,52
4	east facade 2	177,5	1,114	1,00	197,735			6327,52
5	North facade 360mm	202	1,398	1,00	282,396			9036,67
6	North facade 480mm	33	1,114	1,00	36,762			1176,38
7	tower	271	1,114	1,00	301,894			9660,61
8	west facade480 mm	492,9	1,114	1,00	549,091			17570,9
9	inbetween walls360mm	354	1,398	1,00	494,892			15836,5
10	roof	4097	3,041	1,00	12459			398687
11	floor	3577	1,961	0,70	4910,15			224464

Improvements

The walls will be raised to energy standards with a U-value of 0,21 W/K. The roof is improved to 0,125 W/K and floor improved to 0,107 W/K.

The climate envelope for use in Be18 is an estimation rather than a detailed solution.

	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		8891,9		CtrlClick	1035,8			36819,9
+1	South facade360mm	152	0,21	1,00	31,92	20	-12	1021,44
2	southfacade 480mm	33	0,21	1,00	6,93	20	-12	221,76
3	east facade1	177,5	0,21	1,00	37,275	20	-12	1192,8
4	east facade 2	177,5	0,21	1,00	37,275	20	-12	1192,8
5	North facade 360mm	152	0,21	1,00	31,92	20	-12	1021,44
6	North facade 480mm	33	0,21	1,00	6,93	20	-12	221,76
7	west facade480 mm	492,9	0,21	1,00	103,509	20	-12	3312,29
8	roof	4097	0,125	1,00	512,125	20	-12	16388
9	gulv	3577	0,107	0,70	267,917	20	-12	12247,6

Windows

The windows is the existing building is a single pane window, which has a big heat loos. The heat loss has been identified as 5,2 W/m²K. The single pane window is an important element in the façade and will be kept and improved.

	Windows and outer doors	Numbe	Orient	Inclinatio	Area (m²)	U (W/m²K)	b	Ht (W/K)	Ff (-)	g (-)	Shading	Fc (-)	Dim.Insid	Dim.Outs	Loss (W)	Ext
		17			1391,9		CtrlClick	2216,9			CtrlClick				56860,8	0/1
1	west windows	1	270	90	19,6	3	1,00	58,8	0,8	0,53	Default	0,1			1881,6	0
2	East windows	1	90	90	19,7	3	1,00	59,1	0,8	0,53	Default	0,1			1891,2	0
3	south windows	1	180	90	5,3	3	1,00	15,9	0,8	0,53		0,1			508,8	0
4	north windows	1	0	90	5,3	3	1,00	15,9	0,8	0,53	Default	0,1			508,8	0
5	new south windows	1	180	30	150	1,6	1,00	240	0,8	0,53		0,1			7680	0
6	new north window	1	0	30	150	1,6	1,00	240	0,8	0,53	Default	0,1			7680	0
7	skylight north	1	0	25	48	1,6	1,00	76,8	0,8	0,53	Default	0,1			2457,6	0
8	skylight south	1	90	25	54	1,6	1,00	86,4	0,8	0,53	Default	0,1			2764,8	0
9	resturant curtian wall	1	270	90	240	1,6	1,00	384	0,8	0,53	Default	0,1			12288	0
10	cafe curtian wall	1	0	90	100	1,6	1,00	160	0,8	0,53	Default	0,1			5120	0
11	office	1	90	90	100	1,6	1,00	160	0,8	0,53	Default	0,1			5120	0
12	new north windows	1	0	90	50	0,8	1,00	40	0,8	0,53	Default	0,1			1280	0
13	new south windows	1	90	90	50	0,8	1,00	40	0,8	0,53		0,1			1280	0
14	glass courtyard	1	180	90	100	1,6	1,00	160	0,8	0,53	Default	1	20	10	1600	0
15	glass courtyard	1	0	90	100	1,6	1,00	160	0,8	0,63	Default	1	20	10	1600	0
16	glass courtyard	1	90	90	100	1,6	1,00	160	0,8	0,63	Default	1	20	10	1600	0
17	glass courtyard	1	270	90	100	1,6	1,00	160	0,8	0,63	Default	1	20	10	1600	0

Improvements

The building has very few windows in the façade and roof, to open op the building a courtyard is added with curtain walls to bring more light into the building. Additionally, the building has no windows in the north and south façade.

The new north and south windows are:

Velfac 200 energy with Velfac standard pane

U-value: 0,8 W/m²K

g-value: 0,52

glass area:80% = 0,8

	Windows and outer doors	Numbe	Orient	Inclinati	Area (m²)	U (W/m²K)	b	Ht (W/K)	Ff (-)	g (-)	Shading	Fc (-)	Dim.Insi	Dim.Out	Loss (W)	Ext
		13			991,9		CtrlClick	1576,9			CtrlClick				50460,8	0/1
1	west windows	1	270	90	19,6	3	1,00	58,8	0,8	0,53	Default	0,1			1881,6	0
2	East windows	1	90	90	19,7	3	1,00	59,1	0,8	0,53	Default	0,1			1891,2	0
3	south windows	1	180	90	5,3	3	1,00	15,9	0,8	0,53		0,1			508,8	0
4	north windows	1	0	90	5,3	3	1,00	15,9	0,8	0,53	Default	0,1			508,8	0
5	new south windows	1	180	30	150	1,6	1,00	240	0,8	0,53		0,1			7680	0
6	new north window	1	0	30	150	1,6	1,00	240	0,8	0,53	Default	0,1			7680	0
7	skylight north	1	0	25	48	1,6	1,00	76,8	0,8	0,53	Default	0,1			2457,6	0
8	skylight south	1	90	25	54	1,6	1,00	86,4	0,8	0,53	Default	0,1			2764,8	0
9	resturant curtian wall	1	270	90	240	1,6	1,00	384	0,8	0,53	Default	0,1			12288	0
10	cafe curtian wall	1	0	90	100	1,6	1,00	160	0,8	0,53	Default	0,1			5120	0
11	office	1	90	90	100	1,6	1,00	160	0,8	0,53	Default	0,1			5120	0
12	new north windows	1	0	90	50	0,8	1,00	40	0,8	0,53	Default	0,1			1280	0
13	new south windows	1	90	90	50	0,8	1,00	40	0,8	0,53		0,1			1280	0

Ventilation

The existing building didn't have a ventilation strategy. The new strategy is to divide the building into zones as restaurant, office, cafe and museum.

Mechanical ventilation

The values for the mechanical ventilation is decided to sensory comfort [decipol] where the requirement is 1 decipol in comfort category I/A (Dansk standard, 2007, DS/EN 15251)

Thermal efficiency

To minimize energy loss and energy consumption a heat recovery system is used for heating together with district heating. It is assumed that the thermal efficiency is 80 %.

	Ventilation	Area (m²)	Fo, -	qm (l/s m²	n vgv (-)	ti (°C)	El-H(	qn (l/s m²)	qi,n (l/s m²	SEL (kJ/m	qm,s (l/s n	qn,s (l/s m	qm,n (l/s n	qn,n (l/s n
	Zone	3300		Winter			0/1	Winter	Winter		Summer	Summer	Night	Night
1	resturant	1000	1	1,4	0,8	18	0	0	0	1	1,2	3	0	0
2	office	1000	1	1,4	0,8	18	0	0	0	1	1,2	3	0	0
3	cafe	1000	1	1,4	0,8	18	0	0	0	1	1,2	3	0	0
4	musuem	300	1	1,4	0,8	18	0	0	0	1	1,2	3	0	0

Internal heat supply

Persons

Internal heat from people within the building is compliant with the recommendations from SBi213 with a value of 1,5 W pr. Sq. m.

For equipment within the building the heat load is assumed to be compliant with the SBi 213 with a value of 3,5W pr. Sq. m. with a low use and a 6 W pr. Sq. m for high use.

	Internal heat supply	Area (m²)	Persons (W/m²)	App. (W/m²)	App.night (W/m²)
	Zone	2800,0	4200,0 W	12800,0 W	450,0 W
1	office	1200	1,5	6	0
2	resturant	300	1,5	3,5	1,5
3	cafe	1000	1,5	3,5	0
4	museum	300	1,5	3,5	0

Solar cells

The building will have photovoltaic planes placed in the roof to help with the energy frame as renewable energy. The photovoltaics are based on monocrystalline photovoltaics.

Description: Nyt solcelle anlæg

Solar cells

400	Panel areal, m²
0,105	Peak Power (RS), kW/m²
0,75	System efficiency (Rp), -

Orientation and shadows

S	Orientation, S, SE, E, ...		
30	Slope, °, 0, 10, 20, 30, ...		
0	Horizon cutoff, °		
0	Left shadow, °	0	Right shadow, °

Result of energy frame

OLD building

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
70,6	0,0	70,6
Total energy requirement		537,6

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
53,0	0,0	53,0
Total energy requirement		537,6

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
30,3	0,0	30,3
Total energy requirement		537,6

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
27,0	0,0	27,0
Total energy requirement		537,6

Contribution to energy requirement	
Heat	537,6
El. for operation of bulding	0,0
Excessive in rooms	0,0

Net requirement	
Room heating	537,6
Domestic hot water	0,0
Cooling	0,0

Selected electricity requirements	
Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	0,0
Pumps	0,0
Cooling	0,0
Total el. consumption	0,0

Heat loss from installations	
Room heating	0,0
Domestic hot water	0,0

Output from special sources	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

New building

Key numbers, kWh/m² year

Renovation class 2

Without supplement	Supplement for special conditions	Total energy frame
70,6	0,0	70,6
Total energy requirement		52,8

Renovation class 1

Without supplement	Supplement for special conditions	Total energy frame
53,0	0,0	53,0
Total energy requirement		52,8

Energy frame BR 2018

Without supplement	Supplement for special conditions	Total energy frame
30,3	0,0	30,3
Total energy requirement		52,8

Energy frame low energy

Without supplement	Supplement for special conditions	Total energy frame
27,0	0,0	27,0
Total energy requirement		52,8

Contribution to energy requirement	
Heat	61,6
El. for operation of bulding	0,2
Excessive in rooms	0,0

Net requirement	
Room heating	61,6
Domestic hot water	0,0
Cooling	0,0

Selected electricity requirements	
Lighting	88,2
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	11,0
Pumps	0,0
Cooling	0,0
Total el. consumption	42,4

Heat loss from installations	
Room heating	0,0
Domestic hot water	0,0

Output from special sources	
Solar heat	0,0
Heat pump	0,0
Solar cells	10,8
Wind mills	0,0

The new building is achieving renovation class 1, which was the overall goal.

Transmission loss

Total heat loss

Transmission loss 95,5 kW 26,7 W/m²

Ventilation loss without HRV 178,9 kW 50,0 W/m² (in winter)

Total 274,4 kW 76,7 W/m²

Ventilation loss with HRV 35,8 kW 10,0 W/m² (in winter)

Total 131,3 kW 36,7 W/m²

Transmission loss frame

Normal 18,1 W/m²

Low energy 17,1 W/m²

The transmission loss is under 30 W/ m², which was a design criteria.

APPENDIX 3 - RENOVATION DETAILS AND MOISTURE BUILD-UP

Index:

1 - Original roof
2 - New roof
3 -Original floor
4 - New floor
5 - 360 mm wall
6 - New 360 mm wall
7 - 480 mm wall
8 - New 480 wall

Original roof

Roof construction
created on 15.4.2023

Thermal protection

U = 3,02 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

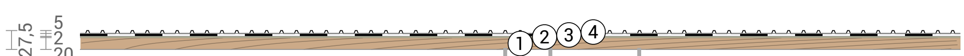
Surface temperature at inside too low!
Dries 45 days
Wood moisture: +0,1%

excellent insufficient

Heat protection

Temperature amplitude damping: 1,0
phase shift: 0,6 h
Thermal capacity inside: 5,7 kJ/m²K

excellent insufficient



1 Pine (20 mm)
2 Asbest lose gestopft (2 mm)
3 Vapor retarder sd=5m
4 trapezoidal sheet (5 mm)

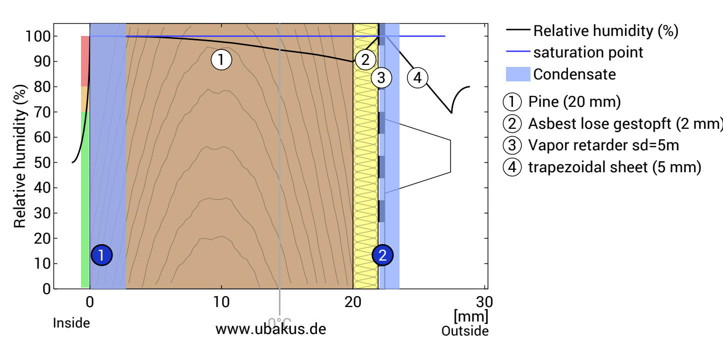
Condensation areas

1 Condensate: Affected layers: Pine

2 Condensate: 1,5 kg/m² Affected layers: Vapor retarder sd=5m, Asbest lose gestopft, trapezoidal sheet

Humidity

The temperature of the inside surface is 4,6 °C leading to a relative humidity on the surface of 100%.Most kinds of moulds start to grow at relative air humidities of 80% or more. Mould grow is expected! To avoid mould formation, the surface temperature should be increased by (additional) insulation.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

New roof

Roof construction
created on 15.4.2023

Thermal protection

U = 0,13 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

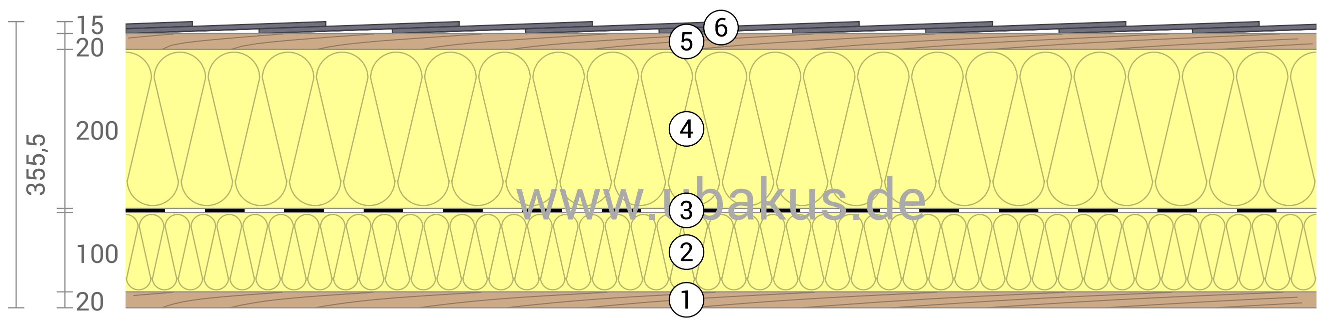
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 16
phase shift: 10,8 h
Thermal capacity inside: 24 kJ/m²K

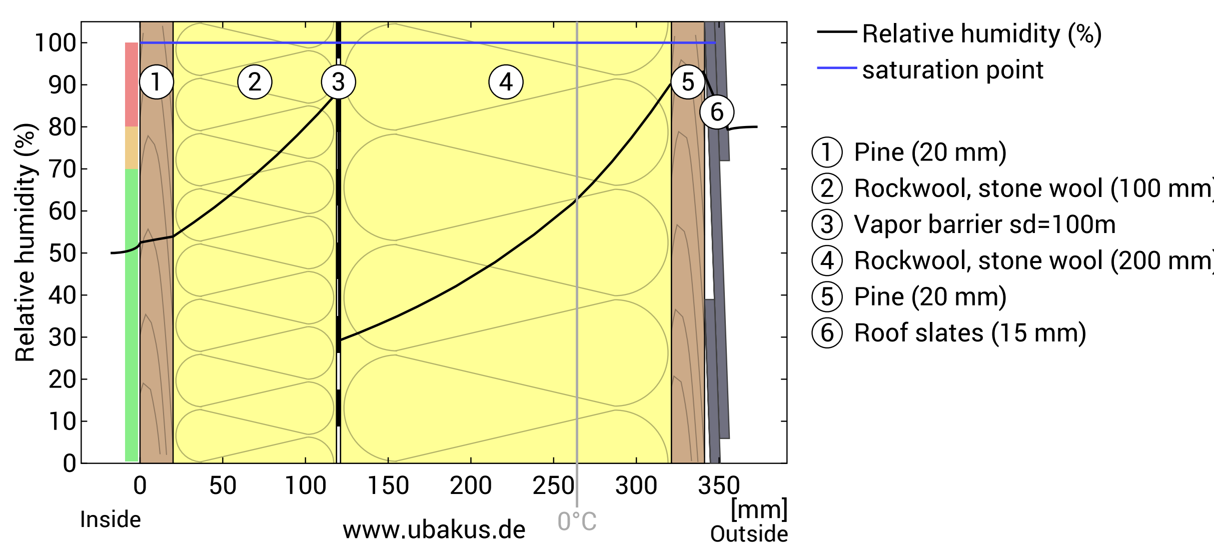
excellent insufficient



1. Pine (20 mm)
2. Rockwool, stone wool (100 mm)
3. Vapor barrier sd=100m
4. Rockwool, stone wool (200 mm)
5. Pine (20 mm)
6. Roof slates (15 mm)

Humidity

The temperature of the inside surface is 19,2 °C leading to a relative humidity on the surface of 53%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

Original Floor

Floor
created on 15.4.2023

Thermal protection

U = 1,96 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

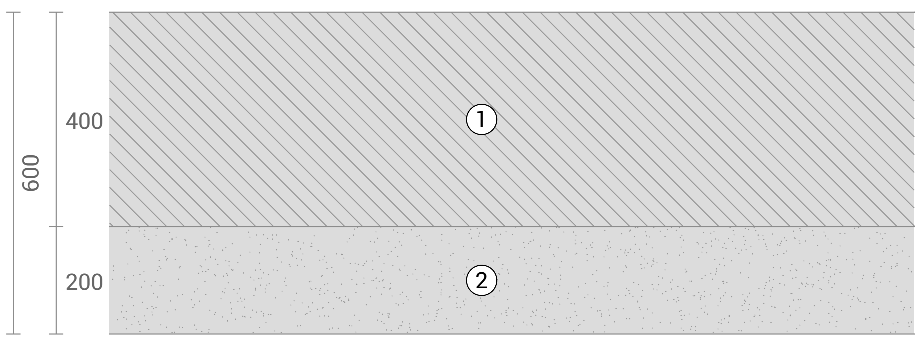
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 25
phase shift: 14,2 h
Thermal capacity inside: 447 kJ/m²K

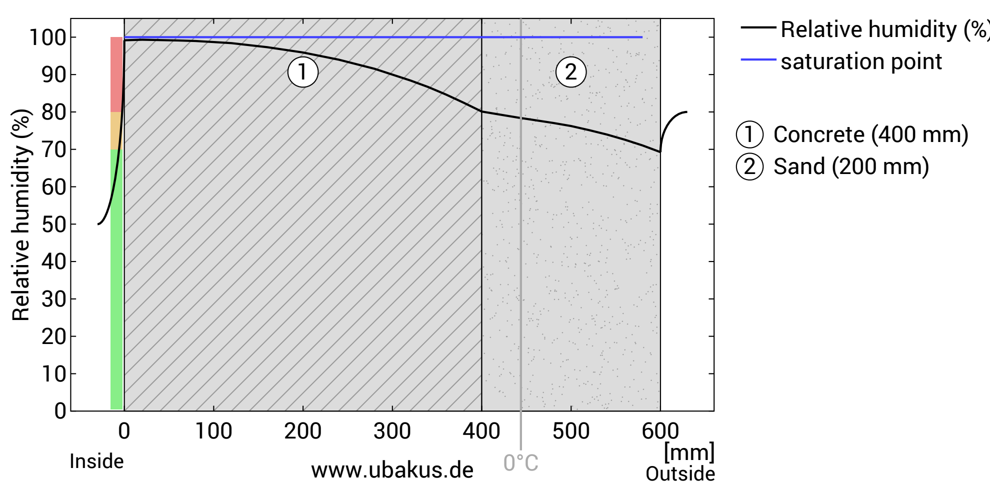
excellent insufficient



1 Concrete (400 mm) 2 Sand (200 mm)

Humidity

The temperature of the inside surface is 9,4 °C leading to a relative humidity on the surface of 99%.Most kinds of moulds start to grow at relative air humidities of 80% or more. Mould grow is expected! To avoid mould formation, the surface temperature should be increased by (additional) insulation.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

Master_Floor_New

Floor
created on 25.4.2023

Thermal protection

U = 0,107 W/(m²K)

GEG 2020 Bestand*: U<0,5 W/(m²K)

excellent insufficient

Moisture proofing

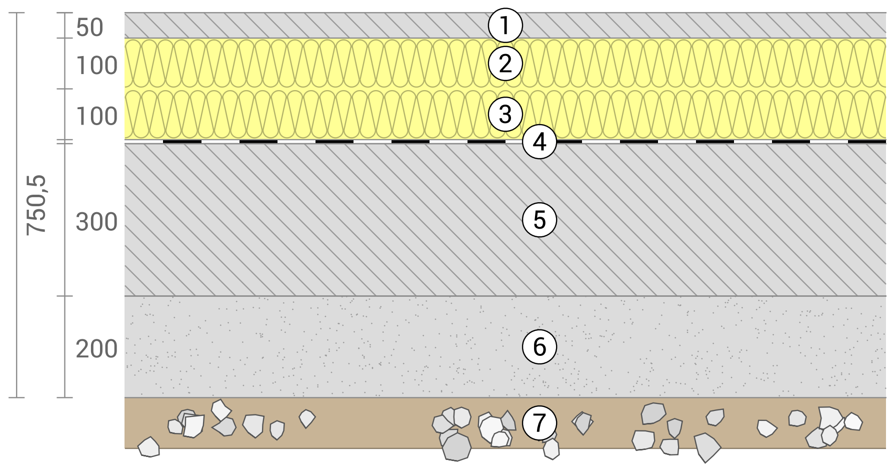
Dries 46 days
Condensate: 23 g/m²

excellent insufficient

Heat protection

Component is adjacent to earth:
TAV and phase non relevant
Thermal capacity inside: 120 kJ/m²K

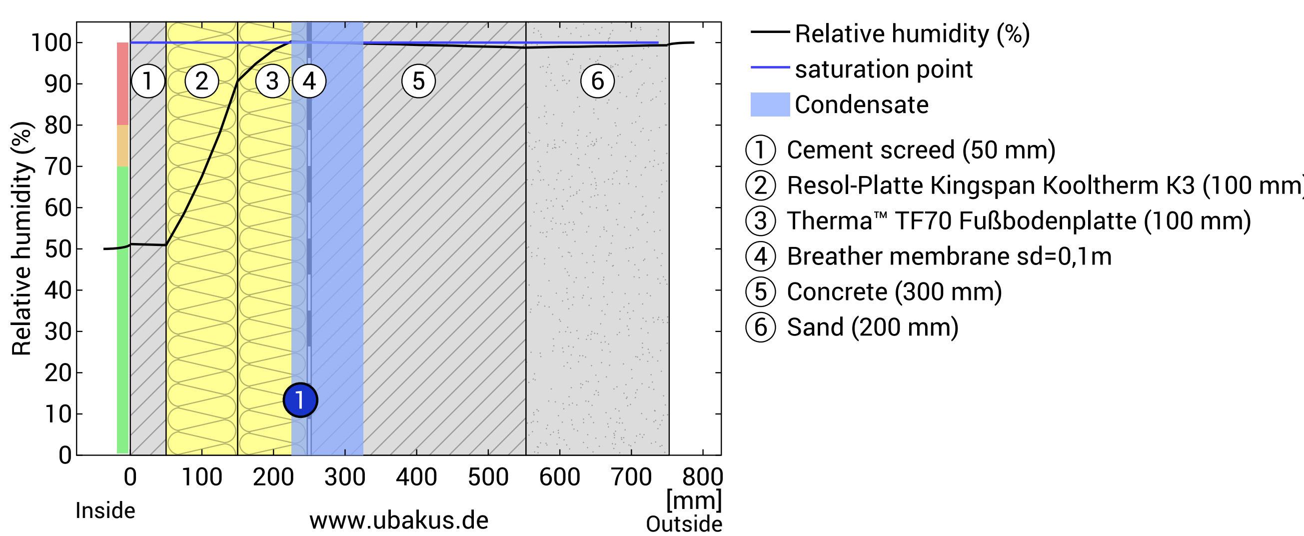
excellent insufficient



1. Cement screed (50 mm)
2. Resol-Platte Kingspan Kooltherm K3 (100 mm)
3. Therma™ TF70 Fußbodenplatte (100 mm)
4. Breather membrane sd=0,1m
5. Concrete (300 mm)
6. Sand (200 mm)
7. Soil

Humidity

The temperature of the inside surface is 19,6 °C leading to a relative humidity on the surface of 51%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

360mm exterior wall

Exterior wall
created on 15.4.2023

Thermal protection

U = 1,40 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

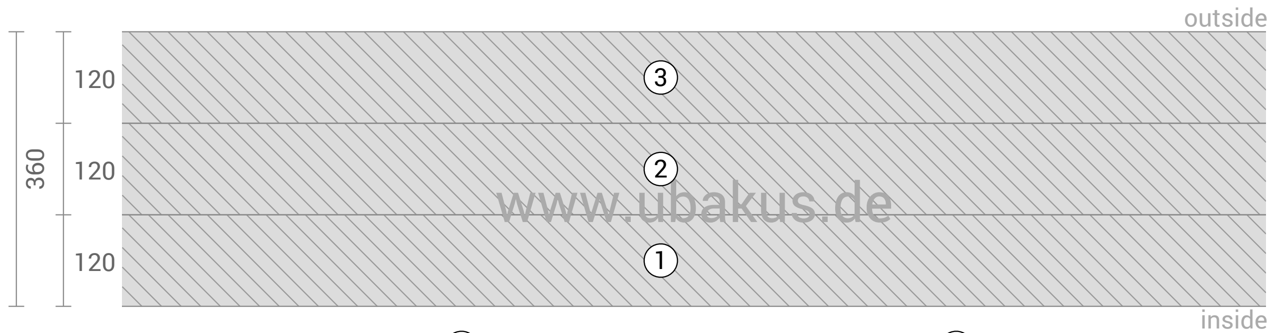
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 13
phase shift: 12,3 h
Thermal capacity inside: 208 kJ/m²K

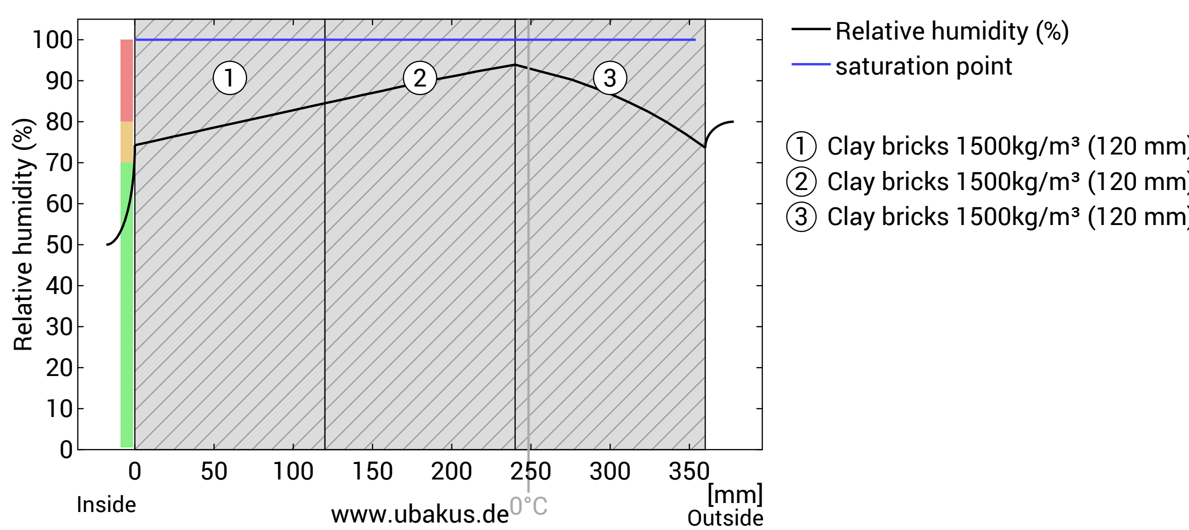
excellent insufficient



1 Clay bricks 1500kg/m³ (120 mm) 2 Clay bricks 1500kg/m³ (120 mm) 3 Clay bricks 1500kg/m³ (120 mm)

Humidity

The temperature of the inside surface is 9,0 °C leading to a relative humidity on the surface of 74%.Some kinds of mould start to grow at relative air humidities of 70% or more, mould cannot be excluded!. To avoid mould formation, the surface temperature should be increased by (additional) insulation.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

new 360mm exterior wall (thick)

Exterior wall
created on 15.4.2023

Thermal protection

U = 0,21 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

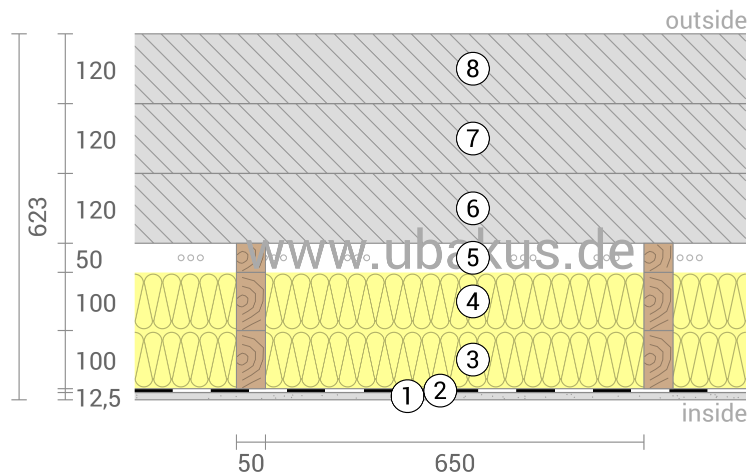
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 6,5
phase shift: 8,8 h
Thermal capacity inside: 22 kJ/m²K

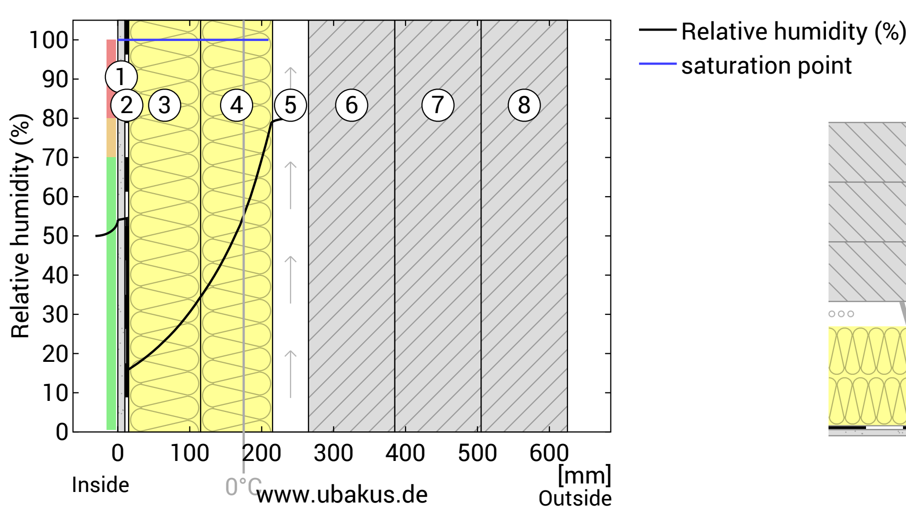
excellent insufficient

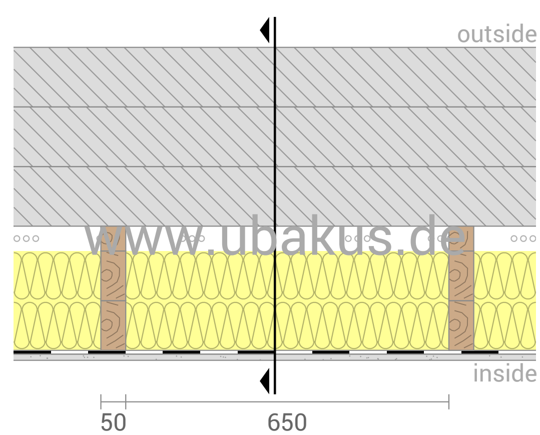


1 Gypsum board (12,5 mm)
2 Vapor retarder sd=5m
3 Cellulose (100 mm)
4 Cellulose (100 mm)
5 Rear ventilated level (50 mm)
6 Clay bricks 1500kg/m³ (120 mm)
7 Clay bricks 1500kg/m³ (120 mm)
8 Clay bricks 1500kg/m³ (120 mm)

Humidity

The temperature of the inside surface is 19,6 °C leading to a relative humidity on the surface of 58%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





1 Gypsum board (12,5 mm)
2 Vapor retarder sd=5m
3 Cellulose (100 mm)
4 Cellulose (100 mm)
5 Rear ventilated level (50 mm)
6 Clay bricks 1500kg/m³ (120 mm)
7 Clay bricks 1500kg/m³ (120 mm)
8 Clay bricks 1500kg/m³ (120 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

480mm exterior wall

Exterior wall
created on 15.4.2023

Thermal protection

U = 1,11 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

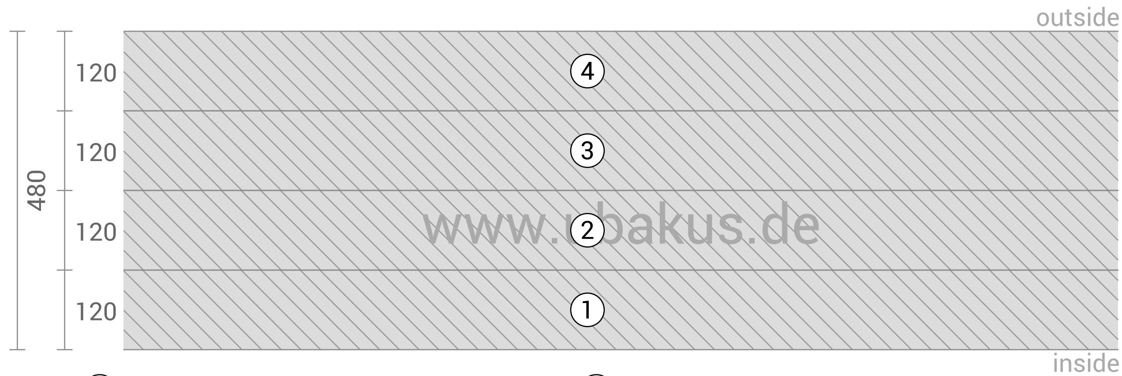
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 43
phase shift: 16,5 h
Thermal capacity inside: 294 kJ/m²K

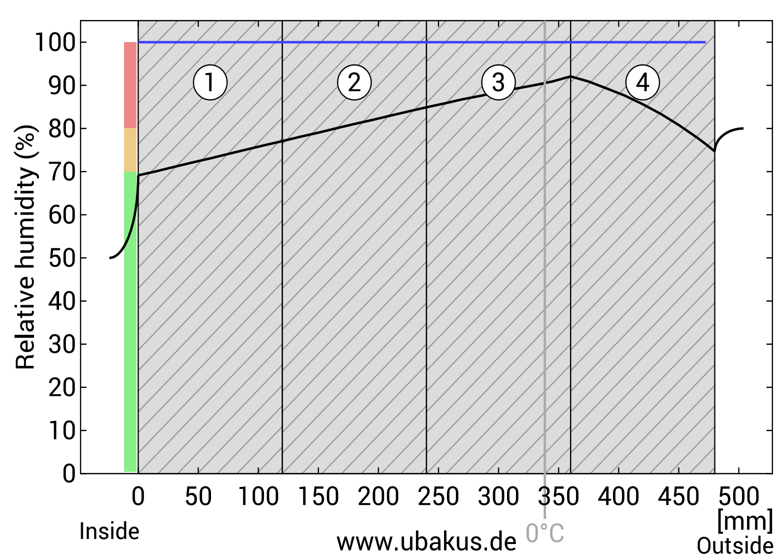
excellent insufficient



1 Clay bricks 1500kg/m³ (120 mm)
2 Clay bricks 1500kg/m³ (120 mm)
3 Clay bricks 1500kg/m³ (120 mm)
4 Clay bricks 1500kg/m³ (120 mm)

Humidity

The temperature of the inside surface is 10,1 °C leading to a relative humidity on the surface of 69%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Relative humidity (%)
saturation point

1 Clay bricks 1500kg/m³ (120 mm)
2 Clay bricks 1500kg/m³ (120 mm)
3 Clay bricks 1500kg/m³ (120 mm)
4 Clay bricks 1500kg/m³ (120 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

new 480mm exterior wall (thick)

Exterior wall
created on 15.4.2023

Thermal protection

U = 0,21 W/(m²K)

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

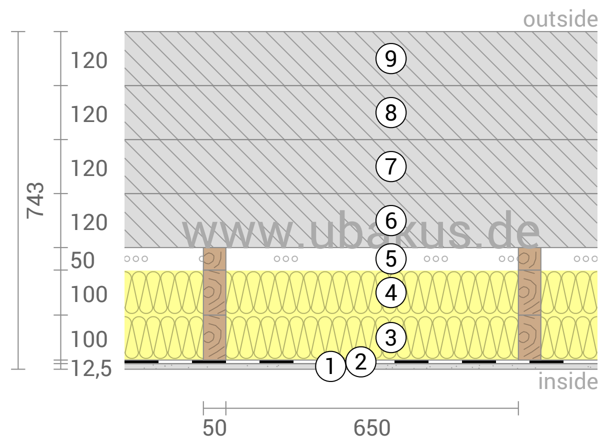
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 6,5
phase shift: 8,8 h
Thermal capacity inside: 22 kJ/m²K

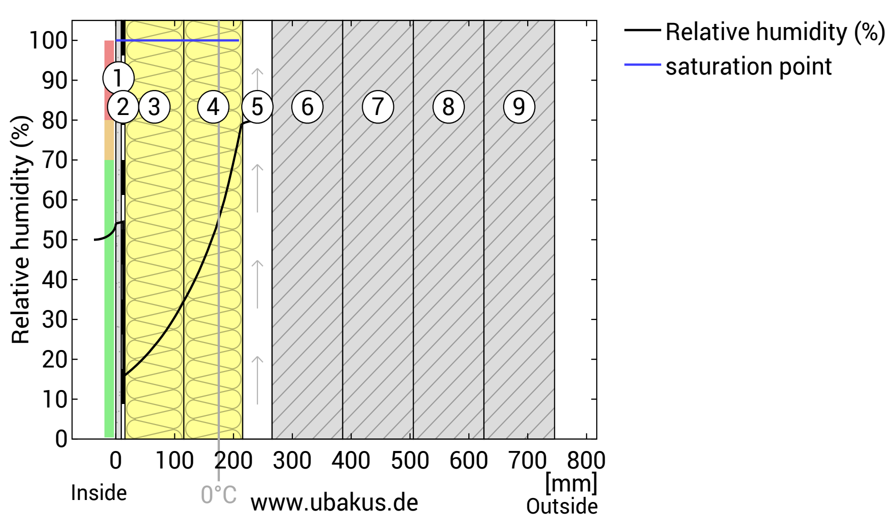
excellent insufficient

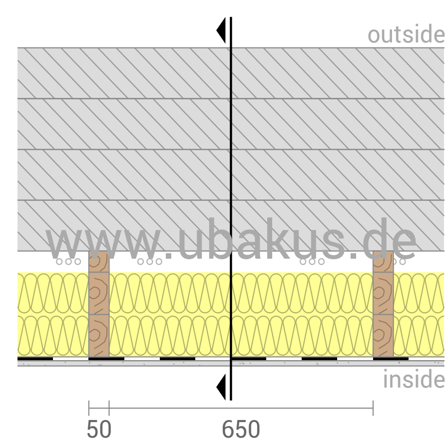


1. Gypsum board (12,5 mm)
2. Vapor retarder sd=5m
3. Cellulose (100 mm)
4. Cellulose (100 mm)
5. Rear ventilated level (50 mm)
6. Clay bricks 1500kg/m³ (120 mm)
7. Clay bricks 1500kg/m³ (120 mm)
8. Clay bricks 1500kg/m³ (120 mm)
9. Clay bricks 1500kg/m³ (120 mm)

Humidity

The temperature of the inside surface is 19,6 °C leading to a relative humidity on the surface of 58%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





1. Gypsum board (12,5 mm)
2. Vapor retarder sd=5m
3. Cellulose (100 mm)
4. Cellulose (100 mm)
5. Rear ventilated level (50 mm)
6. Clay bricks 1500kg/m³ (120 mm)
7. Clay bricks 1500kg/m³ (120 mm)
8. Clay bricks 1500kg/m³ (120 mm)
9. Clay bricks 1500kg/m³ (120 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

Appendix: Structural calculations

The following appendix will cover the calculation of a critical load case. The case will take point in a dominating variable load and has a snow load and wind load as additional variable loads.

The calculations will be done by the FEM-design software" Robot structural design."

The following calculations is done according to (Jensen, B.C 2015, p. 143-157)

Load combination			1	**2**
Reference formular			(6.10a)	**(6.10b)**
Permanent load	Permanent action	Unfavorable	$1{,}2 \times K_{FI}$	$\mathbf{1{,}0 \times K_{FI}}$
Variable load	Leading	Unfavorable	0	$\mathbf{1{,}5 \times K_{FI}}$
	Accompanying	Unfavorable	0	$\mathbf{1{,}0 \times \psi_0 \times K_{FI}}$

Consequence classes

Consequence classes	K fi factor for actions	Description	Example of building
CC1	**1,1**	High consequence for loss of human life	**Public buildings where consequences of failure are high**
CC2	1,0	Medium consequence for loss of human life	Residential and office buildings where consequences of failure are medium
CC3	0,9	Low consequence for loss of human life	Agricultural buildings where consequences of failure are low

Usage class

The usage class is 1 since the structure will not be exposed to outside weather.

Combination factors ψ

Loads (DS/EN 1991-1-1)

Liveload in buildings	
category C: large gatherings	0,6

Snow load	
In combination with leading imposed load category E or with leading temperature load	0,6
In combination with leading wind load	0
Other	0,3

Wind load	
In combination with leadning imposed load category E	0,6
Other	0,3

Characteristic variable loadings q_K

Category	Usage	Example	$q_K\ [kN/m^2$	$Q\ [kN]$
C	**Gathering room**	**Gathering room with no chairs**	**5,0**	**4,0**

Snow load

The value for snow load is defined as followed:

The equation for snowload

$$\boxed{s = \mu_i C_e C_t s_k}$$

μ_i is a formfactor for snow load depended on the shape of the roof

$\boldsymbol{C_e}$ is an exposure factor

$$\boldsymbol{C_e = C_{top} \times C_s}$$

$\boldsymbol{C_{top}}$ is topographic factor

$\boldsymbol{C_s}$ is a sizefactor

$\boldsymbol{C_t}$ is a termical factor. The factor for Denmark is 1,0

$\boldsymbol{s_K}$ characteristic terrain value

the shape of the roof is flat with a slope of 0 degrees.

The formfator is defined by using the following table:

$\mu_i\ = 0{,}8$

Tabel 4.8 Formfaktorer for snelast

Taghældning α	μ_1
$0° \leq \alpha \leq 30°$	0,8
$30° < \alpha < 60°$	$0{,}8(60\ -\ \alpha)/30$
$\alpha \geq 60°$	0,0

Exposure factor

$\boldsymbol{C_e = C_{top} \times C_s}$

$\boldsymbol{C_{top} = 1.0}$ (normal topography)

$\boldsymbol{C_s = 1.0}$ (normal exposure)

$\boldsymbol{C_e = C_{top} \times C_s = 1.0}$

Characteristic terrain value

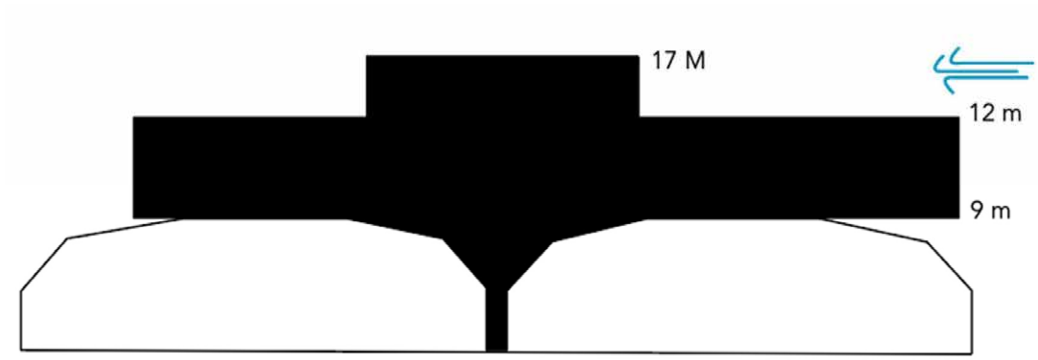
s_K characteristic terrain value

s_K = 1,0 $kN \times m^2$ (DS/EN 1991-1-3)

The Characteristic value for snow load:

$$s = \mu_i \times C_e \times C_t \times s_K = 0,8\ kN\ /\ m^2$$

Wind load



Base Wind speed is 24 m/s

$Z = 17\ m$

$Z_0 = 0{,}3\ m$

$Z_{min} = 5\ m$

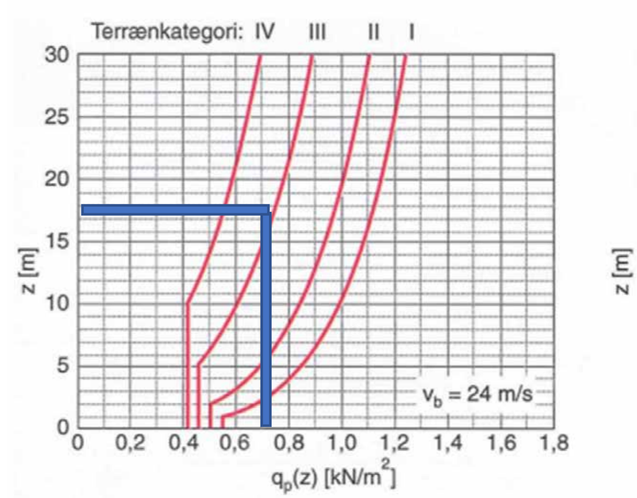
$v_b = 24\ m\ /s$

	Terrænkategori	z_0 [m]	z_{min} [m]
I	Søer eller fladt og vandret område uden væsentlig vegetation og uden forhindringer	0,01	1
II	Område med lav vegetation som fx græs og enkelte forhindringer (træer, bygninger) med indbyrdes afstande på mindst 20 gange forhindringernes højde	0,05	2
III	Område med regelmæssig vegetation eller bebyggelse eller med enkeltvise forhindringer med afstande på højst 20 gange forhindringens højde (som fx landsbyer, forstadsområder, permanent skov)	0,3	5
IV	Område, hvor mindst 15 % af overfladen er dækket med bygninger, hvis gennemsnitshøjde er over 15 m.	1,0	10

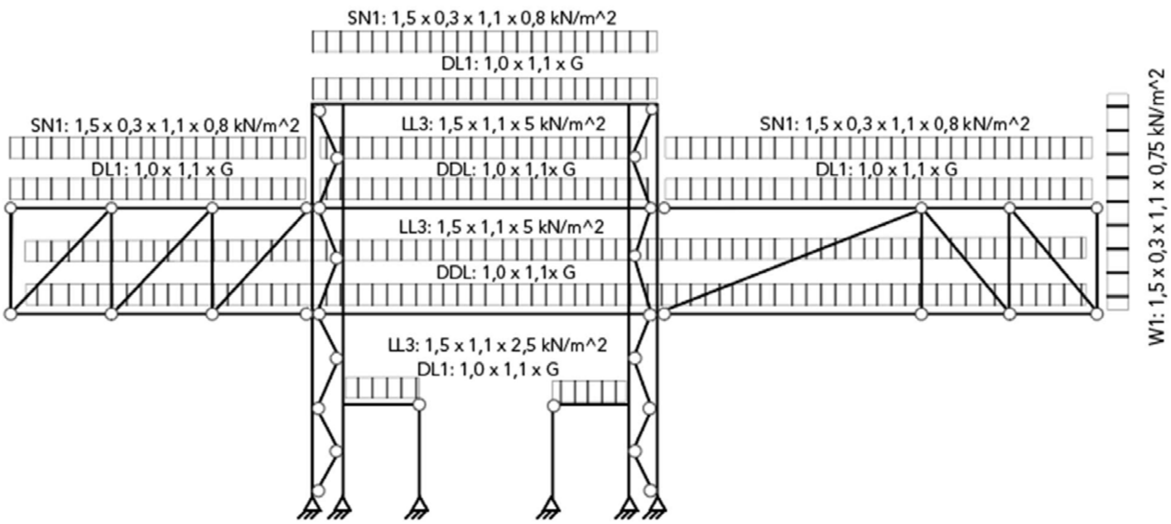
Peak wind speed

Peak wind speed can be checked on the scale.

Peakwind is 0,75 kN/m^2



Load scheme 1 and 2



Deadload 1.1 x 1.0 X G

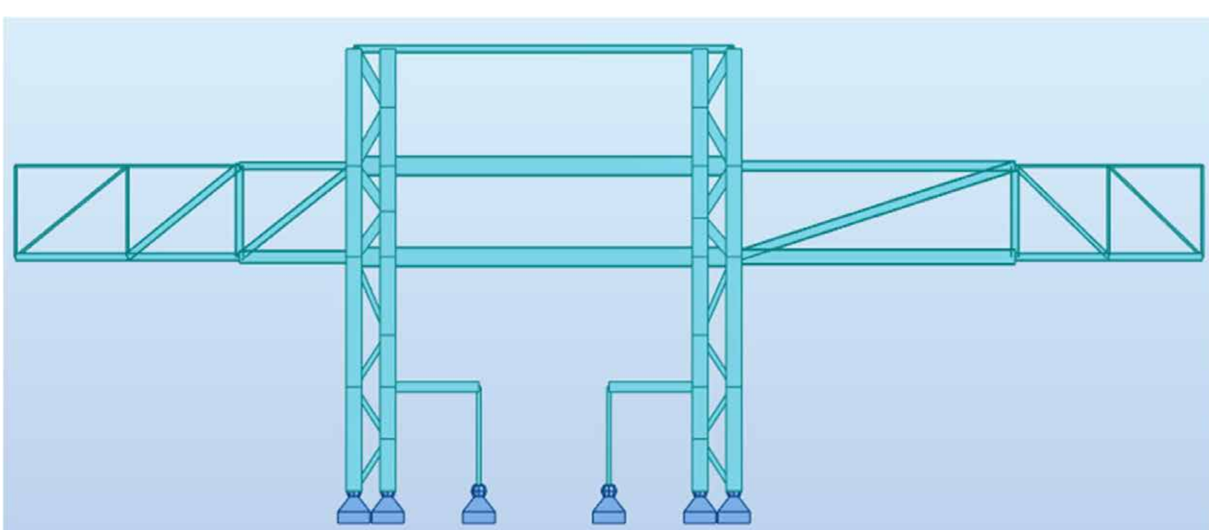
liveload 1.5 x 1.1 x 5 kN /m^2

Liveload resturant: 1,5 x 1,1 x 2,5 kN/ m^2

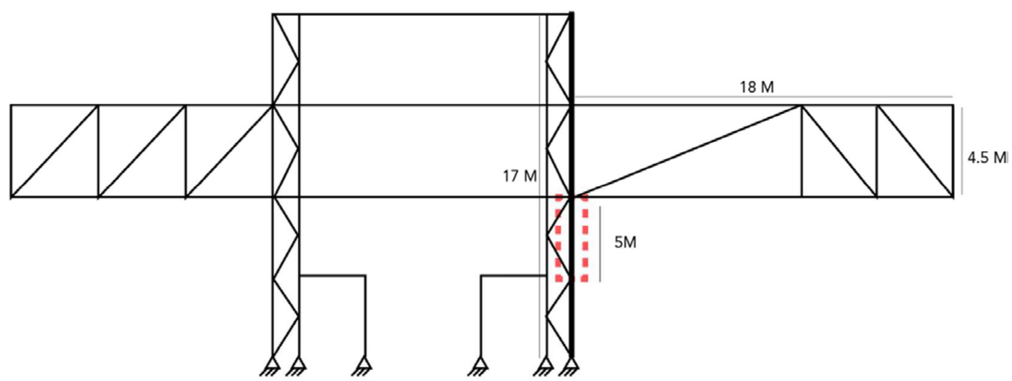
snowload 1.5 x 1.1 x 0,3 x 0,8 kN/ m^2

Windload 1.5 x 1,1 x 0,3 x 0,37 kN/ m^2

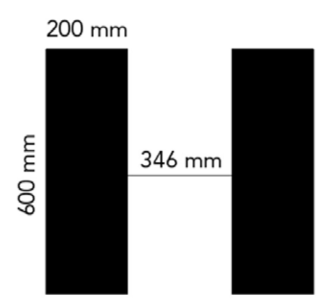
Model in Robot



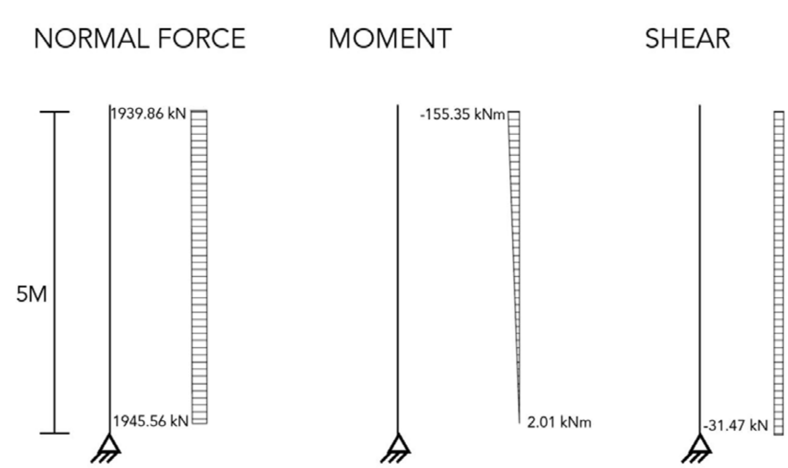
Calculation for column



Column profile



Forces



Structural calculation from ROBOT

TIMBER STRUCTURE CALCULATIONS

CODE: *EN 1995-1:2004/A2:2014*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 453 Timber Column_453 **POINT:** 3 **COORDINATE:** x = 1.00 L = 5.00 m

LOADS:
Governing Load Case: 8 dominerede nytte, øvrige vind/ sne 1*1.10+2*1.65+(3+4)*0.49

MATERIAL GL32h

gM = 1.25	f m,0,k = 32.00 MPa	f t,0,k = 25.60 MPa	f c,0,k = 32.00 MPa
f v,k = 3.50 MPa	f t,90,k = 0.50 MPa	f c,90,k = 2.50 MPa	E 0,moyen = 14200.00 MPa
E 0,05 = 11800.00 MPa	G moyen = 650.00 MPa	Service class: 1	Beta c = 0.10

SECTION PARAMETERS: 600 x 200 = 346

ht=600 mm			
bf=746 mm	Ay=160000 mm2	Az=160000 mm2	Ax=240000 mm2
tw=346 mm	Iy=7200000000 mm4	Iz=18686960000 mm4	Ix=2527861971 mm4
tf=0 mm	Wy=24000000 mm3	Wz=50099088 mm3	

STRESSES
Sig_c,0,d = N/Ax = 1939.86/240000 = 8.08 MPa
Sig_m,y,d = MY/Wy= 155.32/24000000 = 6.47 MPa

Tau z,d = 1.5*-31.47/240000 = -0.20 MPa

ALLOWABLE STRESSES
f c,0,d = 15.36 MPa
f m,y,d = 15.36 MPa
f v,d = 1.68 MPa

Factors and additional parameters
kh = 1.10 kh_y = 1.00 kmod = 0.60 Ksys = 1.00 kcr = 0.67

LATERAL BUCKLING PARAMETERS:

BUCKLING PARAMETERS:

About Y axis:		About Z axis:	
LY = 5.00 m	Lambda Y = 28.87	LZ = 5.00 m	Lambda Z = 17.92
Lambda_rel Y = 0.48	ky = 0.62	Lambda_rel Z = 0.30	kz = 0.54
LFY = 5.00 m	kcy = 0.98	LFZ = 5.00 m	kcz = 1.00

VERIFICATION FORMULAS:
Sig_c,0,d/(kc,y*f c,0,d) + Sig_m,y,d/f m,y,d = 8.08/(0.98*15.36) + 6.47/15.36 = 0.96 < 1.00 (6.23)

(Tau z,d/kcr)/f v,d = (0.20/0.67)/1.68 = 0.17 < 1.00 (6.13)

Section OK !!!

Safety check of column with load combination + liveload

The equation is the relation between normal force applied and moment in the column.

$$\frac{\sigma c,o,d}{(kc,y* \ fc,o,d)} + \frac{\sigma m,y,d}{fm,y,d} = \frac{8.08}{(0.98*15.36)} + \frac{6{,}47}{15.36} = 0.96$$

The utilization of the column is 0,96 / 1

The first part of the formular is the relation between normal force applied and the material properties of the wood. (6.23) DS/EN 1995 FU:2015

$$\sigma c,o,d = applied\ force\ (1939.86\ kN)/\ gross\ area\ (240000\ mm^2) = \ 8.08\ \ MPa$$

The compression stress is then divided by the compression strength of the material $fc, o, d = 15.36$ MPa

kc, y = 0.93 is a Reduction factor due to compression

$$\frac{\sigma c, o, d}{(kc, y * \ fc, o, d)} = \frac{8.08}{(0.98 * 15.36)} = 0{,}53$$

The next part is about moment inside the beam and how the is "first moment of area" (Modstandsmoment) is resisting.

$$\sigma m, y, d = applied\ moment\ (155{,}32\ kN)/first\ moment\ of\ area\ (24000000\ mm^3) = 6{,}47\ MPa$$

The bending stress is then divided by the bending strength of the material $fc, o, d = 15.36$ MPa

$$\frac{\sigma m, y, d}{fm, y, d} = \frac{6{,}47}{15.36} = 0{,}42$$

Both number are divided over first moment of area that's calculated like this:

$$W = \frac{I}{e}\ mm^3 = \frac{7200 * 10^6\ mm^4}{300\ mm} = 24000000\ mm^3$$

I = cross section moment of intertia

E= is the distance from edge to center profile = 300 mm

$$I = \ b * h^3 / \ 12 = 200 * 600^3 / \ 12 \ = \ 3600 \ * 10^6\ mm^4$$

Then the profile is a doublet 600 x 200 mm

Therefore, the profile of the column have a huge impact on the load bearing potential.

Calculation for displacement

Calculation: member displacement x axis

$Vx = 5\ mm$ result form robot

$$Vx\ max = \frac{5000}{150} = 33\ m$$

$$Ratio_{vx} = \frac{Vx}{Vx\ max} = \frac{5}{33} = 0{,}15$$

5 < 33

Calculation: member displacement y axis

$Vy = 0\ mm$ result from robot

$$Vx\ max = \frac{5000}{150} = 33\ m$$

$$Ratio_{vx} = \frac{0}{33} = 0$$

0,0 < 33

Node displacements

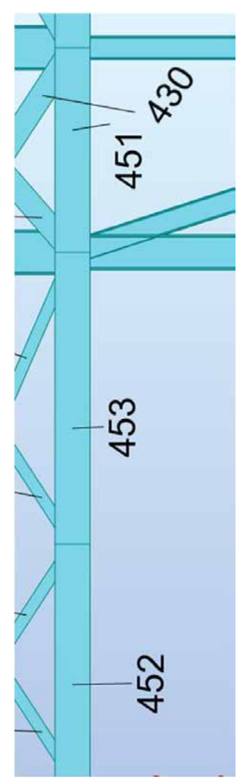
v x = 5 mm < v max,x = L/150.00 = 33 mm — Verified

Governing load case: AGT (1+2)*1.00+(3+4)*0.30

v y = 0 mm < v max,y = L/150.00 = 33 mm — Verified

Governing load case: AGT (1+2)*1.00+(3+4)*0.30

Wood profile check in robot



The profile tested in the calculation has the highest usage rate of a column.

453 Timber Colum	OK	600 x 200 = 3	GL32h	28.87	17.92	0.96	8 dominerede nytte,

The highest usage rate was In the truss in a timber member. Here the critical situation was compression stress of 2133 kN

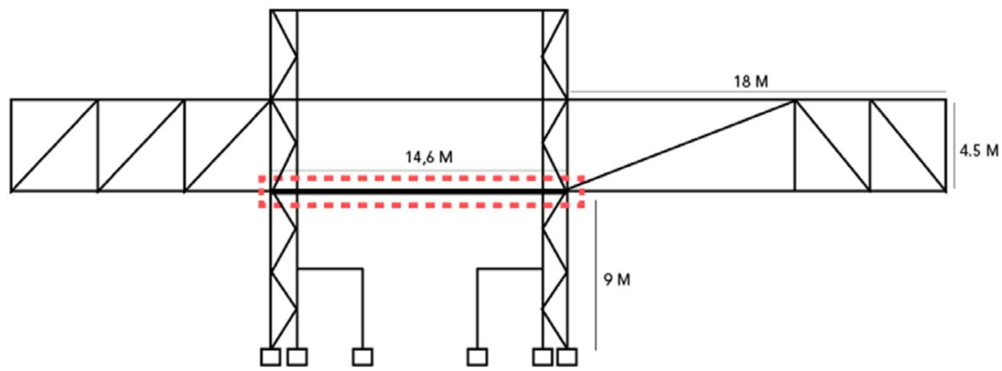
430 Timber Memb	OK	200 x 400 x 2	GL32h	20.66	11.46	0.99	8 dominerede nytte,

Other parts of the column was utilized as shown here:

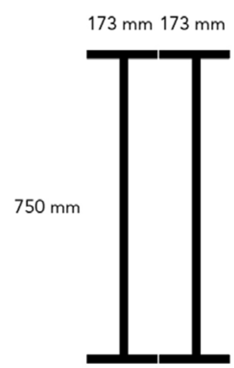
In this situtain the moment was the critical value.

451 Timber Colum	OK	600 x 200 = 3	GL32h	20.21	12.54	0.56	8 dominerede nytte,
452 Timber Colum	OK	600 x 200 = 3	GL32h	23.09	14.33	0.53	8 dominerede nytte,

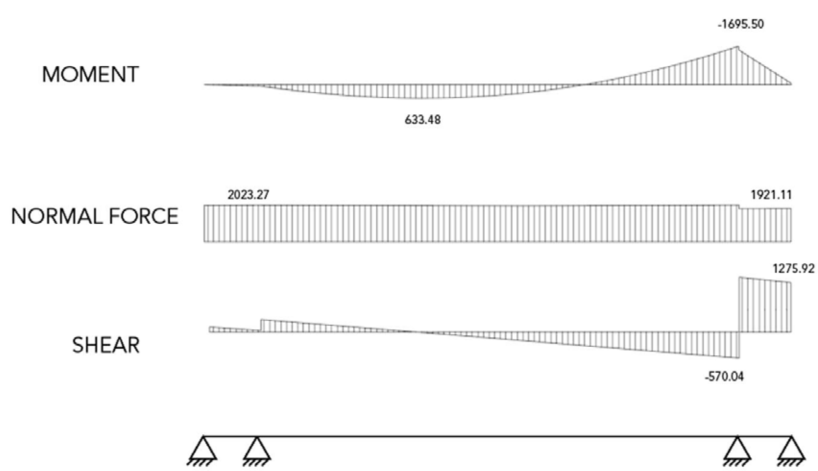
Calculation for Beam



Beam profile



Forces



STEEL DESIGN

CODE: DS/EN 1993-1:2005/DK NA:2015/A1:2014, Eurocode 3: Design of steel structures.
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 391 Beam_391 **POINT:** 3 **COORDINATE:** x = 0.91 L = 13.30 m

LOADS:
Governing Load Case: 8 dominerede nytte, øvrige vind/ sne 1*1.10+2*1.65+(3+4)*0.49

MATERIAL:
Steel (S235) fy = 225.00 MPa

SECTION PARAMETERS: 2 IPE 750173

h=762 mm	gM0=1.10	gM1=1.20	
b=534 mm	Ay=23565 mm2	Az=20701 mm2	Ax=44266 mm2
tw=14 mm	Iy=4116500000 mm4	Iz=926395647 mm4	Ix=1227204534 mm4
tf=22 mm	Wply=12436840 mm3	Wplz=5909564 mm3	

INTERNAL FORCES AND CAPACITIES:

N,Ed = 2023.27 kN	My,Ed = -1695.90 kN*m	
Nc,Rd = 9054.49 kN	My,Ed,max = -1695.90 kN*m	
Nb,Rd = 8299.95 kN	My,c,Rd = 2543.90 kN*m	Vz,Ed = -570.04 kN
	MN,y,Rd = 2543.90 kN*m	Vz,c,Rd = 2444.72 kN
	Mb,Rd = 2331.91 kN*m	
		Class of section = 1

LATERAL BUCKLING PARAMETERS:

z = 1.00	Mcr = 32088.41 kN*m	Curve,LT - d	XLT = 1.00
Lcr,low=14.60 m	Lam_LT = 0.30	fi,LT = 0.49	XLT,mod = 1.00

BUCKLING PARAMETERS:

About y axis:	About z axis:
kyy = 1.00	kzy = 1.00

VERIFICATION FORMULAS:
Section strength check:
N,Ed/Nc,Rd = 0.22 < 1.00 (6.2.4.(1))
My,Ed/My,c,Rd = 0.67 < 1.00 (6.2.5.(1))
My,Ed/MN,y,Rd = 0.67 < 1.00 (6.2.9.1.(2))
Vz,Ed/Vz,c,Rd = 0.23 < 1.00 (6.2.6.(1))
Global stability check of member:
My,Ed,max/Mb,Rd = 0.73 < 1.00 (6.3.2.1.(1))
N,Ed/(Xy*N,Rk/gM1) + kyy*My,Ed,max/(XLT*My,Rk/gM1) = 0.97 < 1.00 (6.3.3.(4))
N,Ed/(Xz*N,Rk/gM1) + kzy*My,Ed,max/(XLT*My,Rk/gM1) = 0.97 < 1.00 (6.3.3.(4))

Section OK !!!

Section check (Bending and compression affected elements with constant cross-section)

DS/EN 1993-1-1 (6.3.3)

$$\left(\frac{N,Ed}{\frac{Xy * N,Rk}{gM1}}\right) + \frac{kyy * My\_Ed\_max}{\left(XLT * \frac{My\_Rk}{gM1}\right)} = 0{,}97 < 1$$

$A_x := 44266\, mm^2$	Croos-section area
$A_y := 23565\, mm^2$	Shear area y axis
$A_z := 20701\, mm^2$	Shear area z axis
$W\_ply := 12436840\, mm^3$	plastic section modulus about the y axis
$W\_plz := 5909564\, mm^3$	plastic section modulus about the z axis

$f_y := 225\ MPa\ (3.2)\ S235$ Design yield strength of material

$N\_ed: = 2036.90\ kN$ Axial force

$x_z = N_{ed}\ /\ Nb,rd\ = 2036.90\ kN\ /\ 8299{,}95\ kN\ = 0{,}24$

$x_z\ and\ x_y = 0.24\ reduction\ factor\ for\ buckling\ (6.3.1.2(1))$

$gM1 = 1.2$ Partial safety factor (6.1.1)

$N_{Rk} = f_y * a_x = 9959\ kN$ carrying capacity over area (6.3.3)

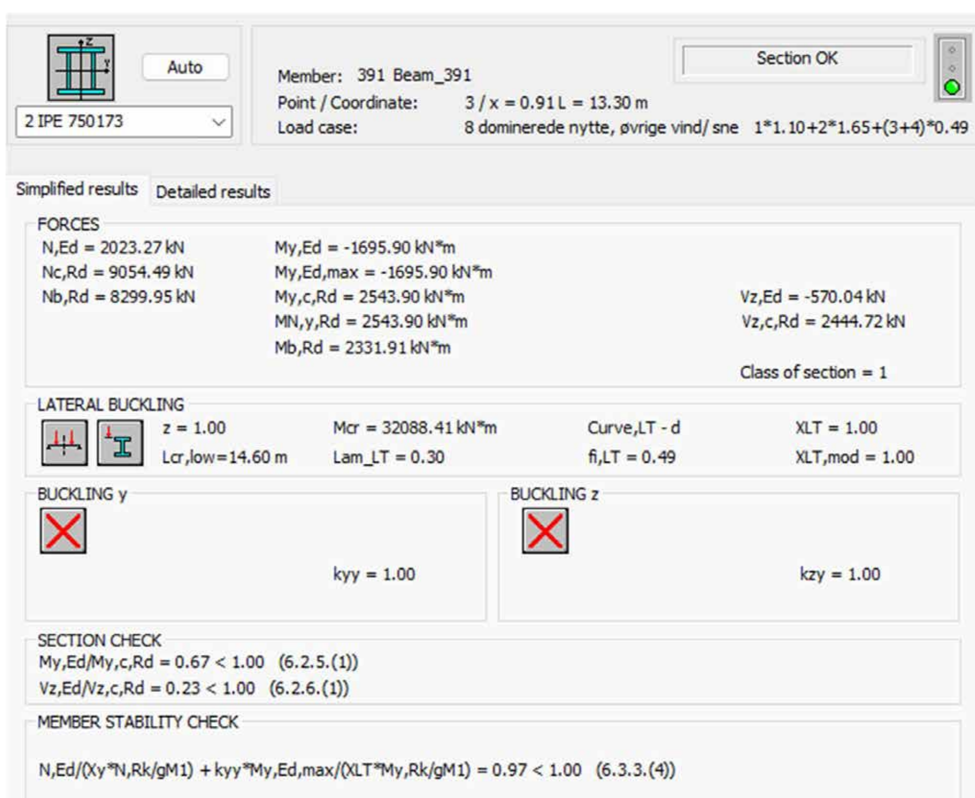
$kyy = 1{,}0$ Interaction parameter

$kzy = 1{,}0$

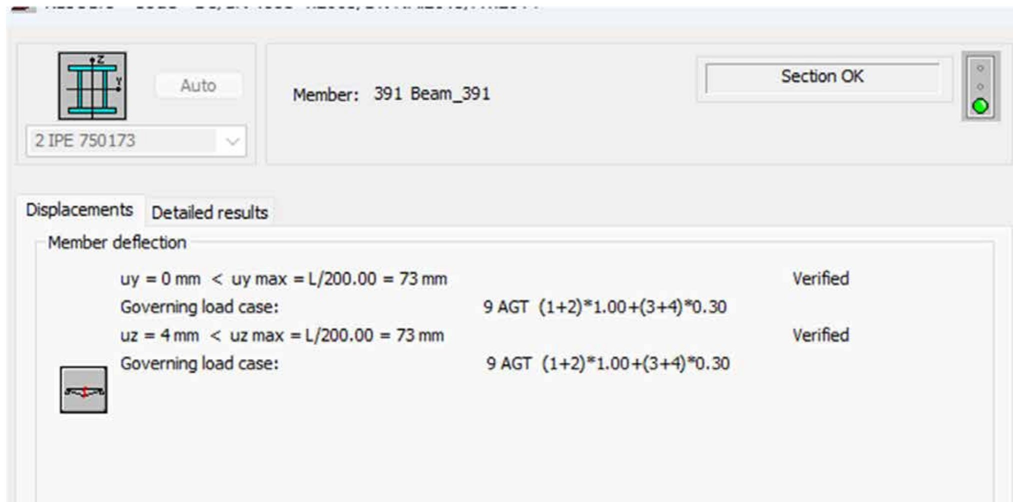
$My\_Ed\_\max = 1688.45\ kNm$ Maximal moment

$XLT = 1$ Reduction factor (6.3.2.2(1))

$My_{Rk} = f_y * W_{ply} = 2798.28\ kNm$ carrying capacity moment over z axis



Calculation for displacement



Member displacement y axis

$uy = 0\ mm$ Member displacement along y axis

$uy \max = L\ /\ 200\ =\ 73\ mm$ allowable member displacement along y axis

0 < 73

Member displacement z axis

$uy = 4\ mm$ Member displacement along z axis

$uy \max = L\ /\ 200\ =\ 73\ mm$ allowable member displacement along z axis

4 < 73

Steel profile check in robot

Member		Section	Material	Lay	Laz	Ratio	Case
21	OK	2 IPE 300	Steel	28.89	43.83	0.69	8 dominerede nytte,
23	OK	2 IPE 100	Steel	88.45	119.31	0.30	8 dominerede nytte,
24	OK	2 IPE 300	Steel	34.51	52.35	0.72	8 dominerede nytte,
27	OK	2 IPE 100	Steel	105.65	142.51	0.47	8 dominerede nytte,
28	OK	2 IPE 300	Steel	34.51	52.35	0.98	8 dominerede nytte,
29	OK	2 IPE 500	Steel	21.54	40.41	0.60	8 dominerede nytte,
30	OK	2 IPE 300	Steel	35.31	53.57	0.33	8 dominerede nytte,
31	OK	2 IPE 100	Steel	105.65	142.51	0.49	8 dominerede nytte,
287 Column_287	OK	IPE 300	Steel	117.16	435.87	0.48	8 dominerede nytte,
316 Column_316	OK	2 IPE 750173	Steel	47.88	100.92	0.67	8 dominerede nytte,
391 Beam_391	OK	2 IPE 750173	Steel	47.88	100.92	0.97	8 dominerede nytte,
419 Beam_419	OK	2 IPE 300	Steel	28.89	43.83	0.50	8 dominerede nytte,
422 Beam_422	OK	2 IPE 100	Steel	88.45	119.31	0.35	8 dominerede nytte,
459 Beam_459	OK	2 IPE 400	Steel	68.61	115.51	0.97	8 dominerede nytte,
460 Beam_460	OK	2 IPE 300	Steel	28.09	42.61	0.68	8 dominerede nytte,
461 Beam_461	OK	2 IPE 100	Steel	85.99	115.99	0.02	8 dominerede nytte,
462 Beam_462	OK	2 IPE 100	Steel	85.99	115.99	0.50	8 dominerede nytte,
463 Beam_463	OK	2 IPE 180	Steel	67.71	100.59	0.54	8 dominerede nytte,
464 Beam_464	OK	2 IPE 100	Steel	123.36	166.40	0.42	8 dominerede nytte,
465 Beam_465	OK	2 IPE 600	Steel	44.45	90.40	0.78	8 dominerede nytte,
466 Beam_466	OK	2 IPE 400	Steel	65.27	109.88	0.96	8 dominerede nytte,
467 Beam_467	OK	2 IPE 300	Steel	45.12	68.45	0.54	8 dominerede nytte,
468 Beam_468	OK	2 IPE 300	Steel	28.09	42.61	0.26	8 dominerede nytte,
469 Beam_469	OK	2 IPE 300	Steel	44.49	67.50	0.32	8 dominerede nytte,
470 Beam_470	OK	2 IPE 100	Steel	85.99	115.99	0.50	8 dominerede nytte,
471 Beam_471	OK	2 IPE 100	Steel	136.22	183.75	0.54	8 dominerede nytte,
472 Beam_472	OK	2 IPE 100	Steel	85.99	115.99	0.01	8 dominerede nytte,

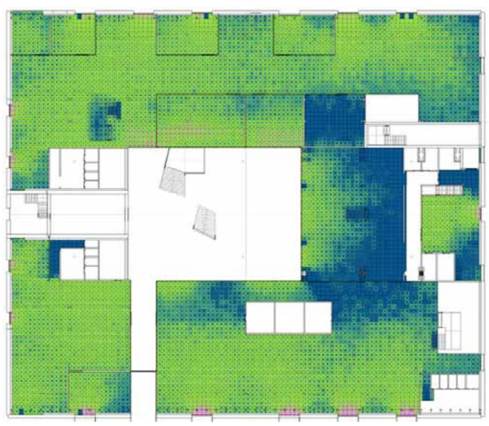
APPENDIX 5 - DAYLIGHT

Appendix: Daylight

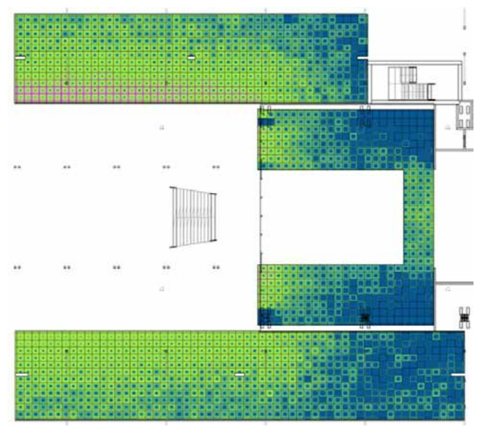
UDI (Useful daylight illuminance)

The result for UDI can be found at the last page of daylight appendix

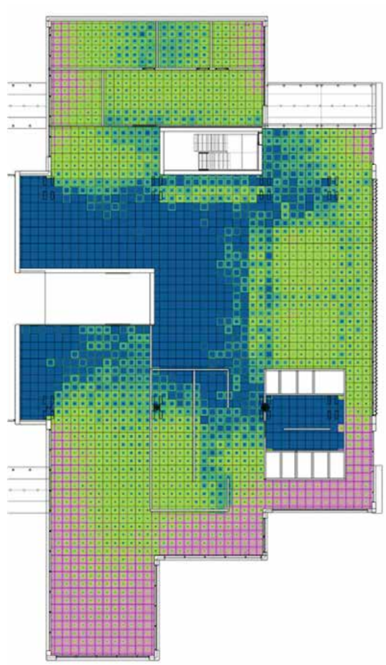
Ground floor



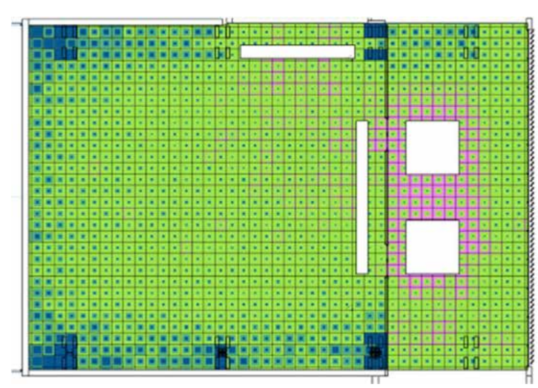
Mezzanine floor



1. floor



2. floor



sDA (Spatial Daylight Autonomy)

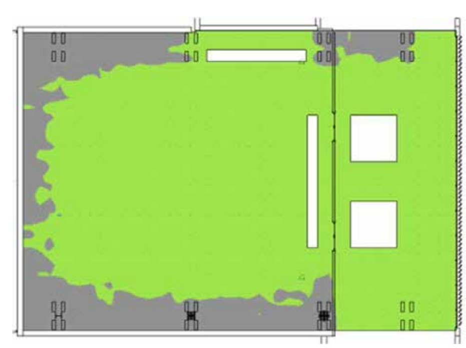
The result for sDA can be found at the last page of daylight appendix

Ground floor

Mezzanine floor

1 floor

2 floor

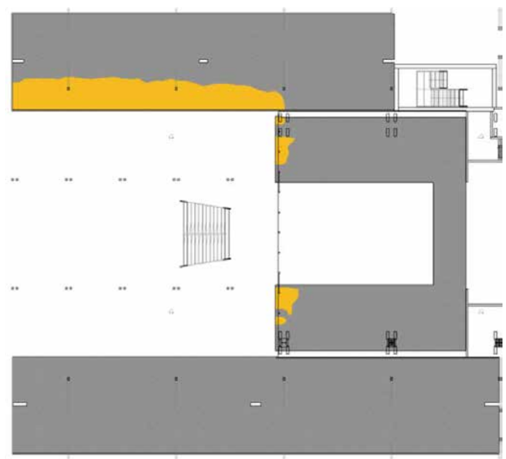


ASE (Annual Sunlight Exposure)

The result for ASE can be found at the last page of daylight appendix

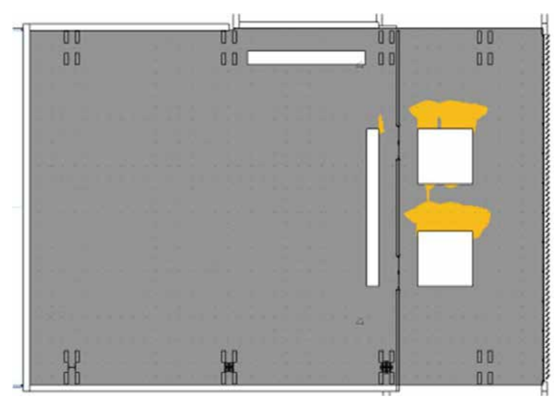
Ground floor

Mezzanine floor



1. floor

2. Floor



Results

UDI

The average UDI is 42,7 % which is a fine result for the building. Areas inside the restaurant and the restaurant padio does not meet the criteria for daylight, but since the restaurant mostly serves people in the afternoon this is acceptable.

sDA

The average sDA is 55,5 % which is a high value and is well above the 50 % target.

ASE

The ASE of the floor area is 6,5 %. Which is under the target 8%

Most of the area which is over lit is hallway and not assigned work area.

APPENDIX 6 - DIGITAL TWIN

The following section showcases exaples of the material library created with the use of Revit. The element library is separated into :column schedule, wall schedule and the framing schedule. Each includes an example of an element list and a maintenance library.
The basic schedule allows for the control of the existing, new and demolished buidling counts and volumes to manage them in case of reuse or replacement. Maintenance library highlights the evaluation of an element (based on the element evaluation conducted in the initial survey) in the Mark property. This allows for better maintenance over the life of the buidling. This section also includes the Last Control Date property to identify the last evaluation time for the mark values. Over the life cycle of the buidling the digital twin model can be updated with element evaluations to enable better maintenance and deterioration prevention.

Column Schedule

Count	Assembly Code	Family	Phase Demolished	Phase Created	Type
12	B1010255	Rectangular Column	New Construction	Existing	180x180
44	B1010255	Rectangular Column	None	Existing	180x180

Grand total: 56

Structural Column Schedule

Count	Assembly Code	Family	Phase Demolished	Phase Created	Type
87	B1010255	Timber Column	New Construction	Existing	120x120
41	B1010255	Timber Column	New Construction	Existing	140x50
41	B1020155	Timber Column	New Construction	Existing	140x140
76	B1010255	Timber Column	New Construction	Existing	180x180
489	B1010255	Timber Column	None	Existing	120x120
85	B1010255	Timber Column	None	Existing	140x50
113	B1020155	Timber Column	None	Existing	140x140
152	B1010255	Timber Column	None	Existing	180x180

Grand total: 1084

Structural Column Maintenance Library					
Assembly Code	Family	Phase Created	Type	Mark	Last Control Date
B1020155	Timber Column	Existing	140x140	AV: 1 SV: 4	20.09.2022
B1020155	Timber Column	Existing	140x140	AV: 3 SV: 4	15.07.2023
B1020155	Timber Column	Existing	140x140	AV: 1 SV: 4	20.09.2022
B1020155	Timber Column	Existing	140x140	AV: 1 SV: 4	07.09.2022
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B1010255	Timber Column	Existing	120x120	AV: 3 SV: 2	07.09.2022
B1010255	Timber Column	Existing	120x120	AV: 3 SV: 4	20.09.2022
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B10	Timber Column	New Construction	600x200mm	AV: 1 SV: 5	15.07.2023
B10	Timber Column	New Construction	600x200mm	AV: 1 SV: 5	20.09.2022
B10	Timber Column	New Construction	600x200mm	AV: 1 SV: 4	20.09.2022
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B1010255	Timber Column	Existing	180x180	AV: 3 SV: 4	07.09.2022
B1010255	Timber Column	Existing	180x180	AV: 1 SV: 5	15.07.2023
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B1010300	HP-Bearing Pile-Column	New Construction	HP360X152	AV: 3 SV: 2	20.09.2022
B1010300	HP-Bearing Pile-Column	New Construction	HP360X152	AV: 3 SV: 4	07.09.2022

Wall Schedule						
Assembly Code	Family	Phase Created	Phase Demolished	Volume	Type	Length
B2010	Basic Wall	Reused	None	0.84 m³	Brick Exterior Wall 360mm	500
B2010	Basic Wall	Reused	None	0.92 m³	Brick Exterior Wall 480mm	500
B2010	Basic Wall	Reused	None	1.22 m³	Brick Exterior Wall 360mm	1000
B2010	Basic Wall	Existing	None	6.53 m³	Brick Exterior Wall 480mm	650
B2010	Basic Wall	Existing	New Construction	0.86 m³	Brick Exterior Wall 360mm	2760
B2010	Basic Wall	Existing	New Construction	0.91 m³	Brick Exterior Wall 360mm	2800
B2010	Basic Wall	Existing	New Construction	34.47 m³	Brick Exterior Wall 360mm	2800
B2010	Basic Wall	Existing	New Construction	1.49 m³	Brick Exterior Wall 360mm	3500
B2010	Basic Wall	Existing	New Construction	10.91 m³	Brick Exterior Wall 360mm	4702
B2010	Basic Wall	Existing	New Construction	11.49 m³	Brick Exterior Wall 360mm	4702
B2010	Basic Wall	Existing	New Construction	133.33 m³	Brick Exterior Wall 360mm	48670
B2010	Basic Wall	Existing	None	1.44 m³	Brick Exterior Wall 360mm	1053
B2010	Basic Wall	Existing	None	1.92 m³	Brick Exterior Wall 360mm	1400
B2010	Basic Wall	Existing	None	2.60 m³	Brick Exterior Wall 360mm	1900
C1010140	Basic Wall	Existing	None	0.85 m³	Exterior Wall Lightweight	3000
B2010	Basic Wall	Existing	None	5.95 m³	Brick Exterior Wall 360mm	4353
B2010	Basic Wall	Existing	None	6.63 m³	Brick Exterior Wall 360mm	4847
B2010	Basic Wall	Existing	None	6.64 m³	Brick Exterior Wall 360mm	4853
B2010	Basic Wall	Existing	None	21.34 m³	Brick Exterior Wall 360mm	5200
B2010	Basic Wall	Existing	None	7.14 m³	Brick Exterior Wall 360mm	5218
B2010	Basic Wall	Existing	None	7.14 m³	Brick Exterior Wall 360mm	5222
B2010	Basic Wall	Existing	None	7.15 m³	Brick Exterior Wall 360mm	5223
B2010	Basic Wall	Existing	None	39.28 m³	Brick Exterior Wall 480mm	5520
B2010	Basic Wall	Existing	None	41.16 m³	Brick Exterior Wall 480mm	5520
B2010	Basic Wall	Existing	None	11.01 m³	Brick Exterior Wall 360mm	6020
B2010	Basic Wall	Existing	None	37.98 m³	Brick Exterior Wall 480mm	6020
B2010	Basic Wall	Existing	None	44.32 m³	Brick Exterior Wall 480mm	6020
B2010	Basic Wall	Existing	None	23.98 m³	Brick Exterior Wall 360mm	9005
B2010	Basic Wall	Existing	None	12.49 m³	Brick Exterior Wall 360mm	9127
B2010	Basic Wall	Existing	None	12.52 m³	Brick Exterior Wall 360mm	9150
C1010140	Basic Wall	Existing	None	6.32 m³	Exterior Wall Lightweight	9391
B2010	Basic Wall	Existing	None	33.70 m³	Brick Exterior Wall 480mm	10620
B2010	Basic Wall	Existing	None	34.88 m³	Brick Exterior Wall 480mm	11000
B2010	Basic Wall	Existing	None	35.64 m³	Brick Exterior Wall 480mm	11895
B2010	Basic Wall	Existing	None	36.75 m³	Brick Exterior Wall 480mm	12075
B2010	Basic Wall	Existing	None	108.24 m³	Brick Exterior Wall 480mm	12690
B2010	Basic Wall	Existing	None	90.84 m³	Brick Exterior Wall 480mm	26790
B2010	Basic Wall	Existing	None	90.96 m³	Brick Exterior Wall 480mm	48542
Grand total: 56				931.82 m³		

Wall Maintenance Library					
Assembly Code	Family	Type	Phase Created	Mark	Last Control Date
B2010	Basic Wall	Brick Exterior Wall 360mm	Existing	AV: 3 SV: 4	10.09.2023
B2010	Basic Wall	Brick Exterior Wall 360mm	Existing	AV: 4 SV: 6	10.09.2023
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B2010	Basic Wall	Brick Exterior Wall 480mm	Existing	AV: 4 SV: 6	25.07.2024
• • •					
B2010	Basic Wall	Exterior_ Reused Wall 360mm	New Construction	AV: 1 SV: 4	10.09.2023
• • •					
B2010	Basic Wall	Interior_Exhibition Wall	New Construction	AV: 4 SV: 3	25.07.2024
• • •					
B2010	Basic Wall	Partition cube	New Construction	AV: 1 SV: 3	15.03.2023
• • •					
B2010	Basic Wall	Partition cube	New Construction	AV: 1 SV: 3	27.07.2023
• • •					
B2010100	Basic Wall	Exterior Wall_Lamellas	New Construction	AV: 2 SV: 5	15.03.2023
• • •					
B2010100	Basic Wall	Exterior Wall_Opaque Cube	New Construction	AV: 5 SV: 3	15.03.2023
• • •					
B2010120	Basic Wall	Wall-Ret_300Con	New Construction	AV: 4 SV: 7	25.07.2024
• • •					
B2010140	Basic Wall	Int_External Wall Insulation	New Construction	AV: 3 SV: 4	10.09.2023
• • •					
B2020200	Curtain Wall	Exterior Glazing	New Construction	AV: 5 SV: 3	10.09.2023
• • •					
C1010140	Basic Wall	Exterior Wall Lightweight	New Construction	AV: 2 SV: 5	15.03.2023
• • •					
C1010140	Basic Wall	Exterior Wall Lightweight	New Construction	AV: 1 SV: 3	27.07.2023
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C1010150	Basic Wall	Int_Restaurant Wall	New Construction	AV: 2 SV: 1	25.07.2024

Structural Framing Schedule					
Count	Assembly Code	Family	Phase Created	Phase Demolished	Type
24	B1020240	Timber Beam	Existing	New Construction	6 7/8 x 6 7/8
210	B10	Timber Beam	Existing	New Construction	50x140
227	B1020240	Timber Beam	Existing	New Construction	140x140
29	B10	Timber Beam	Existing	New Construction	180x180
24	B1020240	Timber Beam	Existing	None	6 7/8 x 6 7/8
398	B10	Timber Beam	Existing	None	50x140
256	B10	Timber Beam	Existing	None	70x140
1029	B1020240	Timber Beam	Existing	None	140x140
14	B10	Timber Beam	Existing	None	140x200
103	B10	Timber Beam	Existing	None	180x180
2314					

Structural Framing Maintenance Library

Assembly Code	Family	Type	Phase Created	Mark	Last Control Date
B1020240	Timber Beam	140x140	Existing	AV: 1 SV: 4	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 2 SV: 3	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 3 SV: 3	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 2 SV: 4	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 3 SV: 3	05.03.2023
B1020240	Timber Beam	140x140	Existing	AV: 1 SV: 4	05.03.2023
B1020240	Timber Beam	140x140	Existing	AV: 1 SV: 4	20.09.2022
B10	Timber Beam	180x180	Existing	AV: 3 SV: 3	20.09.2022
B10	Timber Beam	180x180	Existing	AV: 2 SV: 4	17.11.2022

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B1020240	Timber Beam	140x140	Existing	AV: 2 SV: 4	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 1 SV: 4	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 2 SV: 3	20.09.2022

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B1020240	Timber Beam	140x140	Existing	AV: 2 SV: 3	21.04.2023
B10	Timber Beam	50x140	Existing	AV: 1 SV: 4	05.03.2023
B10	Timber Beam	50x140	Existing	AV: 3 SV: 3	17.11.2022
B10	Timber Beam	50x140	Existing	AV: 2 SV: 3	17.11.2022
B10	Timber Beam	50x140	Existing	AV: 2 SV: 4	21.04.2023

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B1020240	Timber Beam	140x140	Existing	AV: 1 SV: 4	21.04.2023
B10	Timber Beam	50x140	Existing	AV: 1 SV: 4	20.09.2022
B10	Timber Beam	50x140	Existing	AV: 1 SV: 4	20.09.2022
B10	Timber Beam	50x140	Existing	AV: 3 SV: 3	20.09.2022
B10	Timber Beam	50x140	Existing		17.11.2022

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B10	Timber Beam	50x140	Existing	AV: 2 SV: 4	17.11.2022
B10	Timber Beam	50x140	Existing	AV: 2 SV: 3	05.03.2023
B10	Timber Beam	50x140	Existing	AV: 1 SV: 4	20.09.2022
B10	Timber Beam	50x140	Existing	AV: 1 SV: 4	20.09.2022
B1020240	Timber Beam	140x140	Existing	AV: 3 SV: 3	05.03.2023
B10	Timber Beam	50x140	Existing	AV: 2 SV: 4	21.04.2023