Project title	The Architecture of Urban Aquaculture *Design Proposal*
Theme	Architecture & Urban Farming *Long dissertation programme 2013/2014* *Master Thesis Project, Architecture* *Department of Architecture, Design & Media technology* *Aalborg University*
Supervisors	Claus Bonderup *Architect, Professor* *Department of Architecture, Design & Media technology* *Aalborg University* Dario Parigi *Assistant Professor* *Department of Civil Engineering* *Aalborg University*

External Partners and Superviors	Anna Marie Fisker *Architect, Ph.D., Head of Section* *Department of Civil Engineering* *Aalborg University*	Peter Frigaard *Civil Engineer, Head of Institute* *Department of Civil Engineering* *Aalborg University*
	Tenna Doktor Olsen *Cand polyt Arch, PhD.* *Department of Civil Engineering* *Aalborg University*	Anette Rosenbæk *Planlægger* *Team Byomdannelse* *Aalborg Municipality*

Project period	01 Sep - 30 Maj 2014
Number of pages	62
Number of copies	5

Elias Melvin Christiansen

Table of contents

ill. 1: *An Architecture that facilitates a mussel production*

1 .0 Introduction

1.1 From theory to design

Based on the framework provided by the research and theoretical work put forward in the theoretical thesis, the forthcoming vision and project description is the groundwork for the design task and the second part of this master thesis.

Here I will briefly linger on the phenomenon of Urban farming from my own perspective. I see great potentials in Urban Farming to create new and interesting spaces in our cities. I see great potentials in the Urban Farming's ability to change the relationship between the city and citizens. Through Urban Farming we can redefine how we live in and off our cities. The understanding of what the city can provide for us and what we can use it for is greatly extended through the phenomenon, and I recognize great potentials for architects to lead this movement.

But what can it be used for? That is a question for the future to answer precisely. In this project I have sought out to create one initial image of what the phenomenon architecturally and functionally can be used for.

This project should be viewed as an input to a social and architectural discussion that has been going on for some time and probably will continue the following many years. In that sense the project is a statement towards a future lifestyle, a hint of a future use of the city and architecture. This means that the project is conceptual in its programming and architecture, framed for a future in which we shape our surroundings and our lives differently. In my opinion the project assume the role as en entry to a fashion show. A project that should serve as an inspiration for a future use of the city, taken to extreme.

From the theoretical thesis potentials of Urban Farming in a city of the future were discussed. Specifically how urban farming should emanate from historical and cultural legacies was put to great emphasis. Because of this it was chosen to design a facility that will put focus on mussel production, as they historical have had great significance for the fishing industry in Limfjorden, but have never been rooted in the city of Aalborg. The mussel is so popular, that the specific breed is known as 'Limfjordsmuslinger' in the restaurants. The thesis discuss the challenge from an urban perspective and to some extend on an architectural level. In the following design proposal actions toward a more in-depth architectural treatment has been carried out.

The architectural treatment is inspired by the architectural investigations from the theoretical thesis. Investigations which took point of departure in architectural space as a notion, and the conviction that space is the essence of architectural creations. The notion was treated with respect to different approaches. First the unfolding of the theoretical notion, then space in terms of the modernistic mantra 'Form Follows Function' and how some of those architects have treated the coherence between space and function. In the architectural treatment, special attention will be put on spatial creation through spatial experience and functional planning.

The second part of the architectural investigations addressed the issue of spatial creations in relation to the means relevant for the project in the design proposal. The two means discussed was means of water in terms of sensual stimuli and atmospheric affections, and means of art based on the art form 'Installation art' and some of its branches all related to the theme of nature and how art stages experiences.

The following design proposal will be based on these investigations and use the terms unfolded in these chapters. The following description of the initial vision and idea of the project was developed during the writing of the theoretical thesis, hence the vision emanate from these chapters. Summed up, the design part wishes to deal with:

How the potentials of Urban Farming can be unfolded in architecture?
And how architectural space can be the mean?

The vision has been to create a social platform in which an aquaculture approach to Urban Farming can be outworn. The facility shall provide spaces for social gathering based on the appreciation of a local production and consumption of seafood from Limfjorden in the urban settlement. The production will concern mussels, while the restaurant should be based on local seafood in general. The facility will be a nurturing mix of two different user groups concerning production of seafood and cooking of seafood. They are gathered through a shared desire for utilizing the water for new means in an urban context and for growing food in the city.

For the technical aspect of the project, the desire was to find a way in which structure and spatial creation would grow out of the same vision. A tectonic approach with a desire to find a way in which parametric tools to structural design could be used in order to facilitate the desired spatial experience. This has been the main focus in regards to technical solution, but other technical aspects has been used in the integrated design process, to support the creation of the spatial experience.

In order to deal with the qualities of Urban Farming and architecture, and the spatial experience on as high level as possible, the aspect of economy have been diminished in order to achieve a project as true to its concept as possible. Not to neglect the parameter of economy in architecture, but in order to deal with a clean concept, this aspect has been limited.

On the following pages is a description of the site chosen for the project. The site was chosen in collaboration with the city planners at the municipality in order to create a framework based on real world situations. The site is Østre Havn, a city district in rapid development from being an industrial workers harbour, to a dense urban community.

After the review of the site the framework for the building will be provided in terms of functions presented in a table with the spatial programming and an illustration showing the interrelated relations between the functions in a spatial diagram. The information provided within the space program and space diagram is based on similar projects, the outcome of the theoretical thesis, input from the municipality, own preferences, and building codes. The table should be viewed as input from a fictive client.

From the brief contextual reading and the programming the architectural concept of the building will be unfolded explaining the overall ideas of the project.


Østre Havn

1.2 Østre Havn

The site chosen for the project is based on clues unfolded in the theoretical thesis, together with a dialogue with the municipality of Aalborg. In terms of the Urban Farming part the project would reach its highest potential by being placed in a dense urban context in association with urban life and urban functions based on recreational activities. The facility demand access from land and from water.

Based on these demands Østre Havn was chosen. Placed in the adjacent district to the nearly finished House of Music by Coop Himmelb(l)au. This district has a newly approved development plan with a vision covering the forthcoming years of creating a district for a dense and cultural city life (Aalborg Kommune 2012). The inner harbour has a distinct historical significance and the space is steeped in a delicate maritime atmosphere. A project placed in this context would therefore have deep roots in a rich historical culture, but developed along a contemporary prospectively and ambitious vision.

The original harbour was erected in 1901-1903 as a part of the overall upgrading toward a modern industrial harbour. The function historically served the local grain-and feedstuff industry both connected to the train and water infrastructure (Aalborg Kommune 2012, 6). A highly developed system adjusted to service the functional and efficiency demands from a modern industry (Aalborg Kommune 2012, 18). The area was filled with life and a maritime atmosphere related to the mayor industry was present on the site.

Today the district is empty and quiet, but the area still reeks of history from the old dilapidated grand buildings representing the former time of glory. The sensual experience of the site is equally filled with heavy industrial memories and one can almost feel the muscles this district provided back in time. Such an area grown out of history deserves to be treated respectfully, which the municipality notice and attach great importance to in their vision for the impending development (Aalborg Kommune 2012, 12,15,18,22).

The area is in extension of the already established new harbour front in the city centre and the connection to this site has been very important in the design of the new area. The situation of the area is described as being in the periphery of the inner city, which has great significance for the atmosphere. It is not possible to have dense city life everywhere, so it is important to facilitate other activities as well. The site possess great opportunities to recreate the contact between city and water that for a long time due to the industrial activities has been cut of from each other (Aalborg 2012, 6).

In the creation of the entire area the municipality has put great importance on sustainable development in the shape of dense city dwelling with a high level of public transportation, bicycling opportunities, and state of the art sustainable technologies. The area should facilitate a rich city life and promote Aalborg as a visionary sustainable city of knowledge and culture. The cultural and historical legacies of the area are of great importance and should be a part of the future area. Especially the authentic curvy shape of the spaces in between the buildings defined by the train track from train curvature demands, but also the characteristic mix of grand silo buildings and low harbour structures.

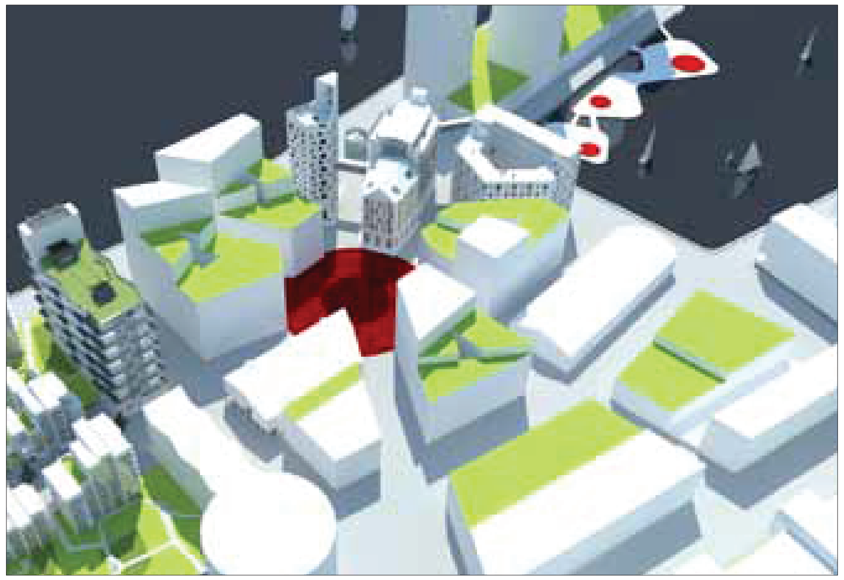
The goal is to create a social diverse urban area with space for everyone and in this scheme is the inner harbour of great importance. This space has the opportunity of creating active, social, and recreational activities that support social life. It is likewise of great interest to think the cities green and blue connections in the area and for this district especially the availability of the water is important. The fjord and the inner harbour should be understood as a piece of accessible blue nature, a place for the joining of nature and culture (Aalborg Kommune 2012, 12-27).

During the last couple of years the harbour front in Aalborg has undergone comprehensive changes. Østre Havn follows a wide range of spaces that have changed according to the new vision of Aalborg as a visionary city based on knowledge and culture. With a site scratched from content like the current stage of Østre Havn, architects are facing the challenge of building up an entirely new context. Østre Havn contains a vast historical and cultural legacy related to the enormous industrial significance the space have had for the city. It is desired to reconstruct a space that reflect this historical legacy in a new and contemporary interpretation with the rebuilding of Østre Havn. The area contain opportunities for creating a facility that promote active, social and recreational activities. Østre Havn will be a manifestation of contemporary lifestyle and will work as a model for future planning in Aalborg and in Denmark.

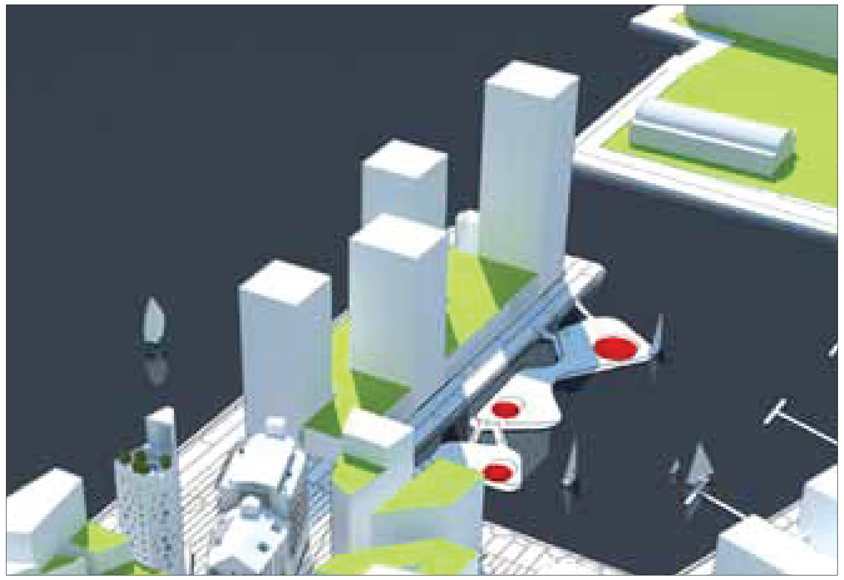
The following page shows a more in detail description of the areas which constructs the overall district. After this a page illustrating images provided by the architects and landscape architects POLYFORM, for the future development of the site.

ill. 3: *Historic picture of Østre Havn before demolition, 2001*

ill. 4: *Kilens Kvarter*



ill. 5: *Stjernekvarteret*

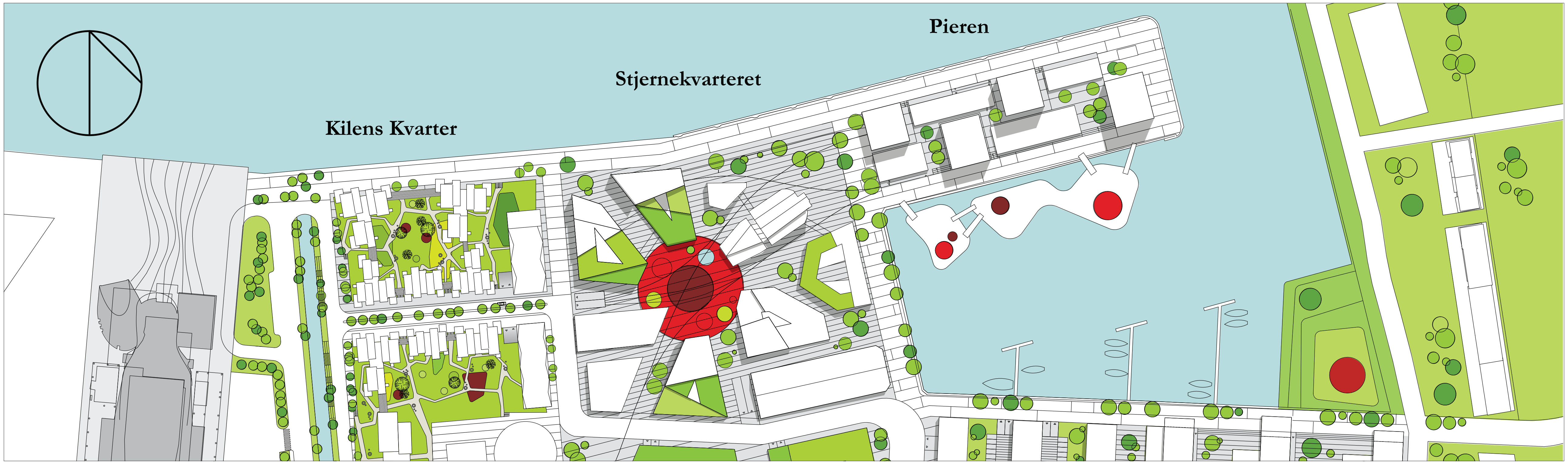


ill. 6: *Pieren*

'Kilens Kvarter' will be considered as a green area is in extension of the green areas from Karolinelund. The build area should seem dense consisting of tall point buildings connected by buildings in small scale. The opening of Øster å pass between 'Musikkens Hus' to the vest and 'Kilens Kvarter'. This will have a severe influence on the spatial experiences in this area.

'Stjernekvarteret', will be constructed according to the structure of the harbour, with simple volumes in different scales and geometry. The former railroad tracks defines the plaza 'Stjernepladsen' in the middle. This plaza will be the centre of the overall district containing retail, penthouse apartments, and offices. The urbanity will be centred from this plaza.

'Pieren' should be constructed with tall buildings and in the bottom are placed smaller buildings and pocket parks. They cover the inner harbour from the heavy wind known to occur in the site. High rises and skylines mimics the historical building shapes present on the site in the time of industrial glory.



ill. 7: *The vision plan for the future of Østre Havn*

Østre Havn vision images

The images on this site illustrates the vision put forward by the architects, city planners, and landscape architects for the spaces in between the buildings on the future Østre Havn. They should give an impression of the vision put forward by the municipality and should serve as a framework for design. All images have been borrowed from POLYFORM - *Østre Havn Dispositionsfoslag* (POLYFORM 2014) and Østre Havn - *Kvalitetsprogram* (Aalborg kommune 2012).

The images clearly shows the vision of rooting the site in natural landscapes and using the water and the vast historical legacy in the creation of the coming Østre Havn. Even though the space can be considered very urban and dense, nature and the fjord plays an important role in the atmosphere and the identity of the site.

From the site the following will be used in the design:

The historical and cultural legacy and the connection to the water and nature build in the vision for the area. A dense urban community with huge structures in steel, concrete, and glass needs a small, human scale and human related facility that could create identity and cozy atmospheres in a highly urban area.

ill. 8: *Vision for Østre Havn. Reuse of old buildings*

ill. 9: *Vision for Østre Havn. Nature and contact to water*

ill. 10: *Vision for Østre Havn. Harbour front*

ill. 11: *Vision for Østre Havn. Between buildings*

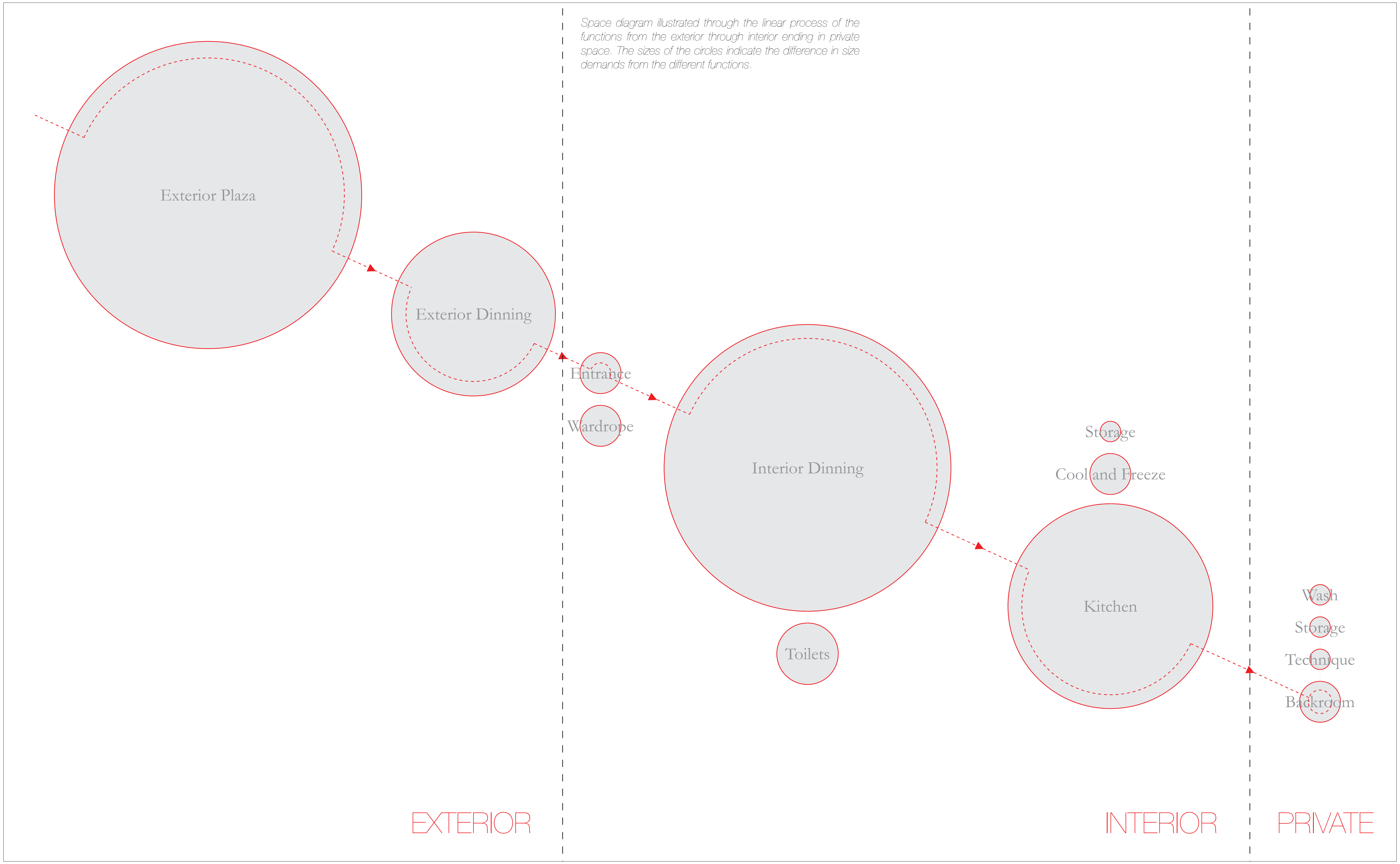
ill. 12: *Vision for Østre Havn. Inner harbour*

1.3 Space Program

Function	Description	Area	Atmosphere	Light	Materials	Extra notes
Mussel plaza (Mussel farming)	*Plaza related to mussel production. Mussel farming inspired by the method of Bouchot mussel farming on poles.*	150 m²	*Cozy, inviting to social gatherings and meetings between humans, related to the water and the place.*	*Natural light.*	*European White oak covering all surfaces.*	
Exterior dinning space (25 guests)	*Exterior dinning space on the water. The space is placed in connection with the arrival to the facility.*	80 m²	*Cozy, inviting to social gatherings and meetings between humans, related to the water and the place.*	*Natural light shielded with sails to protect from overheating. Artificial lighting at night.*	*European White oak covering all surfaces.*	
Entrance	*Entrance to the restaurant space. Arrival of the restaurant guests.*	20 m²	*Open, welcoming, overview of the interior*	*Natural light. At night artificial lighting.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	
Wardrope	*A space dedicated to hanging coats and leaving accessories*	20 m²	*Open, welcoming, overview of the interior*	*Natural light. At night artificial lighting.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	*Adjacent to entrance space*
Interior Dinning space (50 guests)	*The main space of the structure and of the facility. This eating space should provide a unique spatial experience.*	140 m²	*References to interior of a wooden ship, main spatial experience.*	*A well-lit room from natural lighting. At night artificial lighting.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	
Kitchen	*Open and involved kitchen. Minimal requirements,*	100 m²	*Open kitchen, a part of the restaurant experience to see the chefs in action, inviting to participate.*	*Natural light. Spot lighting for the chefs.*	*Interior in steel and wood. Surfaces like restaurant.*	*Connected to water, electricity, and gas.*
Restaurant storage	*Storage of plates, cutlery, glasses and other things related to the waiter's job of taking care of the customers.*	10 m²	*Visual accessible to the restaurant space. Be a part of the open atmosphere in the dinning space*	*Artificial light. The storage is on display for the visitors, and is highlighted.*	*Refrigerators and freezers in aluminium and storage shelves in wood*	*Adjacent to the kitchen space.*
Cool and Freeze	*Storage of food and products for the chefs to use during the cooking. The equipment should include cool and freeze.*	20 m²	*Visual accessible to the restaurant space. Be a part of the open atmosphere in the dinning space*	*Artificial light. The storage is on display for the visitors, and is highlighted.*	*Refrigerators and freezers in aluminium and storage shelves in wood*	
Wash	*A space dedicated to washing dishes and cleaning plates.*	10 m²	*Efficient working space.*	*Artificial light suitable for an efficient workspace.*	*Dishwashers and counters in aluminium.*	*Close to restaurant storage and kitchen.*
Toilets	*Toilet facilities serving the customers and the workers.*	30 m²	*Interior and under water qualities from the restaurant atmosphere present.*	*Artificial light, with a little light coming from the underwater exterior through windows.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	*Handicap friendly, accessible from restaurant.*
Backroom	*Resting space for the staff and office space related to running the restaurant.*	20m²	*Backroom to the staff, office space. Interior and under water qualities from the restaurant atmosphere present.*	*Artificial light, with a little light coming from the windows in water level.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	
Backroom storage	*Storage of larger interior needs related to the kitchen, office, and the dinning space.*	10 m²	*Efficient storage space.*	*Artificial light.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	*Adjacent to the backroom space.*
Technique	*For maintenance of the structure in relation to ventilation.*	10 m²	*Efficient work space.*	*Artificial light.*	*Wall and roof surfaces from light ash panels, floor from dark smoked oak panels*	*Hidden away, connected to all rooms.*

ill. 13: *Space program*

1.4 Space Diagram

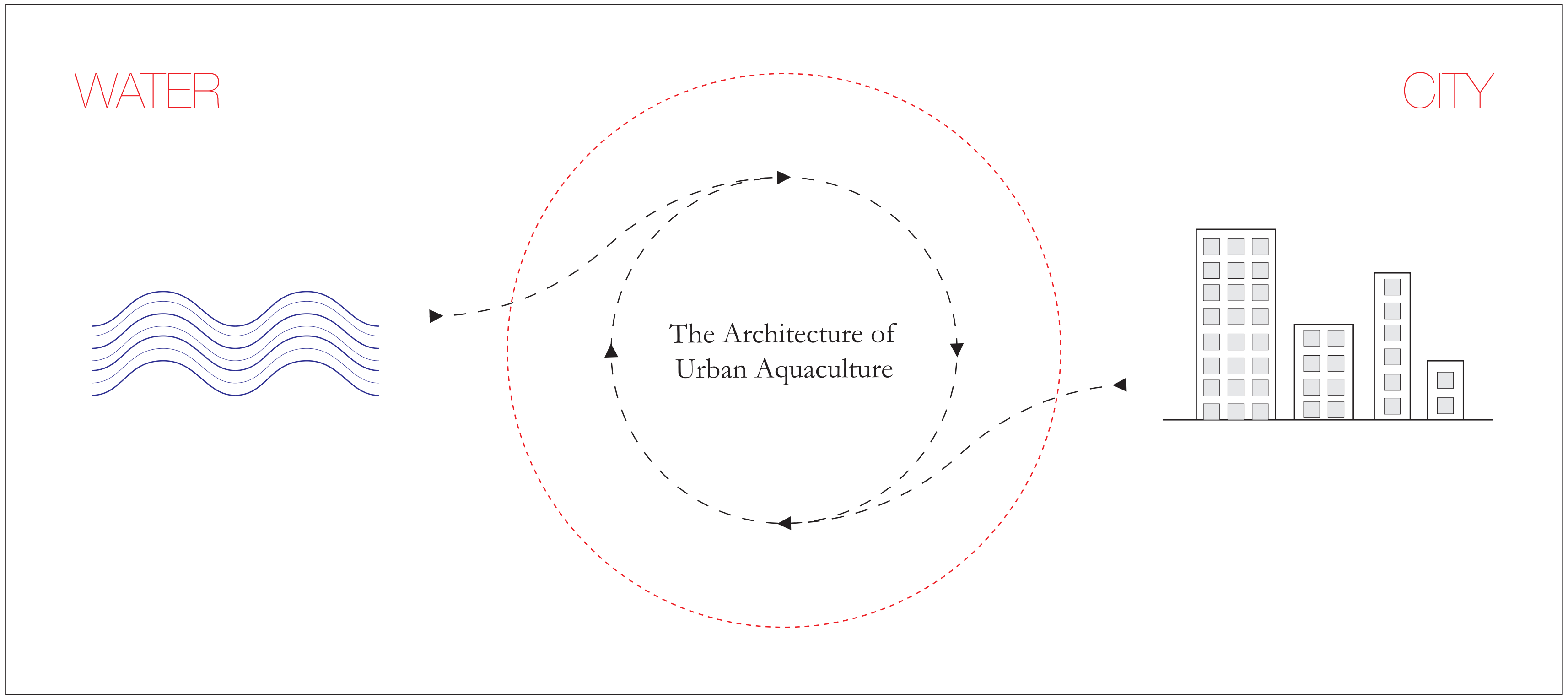


ill. 14: *Space diagram.*

1.5 Concepts

Urban Concept

The urban concept relates to the main function of the facility. As the illustration to the right indicates, the joining of water and urban activities is the main function. The facility introduces the water into the realm of the city and brings the city out on the water.



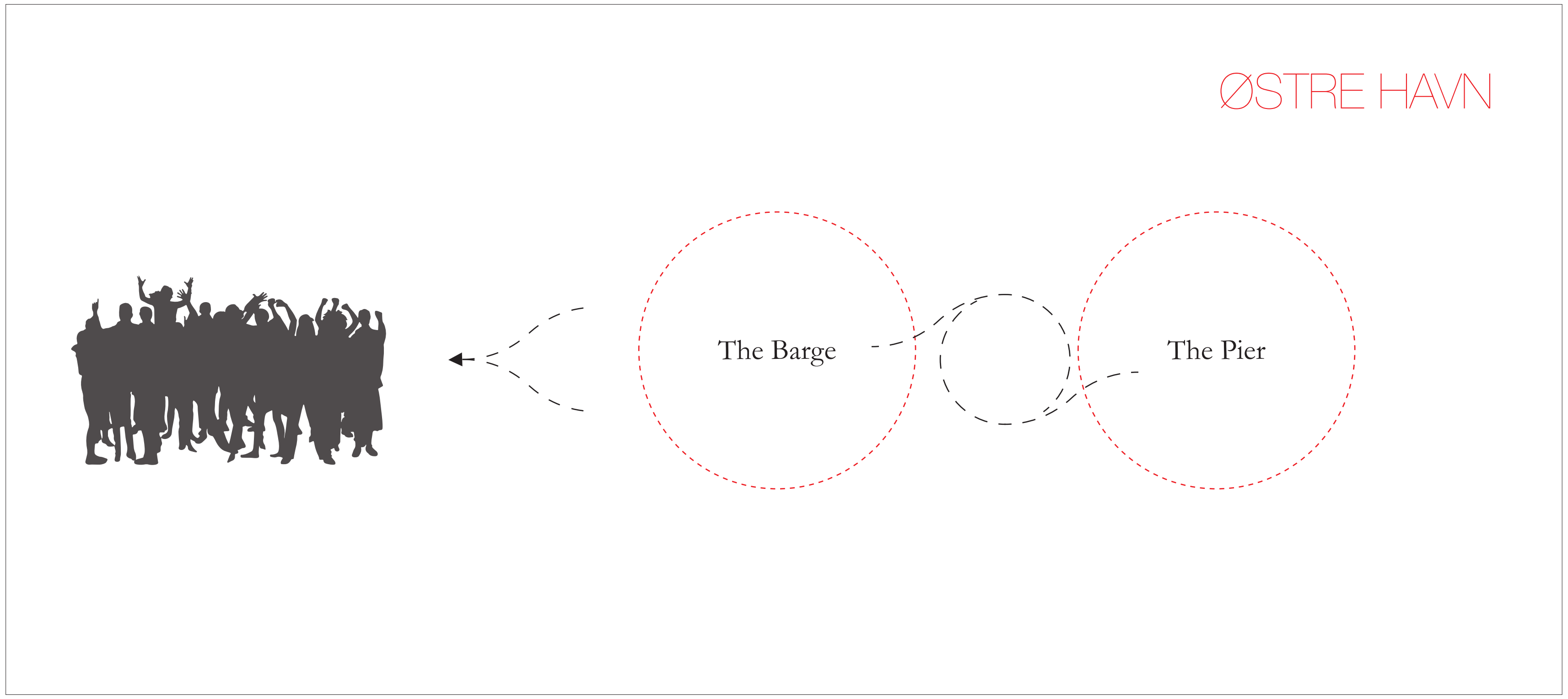
ill. 15: *Functional concept*

Architectural Concept

The project will constitute of two parts according to the two user groups but physical placed adjacent to each other. The two parts will be referred to as the 'Pier' and the 'Barge'. The 'Pier' is a fixed structure facilitating social gathering based on the production of mussels, and the 'Barge' is a floating structure dedicated to the cooking and consumption of seafood, in shape of a contemporary seafood restaurant.

The architectural concept of the relationship between these two structures is represented in the diagram to the right. The two facilities has a connection between them manifested on the site of Østre Havn. But on special occasions, the Barge is able to be dragged away by tugboats, in order to dock on other locations for special events.

In the following, this will be elaborated.

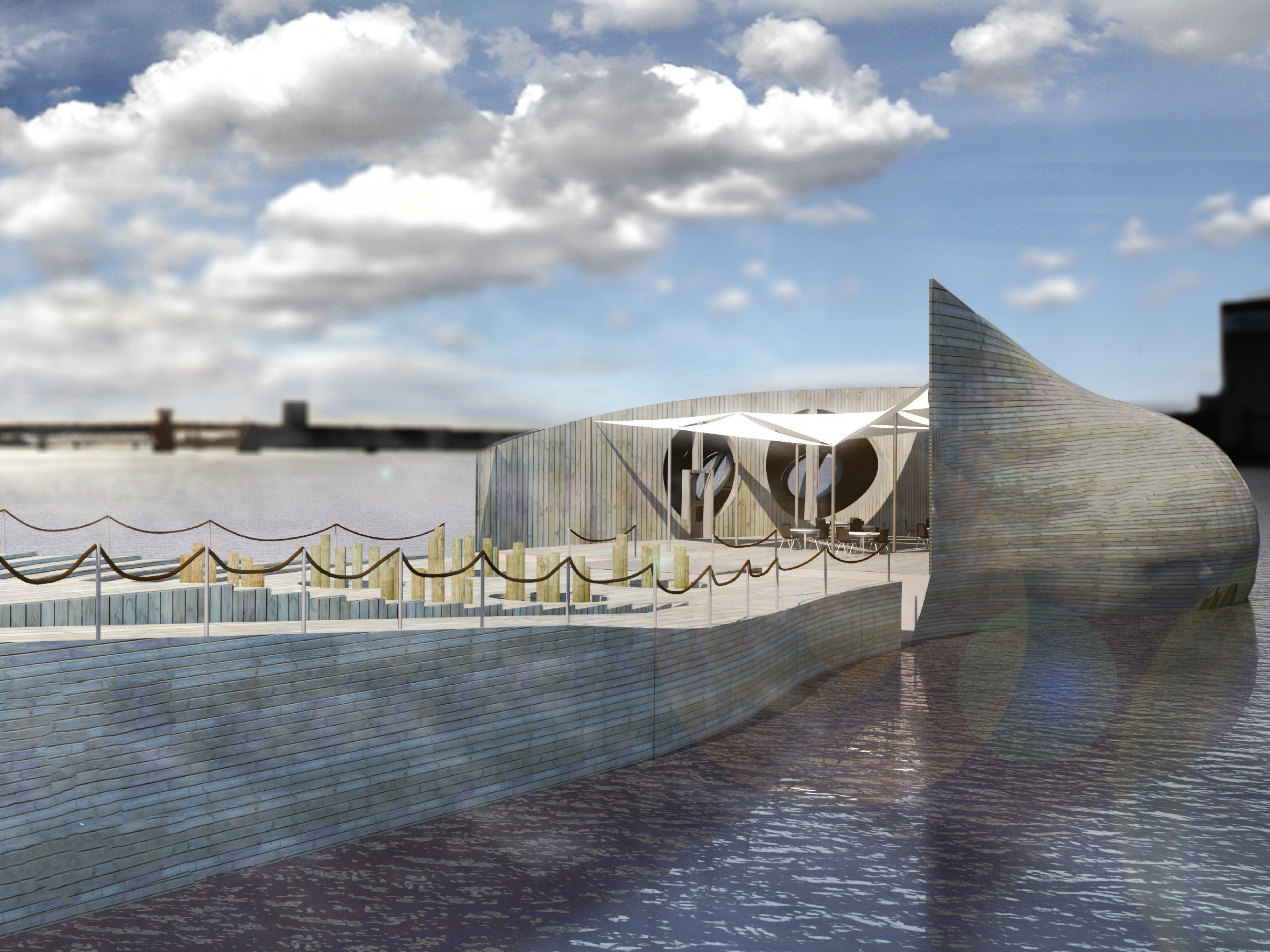


ill. 16: *Architectural concept*

2.0 Urban Scale

Placed in an enchanting aquatic scenery by Limfjorden in the centre of the city of Aalborg, the iconic building grows out from the point where water and city fuses together. It almost floats out from the shore and onto the never-settling ocean, swaying slowly to the mesmerizing rhythm of the waves hitting the concrete wall, that separates water from the static, yet intense, and dynamic city. As a guardian, the structure sits on the border of water and city, assisting people to venture out on the untamed sea, and likewise, invites the water to be a part of the complicated system of the city.

ill. 17: *Urban scale. How the Citymeets the facility*



2.1 Masterplan

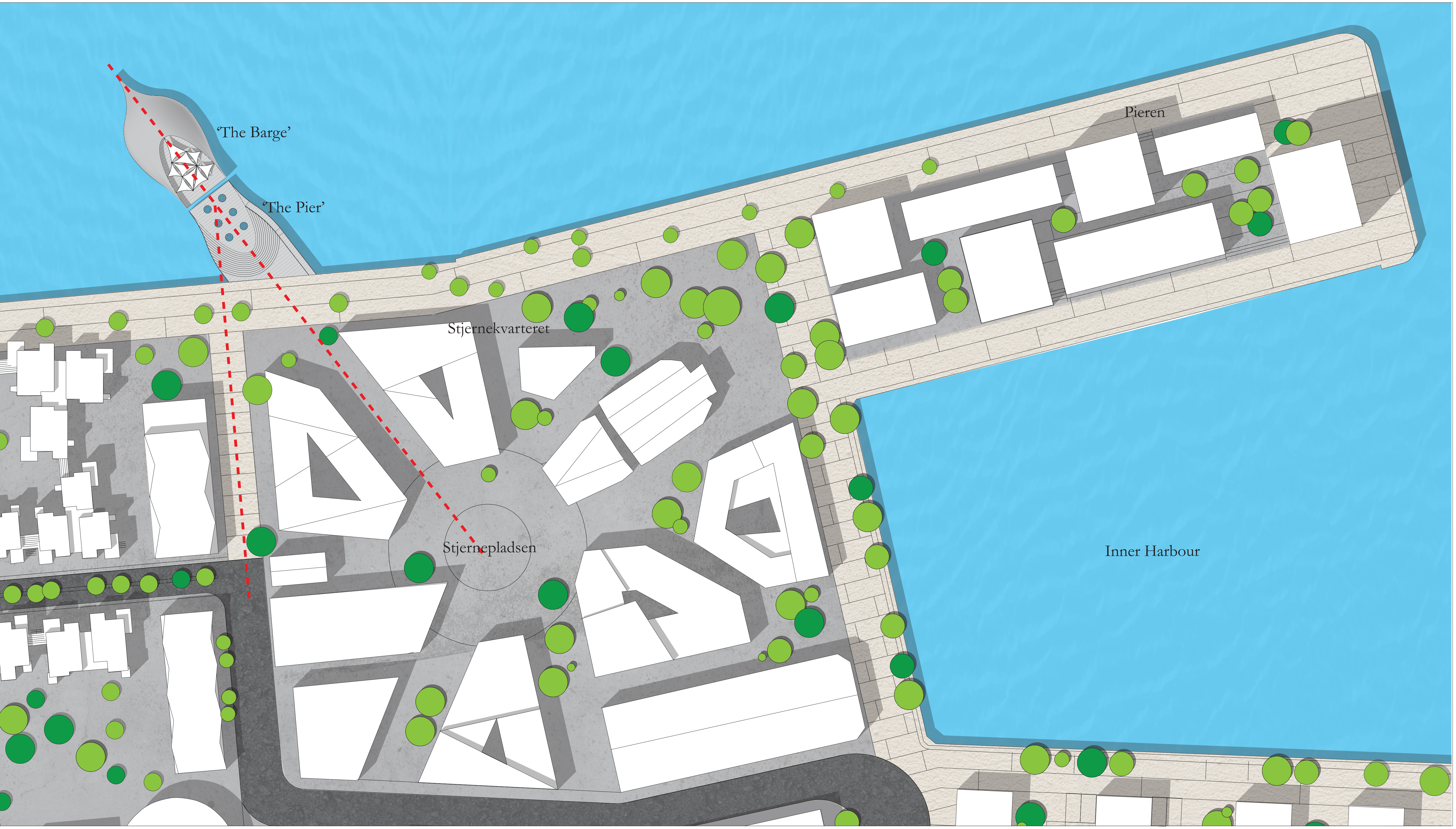
In Østre Havn there is two main areas where a facility on the water will be able to dock. In the inner harbour and out on the fjord. In order to attach itself to Østre Havn and still be able to stand out and have its own identity, the facility is placed along the harbour front in relation with the fjord. This situation is shown on the masterplan on the right. Furthermore, mussel production demands a certain change in water in order to get a continuously supply of oxygen. The still water within the inner harbour of Østre Havn will then not be sufficient enough to produce mussels. Therefore is the choosing the site out on the fjord, the best suitable.

The facility is placed right in front of the district 'Stjernekvarteret' in the end of two of the main paths within the site, allowing itself to be seen from many spaces and become an important creator of identity in Østre Havn. Easy accessibility from the main infrastructural elements is likewise of importance. On the masterplan the two connections to the main access routes and how the pier is a direct extension to 'Stjernepladsen' is marked by the red dotted lines.

The pier is placed as an extension of the a straight connection to the central 'stjernepladsen' and in relation with the whole promenade along the fjord. Due to the curved harbour front of both Aalborg and Nørresundby the facility will also be visible from the rest of the city. In this way it will form a backdrop to many activities on the site, and to some extend the rest of Aalborg. It will stand as a significant exponent of aquaculture, sustainable living, and a future lifestyle on Østre Havn, but reaches beyond and far out in the urban landscape.

In scale, size, and materiality the facility stands out in relation to the adjacent buildings. The facility seeks to meet people at eye level.

ill. 18: *Masterplan*


'The Barge'
'The Pier'
Pieren
Stjernekvarteret
Stjernepladsen
Inner Harbour

2.2 Alternative sites

The architectural concept of the facility include the possibility for the Barge to un-dock from Østre Havn and embark on journeys on the fjord to new and exciting happenings. Dragged by tugboats, the facility is able to travel away and temporarily dock onto other locations. In the following images of such journeys will be painted.

In the latest years, Aalborg has experienced an increase in the use the Fjord as a scenery for bigger events, gatherings, or everyday activities. This follows the significant rebuilding the harbour has undergone. As explained in the thesis, the harbour front has changed from being dominated by heavy industry to be defined by spaces for leisure and activities. On a daily basis several hundreds, if not thousands of people use the harbour fronts for gatherings, walks, exercise, activities and so on.

Festivals likewise use the spaces along the fjord in the summer months as a scenery for their celebration. This includes among many others 'Aalborg i Rødt', 'Den Blå Festival', and 'Karneval' but also many pop-up festivals and one day events like 'Chill i parken' utilize the maritime atmosphere. It will be possible for the barge to tag along and become a part of these celebrations. Many of the events already have food stands and other food related experiences included within the concepts. By including the Barge, a gastronomic experience based on the historical and cultural legacy of the Limfjord Mussel will be available to the visitors as an alternative to the aforementioned food stands. It will stand as a beacon on gastronomic experiences founded on local sea food productions and thus a billboard for the city of Aalborg and sustainable lifestyles.

During the summertime, even more tourists tag along the growing interest for the harbour front. They visit Aalborg among others for its fantastic connection to the fjord. Following this, great cruise ships visit the city every summer infiltrating the city with tourist from all over the world.

In summertime the activities in the marina out in the west from the centre is filled with these tourist enjoying the life by the sea and the many small boats that come visiting every year. Each summer, the Barge would travel for a week or so to pop-up and introduce the tourists to a piece of local produced sea food on this location. The pop-up could include several different restaurant experiences, and embark on the contemporary and very hyped phenomenon of pop-up restaurant concepts. This could include different ideas of involving the visitor in the cooking process, or create completely designed experiences based on the food experience. This could be done on more harbour locations dedicated to the tourist season.

But the Barge likewise has potentials to pop-up and become its own celebration. For a week each year, the Barge would travel to the inner city and celebrate its own annual festival, 'Muslinge festivalen' to a wider audience. By using the method of pop-up, the restaurant would thrive on the hype and the history of its travels. By using the mean as Cronhammar used in his Elia, described in the theoretical thesis. The stories and the myths of its travels would work for the restaurants advantages and create an undefinable aura of the facility that could lure attention.

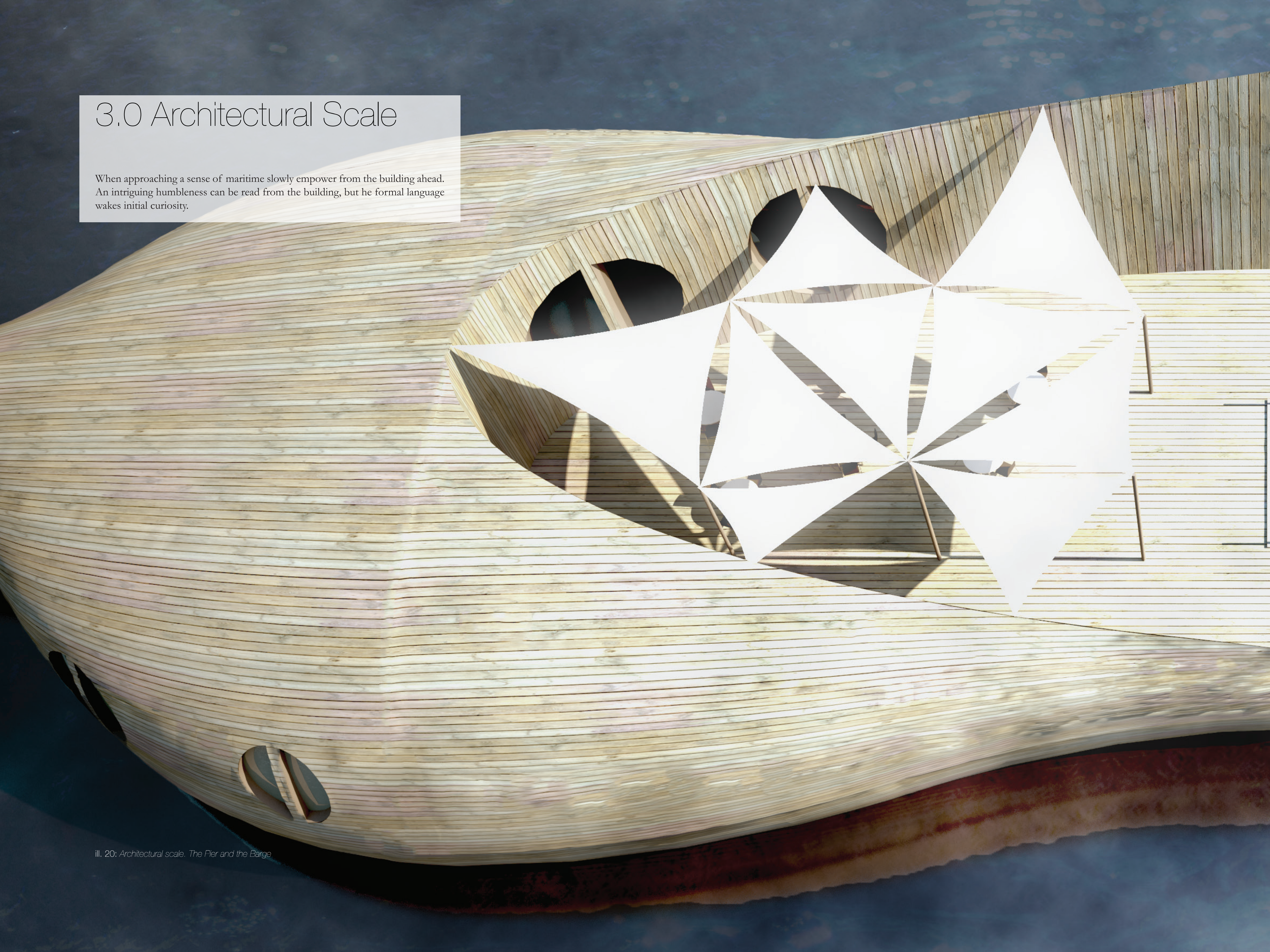
The image on the following page shows a collage of how a pop-up event could be experienced on the harbour front.

These are examples of immediate accessibility, but the intriguing travel concept could just as easily be extended to cover more than the harbour of Aalborg.

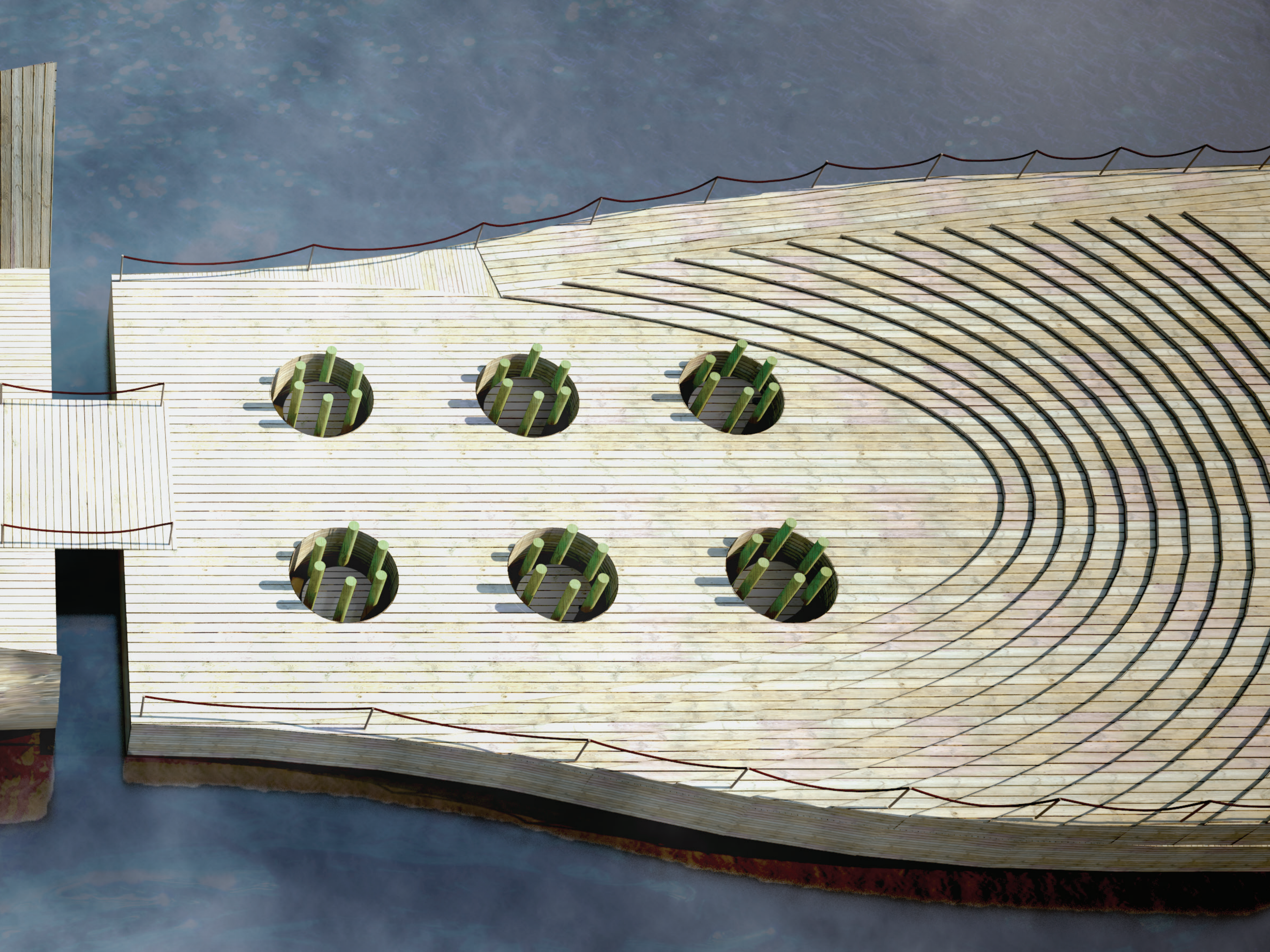
ill. 19: *The Barge in the harbour front for the yearly Mussel Festival*

3.0 Architectural Scale

When approaching a sense of maritime slowly empower from the building ahead. An intriguing humbleness can be read from the building, but he formal language wakes initial curiosity.



ill. 20: *Architectural scale. The Pier and the Barge*



3.1 Roof plans

The Pier

The first meeting with the facility is the Pier. It is constructed from White European Oak which is also to find on the Barge. A long curved stair takes the visitors from the level of the harbour front to the level of the mussel production 90 centimeters below. The stairs operate with a 8 cm rise and a 50 cm thread., which makes the stair long and very smooth to walk on. The shift in level will almost seem non-existence and the Pier will work as a natural extension of the harbour. On the east side of the Pier a ramp for disabled people is located. Two slopes on 10 meters each with a central platform makes the pier accessible for wheelchairs as well. In the bottom of the stair is the plaza situated. All edges of the pier is secured by a rope fence.

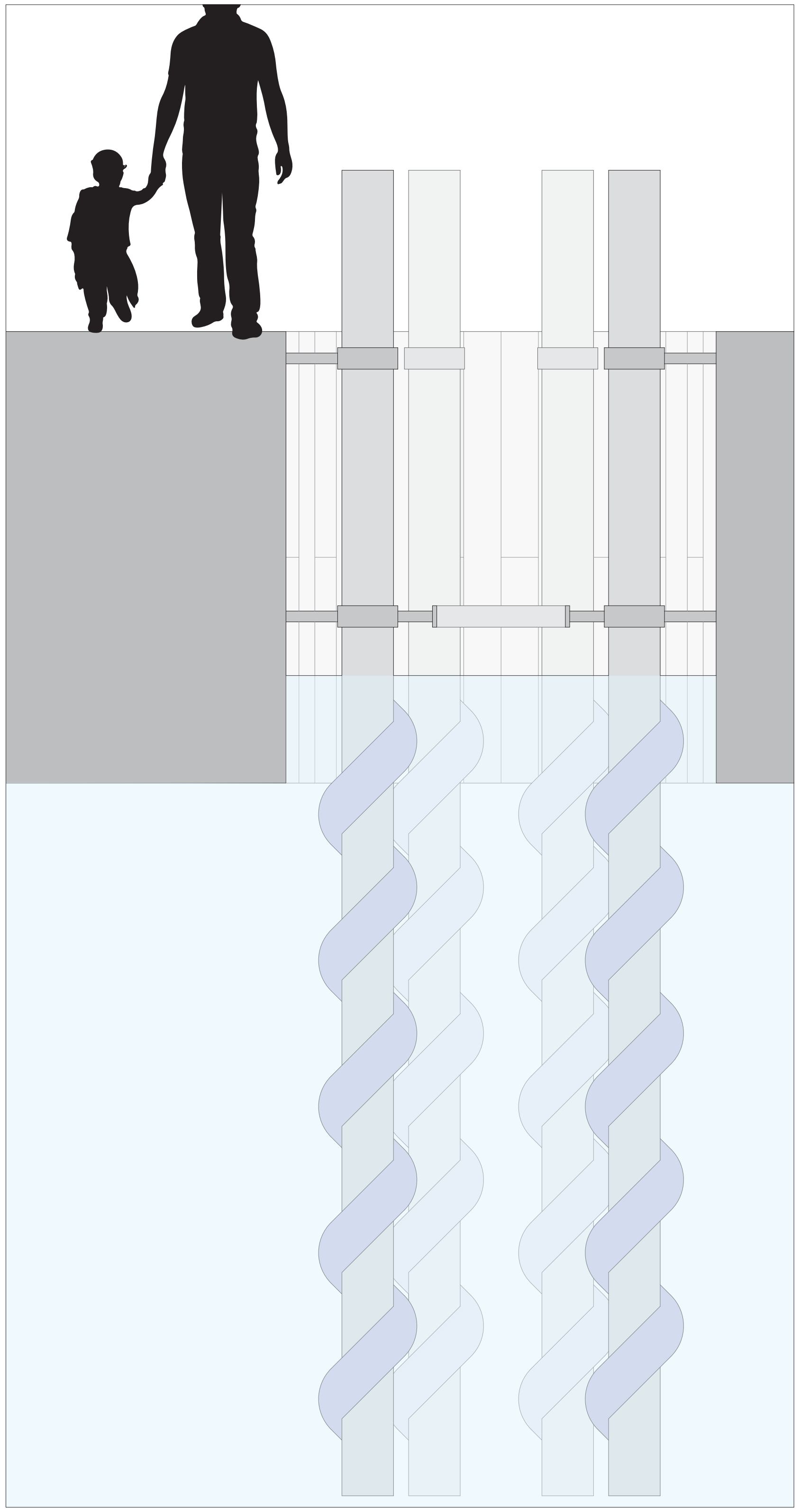
On the plaza in the middle of the structure, in size and shape identical to the one on the barge, is the mussel production taking place. On this plaza people can utilize their own part of the Fjord and grow mussels in the water. The method proposed is a method inspired by the French Bouchot mussels described in the theoretical thesis and shown in the image to the right. The principle is to grow mussels in stockings on a pole. But instead of fixing the pole in the bottom on the shore, like Bouchot mussels, the poles are fixed in the top and lowered from the Pier.

Six circular holes, 2 meters in diameter constitute the space dedicated to mussel production. Once put in stockings and put into the water, the mussels almost take care of themselves until harvest 10-18 months later. The poles should therefore not be designed for everyday access.

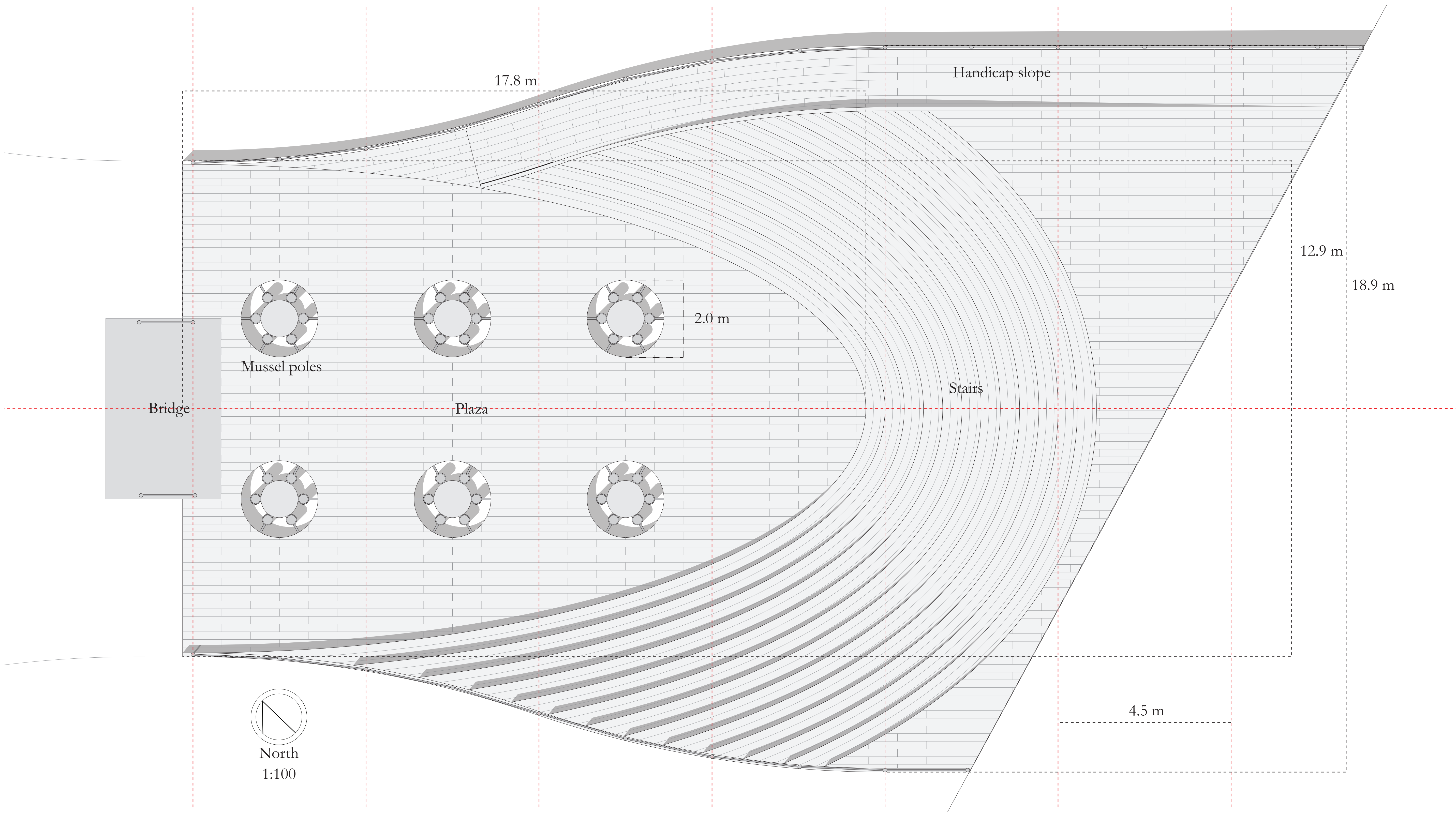
Each of the aforementioned holes contains six mussel poles placed in circular array with a circular platform with a diameter of 1 meter in the middle. This platform constitutes the work space needed for placing of the stockings and for harvest. The poles are fixed to the platform with circular brackets so the poles are able to turn in their own axis and raised from the water without loosing its fixture and stability. This is convenient when the stockings with mussels should be placed and harvested from the water. On the illustration to the right is a section showing how the method proposed are working conceptually.

From the big plaza a small bridge will lead the visitor from the pier to the barge. The sides of the bridge like the pier is edged by a rope fence.

ill. 21: *Bouchot Mussel poles.*



ill. 22: *The physical extend of the mussel production method proposed in section.*



ill. 23: *The Pier roof plan*

The Barge

When going from the Pier to the deck of the barge you will be met by a small embracing space. When the weather allows it, outdoor serving from the restaurant occurs in this space. Chairs and tables are placed in the middle embraced by the walls from the barge. In the harbour in Aalborg, the wind is often experienced very heavy, which potentially could ruin the restaurant experience on the deck. Hence the choice of making an embracing structure instead of an open.

The transition from the Pier to the barge happens on a small bridge which is hinged onto the deck and lays on top of the pier. When the barge is sailing away, this bridge will be folded up and upon arrival at the new location, lowered and placed as a bridge again.

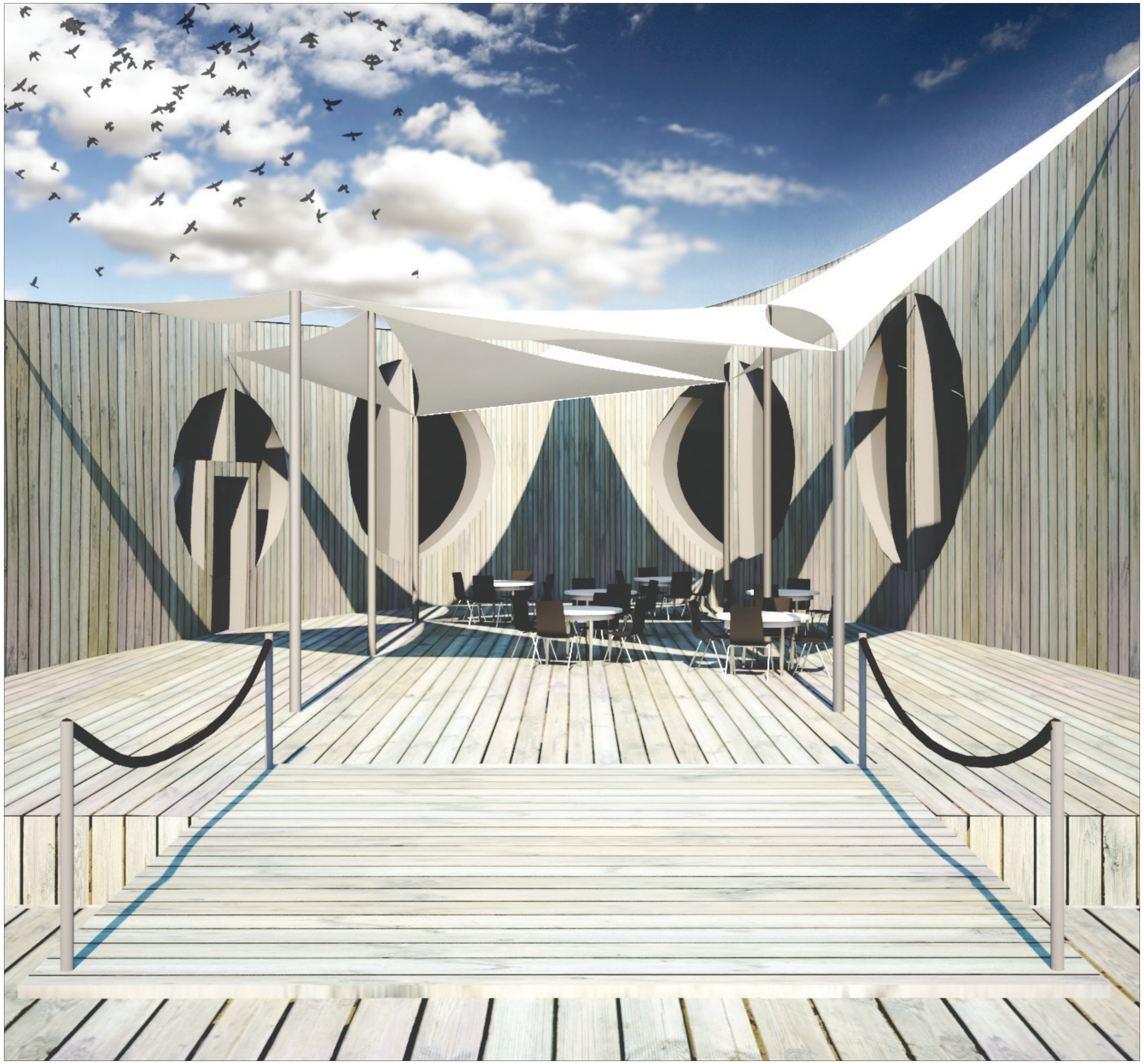
The facades of the deck constitutes of European White Oak like the Pier and rest of the outer faces on the Barge.

The outdoor serving space is covered in big white sails suspended from the barge itself and from 6 steel poles in the middle of the deck. They are placed in the same grid as the holes for the mussel poles on the pier, creating a connection between the spaces. The sails provides shadow on the deck, which could be very hot in the summer under the burning sun.

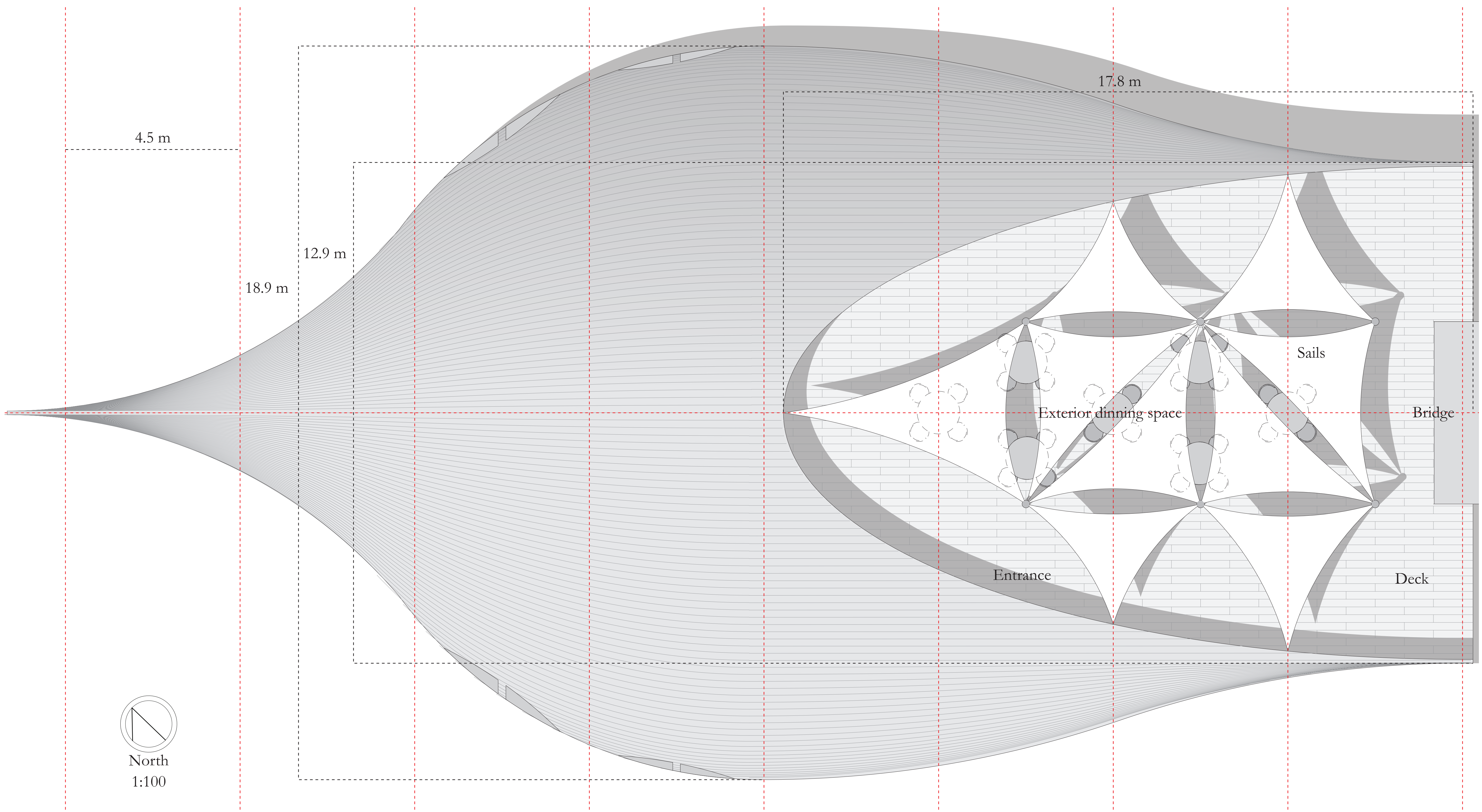
From the tables the shape of the barge clearly indicates a unison to the Pier and mussel poles. When the Barge is located somewhere else, the shape perform an inviting gesture towards the adjacent space, and almost lure the transient people onto the deck.

On the deck of the Barge eight large semicircular windows, increasing in size following the shape of the barge, creates a visual connection between the interior restaurant space where the floor area is visible through the windows. The semicircular windows are placed in pairs, making one pair create a complete circle.

The entrance to the interior of the Barge is in the middle of the two smallest window to the one side of the deck.



ill. 24: *Entering the Barge*



ill. 25: *The Barge roof plan*

4.0 INTERIOR

Entering the building an accommodating warmth embraces the visitor and the diversity in the room reveals the complexity in the composition of users in this unique building. From this room the composition of the spaces is evident, and the different sceneries is revealing just enough of themselves to keep the spectator interested. There are no defined borders in this room, and every function floats in and out of each other, creating healthy symbioses, but without loosing its own uniqueness. The range of moods and impression are all rooted in maritime atmosphere and the social environment.

The immediate reference in the interior space is related to an experience of being in a light open room in the interior of a wooden ship. This narrative follows the story of the Barge being able to sail away. Inspired by the beautiful structures of wooden ship construction this interior space is greatly affected by the series of glu-laminated timber beams along the faces. The horizontal light ash panels for the shell, with the rich texture and tactility, as well as the dark smoked oak for the flooring defines the interior atmosphere. The contrast in the materials creates a pleasing diversity in the room. The vast amount of natural light comes from the large circular windows placed in the top of the ship both from the deck and on the outer shell of the Barge.

In eye level within the space on the restaurant floor, is a range of smaller windows placed all along the facades. From these windows the visitors will be able to see the level of the water outside, which is carefully designed to be placed in this particular level. On this way the experience of the world beneath the water is part of the interior experience in this unique space.

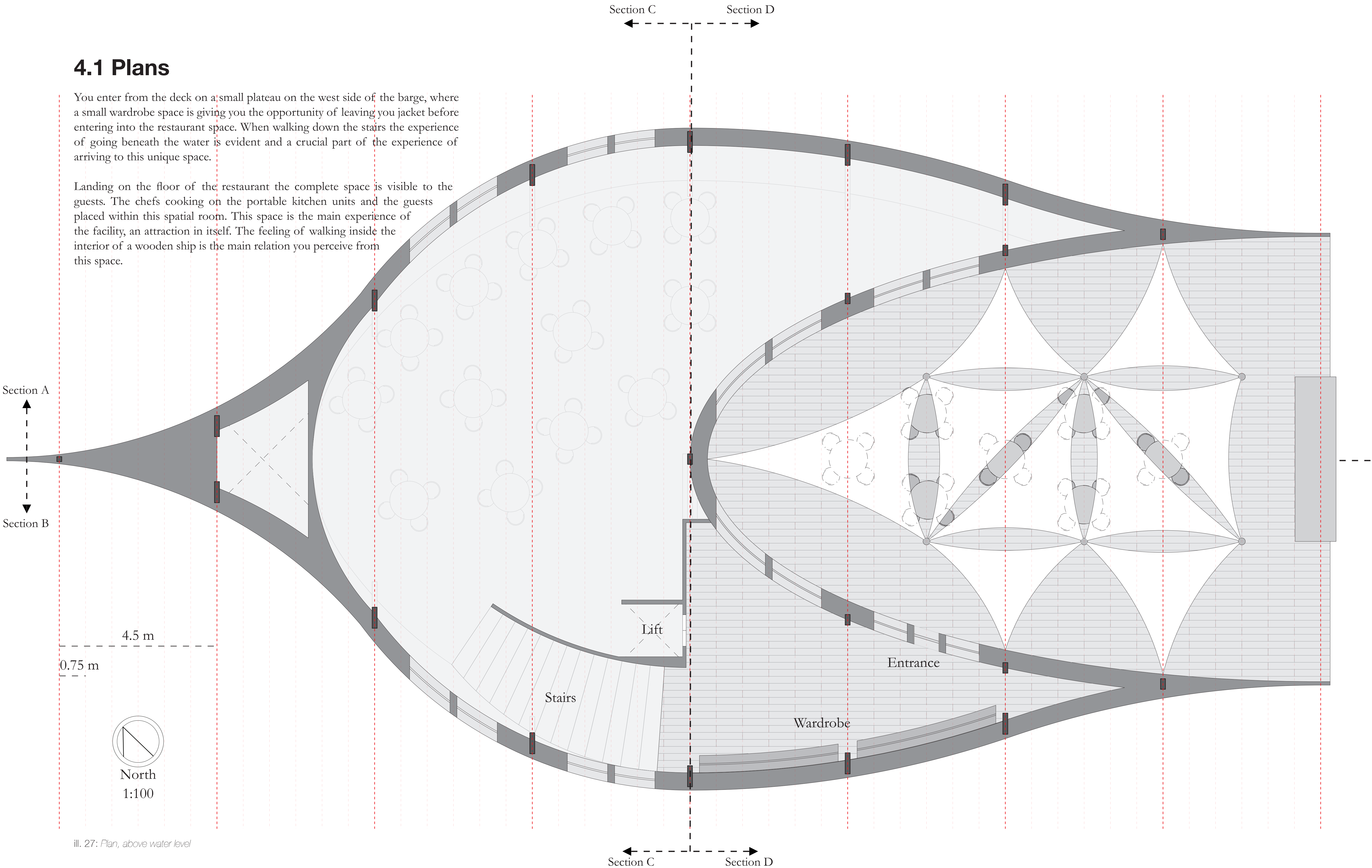
The atmosphere of the space is light and open. The space encourage to social gathering and a casual mood between the visitors. A space that reeks of maritime references which radiates through the spatial atmosphere.

ill. 26: *Interior*

4.1 Plans

You enter from the deck on a small plateau on the west side of the barge, where a small wardrobe space is giving you the opportunity of leaving you jacket before entering into the restaurant space. When walking down the stairs the experience of going beneath the water is evident and a crucial part of the experience of arriving to this unique space.

Landing on the floor of the restaurant the complete space is visible to the guests. The chefs cooking on the portable kitchen units and the guests placed within this spatial room. This space is the main experience of the facility, an attraction in itself. The feeling of walking inside the interior of a wooden ship is the main relation you perceive from this space.

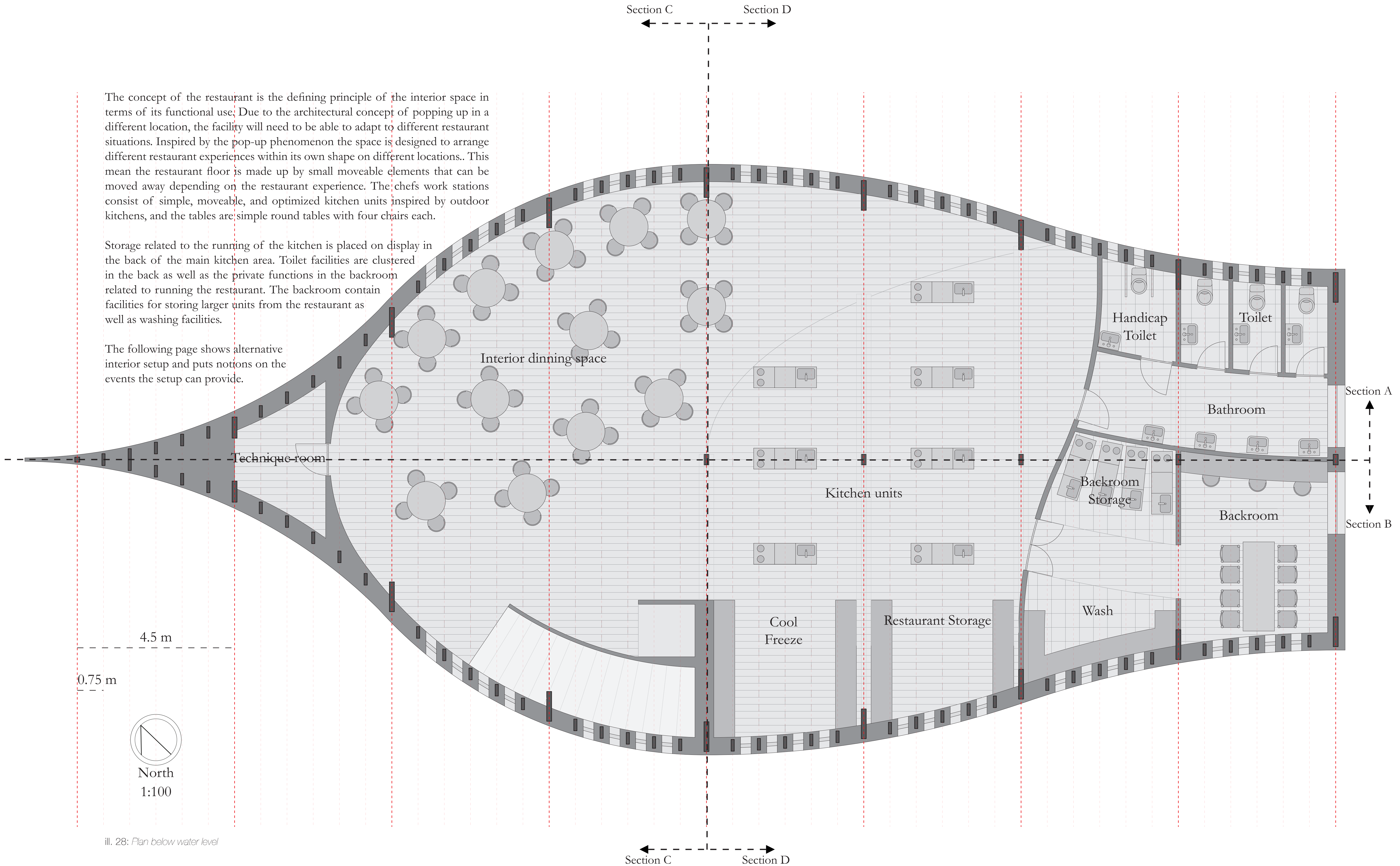


ill. 27: *Plan, above water level*

The concept of the restaurant is the defining principle of the interior space in terms of its functional use. Due to the architectural concept of popping up in a different location, the facility will need to be able to adapt to different restaurant situations. Inspired by the pop-up phenomenon the space is designed to arrange different restaurant experiences within its own shape on different locations.. This mean the restaurant floor is made up by small moveable elements that can be moved away depending on the restaurant experience. The chefs work stations consist of simple, moveable, and optimized kitchen units inspired by outdoor kitchens, and the tables are simple round tables with four chairs each.

Storage related to the running of the kitchen is placed on display in the back of the main kitchen area. Toilet facilities are clustered in the back as well as the private functions in the backroom related to running the restaurant. The backroom contain facilities for storing larger units from the restaurant as well as washing facilities.

The following page shows alternative interior setup and puts notions on the events the setup can provide.

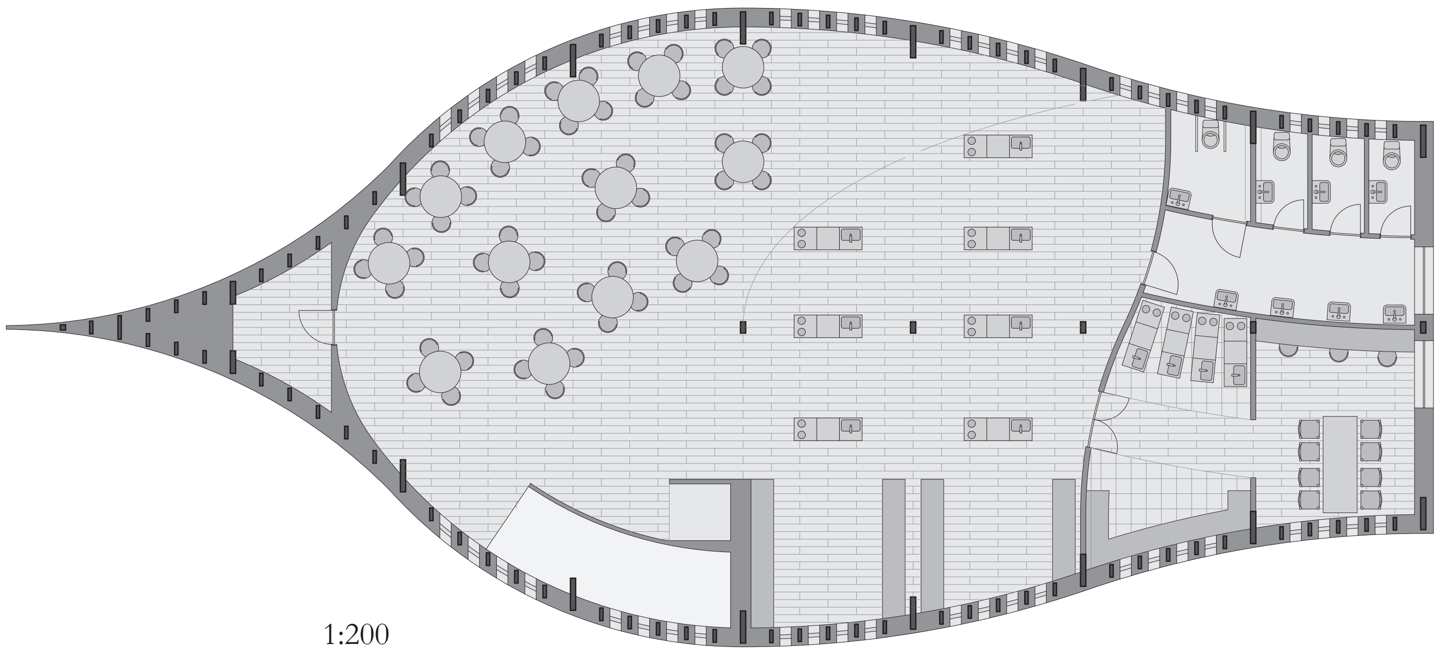


ill. 28: *Plan below water level*

Alternative interior

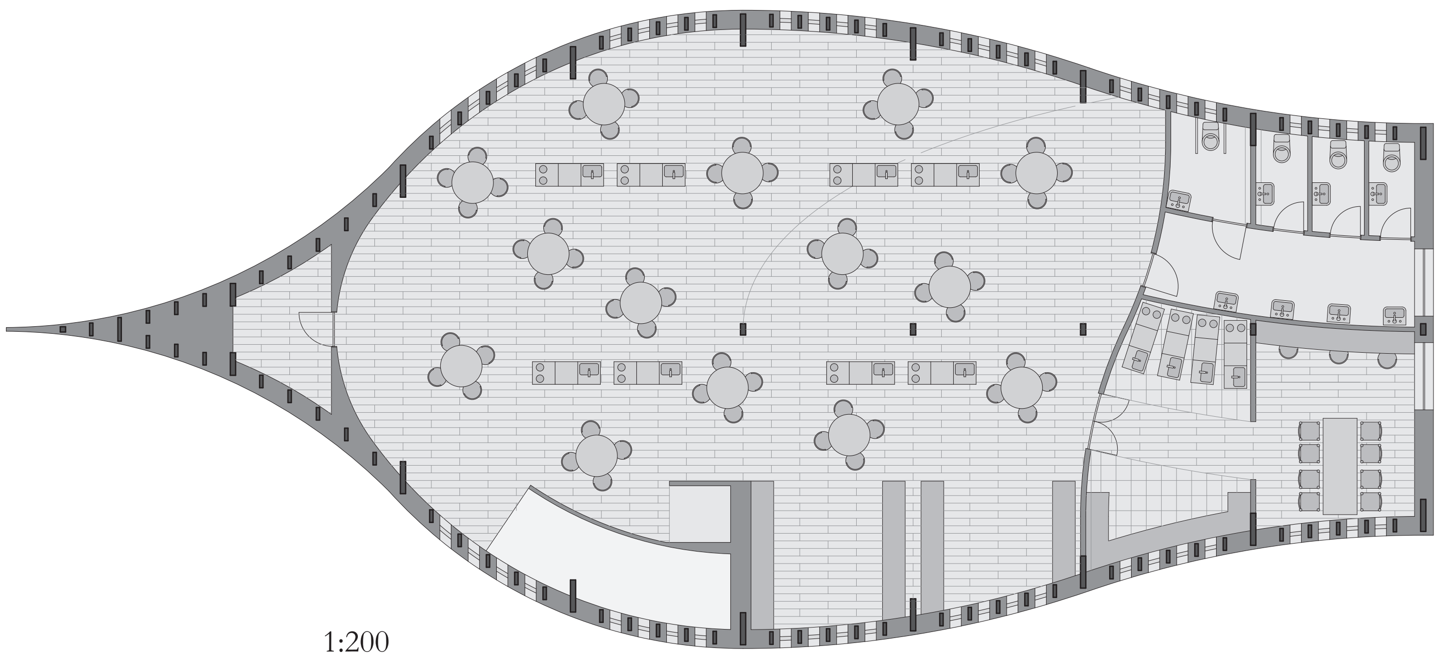
The restaurant concept, as mentioned above, is inspired by the phenomenon of pop-up restaurant, where restaurants suddenly opens, and hence pop-up, in a new locations, untraditional for restaurants. Here they can present a unique dinning experience for a new crowd of people. In order to be able to create this concept in the same space, but in different locations, the space needs to be very flexible and able to accommodate very different settings. On this page is four examples of these different settings briefly explained in order to outline the possibilities within the concept of the restaurant space.

The standard furnishing of the restaurant is very traditional with the tables clustered on one side and the kitchen in the other. The kitchen is open and inviting, but the separation of guests and kitchen staff is clear.



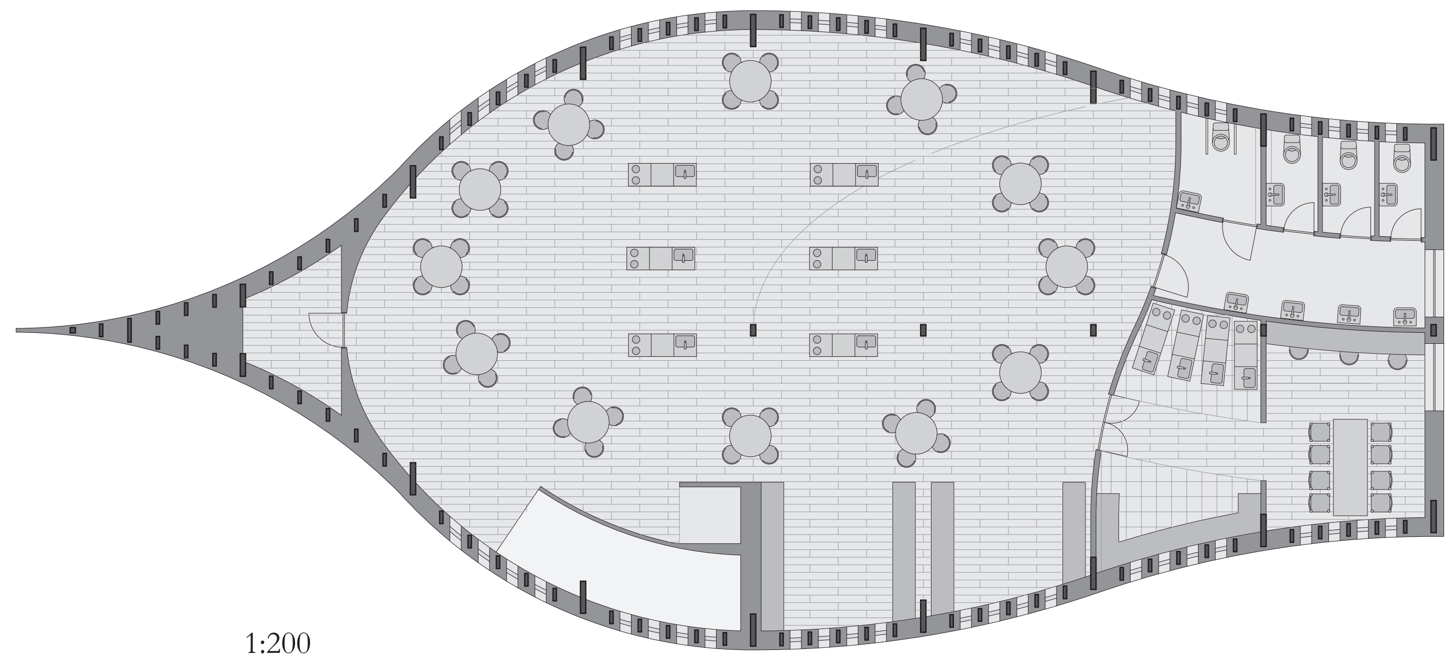
ill. 29: *Plan, standard*

Placing the tables and the kitchen units in clusters, like the illustration to the right shows, can facilitate cooking class events or restaurants experiences where the chef and the visitors are in dialogue during the cooking an perhaps the eating. People can cook together, eat together, and share an experience based on the preparation of food.



ill. 30: *Plan, clusters*

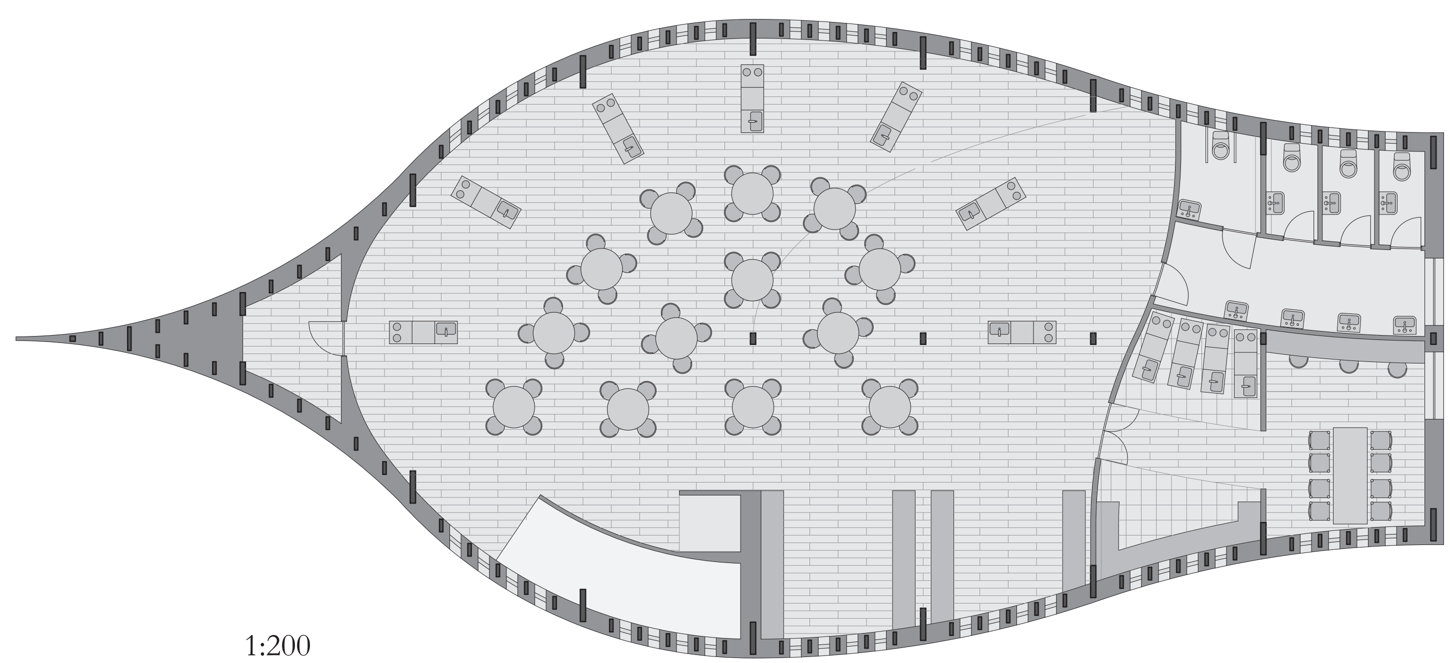
Placing the tables and kitchen units ias shown on this illustration puts focus on the cooking situation and letting the eating situation becomes secondary. Cooking shows and events that stages the cooking process will be facilitated by this interior.



ill. 31: *Plan, stages the cooking*

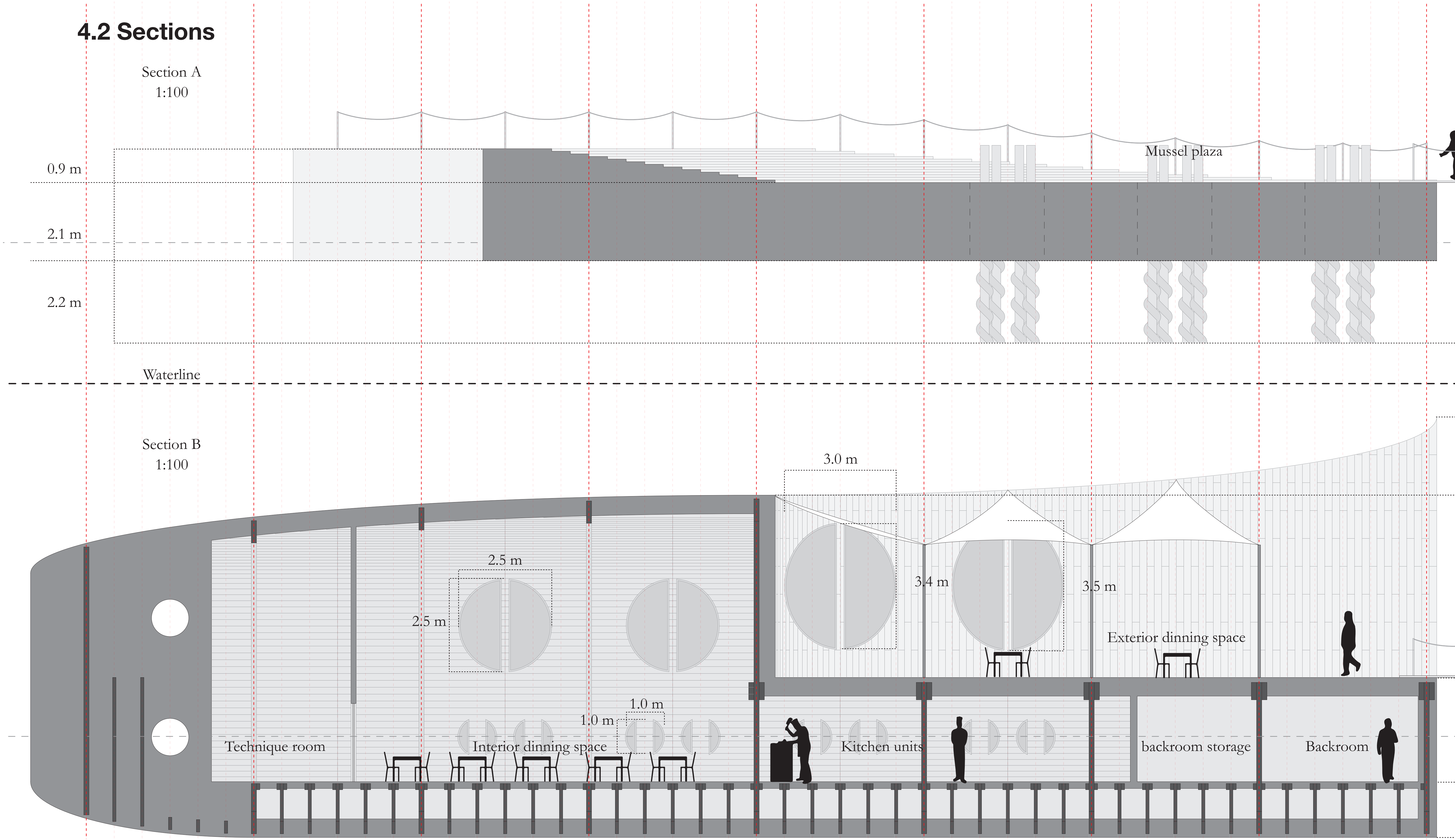
The reversed way of placing the tables and kitchen units puts the focus on the eating situation and letting the cooking becomes secondary. In this way, events that emphasize the social and gathering aspect of eating can be facilitated by the interior. The yearly mussel harvest could be celebrated by a shared cooking festival in this manner.

The following pages shows longitudinal sections and the facades of the facility.

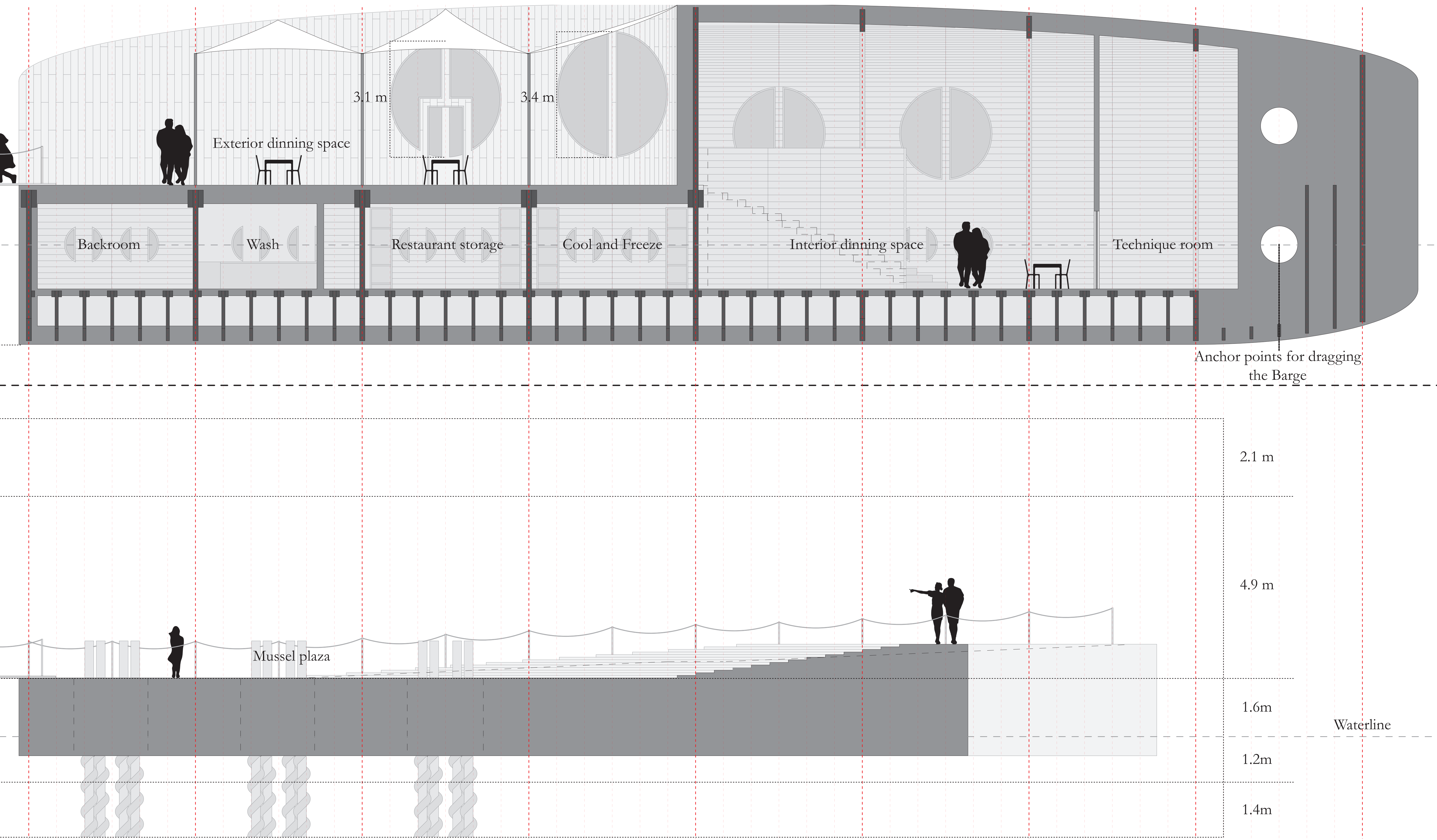


ill. 32: *Plan, stages the dinning*

4.2 Sections

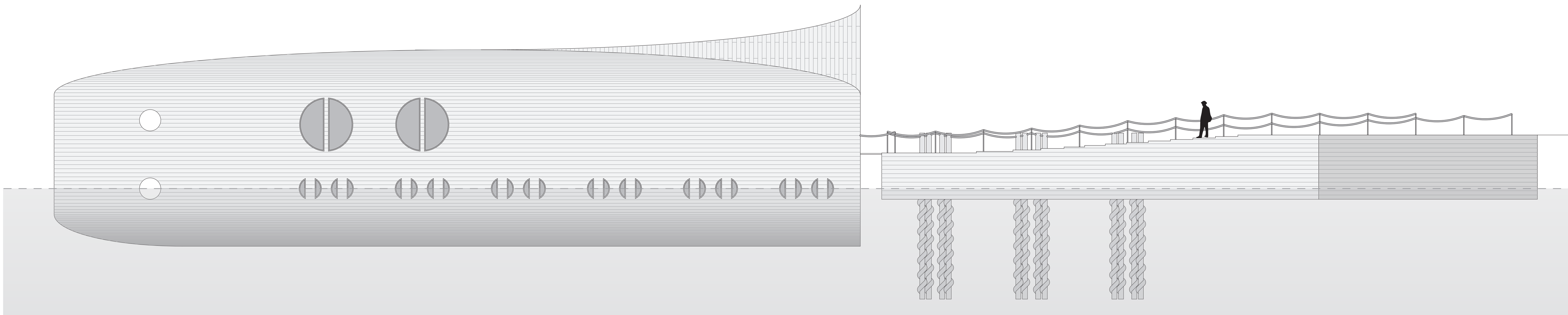


ill. 33-34: *Section A and B*

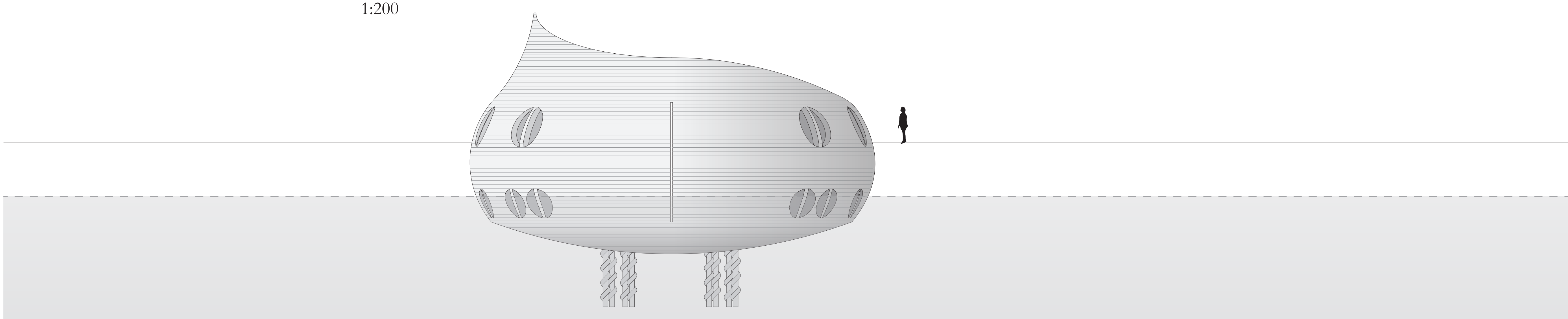

Exterior dinning space
3.1 m
3.4 m
Backroom
Wash
Restaurant storage
Cool and Freeze
Interior dinning space
Technique room
Anchor points for dragging the Barge
2.1 m
4.9 m
Mussel plaza
1.6m
Waterline
1.2m
1.4m

4.3 Facades

West
1:200

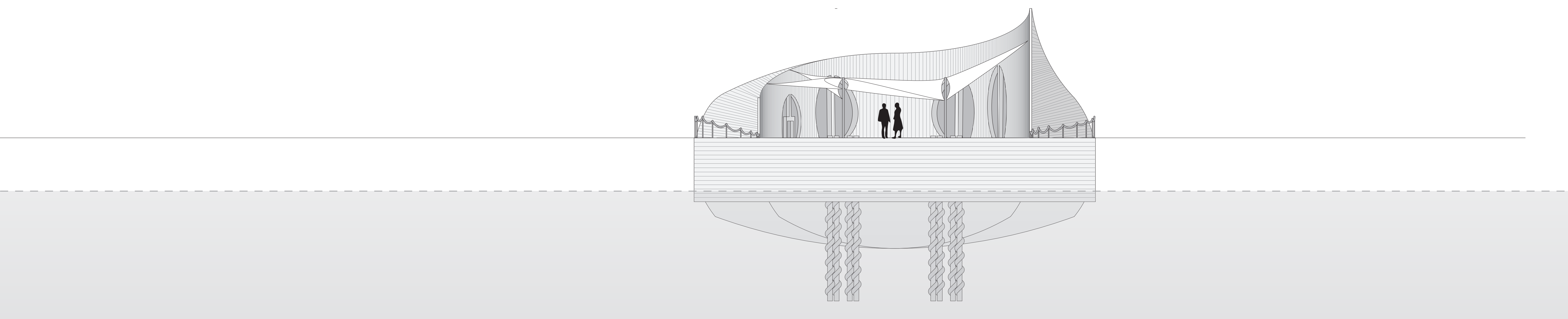


North
1:200

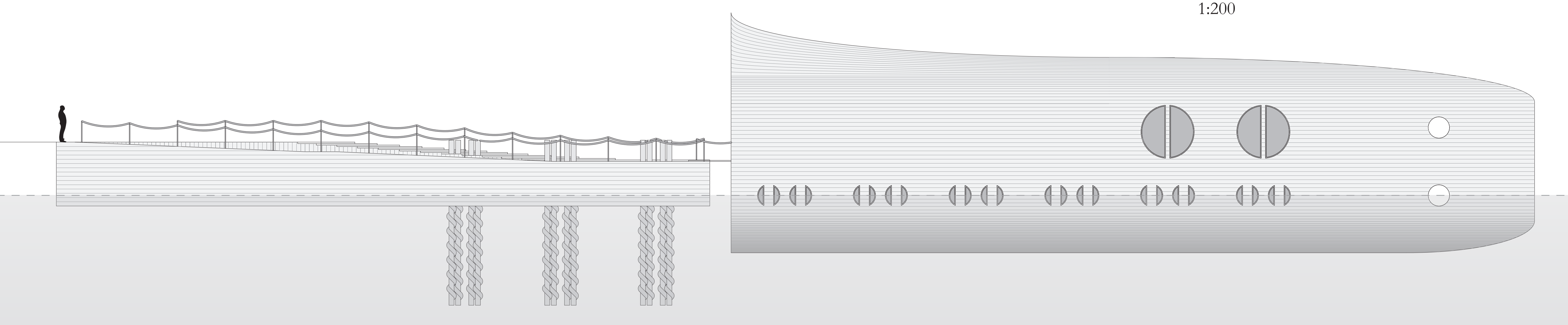


ill. 35-38: *Facades*

South
1:200



East
1:200



5.0 Details

There is a mysterious feeling of unity when embarking into the different parts that constructs the complex. A natural coherence floats through the building, gluing and embracing all of its diversity. But then, when lingering long enough in each and every fragment, a certain kind of uniqueness, flavour comes sneaking up from underneath the floorboards and reveals itself in front of your eyes.

ill. 39: *Detail scale. Interior view from the kitchen area*

5.1 Structural design

Structural design for a floating facility is not a typical task within architectural engineering. That is why the task has been approached with inspiration found in the composition of traditional wooden ship construction. The picture in the bottom illustrates some of the structural principles used for the hull of Barge in this project. Merging a wooden ship structure with traditional house structure has been the subject of this design task.

The structure proposed is two parted, where the two systems merge into each other. The illustration on the following page show this duality and how the two systems support and grows out of each other. All the elements are created in glue-laminated timber classification GL28h.

The duality grew out of the two main task the structure should concern. The first is defining the interior space and the outdoor patio. The second is withstanding the pressure from the water. On the illustration on the following page, the two structures, for illustrative purposes, are separated in the isometric illustration.

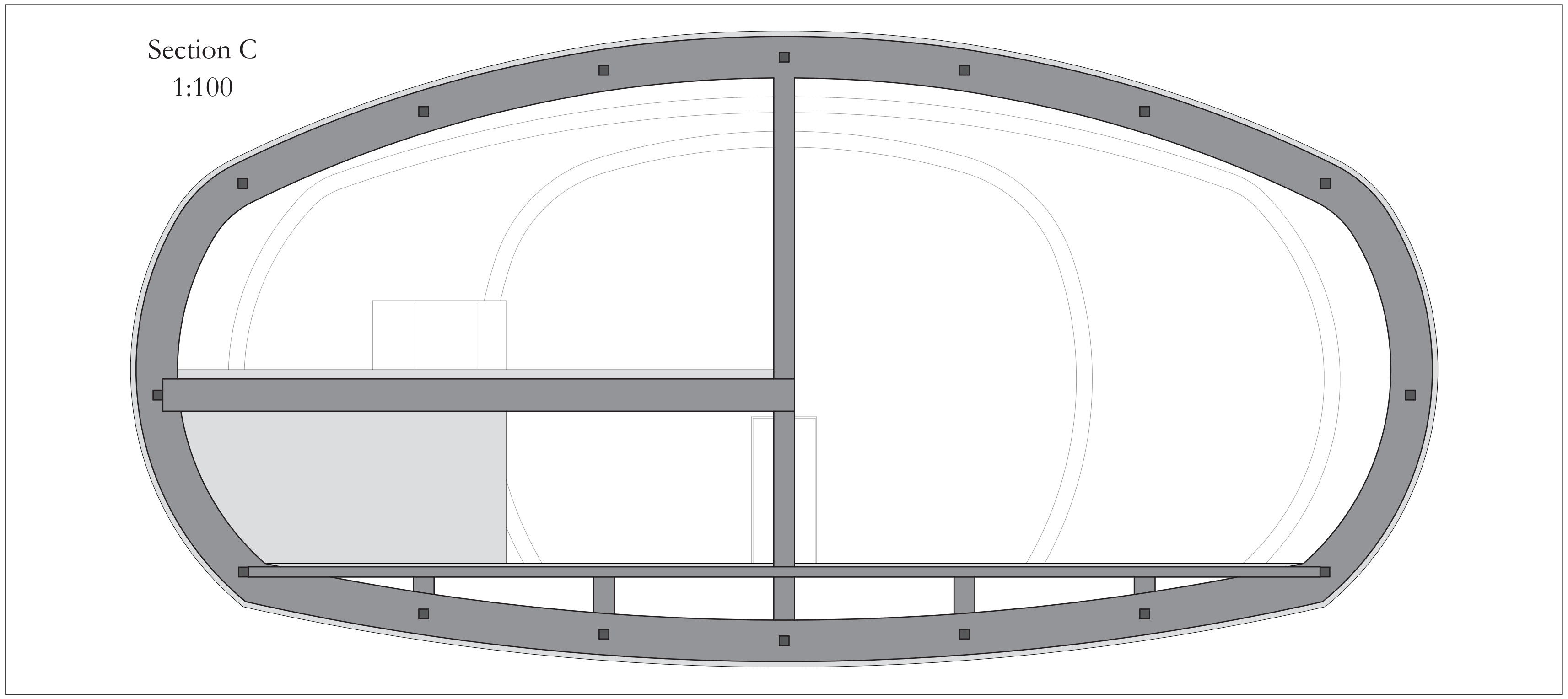
The experience of being in the interior of a wooden ship is, as mentioned, the main reference for the interior space. This created demands easily recognisable from the image below for the structure of the barge. To support the experience, a partly exposed structure dominates the interior space creating clear references to the notion of wooden ship interior.

The concept of the restaurant as explained called for an open flexible space. This demands a structure that interferes with the space it creates the least. Due to this, the structural members for the interior space are dimensioned to make the outer shell self bearing, with no need for additional internal support. The patio is supported only by one column in the middle and otherwise carried by the large beams in the shell. In this way a grand space with very little complications were obtained and the structure optimized for the functional need of the space.

The second task of the structure, was created by placing smaller beams in between the large beams. These smaller beams creates a coherent hull that can withstand the pressure from the water. The distance between the small beams have great influence on the size of the interior windows below the water surface. Section C to the right illustrates how the beams are connected in the other direction to obtain rigidity and create a coherent hull structure. The hull principle described is inspired by the image of the wooden ship structure to the right.

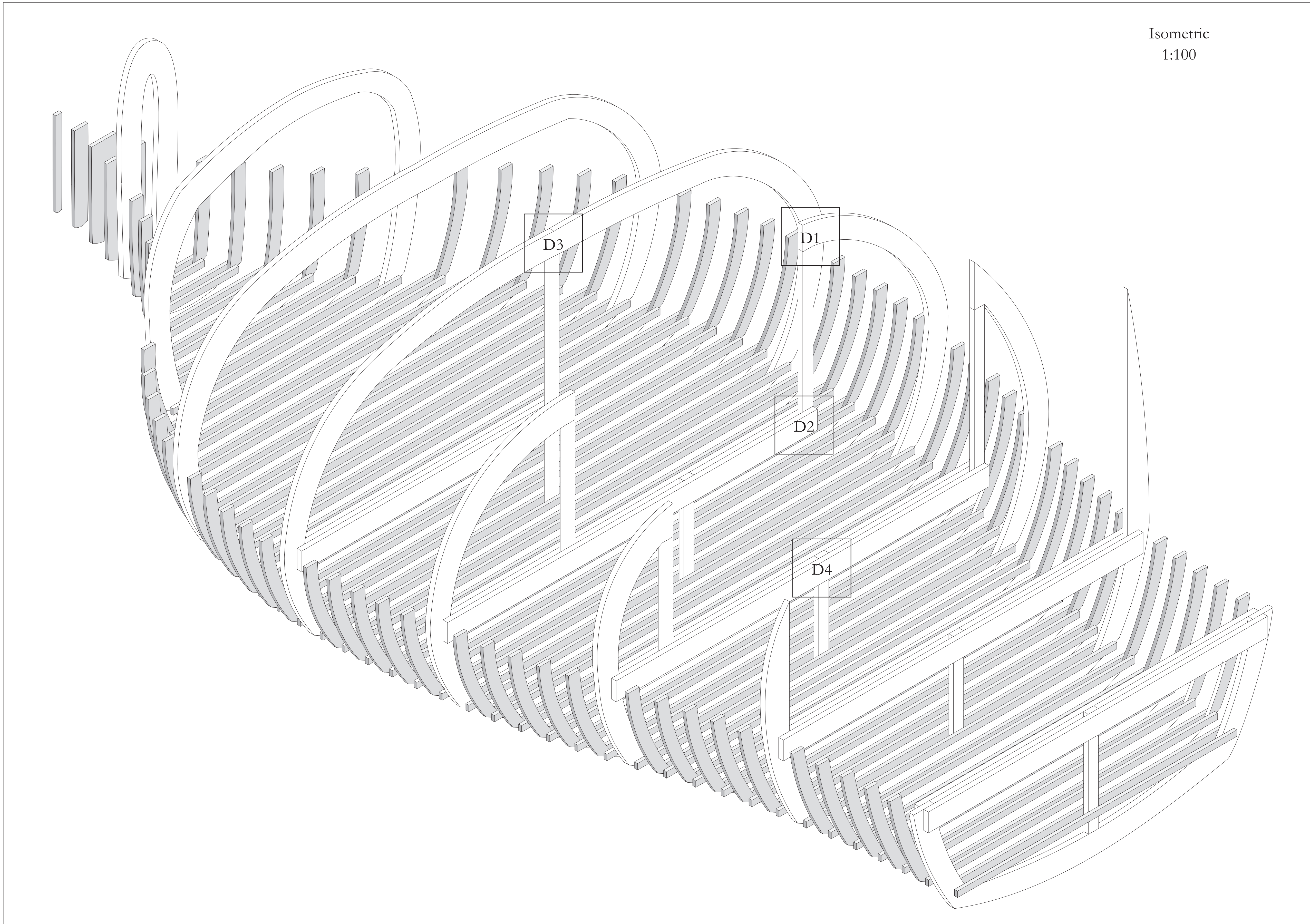
In the process of calculations the plug-In to the parametric software Grasshopper, 'Karamba' has been used for FEM-calculations. In the appendix this process will be further reviewed.

On the following page is illustrations of the four most crucial details in terms of the structural design.



ill. 40: *Section C, structural concept section*

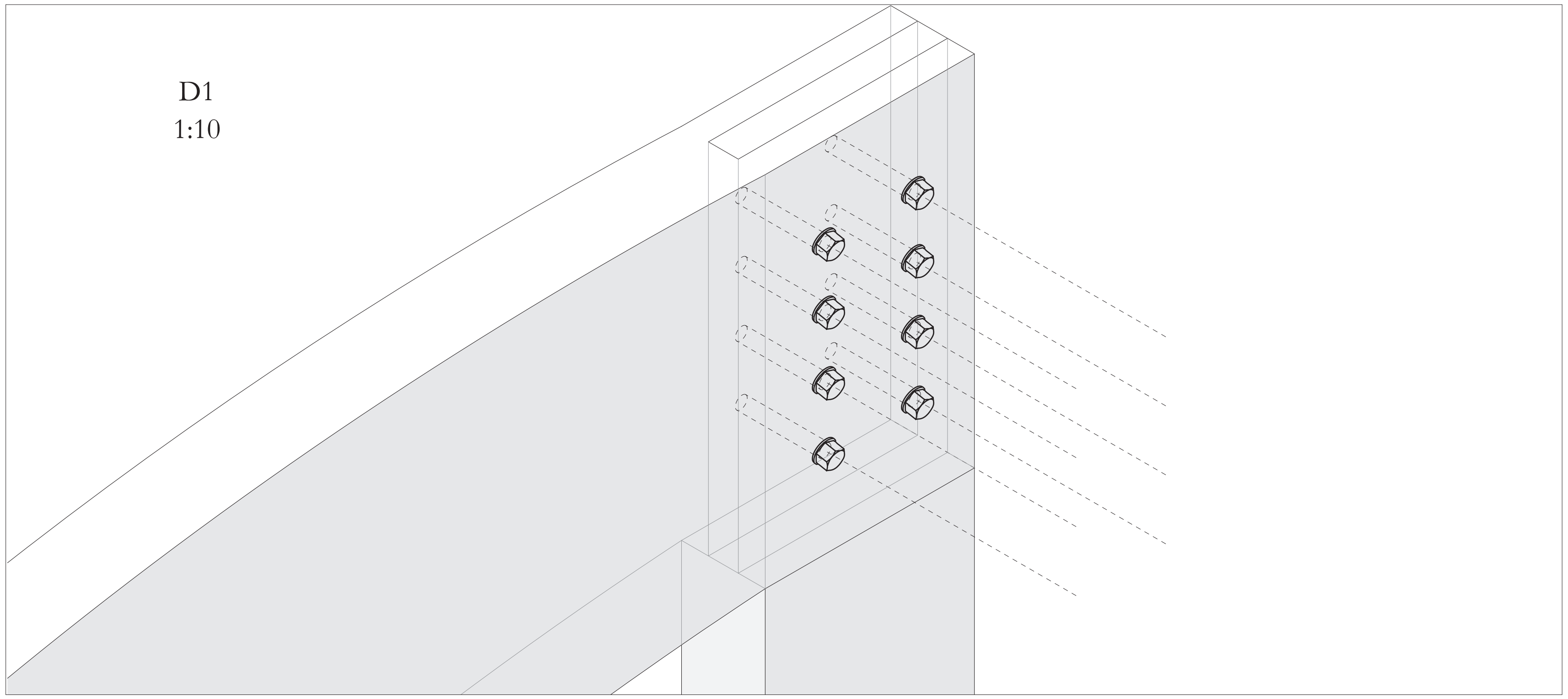
ill. 41: *Wooden ship construction*



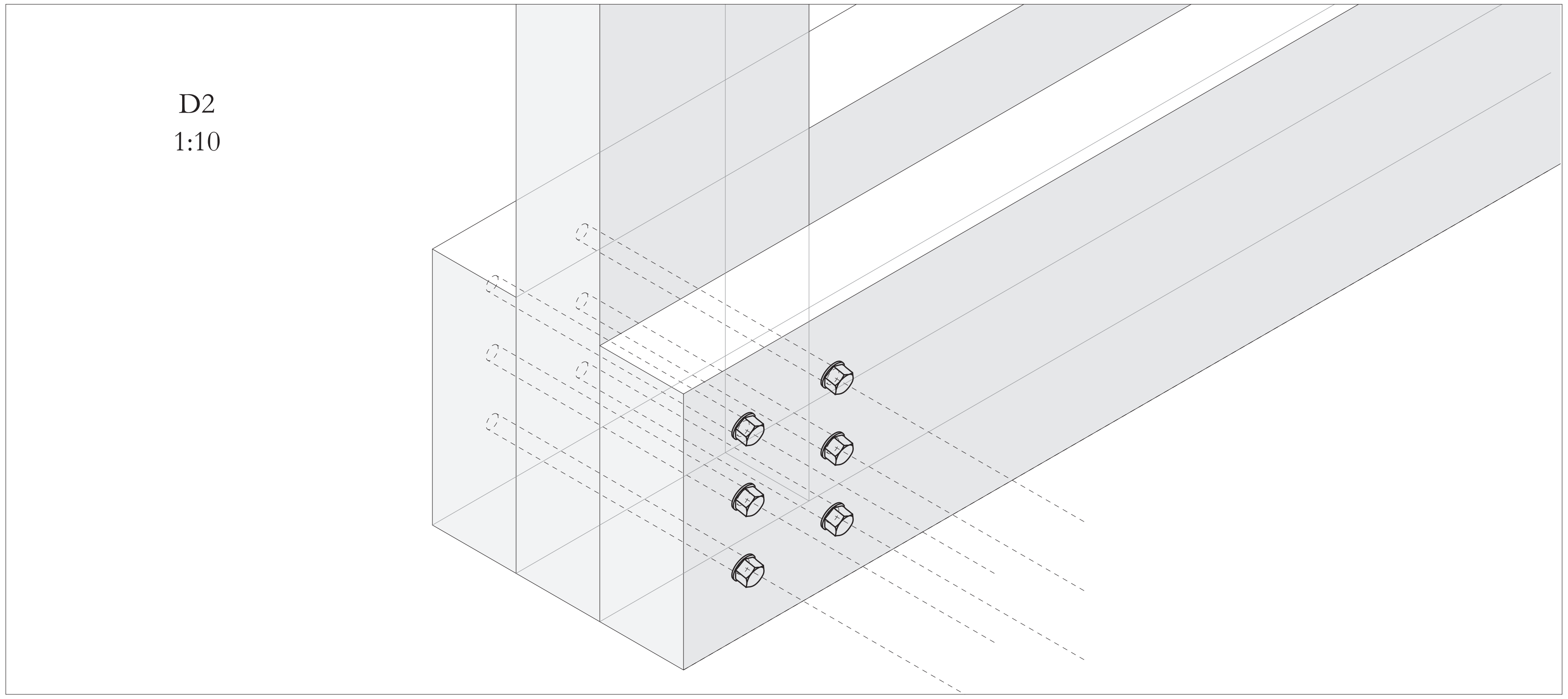
ill. 42: *Structural design. Two parted structure*

Structural details

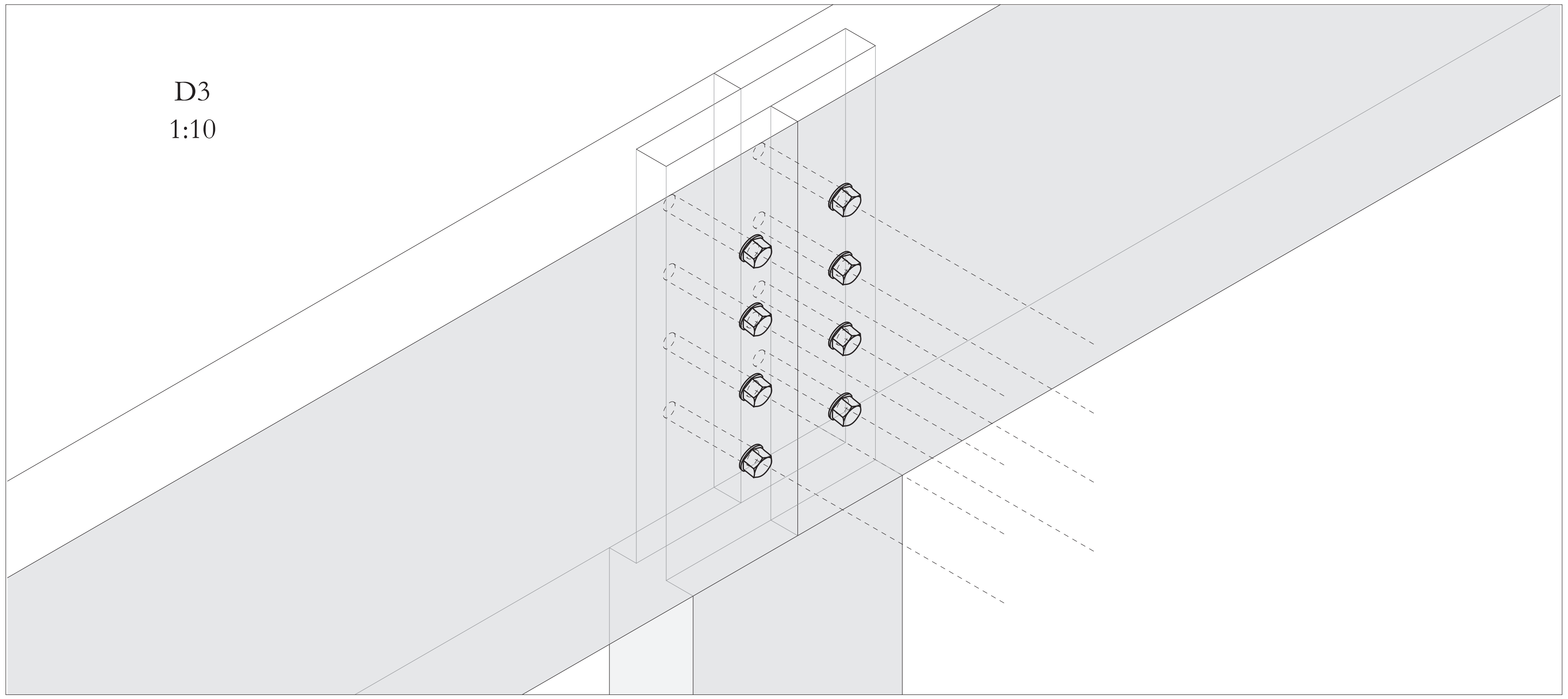
The illustrations on this page shows four of the structural details relevant for the structural system. The details have been solved using simple means in order to create a structure that disturbs the experience of the space the least.



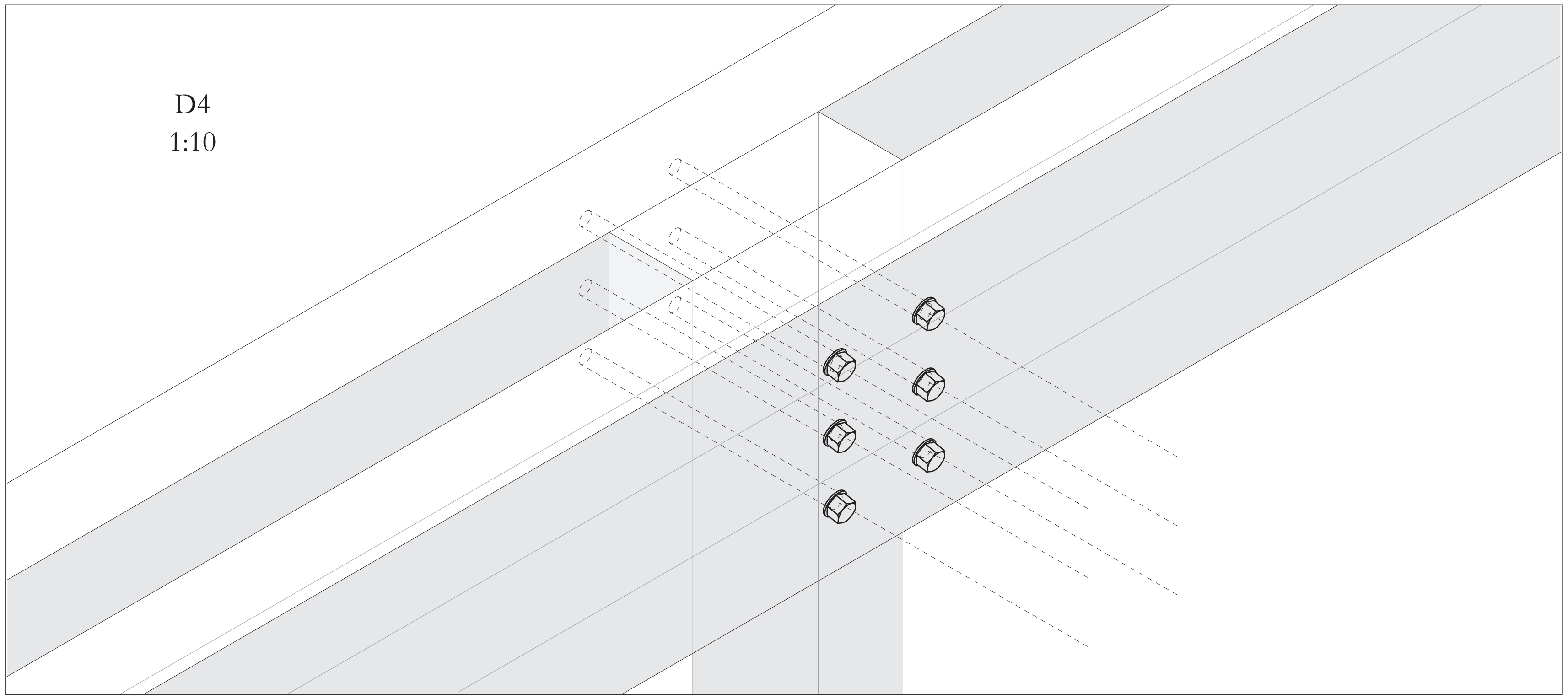
ill. 43: *Detail, beam and roof column*



ill. 44: *Detail, roof column and build-up beam*



ill. 45: *Detail, column and roof beams*



ill.46: *Detail, floor column and build-up beam*

5.2 Light design

The functional design of the light in the restaurant space is related to both natural and artificial lighting. A restaurant space is just as much used at night when sufficient daylight is not present. In order to create a spatial experience that is present at evening, the design of artificial lighting is equal important.

The design of lighting is one of the significant areas from which the sensual experience of space is affected. Light possess qualities appealing to several senses at once and should be designed carefully with the visitor in mind.

Natural light

The vision was to create a space in which the natural light is present, both directly and indirectly.

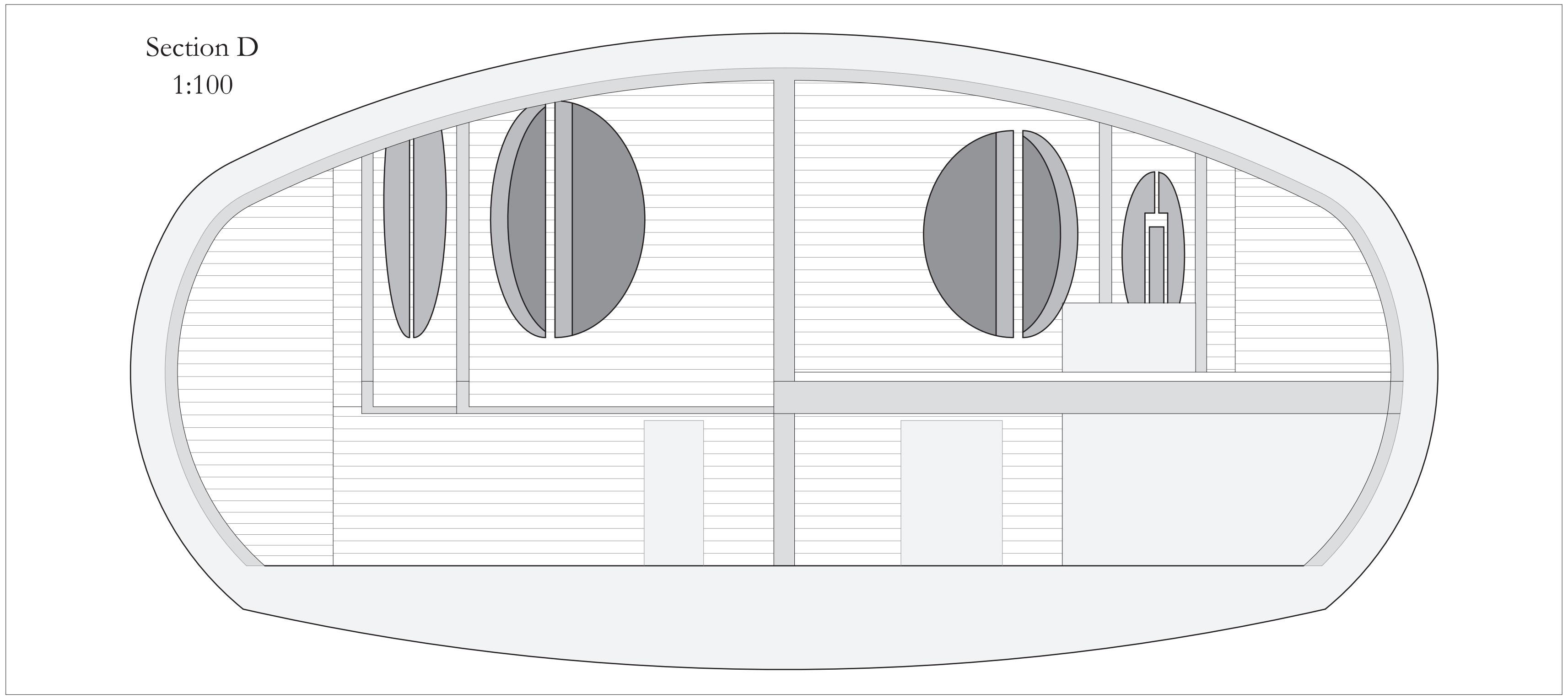
The design of natural lighting is also about the design of window openings, size, and forms. To accommodate the organic building shape, round windows build up by two semi-circular windows placed in pairs, are proposed for all openings. The size of the window openings are designed by the amount of light needed for illuminating the interior space and to create the open light atmosphere desired, and the expression of the window proportions in relation to the space.

Especially in the windows between the deck and the interior space, the expression was an important factor. The illustration to the right shows the conceptual expression of the windows in relation to the interior space. In the appendix, light calculations with 'Velux Daylight Visualizer 2' is reviewed for the restaurant space.

Artificial light

Artificial lighting is designed to accommodate the interior space and enhance the visual impression when minimal natural lighting is present. The experience of being inside the interior of a wooden ship is likewise the desired expression at night when the sun is not shining through the windows. Thus should the artificial lighting be secondary and not take away focus in such an open space.

The system proposed for the artificial lighting constitutes of a series of spotlights placed along the interior walls in relation to the exposed beams. The spot lighting will shoot light from the floor up on the curved interior faces and hence illuminate the interior space with indirect lighting. In this way the interior space will be lit and focus will be put on the interior faces. The artificial lighting will then enhance the experience of the space. In the illustration to the right an interior rendering of the effect from the spot light system is illustrated.



ill. 47: *Section D, light concept section*

ill. 48: *Artificial lighting principle*

5.3 Material design

The wish for creating a structure that stands out on the urban harbour front of Østre Havn is achieved in the materiality of the facility. When the desire to stand out in an area filled with concrete, glass, and steel, the texture and tactility of the material plays an important role. That is why the facility is proposed to be build from wood, building on traditions of wooden ship constructions and take advantage of the natural texture and tactility found in wood.

To obtain the desired experience of being inside an open light room in the interior of a wooden ship, the material appearance plays a significant role. The tactility and texture of the surfaces creates a connection between the space and the visitors, and should therefore be delicately designed. At the same time, qualities of reflecting light within the space, have great significance in the choice of materials for the interior space.

Exterior - European white Oak

For the exterior, the harsh climate by the water sets demands to strength, hardness, and elasticity of the material used for the facade. Traditionally oak has been one of the most used materials for wooden ship constructions in Denmark. All exterior faces are proposed coated by European white oak, which is impermeable to moisture and thus very usable in ship constructions, and thus also this facility.

European White Oak is very elastic. It can thus be used to create the double curved surface with horizontal linear boards. The surface of the boards need to be treated with oil or marine varnish in order to protect the wood from the harsh environment created by the water.

Interior - Ash tree

A light material on all the interior faces is chosen to reflect the light coming through the windows. At the same time, demands of elasticity is likewise present in the curved faces in the interior space. Ash trees, a local material like oak, are growing all over Denmark. Horizontal linear boards will cover the faces of the interior space, except the flooring, and introduce a horizontal orientation in contrast to the tall room.

Ash is known to be very rich in texture and tactility, and will therefore enhance the spatial experience of the space all the way down to the detail.

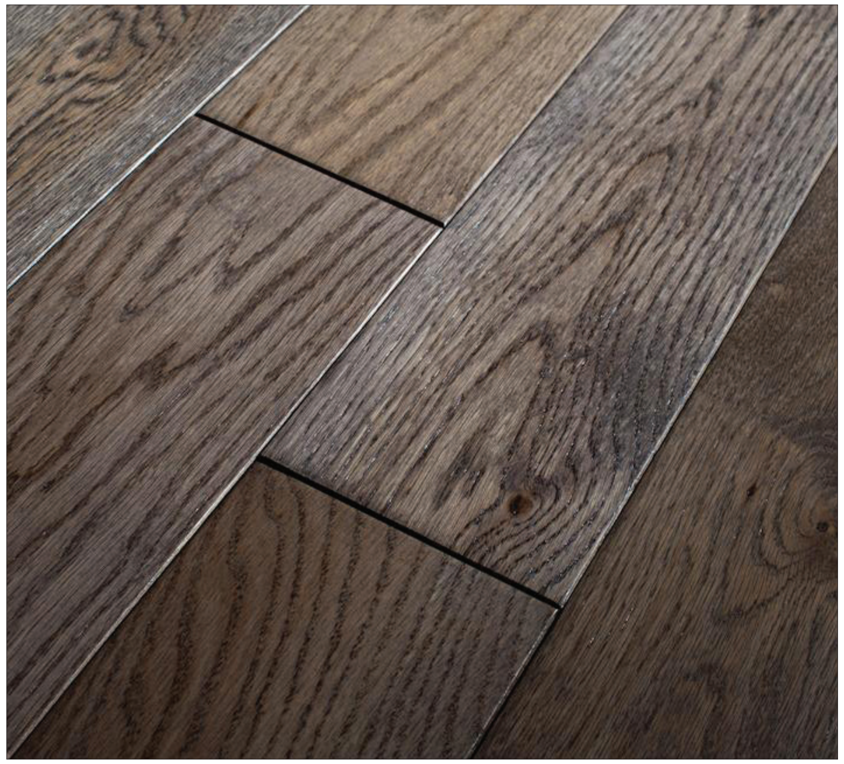
Interior - Smoked oak

The floor is proposed to be made from smoked oak boards with a matte finish. The dark colour have a clear reference to worn out wood associated with old wooden ships, and at the same time, the matte surface will avoid the intense light from the windows to be reflected upward and bother the visitors.

The contrast between the light walls and the dark floor likewise have an aesthetic argument. The experience of the room as open and light is supported by the contrast in the materials. The contrast enrich the space and gives it depth.

ill. 49: *European White Oak boards*

ill. 50: *Ash tree surface*



ill. 51: *Matte smoked oak surface*

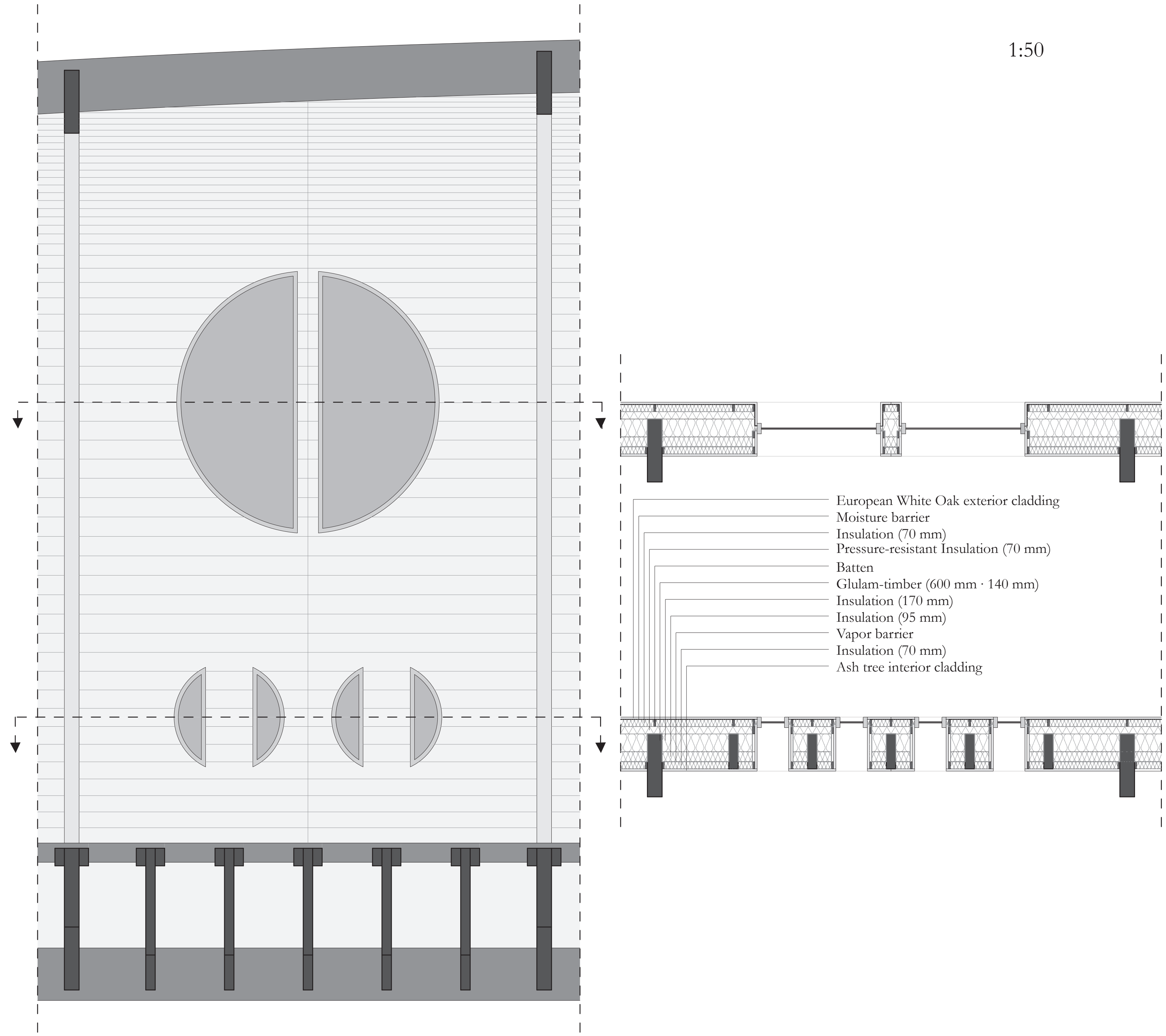
5.4 Wall construction design

On the right is a conceptual illustration showing a section of the wall of the barge that contains two crucial wall construction principles. The illustration shows the difference between the lower and the upper part of the barge, and is interesting in relation to the window and wall construction.

In the lower part all the hull structural members are present due to the withstand of the load from the water. The distance between the beams have great influence on the size and how the windows fits in between the beams.

In the bottom of the interior the windows are placed in line with the facade. This has he purpose of getting as close to the water as possible from the interior space, but also to avoid too many uneven edges on the exterior facades, that inevitably would create fraction with the water and thus could damage the structure.

The upper windows are placed in the middle of the windowsill to obtain some cover from the direct sun light.



ill. 52-54: *Wall constructios*

5.5 Supply design

The design of the system for ventilation and for plug-in of water and electricity is described with the illustration below. All piping system should be distributed through the lower hull beneath the floor.

Ventilation

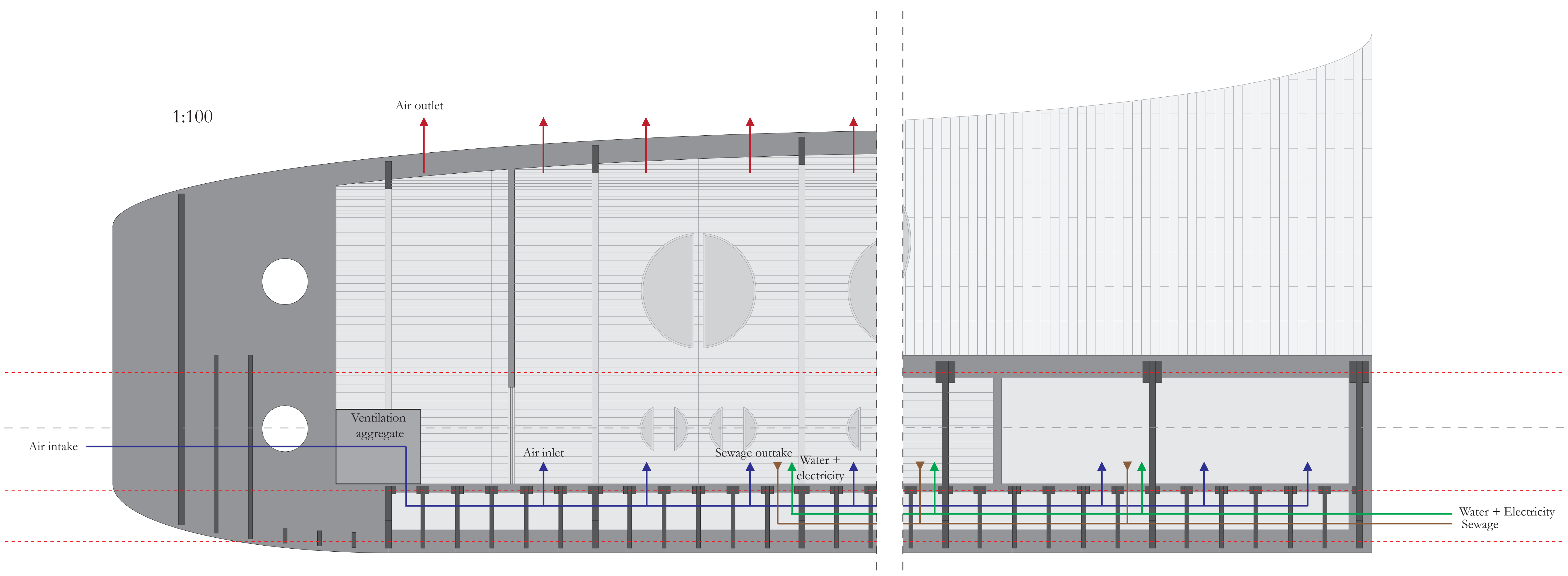
The room in the tail of the Barge is dedicated to technical and functional aspect of running the restaurant. A proper ventilation principle is needed to create an atmosphere suitable for dinning, and take care of the necessary air change. That is why the concept for ventilation is needed to be integrated within the design of the structure.

The proposed concept is a hybrid ventilation system utilizing both mechanical and natural principles. Intake of clean air happens in the end of the Barge in relation with the technique room. In here is placed an aggregate controlling the system. From here the air is let through pipes in the floor with inlets along the flooring. The natural principle of thermal buoyancy makes the air rise up through the room, and in the roof air outlets will let the air out of the Barge. The bathroom, and the backroom will have air outlets in the facades.

Additional piping

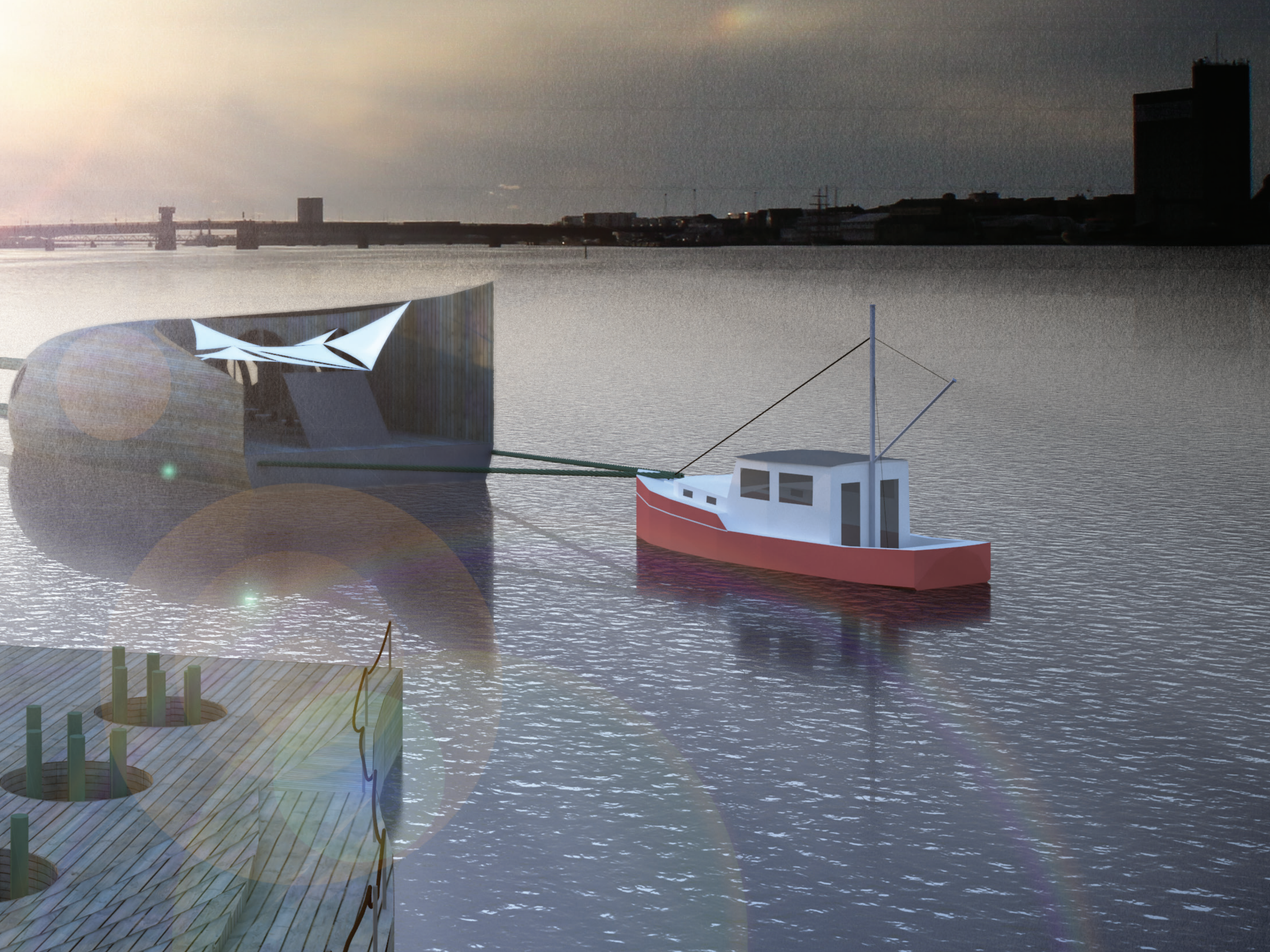
The concept of the restaurant, with flexible interior creates special demands for running the restaurant. But also the principle of being located on the water creates alternative demands. The kitchen units needs to be plugged in to electricity, water, and sewerage. This means that a customized plug in the floor should be designed and available a few places along the floor area.

Water, sewage, and electricity are plugged into the front of the barge from pipes running under the Pier. From here it is carried beneath the floorboards and all through the barge like the ventilation. Access to the fixed points in the back room and toilet facilities and to fix points within the restaurant space goes through the floor.



ill. 55: Section A, *Supply concept section.*

ill. 56: *The Barge being dragged away*



6.0 Conclusion

The design proposal presented in this rapport conclude of a one year study of the Urban farming phenomenon and the notion of architectural space. The one year long agenda has been to locate potentials within architectural treatments of Urban Farming and create a specific design proposal that utilize those potentials. Furthermore the agenda was to elaborate on the notion of Architectural Space and how this notion could be the mean in which the potentials of Urban Farming was expressed.

In relation to Urban Farming the design proposal has sought out to create a platform from which the citizens of Aalborg can venture out on a mussel growing adventure. The proposed method of production was a reinterpretation of the French traditional method of culturing mussels, called Bouchot mussels.

The first principle based on the potentials outlined in the theoretical thesis, was to let Urban Farming grow out of local history and cultural legacy for the project to express qualities in the local environment, and thus catalyse the qualities of a given site. The site chosen was Østre Havn with a close connection to the fjord. With these preconditions local cultural potentials was sought out within the fjord itself. Mussels is a traditional seafood cultured in the water masses along the fjord, often referred to as 'Limfjordsmuslinger'. But yet today they are not rooted in the city of Aalborg. Potentials in manifesting 'Limfjordsmuslingen' in the largest city the Limfjord runs through was therefore seen as an interesting design task and a way in which to build upon the local potentials.

Furthermore the site provided a few additional clues to the cultural and historical legacy for the facility to emanate from. Traditional Østre Havn was a space for activities utilizing potentials of the nearby Fjord. By creating a new facility that nurtures from the same potentials in Limfjorden but reinterpreting the traditional activities in a contemporary context the facility would help revitalize Østre Havn as a scenery for a new and contemporary sustainable lifestyle. The relationship between people and the water would be reestablished through means of Urban Farming and Urban Aquaculture.

The second principle outlined was to make architecture and hence architectural space express the potentials of a sustainable lifestyle. In relations to architectural space, it has been sought out to create an appealing space that by itself form an attraction. A space that would address human senses and be designed according to its functional use. The main space embraces the function of a seafood restaurant, in the environment reminding of the interior in a wooden ship. The space should be used in different settings, due to the architectural principle of the Barge. The space is therefore in its design flexible to accommodate the changing spatial needs. This flexibility has mainly been achieved through carefully structural design.

In terms of the sensual experience, attention to the shape of the interior, light, and textural and tactile qualities has been given. The wish was to create a space that was appealing to the senses in more than one way, and could create experiences down in the detail.

In the theoretical thesis attention was given to the means of art and water in spatial creations. The idea was to be inspired from these means in the creation of the spatial experience. Water plays a significant role in the experience of the interior space as all along the interior facade small windows let in the atmosphere from below the water surfaces and facilitate the under water experience as they becoma a part of the safe environment of the interior. These windows enhance the experience of aquaculture and maritime qualities within the space, and the mysterious and adventurous life from underneath the water surface becomes a part of the interior spatial experience.

The inspiration from art has been in relation to the narrative of the facility and the space. The space can be moved away and sail to a different location, which in the space is indirectly expressed by mimicking the interior of a wooden ship. The history of the barge and the wooden ship form an intriguing narrative of an adventurous traveling facility. The narrative becomes a clue in which to read the space, and thus a part of the spatial experience.

On this note the space becomes the expresser of potentials within Urban Farming and urban aquaculture. Urban aquaculture is an adventurous journey with the effort of being a part of the magical universe below the water surface, and the restaurant space represents a little part of this adventure, in an architectural, spatial setting.

ill. 57: *The Barge arrived at the city centre*

7.0 Appendix

7.1 Structural design

Verification of the structural elements have taken point of departure in a complete structural model, and calculations performed with the FEM modelling program Karamba. Karamba is a plug-in to the parametric modelling program Grasshopper which works in the Rhinoceros 3D environment. This software was chosen due to the ease in making iterations and get precise numbers out that can clarify potentials right away. There is a short distance between idea and preliminary results when using Karamba. Because of the parametric approach in 'Grasshopper' and 'Karamba' they make the combination of architectural and engineering processes more integrated as they occur parallel. Principles of form and structure can be developed simultaneously and add to each other along the way.

In this case Karamba is used to calculate correct loads and how the elements are affected by them. Karamba has likewise been used to compare different forms in relation to structural performance. Verifications have been limited to the crucial structural elements that affect the spatial experience within the interior space. The beams for the hull, the beam for the roof, the build-up beams for the deck and the columns.

As the project can be categorized more as a boat than a building, the calculations performed in Karamba cannot be considered completely verifying. When designing boat constructions comprehensive calculations of stability, floatation, and durability are needed. Calculations which lies beyond my curriculum. That is why the results can only be considered guidelines where structural members have been verified in terms of durability and displacement. But, when taking the dimensions of the construction into account, being quite wide in relation to its height, the structure is though most likely able to pass the calculation of stability and floatation.

Calculation methods are inspired by the ones exemplified in '*Structural Timber Design to Eurocode 5*' (Porteous 2007).

1. The system and parameters

The dual system explained in the structural design section, is build into Karamba. It is graphically explained in the illustration to the right. It constitutes of a series of large beams that defines the interior space, and smaller beams in between that creates the hull that will withstand the load from the water.

Below is an illustration showing the parametric parameters used in Karamba. The parameters concerns geometric and structural properties as well as how deep the Barge is supposed to sink into the water.

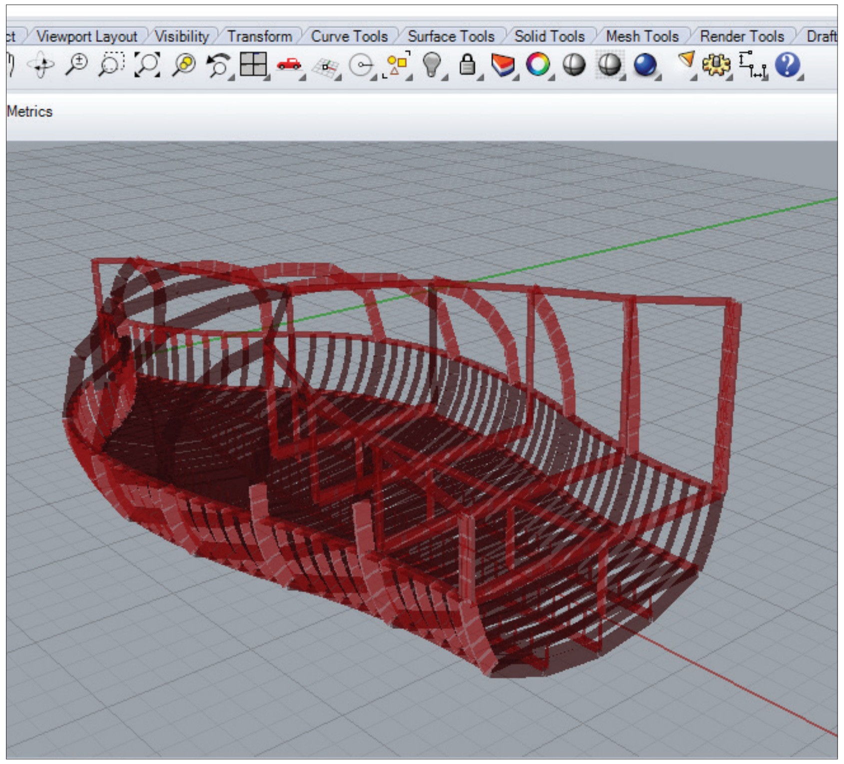
The geometrical properties is related to the shape developed through the preliminary architectural process. Dealing with the height and width in important fix points along the form. When the design was at a sufficient level, the shape was developed in the Grasshopper/Karamba environment. From here structural as well as formal changes within the proposed concept was available and with structural conditions apparent for every iteration.

The formal parameters relies to the width in the middle and the end, the height of a storey, height of the top point, and the depth of the hull. These parameters could be manipulated to create a geometry that were better suited for the loads applied to the structure. It was important to find suitable size for the interior space, as well as the structural size of the beams.

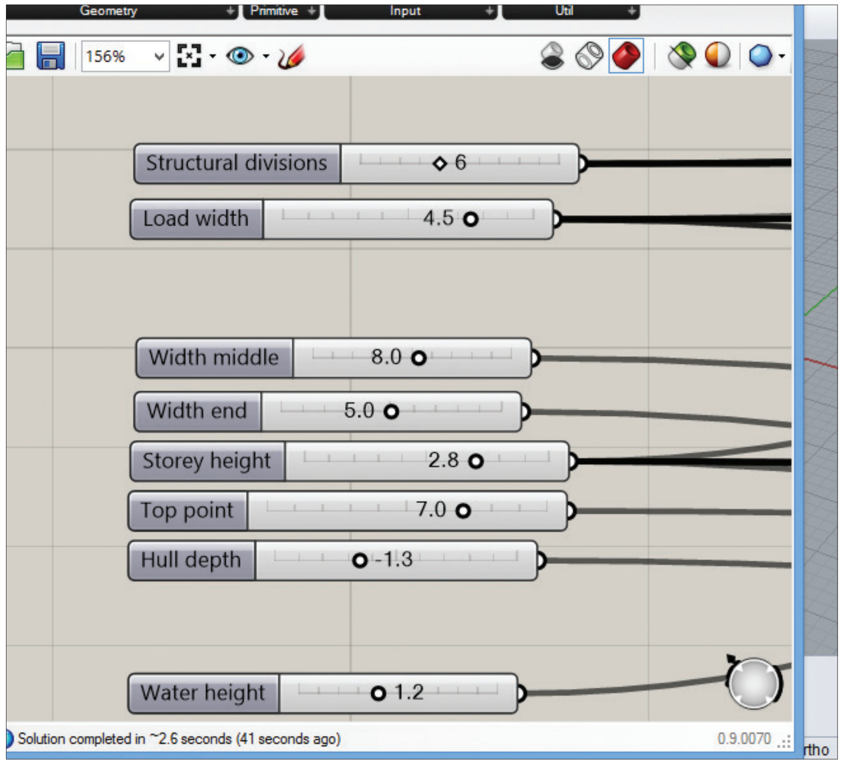
The structural parameters is related to number of beams for the hull and the width between the large beams for the interior space, and thus the hull beams as well. These parameters were important in order to create enough space for the windows between the beams in the hull, and to have the beams small enough to hide in the walls, so they would not interfere with the interior expression.

The last parameter was related to the height of the water and thus the amount of pressure on the hull. This was also affected by the depth of the hull in the geometrical parameter.

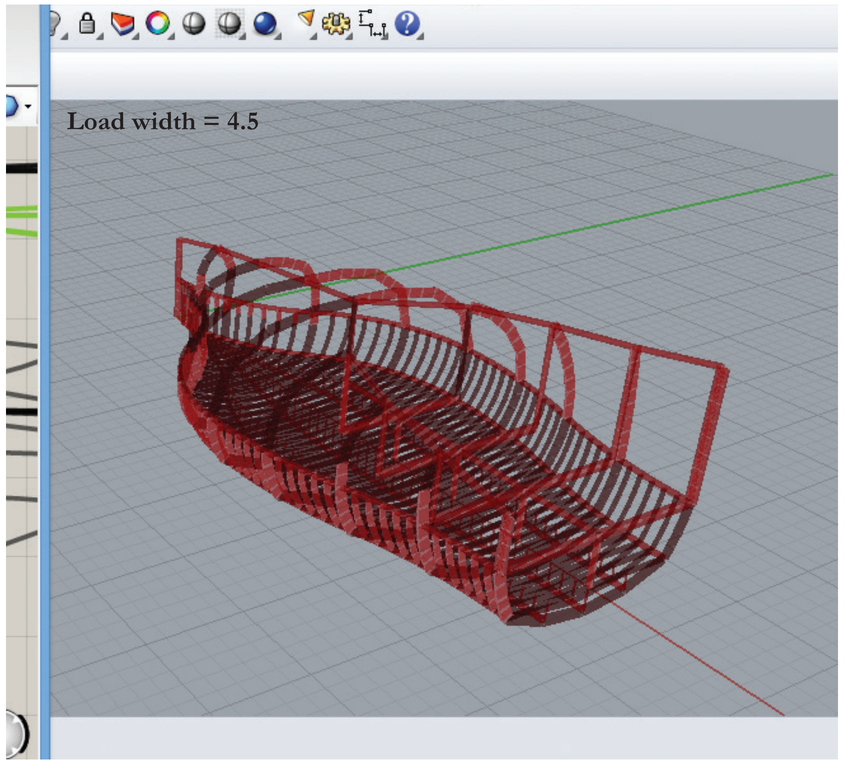
On the following page is illustrations showing the structural changes and the geometrical changes available from the parameters within the program.



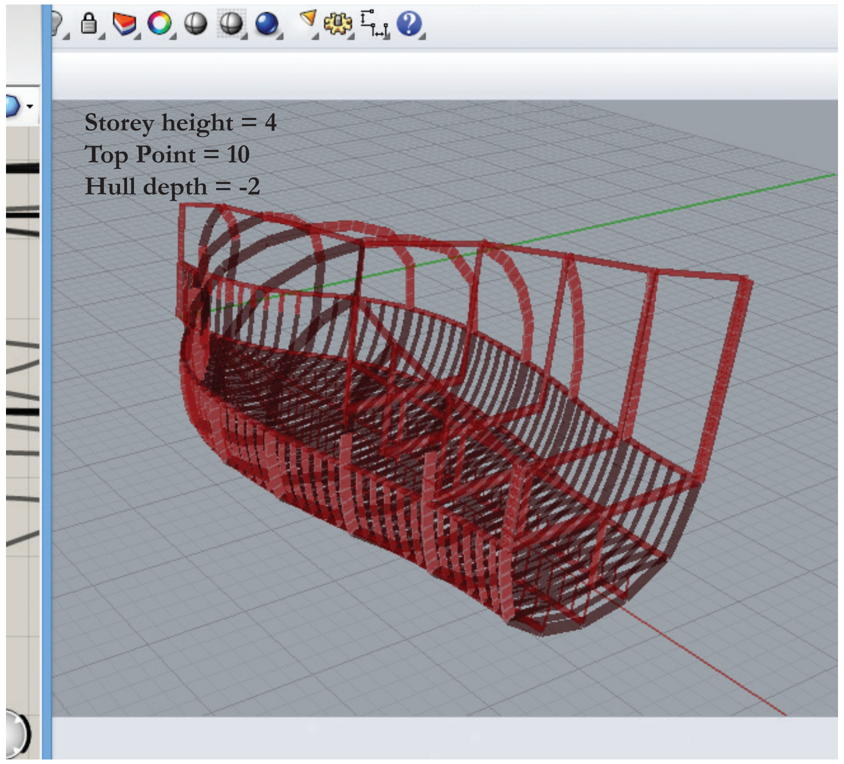
ill. 58: *Complete structure*



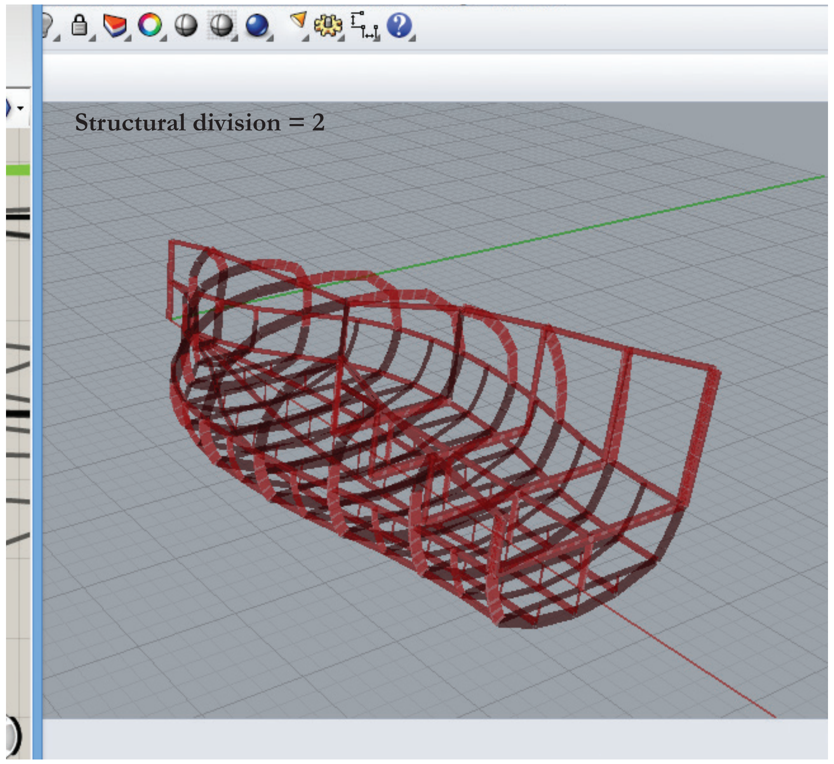
ill. 59: *Parameters*



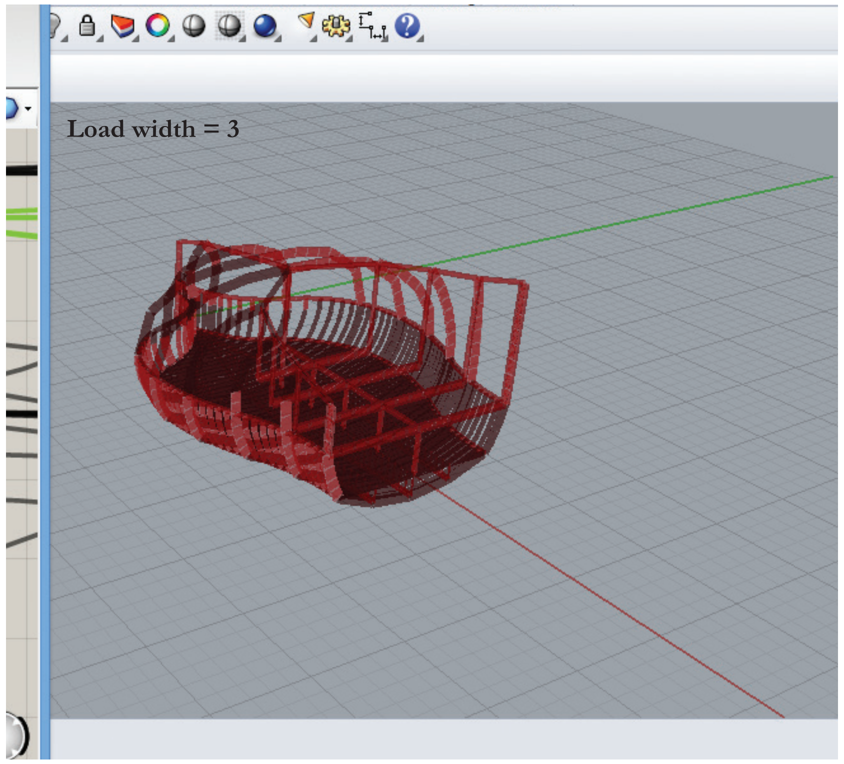
ill. 60: *Change in parameters 1*



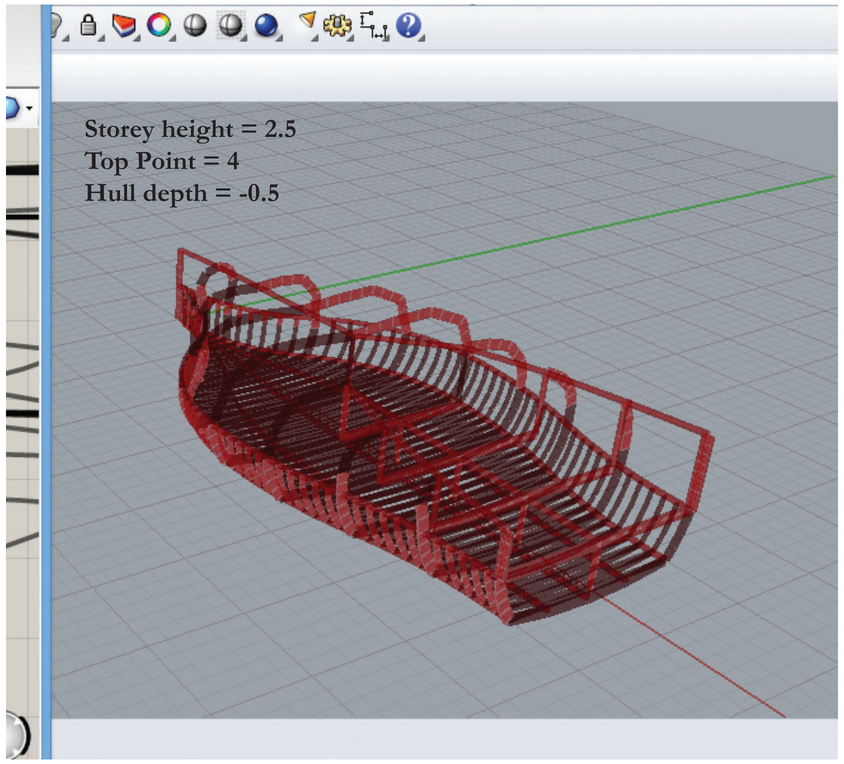
ill. 62: *Change in parameters 3*



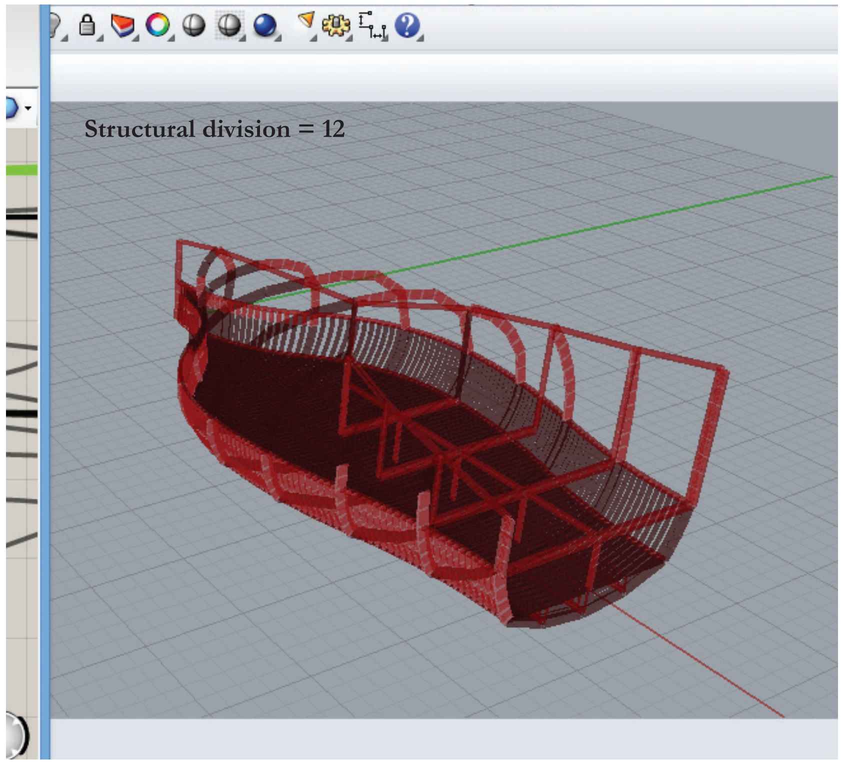
ill. xx: *xx* ill. 64: *Change in parameters 5*



ill. 61: *Change in parameters 2*



ill. 63: *Change in parameters 4*



ill. 65: *Change in parameters 6*

2. Material Properties

The calculation has taken point of departure in the important members in relation the spatial experience of the interior space. The beams for the overall structure, the beams for the hull, the build-up beams for the deck and the columns are the ones calculated.

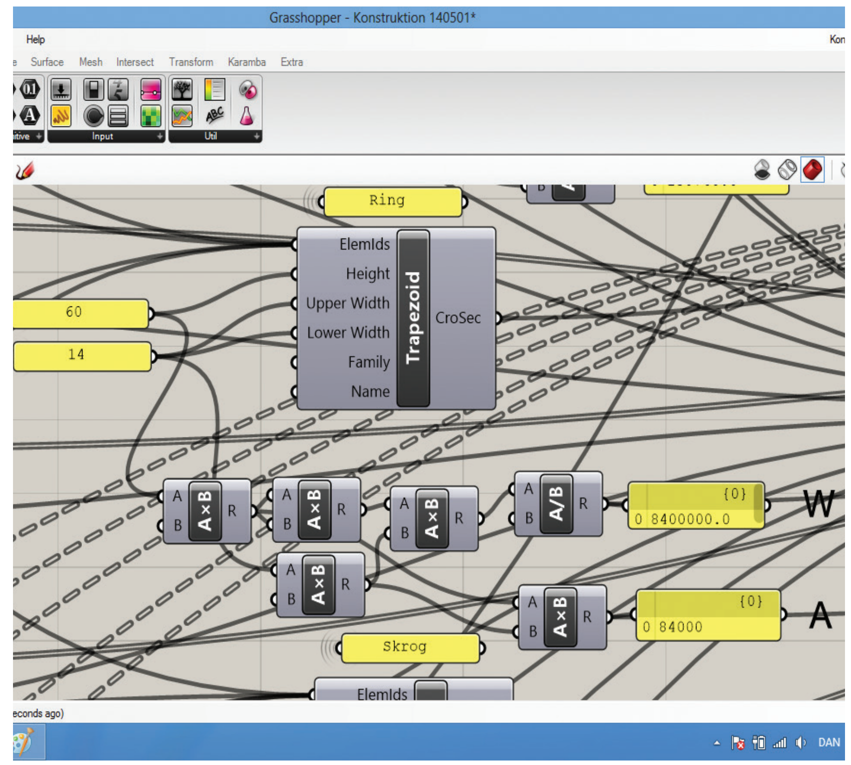
All the members are glulam beams grade GL28h and function in service class 1. The illustrations on this side shows the geometrical properties to the different members used in the Karamba file. The width, the height, the area (A) and the section modulus (W) for each structural cross section is shown.

The cross section for the build-up beam in the deck is in Karamba calculated as a coherent beam with the cross-section of the two individual together

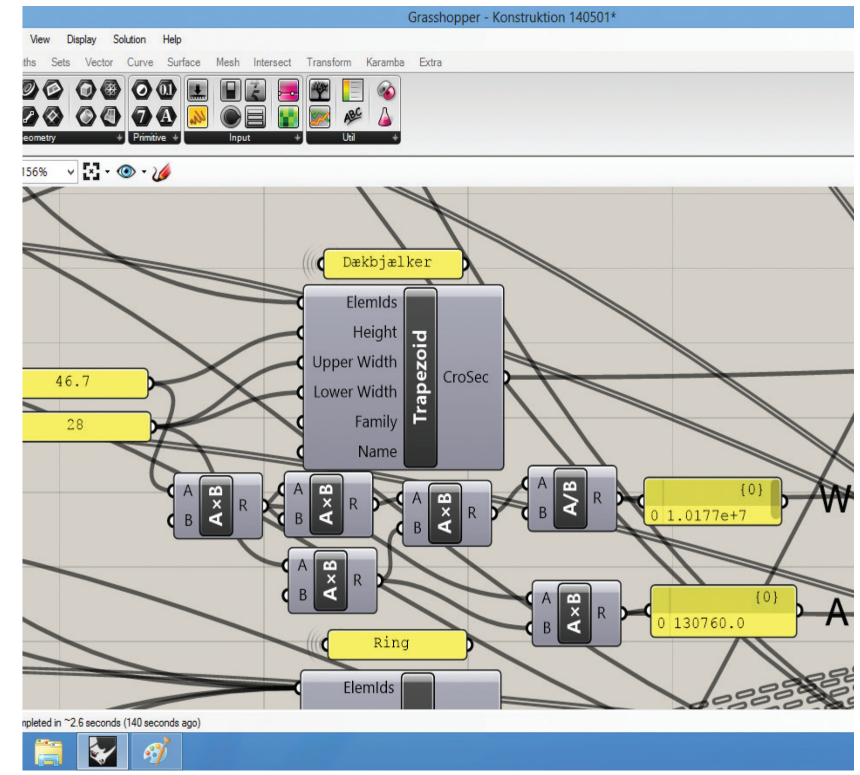
The glulam properties used for calculations is:

Design bending strength, $f_{m,g,d}$ $\quad f_{m,g,d} =$ 12,9 **N/mm²**
Design shear strength, $f_{v,g,d}$ $\quad f_{v,g,d} =$ 1,48 **N/mm²**

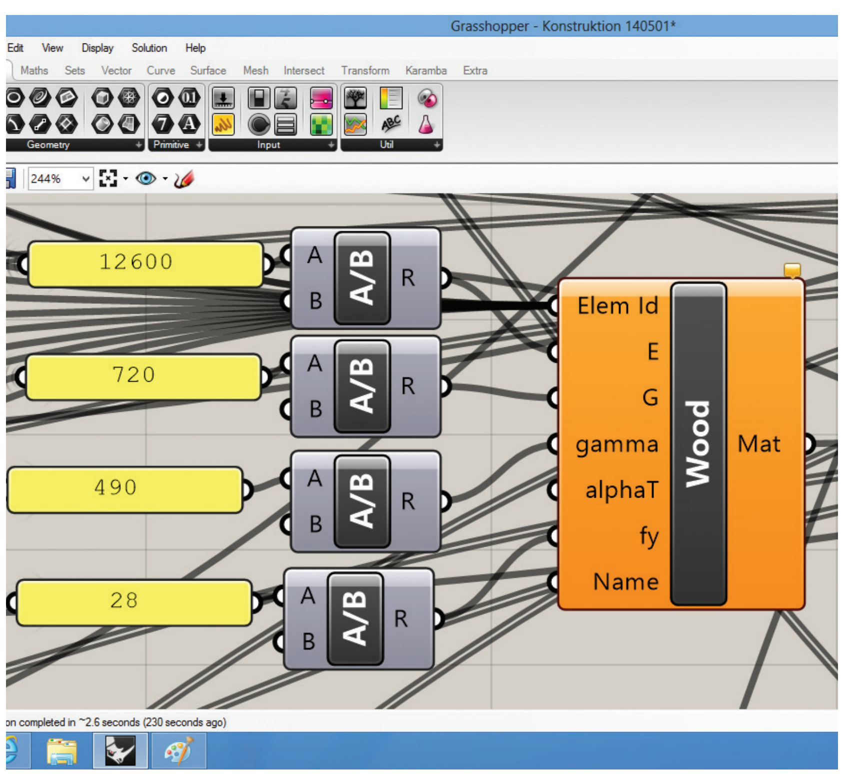
(Values from 'Teknisk Ståbi' tabel 7.2b (Teknisk Ståbi 2011, 315))



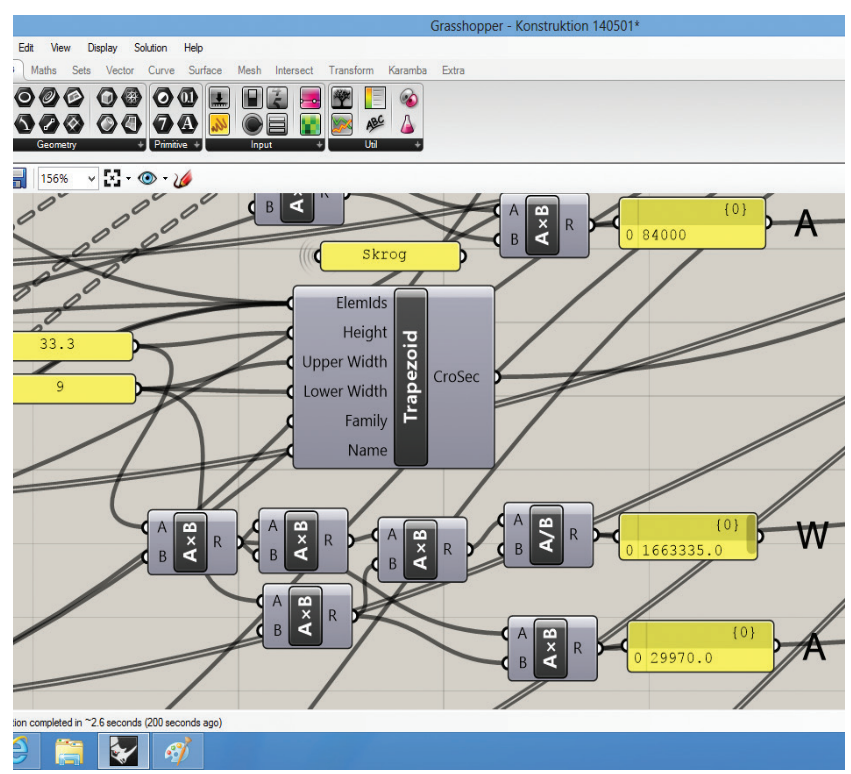
ill. 67: *Properties for the beams of the overall structure*



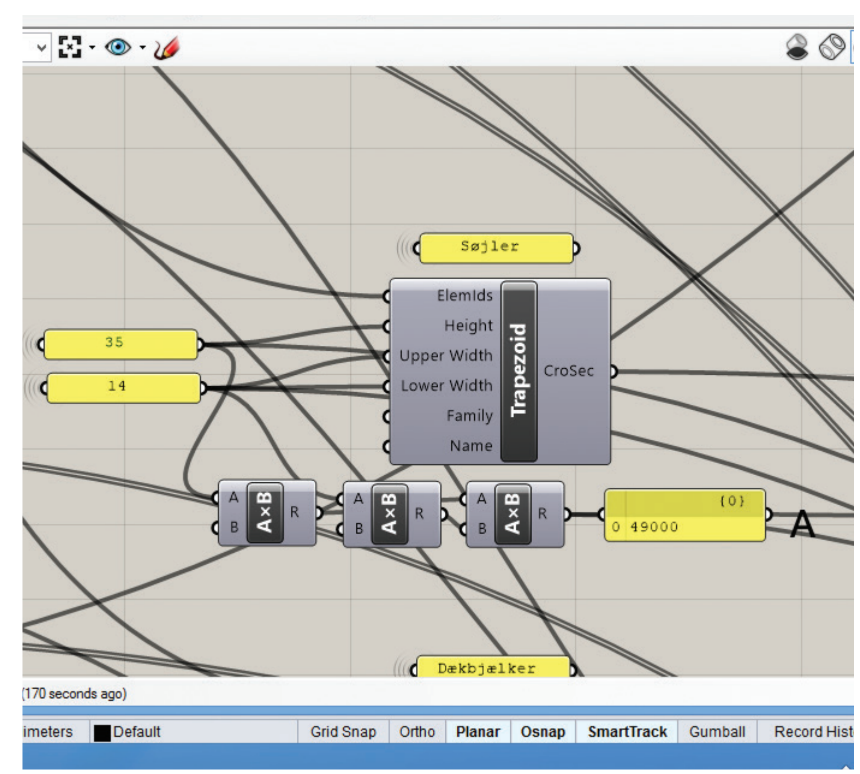
ill. 69: *Properties for the build-up beams in the deck*



ill. 66: *Glulam GL28h properties*



ill. 68: *Properties for the beams in the hull*



ill. 70: *Properties for the columns*

3. Loads

Calculating loads in a structure exposed to water pressure is an untraditional task within architectural engineering. Because of the spatial experience of the space, the demand for a specific level of water has been needed. The water level was wished to be visible through the windows in the interior space to be a part of the spatial experience within that space.

The loads was applied in three positions: load roof, load deck, and load floor, as illustrated to the right.

The loads are calculated through load combinations. The worst case is calculated below:

$F_{roof} = 1 \cdot F_{own} + 1.5 \cdot F_{snow}$
$F_{roof} = 1 \cdot 1.2\ \mathbf{kN/m^2} \cdot 4.5\ \mathbf{m} + 1.5 \cdot 0{,}72\ \mathbf{kN/m^2} \cdot 4.5\ \mathbf{m}$
$\underline{F_{roof} = 10.3\ \mathbf{kN/m}}$

$F_{deck} = 1 \cdot F_{own} + 1.5 \cdot F_{snow} + 1.5 \cdot F_{Utility}$
$F_{deck} = 1 \cdot 1.2\ \mathbf{kN/m^2} \cdot 4.5\ \mathbf{m} + 1.5 \cdot 0{,}72\ \mathbf{kN/m^2} \cdot 4.5\ \mathbf{m}\ 1.5 \cdot 2{,}5\ \mathbf{kN/m^2} \cdot 4.5\ \mathbf{m}$
$\underline{F_{deck} = 27.1\ \mathbf{kN/m}}$

The load on the floor is distributed to the columns of the hull structure, so the catchment is smaller than the one from the roof and the deck.

$F_{floor} = 1 \cdot F_{own} + 1.5 \cdot F_{Utility}$
$F_{floor} = 1 \cdot 1.2\ \mathbf{kN/m^2} \cdot 0{,}75\ \mathbf{m} + 1.5 \cdot 2{,}5\ \mathbf{kN/m^2} \cdot 0.75\ \mathbf{m}$
$\underline{F_{floor} = 3.7\ \mathbf{kN/m}}$

These load combinations is what the structure should withstand in order to meet the eurocode standards. But in these load combinations, no data of the load from the water is incorporated. This is where the project enters in on naval engineering, and goes beyond my curriculum. But in order to get an idea for the structure, I create a fictional load, that correspond to the load of the water.

The load action from the water is derived from the principle of Archimedes saying that the buoyancy from the water equals the force from the water that it replaces. This means that the mass of the Barge equals the water mass it replaces.

This means that the action effecting the hull can be calculated with Archimedes Principle.

$$F_{up} = V_{water} \cdot \rho \cdot g$$

This calculation is made parametrically in Grasshopper from the volume of the barge covered in water related to the height of the water line and the depth of the hull. The value calculated in the program is *27.4* **kN/m**. The total load from above in relation to the catchment from the hull is

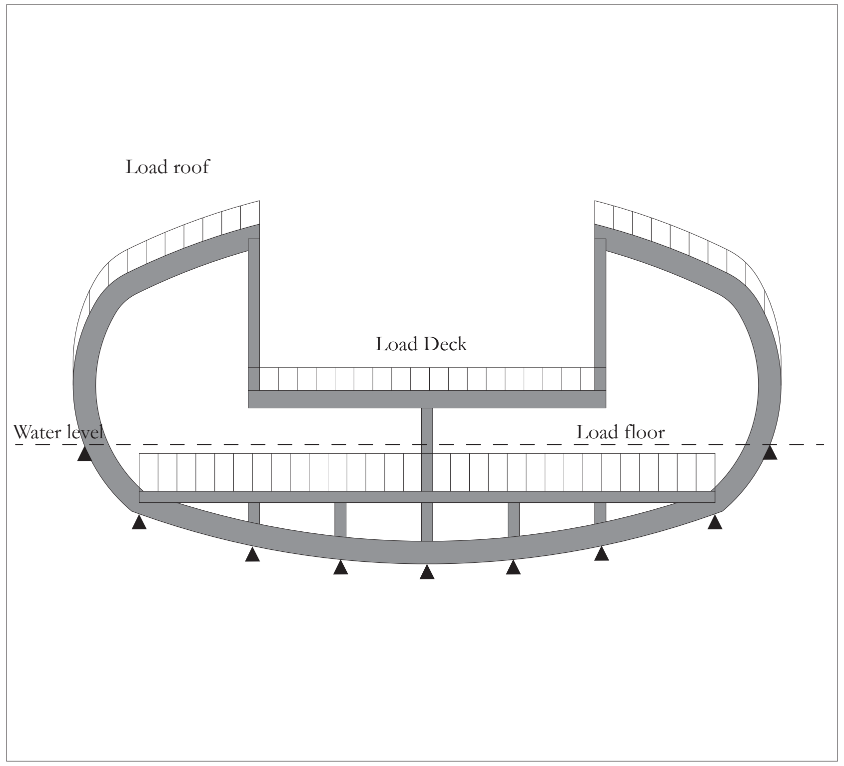
$F_{total} = F_{roof} + F_{deck} + F_{floor}$
$F_{total} = 10.3\ \mathbf{kN/m}/6 + 27.1\ \mathbf{kN/m}/6 + 3.7\ \mathbf{kN/m}$
$F_{total} = 9{,}93\ \mathbf{kN/m}$

This means that the load from the water, which is necessary for the ship to be placed in the right height exceeds the actual load the structure should withstand from the eurocode.

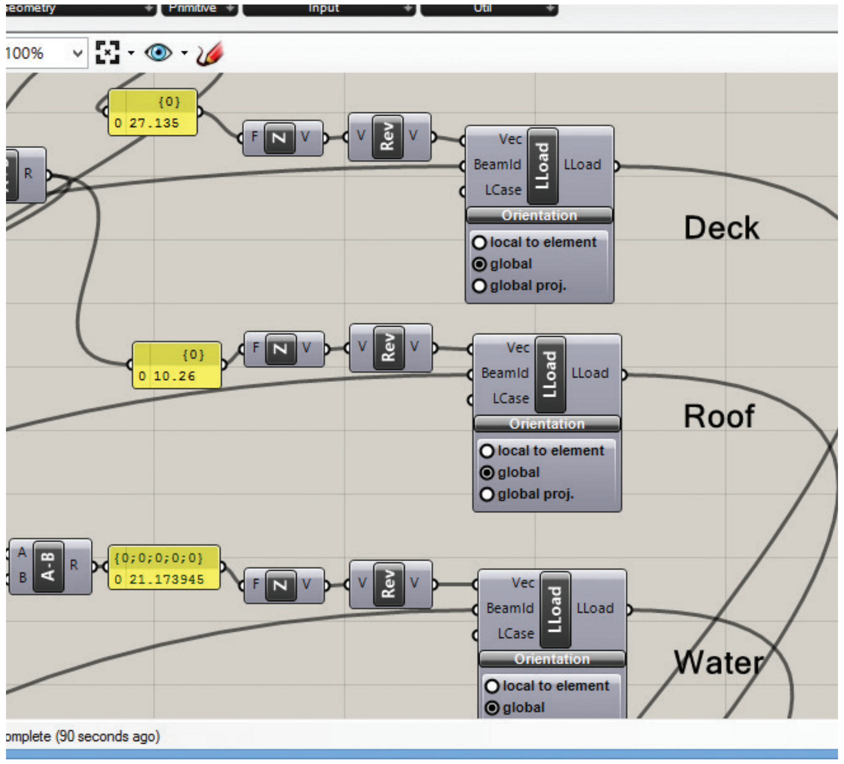
In practical the solution for lowering the Barge into the wished level, is by letting pumps in the bottom of the barge take in water, so that the weight of the barge equals the force of the replaced water.

In order to make a system that take the water load into account, the loads applied to the system should in total become the one calculated from Karamba. We already know the loads on the roof and on the deck, and the rest would be applied on the floor.

This means that the different loads will be applied as illustrated in the illustration in the bottom.



ill. 71: *Structural principle*



ill. 72: *Loads*

4. Beams

Verifications of the beams is calculated in Karamba. Method is Inspired by the calculations in '*Structural Timeber Design to Eurocode 5*' (Porteous 2007, 227).

The first calculation is checking for bending strength. In the illustration below is a screen dump from Grasshopper showing how the different beams a handling the bending stress. The three different tables responds to the three different beam cross sections. The section for the overall structure, for the hull, and for the deck.

The formula used for this calculating the design bending stress is:

$$\sigma_{m,y,d} = M_d / W_y$$

The moments, M_d, are calculated in Karamba.

The number on the right is the design bending strength of the beams. As the panels shows, no of the beams are exposed to bigger design bending stress than the beams can withstand, so bending strength is satisfactory.

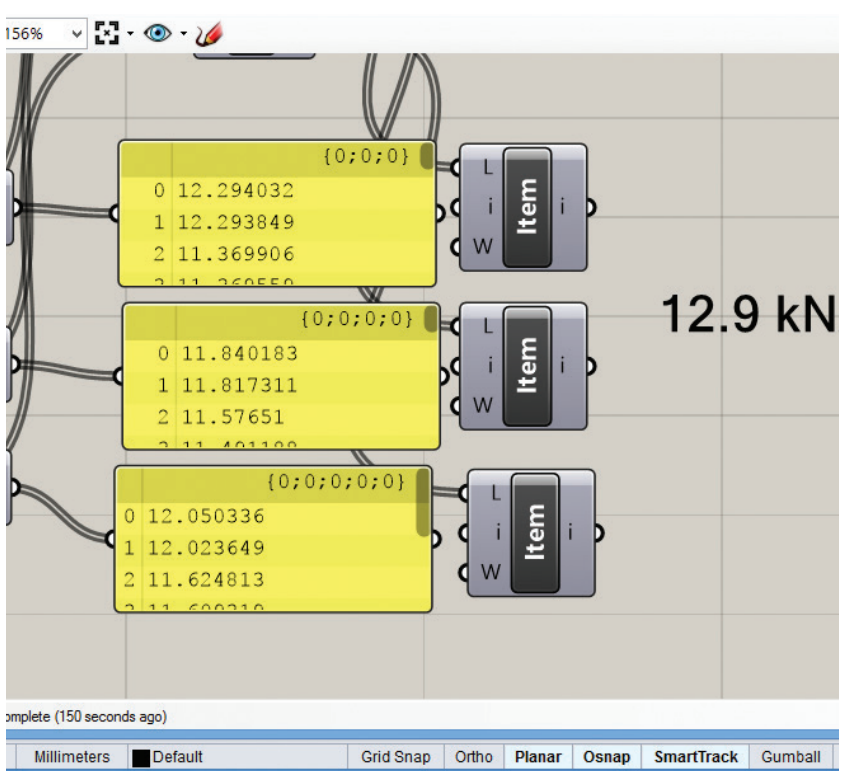
The second calculation is checking for the shear strength. The calculation is likewise performed in Grasshopper and the illustration below shows the results. The three different tables correspond to the three different beam cross sections like the first calculation.

The formula used for calculating the design shear stress:

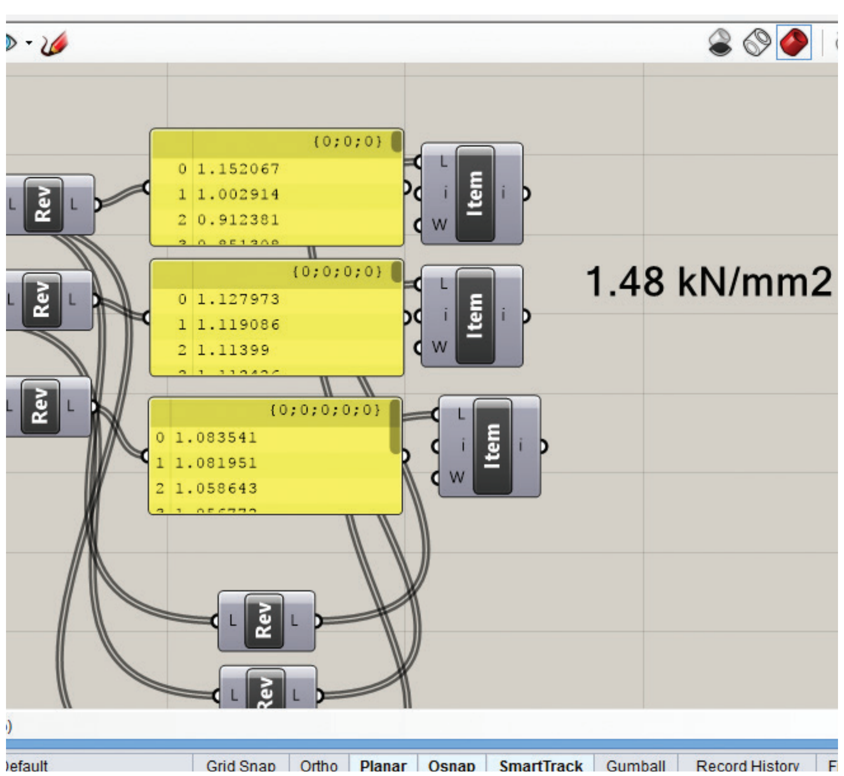
$$\tau_{v,d} = 1{,}5 \cdot V_d / A$$

The shear forces, V_d, are calculated in Karamba.

The number to the right of the panel is the design shear strength. As the panel show, no of the beams are exposed to bigger design shear stress the beams can withstand, so shear strength is satisfactory.



ill. 73: *Design bending stress calculations*



ill. 74: *Design shear stress calculations*

5. Columns

Verifications of the columns is calculated in Karamba. Method is Inspired by the calculations in '*Structural Timeber Design to Eurocode 5*' (Porteous 2007, 177).

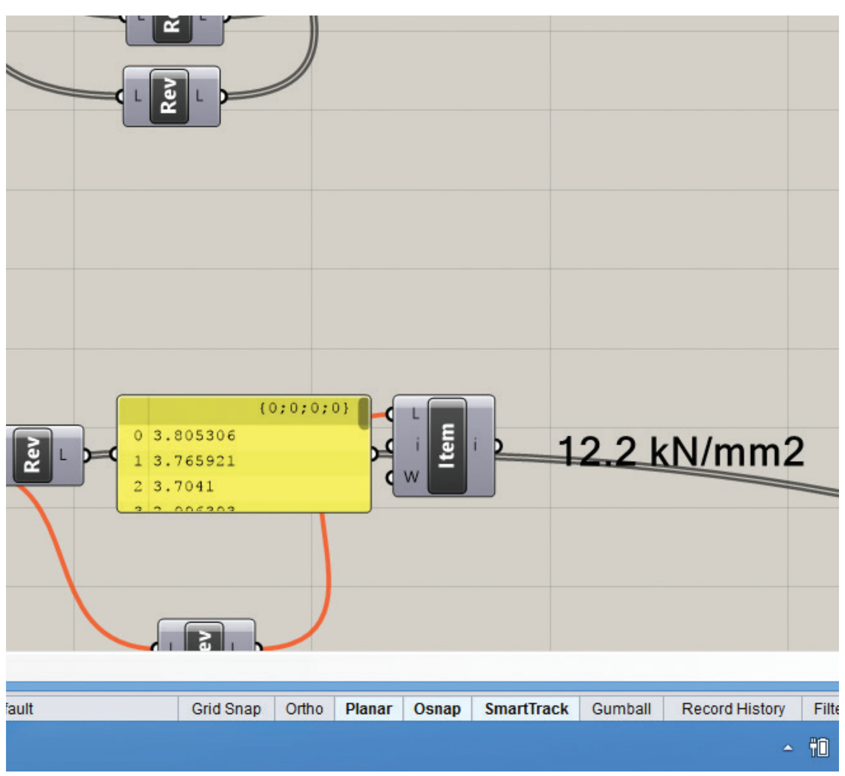
The first calculation is checking the axial compression of the columns. The illustration below, in the panel, is showed how the columns perform.

The formula used for this calculating the design compression stress is:

$$\sigma_{c,0,d} = N_d / A$$

The axial forces (Normal forces), N_d, are calculated in Karamba.

The number to the right of the panel is the design compression strength. As the panel show, no of the columns are exposed to bigger axial compression than they can withstand, so compression strength is satisfactory.



ill. 75: *Design compression stress calculations*

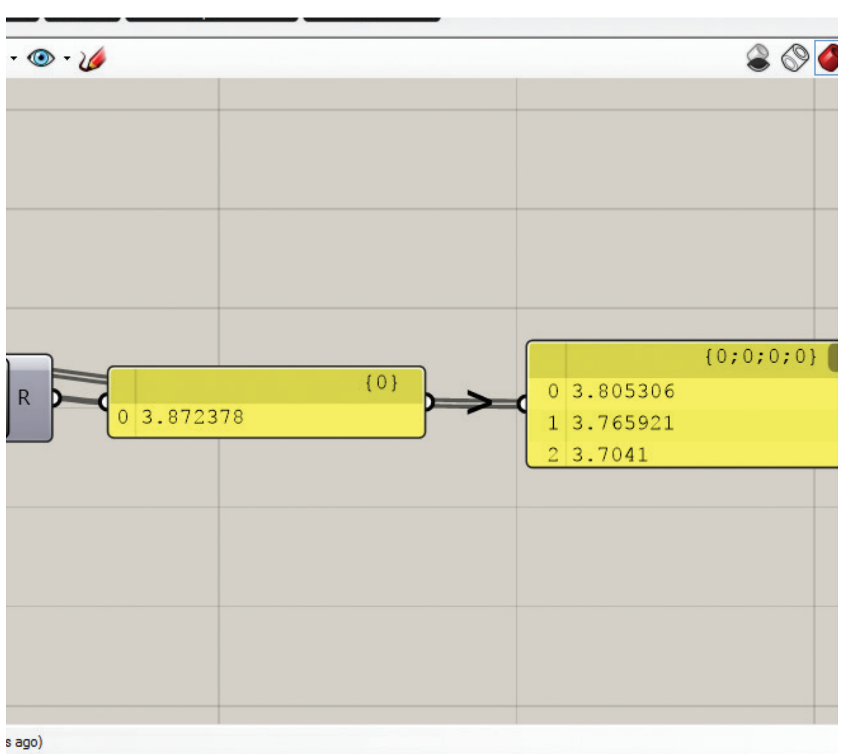
The second calculation is checking for buckling of the columns. The illustration below shows the worst case of the columns in terms of buckling resistance.

The formulas for calculating the buckling resistance are a few steps. It starts with calculating the relative slenderness from second moment of area I, radius of gyration i, and slenderness ratio λ, for both the y and z direction. The biggest of the relative slenderness is used to calculate the instability factor $k_{c,z}$. The design buckling strength is calculated from the formula:

$$k_{c,z} \cdot f_{c,0,d}$$

The result is the number is in the left panel in the illustration below.

The numbers in the right panel are the design compression strength again. As the below inequation is correct, the design stress is less than the design buckling strength.



ill. 76: *Design stress and design buckling strength calculations*

6. Conclusion

For this project Grasshopper and Karamba was used to create fast and reliable ideas of constructional potentials. The parametric calculation methods within the programs creates possibilities for fast iterations with a reasonable structural result for every shape.

The program has many advantages, and can be a great assist in an iterative design process. The program can deliver fast results about structural stability and rigidity. In this project, the initial structural assumption was that the cross section of the large beams creating the space should be supported by a structural member in the middle both in the vertical and horizontal direction. This would have had severe consequences for the interior space and would have limited the possibilities in the spatial creation. But iterations in Karamba revealed them to be unnecessary and further iterations in the structural system around the deck showed that increasing the size of the column in the centre axis of the Barge, would eliminate the need for further support of the deck. Iterations within Karamba already in the design phase created precise ideas of the structural system necessary for achieving stability in the Barge.

But the program come with a few limitations which affected the result in different ways. The calculations within Karamba take only the worst case scenario of moment into account. That means that a complete verification in relation to the eurocode is not possible within the program. For a sufficient calculation the structure would have to be tested in programs like Autodesk Robot. But for an iterative design process where final precise calculations are not necessary at this point of design, Grasshopper and Karamba can be a very useful tool for elaborating initial structural presumptions.

One of the biggest concerns in regards to using Karamba in a design process is when to introduce the tools in the structural calculations. A project needs to be at a certain level before a more precise structural analysis will proper assist. It depends on the project when the correct time for introducing the tools is. But in order to make rewarding iterations the structural concept needs to be approximately developed before. In this project, the structural concept was exposed to a few changes during the process, which meant that the Grasshopper, and thus the Karamba model was rebuild a few times. It is though difficult to argue that an introduction of the program was premature, because some of the iterations happened because of the results received from the previous versions of Karamba. The previous example with the vertical and horizontal beam was one of the iterations which came from a rebuilding of the model. A way to accommodate this dilemma in an iterative design process will be if the Karamba system has sufficient enough parametric parameters to handle changes in shape, as well as dimensioning.

For a further development of the structure with the Karamba model, solvers can bee used to optimize the structure. In this project it is a balance between sufficient enough space in the interior, size of windows between the structural members, and the number and dimensions of the structural members. The difficult in this approach is the decision of how to weight the different parameters according to each other, as no single solution would be the best in all parameters.

7.2 Light design

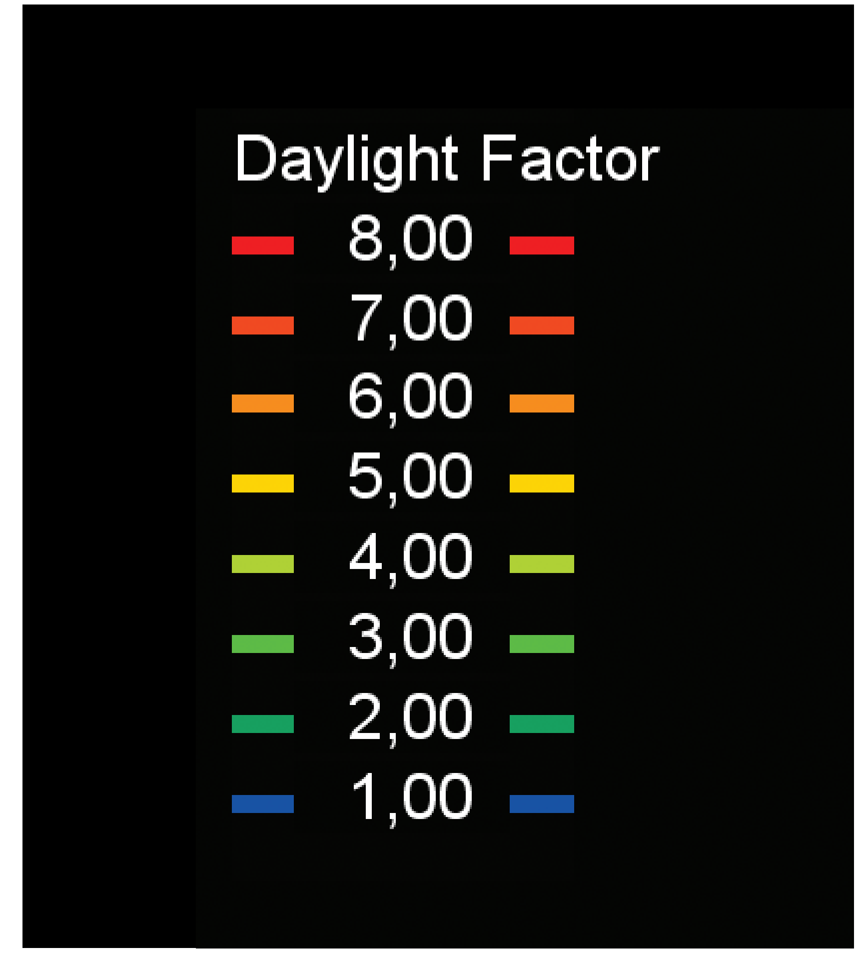
For the development of window sizes and notes on glass properties the computational programme 'VELUX daylight visualizer 2' has been used. The programme is able to give a graphic illustration of the daylight factor based on a 3D-model with surface properties and window classification.

In this project a simple iteration was developed based on window size and window properties.

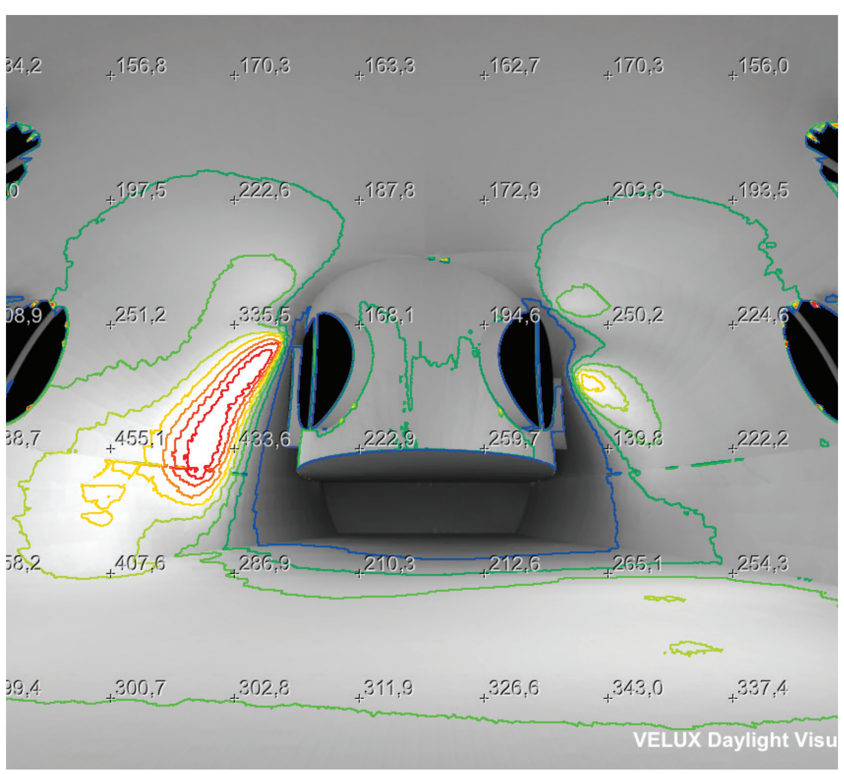
The objective was to let enough light in to create the experience of being within a light open space with clear references to being inside the interior of a grand wooden ship. Translated into technical terms the demands for the light was to exceed 2 % in daylight factor and between 200 and 500 lux on the majority of the floor area in the interior. These boundaries are based on recommendations from SBi on rooms similar in use to the restaurant space.

The matrix of illustrations on the following page is illustrating the daylight factor. Three different window sizes and three different transmittance level for the windows. The table of daylight factor levels on the right shows the curve level in daylight factor to the matrix.

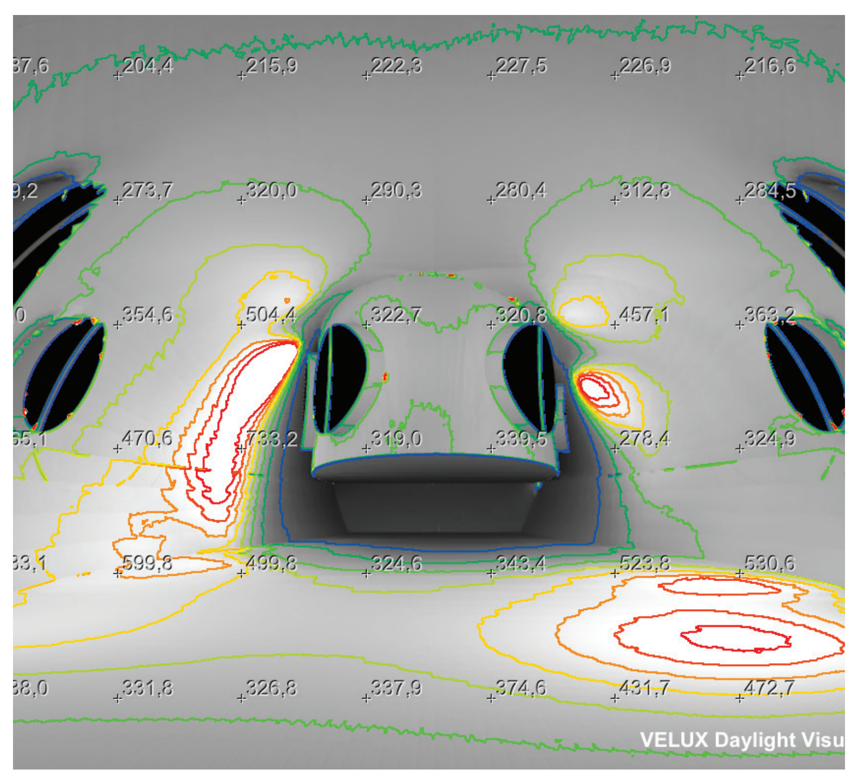
From that matrix, the one in the red box was picked out because the floor level exceeded 2% in daylight factor, and was analysed for illuminance as well. The pictures below shows the lux level in March, June, and September for the restaurant space. and as the illustrations shows, the majority of the floor area is in a sufficient amount of lux level in al three time seasons.



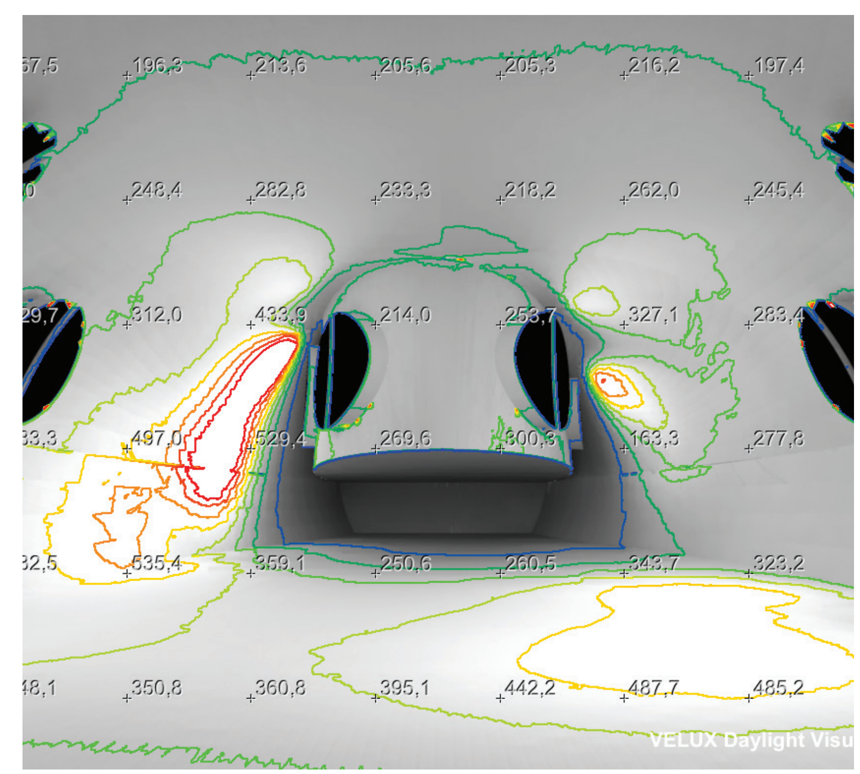
ill. 80: *Daylight factor for the following pages illustrations*



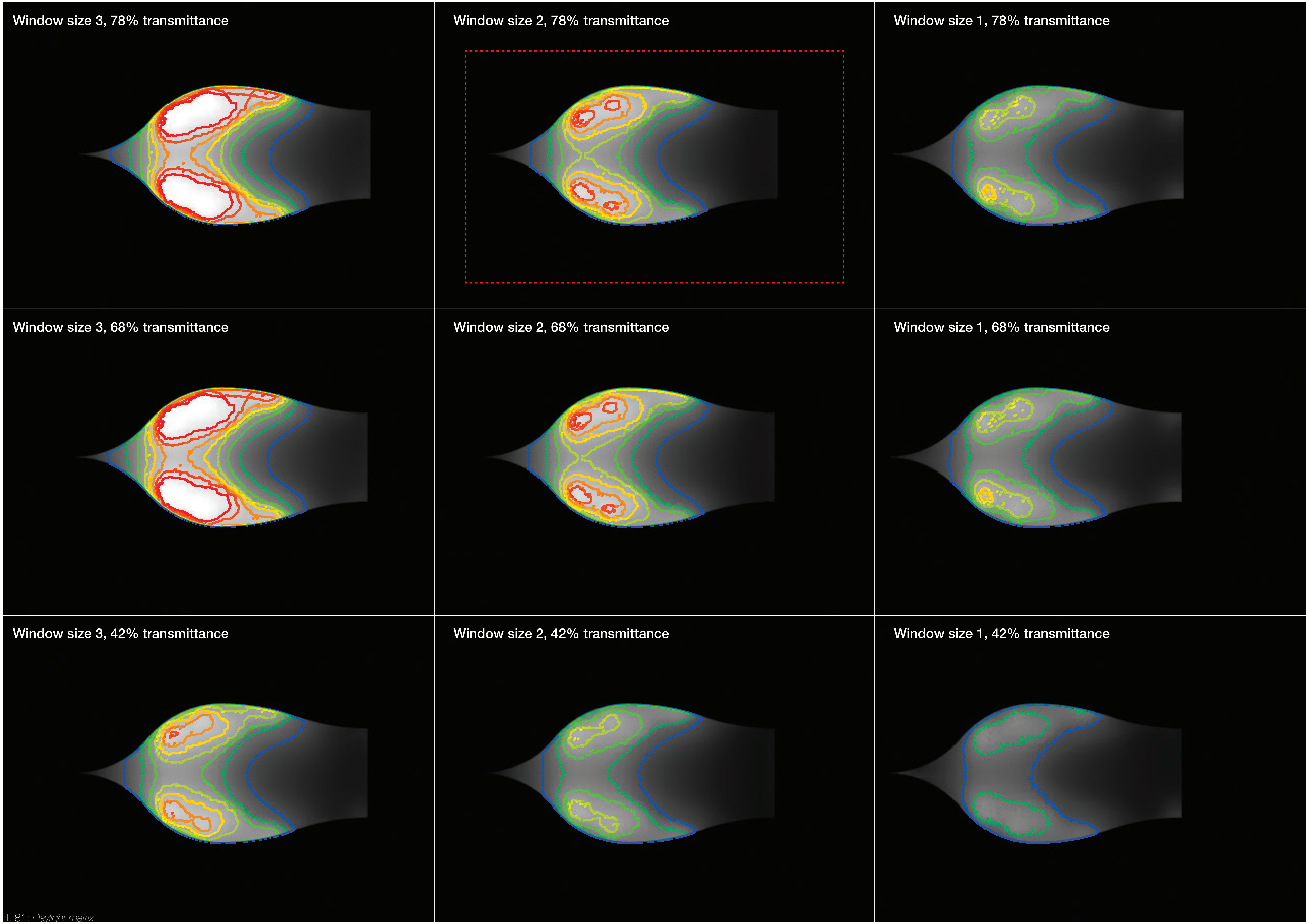
ill. 77: *Illuminance on midday in March*



ill. 78: *Illuminance on midday in June*



ill. 79: *Illuminance on midday September*



ill. 81: *Daylight matrix*

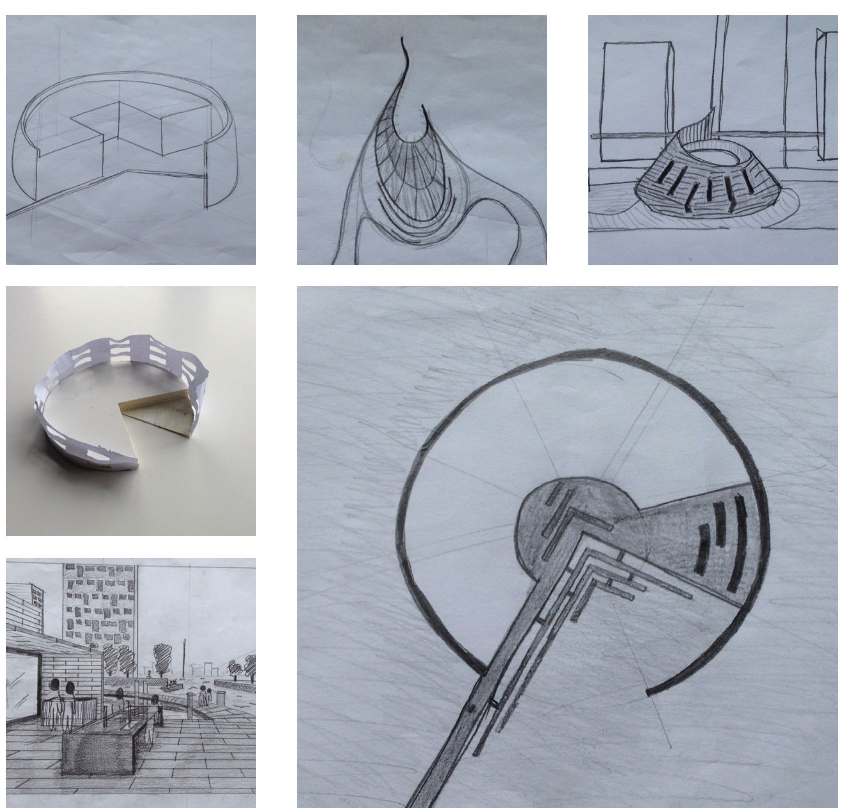
7.3 Process

1. iteration - First drawings

The first drawings related to the project began by an exploration of contrast to the very urban tall buildings proposed for the site of Østre Havn. At the same time drawings related to the atmosphere within the interior space.

The approach was that a dense urban community needed a small, human scale and human related facility that could create identity and cozy atmosphere in a highly urban area.

The drawings were intuitively round and a bit organic in expression due to the contrast to the box-like structures on Østre Havn. At the same time material properties related to wood began to emerge as a response to the concrete, glass and steel on the images.



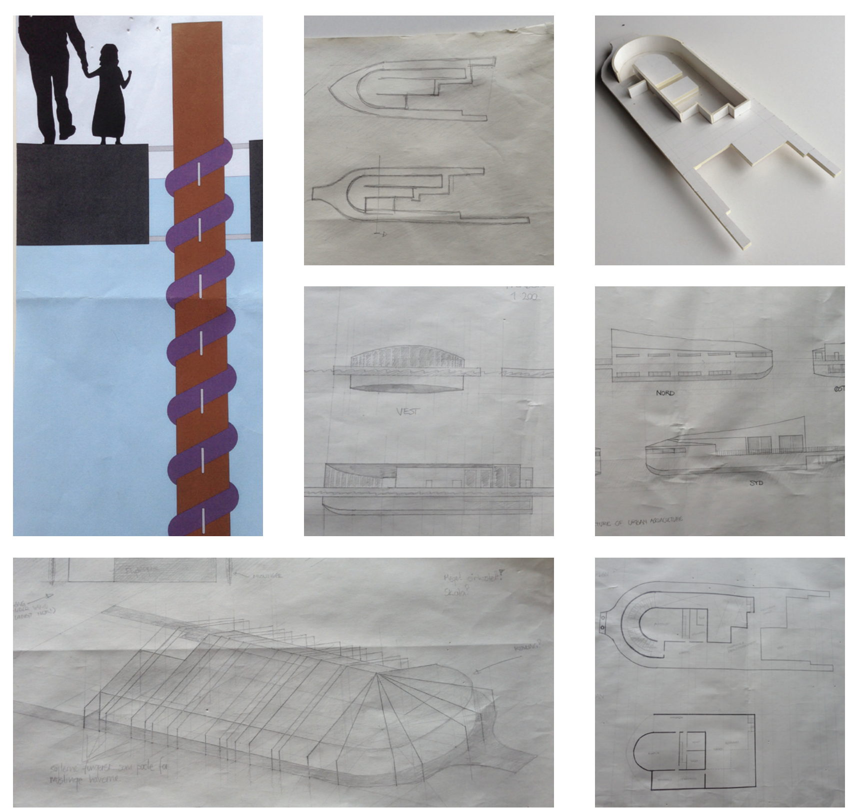
ill. 82: *Drawings related to the 1st iteration*

2. iteration - Overall boundaries

The second iteration of drawings emerged from the principle of creating a floating structure that could be moved away by tugboats. The shape began to look like a ship structure itself, and began to develop a boat-like appearance.

At the same time the principle of Bouchot mussels were developed and together with the initial plan organisation based on the principle of approaching the main interior space and the experience of going beneath the water the first complete set of drawings were developed. At this point the facility constituted a house on top of a barge, with a lower deck beneath the water level.

The non-flattering boat-like appearance and the lack of integration between the barge and the building was the conditions that inspired the next iteration.



ill. 83: *Drawings related to the 2nd iteration*

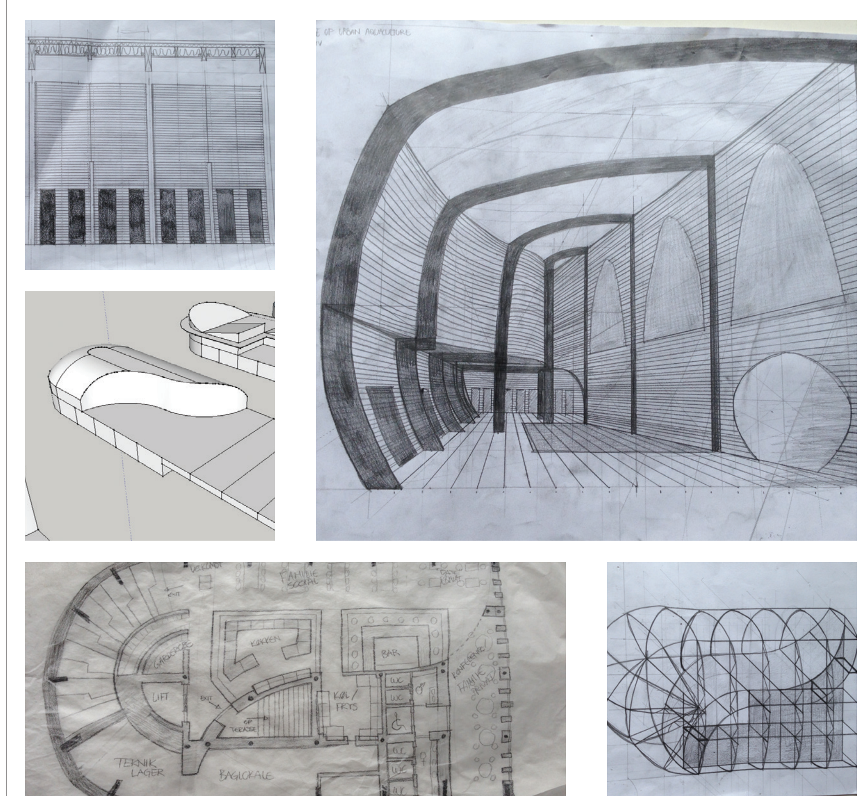
3. iteration - First organic and structure

The third iteration started out with a slightly more organic approach to the shape of the facility. The barge and the building emerged into on coherent shape and the outdoor space was trimmed, optimized, and more usable.

Interior space and the atmosphere within this space was starting to be developed and the coherence between the construction of the wall and the interior expression began to work together. Interior features like doors and windows were taken into account in the interior development. Matching normal rectangular elements in an organic space was difficult and experimentation with rounded elements were initiated.

Furthermore the structure of the barge began to be developed both in relation to architecture and the stability of the structure. Matched with a suitable Karamba file (explained in the structural appendix) the principle for the construction were developed.

The need for a structure that complicated the interior space as well as the need for even more experimentation within the organic shapes provoked the next iteration.



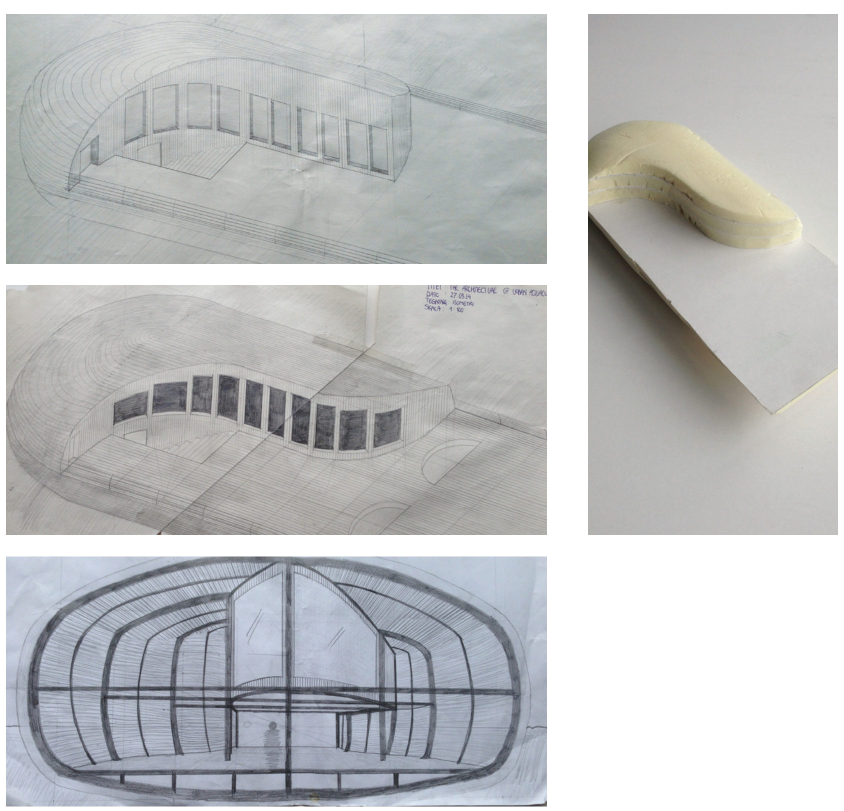
ill. 84: *Drawings related to the 3rd iteration*

4. iteration - Extended organic

Even more coherence between the barge and the building initiated this short iteration. A cleaner interior space and a developed structure made this iteration possible.

The great windows in the main exterior space was also subject to experimentation in this iteration. The connection between interior and exterior was a great influence in this experimentation.

The issue of letting the complete structure be dragged away as well as a messy entrance area sparkled the next step which came as a response for the need of a better programming of the spaces.



ill. 85: *Drawings related to the 4th iteration*

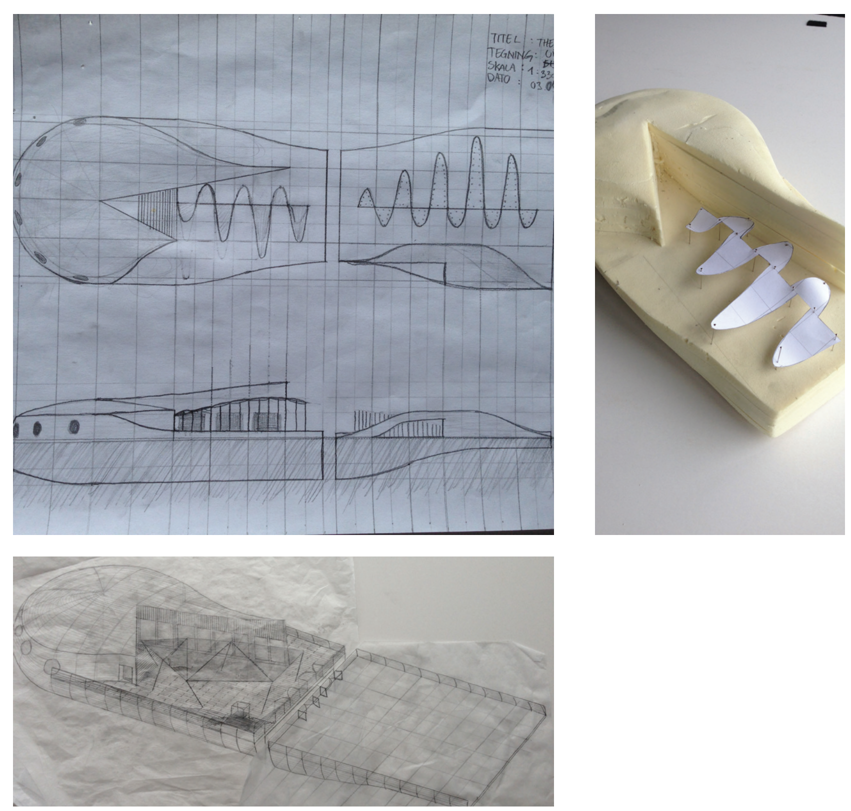
5. iteration - Dual structure

The idea of dividing the structure in two parts, and letting the aquaculture part of the facility and the restaurant space become two separate structures, was the initiating issue in this iteration.

The coherence between the two facilities was the main concern in this iteration as well as the planning of the two structures separately.

The principle of how the structure was able to be dragged away, was an important part of this iteration. This affected the overall shape and to some extend the interior organisation.

The reappeared lack between the barge and the structure was the issue created the foundation to the next iteration.



ill. 86: *Drawings related to the 5th iteration*

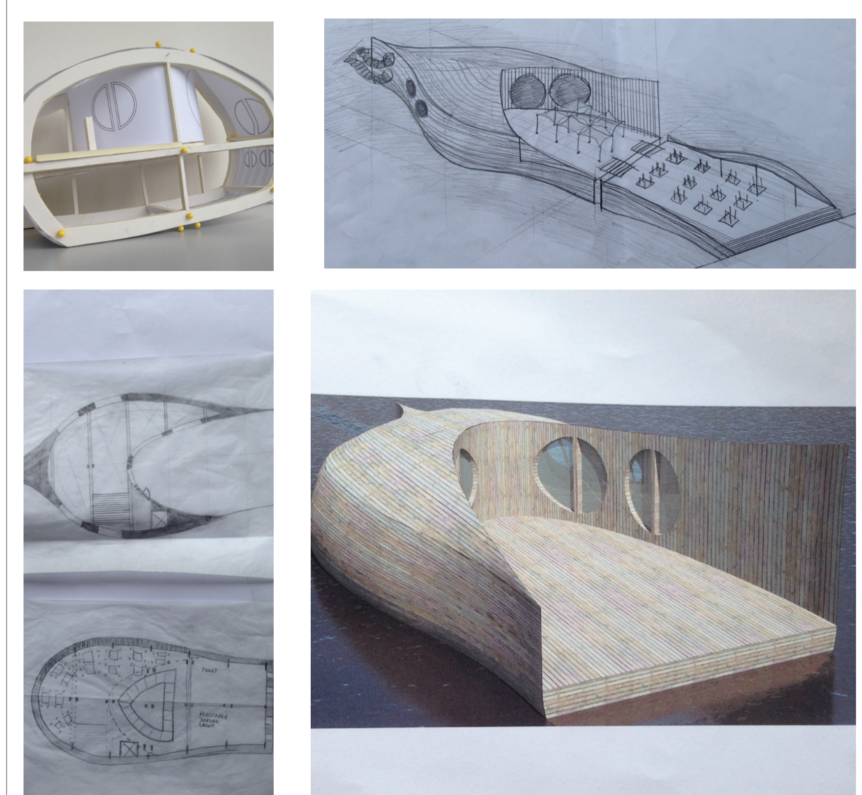
6. iteration - The Pier and lighting design

The final iteration was developed with the shape in mind. The shape of the facility were further integrated and the coherence between the barge and the pier was the important subject.

The windows in the exterior space as well as the interior space was experimented with and the solutions were tested both in 3d-programming and in models.

Structure-wise this iteration ended up showing that the interior beam and column which earlier had seemed very important, could be avoided by tweaking on the structural parameters. This created the foundation for the final interior space without any structural members present in the main space of the facility.

Small changes are between this iteration and the final one presented in the rapport.



ill. 87: *Drawings related to the 6th iteration*

8.0 References

8.1 Litterature

Aalborg Kommune 2012, *Østre Havn - Kvalitetprogram*, (online) Available from: <http://tinyurl.com/p8adhrx> [13 November 2013].

Kiib, H, 2007, *Harbourcape*, Aalborg: Aalborg University Press

Knudstrup, M-A 2003, *'Integrated Design Process i PBL'*. Aalborg: Aalborg University Press

Petersen, J. K.; Maar, Marie; Holmer, Marianne 2010, *Muslinger som virkemiddel - Et pilotstudie*, (Online) By- og Landsskabsstyrelsen, Available from: <http://forskning.skaldyrcenter.dk/files/Muslinger%20som%20virkemiddel_rapport.pdf> [12 November 2013].

Portous, J.; Kermani, A 2007, *Structural Timber Design to Eurocode 5,* Oxford: Blackwell Publishing

Stickney, R. R. 2009, *Aquaculture - an introductory text*, 2nd edition, Cambridge: Cambridge University Press

Teknisk ståbi 2011, udg. 21, Valby: Ny teknisk Forlag

POLYFORM 2014, *Østre Havn - Dispositionsforslag*

8.2 Websites

BST Oysters 2009, (website) Available from: <http://www.bstoysters.com/index.php?id=products_farm%20layout>
[10 December 2013]

Dansk Skaldyrcenter 2013a, (website) Available from: <http://www.skaldyrcenter.dk> [20 November 2013]

Dansk Skaldyrcenter 2013b, (website) Available from: <http://www.e-learning.skaldyrcenter.dk> [20 November 2013]

Geodatastyrelsen 2012a, 28. December 2012, <http://www.danskehavnelods.dk/#BID=8> [25 February 2014]

Geodatastyrelsen 2012b, 13. June 2012, <http://www.danskehavnelods.dk/pdf/havnelodsenpdf.dll?WEB=1&TYP=0&ID=474&NR=1> [26 February 2014]

Geodatastyrelsen 2013, 11. December 2013, <http://www.danskehavnelods.dk/#BID=7> [25 February 2014]

Pleinemer 2012, (website) Available from: <http://www.pleinemer.com/mussel-work.htm> [27 February 2014]

8.3 Illustrations and pictures