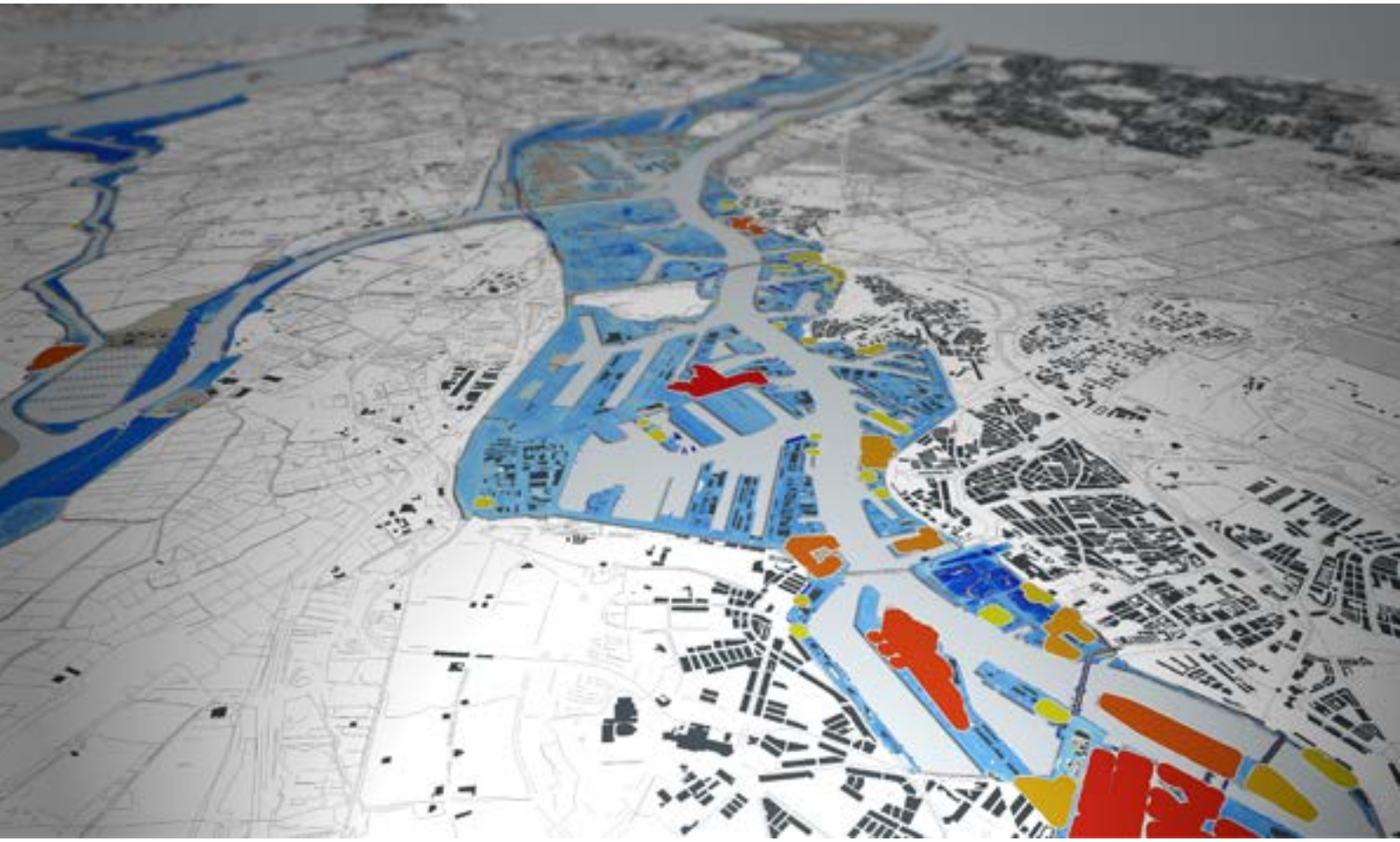
Graduation Report

Building Technologies for Climate Change Adaptation

Case study Rotterdam Rijnhaven



Smart Urban Design
Form Follows Sun & Floating Water Homes

Name **Loran Mynett**
Number **1533584**

TU Delft Delft University of Technology

Master **Building Technology**
Date **11.12.2014**

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Colofon

Loran Mynett
Papsouwselaan 264
2624 EJ Delft

L.S.Mynett@student.tudelft.nl
Loranmynett@gmail.com
+31 6 39.77.24.57

Mentors

1st: Ir. Jan van der Voort (Architectural Design)
2nd: Dr. Craig Lee Martin (Sustainable Design)

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Acknowledgement

First of all, I would like to thank my mentors: Ir. Jan van der Voort and Dr. Craig Lee Martin.

Jan van der Voort has been from the beginning very helpfull in order of reaching the right information and literature. In the early phase of my graduation I was welcome at his library on his office where I found a lot of information and books I found inspiration. I want to thank him for that, this gave me the opportunity to get inspired by many floating houses right away.

Craig Martin had exactly the openminded and futuristic view I was looking for to reflect my own ideas with. His future perspectives and sustainable approach, not only on buildings but on a way of life was for me a great example that thinking outside the box in a realistic way is a lot better to be innovative then short sighted people most of us are daily dealing with.

Both mentors gave me valuable input and feedback on this research, from their own points of view.

Then I would like to thank Duzan Doepel who gave me the opportunity to work on an a real life urban plan for my case study the Rijnhaven. For more then two months I felt more then welcome at DoepelStrijkers architecten office in Rotterdam. The products we made were usefull for both of us and for me it was an unique and strong urban plan as starting point which can not have been more realistic.

Therefore, I would like to thank all others at Doepelstrijkers architecten whom I have been in contact with. I have been able to talk and discuss with them about the urban plan and exchange ideas. All showed their interest and support in this research project, which provided me with a lot of information, feedback and motivation.

Especially, I would like to thank Chris Zevenbergen, Professor of Flood Resilience of Urban Systems, working at Clean Tech Delta and UNESCO-IHE. He has provided me with a lot of information about the harbours of Rotterdam. He also got me in contact with Duzan Doepel where I got the opportunity to work on a urban plan by means of an intership.

Additionaly, I would like to thank Associate Professor Lex Keuning working for the TU Delft on the maritime engineering faculty was from great importance consulting me about the stability and hydrostatica of my design, concluded the building is extremly stable and easily meets the safety requirements of obliquity.

Other companies I would like to mention and thank are Willem Visser working for ABC Arkebouw for providing me with very usefull feedback on the specification of the floating concrete box they make as a company.

Finally, I would like to thank my parents for their financial and psychological support throughout my studies.

Preface/Motivation

Many countries like Holland are dealing with the major problem of higher water level then ground level. This means technique is needed to make living possible. To build against the principles of the nature isn't the easiest way to build. Floating development is still under construction. The technique is allready there but still there isn't a lot of floating residentials in practice.

The floating development is a growing market. More and more there will be developed on water and there is also need for. Climate adaptive cities are the future and a great solution for places dealing with flood risks, like China, India, Bangledesh and Holland.

This floating business is up coming but research shows it is not the technique why it's not been taken to the next level. This is developed many years ago and can be applied already. So what is it why it's not coming of the ground? In my research I found that the benefits of the whole floating part is not clear for all parties.

What will be the key, coming out of my research, is the sustainable aspect what is can be convincing to participate for all parties if the benefits of these are clearly present. Briefly stated; people has lower energy bills, Municipality climate adaptive cities with no risk for floods, and the city has world leader fame, which can cause tourism and media attention.

This is why I want to graduate in this topic. I see potential in floating development and have personal fascination in new techniques and innovative solutions for complex urban situations

The case I use is the "Rijnhaven" in Rotterdam. I had an internship at Clean Tech Delta who are also elaborate new plans for the city harbours of Rotterdam.

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Oude-Tonge, Netherlands, Jan 1953

Bosten, USA, June 2008

Bangkok, Thailand, July 2011

01. Introduction

Fig. 1.2.1

Waternoodsramp in Netherlands in 1953. The dikes collapsed and many people died.

Fig. 1.2.2

Bosten recently hit by floods

Fig. 1.2.3

Bangkok totally flood in 2011

1.1 Building Technology lab

This report contains the graduation research documents of me, Loran Mynett, student of the Building Technology department at the TU Delft. The graduation studio "Building Technology" focuses on the technical aspects of a building design. Climate, structure and facade aspects are the three graduation topics for furthur elaboration. Although a good integration of those three topics is needed to reach a good final result, I have chosen climate design.

A building technology graduation student is required to focus on innovative technical solutions. Afterall the student becomes structural-, facade- or climate designer instead of architect, but he has, because of his architectural backgrond, a good integration between the architectural and engineering side.

The architectural side will attend the urban context and formulate a problem statement, while the engineering side will attend the context of technical innovations supported by the rationality of the engineering. A personal fascination is added in both contexts.

1.2 Problem statement

Climate change forces reconsidering the way we build nowadays. Areas outside the dike are flood prone and need more attention to become flood resilient. Those areas are mostly located pretty much in the centre of the city which provides an appealing location for new buildings and residentials, but building outside the dike brings a complex situation with lots of needs and requirements from all different angles which should be analysed, made clearly visible and taken care off before developing can take place.

A problem which is allready been taken care of is the area enclosed by the dike. The dikes of the Netherlands are known for the safest dikes of the world. There is actually not so much te be concerned about if we are talking about the area enclosed by the dikes. There is only one problem: if somewhere the dike breaks, there are no compartments, so everything will be flooded.

The area outside the dike is not protected (in a certain way) and will flood in a period of time. Rotterdam wants this place for new buildings, but a bigger result will be given if there is a way to build in a water adaptive way, so countries who has to deal with the problems of flooding enclosed by the dikes, has a solution. Then they can assure there people for no floods because the buildings are climate adaptive and go with the water flactuations whenever the waterlevel is rising.

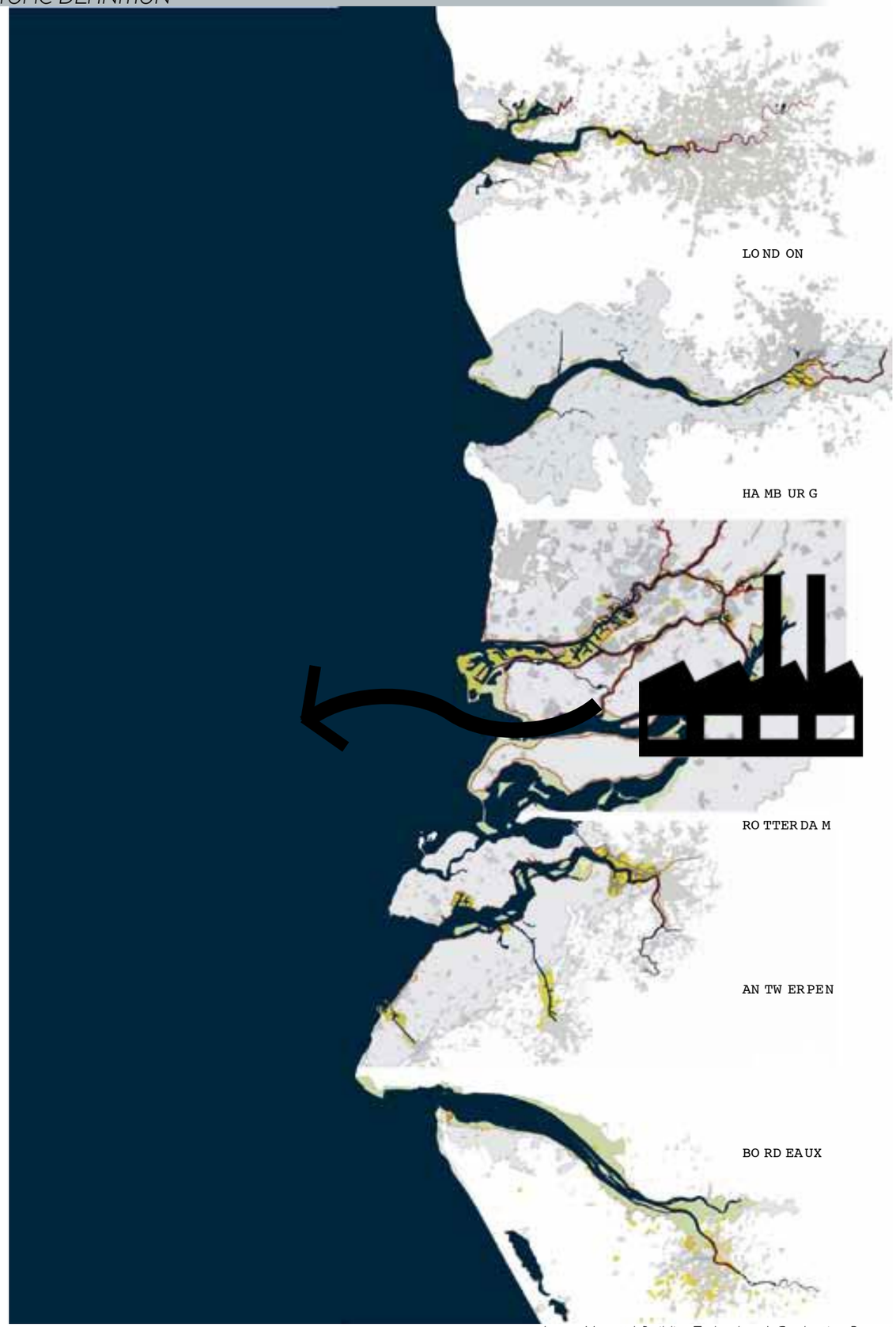


Fig. 1.4

Harboars located nearby the sea and are expanding towards the sea. (Hoogheemraadschap van Delfland)

1.3 Relevance

First, socially the relevance of this research lies in the liveability of old harbors where industry disappears and flood risks are possible. In our current building development we see that buildings can float, go with the water if there is a dynamic landscape and find more possibilities to become water adaptive. As a surplus, the density of our cities gets higher due to higher ground prices and the amount of free land to build on gets less. Thereby the more ground is paved or hardened the bigger the water drainage problem in the city becomes.
Water needs space, if it has not problems arise. Building on top of the water provides space both for water and for buildings.

The landscape undergoes a transformation of hardening. This has consequences for the rainwater drainage system, less green means less delay for draining the water. This results is a obstruction because the drainage can not handle al the water at the same time, which can give lots of troubles on the long term. To prevent this from happening green has to be implemanted in the city, for example on the roofs to slowdown the water and provide a more gradual inclusion but a much better solution can be found in increasing the space for water in the city

The harbors of Rotterdam located nearby the heart of the city have a great location for residentials, but first there has to be taken care of the water fluctuations. Outside the dike the water is free to go and it will certainly flood. To use this space there has to be build in a climate adaptive way. If this has been achieved, Rotterdam can proudly say to be the first water adaptive city in the world and becomes world leading in floating developments

1.4 Research questions

"How can we transform old harbors with high flood risks into a climate adaptive comfortable urban living environment?"

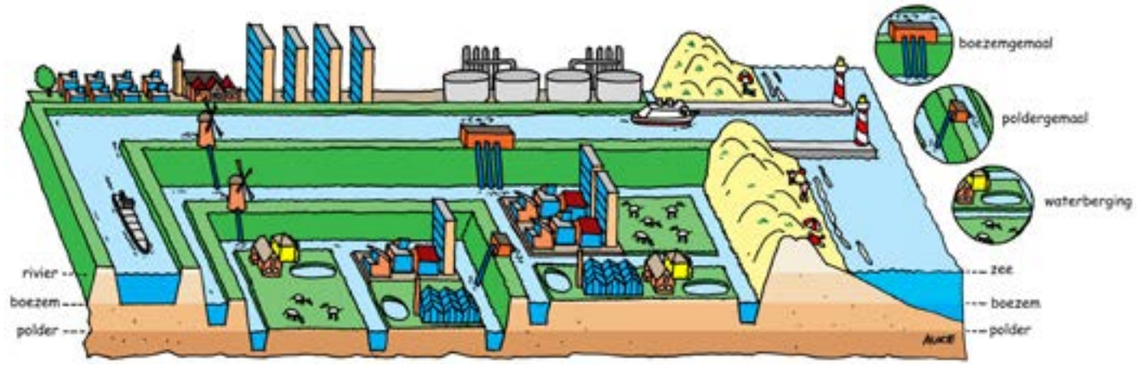
Sub research questions are:
-"What are the complexities for the case study Rijnhaven?"

-"How can these be addressed in a sustainable way?"

-"What does this imply for the predesign?"

-"What are the design considirations?"

02 Water in the City



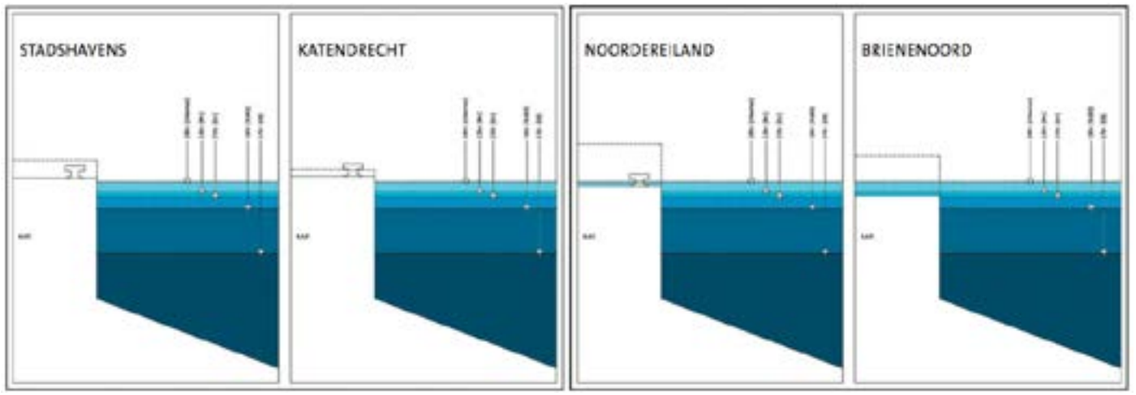


Fig. 2.1.1

IThe extremely complex waterregulation system of holland (Hoogheemraadschap van Delfland)

Fig. 2.1.2

Map is trying to illustrate the flooding events recurrences in years (Rotterdam adaptive)

Fig. 2.1.3

A vertical drawing which indicates the flooding at different water levels. (Rotterdamse Stadshavens)

02. Water in the City

2.1 Purpose change

Water in the city is a hot topic started in 2000 with a first waterplan made by and for Rotterdam. This plan has been enlarged till futuristic city visions, interests from different parties and the drive to become world leading on floating development. Water in the city can be expierenced as good or bad. "Nowadays water in the city has been seen as an opportunity" says John Jacobs, senior counselor in the Rotterdam climate proof development.

In origin the purpose of water in the city wasn't only to have dry feet but most of all to be used for traffic and trading aspects. This is why there are beautifull big houses next to the water in big cities. Between the 15th and 19th century most of the cities arised by means of the construction of waterstructures. Soon enough it becomes clear it wasn't that easy to regulate the water in a collective way

Since the second half of the 19th century the relationship between water and city had a drastic change. Clean drinking water was supplied with pipes, dirty water was drained by a sewage system, rainwater had his own drainage system and the trading has been done more and more over land, espescially because of the upcoming train and car.

Nowadays the purpose of water in the city has changed again. Not so long ago they tried to put all the water systems as much as posible out of sight, just pretend it has never ben there and nobody is using it or suffers from it, but now water comes more and more back in sight. Three main factors are leading in this change:
1. *Revaluation*
2. *Climate change*
3. *Social changes*

2.2 Multifunctional water

There are five different kinds of water which occurs in the city; drinking-, ground-, sewage-, surface-, and rainwater. Each water flow needs a certain amount of space or storage and this infuences the urban design. To design the water and including it in the design proces there needs to be found a way which provides grip the design aspects of it. This can be achieved by determining a certain hierarchy. In this hierarchy the people who design with water have some handles to form it in the design
1. safety first
2. passing on
3. water flows from clean to dirty
4. make it fun
5. build water aware

The vertical drawing of a plan has more information and gives more view about the consequentes and form then the plan could tell. However in practice you see almost only maps which have been put lots of effort and time into and there is barely a cross section of the area. Although this is the only drawing where you can see the dynamic aspects of water fluctuation areas.

There are different gradations which can be clearly seen in a cross section:
a. Normal water fluctuations
b. Waves and wind actions
c. Variation in level under normative conditions (1/10 year)
d. Variation in level under extreme conditions (1/250 year)

Fig. 2.3.1
Old map of Rotterdam where water was used for trading aspects.

Fig. 2.3.2

Historical view of the Rijnhaven (Drijvend Ontwikkelen)

Fig. 2.3.3

Historical view of the Wilhelminapier (Drijvend Ontwikkelen)

Fig. 2.3.4

Historical view of the harbor industrial area (Drijvend Ontwikkelen)

Fig. 2.3.5

Historical view of Katendrecht (Drijvend Ontwikkelen)

2.3 Urban basic principles

Water-based living is different from living on the land at every level of planning. Designs can only be succesfull if all aspects has been taken into account. The most significant urban principles are routing, privacy, positioning and water level.

Routing

Normal streets have no dead ends and provide routing for anyone. Jetties give just like streets with dead ends no reason for people to enter which automatically transform this space to semi-private. Cross-connections or public functions can be used for lifting the barrier to set foot on the jetty

Privacy

Water is mostly labeled in water-dwelling-designs as public. With can give problems if the view is shared with private and public spaces. This means from the public area can easily be watched into the private space of the living. Distance is one of the options to avoid this problem. Also placing obstacles in the water can be used as a barrier.

Positioning

The relationship between dwelling and bank can be categorized in three groups; the house partly on land, the house on a bank on the edge of land and water and the house in the water. A small space between land and property in combination with a clear view on the water around the dwelling is sufficient enough for the dwelling to be perceived as a water dwelling. When the distance increases it becomes clear it is a fully water dwelling so the water experience increases.

Water level

Fluctuations in the waterlevel can have a major impact in which waterdwellings relate to the water. When the waterlevel is constant, the building can be erected close to the water, making it a safe and above all aesthetic environmental feature.

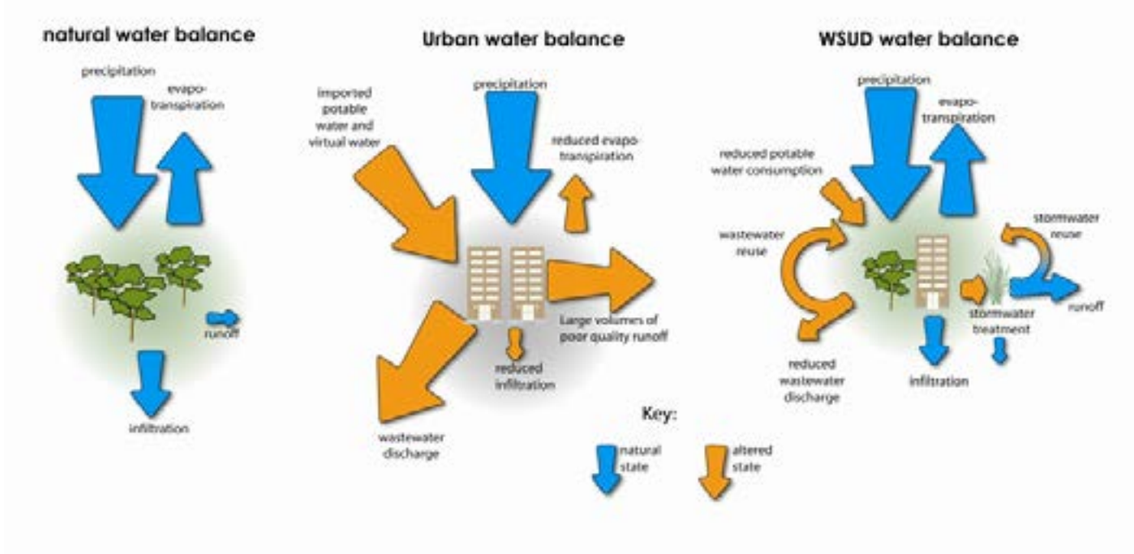
2.4 Revaluation

In the beginning of the nineties a transformation started in all abandoned old harbor from empty to beautifull waterfronts. People have a preference for water which opens a market for new residentials in old harbors.

The cultural revaluation of the water what was upcoming from around the seventies as resistance against the monotonic urban design from the years before. Water lost his utilitaire rol and is used in a way to add identity to the city. Water in the urban center brings back the characteristic look of how it was in the first place. Mostly the use of it now in an urban design is only supported with esthetical reasons.

Not only climate change forces the city to adapt water, but nowadays the old historical view of the city filled with water is hot. Most of the cities exist because there was water in the first place, used for trading. Back in the sixties when the car industrie came up, most of the canals were muted to build new roads. If old canals are excavated again is this because of esthetic reasons in stead of practical or funcional reasons as they were made in the first place.

Social changes ensures that the faith in the government is becoming less. The market on the other hand is getting more powerfull and wants to determine the place and function of water aswell. This changes the responsibility and the ones who pays. Because who pays determines. Partly because of the financial crises we have to deal with nowadays, there is a leak of courage to spend money on innovative projects. Certainly when the changes are aesthetic.



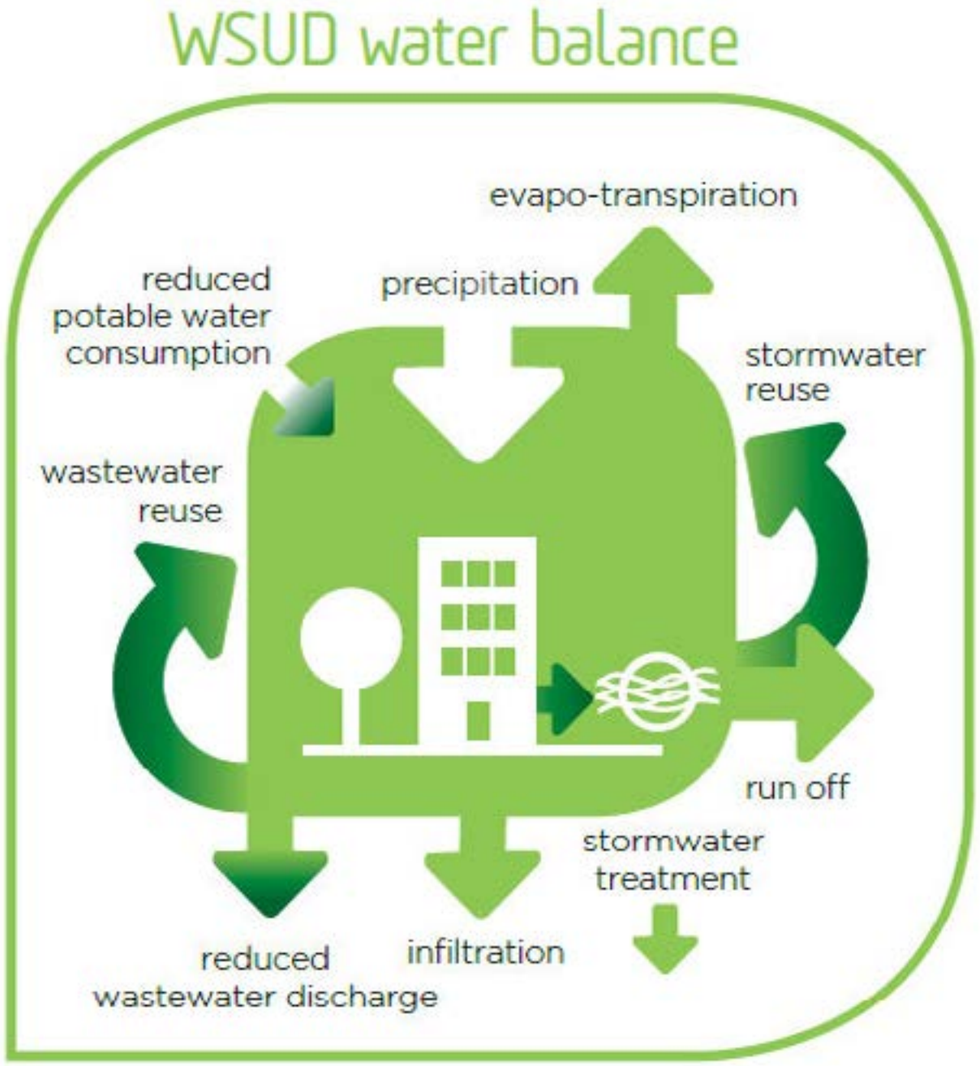


Fig. 2.5.1

Illustration of the water cycles in a natural, urban and WSUD way. (WSUD)

Fig. 2.5.2

The WSUD water balance illustrated/ Arrows going back stands for reuse, down are going into the ground and up into the air. (WSUD)

2.5 Water Sensitive Urban Design

WSUD is a land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal

Principles

Protecting and enhancing creeks, rivers and wetlands within urban environments;
Protecting and improving the water quality of water draining from urban environments into creeks, rivers and wetlands;
Restoring the urban water balance by maximising the reuse of stormwater, recycled water and grey water;
Conserving water resources through reuse and system efficiency

Objectives

-Reducing potable water demand through demand and supply side water management;
Incorporating the use of water efficient appliances and fittings;
-Adopting a fit-for-purpose approach to the use of potential alternative sources of water such as rainwater;
-Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse and/or release to receiving waters;
-Treating stormwater to meet water quality objectives for reuse and/or discharge by capturing sediments, pollution and nutrients through the retention and slow release of stormwater;
-Improving waterway health through restoring or preserving the natural hydrological regime of catchments through treatment and reuse technologies;
-Improving aesthetics and the connection with water for the urban dwellers

Techniques

The use of water-efficient appliances to reduce potable water use;
-Greywater reuse as an alternate source of water to conserve potable supplies;
-Detention, rather than rapid conveyance, of stormwater;
-Reuse, storage and infiltration of stormwater, instead of drainage system augmentation;
-Use of vegetation for stormwater filtering purposes;
-Water efficient landscaping to reduce potable water consumption;
-Protection of water-related environmental, recreational and cultural values by minimising the ecological footprint of a project associated with providing supply, wastewater and stormwater services

Fig. 2.6

Futuristic plan of Royal Haskoning, winner in 2006 (Drijvend Ontwikkelen)

2.6 Innovative

Climate adaptive living is the solution for the risk an area can flood. Floating dwellings is an adaptive way to deal with climate changes. Especially countries who deal with floods can save a lot of money the damage can give. In economical perspective it is more interesting for countries with higher flood risks like China, India or Bangledesh. Inside the dike developing floating houses has nothing to do with water safety. The only thing reached is the area for water storage and the double use of the ground, which is a good thing.
Although living on water was in Lelystad so willed, they made first the water and then they builded on top of it. Apparently water is just as feasible as land to make in the Netherlands.

Rutger de Graaf, co-founder of DeltaSync is convinced our future is on the water. In 2006 the Royal Haskoning Awards won with the futuristic plan of a floating city for 20.000 people on the IJmeer as location. Floating development goes furthur then only residentials. "Currently we are working on a mobile utility unit. If there is no more navel cord nessesary to the main land, cities can be completely autonomous, which is the beginning of a floating self-sufficient city."

City apps is the future according to Koen Olthuis, founder of waterstudios.nl. Different parts can be moved elsewhere if they are no longer needed on a certain spot. Shipping houses, agriculture, infrastructure or powerplants makes them more sustainable.

03

Stakeholder views

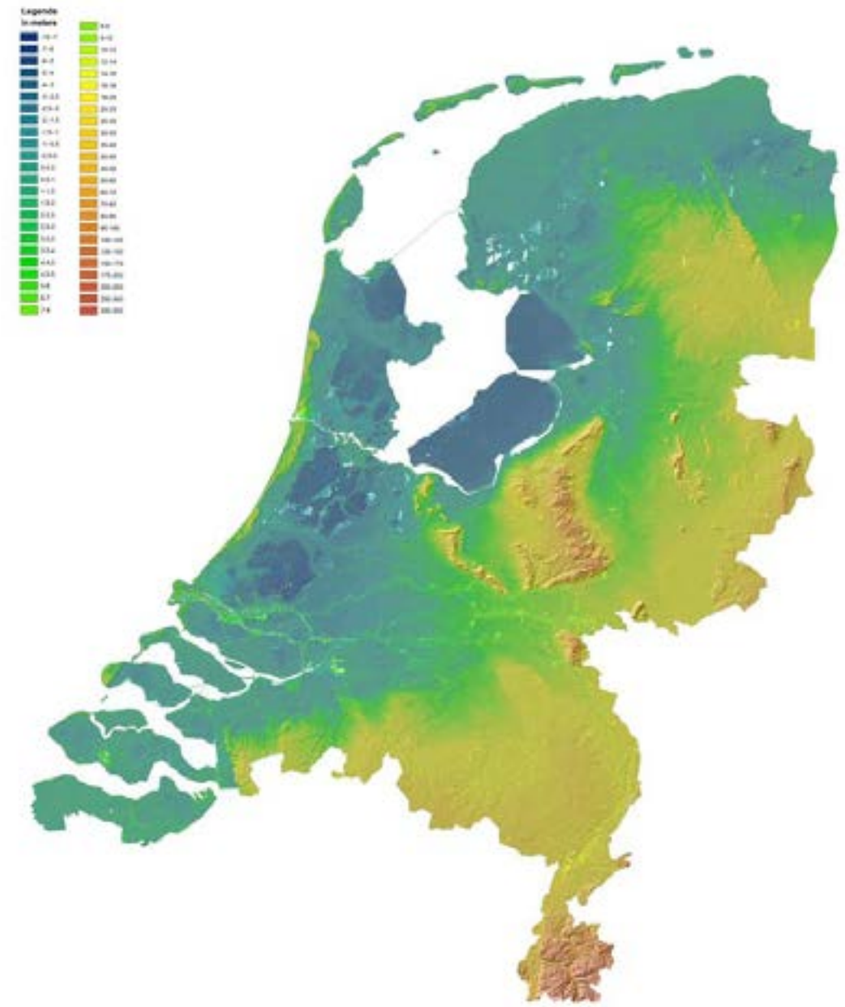


Fig. 3.1.1

Depthcard of the Netherlands. Clearly shows two third part of the country is originally under sea level. (Rijksoverheid Illustration)

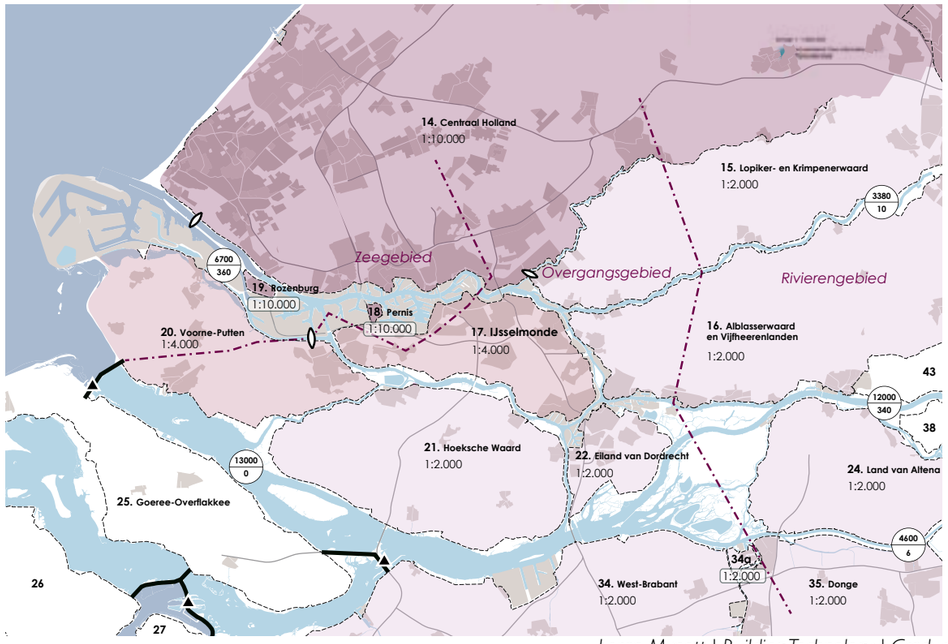


Fig. 3.1.2

The Randstad with the flood risk departed in different divisions (Rijksoverheid Illustration)

03. Stakeholder views

3.1 Consciousness

The dutch people feel very safe about their living and the chance there will be a flood. This is the outcome of research done in 2010 by Altera - Wageningen University.
87% feels safe, (but feelings are mostly) based on ignorance.
68% underestimates what the water level will be like and more then a quarter thinks their house can not be flooded.
Fortunatly 56% admit not to be prepared well if there will be a flood. This while 76% thinks waterlogging and flooding will apare more and more. It is more than logic people are not well prepared for flooding if they never experienced a flood in real life. Untill the dikes flood, it is very hard for a layman to say how safe we are for floods. It is all managed by the gouverment, that's why people don't feel responsible themself. This in huge contrast with for example in the United States, where people are prepared to recover as soon as possible after a flood.

The world risk report of the United Nations concluded Holland first of all European countries concerns the risk of a natural disaster. The question if Holland is safe is not easy to answer. Two third of the country is below sea level. Even if the safety requirements are from almost 50 years ago, their still very high, the highest of the world, this is why we are relativley more safe then other countries.

We do have a really safe dike, with a safety-factor of 1/10.000 years, but if it brakes, there is no compartimentering. There is a law which includes all dikes and dams have to be tested every five years, but this generally does not happen. There is money coming in on a regular basis for maintenance. The costs are 2,5 times more expensive than the incoming amount and therefore there is a shortage. Although we have a well working network of infrastructure and communication, the most concentrated populated country of Europe does not have a national evcuation plan.

3.2 Water lives

There are four types of people who would like to live on the water, which can be coupled to four location typologies.

1) Free living with high pile fluctuations; "uiterwaard" location, respect and love for the nature, they prefer detached houses for a maximum nature experience. No preference for floating or pile dwellings. This group are modern orientated and are focussed on the material and view of the dwelling.

2) Free living with low pile of fluctuation; polder location, this group likes to have a small closed community like a village which provides in a certain comfort, safety, shared and supervisioned public spaces.

3) Urban living; urban water zones as location, mainly young people between 18 and 34 year, earning 2,5 times the average has the desire to live in an urban context with lots of facilities and a large living with an exclusive character.

4) Active water living; a recreation area full of water as a location. Extremely exclusive is what this group is looking for with a well regulated accessability where they can make a lot of fun and enjoy the water every day in a active way.

Fig. 3.3.1

Futuristic impression of the Wilhelmina pier of rotterdam. (Rotterdam climate proof)

Fig. 3.3.2

Schematic illustrated where the potentials are of the stadshavens Rotterdam (Drijvend Ontwikkelen)

Fig. 3.3.3

Program of rotterdam filled in the rijnhaven (Drijvend Ontwikkelen)

3.3 Vision Rotterdam

"In 2010, Rotterdam will continue to work on climate proofing the city. The plans are predominantly aimed at the realization of additional water storage, such as green roofs and water plazas. It is not yet clear exactly what the impact of climate change on Rotterdam will be, which is why Rotterdam will need to invest in further research. At the same time, as a result of the combination of implementation and research, Rotterdam is successfully branded as an innovative water management and climate city.

In the period between 2011 and 2014, Rotterdam will proceed along the same line, continuing to emphasize the implementation and realization of innovative projects in the city. In doing so, it will take into account the results of research focused on the themes of flood risks, scenarios for flood management and accessibility of the city and port, optimization of the urban water system, adaptive building, and the urban climate.

New delta plans for Rotterdam will secure Rotterdam's position as a leading city in the area of intelligent water management and in the direction and coordination of the efforts to climate proof a delta city. Also the spatial plans will be climate proof in 2012, if not earlier and other climate adaptation themes will by then have been adequately embedded and incorporated in standing policy and planning procedures. Even more than before, the emphasis will be on the economic spin-off as a result of the image Rotterdam has built up as an innovative water management and climate city.

The international collaboration with other delta cities in the next few years will definitely gain momentum. The Rotterdam approach plays an important role in the demand and supply concerning water management and delta technology. This will lead to growth for the regional and national water sector.

An important milestone in 2012 will be the opening of the national water centre in Rotterdam, concurrently with the nation-wide dutch delta design event to position the Netherlands even stronger as the water nation all over the world. Rotterdam will take up a central position in this respect. For this reason, both the start and the conclusion of this dutch delta design process event will take place in Rotterdam. This way, Rotterdam will demonstrate that climate change offers opportunities for an attractive and economically strong city." (Rotterdam Climate Adaptive)

Fig. 3.4.1

Futuristic impression of the Wilhelmina pier of rotterdam. (Rotterdam climate proof)

Fig. 3.4.2

Schematic illustrated where the potentials are of the stadshavens Rotterdam (Drijvend Ontwikkelen)

Fig. 3.4.3

Program of rotterdam filled in the rijnhaven (Drijvend Ontwikkelen)

3.4 Potentials

Water is associated with peace, calmness and free sight, which can be seen as qualities. It creates a shelter of personal space around the house and increases the feeling of privacy. The movability of the residentials are a advantage because it gives them the flexibility to change location on the long term, simply by shipping the house to an other place. It is also possible to share utilities with other cities, so it does not have to be build seperately in each city appart. In spite of the fact there are a lot more plans of amphibious houses then there are actualy realized, this is a growing market and will grow furthur untill the water and housing problems are resolved in urban areas.

Water adaptation is nessecary to regulate all the water in the right directions. A huge different can allready be achieved when all the roofs are green. Watersquares are an innovative solution for water storage in the city. The enormous amount of water falling down when there is heavy rainfall will be collected and gradually flow in the drainage system. Besides the watersquares for water adaptation there are several experiments going on for water storage; "de trapdijk" to gain more space with a dike, "dakpark" which combines shops, dike and a park, "City water lounge Rotterdam" and a climate square. "All these things cost a lot but we have to spend money on water anyway, so why not making nice public spaces at the same time" Florian Boer.

The Netherlands has always dominated the landscape. It decided where building took place using dikes pumps and polders. Helped by new techniques we were getting better in dictating the landscape. It will always be a artificial, high maintenance country, but whether there are many strict safety rules, new plans are forming a new way of living, closer to the will of nature. A floating hightech city which goes up and down with the tide with a lowtech look.

3.5 Considerations

"You cannot fight water, you have to learn how to live with it", states minister Sybilla Dekker. Her department has arranged a competition for engineers, urban planners and architects to design living accommodation, glasshouses, parking lots and factories which would float and could grow into "waterproof" towns.

The origin of floating houses can be found in converted ships. After a lot of development and transformation the floating houses has still one big difference towards houses on the mainland. The floating part also called the substructure can be made traditional of concrete, as of foam or plastics.

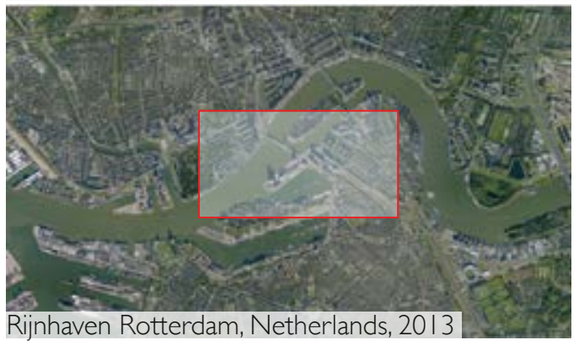
The complications of water like variable waterlevel, tilt, fluctuations and noise which can go over the water without being interrupted, has to be taken into account while designing floating buildings.

Real estate or property
The differents if a floating house is real estate or property are considerable for both the government as the inhabitant. Requirements, taxes and mortgage applications are different. An other important choice is related to the law, because if the house is able to move, it is movable property and if it is fixed it is real estate.

04

Urban Design

04. Urban Design. **Macro**



Rijnhaven Rotterdam, Netherlands, 2013

Stadshavens Rotterdam, Netherlands, Bird's eye view

04.Urban Design

Fig. 4.1.1

Top view of the location zoomed in three parts. (Google Maps)

Fig. 4.1.2

Bird's eye view of the casus Rijnhaven Rotteram (Bing Maps)

Introduction

In this design the integration between the urban plan, architectural desing, and the building technology are strongly presented. Now more then normally those three are closely linked to each other. Starting from macro scale and pragmatically zoom till building details which represent the micro scale. The cohesion between the scales brings this design to a higher level.

According to John Jacobs is this the wrong way to look at the situation: "skyscrapers are a nichemarkt aswell because they are for only a few procent of the population but still they are characteristic for the City. This is where it goes all about at the end. With floating development, Rotterdam has the possibility to distinquish himself from the rest of the world.

4.1 Case study

The old harbors of Rotterdam are moving towards the sea. A lot of things can be done with the space that will open up. The whole area includes 1600 ha. To have more grip on this number think of 3200 footbal fields or a lane of footbalfield from the top of Netherland till the bottom. 16.000.000 m2 is the total area of the stadshavens and 21 ha thereof is the Rijnhaven.

The area is located next to the Wilhelminapier where also Hotel New York is located. The other famous eyecatcher is the erasmus bridge which connects the south of Rotterdam with downtown.

The whole new part of Rotterdam which is called "Kop van Zuid" is outside the dike. This includes the Old-. Maas-. Waal-, Eem-, and Merwe-Vierharbors. All these harbors are bundled under the name "Stadshavens" of Rotterdam.

This area will be Rotterdams most important urban expansion with 13.000 new dwellings whose 5.000 will be floating. Floating housing has been seen by some as a nichemarket like Roland Goetgeluk, researcher at ABF office, who is specialized in the real-estate housing. "Residentials on piles or floating ones is mostly and only something for watersport lovers, but the big market is not responding on it.".

Fig. 4.2.1

Section of the urban plan made in cooperation with Doepelstrijkers architects. (Own Ill.)

Fig. 4.2.2

Top view of the urban plan made in cooperation with Doepelstrijkers architects. (Own Ill.)

4.2 Internship Doepelstrijkers

During my internship at DoepelStrijkers architects I worked on the plan, section and impressions. The main idea was to create two islands where the harbour was less steap (minst diep/zie kleurenkaart). Taking note of the natural deepness of the harbour and lift the parts who were the less steap the natural surface brought above sea level. The islands and the park at the side are made of GEO-Tubes. extraordinary large flexible tubes filled with bio trash with a 3 meter wide diameter. With these tubes it will be relative easy to create fast land in the deep Rijnhaven.

In the middle of the Rijnhaven, on the biggest island, a data centre will provide a lot of energy. This data centre is placed underground and releases a lot of warmth. Using the water of the Rijnhaven to cool this data centre and taking the energy out of the warm water will gains a enourmous amount of energy. This energy can be used by other buildings or aspects. In this way the area will be selfsufficient and energy waste and water circles will be closed. Closing those circles is of great importance in this plan but also in designing in the future.

The jetty will contribute as viens to objects or buildings allong the jetty. Adding a component to the plan changes the flows. An urban district needs energy and potable water for example but can give biowaste materials and collected rain water in return. Those exchanges contribute to an diversity of the plan.

4.3 Preliminary urban plan

After the plan was officially handed in and presented to the municipality of Rotterdam the collaboration between Doepelstrijkers and me was done. The agreement was that I worked on the plan without zooming into a specific area, and creates and makes the urban plan with some different impressions.

These products formed the starting position for my graduation. Before I allready found a suitable location and now I also have a interpretation of the context were I will design fifty floating dwellings as agreed after my scientificly research part.

Where I would plance my floating dwellings was not a difficult choice. On the south side industrial work is still in progress which uses the water as transport medium and produces noise and odor, this makes the whole south side of the plan not suitable for a new living area. On the north side,adjacent to the Wilhelminapier the east part is also adjacent to the new park and the west side is a pretty small spot and misses good connections with the preliminary urban plan. Therefore the zone in the middle at the north side, surrounded by the plan and the islands suits as the best option and is also the deepest part of the plan. (Ill selection location in plan)

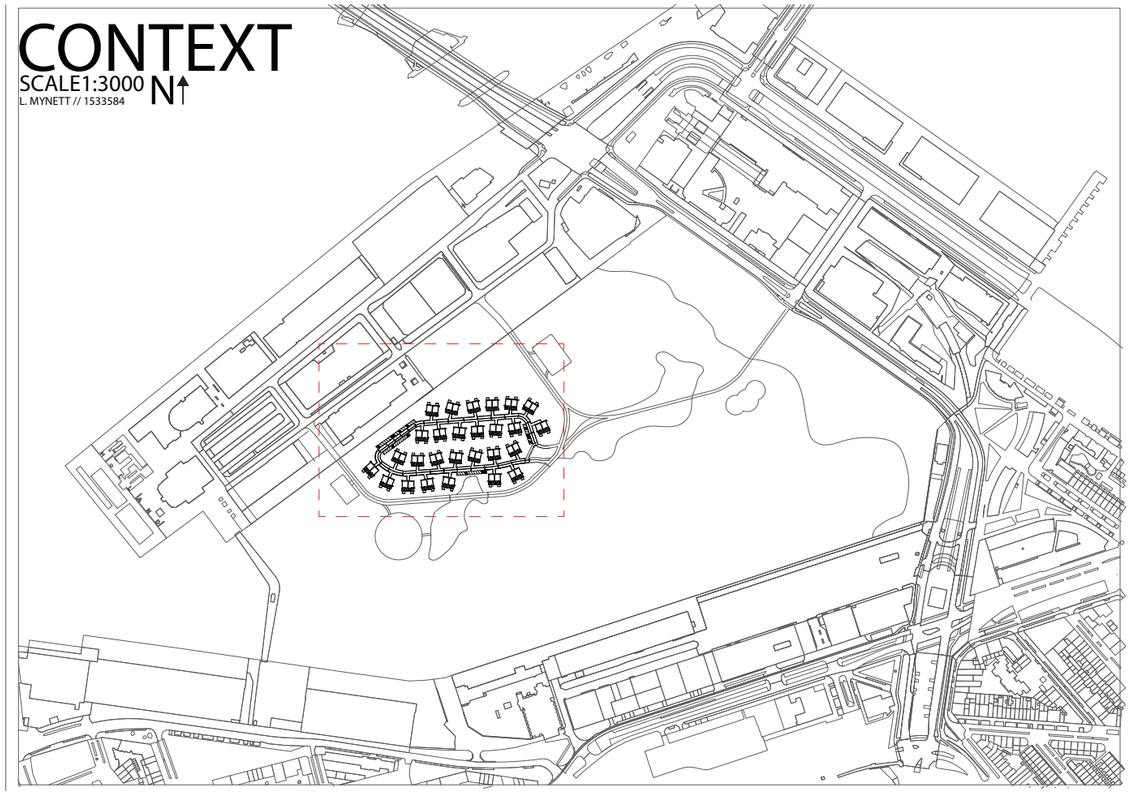


Fig. 4.4.1

Section of the urban plan made in cooperation with Doepelstrijkers architects. (Own Ill.)

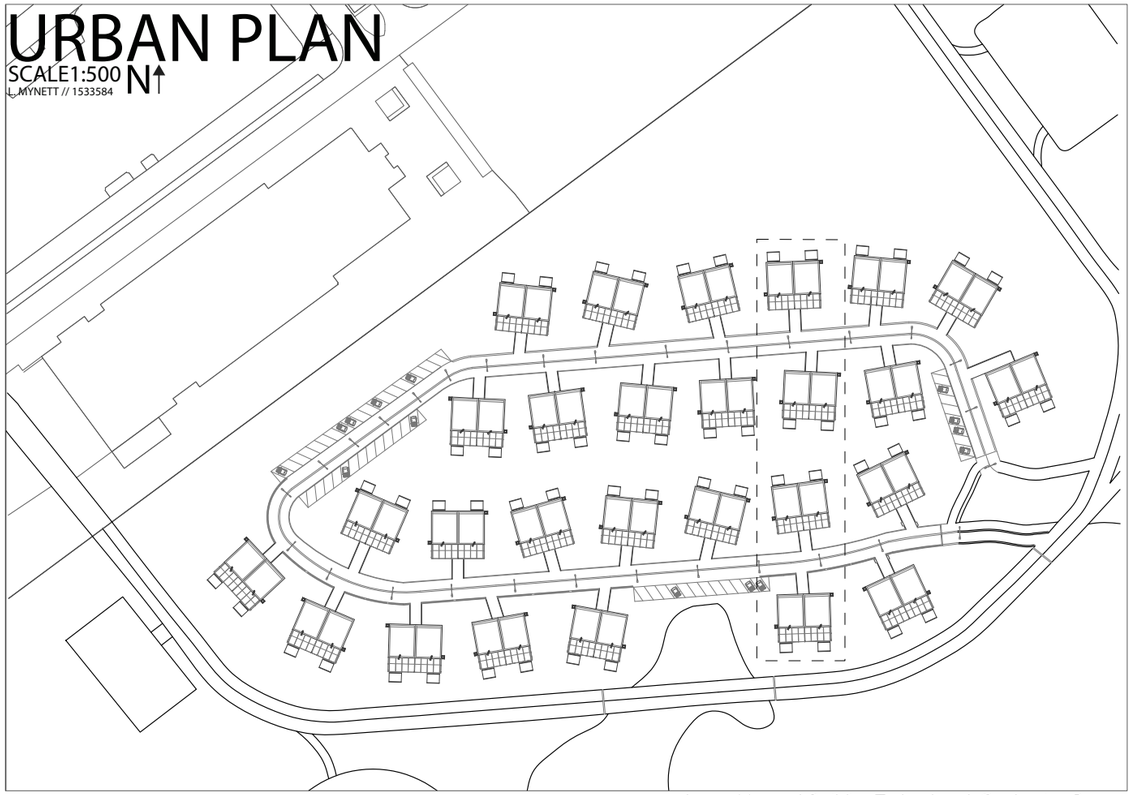


Fig. 4.4.2

Top view of the urban plan made in cooperation with Doepelstrijkers architects. (Own Ill.)

4.4 Urban principles

As an urbanism the surrounding for a new plan is the most important aspect. Taking good notice of the things that are available on sight can improve the efficientcy of the plan considerably. An other benefit of a good urban plan is the life time. If the plan is flexible to social and technical changes and adaptive to changing circumstances the life time wil increase which contributes to a durable city.

Optimizing jetty-house ratio

When designing the urban plan there were three aspects I had to classify and prioritize before I could start designing. The jetty-house ratio, the fire safety and the parking problem. Because jetties are relative extremly expensive this was the first priority to take care of. Minimizing the amount of jetties while on the other hand maximizing the amount of houses. Finding an optimum between those two, keeping in mind to retain the firesafety gave the following urban plan (see figure x.x) The jetties should be orientated east-west more or less, because the houses are orientated north-south And because of the drop shadow of the house which around 15 meters and the dimensions of the area, two rows are the most efficient (figure of 2 rows in the area). To avoid dead ends and a two way road with a turning point at the end, a circulair approach is the best option.

Fire safety

Not only buildings has strict requirements when it comes to firesafety, also the urban plan needs a fire safety plan what includes always two ways to escape. When developing on water this brings more complicated situa tions then on land. Connecting the two jet ties creates the fire safety of the plan. If there is a fire, people have two ways to escape. flashover will probably not appear because the houses have a circum distance between each other which is minimal 7 meters. The jetties are not designed for big fire trucks. the corners are too sharp to turn. but their water hoses can be connected to a pumping system which provides extinguishing points all over the urban plan.
Alternatives to make the plan fire safety were fire partitions who are really awfull to see, or escape bridges to the quay what is extremely costly.

Parking

Parking was one of the most important things to take care of in a preliminary stage. Cars need a serious solution and can not be placed somewhere on the quay outside the designed area. This gives three options, a parkingplace next to the house, on the jetty or on the quay which requires an expanding of the design area.
Before solving the parking problem I made a really clear future vision, a vision how it should be, goals to aim at, a durable city with low energy requirements. After this I took the parking problem and implemented it in my plan. Normally there should be 1.6 parking spots per house. This number is increasing in the last decades and is only getting more and more. The use of cars is extremly contradictory against a durable vision. Besides the location is down town in Rotterdam, one of the biggest cities of the Netherlands and parking spots are very scarce. This makes it not realistic to hold on to the 1.6 parking spots per house. In 2050 people are sharing cars and the amount of parking spots per house will be less then 1. In this case of view there is no need to make an urban plan with so many parking spots. That's why in this design every house has 1 parking place, so there is no need to share cars and it is still to the minimum.
The parts where no houses can be placed are perfect to station the cars. In this way the cars are situated nearby the houses, not in front of the house where people are forced to look at cars when looking outside the window. A solution is found in the urban design and implamented in the plan and not shifted away.

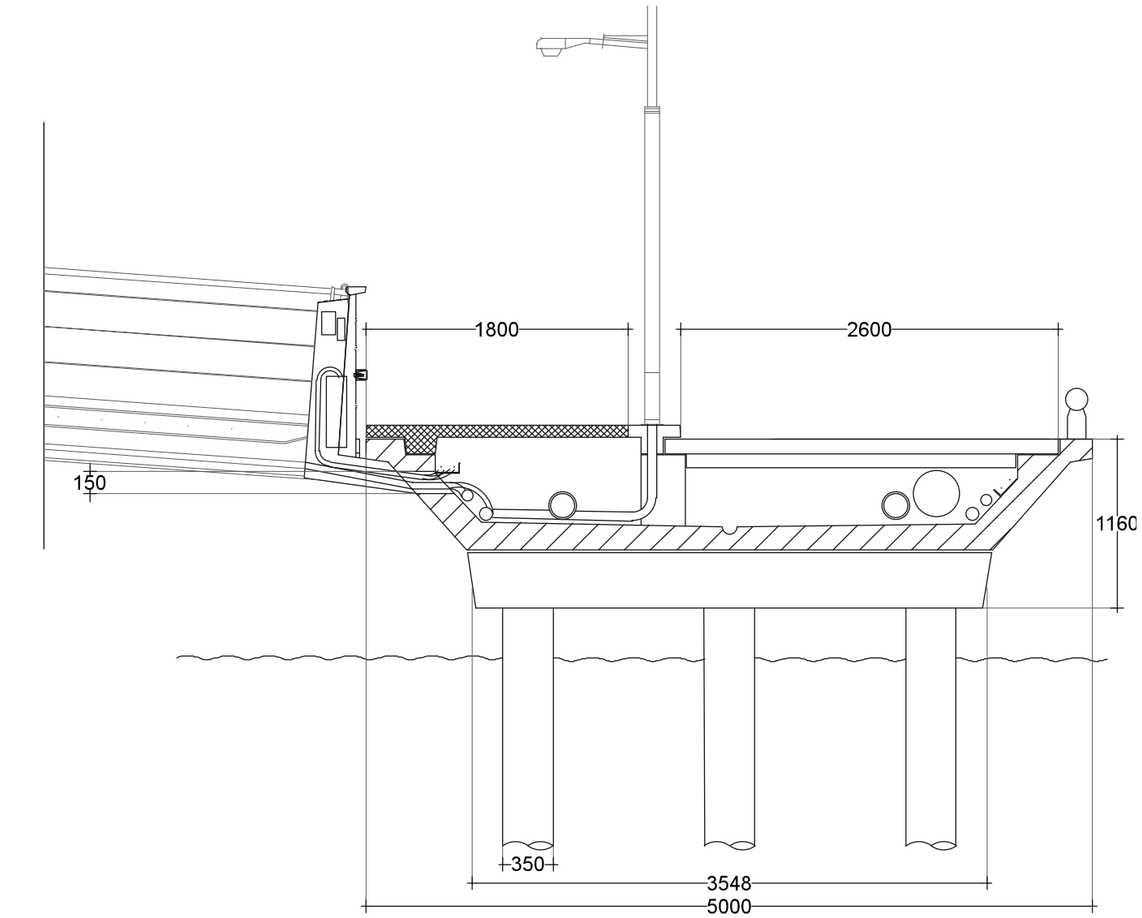


Fig. 4.5

Section of the Jetty with measurements. (Own Ill.)

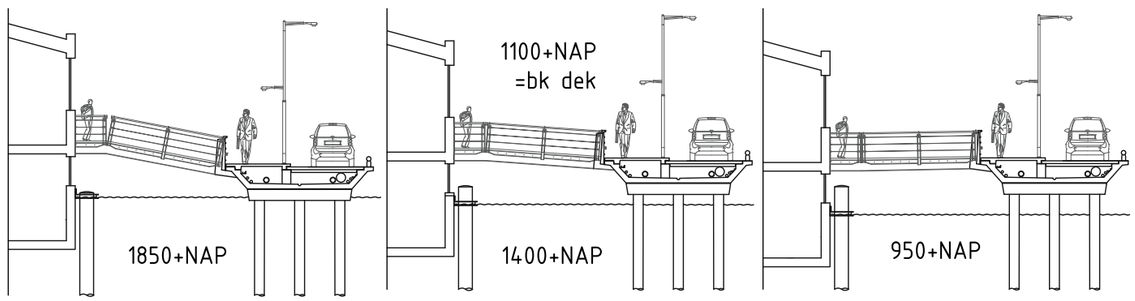


Fig. 4.6

Section of the water fluctuations relatice to the Nederlands Amsterdam Pijl (NAP) (Own Ill.)

4.5 Jetty

Jetties are public spaces just like a street this ensures a certain level of design. Besides the pure functional aspect of making the residentials attainable, there is also the need of fire safety and pedestrain friendly

The residentials need all there utilities just like a normal living. These can be combined with the jetties. How these will look like is essential for the neighberhood. Villanova architect designed the waterarea in IJburg taking all aspects into account; shape, railing, tread and the pipes and cables bundled out of sight. Light is integrated in the railing so you still see in the night where to go without disturbing the sky full of stars.

Railing is a must to ensure the safety of playing kids. They are made out of alminium which is light and strong and it gives it an industrial look. Firesafety and emergancy situations has a lot requirements for the jetties, it has to be wide enough, always two possible exits to escape. If the jetty isn't floating a distance has to be covered between the house and the dwelling. Building regulations has determined a maximum angle what is allowd in terms of safety matters.

The jetty is one of the most expensive parts of the plan. To lower the cost, minimizing the length and width is nessecary. The jetty should hold the weight of a small car, approxiatly around the 1100 kg. The cars can only drive in one direction which makes the jetty less wide and it can be less strong . To provide some room for the pedestrain area or in case somethings unaspected happens the walking part is quite wide what brings the total width on 4,5 meters. The low car guardrail is to stimulate low speed traffic. At the pedestrain side there is a normal height guardrail including a carprove part in the lower part of the rail. The jetty is holder formed and includes all the utility facilities. Those pipes are covored with sand for insulation and pressure reasons.

4.6 Water fluctuations

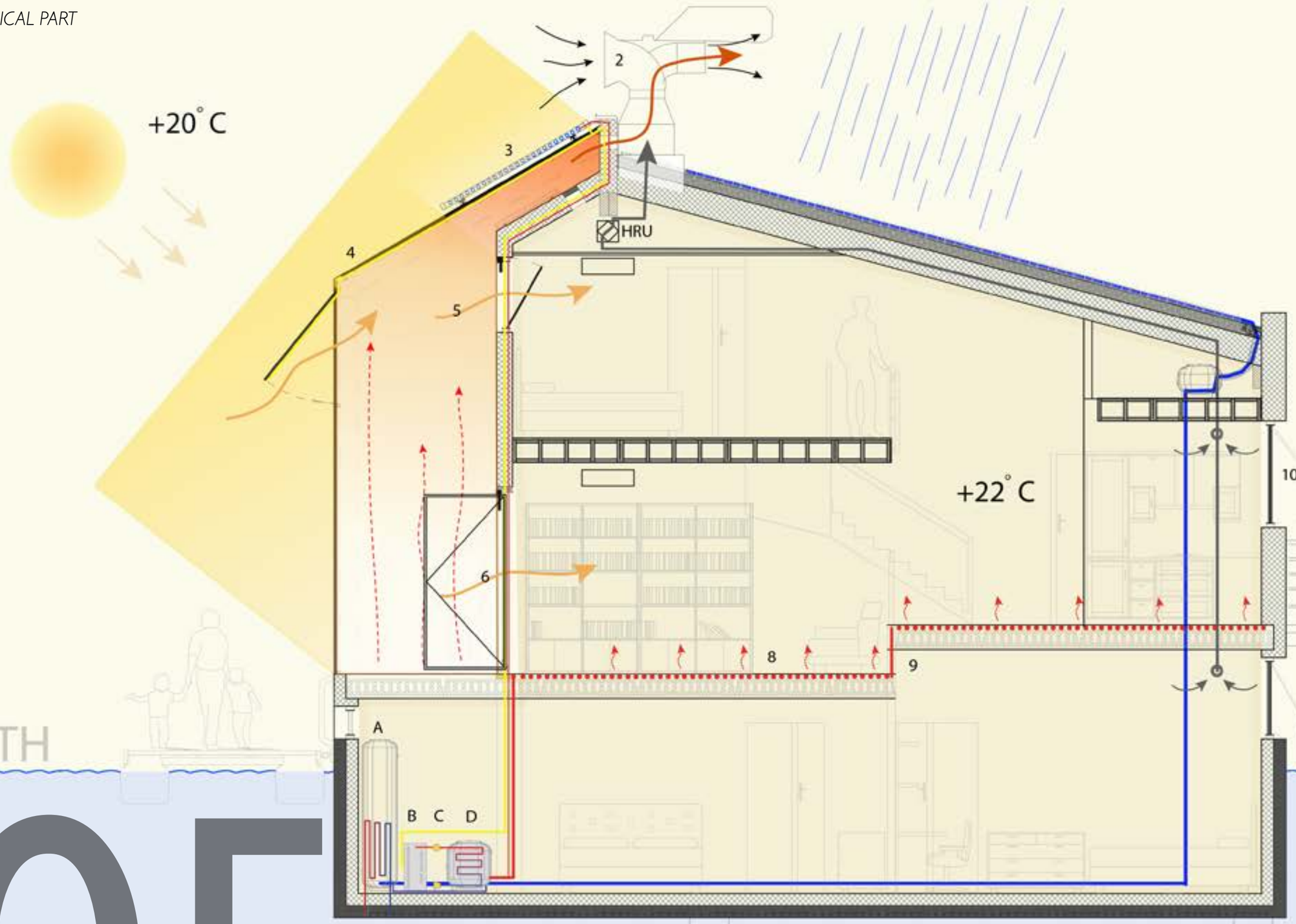
Water is dynamic and that's why every regular design choice has to be taken into account again. Water level flactuations are really important when it comes to the connection between the floating dwelling and the fixed jetty. The water fluctuate maximal 200 mm up and 200 mm down in a year. Allthough this flucuation isn't that big, these are not the numbers architects handle while designing floating buildings. The extreme flactuations which happens once in a hundred year are the fluctuations that are used; 450 mm.

The differents between the smallest position when the gangway is flat and the largest position when the water is at the highest point is 200 mm. Due to two pivots and a adjustable gangway this difference has been taken care of.

The utilities, electricity, potable water and sewage enters the house under the gangway. This requires also adjustable length for those cables and pipes. For the gas connection this is problematic, therefor the floating dwellings do not use gas, but heat and cook on electricity. In order to be selfsufficient a gas connection is not an informed choice aswell. It makes the house dependent and goes against the self generating energy concept.

Conclusion

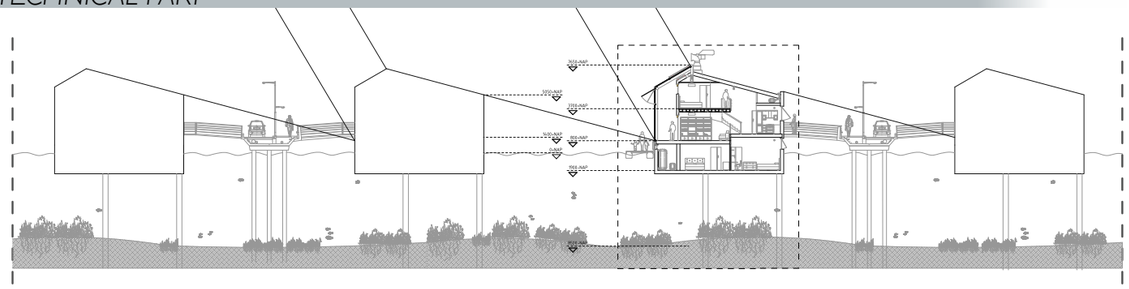
The main goal of the macro scale was to create an urban design with as much dwellings in the area as possible with taking into account that the amount of jetties should be reduced to a minimum, combined with the firesafety protocol of two ways to escape and the parking places for the small cars. This plan brings all those aspects togeher and provides a stable and realistic basis for the architectural design on the meso scale.



05

+11° C

Climate Design



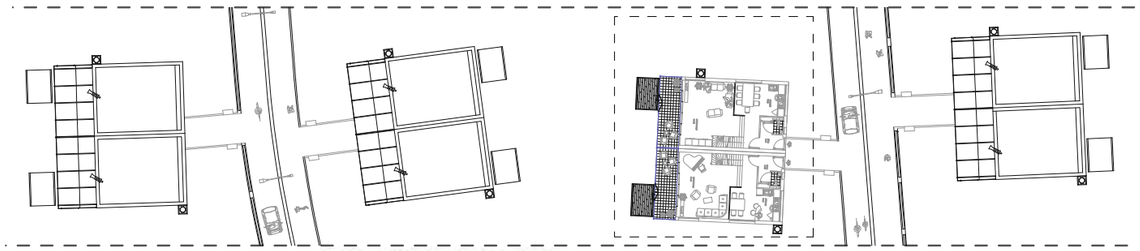


Fig. 5.1.1

Section urban plan where the four houses are shown. The creation is shown in the 4 different dwellings, each dwelling shown a different aspect how the dwelling is formed.

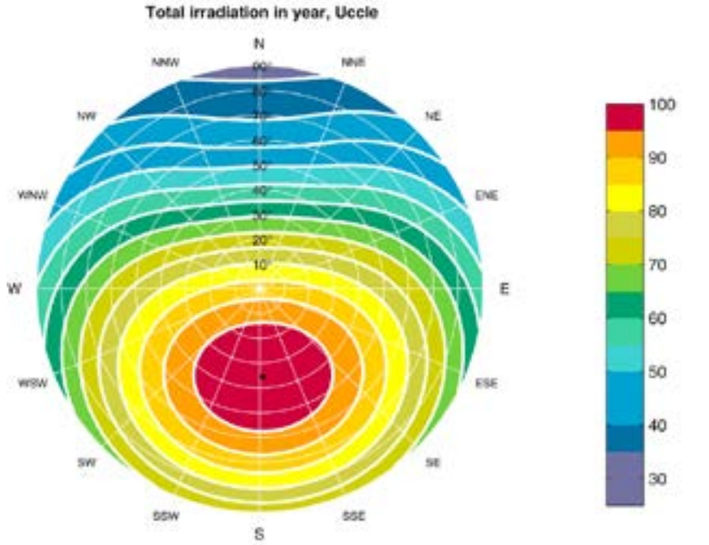


Fig. 5.1.2

A solar indication map where the most sun comes in a year and under which angle.

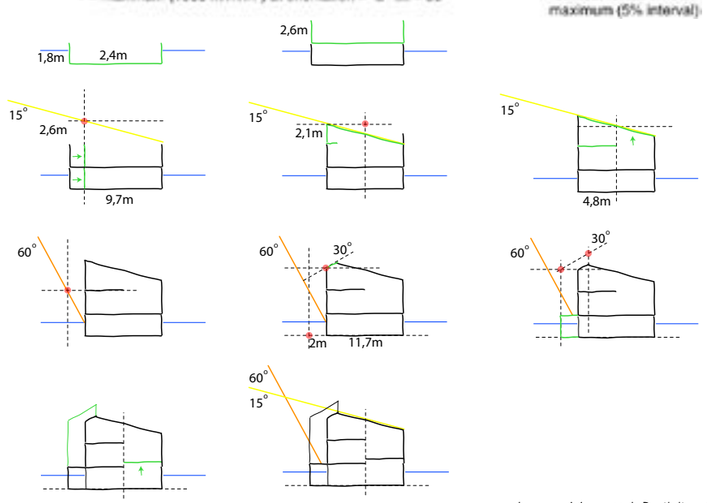


Fig. 5.1.3

The four steps sketched to illustrate the design considerations. (Own Ill.)

05. Climate Design

MESO

Introduction

In the meso scale the building has direct connections with the urban plan and the details. The shape of the building is there for a climatology reason and the south-north orientation creates a dichotomy in the building. The south side to gain solar energy and the north side to collect rain water contain the indoor climate with a thick pack of insulation. All the aspects will be fully explained in this chapter.

5.1 Form follows sun

The final form of the dwelling is created in four steps. Therefor I will explain step by step the design considerations.

1) The width of the dwelling is determined by the width of the narrowest canal from the buildingplace in Urk till the final location; the Rijnhaven. This is 7 meter that's why I took the width of 6,5 meter including facade and construction for this dwelling which results in a 6 meters netto width. In other floating dwellings like in IJburg they made all the dwellings 2,5 stores high. 2,5 floors will give the amount of square meters what belongs to a two under one roof dwellings (140-180 m2).

2) For the length of the dwelling the angle of the winter sun is used to shape the roof. Using this angle will reduce the length of the shadow of the building so the next building can be built as close as possible to the other buildings. At the +1 floor I decide to put the roof at a 2,1 meter height. This brings the two rooms visually closer together and also contribute to a less far shadow in winter.

3) The summer sun comes in with a 60 degree angle and is not desired. To protect the dwelling from the heat of the summer sun a glasshouse is placed at the south side of the building. This zone helps regulating the climate comfort of the building.

To optimize the energy gain from the sun using PV cells the angle is from great importance. Creating a south facade perpendicular to the sun ensures the PV panels can put flat on the facade and still has the perfect angle towards the sun.

4) The concrete box has a draft of 1,5 meter. With a passage height of 2,4 meter in the basement and a thirty centimeter free space above water level, there is only a 60 cm for assemble windows. This small stroke gives not the pleasent aspect in all rooms. Therefor I lifted the floor at the north side of the building 60cm to provide a double length of the windows. As can be seen in the section, the room above this part of th building had allready a heigher roof because of the mezzanine of the building.

After those design considerations the dwelling has reached its final form. In stead of designing a building and trying to make it sustainable and energy efficient afterwards, a much better result can be reached when working the other way around. Using the angles of the sun to create the south facade and roof results in technical supported choices.

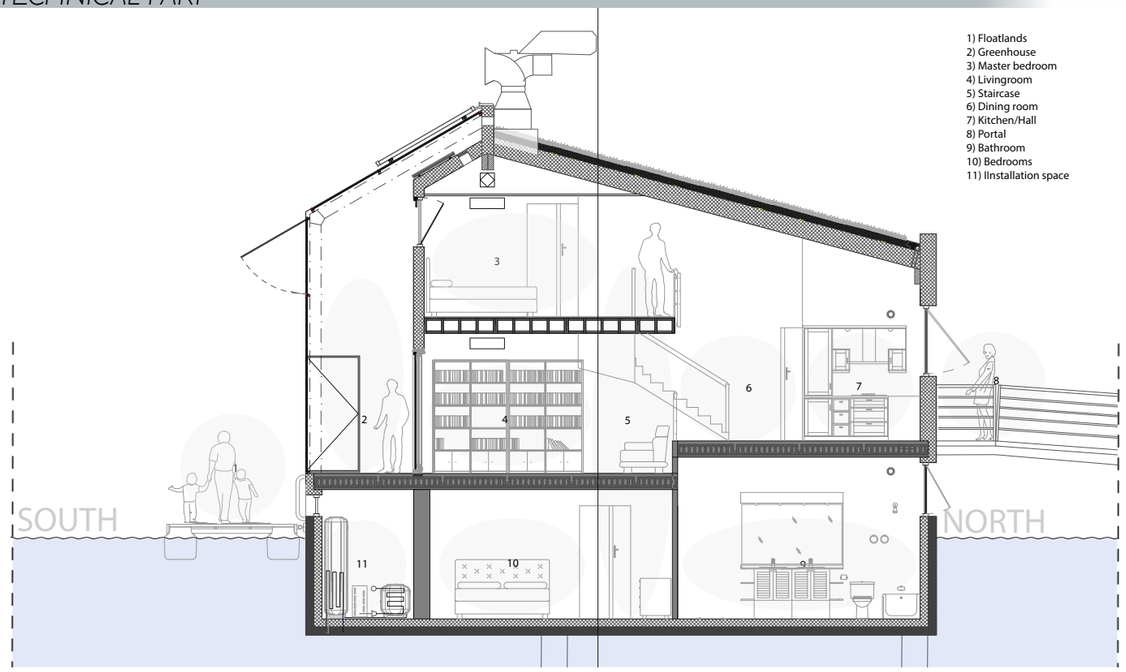


Fig. 5.2

A Section of the dwelling with all the zones indicated. (Own Ill.)

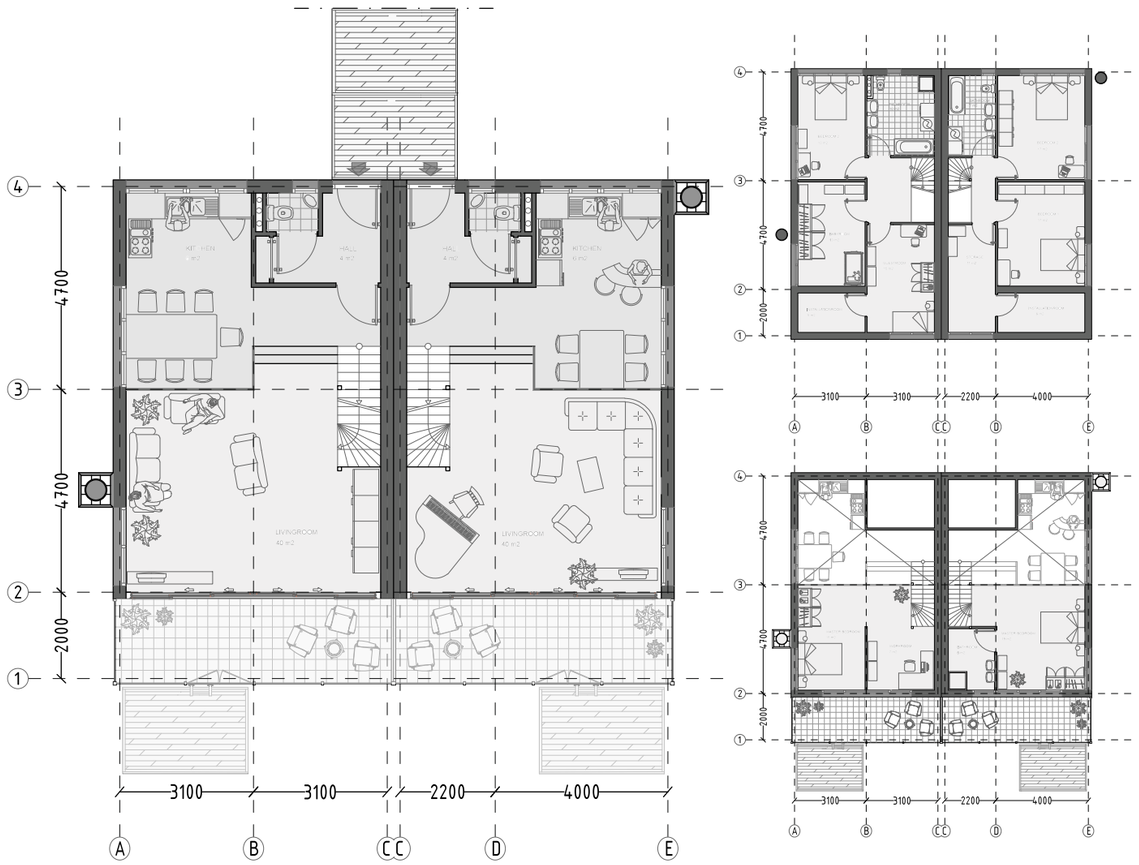


Fig. 5.3

The floor plans of the dwelling with the grid underneath. (Own Ill.)

5.2 Section dwelling

The basement is mostly under the waterlevel and has a small stroke where windows can be placed to provide incoming daylight. Daylight is here the less needed because this zone is mostly used in the evening and night but to increase the quality of the room there has been made an improvement. At the north side of the house the floor has been lifted op so there has been created small different in heights. This results in the possibility of putting much higher windows in the basement which gives a much more spacious and wider feeling. (figure lifting floor) The floor above will have a less high roof but had allready a higher roof because of the vide.

The mezzanine provides not only space but also light. Because the room is in contact with each other without partitionwalls light can reflect deep into the house(figure winter light into the house).

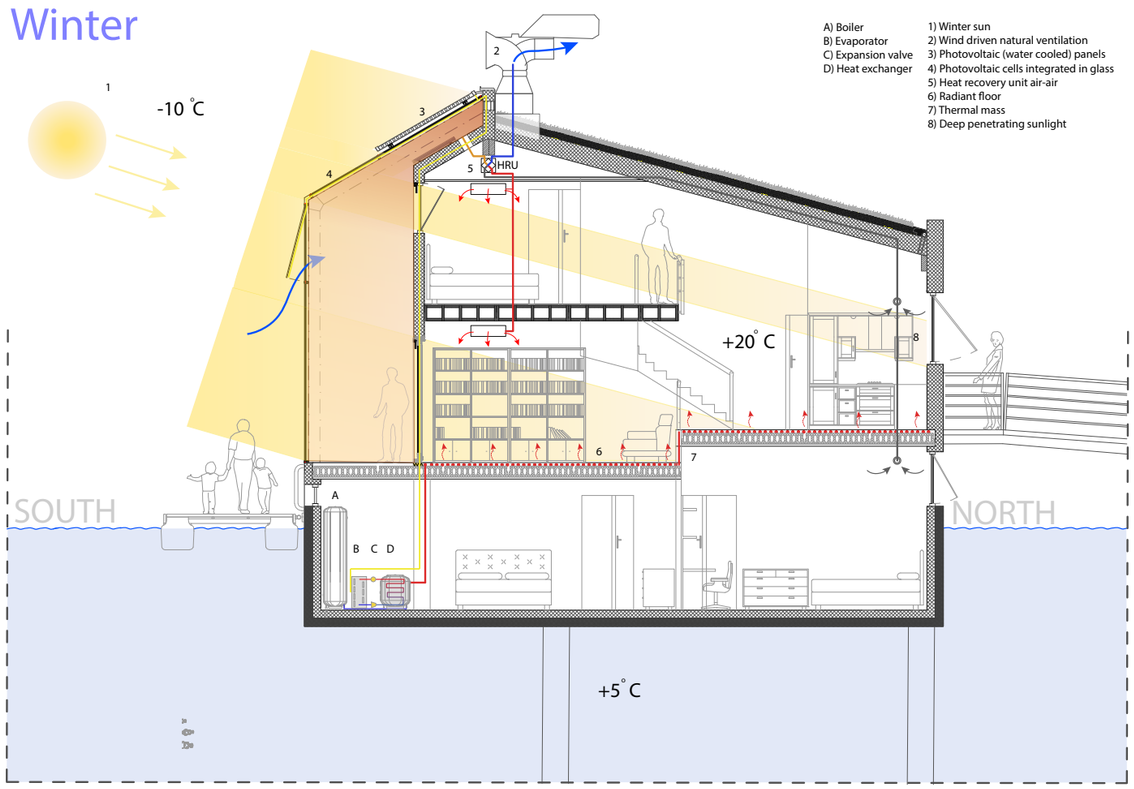
One big advantage of floating houses is the reflecting characteristic of water. The amount of difuse light because of the reflection not only more, the incoming angle is also different. It bounces from the water to the roof what result in a much brighter effect. Incoming light from the south can deeply penetrate the house without being barely interrupted.

The roof angle demands where the vide will be. The extra floor is half of the floor area, so in total there is two and a half floor. In the top part is the master bedroom which has great view over the water and a direct connection with the living area and kitchen.

The groundfloor is around 1 meter above waterlevel and is connected with the jetty on one side and the glasshouse with floatlands on the other side. Here you find the kitchen diner area, living area and the glasshouse from north to south. In the basement you find all the bedrooms, storage place and installation room which is relative quite big because of all the climate facilities.

5.3 Floor plans

Taking into custady the house is orientated towards the south and you enter at the north side does place allready in a preliminary design some zones in the house. Based logic decisions a simple design was the main goal. The vertical shaft is at the side where the house is bundled with the other house, which also provides less hall and more square meters for rooms or spaces.



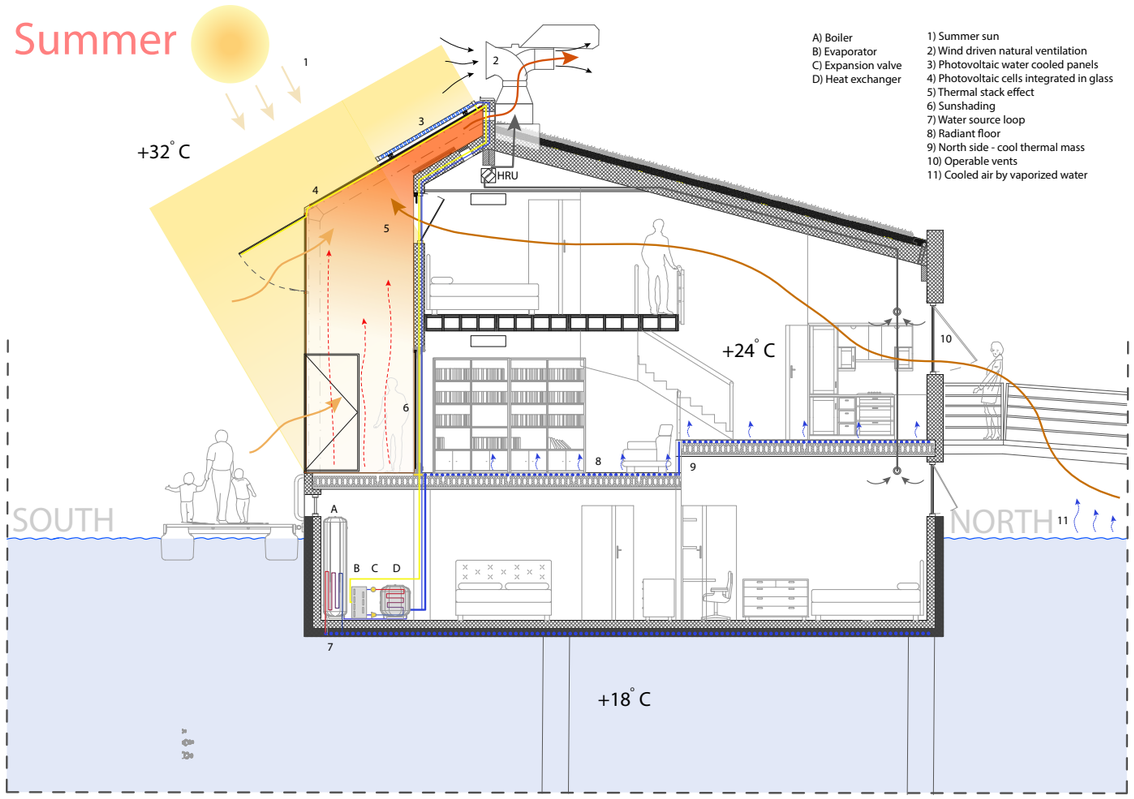


Fig. 5.5

Summer situation illustrated with all the climate aspects. (Own Ill.)

Fig. 5.4

Winter situation illustrated with all the climate aspects. (Own Ill.)

5.4 Summer situation

In summer the sun is unlovable. To keep the heat of the sun outside the house as much as possible, direct sunlight should be blocked. The external sunshading on the ground floor ensures no heat is entering the house. On the mezzanine the PVT panels are even blocking incoming sunlight completely when it is summer.

The glasshouse heats up very fast. By opening the operable vents of the Southern facade completely the warm air will rise and the heat will leave the glasshouse in the top through a wind cowl. This wind cowl provides a wind driven natural ventilation system.

This stack effect also sucks air at the south side out of the house. Relative cool air cooled by vaporization of the open water coming in from the north side. This results in a low-north to high-south air flow.

The Northern side protects the house with the extra isolation layer and with the green roof. The green roof leads to gradual discharge of rainwater and has a lower surface temperature. Besides it compensate the lack of green in the city and helps purifying fine dust.

The thermal mass with Northerly orientation can be used for constant coolig throughout the day. The water under the house will be used to cool this floor. Getting rid of the heat by using the water brings a great solution to reach a comfortable indoor climate in the summer.

The thirty square meter PV cells Southern orientated harvest the energy of the sun. This is 20% of the gross floor area which is more then enough to make a house self sufficient according to the 2014 energy manual of the ministry (Going EPC<0)

5.5 Winter situation

In winter the sun is the heat source to bring warmth to the house. Allmost perfectly south facing contributes enourmous to this aspect. Facade openings are made in a way that the sun light and warmth can penetrate deep into the house. Between 10:00 and 17:00 the thermal mass heats up and the warmth will gradually heat the room during the evening. In the morning is the most difficult time for the house to reach a comfortable temperature.

The air in the glasshouse will warm up and be gathered in the top of the building. The fresh preheated air is used by the ventilation system. It goes through a heat recovery unit what brings the temperature to the demanded level. In this way the heat loss will be reduced and relative cold poluted air will leave the building.

One of the main energy sources can be found in the integrated PV cells in the glass of the glasshouse. Slightly opening the window for incoming fresh air will provide a perpendiculair angle towards the sun optimizing the energy gain. Although there be taking into custody the solar power is relative weak in comparison with the summer. Besides there are days in winter when the sun is barely shining. In this case no energy can be given to the heatpump to warm the water.

When there is no solar energy the water can be used as an energy source as well. The difference between the water temperature and the air temperature can be used as a catalyst for the heatpump. Energy will withdrawn from the water to the heatpump which heat a 300 litres water tank to 55 °C. This heated water can be used for heating the thermal floor and as hot tap water.

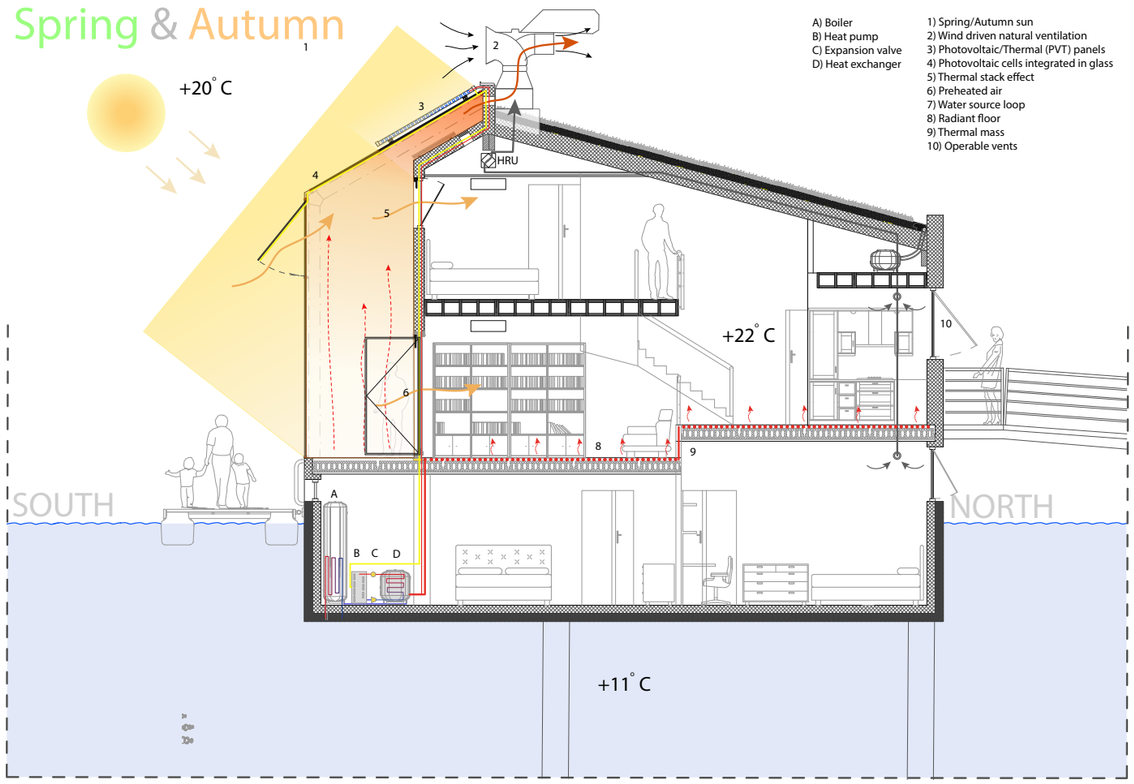


Fig. 5.6

Climate section how the dwelling regulates the climate during the seasons between summer and winter. (Own Ill.)

Fig. 5.7

The city of the sun, designed by ashok bhalotra, urban planner and architect. (Google earth)

5.6 Equinox

During spring and autumn also well known as the mild and wet seasons in the Netherlands the dwelling is on his best in case of energy efficiency. When opening the doors and windows passive heating is enabled. Preheated air coming from the glasshouse can enter the house right away at the south side, while extraction takes place at the north side of the house. The glasshouse is a nice place to enjoy the evening sun and relax after a long day at work in a comfortable temperature. This makes the outdoor glasshouse an extension of the housing. Energy efficient applications like these can be seen as devices for the habitants. Smart climate designs can score great on the tests while calculating the efficiency, allthough a smart user who knows how the system works and understands which steps there needs to be taken to make this an energy efficient house is another thing. Energy efficient behaviour is an other graduation topic where big steps forward can be taken, like switching all devices completely off when no one is home, heating the house not during the whole night but just before you wake up and ventilate the house in the right amount and on the right time of the day, are all human behaviour aspects which will reduce the waste of energy significantly.

The water collecting feature uses gutters which are connected to a 1,200 litres storage tank, but before it goes right away in the big storage tank it goes through a much smaller tank of 120 liters. This water will be used directly to flush the toilets. Placing energy-efficient toilets using only 3 litres per flush makes this tank provides 40 flushes. The smaller tank is placed right under the roof and above the toilets. In this case adding pressure on the water pipes is unnecessary.

5.7 Solar cities

The city of the sun in Heerhugowaard was the first city fully design to the sun. In the urban plan was the south-north orientation allready determined so architects can more easy make the stap towards gaining solar energy.

This urban plan has already been developed and was designed in the 90s. In 2009 the city has been opened and in september 2014 I visited the city by joining a excursion organized by UNESCO-IHE. During the excursion we walked through the whole city and it was remarkable nothing seems to be different in comparison to an ordinary city, concluded orientation does not has to influance the urban environment. Allthough the orientation contributes to the energy efficiency.

The city of the sun has there roots of the water lake how it was from origin. The urbanism thoughts were to let this lake come back and build a city in the middle of that lake. The urban plan was free from orientation. That's why the whole square is orientated to the south. In this way urban design considerations can improve the architectural design. Orientation is crucial in order of optimize the energy efficiency and was the number one aspect I wanted to achieve in this Design.

Fig. 5.8.1

Wind cowls on de BedZED dwellings in London. (BedZED, UK)

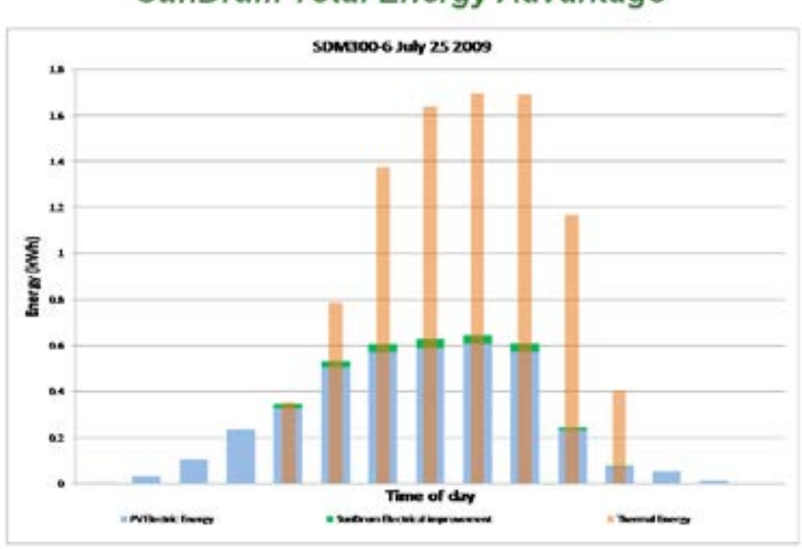


Fig. 5.8.2

Graph including the amount of energy in comparison to a normal PV panel. (Sumdrum, 2006)

Fig. 5.8.3

A PVT panel before it is mounted to the roof (Sumdrum, 2007)

5.8 Climate regulators

PVT Panels

In the sustainable energy industry, it's commonly known that solar water heating offers a quicker payback period and a higher return on investment than photovoltaics. This is because solar radiation already contains a large amount of heat, so using the heat directly is more efficient than converting it to "high-grade" energy like electricity. Your mileage may vary, but on average a solar water heating system will pay for itself in about 4-7 years, where a photovoltaic system could take 10-20 years.

But the reason electricity is considered "high-grade" energy is that it's more versatile. Heating water is great, but it's only one job. Converting sunlight to heat and electricity, and doing both efficiently, would be a double-win where it also gives it a short payback period.

As you can see from the chart on the other page, a PVT panel produces only a modest increase in electrical production but nearly triples the total usable energy that the system produces, bringing the total efficiency of the system to around 70% without increasing its overall footprint.

A PVT system includes a solar thermal collector that mounts underneath a photovoltaic panel. A typical PV cell has an efficiency of 15% under ideal conditions. When a PV panel heats up, as dark objects facing direct sunlight tend to do, its efficiency and lifespan will both decrease. Remove some of that heat and the panel will achieve closer to its ideal efficiency and be less prone to heat-related failures. PVT panels are 22C cooler than standard PV panels. These are results of tests for a normal roof situation. In this case the temperature will be much higher in the top what will reduce the efficiency of a normal PV panel even more.

Wind Cowls

The distinctive BedZED wind cowls, the same wind cowls I use in my design provide ventilation into homes while minimising heat loss. They will contribute to the natural ventilation by the wind driven aspect. The natural stack effect what will occur during summer will be achieve better results, leading to a better ventilated glasshouse.

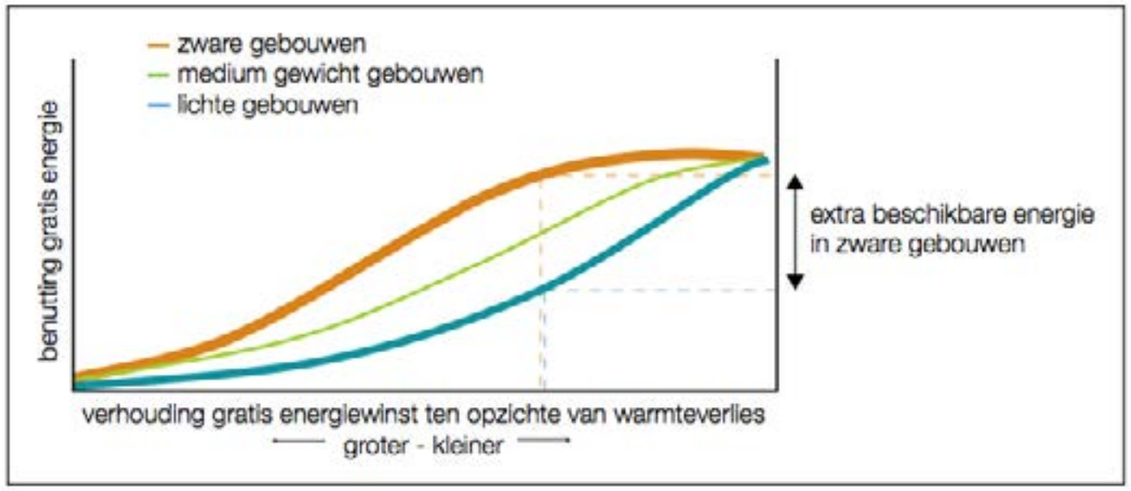


Fig. 5.8.4

Influence of themal mass on comfort (Thermal mass for housding, the Concrete Centre, UK)

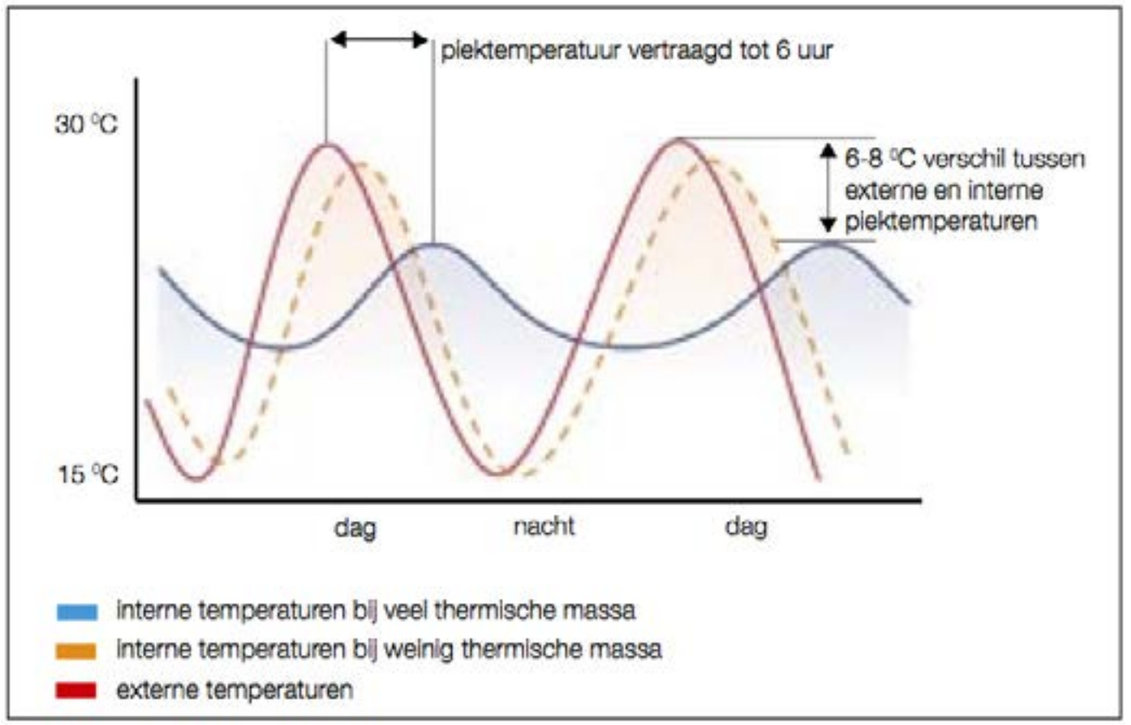


Fig. 5.8.5

Tabel of number of hours exceeding the indoor temperature per year for three a casco variants. (Passiefhuis in Nederland, 2006)

cascovariant	ruimteverwarming		oververhitting*
	vraag (GJ/jr)	piek (kW)	aantal uren > 25 °C
beton	1,1	0,6	18
beton met hsb binnenspouwblad	1,1	0,5	20
houtskeletbouw	1,1	- 0,6	97
kalkzandsteen	1,1	0,5	22

Fig. 5.8.6

Number of overheating hours a year with different types of constructions. (Passiefhuis in Nederland, 2006)

5.8 Climate regulators

Thermal mass

The temperature in the house is constantly changing. Large differences between seasons but also smaller ones between day and night has influence on the indoor climate. Allmost the complete house is made of timberframe. Allthough I have chosen for a thick (200mm) layer of insulation keeping the warmth or cold inside is nearly impossible without a source where the heat can be stored at; thermal mass.

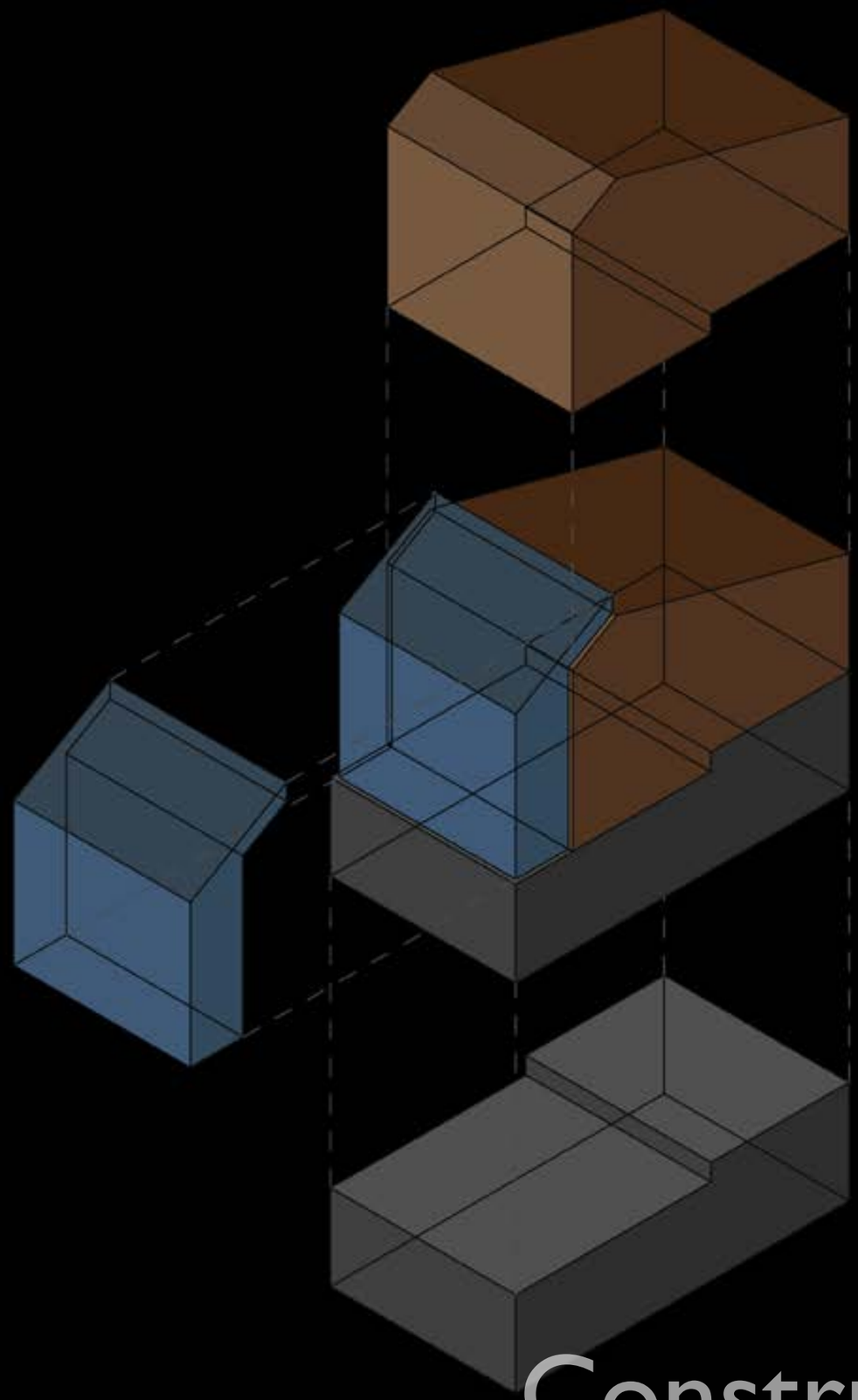
Thermal mass reduces the extreme temperatures and ensures the amount of overheating hours by 80%. In summer the thermal mass holds cold, even longer when the mass is situated on the north side of the building.

Adding a thermal mass floor on the timber frame should be done in the right way. The east and west sides of the house are loadbearing. To find the right floor I compared different floors.
- Wooden + beams (30kg /m2)
- concrete hollow core slab (382kg /m2)
- wooden hollow core slab (59kg /m2)
- steelplate concretefloor (283kg /m2)
- Bubble deck floor (470kg /m2)

Because I am looking for mass the two wooden floors are not suitable. A bubble deck floor is the heaviest but also the thickest. remaining the hollow core slab and steelplate floor.
I have chosen the hollow core slabs floors to span the floor in once. Afterwards it might makes more sense to use a floor which uses all sides for loadbearing, because all sides can be used as loadbearing walls. On the other hand, hollow core slabs are relative cheap and easy to assemble.

Conclusion

Regulating the climate around you to a comfortable and satisfying result is the main reason why we build. Creating the perfect tem perature and humidity cost energy when the surrounding deviates a lot. These houses are designed in a way to optimize the energy demand and minimize the heat loss with the sun as most important factor. Gaining solar power from the south facade, collecting rainwater from the roof and a thick pack of insulation to prevent heat loss are well known sustainable aspects who are added everywhere you see to existing buildings. Designing with those well known aspects in a early stage forms literally the house. The famous sentence "form follows function" can be bend to "form follows sun" for an as energy efficient house as possible.



06

Construction Design

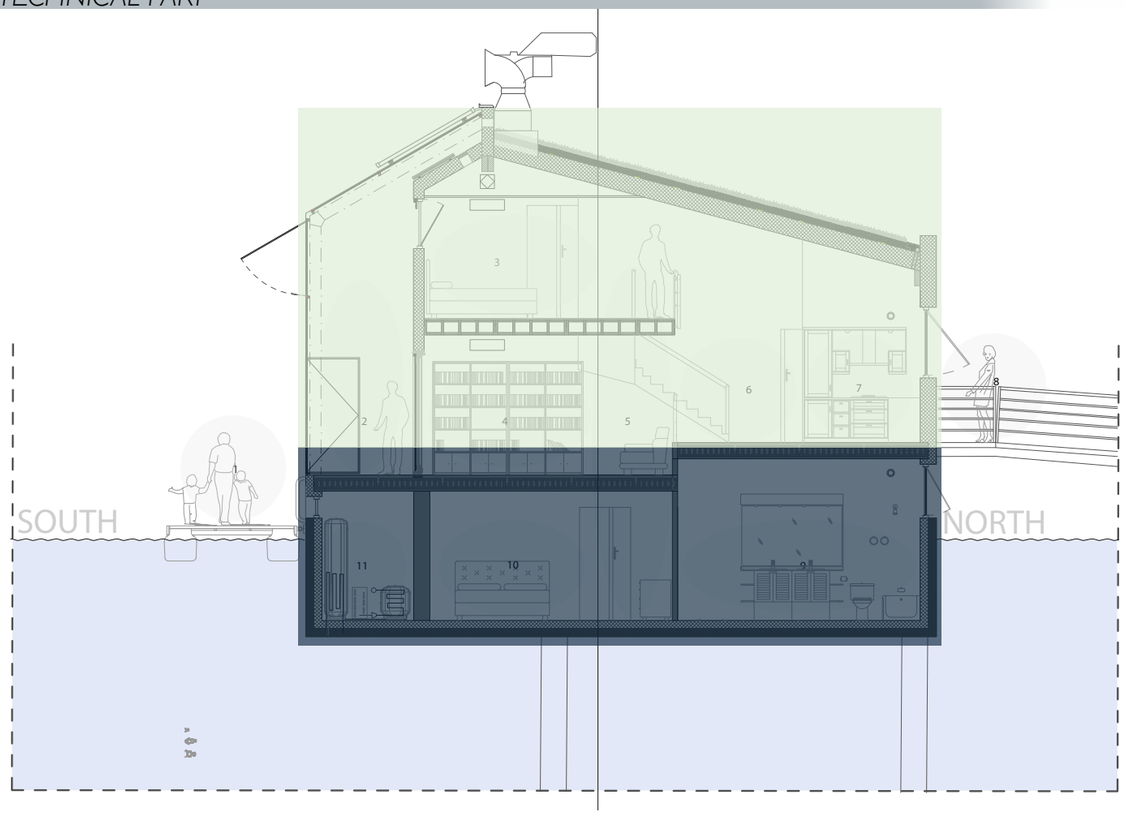


Fig. 6.1

Section of the dwelling illustrated the heavy and the light part. (Own Ill.)

06. Construction Design

MICRO

Introduction

Although most of the design desicions seems quite logic, for some aspects or parts, an explaination is required to fully understand how these principles are achieved in detail. A plan may contain great ideas but translating these into a final design where all the components are connected to each other is ultimately necessary in order to succeed, the design.

6.1 Buoyancy

The concrete box floats on itself, even when it's loaded with a timberframe house on top and filled with interior. This can be easily explained by the laws of archimedes which indicates that: *'the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces."*

To ensure the concrete box is waterthighness it is made in one time so there will emerge no cracks or cervices. 300 mm above the point where the water level has to be free to guarentee a certain level of buoyancy safety, to prevent the concrete box will be filled with water when the house is under extreme load. Ensure de safety when the house is under extreme load like a thick pack of snow on the roof or during a party when a lot of people are inside the house at the same time, is the most important part of a floating building.

6.2 Stability

The stability won't be guarenteed by the piles where the dwelling is attached to. Those piles are primairy for anchoring reasons keeping the house stable in the x and y directio, and are not dimensioned to absorb forces in the z direction what theoretical results in the possibility of a crooked house.

In order to make a floating building stable there are three aspects who have influence.

1. Center of gravity
2. Enlarge the surface
3. Enlarge the weight

The concrete box is the heavy part of the building what enlarges the weight. The center of gravity has been lowered because of the use of light timber frame on top of the concrete. Enlarging the surface has been reached by connecting two dwellings to each other what brings the total to a very stable floating house.

The obliquity of the dwelling has to be less then 2 % for a comfortable living environment but because this dwelling has taken all three stability factors into account, the dwelling will be experienced as very stable with with virtually no misalignment

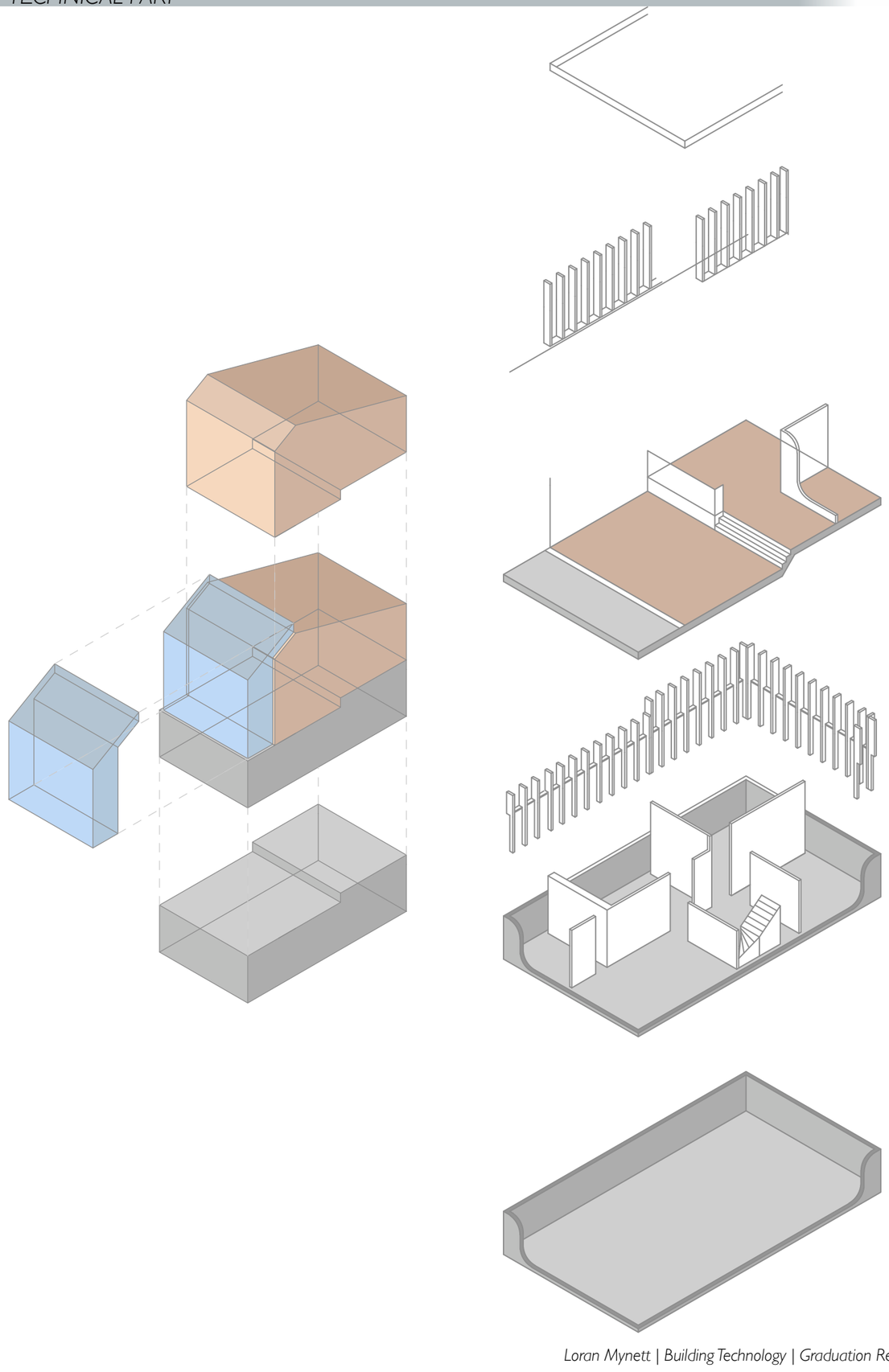


Fig. 6.3.1

An primitive axonometry of the three elements coming together. (Own Ill.)

Fig. 6.3.2

A axonometry over the Z axis to show how the components come together. (Own Ill.)

6.3 How it's build

The design is made out of three components. The concrete box serving as the floating part, the timber frame to build an as light as possible construction in order to ensure the low center of gravity and the glasshouse functioning as climate buffer zone. These elements are well known in the building industry, nothing new so far, but combining those three in one design working together to become a climate adaptive energy efficient and sustainable design is where the innovation comes in. The building proces is not that complicated and will all take place inside a engine house in Urk. All building phases can be done right after each other and only one company is building it what reduces the costs and decreases the production time.

Concrete box

To ensure the building is waterproof and keeps floating the concrete has to be poured in once. Only then there are no crachs or crevices. After the concrete box is finished the timber frame will be placed partly starting from the bottom and partly from the edge of the concrete box. Because there will be a heavy thermal mass floor on top of the timber frame besides the continuation of the timberframe to the next floor, the timberframe is extra thick in the lower part of the house.

Timberframe

After the connection of the timberframe with the concrete, the house is completely build out of wood. The mezzanine and roof are from Lichnatur, a company who makes prefab wooden hollow core slabs, ideal to build light. Those elements span the 6,5 meter in one time so there are no beams needed to hand over the forces to the load bearing walls. In the ridge of the roof are two wooden beams. Those beams carry the roof curb where also the wooden beams are attached to who carry the glasshouse. The timberframe is 184mm thick filled with insulation. This thick pack of insulation contributes to reduce the overall heat loss of the building.

Glasshouse

The glasshouse is overarching the complete south facade. The total amount of glass is around the 80 m2. This glass can't carry it's own weight, therefor wooden beams are placed, standing each 1,5 meter, who are loadbearing and can carry the glass. The glasshouse has to be air tight in the top. This is the place where all heated air is collected. A leak would be decisive for the design and the function of the glasshouse. On the sides and at the bottom is an other story. First of all the air is in the lower part of the glasshouse not that much warmer then the air on the other side of the glass. Secondly the air will be used at the top for the stack effect principle in the summer and for heat recovery in the winter, resulting in a pressurized in the bottom of the glasshouse. This can be compensated by opening a vent for example.

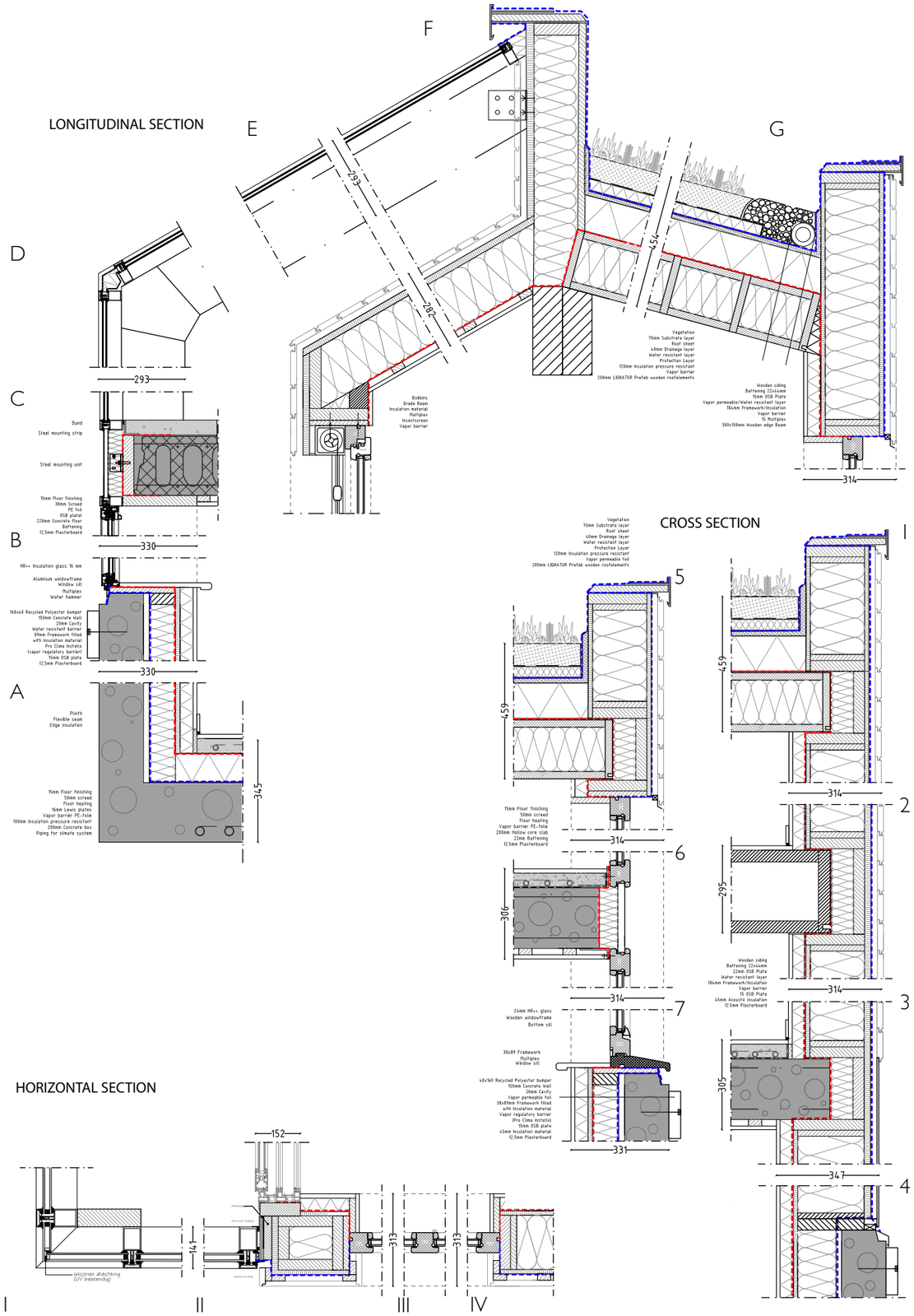


Fig. 6.4.1

Longitudinal, cross and horizontal section of the building With all details corresponding to the letter or numbers. (Own Ill.)

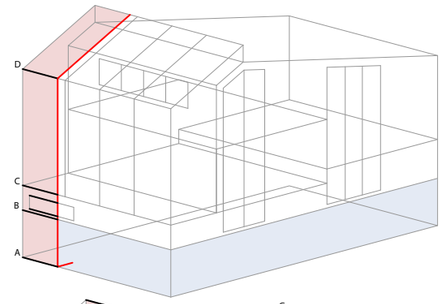
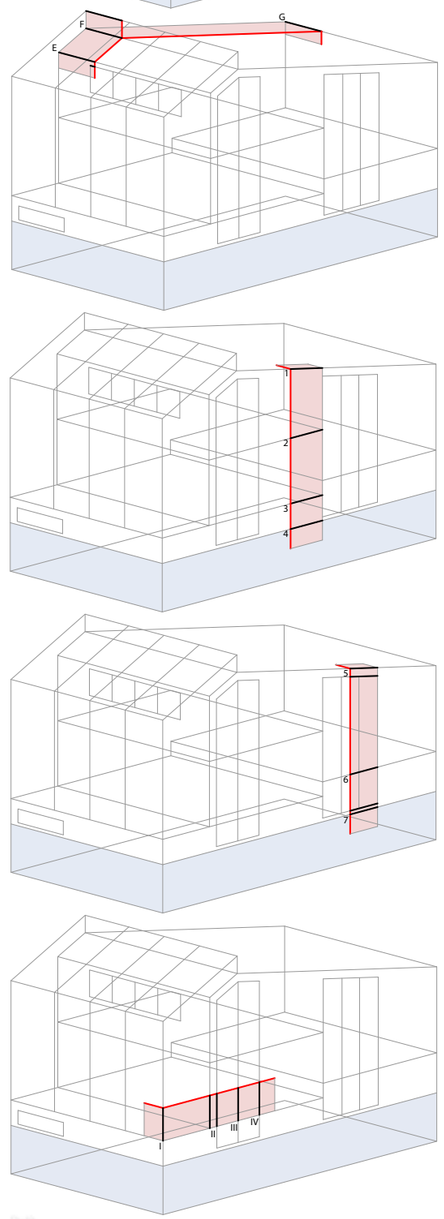


Fig. 6.4.2

Schematic illustrated where the section is taken. (Own Ill.)



6.4 Details

Longitudional section

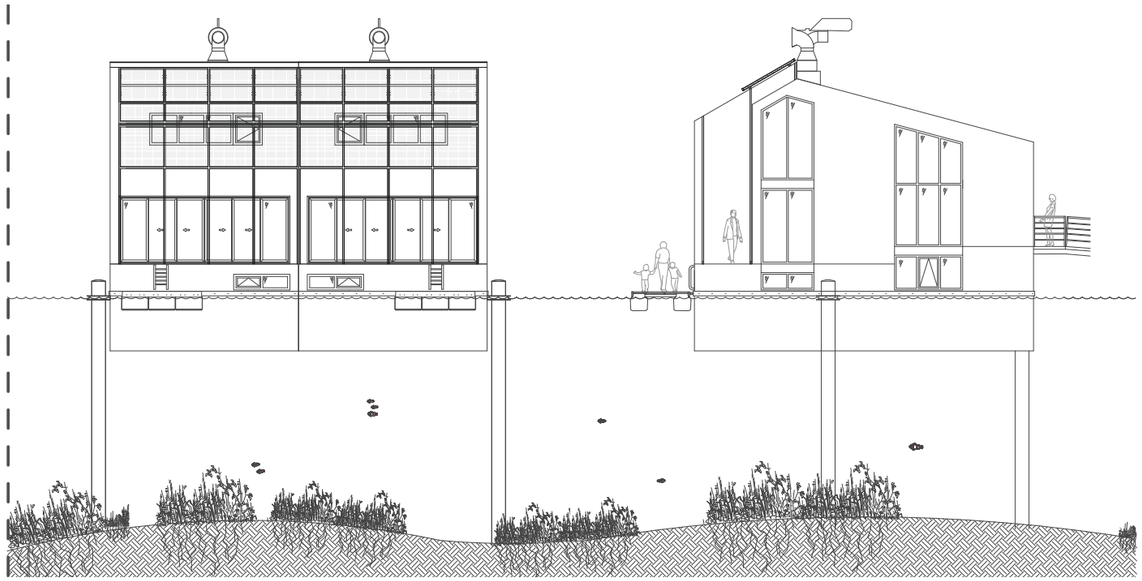
In the longitudional section (AtmG) we clearly see the meeting between the floating concrete box, glasshouse and the timberframe. Markable are the wooden beams carrying the curtain wall. In the rafters they come together with the timber frame so the forces can flow directly into the bearing walls. The water resistant layer is not needed in the inner part of the south facade.

Cross section

The cross sections (1tm7) has been taken where the wall meets all 3 different floors; roof, mezzanine and the thermal mass floor. The roof and mezzanine are prefabricated wooden elements who can easily span till 12 meters. The 6,2 meter in this dwelling is therefor no problem. For the roof is a less thick lichnatur 200mm floor chosen with insulation. This because the is no need to walk on the roof and the extra insulation is always welcome in case of reducing heat loss. The mezzanine floor is 280mm without insulation. These prefabricated wooden floor or roof elements are easy to assemble and contribute to a lightweighted structure.

Horizontal section

If we take a look at the horizontal section (I tm IV) we see the facade opening or windows are layed back a little aswell as the glasshouse. For the windows it is to provide the cohesie between the two elements, but for the glasshouse it is to make sure the glasshouses are not hitting or scratching each other when the two houses will be connected to each other.



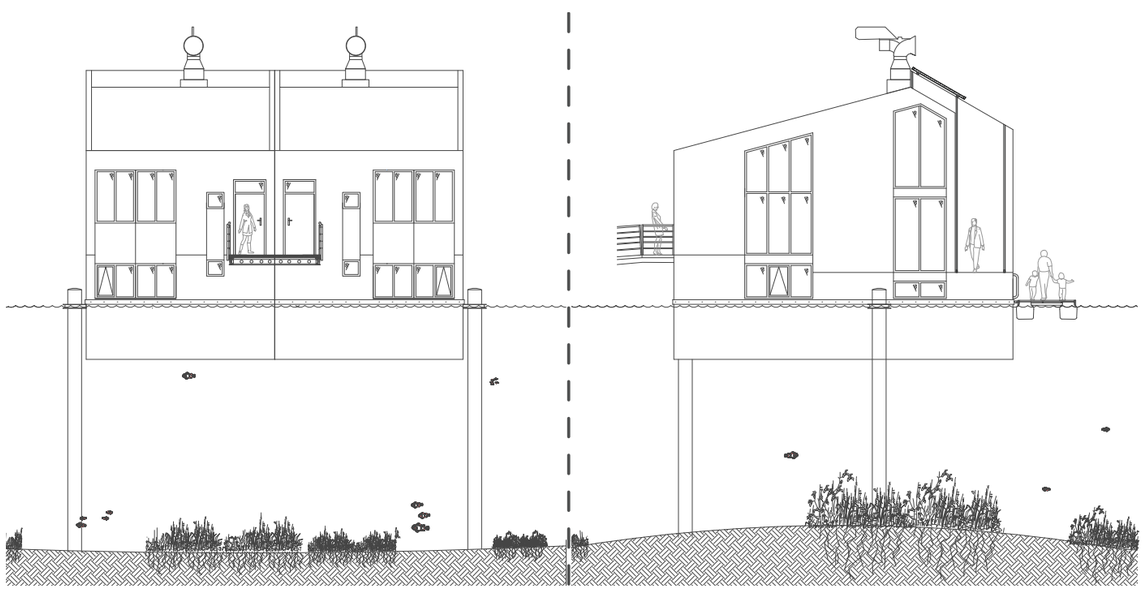


Fig. 6.5

The four elavations of the dwelling. (Own Ill.)

6.5 Elavations

A normal house has 5 facades. North, West, South, East and the roof. In this design the facades differ from each other because they have different purposes or function. Each face will be explained seperatly.

When the dwellings are entering the urban plan they will be connected to each other to increase the stability and decrease the fluctuations what results in a facade with no openings. This side of the house, the west or east side, is the constructive facade. It has only the aim of connecting the houses to each other. The whole facade has no openings which improves the Rc value. To make the connection water tight or let it open is a quistionable point. In this elaboration the space in between, around 8 centimeters, is open.

The roof has this 15 degree angle and is used to collect water. The roof consist of a green roof what brings many advantage. It is not only better for the durability fo the roof, it also contributes filtering fine dust out of the air, and gradually discharge the rainwater. Compansating the lack of green down town not even mentioned.

The North facade has the main function to connect the house with the jetty and the utilities of the main land. The enterance is on the side of the dwelling located next to the neighbors so the walkway to the jetty can be made out of one and has the minimal width.

The side of the building has aswell as the north side eastheticaly intentions. The concrete box makes this house float. Therefor the transition from concrete to wood is an important aspect what has been emphasized in the external view. The windows in those two facades are deeper and are not disturbed when a floor occurs. The facade opening continues and what visually contributes on the transition between the two elements, concrete and timber frame.

The South facade has primary climate based considerations and is there to optimize the climate aspects of the building. The top part of the vertical glass is has intergrated PV cells. While the lower has no PV cells so the horizontal view wont be disturbed. The inclined portion of the roof is partly filled with the same integrated PV cells but has on the top- PVT panels who are not translucent.

The inner facade has on the ground floor large sliding doors allmost completely out of glass to provide the winter sun to heat up the thermal mass. The windows on the mezzanine are has other intentions then the windows on the North and side facade. Those windows are important for air flow reasons. The operable vents contributes to the stack effect in summer and letting preheated air in during the equinox.

Fig. 6.6.1

Route over water from Urk where the engine house is located till the final destination in the Rijnhaven of Rotterdam. (Google Earth)

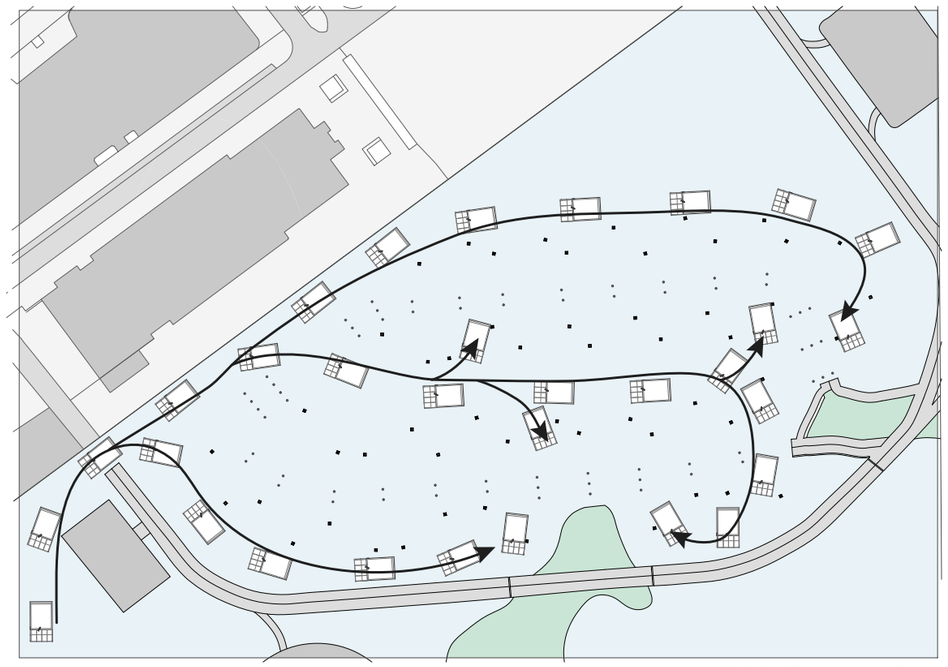


Fig. 6.6.2

After the floating dwellings have been transported they need to be put on their place really carefully with all the piles and in a certain order. (Own Ill.)

6.6 Transport

The whole building will be constructed and brought to water in a shed. The company who can do this and have done almost the same task for floating dwellings in IJburg in Amsterdam is ABC Arkenbouw located in Urk. From there the dwellings will be transported over water to the Rijnhaven in Rotterdam. In total a journey of 160 km.

This journey will take over a whole day because the rapidity over water isn't the same as over land. One of the reasons of the speed is limited is the splashing of the water while sailing and the other one is the stopping distance.

Transporting the dwelling over land is also an option when there will be proceeded very carefully. additional difficulties are that a crane is needed to bring the house into the water.

The plan includes 54 dwellings and each one of them need has to travel all the way from Urk to Rotterdam. Financial reasons will determine which transport possibility will be chosen. Nevertheless will it be a challanging project to transport all of the houses to the final location without damaging one of them, which is worth around the 600.000 euro compared to similar projects.

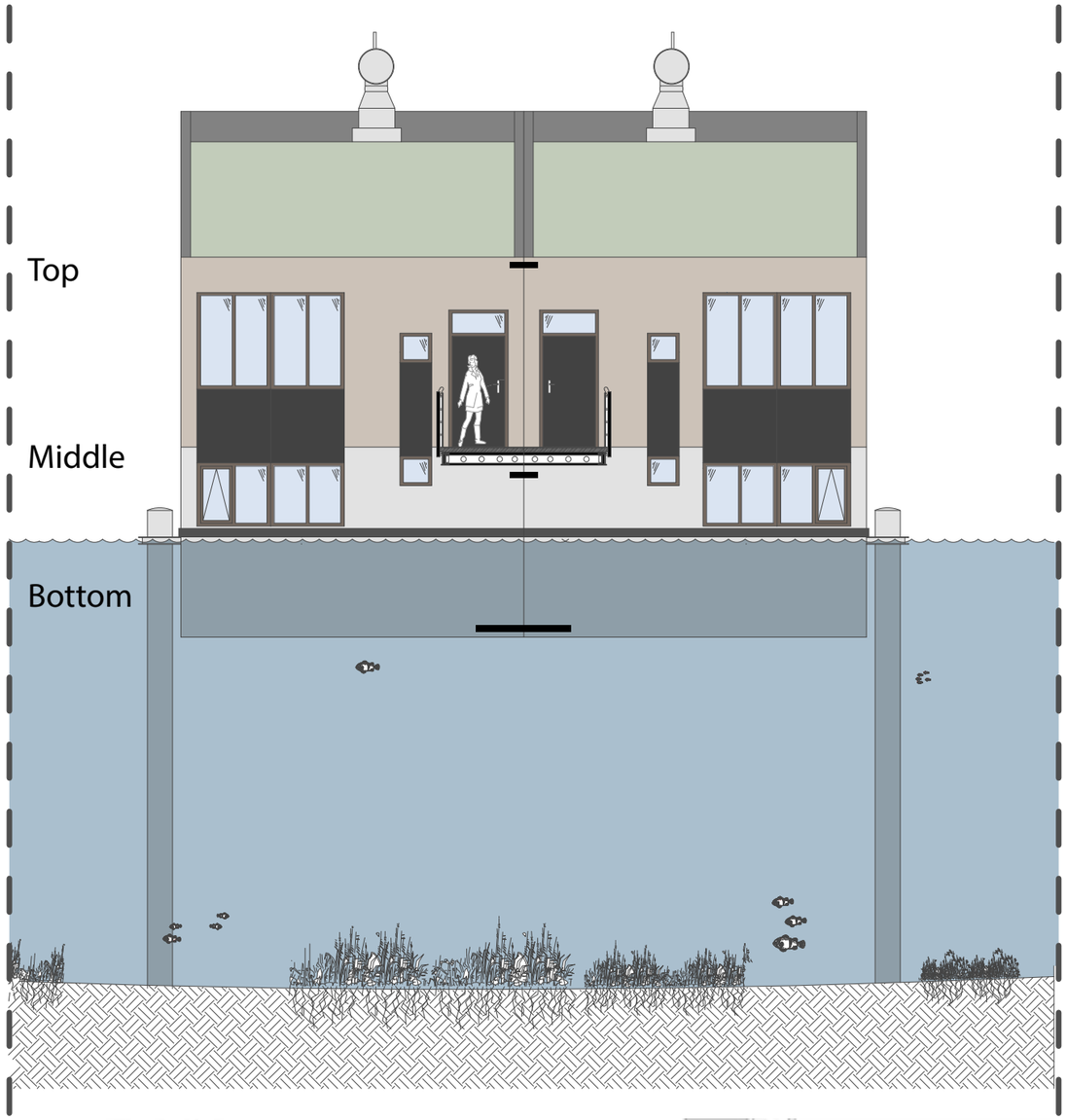


Fig. 6.7.1

Three constructive attachments who will be done on sight. In the bottom is the largest one tha provides the stability. The one in the middle and top are to prevent friction and scraping. (Own Ill.)

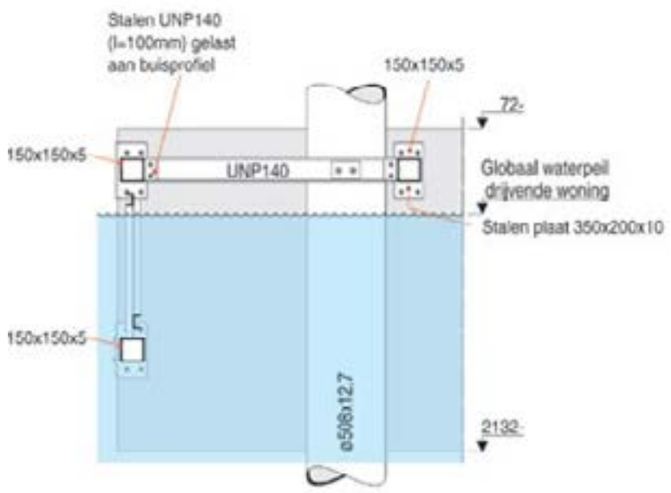


Fig. 6.7.2

The margins can be to much in practice to make it fit right away. This rail can be add to make it fit on sight. (Own Ill.)

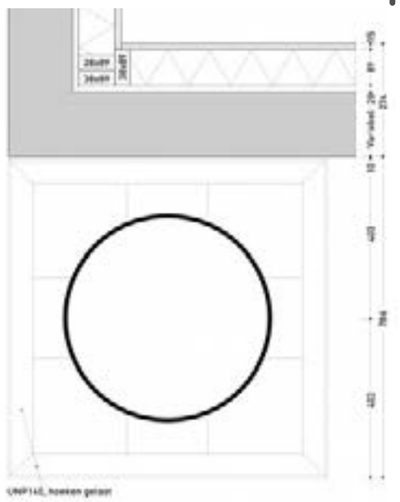


Fig. 6.7.3

Top view of the attachment form concrete box to pile holder. (Own Ill.)

6.7 Anchoring

After the floating dwellings arrived in the Rijnhaven they have to be anchored carefully on their place. Drifting the dwellings in the plan has to be done in a certain order to make sure there is enough space. This proces takes place after the jetties are on there place except for the houses at the most south part. The two houses are connected to each other to increase the stability and decrease the fluctuations. This will take place on three places. Top, middle and at the bottom there will be an attachment. This connection will be done on sight. When connected the houses function as one and can only move vertical along the piles. There are two piles the two homes will be anchored to. The position of those piles is in the extenstion of each other and has only the function of holding the homes on their place. Sliding in the vertical direction is possible. There are rubbers placed to prevent shocks when the dwellings are wobbling. It is practically impossible for the house to get disconnected from the piles, because under normal circumstances the fluctuation wont be more then 20 centimeter. This is why there is always a piece of the pile in sight from external view, but they are positioned in a way you don't notice when you are inside.

Conclusion

In the micro scale all the elements or components came together. All seperate elements are well known in the building technology world. Floating concrete boxes, glasshouses and houses made of timber frames isn't innovative. Putting those three elements together, the cohesion between those three and the way they work together to reach the main goal "A climate adaptive, energy efficient and sustainable urban dwelling " that's innovative.

Conclusions

If we look at the energy consumption of a household we see transport is number one. Open area downtown is not easy to find what explains the long travel distance people make. Old harbours are located in the center of a city on the other hand and are mostly a wasteland. The reason therefor is that the area has a high floodrisk because it is located outside the dike. To develop outside the dike there needs to be build in a climate adaptive way what trips the problem of flooding.

Urban

The urban plan had a few criteria which were taken into account. Minimize the amount of jetty, maximize the number of dwellings, creating parking places and making the plan firesafe were the main points. Fitting as many houses as possible in the plan was would make the plan on the financial aspect more convincing. Ensuring the firesafety of the plan means always two ways to escape, therefor the circulair infrastructure. This plan brings all aspects togeher to provide a stable and realistic base for the architectural design on the meso scale.

Climate

The house is using the sun and the water to regulate the indoor climate during all seasons. There are active and passive energy systems integrated in the design. The active energy system are PV cells integrated in glas, PVT panels, heat recovery unit, floor heating/cooling, collecting rainwater and in the bottom of the concrete box is a system of pipes positioned to transfer heat and cold with the ambient water.

The passive energy systems contributed to the shape and orientation of the design. Thermal mass on the North side for cooling during summer, thermal mass on the South side absorbing deep penetraiting sunlight during winter, wind cowls, thick insulation and good crack sealing are the main passive aspects. The green roofs lead to gradual discharge of rainwater, provide better isolation, increase rooftop protection durability, provide compensation for lack of green in cities and helps purify from fine dust.

An other great passive aspect is the incoming light which is reflected on the water to the ceiling what gives a beautiful visual experience.

Construction

The homes are composed of 3 elements:
- The concrete box fuctions as floating part
- The timber frame lowers the centre of gravity
- The glasshouse for climate regulating

These three elements together lead to an architecturally, technical and aesthetically interesting design. With the details has been proved that the design could be constructed flawlessly.

The homes are designed as two-under-one-roofs. After being transported independently to their location they will be connected to increase the stability and decrease the obliquity.

The main goal "Designing a climate adaptive, energy efficient and sustainable dwelling" has been achieved because of the good integration between the macro, meso and micro scale in this design

Recommendations

After finishing my graduation project I would like to suggest some improvements what can bring this design to a higher level. Time is relative an old saying of Albert Einstein, but during a project there is always a deadline and time becomes automatically less relative, what results in a certain level of elaboration. Assuring all the different aspects and scales are elaborated till the same level is the most important But if there was more time there were certainsome aspects what could have some more attention. Therefor I present you my recommendations.

Macro

On the macro scale there is infrastructure, parking places and a good accessibility of the dwellings but one thing is mising. Urban plans need public space. People shouldn't be isolated to there homes. Feeling free to leave your house and meet people in public spaces like parks, or squares are essential to making a urban plan succeed.

Green can be found on the islands and the Rijnhaven-park situated parallel to the whole length of the road. But this public space is nearby the urban plan and not integrated. Elaborating the urban plan on a macro scale could increase perception or experience of the neighborhood. People who would like to fish on the side of the jetty or kids who always love the play a little soccer for example have to find their own spot now. Creating a urban plan what can be build, is safe and has all the technical aspects and fulfills the requirements is one, but integrating those requirements in a loved urban plan is another.

Meso

The dwelling is formed to optimize the indoor climate what is clearly explained in chapter fife. Form follows sun is the formula which is applied to form the dwelling. Allthough the simplicity of the design is also the key to succes, the design how it is drawn now could be elaborated even furthur. Half of the dwellings of the plan do have the entrance on the other side of the building. The jetty is used like a corridor to reduce the amount of needed jetty. The principle of the other dwelling is the same but the floorplans will be definitly different, aswell as the place of entering the house. More likely is to enter the house from the side to enlarge the private feeling of the glasshouse.

But also the dwelling I designed could be seen as a preliminairy design. In my opinion it is completely finished but the mass is relative simple and a challenge could be found in giving the dwelling a more complex mass decreasing the climate aspect. Allthough the dwellings are connected to each other what make them certainly different from each other. One has a West and the other an East facade. Also in this aspect could be found a diversity. To summarize the different buildings according to the sun in this plan there are 4 types. South-East, South-West, North-East and North-West. Making distinction between those types could optimize the design even furthur, if it's done correctly.

Micro

On micro scale this is one of the many elaborations interpretations of the concept. The concept is to clearly show the dwelling consists of three different elements. The floating concrete box, the light timber frame construction on top and the climate regulator zone fully made out of glass. Those three elements have a diversity of materials. Wood for example is a product whith many different colors, ways to attach and structures. Choosing a different type of wood completely chances the external view of the house.

With this aspect there are endless numbers of possible combinations to diverse in the

Reflection

Motivation

This graduation project has started with my interest in developing on water. Before I started my graduation project I went with the Building Technology S.W.A.T. Studio on a excursion to Sarajevo in Bosnië-Herzegovina. The only water problem we found was the sewage which flew right through the city. The whole country is around 500 meters above sea-level what explains why there is no flood risk for example. Back in holland I was deeply interest in water development and floodrisk areas. Two third of the world is water with everywhere flood risks as a result. The flood issues in Asia and parts of the United states are enourmous but before failing in an attempt to improve the world I realized I should start small.

Problem Statement

Holland, also two third under water if there were no dikes and pumps is also dealing with water issues. The dike prevents us from flooding. Pumping water upwards give us dry soil where we can build on inside the dike. Outside the dike on the other hand, it is not safe to build, because there is no control on the water-level. Therefor it is impossible to unsurance a building. Building in a climate adaptive way where houses rising together with the water by floating for example can provide oppertunities.

After some research and talking to lots of different people I came in contact with Prof. Chris Zevenbergen who introduced me to the "Kaviaar aan de Maas group" a group of people working together to design a urban plan for the Rijnhaven in Rotteram. The Rijnhaven was also the case study I had chosen for my graduation project. One of the participants was ir. Duzan Doepel who offered me an Intership at his architectural office DoepelStrijkers architecten office. In cooperation with office I made the urban plan for the Rijnhaven, the same urban plan I used as a starting position.

Research Question

My research question reads:

"How can we transform old harbors with high flood risks into a climate adaptive comfortable urban living environment with an energy-efficient design?"

Before answering this complex question I devided it into the following subquestions:

- *"What are the complexities for the case study?"*
- *"How can these be addressed in a sustainable way?"*
- *"What does this imply for the predesign?"*
- *"What are the design considirations?"*

Research & Design

In my research I red a lot about floating dwellings, floating development and urban plans including a lot of water. There are many reports written about being a climate adaptive city; Rotterdam Climate Adaptation, Rotterdam Climate Proof, Floating Development, Waterplan, Ready for high water, Advice Deltacommision Waterdistrict, Structural vision, Delta innovations, Creating on the edge, Rijn-Maasharbor future vision.

After reading them I came to the conclusion Rotterdam can't wait to be climate adaptive. The city can't wait to be water proof, the first water proof city of the world. Being world leading on the major issue is the true dream of Rotterdam.

But what stops them from doing it, why don't they start building on water, start using all this free space with floating developments. Money is the answer. Not all the parties are completely convinced and in these days investments in projects which have never been done before is too a big risk, especially for developing at the large scale Rotterdam would like to see.

Learning from these visions and with all the knowledge of floating buildings I started sketching and came up with a priliminairy design. All the complexities of a normal dwelling put into an urban plan which contains a lot of water and only a small number of jetties ensured, I had to consult not only the literature but also companies like ABC Arkenbouw quite a few times.

Theme & Studio

The studio building technology lets you quite free in finding a topic that fits you best. In comparison to my fellow students my graduation project is completely different, allthough my final design is in my interpretation really a building technology subject. Before my design and after my research, we are talking around the P2 period I had quite a difficult time. Thanks to the feedback during my P2: "you need to make things concrete for yourself or else you can never take this graduation to a higher level, I found a way forward.

If I were in the Urbanism master track course I had elaborated the urban plan with love or a system with maybe phases how old harbours can operate again. Or an approach to restructure these parts of the city and connect them back to the living areas, but all of these elaborations do not meet building technology, the mastertrack which is my first choice.

In case of making a design which unites the floating development theme and the mastertrack building technology I determined to design a floating district. A district which can be plugged into the urban plan I made during my internship having the main theme of connecting energy, water and waste flows to create a closed cirlce. A floating energy efficient district located in the middle of the Rijnhaven gives a great impulse to the urban plan.

Studio Approach & Chosen Method

In the S.W.A.T. Studio we worked al lot with the macro-meso-micro principle. Zooming through a plan or design treating all different scales contributes to the integration of the design with the context. Pragmatical working gives the design all the content it needs. I found out this approach was really working for me, because one of my least good point is keeping the overview in the project. I know from myself that I can easily loose myself in perfecting a detail or less important part of the design, allthough it is good to know your own weak sides so you can prepare and prevent yourself doing it.

I applied the macro scale for the urban design. After macro I found the meso scale in my dwelling design and lastly the micro scale in the details. All scales affects each other and the macro-meso-micro approach helps integrating these scales.

Design & Social Context

The problem I found in my problem statements names developing outside the dike. Because this goes so rigid, old harbours who are loosing their industrial harbour function become empty and are desperetly in need of a new function to prevent the quality of the districts decreases exponential. Now open areas are plagued by criminality and are unsafe.

Developing in these old harbours, which created the city in the first place would resurrected the area and brings revaluation to the now unliked areas. Social control will rise when people live there and the criminality will slowly pushed out of the area.

The Wilhelminapier is leading this future image and I think this project is a great way to achieve this perspective and contributes to making this restructuring a succes.

Colofon

Loran Mynett
Papsouwselaan 264
2624 EJ Delft

L.S.Mynett@student.tudelft.nl
Loranmynett@gmail.com
+31 6 39.77.24.57

Mentors

1st: Ir. Jan van der Voort (Architectural Design)
2nd: Dr. Craig Lee Martin (Sustainable Design)

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