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Fig. 1. AAU

ABSTRACT

Evolving Environments is about designing experiences and extending the understanding of alliesthesia; thermal, visual, acoustic, spatial and social.

The Spa House in Aalborg transforms the Pier into a new gathering place, as one of the last free spaces near the inner city.

The performance-based building design integrates investigations of occupants, the building envelope and the climate. For instance, the nearby context, industrial history of Østre Havn, a diverse user group, climate conditions, and perceived ambience.

The Integrated Design Process guides the project's iterative design workflow by combining engineering and architectural knowledge. To that end, the project aims to bridge quantitative simulations with qualitative, phenomenological and poetic dimensions of architecture when shaping indoor environmental qualities.

Therefore, psychrometric charts, shadings masks, radiation and UTCI studies, daylight analyses, and false-colour renders are used to inform the experience of the Spa House.

READER'S GUIDE

This Master Thesis consists of three main chapters; Program, Process and Presentation, further divided into subchapters. Sub conclusion will be presented continuously.

The report introduces the project scope, themes and precedent studies before presenting the site location and analysis from which goals, means, and criteria are derived to guide the design process. Additional material to the design process, such as complete design investigations are found in the appendix. Lastly, diagrams, masterplan, elevations, sections, floor plans, simulations, and renders present the final design proposal.

Some material considerations presented in the report arrive from exam material made by the group members in previous semesters.

All figures are made by the group members unless other is stated. Harvard references are listed in the back.

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When discussing thermal and public baths, the existence of water becomes one of the essential appearances. Water pools in human society go beyond the simple purpose of hygiene. Since the early establishment of civilisation, water assumed mystical, sacred, and even medicinal roles, included in ceremonial rituals and the everyday life. The first thermal bath that we know of was in ancient Greek, located near natural hot springs because of their belief in the restorative effects in health by hot water and vapour. The Romans made the thermal bath into a social activity for everybody as a part of everyday life (AIRE, n.d.). However, the thermal bath today has the potential to act as a treatment method, e.g., for issues related to muscles and joints, reactivating the blood circulation, or as an activity for delight and well-being.

Denmark does not have natural hot springs, hence a Spa House will require artificial domestic hot water, which is disadvantageous to the energy consumption. Nonetheless, a Spa House in Aalborg will provide a new node for gathering and social activity that ideally utilise Limfjorden as a resource. To inform the design further and meet the existing culture, scale and co-relation to the nearby environment, it becomes interesting to investigate how to respond to what opportunities and limitations the location in Aalborg provides (Lund, 2001).

Alliesthesia

The building volume of approximately 4000 m^2 aims to house facilities of varying nature and thereby create a sequence of experiences controlled by the indoor environment. To that end, alliesthesia must be mentioned in relation to the physiology of the human body when exposed to changes. For instance, sensing thermal changes in skin temperatures exemplifies an external stimulus leading to a bodily response that induces a positive affective sensation. The strongest effect of alliesthesia is expressed in opposed extreme experiences, implying a need for occasionally challenging and complementing the steady-state condition often aspired to sustain the conventional indoor comfort conditions, as illustrated in fig. 2 (Parkinson and de Dear, 2016). Therefore, when designing the experiences of a Spa House, variations must be considered contextually to the indoor environment to enhance a pleasant perception when moving between different environments.

The concept of alliesthesia goes beyond the sensory perception of e.g. temperatures. In this project, a Spa House will mediate contrast and variations in both thermal, daylight and acoustic (Cabanac, 2020). Additionally, spatial alliesthesia is introduced to communicate an experience of variating spatialities, and social alliesthesia to communicate a condensing of people of different backgrounds. The relevance of social alliesthesia emerges when designing spaces that activate the city.

Evolving Environments

"I think architecture attains its highest quality as an applied art. And it is at its most beautiful when things have come into their own, when they are coherent. That is when everything refers to everything else and it is impossible to remove a single thing without destroying the whole." - (Zumthor, 2006, p. 69)

TThe citation from Atmospheres from 2006, written by the Swiss Architect Peter Zumthor, exemplifies the importance of embedded qualities when designing and emphasising the potential of each element or detail in the building. Therefore, when discussing Evolving Environments and alliesthesia, it becomes interesting to investigate the relationship between the measurable aspects and qualitative dimensions by phenomenological approaches. For instance, the sensory experience of time as an integrated part of the Indoor Environmental Qualities (IEQ).

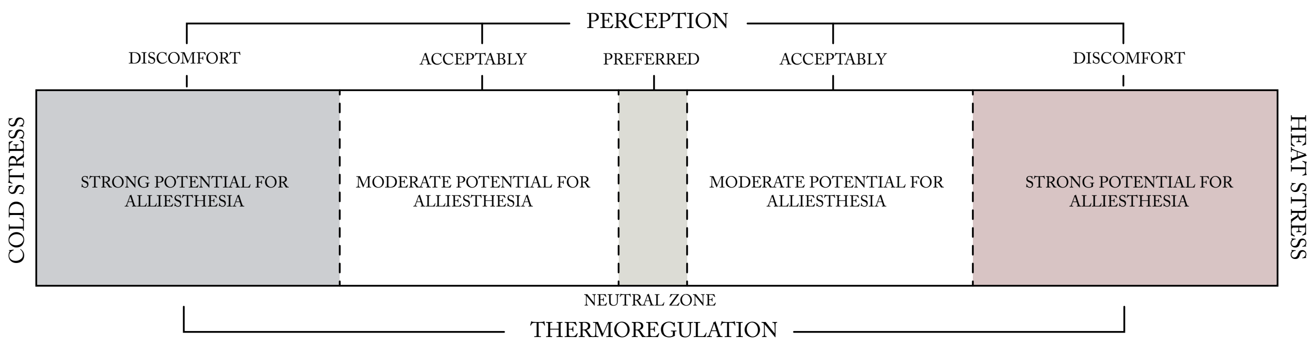


Fig. 2. Alliesthesia (Parkinson and de Dear, 2016)

The aim is to challenge the sub-division of the two worlds by balancing and merging computer simulations of high-performance buildings and poetics, by utilising data to inform the design without neglecting the atmospheric dimension. When integrating both dimensions into a seamless workflow, the design aims to combine aesthetics, durability and convenience in timeless, sustainable architecture. Three unseparately parameters that bring individual ideals to the design, inspired by the Roman architect-engineer Vitruvius and his 2000-year-old theory of quality architecture (Morgan, 1914).

Therefore, when designing a high-performance building, the synergy of intertwined strategies becomes crucial, e.g. considerations about; time aspects of activities, intended use, overlapping user groups, thermal storage or renewable energy utilised during occupied hours of a Spa House. Outside occupied hours, the strategies might contribute to the city-grid in terms of heat, electricity, or the like. Hereby, generating an invisible but decisive relation between different zones of the city.

However, this requires a contextual understanding of the place due to the complexity of integrated solutions based upon technical data such as analysis, predictions, visualisation tools and 3D modelling, as well as a poetical vision for the experienced building design. The scale on data and registrations becomes beneficial for different purposes, to determine and derive design patterns and solutions, both hourly, weekly, monthly, seasonally and annually (Keck, 2020 ; Levitt et al., 2013).

A research paper by Brendon Levitt et al. introduces Thermal Autonomy as a metric that relates comfort, building envelope, occupants and the climate. This approach invites for building performance primarily driven by passive means, by utilising the capabilities of free renewable resources provided by the climate, instead of, e.g. a continuously dominating active system. The Spa House might benefit from thermal zoning and controlled openings related to solar gain to enhance the experience of alliesthesia. The indoor environment of the Spa House will then derive from patterns and simulation results to inform the building design (Levitt et al., 2013). In zones not directly linked to the spa, the occupants could adapt by the amount of clothing and appreciate natural ventilation to be comfortable, as varying strategies related to time and season.

In this project, thermal, daylight and acoustic aspects of the built environment are central to shape unique sensory and spatial experiences by different mediating and contrasting environments.

Nowadays, people spend close to 90% of their time inside. Therefore, regarding daylight, the integration of natural light permits access to the natural rhythm of the outdoor conditions, expanding the understanding of time and seasons. Besides, natural light is available for everyone regardless of the type of project, and even without high additional costs, which makes it evident for embedding qualities and a desired atmosphere to the design (Heschong, 2021).

This master thesis defines atmosphere as the poetic, phenomenological and qualitative dimension of a place. The environment is defined as the setting based upon quantitate measurements, such as the experienced indoor conditions that influence the occupants. The Spa House aims to mediate contrasting atmospheres of different environments, to enhance the experience of variations.

Noticeable variations in our thermal environments excite the nervous system, making us more engaged with our surroundings than if exposed to steady and neutral thermal environments. Thermal information is never neutral since the body registers whether it is losing or gaining heat, to which the body, in just a short time, can adapt to the environment. Besides, thermal perception is biased by individual preferences, which should be deemed when considering water and air temperatures, characteristic for a Spa House. However, contrasts and a range of temperatures might be interesting when designing a desired experience. Extreme thermal environments often have their opposites nearby to maintain a perceived thermal balance when moving between different settings and acute the contrast to the other by contradictions (Heschong, 1979).

The thermal extremes activate different bodily responses related to the various stages of thermal perception. Therefore, a sequence of opposites will be relevant to integrate when designing experiences for alliesthesia:

» *Cold environments*: Muscles tense up to generate more heat.
» *Warm environments*: Counteract the tension with comfort, and help to relax
» *Overheated*: Feel dozy, slow, indolent. (Heschong, 1979).

PROCESS METHODS

Integrated Design Process
Because of the strict building codes and increasing need for greener, sustainable, and high performing buildings, it is crucial for architects and engineers to collaborate in integrating architectural qualities and technical aspects from the initial design stages to progressively improve and optimise the overall performance of buildings (Klima-, Energi- og forsyningsstyrrelsen, 2020).

The Integrated Design Process (IDP) structures the overall process of this project. IDP consist of five stages; *Problem, Analysis, Sketching, Synthesis, and Presentation.* The process is presented to be linear, but the execution happens iteratively, which means that all the phases are interconnected (Hansen and Knudstrup, 2005 ; Botin and Phil, 2005).

The problem phase defines the problem and hypothesis, which sets forth an understanding of the field of investigations. The analysis phase supports the sketching phase by deriving and concretising various aspects of the site into design parameters or criteria, based upon architectural and technical analyses. The sketching phase condenses and initially integrates the analyses into design ideas. In the synthesis phase, all aspects of architectural, functional, structural, energy, and climate-technical qualities are synthesised into a design proposal. Finally, the presentation phase communicates the design through drawings, models, and visualisations, summed up in the final report (Hansen and Knudstrup, 2005 ; Botin and Phil, 2005).

Coupling Parametric and Performance-based Design
Parts of the design workflow in this master thesis merge Computational Design (CD) approaches, Parametric Design (PD) and Performance-based Design (PBD). The combination of such techniques allows the following:

- (i) Explore and analyse a considerable variety of design alternatives or instances
- (ii) Steer the design process towards pre-determined performance goals and criteria
- (iii) Map quantitative aspects alongside qualitative ones

Using PD, a building can be parametrically modelled; this allows for interconnectivity between different elements, which means when one element is changed, all others follow. In continuation, the method of Performance-based Design (PBD) is introduced. PBD is executed by defining goals and criteria for various parts of the building, which are then used to steer the design and evaluation of the building (Oxman, 2008). Goals are defined as the overall desired achievement where criteria are the measurable aspects of the goal.

The instantiation of the parametric model generates a design space, i.e., all the potential variations for a design. The building performance aspects of each design instance are analysed using PBD approaches. Such approaches impart manual qualitative methods (i.e., executed by the designer), design rules-of-thumb, and sophisticated digital building simulation methods. By defining performance criteria upstream, it is possible to devise a search algorithm that steers the exploration of the design space to find valid (i.e., solutions that meet the performance criteria) and designs of high-performance (i.e., solutions whose performance goes beyond criteria satisfaction) (Monks et al., 2000).

In this thesis, the evaluation of each design instance imparted quantitative and qualitative analysis. The quantitative performance outcomes are analysed either separately (i.e., one by one) or altogether by combining them into a mathematical function to be minimised, the objective function. Such functions allow automatic optimisation of different building performance aspects in a goal-oriented design method that borrows sophisticated metaheuristics from Artificial Intelligence to automate the design space search (Monks et al., 2000, Caldas 2008). Nevertheless, this thesis will use an iterative approach where the designers compare the performance outcome against predefined performance goals and criteria. This manual iterative approach allows better integration with qualitative performance aspects of the design. The evaluation of qualitative design aspects, such as the phenomenological, aesthetic, poetic, and atmospheric criteria, is exclusively dependent on the designer's appreciation, thus, being subjective in nature. Nevertheless, such evaluations are compared with quantitative simulations to minimise possible subjective bias. Sketches, drawings, 3D visualisations, 3D models, and collages are done to assess such aspects (Monks et al., 2000). The combination of PD and PBD and subsequent integration into the IDP methodology is illustrated in Fig. Xx.

ANALYSES METHODS

Literature reviews are the foundation for academic research. In this project, it serves as support to theories, provides evidence and backup for statements and building codes. Literature-Review will mainly take place in the problem and analysis phase.

Site analyses give an understanding of the context and site. In this project, site analyses will be executed in the analysis phase, and further support the decision-making in the sketching phase, which will be the foundation of the inputs in the simulations.

Mapping highlights specific elements in an area as separate layers estimated to be relevant (Corner, 1999 in Steinø, 2016). When correlating the mapping, opportunities and limitations can be derived from the data to inform the design.

Drifting investigates the genius loci of the place by walking around without having a predefined route planned (Corner, 1999 in Steinø, 2016). In this project, it results in an understanding of the place, communicating atmospheres and structures at the site.

Urban Tomography presents the natural curiosity, when visiting the site through a series of pictures or a collage guided by predefined keywords, from which atmospheres and details are registered (Krieger, 2011 in Steinø, 2016).

Climate analyses result in an understanding of the surrounding environment, especially important when designing high-performance buildings as they rely on utilising passive means.

Morphology represents how a conceptualised geometry impacts the surrounding area in both footprints and sections. To that end, a correlation between climate conditions and the shaping of the building becomes interesting.

Simulations are used to model a particular phenomenon or to predict a specific behaviour related to the building. In this project, simulations are used to describe, understand, test, and simulate different design aspects.

Physical simulations through model making provides a deeper insight of different spatialities, materiality, and the mapping of conceptual ideas into reality.

Computer simulations predict different performance aspects (e.g., thermal and visual related phenomena) of any design instance using digital computers. Such design instance can either be generated by a parametric model or manually modelled. The information obtained from the simulations is subsequently post-processed (e.g., using visual or statistical means) to provide valuable inputs to support the decision-making processes in the design.

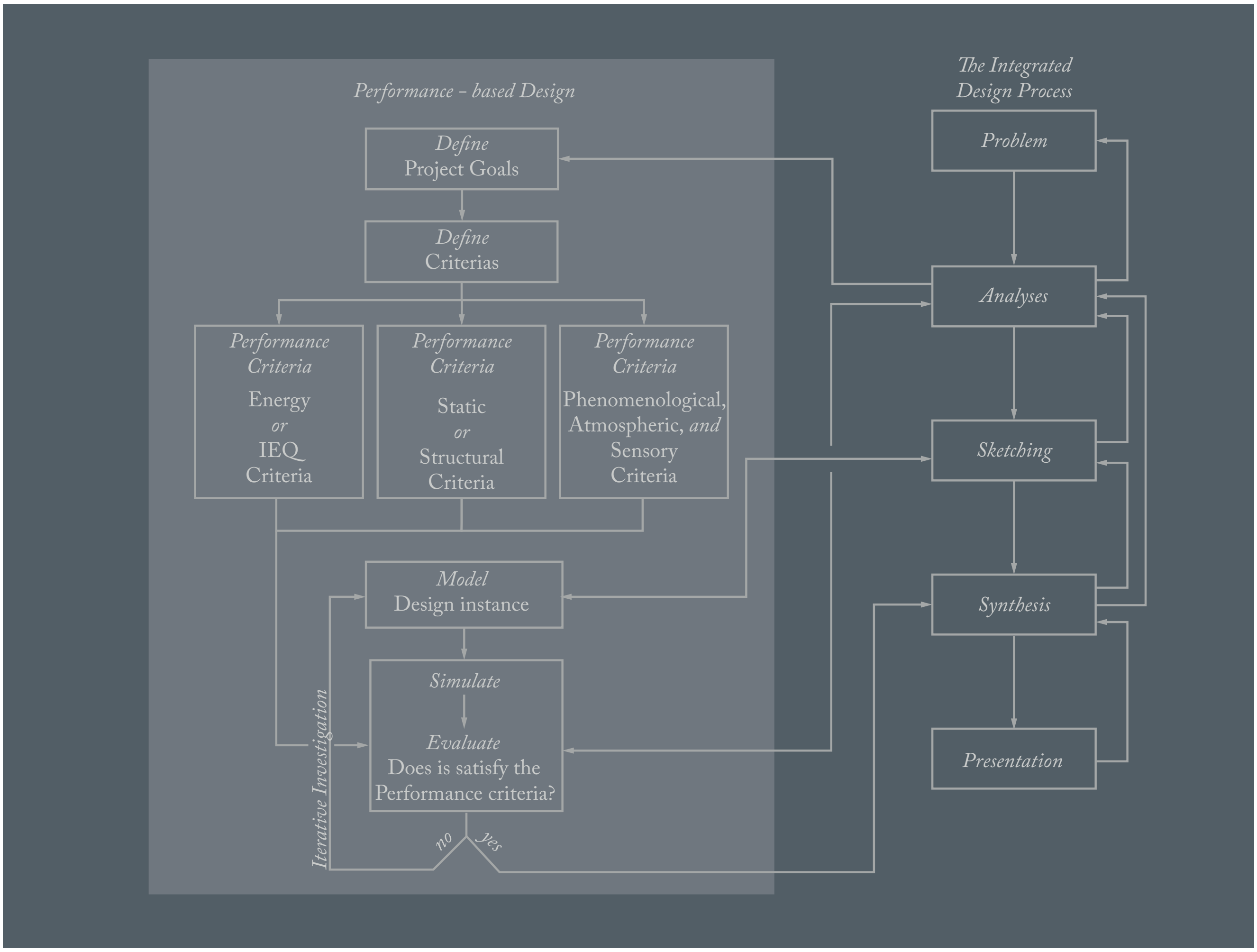


Fig. 3. Methodology diagram

INTERNATIONAL PRECEDENTS

When designing a Spa House, the intent is to design a built environment as the physical setting and likewise designing an experience. An intended use. An atmosphere. Human beings experience spaces through the body as a sensation that leads to a multi-sensory perception of the surroundings (Durie, 2005).

"One of the magical things about our senses is that they do not function in isolation. Each sense contributes to the fuller comprehension of other sensory information. Indeed, one may not even be able to understand the information from one sense properly until it can be related to information from other senses"
- (Heschong, 1979, p.24)

TThe citation from the book Thermal Delight, written by the American Architect Lisa Heschong in 1979, states the importance of stimulating several senses when experiencing architecture. Contrasts emphasise contrary qualities and evoke an inherent awareness when simply being present in the spatiality, to which contradistinction and variation contribute to the impressions accentuated in the design (Durie, 2005 ; Heschong, 1979). Hence, the transition between atmospheres can enhance the contrasts experienced in several ways, for instance, by utilising natural resources such as artificial and natural daylight: " […] I have to admit that daylight, the light on things, is so moving to me that I feel it almost as a spiritual quality" - (Zumthor, 2006, p. 61). To that end, manipulating light allows for natural light, light-filtering, colours, controlled light, defined views, depth, reflections, contrasts, highlighting light and shadows of texture, etc., as means to create a desired atmosphere.

The thermal bath Therme Vals in Switzerland exemplifies the theories of Zumthor. Inherent to the thermal bath, several IEQ principles become essential; designing with the everchanging light, material compatibility and texture, surrounding objects, level of intimacy, the sound of spaces, the temperature of a space, etc. Integrating this into the architectural setting results in an atmosphere and a first impression when entering the space. The architecture leads to a spontaneously emotional response when moving around:

"Architecture, like music, is a temporal art. That means thinking about the way people move in a building […], an example, in connection with some thermal baths we built. It was incredibly important for us to induce a sense of freedom of movement, a milieu for strolling, a mood that had less to do with directing people than seducing them."
- (Zumthor, 2006, p.41)

Therme Vals
Therme Vals includes a hotel and a spa built over the thermal spring in Graubunden Canton, Switzerland, see table 1 and fig. 4. A curved tunnel frames the access from the hotel to the spa area, a transition that permits a slow pace as the sound of trickling water becomes clearer (Ryan, 2015).

The spa facilities are inspired by a cave, half enclosed by the hillside and green roofs. Local stones set the physical frame and state an authentic atmosphere of the natural surroundings shaping a unique sensory perception of the space. Shafts in the celling allow streaks of sunlight from above to enter, from which

	Therme Vals	New Royal Bath
Location	Graubunden Canton, Switzerland	Bath, United Kingdom
Architect	Peter Zumthor	Nicholas Grimshaw
Area	approx. 3360 m^2	3650 m^2
Completion	1993-1996	2000-2006

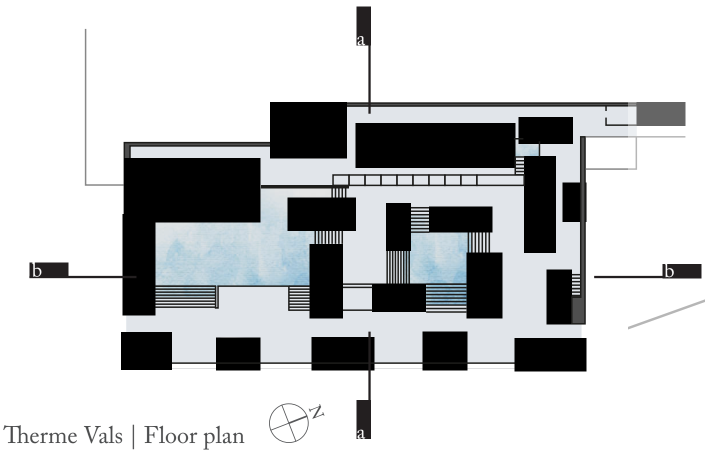
Facilities	Hot room 42 deg., indoor pool 32 deg., outdoor pool 36 deg. Stone Island, Stone terrasse, Fountain grotto 36 deg., fire bath 42 deg., Cold bath 12 deg., flower bath 30 deg., rest spaces, massage, outdoor shower stone, etc. Changing facilities.	Basement – Hot Bath, 1st Floor – Arrival, shop, and Minerva Bath, 2nd floor – Changing suite and Café/Restaurant, 3rd floor - Massage suite, 4th floor – Steam Room, 5th floor/Rooftop – outdoor swimming pool (Grimshaw, n.d.).

Table. 1. Cases | Information

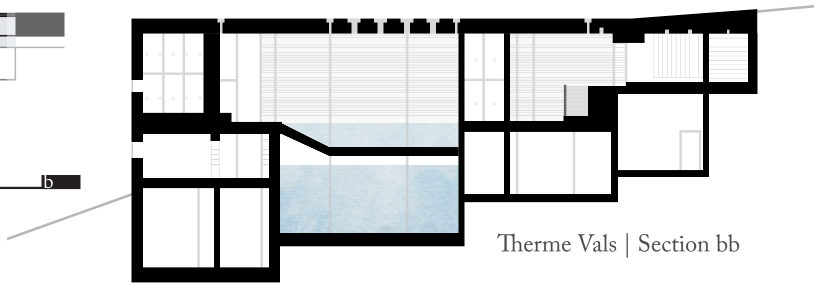
elements of light interpret zones and directions. The architecture defines pre-determined areas to explore, guided by circulation and controlled views, to which a combination of light and shade, open and enclosed surfaces emerge as embedded qualities of the spatial experience (Ryan, 2015 ; ArchDaily, 2009).

The monolithic expression of stone surfaces leads to a private atmosphere and an exploring approach when navigating at the thermal bath. Aspects that imply a focus on introvert facilities and enclosed, sheltered spaces, which requires an attentive mind when moving along the hallways and the in-between spaces. The linear design is based upon rectangular introvert blocks orthogonally arranged, from which the enclosed functions become the loadbearing element for the cantilevering roof with varying ceiling heights. This structure combines the aesthetical, functional and technical dimensions of the design, as an immanent gesture of the architecture.

Besides, differences in ceiling height and floor levels permit sequences of volumes, from which spatial contrasts are explored to emphasise the individual spaces and their functions, e.g. warm and cold rooms and baths, changing facilities, outdoor pools and shower stones, etc. Playful water surfaces become intensified in terms of a variation in the smoothness of the polished stones. Contrary to the heavy and massive surfaces of concrete and stone, the leathers and mahogany add lighter structures to the building design, and the detailing in bronze, such as handrails, doors, and grips, with a metallic glow, contrast the rough settings (Ryan, 2015).



Therme Vals | Floor plan



Therme Vals | Section bb

Therme Vals | Section aa

Fig. 4. Therme Vals

New Royal Bath
Unlike the horizontal floor plan of Therme Vals, characterised by a spatiality created in-between volumes, the plan structure in New Royal Bath is defined by several levels in a vertical constellation, as illustrated in fig. 5.

The vertical structure permits a flow that results in a different experience, when the transition from one level to another requires an active and conscious action from the visitor. The internal motion is directed by a continuous hallway, from the entrance in the ground floor to the rooftop. The controlled shifting between the facilities empowers a controlled but nuanced experience of contrasting facilities.

New Royal Bath is a restoration project that connects five existing historic buildings, of which four are used in the plan of the thermal bath, with the main entrance from 7/7a Bath Street, Bath, UK. The individual buildings are connected by bridges and additional glass surfaces as the building envelope, adding transparency to the movement between the cultural history of the place. Besides, the modern and light glazing derives a material contrast to the old massive stone and bricks from the original townhouses.

On each level of the townhouse, the occupant finds a different sensory gest and atmosphere. The 1st floor is supplied by the natural thermal waters beneath the city. The pool has air inlets, making the water guide the occupant while floating. The second floor consists of changing rooms and a small café.

The third floor is characterised by wellness and niched perception rooms; a steam room with a very humid and warm environment, an ice chamber as a light, cold and dry room, an infrared room with wooden textures and slightly high temperature and dry environment, to experience showers with varying water pressure and compelling sounds in a dim-lit room. Moreover, a celestial relaxation room mimics a celestial atmosphere in a dark room with twinkling lights and an audio-video experience with pleasant pictures. The room is experienced as floating in the dark, with temperature and humidity close to the conditions of the skin. From the top floor, an open-air rooftop pool offers a view of the city and an authentic atmosphere directly exposed to the climate, unlike the controlled conditions inside (Hull, 2012).

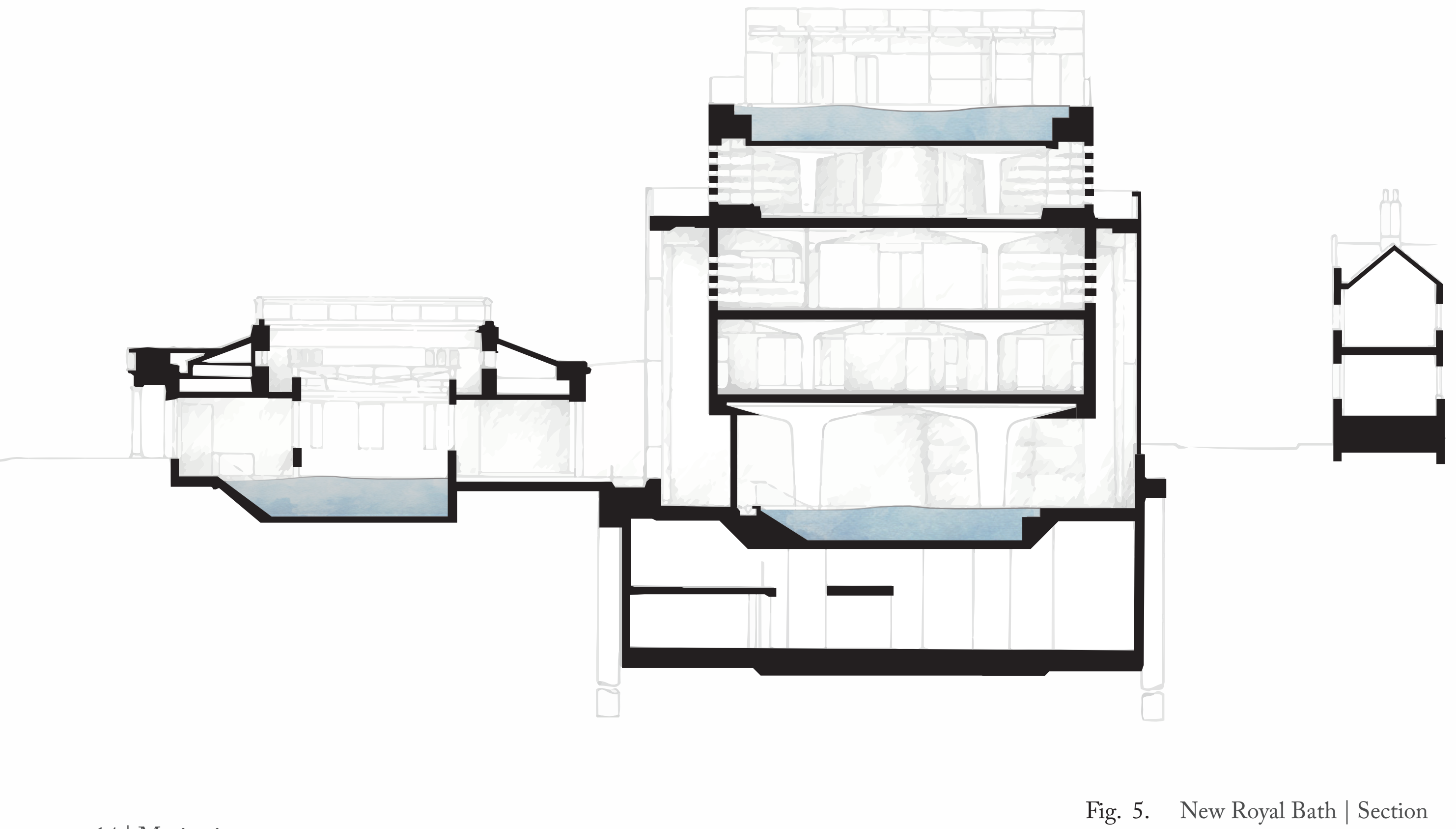


Fig. 5. New Royal Bath | Section

POTENTIAL ENVIRONMENTS

Thermal environment
In addition to the saunas found in the presented president studies, the psychrometric chart maps the conditions of several saunas to identify different experiences, comparing the indoor environment with the conventional comfort zone. The aim will be various combinations of opposed conditions of both mild and strong alliesthesia to accede a wide range of occupants. Hence, how strong alliesthesia is perceived is related to the amount of warm or cold heat stress of the body. Thus, the experienced contrast will be greater switching between strictly conditioned spaces of temperatures and/or humidity.

As illustrated in fig. 6, environmental properties will drive the design process of thermal alliesthesia by internal flows, mechanical conditioning systems, and implicit identifying rooms that might be critical in insulating needs and condensation risks.

Visual environment
Along with the thermal environment, the visual environment underlines the atmosphere and creates highlights that guide the occupant, which is poetically exemplified in Therme Vals. The use of skylights highlights textured walls and lightning up the surface to follow the narrative of being in a thermal cave.

In this thesis, light intentionally challenges the comfort zone and perception of spaces, highlights transitions, and underlines different environments. The Luminance Contrast Ratio (Lr) is used to analyse the quality of light to determine visual comfort. Lr is the lux difference between two faces. The eye perceives light from different directions differently, meaning that the Lr at which glare is experienced can be greater when the glare occurs in the periphery than in the centre of the eye. Therefore, the eye is sectioned into three sections, as demonstrated in fig. 7:

» The central zone, which is in the line of sight and close to the eye, experiences glare at Lr = 1:3.
» The adjacent zone, a cone of sight spanning from -30° to 30°, experiences glare at Lr = 1:10.
» The non-adjacent zone spans from -60° to 60°, and experiences glare at Lr = 1:20. (Osterhaus, 2009)

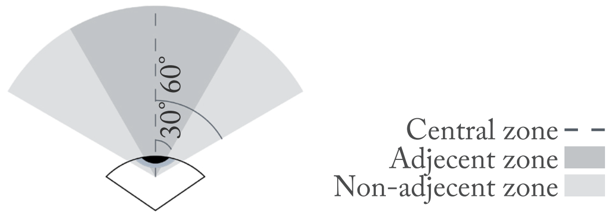
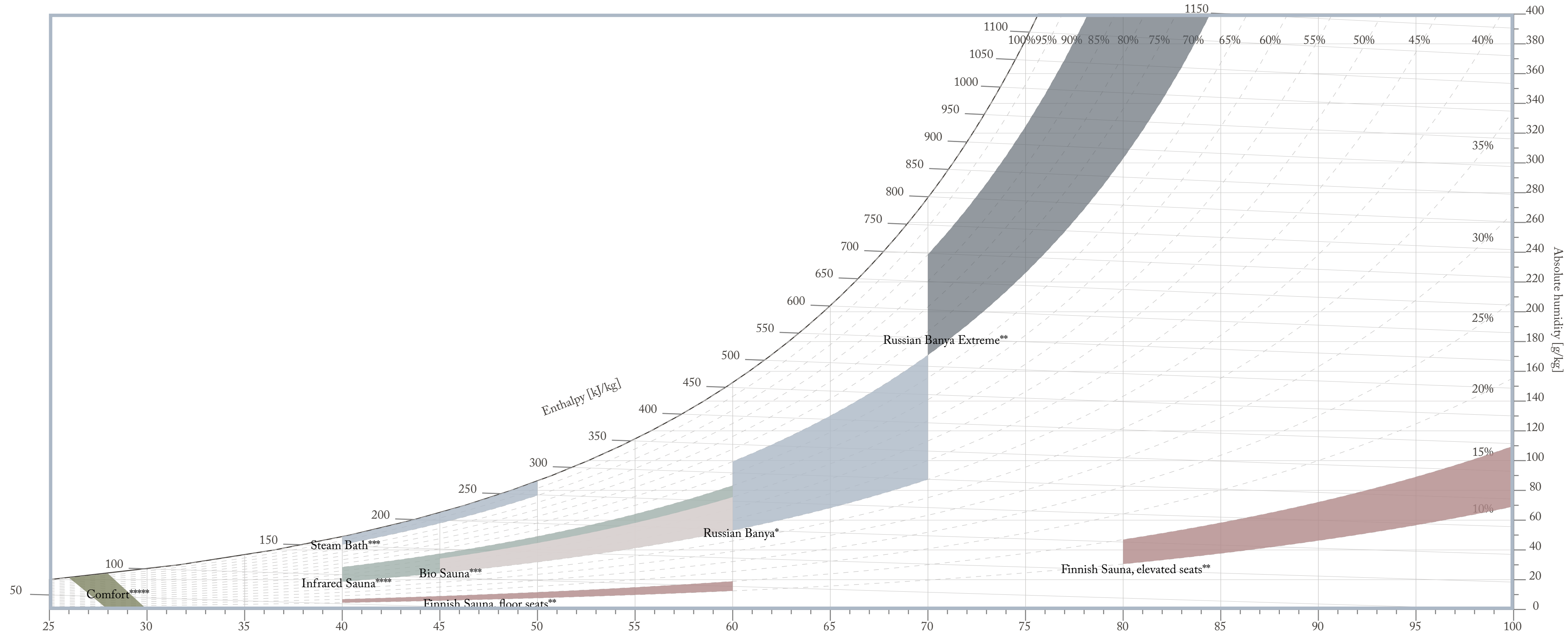
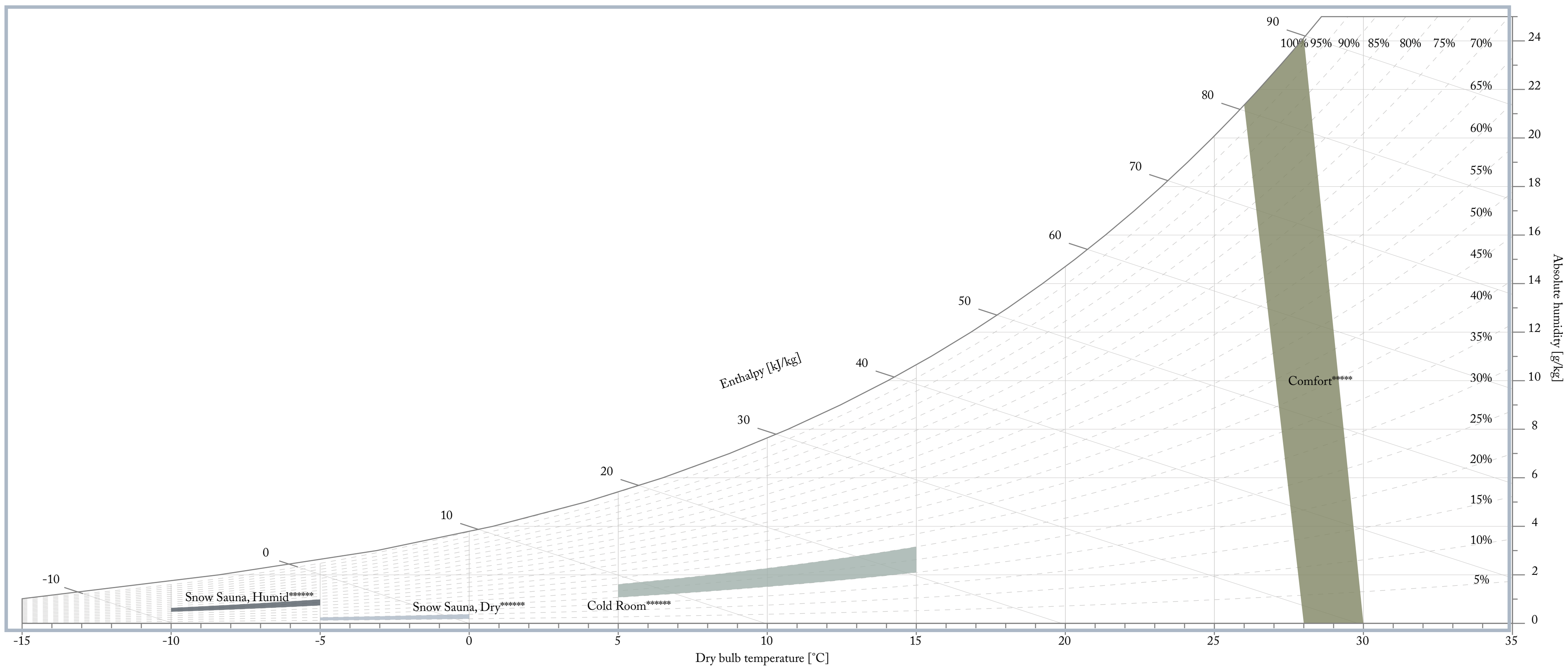


Fig. 7. Sections of the eye represented in plan



Psychrometric chart | High temperatures | *= (Banya no.1, n.d.) | **=(Homestratosphere, 2019) |***=(HaveHus, nd.) | ****=(InfraredSauna, 2021) | *****= (Tartarini et al., 2020)



Psychrometric chart| Low temperatures | *****= (Tartarini et al., 2020) | ******= (Banya no.1, n.d.)

Fig. 6. Psychrometric chart

DANISH PRECEDENTS

After the oil crisis in the 1970s, the Danish energy policy focused on pricing and supply security. Later, the emission of greenhouse gasses was implemented in the policy. Today the goal is to have a secure and stable energy supply while aiming to be independent of fossil fuels by 2050 (Jensen, 2016). This ambitious goal has pushed Denmark to evolve the use of renewable energy sources and decrease the energy consumption.

The energy consumption in buildings accounts for almost 40 % of the total energy consumption in Denmark. This energy is primarily used for heating, ventilation and lightning (Energistyrelsen, 2016). Therefore, to reach the 2050 goal, it is necessary to improve the energy frame in buildings and introduce a greater amount of renewable energy sources. Therefore, to keep up with the development, new buildings should focus on passive strategies for heating and cooling and utilise the local conditions for harvesting energy.

A spa requires massive amounts of energy for heating and electricity. The energy demand depends on the size of the facility, but a general rule of thumb is that a third of the energy consumption is due to heating and pumping around domestic hot water and pool water (Teknologisk Institut, 2015). From an environmental point of view, a Spa House may seem unnecessary and a waste of energy and resources. However, from a social perspective, a Spa House can facilitate an innate need for self-actualisation in a modern society where most people have their basic physiological needs fulfilled in form of food and security. According to Maslow's theory of human motivation, this liberates dormant perceptual, intellectual and learning capacities that seek to gain a higher understanding of oneself (Maslow, 1943). Only here people are willing and able to explore themselves and challenge their comfort zone. A Spa House can set the scene for new social connections for individuals lacking a feeling of belonging. People with similar interests or backgrounds can meet and interact across ages, occupations, and abilities. In sum, a Spa House can help develop the individual through self-exploration and social interactions and thereby create a social cohesion that enhances the social sustainability of an area (Stender and Walter, 2019).

AIRE

According to futurologist Liselotte Lyngsøe, people use wellness experiences as periodic breaks from their everyday lives. She predicts that wellness in the future will focus more on the mind through spirituality. However, today most spas follow the same design principles, meaning that you cannot differentiate if you are in a spa in Denmark or New York (Varming, 2015). An example of a non-location specific spa is the Aire Ancient Bath, see table 2. A Spanish-based company that operates luxurious spa facilities inspired by the old roman bath culture, placed in older, industrial buildings (AIRE, nd.). The spa in Copenhagen is placed below Maltmagasinet in Carlsberg Byen, which has been a central element in the Carlsberg Brewery containing Ny Carlsberg Bryghus, the technical section and malt storerooms (Carlsbergbyen, 2020).

All Aire spas are created with the same design principles. In Copenhagen, the spa is carefully adapted to the existing structures of the building's basement and its qualities. The new spa's smooth texture contrasts and enhances the old, coarse brick walls and arches. The underground location creates unique possibilities to control the light and visual atmosphere of the spaces. Here the pools have a compelling blue hue that

	AIRE Ancient Baths	Romulus
Location	Ny Carlsberg Vej 101, 1799 København V, Denmark	Part of Skallerup Seaside Resort, Feriebyen 915, 9800 Hjørring, Denmark
Architect	Arkitema	Finn Østergaard
Area	approx. 1800 m^2	600 m^2
Completion	2017-2020	2005
Facilities	Different pools ranging from 6, 16, 36 and 40 degrees, salt water pool, jet pool, steam bath and massaging room. Signature treatment – red wine bath and beer bath (beer due to the location) (Arkitema, nd.), (AIRE, nd.).	Four thermal baths on resp. 28°C, 34°C, 36°C and 38°C. Cold water bath and outdoor hot water pool. Sauna, steambath and sensorysaunas. Resting lounge and water massage (Skallerup, nd.)

Table. 2. Thermal baths | Information (Arkitema, nd.), (AIRE, nd.), (Skallerup, nd.).

illuminates the blue tinge of the concrete ceiling. To contrast the cold tone of the rooms, candlelight and lamps with a warm tone is used along the brick walls. The placement of the warm lightning accentuates the roughness of the bricks while providing a warm and relaxing atmosphere, see fig. 8.

ROMOLUS

Another spa that tries to relive the Roman bath tradition is Romulus at Skallerup Seaside Resort. Here it is a more literal translation where the interior imitates old roman structures. The unexpected interior pulls visitors out of their everyday routines and thought patterns when entering Romulus. Contrary to the Aire Ancient Bath, Romulus utilises its location in its spa experiences. Here an outdoor heated pool exposes the visitors to the elements and thereby experience thermal alliesthesia. At the same time, the pool is slightly elevated to create a view of the ocean and sand dunes. Therefore, despite the roman inspired interior, Romulus still offers a Danish spa experience by using its local surroundings and climate.

HEATING STRATEGIES

A spa will undoubtedly have a high heating demand for both space heating and heating of pool water. Both solar collectors and heat pumps can utilise the local conditions, while renewable energy sources can produce electricity for running the pumps. However, solar collectors are most efficient during the summer half of the year, which leaves a gap in the heat supply in the winter when it is most needed (Bejder et.al., 2014). Therefore, a solar collector system cannot be a standalone heating system as a second heating strategy must assist it. Skallerup Seaside Resort uses thermal collectors combined with an automatic stoker for heating their main building and the pool water in the aquapark and wellness area, Romulus (Skallerup Seaside Resort, nd.).

Contrary to solar collectors, a heat pump can be used all year. The aqua park, Lalandia, uses a heat pump connected to a nearby tap water pipe. By cooling the water from 7-9°C to 3°C, enough energy is produced to heat the pool water to 65°C (Sweco, 2021). Different types of heat pumps can utilise different heat sources for space heating and domestic hot water (DHW). Furthermore, when reversed, a heat pump can be used for cooling (Danfoss, 2012).

Fig. 8. AIRE | Atmosphere

SUB
CONCLUSION

This project is about designing experiences enhanced by contrasts, to which indoor environmental qualities become essential. Therefore, when creating a sequence of opposites, computer simulations and poetic dimensions of a space should be merged to shape a desired atmosphere. To that end, thermal, luminous, acoustic, spatial and social alliesthesia will be decisive when designing a Spa House that should be characterised by a multi-sensory perception of the space, the setting around and the experience of moving between functions.

Although the project is expected to be expensive because of materials, use of square meters and expected features, the project will accede qualities of social sustainability. The building must be concerned about integrating renewable resources to produce energy, such as artificially heated domestic hot water. Besides, embedded gestures of the architecture state holistic experience when combining aesthetical, functional and technical ideals to the spa.

LOCATION

Ill. 4. Boat at Dok Øst

LOCATION

The east half of Aalborg appears to be most evident for locating a Spa House, based on the investigations of activities and structures closest to being competitive, as shown in table 3 and fig. 10. Stigsborg and Østre Havn are estimated to have potential because of the orientation and the context, respectively.

Østre Havn is close to Aalborg midtown and the newly developed square Stjernepladsen nearby and permits the longest views along the curved fjord, including a view toward the future Stigspark, visualised in fig. 9. Besides, this location state an existing context, with the feature of having water on three sides. Stigsborg has a great potential for utilising solar radiation but no enacted plan for a future context.

Østre Havn
This master thesis takes place at Østre Havn with references to the industrial and cultural history of the place. Østre Havn, close to the centre of Aalborg, is under development, to which the Pier becomes a natural extension of the harbour front. The basin houses existing informal activities, such as the Cable Park, SUP-boarding, free swimming and winter bathing, whiteout a built structure to facilitate the activities. To embrace both present and future activities, the Spa House must accommodate the diversity in user groups of the basin, creating spaces for the informal and active segment, as well as luxurious and relaxed spaces.

The Stigsborg area north of the fjord is in the early stages of development, and since an additional connection between the two harbour fronts is planned close to the project site, it might be relevant to consider cooperation across the fjord. It is being discussed to establish a canoe park on the north side, which potentially could act as one of two poles, connecting the activities at Østrehavn with Stigsborg. Such connection should embrace the differences in both spaces regarding activities, functionality, etc. and strengthen their individual concepts, and pull the two harbour fronts closer together

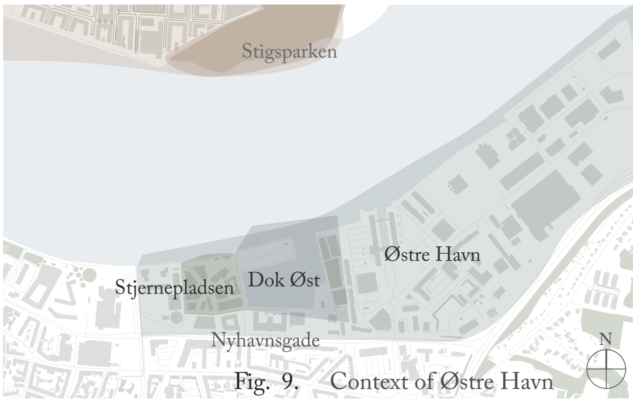


Fig. 9. Context of Østre Havn

1. Vestre Fjordpark
- Open-air swimming pool
- Bathing jetty
- Diving board
- Sauna
- ”Beach”
- Sunbathing
- Children area
- Playgrounds
- Kiosk
- Clubs
  - Sea kayak
  - Swimming and diving
  - Winter swimming

2. Aalborg Havnebad
- Open-air swimming pool
- Bathing jetty
- Diving board
- Sauna
- Sunbathing
- Playgrounds
- Kiosk
- Clubs
  - Winter swimming

3. Haraldslund vand og kulturhus
- Swimming pool
- Kids pool
- Hot water pool
- Cold water pool
- Outdoor pool
- Outdoor shower
- Infra-red-sauna
- Sauna gus
- Spa
- Massage
- Fitness
- Clubs

4. Østre Havn
- Open-air swimming pool
- Diving board
- Winter swimming
- Outdoor shower
- Sauna
- Clubs
  - Cable park

5. Harmonie spa
- Beauty treatment
- ”Spa”
- Massage
- Light therapy

6. Nørresundby Idrætcenter
- Swimming pool
- Kids pool
- Hot water pool (in .&Out.)
- Cold water pool
- Sauna gus
- Sauna panorama
- Steam bath
- Cafeteria
- Sport
- Clubs

7. Svømmeklubben Nord
- Swimming pool (competition)
- Clubs
  - Swimming (aalborg)

8. Gigantium
- Swimming pool
- Kids & baby pool
- Hot water pool
- Cold water pool
- Infra-red-sauna
- Low temperature sauna
- Family sauna
- Finnish sauna
- Sauna gus
- Steam bath
- Spa
- Fitness
- Sport
- Clubs
  - Swimming

9. Sofiendal svømmehal
- Swimming pool (competition)
- Clubs
  - Swimming (aalborg)

Table. 3. Competing functions | In Aalborg

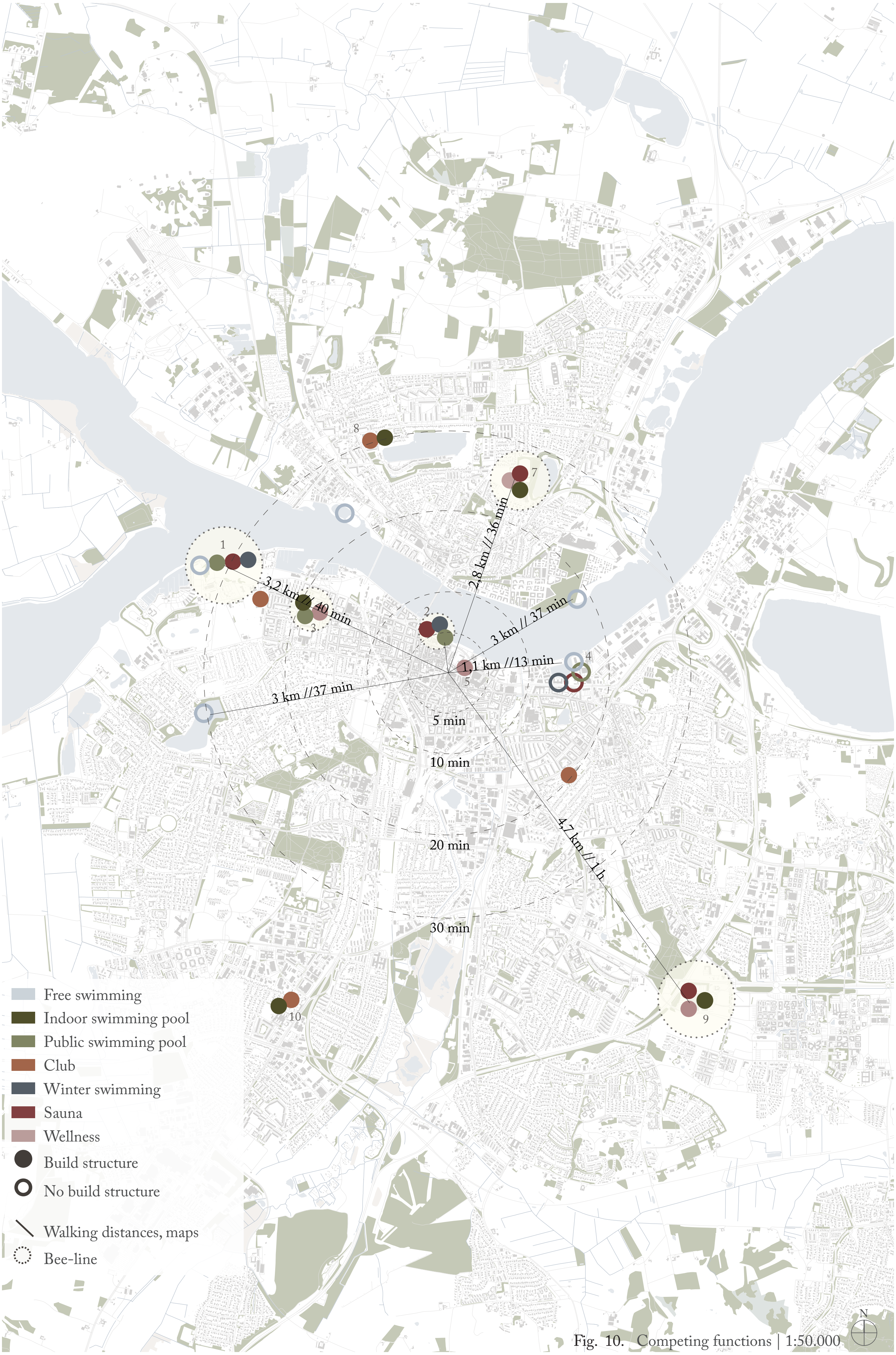


Fig. 10. Competing functions | 1:50.000

THE HISTORY OF DOK ØST

he cultural history of Dok Øst is today represented by preserved renovated buildings, old relics and original train tracks that reflect movement and previous work processes at the Pier, see fig. 11-12. Those relics on-site are two existing structures; an old control tower that registered and helped ships when passing by, and a metal structure that off-loaded grains from the ships.

The footprint of the original buildings of the factory at the Pier was shaped with the train tracks directly connected to Stjernepladsen and the harbour front. The connection indicates the workflow of the time that assumably has always been occupied by workers. The Dok Øst furthermore used to house common activities outside work hours, such as water polo with numerous spectators, to which the Pier became a gathering place for the citizens in Aalborg (Aalborg Stadsarkiv, 1914).

When redesigning the Pier, it has the potential to utilise the connection between renovated buildings and redeveloped areas that creates cohesion based on the common industrial background. Besides, recreating the activity and social purposes of the Dok will be inspiring when designing a Spa House close to the inner Aalborg.

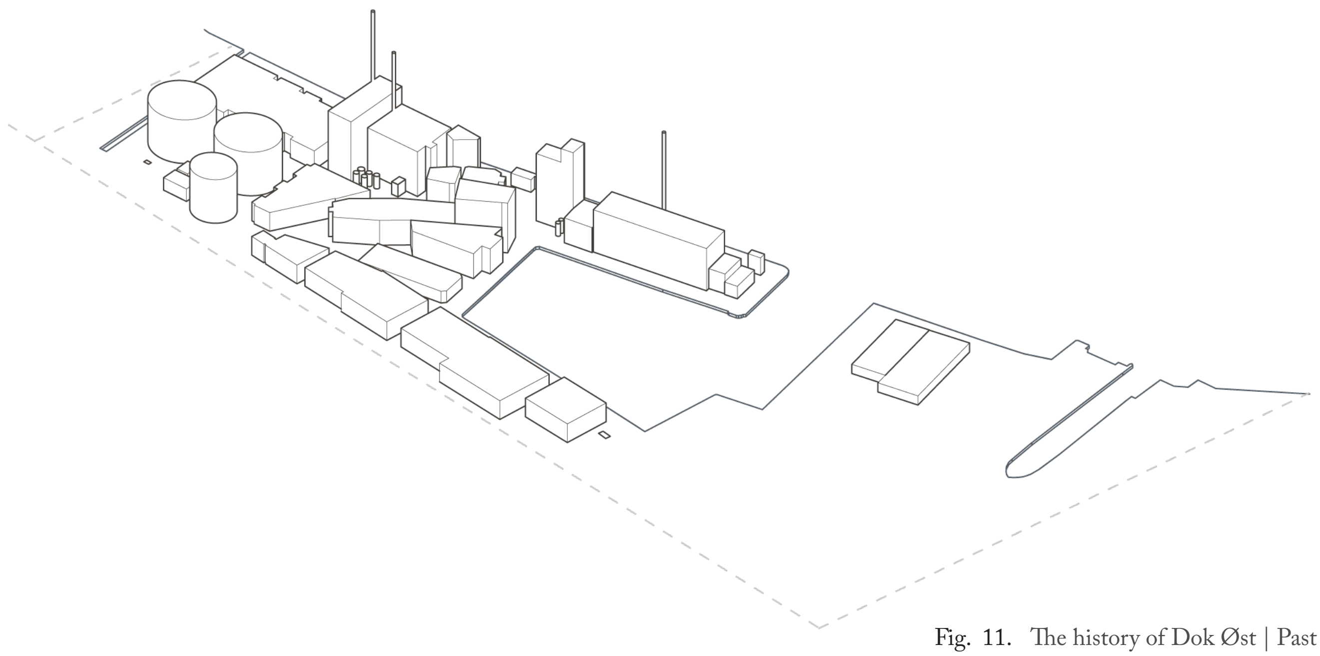


Fig. 11. The history of Dok Øst | Past

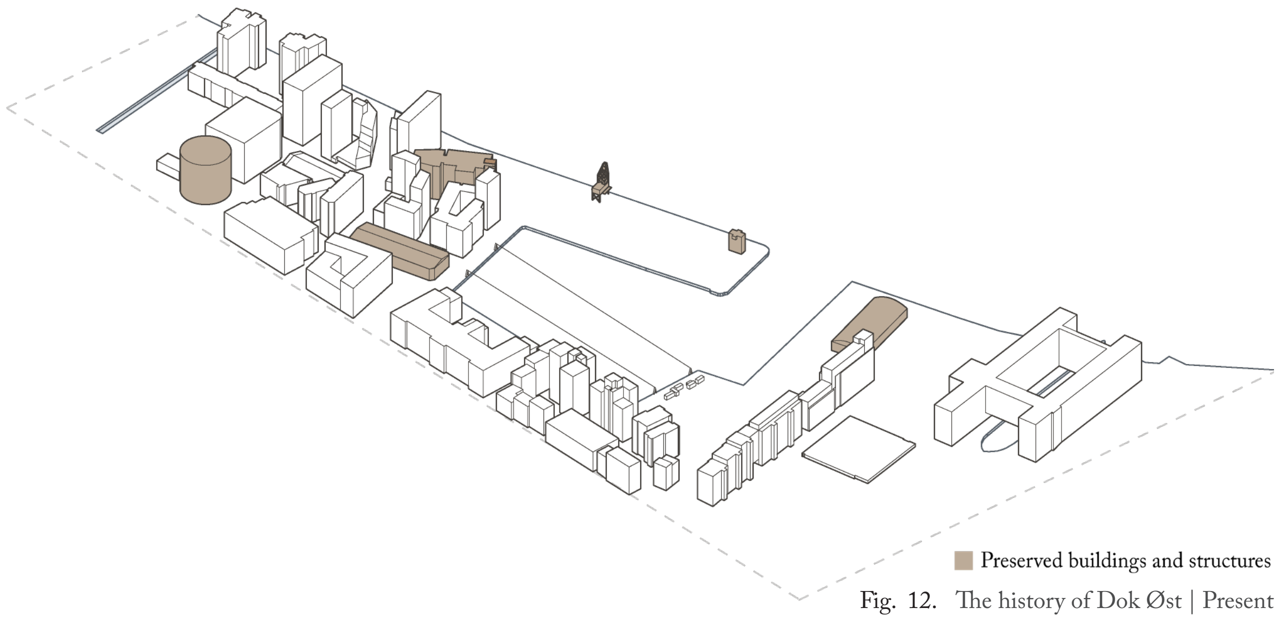


Fig. 12. The history of Dok Øst | Present

LOCAL PLAN

"The individual buildings plots are preferably designed as sculptured blocks" - (Aalbrog Byråd, 2017).

The local development plan requests one or more building volumes sculptured and shaped to follow the varying skyline inspired by the industry, to which the Pier is subdivided into zones with different maximum building heights, as illustrated in fig. 13-15. The plan suggests that parts of the building volume are built into the basin to embrace a close connection to the water. Besides, the old control tower and the green metal structure can be torn down if preferred; otherwise, greater restoration will be needed.

Some of the initial considerations and suggestions introduced in the Local Plan could be guiding the upcoming design process of the Spa House that integrates the intentions for the space, such as building zones and involving the Dok (Aalbrog Byråd, 2017 ; Slots- og Kulturstyrelsen, n.d.).

Fig. 13. Local plan | Industrial skyline

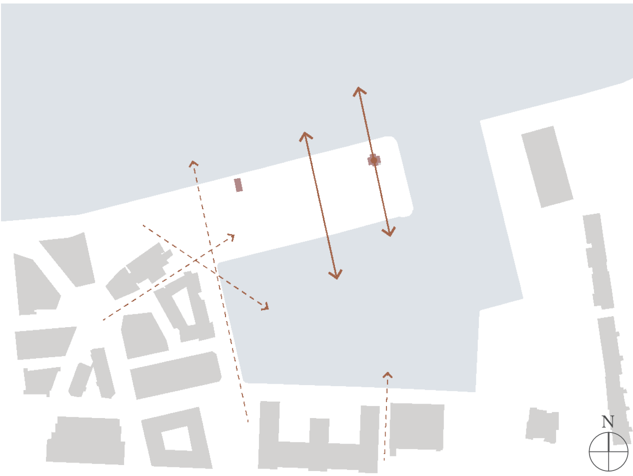


Fig. 14. Local plan | Lines of sight

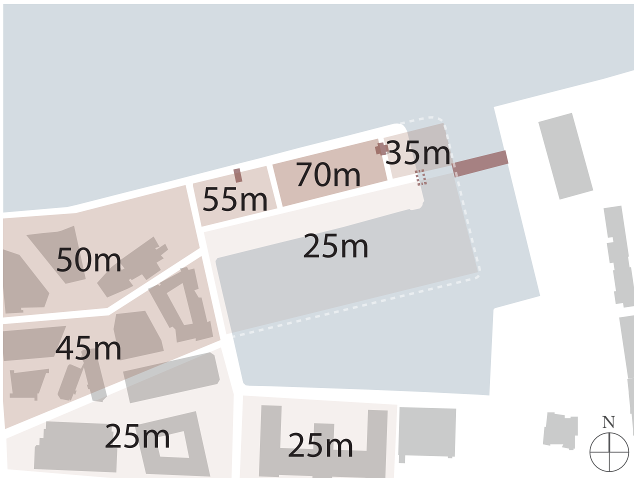


Fig. 15. Local plan | Heights

DEMOGRAPHICS & USERS

Nowadays, a tendency of increased interest in health and well-being become more common for a wide range of people, compared to previous decades when prioritising and the economic base was different. Therefore, the experience of self-indulgence appears to be relevant for a greater part of the Danes (Nielsen, 2016 ; Nielsen, 2019).

When designing a Spa House close to the inner Aalborg, it should articulate enjoyment and care with respect for the broad diversity in demographics represented in Aalborg (Klassesamfundet.dk, 2021 ; Klassesamfundet.dk, 2019).

In detail, the demographics shown at fig. 16 nearby Dok Øst inform the project to facilitate multiple user groups; *The returning spa guest, one-time spa guest, students/young, new parents, Cable Park, and Winter swimmers*. Therefore, the Pier must accommodate zones and areas for potential visitors reflecting those groups and their varying hours of use. The main occupied hours of the spa facilities will assumably be after work hours although it depends on professions and work state. However, most activity is assumably in the afternoon and evenings, besides weekends and holidays (Lederne, 2021).

To embrace such diversity, the aim is to shape spaces that by environments, embrace social differences and create room for everyone. Shared functions and overlapping hours might invite for mediation between user groups and level of formality, as represented in fig. 17-18, and thereby give the city a new place for gathering.

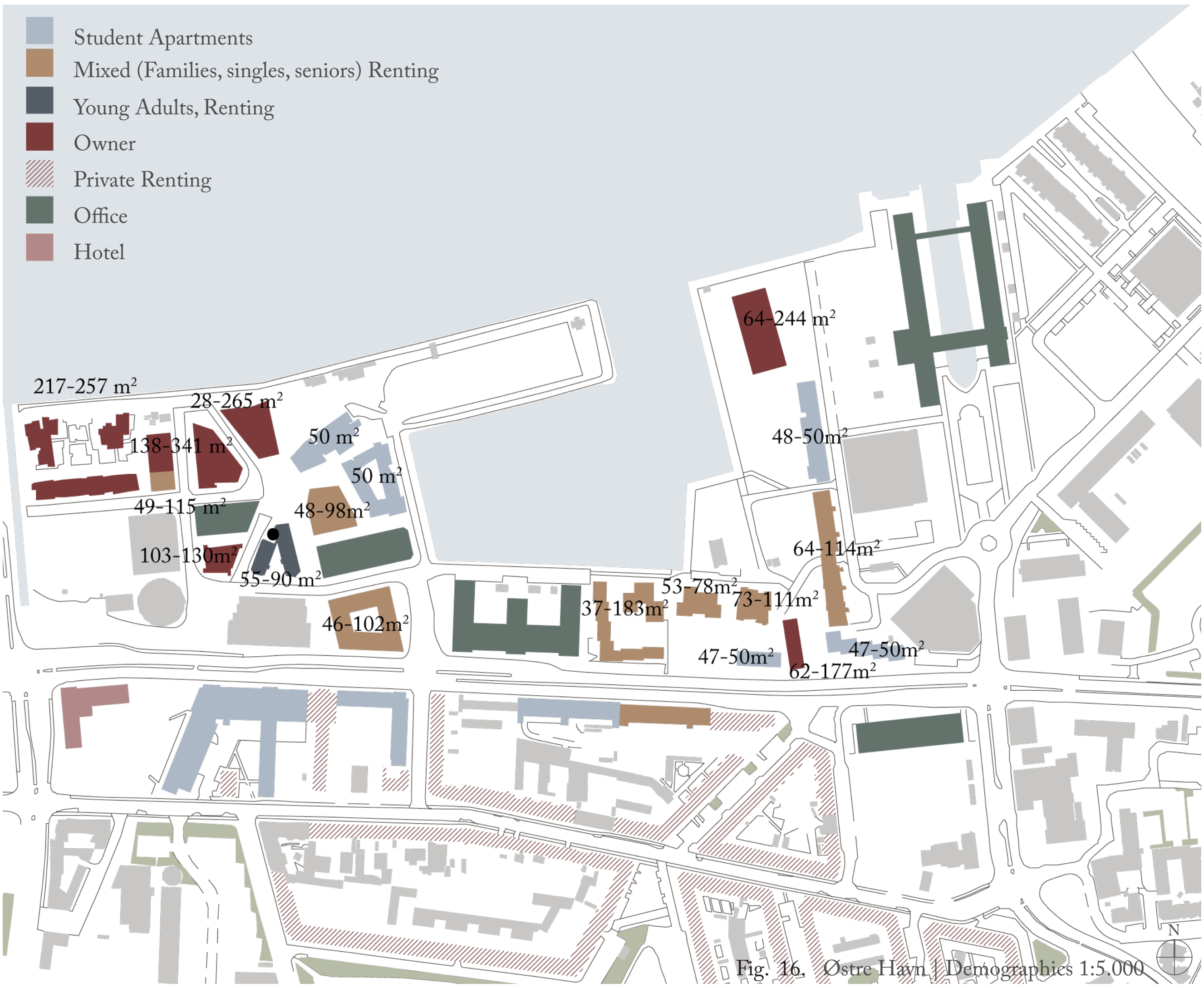


Fig. 16. Østre Havn | Demographics 1:5.000

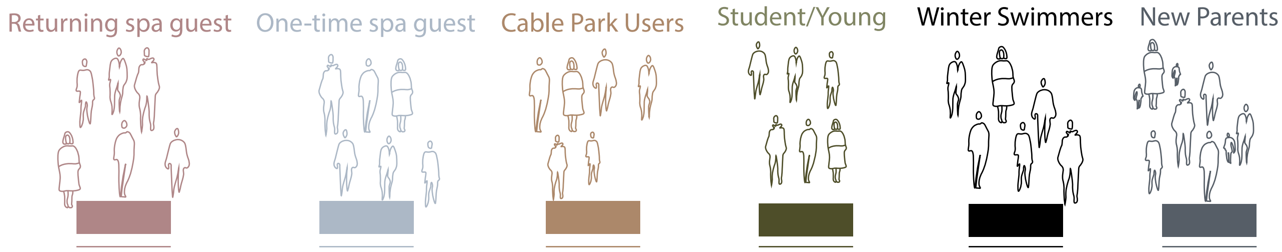


Fig. 17. User group

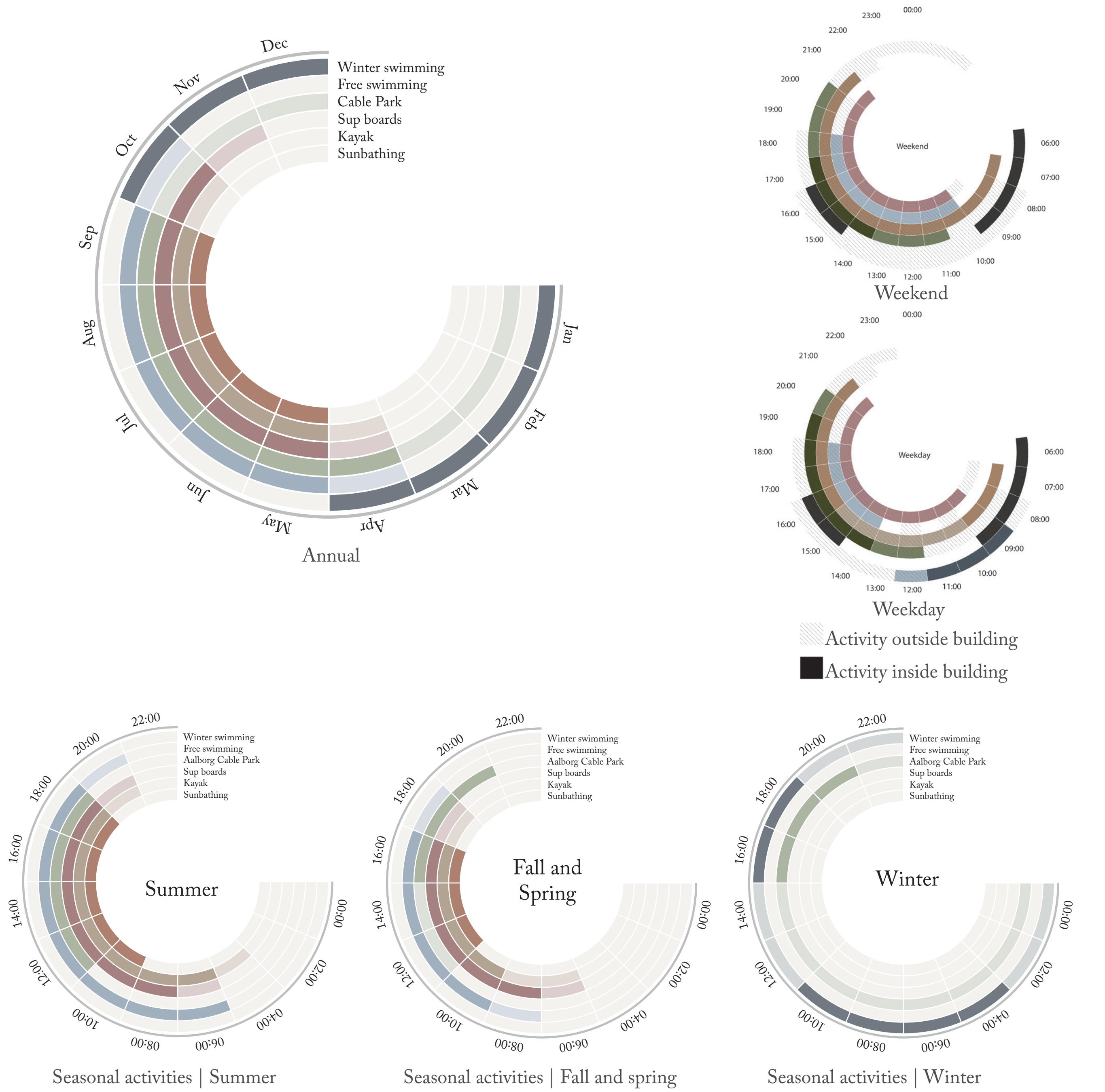


Fig. 18. Schedules at Dok Øst

SUB CONCLUSION

Østre Havn is in development characterised by both new and renovated buildings from the industrial background, which the spa must consider along with expectations from the development plan.

When activating both the Pier and the basin, the shaped environments must embrace the diversity of Aalborg as an addition to Stjernepladsen. To that end, mediation between user groups must be considered in relation to the time aspects for the outdoor space and the spa, respectively. Besides, the location has the potential to create a visual connection to water-related activities in Stigsborg, and thereby pull the two harbour fronts closer together.

SITE

Ill. 5. Context building

DRIFTING

The *Genius Logi,* the spirit of the place, at the Pier is characterised by mixed experiences. Contrasts of small spatialities and dense areas, as opposed to the open space of the Pier, and the transition between such spaces. The nearby context is marked by development and construction, in which a wide range of heavy materials, joints and compositions dominate the first impression of the place. A specific notion from the project site is movable and fluent elements referring to the cultural background of industrial purposes, which might be inspirational for the Spa House, as well as differentiating in levels and overhangs, see fig. 19-20.

A Site Visit

Walking along the harbourfront, crossing a small bridge, noticing the long views toward the east. The colour of water, the industrial skyline of Aalborg Portland, and the composition of built environments and the gaps in-between.

At the Pier, a relic from the industrial background is preserved but worn, a green metal structure with a small worn workspace hovering above the ground. Getting closer, an old slim building volume becomes visible. Damaged and abandoned. Traces of the original industrial identity of the place.

An early and windy February morning with temperatures close to 0 Celsius degrees, the wind feels cold. Exposed and unpleasant. Jackets, several layers, scarfs, gloves. Freezing. The sound of the waves and the wind drown whatever other sounds present, with only a few scattering, cracking and whining sounds from movable structures on the site. However, when visiting the site a few days later, a sunny afternoon, the experience changed. A small niche carved into the Pier is discovered, stepping down a few steps. The spot hosts a short break in the sun, observing people, silence, and space. A spot in the winter sun, feeling warm, calm and present.

A woman runs by, following the shape of the Pier.

On the Southern side of the Pier, an informal constellation of containers provide shelter from wind, as a casual meeting place furnished by pallets and drums. The informal use of containers and pallets refer to the informal setting on the other side of the basin, housing Cable Park and their basic club facilities. In relation to this, a floating plateau of wood creates a room on the water, mirroring the playful motion of the waves. Feeling connected to the movement of the water, when stepping down to the detachable structure, ad odds with the heavy appearance of the massive and solid Pier.

In the gaps between buildings of varying idioms, views are framed. Views from where glimpses of what come next invite for continuously investigating the unknown. A passage. Walking under an urban roof, a sheltered space. A sequence of spatiality; from the open air to being surrounded by surfaces and back to an unlimited height of the sky.

Moving along the path shaped by the dock observing the Pier, walking close to the big building volumes that indicate the path. Noticing the diverse context, both existing and in development, new, old or renovated. Offices, residences, student apartments, small shops, luxury residences, etc. Naturally guided back to the fjord.

Walking along the harbourfront with Østre Havn behind, crossing another bridge. Industry, history and fences. Change in purpose, change in atmosphere, change in scale.

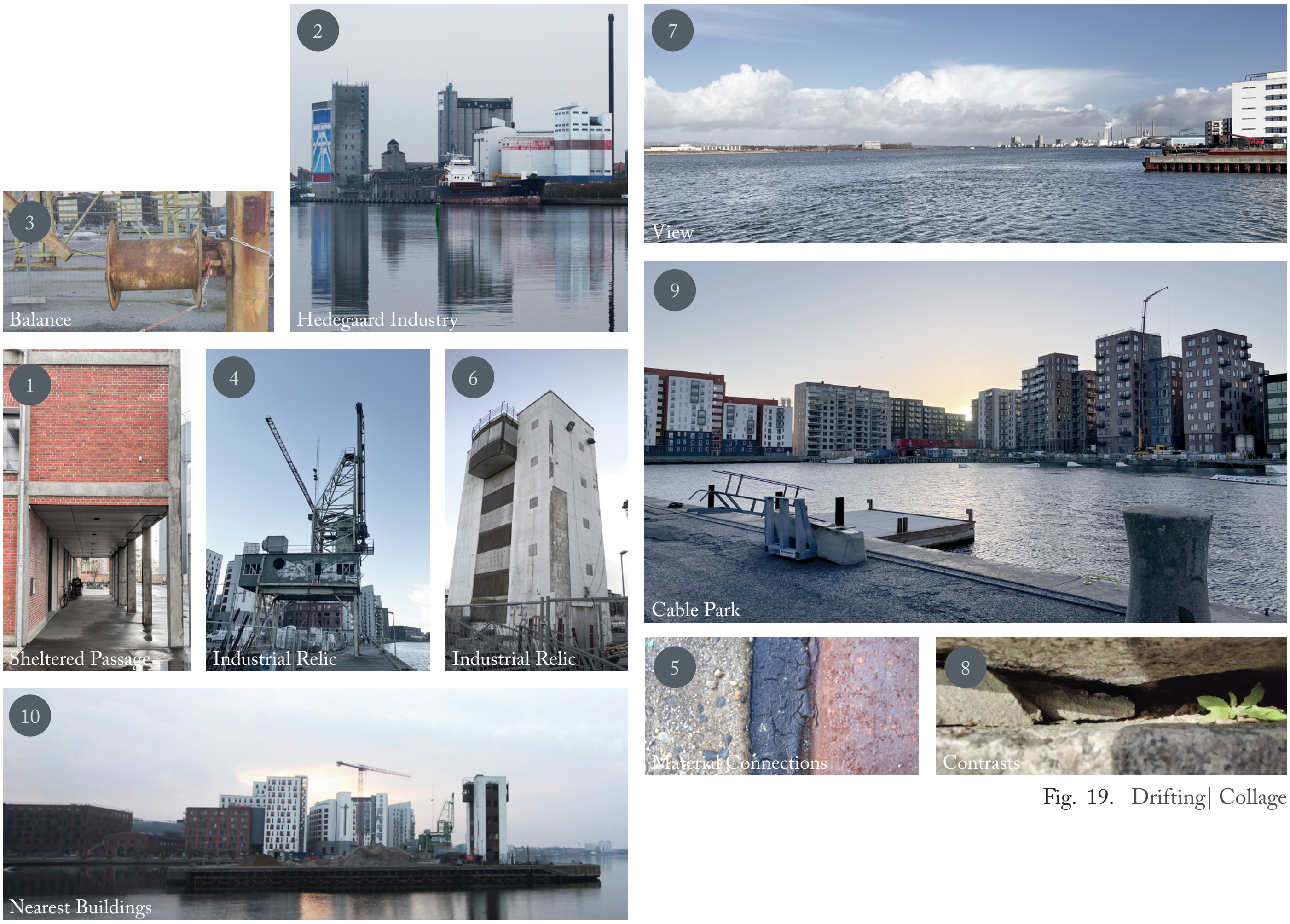


Fig. 19. Drifting| Collage

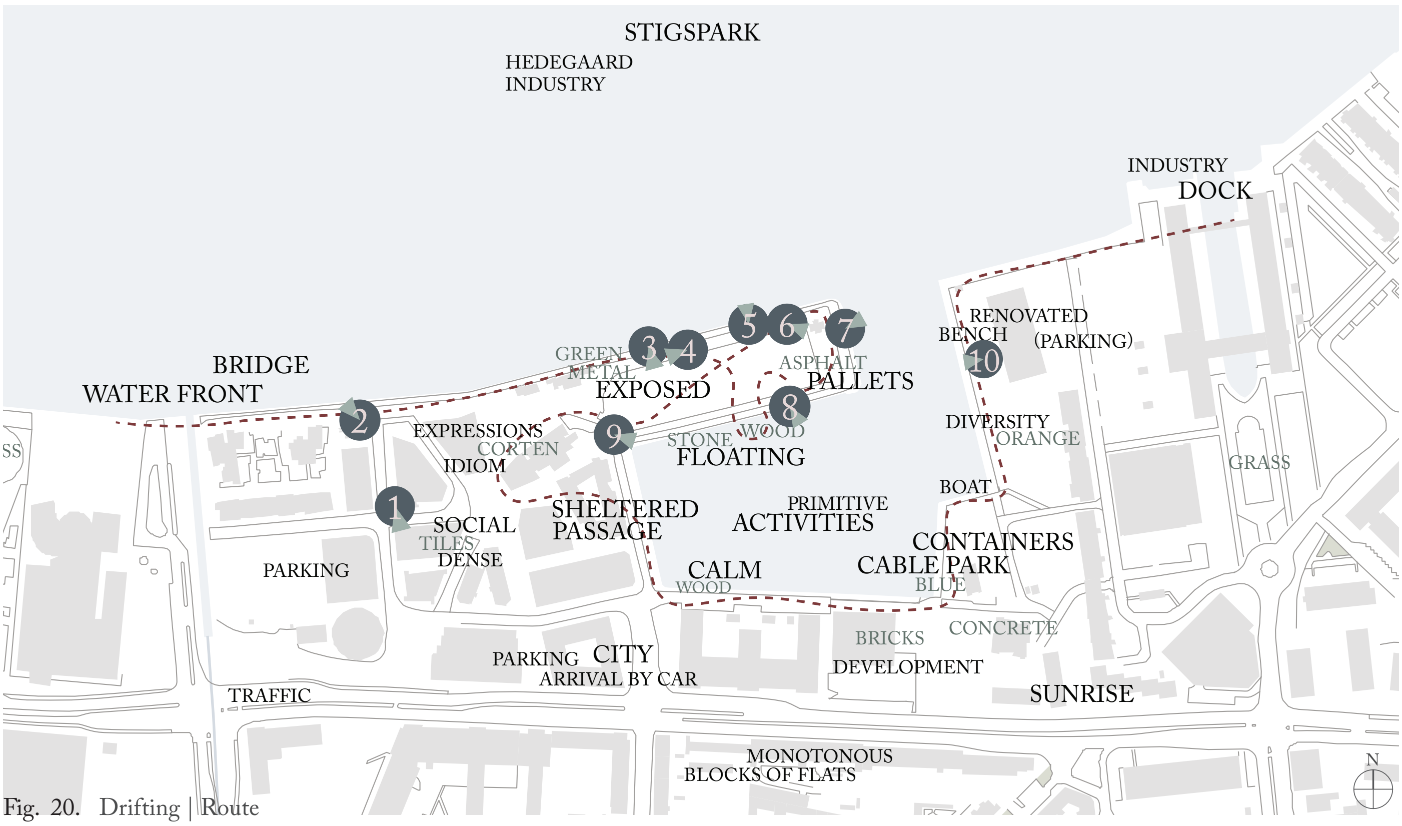


Fig. 20. Drifting | Route

AREA USAGE

Earlier Østre Havn were used mainly for industrial purposes, but with the current population growth in Aalborg, the inner city slowly expands, both now and in the future (Christensen, 2021). Therefore, Østre Havn and Stjernepladsen are being developed into an urban area, close to newly developed housing for various user groups. Many dwellings and a few offices are present near the Pier, as shown in fig. 21, which contrasts the original occurrence.

In extension to the development of Østre Havn and Stjenepladsen, the other side of the fjord is in development as well, though in an earlier stage. Nonetheless, a fjord bus is planned to connect the areas in the future, complementing the current transition of crossing the bridge.

Because of the increasing population, growth in activity levels is expected at and around the site. Furthermore, the district will have a lot of high-density zones and only a few planned green areas. For that reason, it would be beneficial for both the area nearby and the approach of the Spa House, to design a park that shapes an open outdoor space while stating the arrival of the building, and thereby preserve one of the last free spaces close to the inner city.

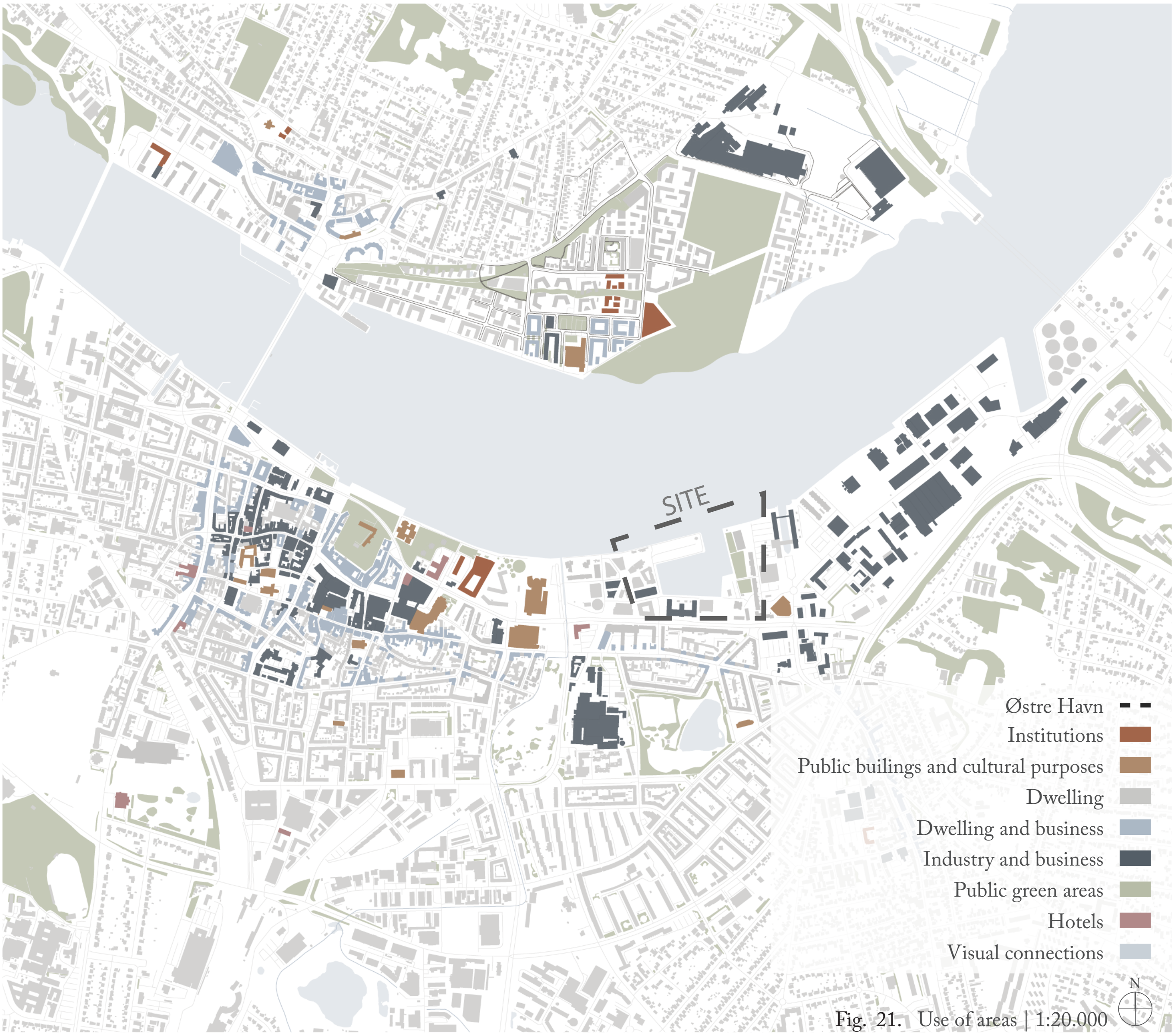


Fig. 21. Use of areas | 1:20.000

THE HARBOUR FRONTS

Østre Havn is a natural extension of the harbour front of Aalborg. From Vestre Fjordpark to Musikkens Hus, the harbour front is characterised by multiple gathering points and historical as well as modern icons, demonstrated in fig. 22. Vestre Fjordpark and Jomfru Ane Park attract people during the year because of their facilitated activities such as swimming and sports. A main distinction between the two is that Vestre Fjordpark facilitates spaces for different water-related clubs, while Jomfru Ane Park partly is an informal transit area. People walk down the harbour front through Jomfru Ane Park, which offers various sheltered seating possibilities. Therefore, a stay at the park is not always planned, contrary to a stay at Vestre Fjordpark.

Østre Havn permits an opportunity to create a new gathering point in the east half of the inner city that may complement and pass on qualities from Vestre Fjordpark and Jomfru Ane Park. Another mean to extend the harbour front could be the sequence of existing landmarks and icons, related to different time periods and activities. Besides, an additional icon placed at Østre Havn could then act as a visual bridge to Stigsborg, strengthening the connection between the two poles.

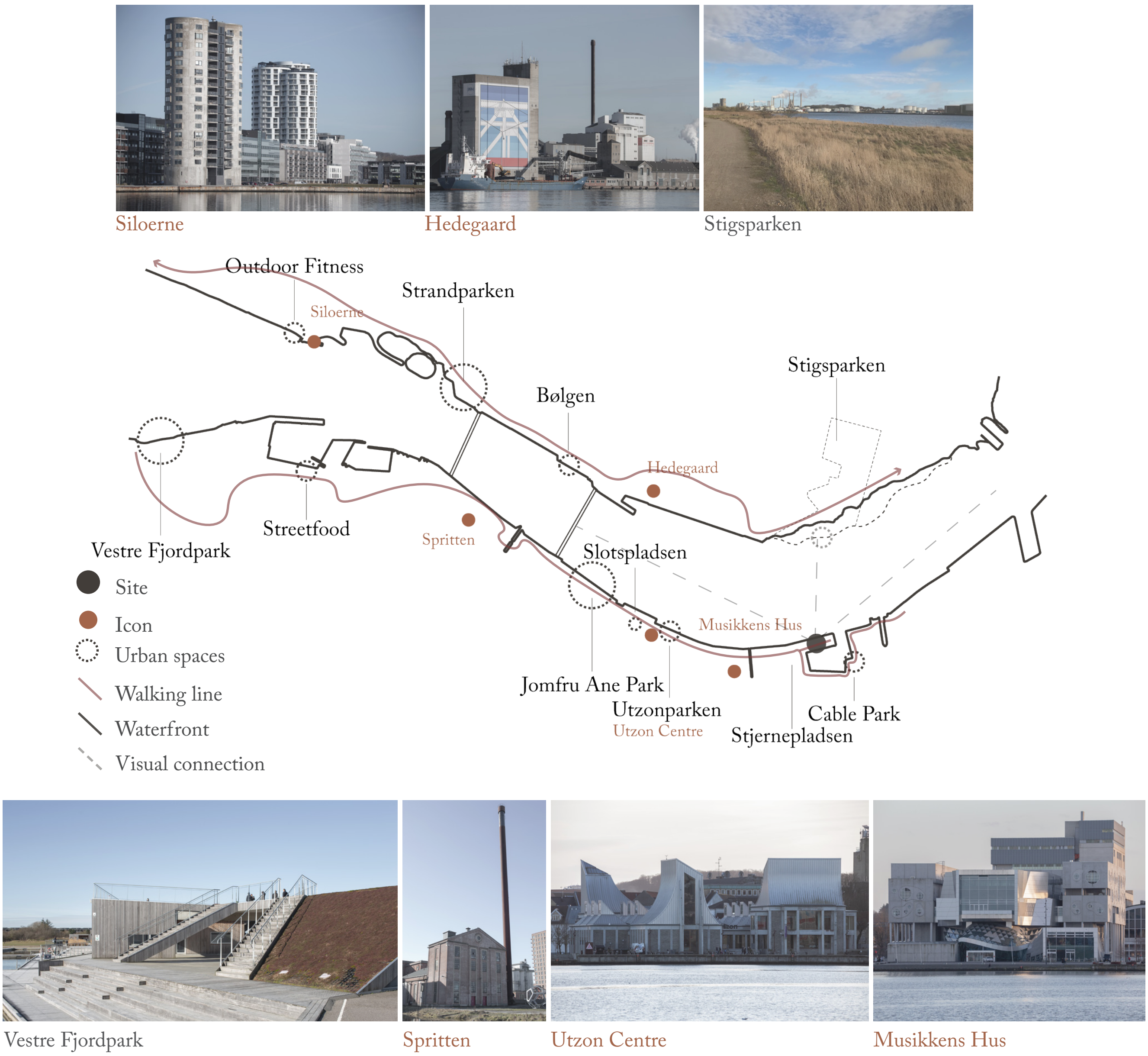


Fig. 22. Gathering points and icons at the two harbour fronts

Fig. 23. Infrastructure | 1:20.000

INFRASTRUCTURE

The site is within walking and bike distance from Aalborg midtown. For instance, fig. 23 illustrates that it takes approximately 20 minutes to walk from either the pedestrian street or one of the train stations to the site. Besides, the extremities of Aalborg are well connected to Østre Havn by public transportation and mobility, as multiple bus routes pass by the site. The freeway and neighbouring parking zones make it possible to get to the site by car, thereby increasing the range of visitors.

As investigated in fig. 24, a potential bridge across the basin would continue an undisturbed flow along the harbourfront leading the flow either past or through the site, assumable including a fast flow of cyclists. Without a bridge, parts of the Pier might, to a greater extent, invite for staying and low pace. However, when adding a building to the Pier, the volume must either be shaped by the flow, or the flow will be shaped by the volume. This should be considered concerning the varying flow observed at the site and the expected flow in the future.

To embrace the free space close to the inner city of Aalborg, a low pace and stayings are preferable. How people then interact with the building by walking to or around it, depends on its placement and form. For instance, it leads to different invitations and experiences, whether strolling past, under or above the volume. Therefore, it should be considered how the building responds to the flow of the site; what parts of the current flow the Spa House seeks to enhance or redirect.

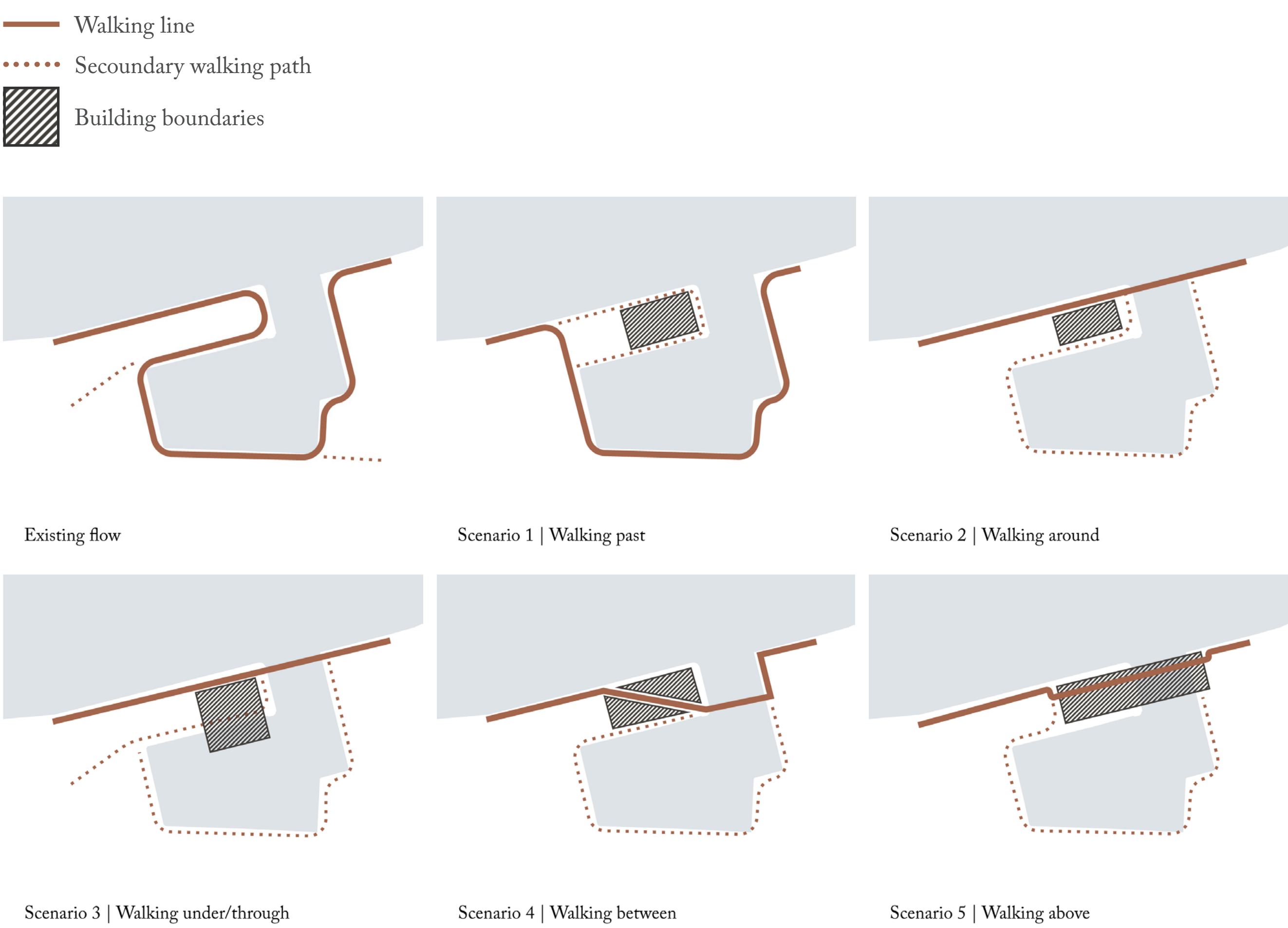


Fig. 24. Building placements and possible flow lines

BUILDING HEIGHTS

The existing skyline is characterised by compositions of low and tall, wide and slim. An additional one-storey building would blend in the background, while a ten storey would be too dominating, as seen in fig. 25-27. Besides, a volume of varying heights reflects the existing expression, to which the Spa House can either follow the intended identity inspired by the industrial background or stand out by doing the opposite.

A high rise predicts a vertical flow and views from different storeys. Potential outdoor areas, such as balconies or elevated outdoor areas, could, to a greater extent, benefit from the sun but will assumably be more exposed to wind. Contrary, a low, wide building has a stronger connection to the ground, and the horizontal flow is beneficial for level-free access. Although a big footprint results in a deep volume, courtyards add light and small enclosed spaces for exploring the outdoor conditions. A hybrid of the two combines the individual opportunities, combing different spatial experiences and transition flows, but self-shading is crucial to examine.

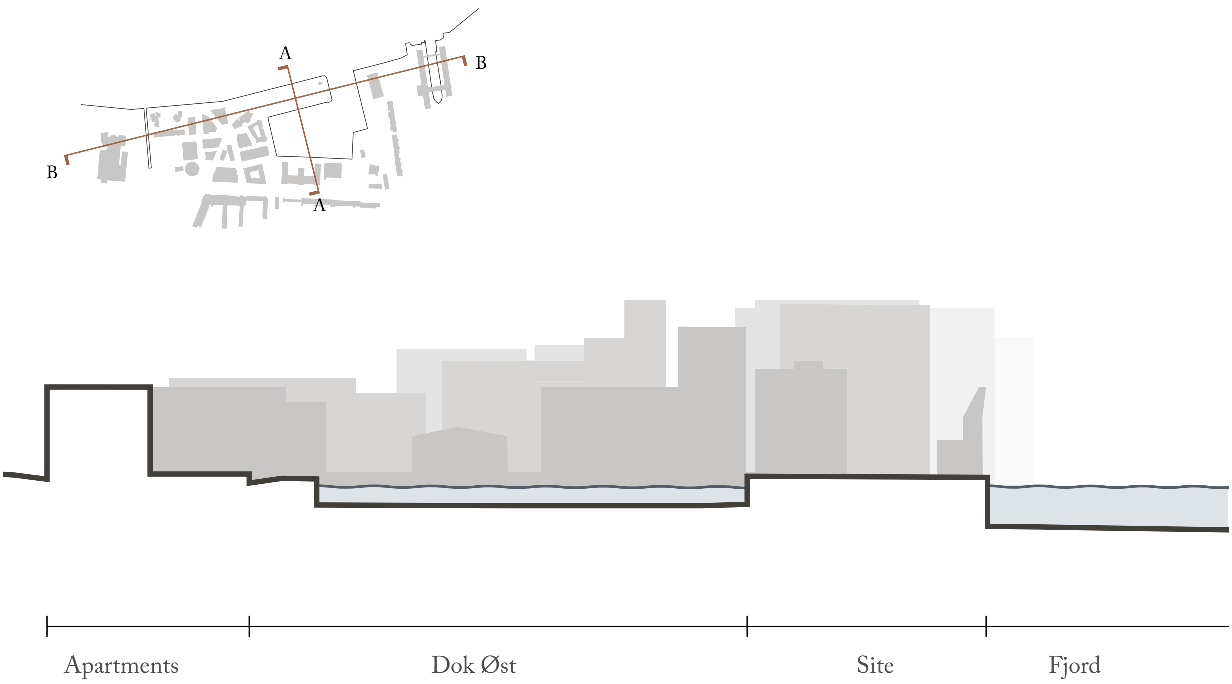


Fig. 25. Section AA | 1:2000

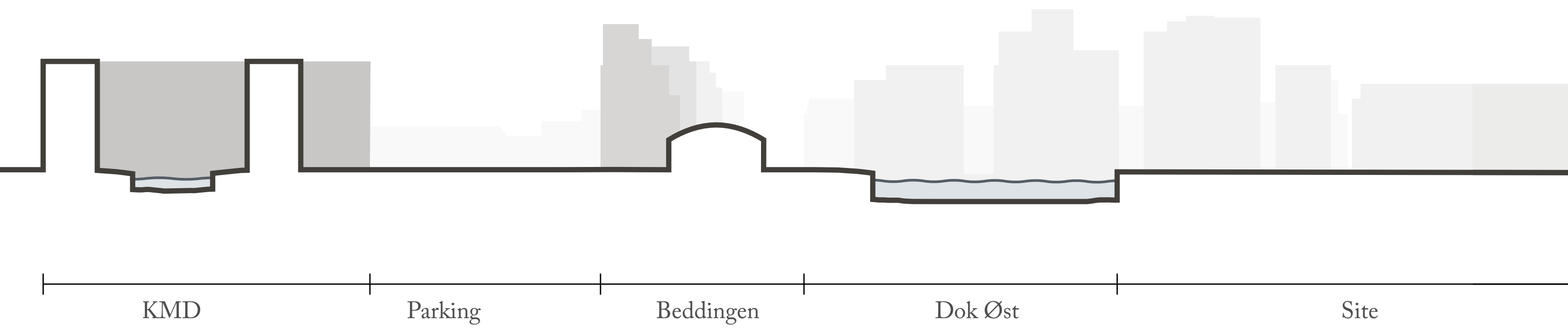


Fig. 26. Section BB | 1:2000

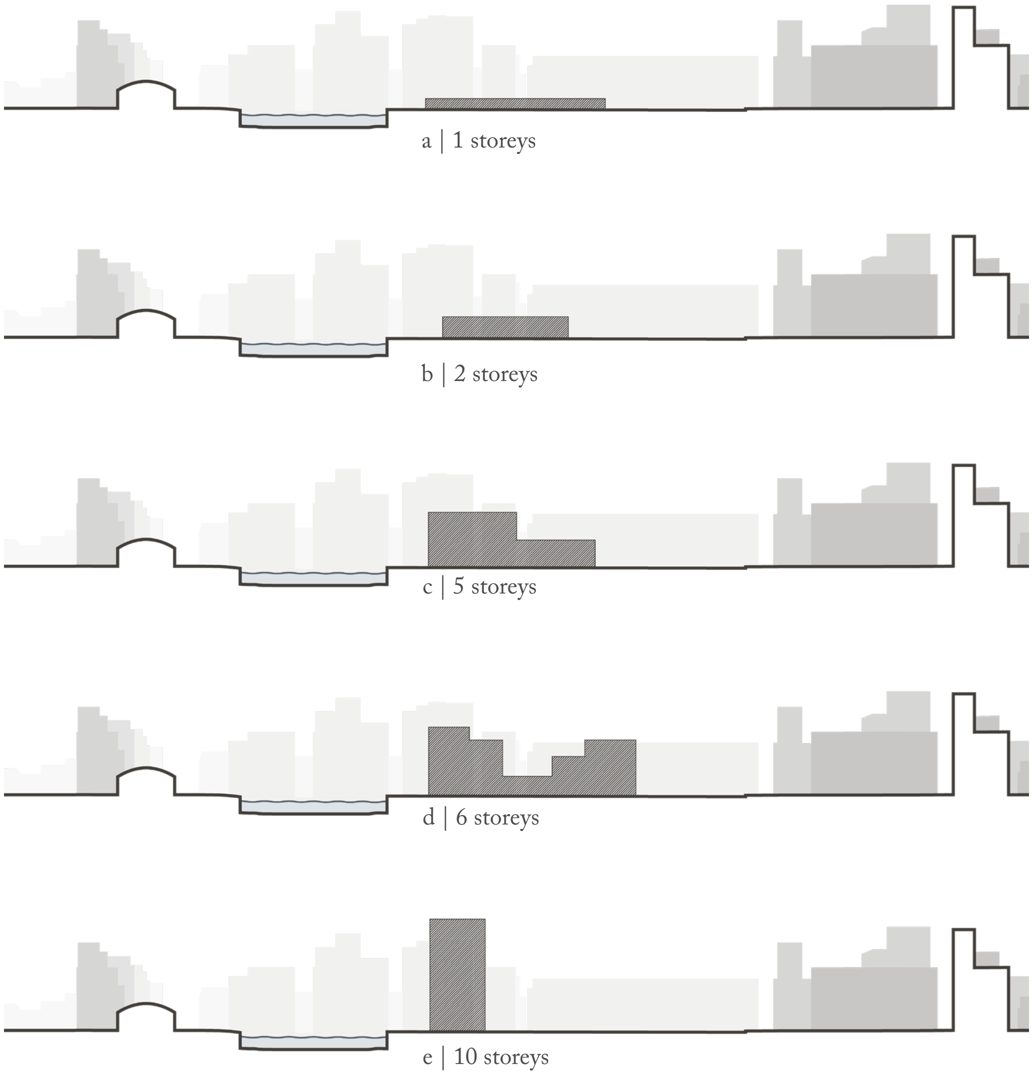
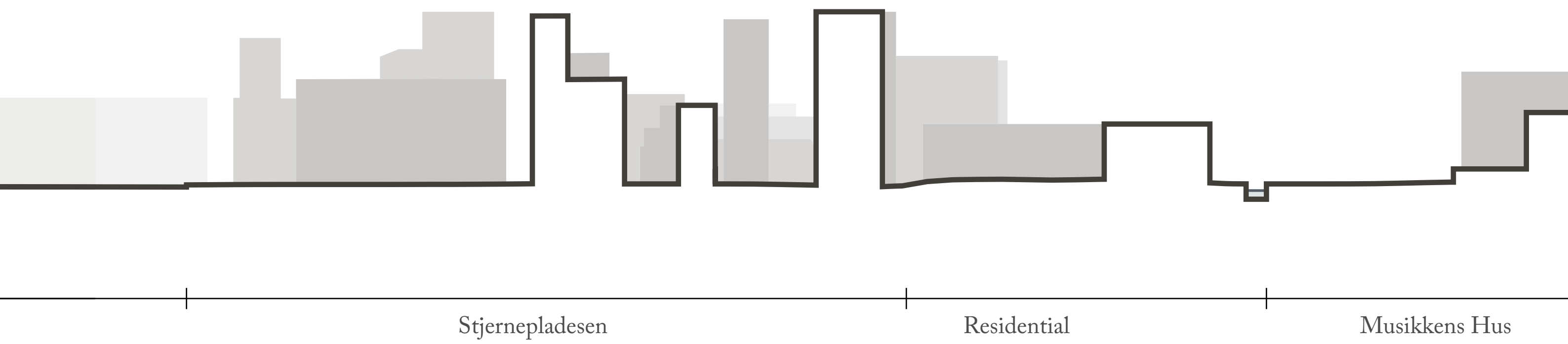


Fig. 27. Diagramatic morphology study | a-e



URBAN TOMOGRAPHY

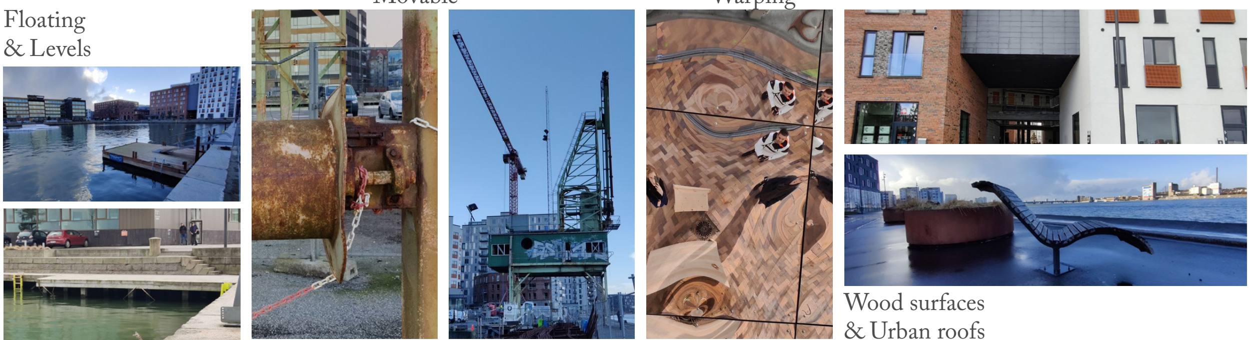
A site visit guided by predefined themes; materials, balance and views highlighted unknown aspects of the place, presented in fig. 28-29. The industrial heritage of the area is reflected in dense and heavy materials and toned colour schemes, such as grey, brown, red bricks, stone and concrete. Several of the buildings near Østre Havn have a different base, a change in the façade that indicates the ground floor, which appears to lift the massive buildings from the ground. Besides, this principle reflects a gradient in privacy when the building has common or public ground floors.

This principle could even be enhanced or balanced by contrasts like light and massive, round and square, hovering elements, or building into the water, where the boundary between manmade structures and nature is blurred or strengthened. When designing the threshold between building and outdoor space, there is a potential to translate this into the Spa House.

MATERIALS

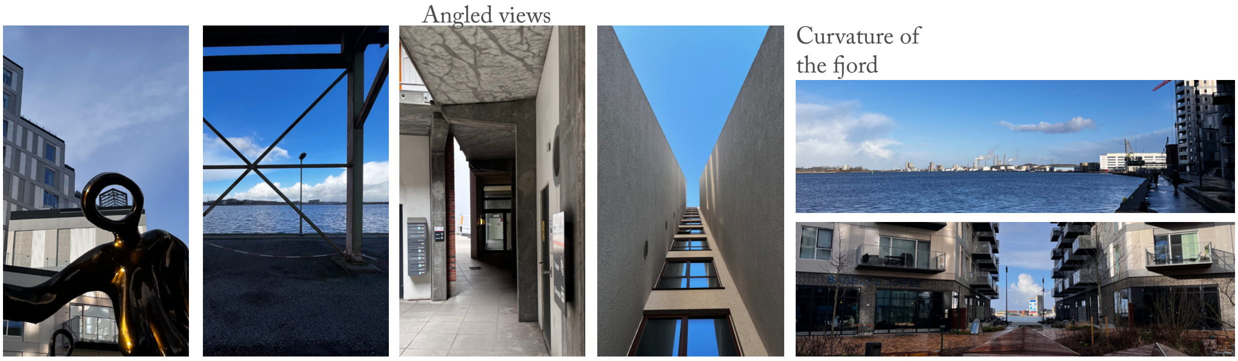
a | Urban Tomography | Materials

BALANCE



b | Urban Tomography | Balance

VIEWS



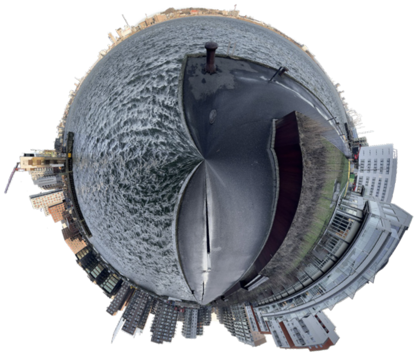
c | Urban Tomography | Views

Fig. 28. Urban Tomography | a - c

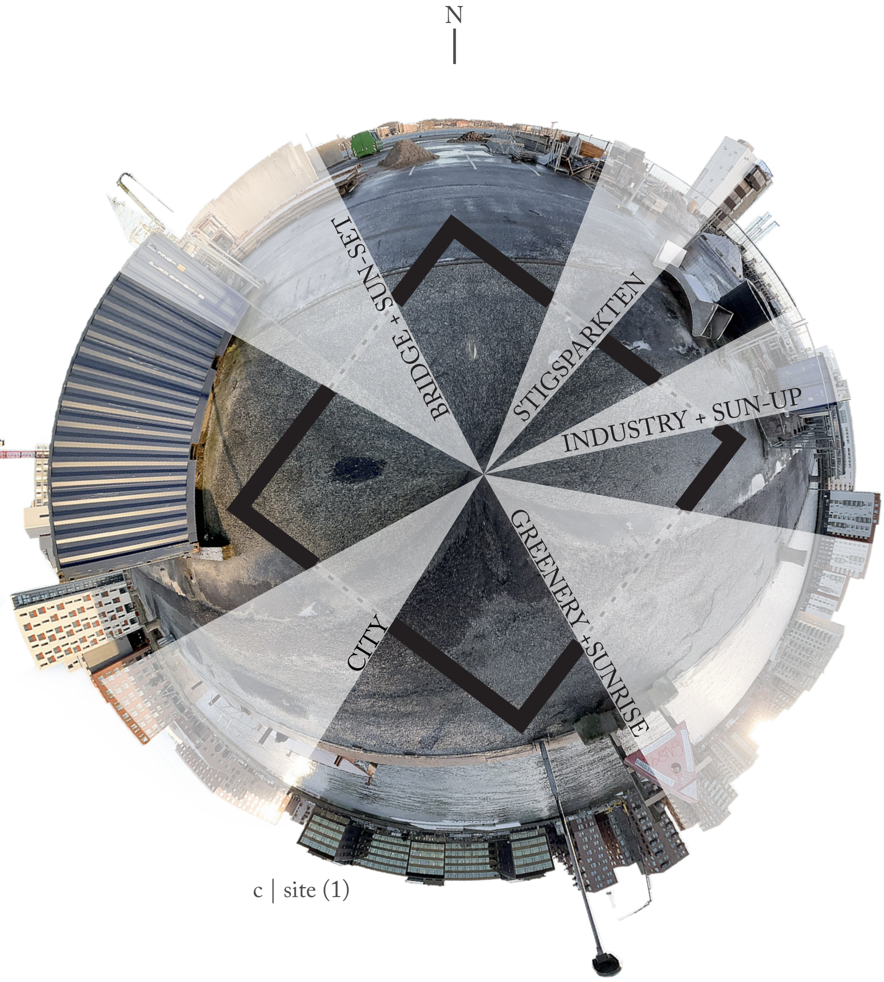
VIEW ANALYSIS

The Pier offers a wide range of views of water, sky, skylines and different urban environments. The Spa House might frame some of the views when walking nearby the building, as well as inside the building. By creating angled views and using various scales and strategical placements of windows, a stronger connection to the surroundings is obtained. Furthermore, the framing of views both inside and outside of the Spa House can help guide the flow of people based on humans' innate curiosity. Fig. 30.a-b indicates views at the site, and fig. 30.c exemplifies how a potential utilisation of the sights could be implemented in the building design.

a | South of site (2)



b | East of site (1)



c | site (1)

Fig. 30. 360 ° view | a-c

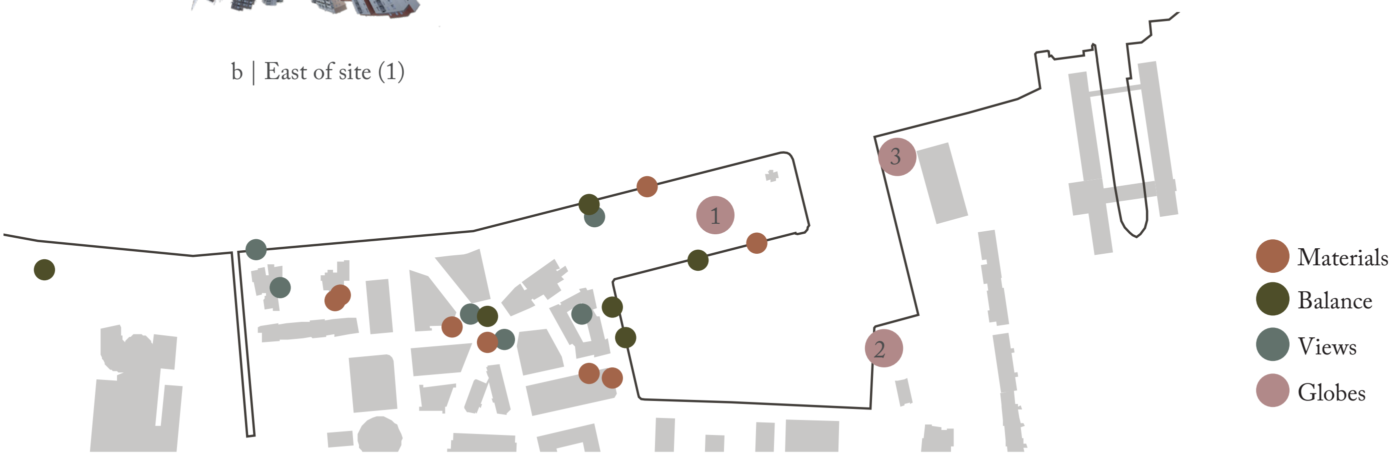


Fig. 29. Picture and globe location | Diagram

WEATHER CONDITIONS

Most of the activity in the Spa House is expected to happen in the afternoon, to which the increased outdoor temperatures can be utilised for outdoor functions in summer, see fig. 31. Such an outdoor area extends the built square meters and generates a connection between the interior and exterior, the building and its context. Fortunately, the temperature is commonly warmer when the wind is coming from the west, which is the usual tendency for Aalborg.

In summer, the relatively stable temperatures benefit from the cloud cover, resulting in warm evening hours, unlike the spring with fewer clouds and greater diurnal temperature swing. Therefore, thermal mass might be helpful to stabilise the indoor comfort in some parts of the building that houses functions that aim for more stable and neutral thermal environments, such as offices, kitchens, or the like.

The winter is marked by an overcast sky and high humidity, which in periods result in consistent rainy weather, see fig. 32. The summer is marked by rain occurring in shorter periods. However, direct radiation decreases when the sky is overcast, which might challenge the utilisation of solar radiation and, potentially, solar panels. The amount of radiation is lowest in the fall and wintertime, thus requiring a greater need for heating sources.

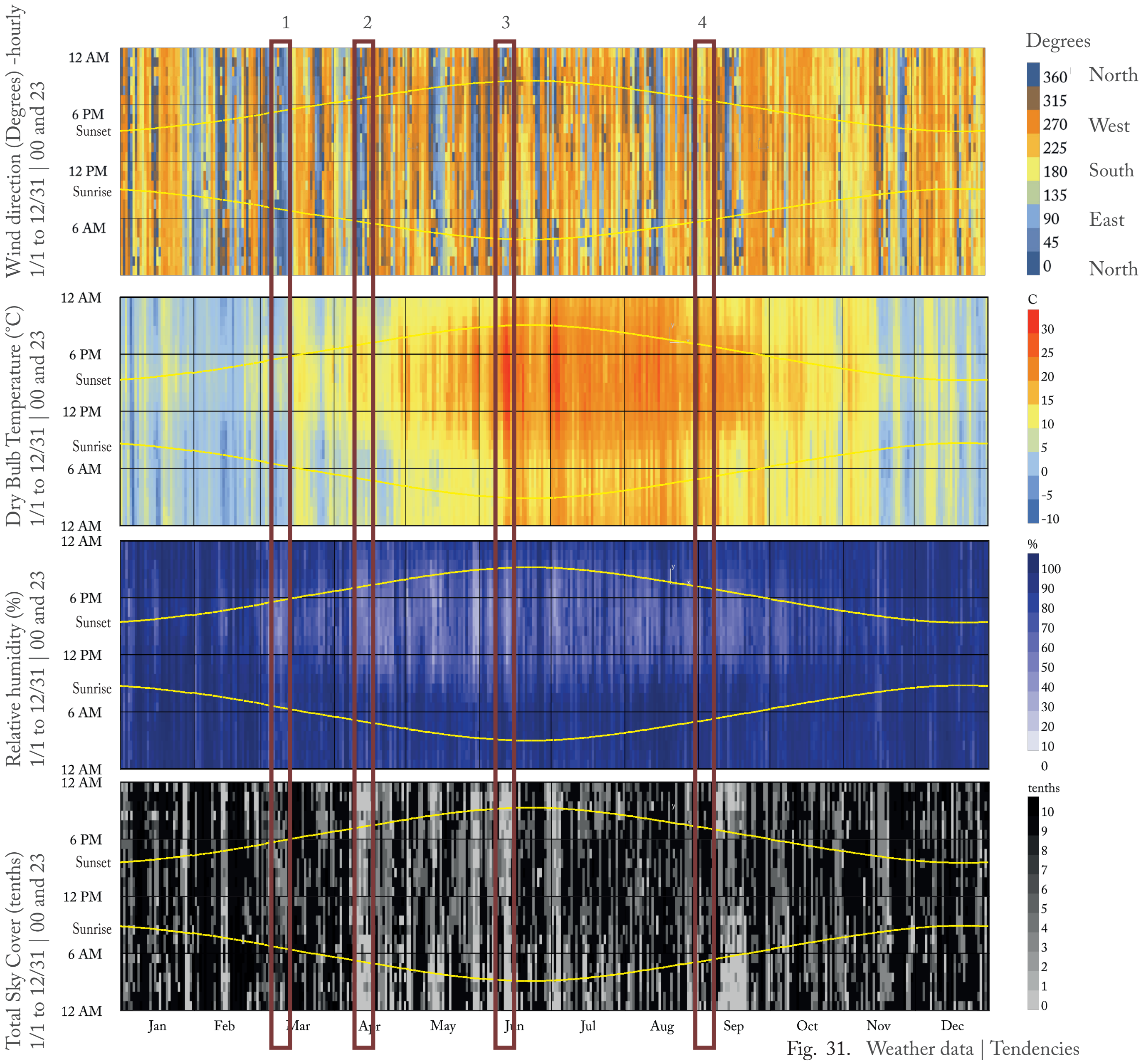
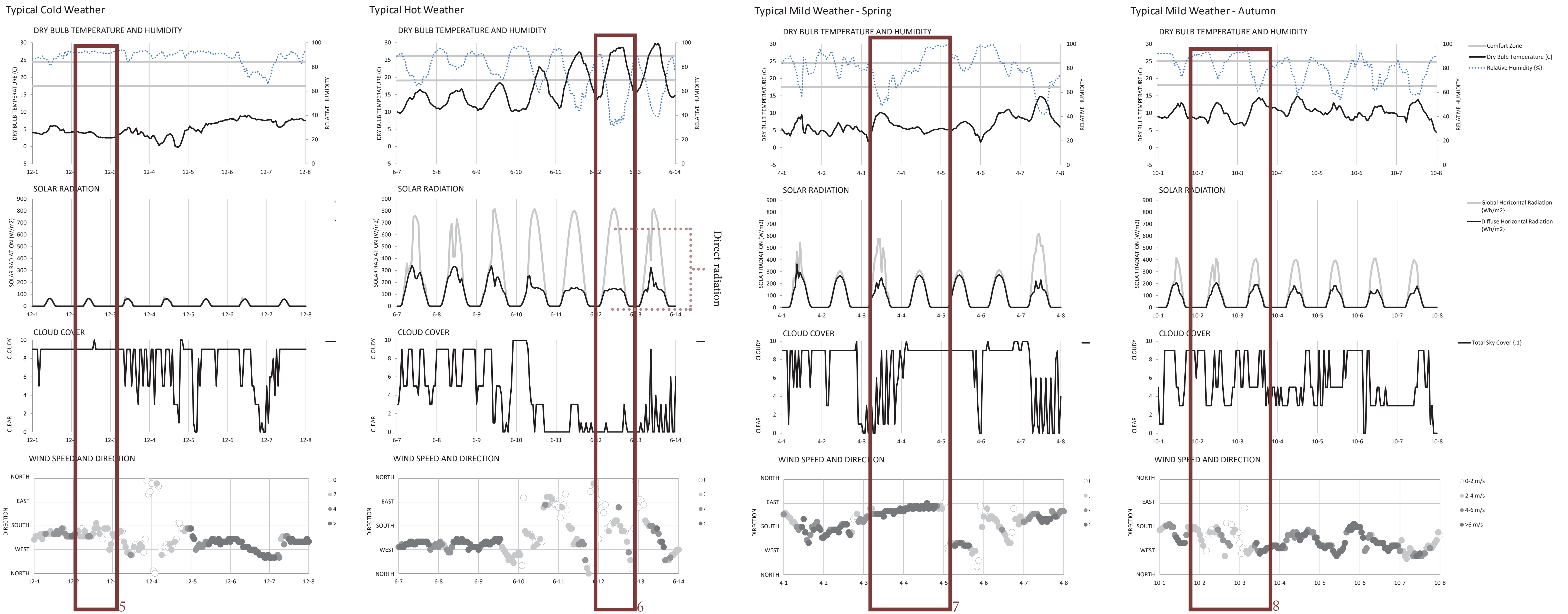


Fig. 31. Weather data | Tendencies



a | Typical Cold weather - Winter

b | Typical Hot weather - Summer

c | Typical Mild Weather - Spring

d | Typical Mild Weather - Autumn

Fig. 32. Weather data | a-d

1 Cold wind from north-east
2 No sky cover changing temperatures
3 Heat storm with direct sun
4 Stabile temperatures but rainy

5 Winter: Cloud cover and steady temperature
6 Summer: Clear sky and temperature differences
7 Spring: Similar condition with occasional aberrations
8 Fall: Quite consistent weather conditions

WIND CONDITIONS

When comparing the wind direction with the wind speeds, it is possible to derive general ventilation strategies for a potential building. Here the west wind has the highest velocity as represented in fig. 33-34 and table 4, which can be utilised for natural ventilation by placing windows or openings in the façades. However, it will be impractical to use natural ventilation in several functions related to a Spa House, as it is necessary to precisely regulate and control the indoor climate to ensure indoor comfort and desired atmospheres. Besides, the design aims to avoid drafts when the occupants move around being wet and with bathrobes. Therefore, natural ventilation strategies can be used in administrative rooms, lounges and some circulation spaces, where adaptive comfort is possible.

The wind direction during the year is primary from the west, but in the spring, the wind direction shifts more. Besides, the speed increases during the afternoon concerning the outdoor spaces, when visitors are expected to use potential outdoor facilities. Therefore, to create sheltered outdoor areas, these need to be placed toward the north or east to face the less critical wind situation, derived from the wind conditions data in Aalborg, see table. 5 and fig. 35. However, this is not an optimal position for sun exposure since the space will be shaded most hours a day. Luckily, the lowest consecutive wind speeds happen from May to August, when the most outdoor activity is expected, to which the need for shelter is less decisive. The shape and placement must rely on an evaluation of what factors are estimated to be the most important in each situation.

It is essential to note the height above the ground when considering the wind speeds. The greater the height, the bigger velocities. This information is crucial in designing elevated outdoor areas, such as balconies, patios, roof terraces etc.

Fig. 33. Windrose | 10 m for March. Example of shifting wind directions

Fig. 34. Windrose | 10 m for October. Example of period with consistent wind

Wind speed [m/s]	Percieved wind speed Indoor
0.05	Stagnant uncomfortable
0.1	Default, used for heat transfer calculations
0.2	Barely noticeable but comfortable
0.25	Design velocity for air outlets that are near occupants (e.g., UFAD)
0.4	Noticeable and comfortable
0.6	Typical of a ceiling fan
0.8	Very Noticeable but acceptable in certain high-activity area if air is warm
1.0	Upper limit for Air-Conditioned spaces
2.0	Good air velocity for ventilation in hot and humid climates (Natural ventilation)
4.5	Considered a gentle breeze when felt outdoors

Table. 4. Wind speed and perception | Indoor (Lechner, 2014)

A Speed difference between north and west wind.
B Slow north-east wind.
C/D Fast south-west wind.
E Shifting direction with low speed.

Maximum wind speeds in relation to height above ground
1 m 13,9 m/s
10 m 17,5 m/s
20 m 18,8 m/s
30 m 19,5 m/s
40 m 20,1 m/s

WIND CONDITIONS

Wind comfort			
P(VIS > 5 m/s) in % hours per year	Activity area		
	Traversing	Strolling	Sitting
> 20	Poor	Poor	Poor
10-20	Moderate	Poor	Poor
5,0 - 10	Good	Moderate	Poor
2,5 - 5,0	Good	Good	Moderate
< 2,5	Good	Good	Good

Table. 5. Wind speed and perception | Outdoor (Santos, 2022)

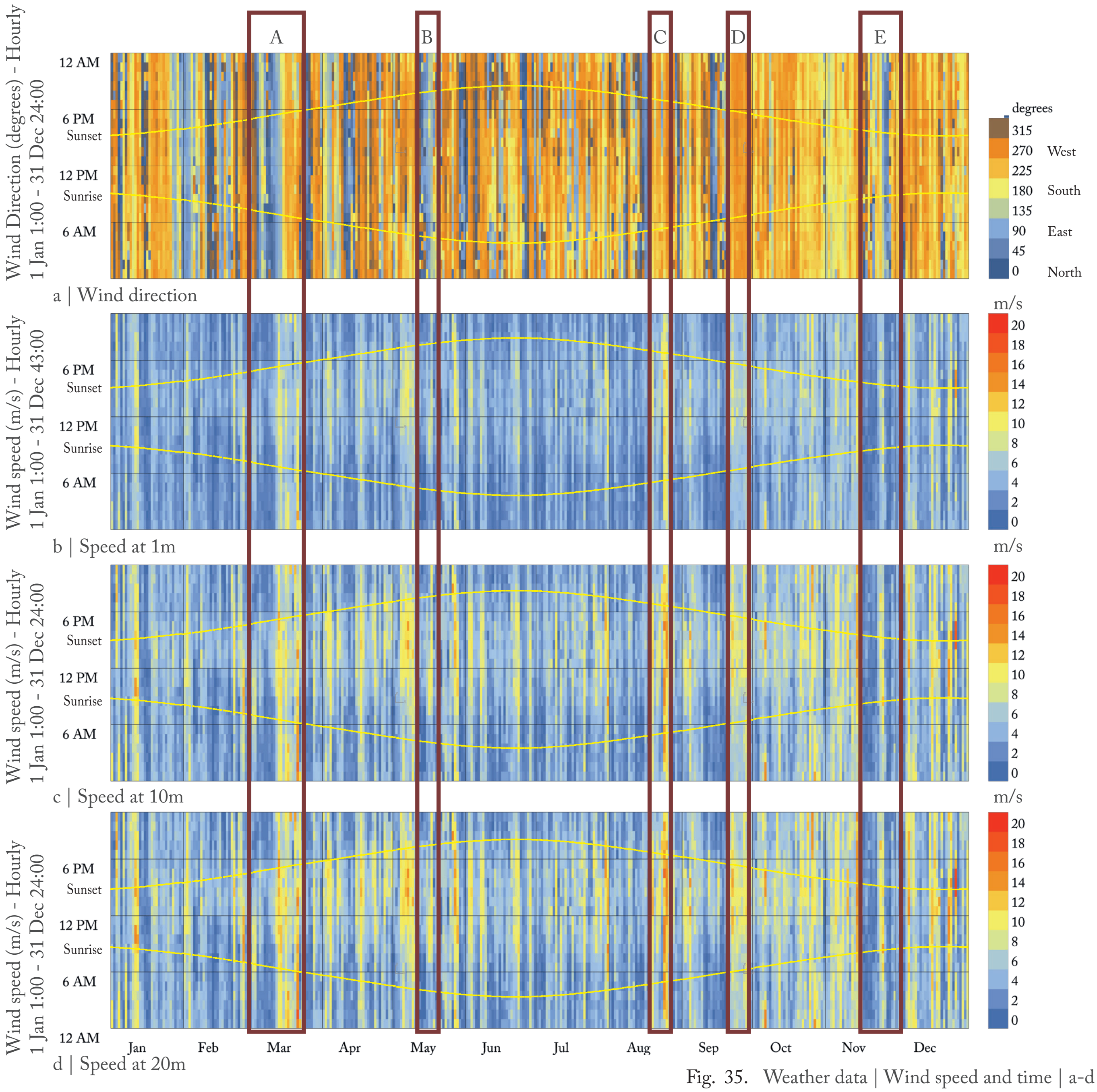


Fig. 35. Weather data | Wind speed and time | a-d

UTCI

The level of perceived thermal stress is an important factor related to the future urban dwellers of the Pier. Such perceived thermal experience can be estimated in outdoor settings using the Universal Thermal Climate Index (UTCI). UTCI considers different weather features such as wind speed, radiation, humidity and air temperature (Bröde et al, 2012). investigation combines conditions to identify tendencies that affect the urban dweller, when tweaking a design parameter such as blocking for sun or wind.

When combining wind and sun, the wind drastically lowers the experienced temperature since the wind blows away the warmed air near the skin faster than the body manages to heat up the replaced air. Therefore, it would be beneficial to consider the wind conditions when placing and orienting a building volume.

The sun and the wind improve the perceived outdoor thermal comfort, to which the mapping in fig. 36-37 and table 6 demonstrates that an outdoor area can be comfortable with wind if not shaded if thermal heat stress is intended. In other situations, a shaded area with no wind will be suitable to avoid thermal stress.

The dwellers of an UTCI investigation are assumed to attend an activity and typical clothing level for the corresponding season, which the urban dwellers of the park likewise will be expected to. However, if shaping additional outdoor spaces for the visitors of the Spa House, they will not be dressed for the weather when circulating between pools and saunas. Therefore, this investigation probably will be most relevant when designing the site strategy of the Pier.

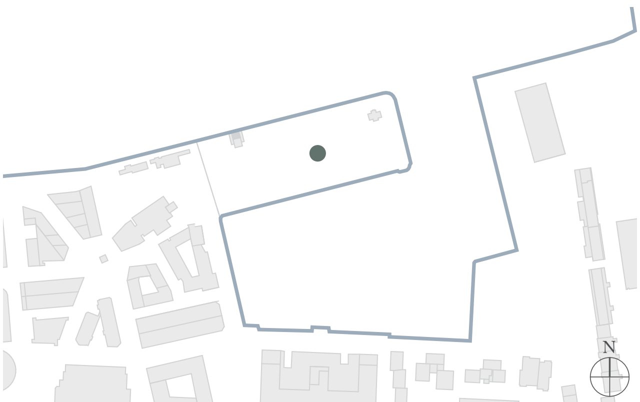
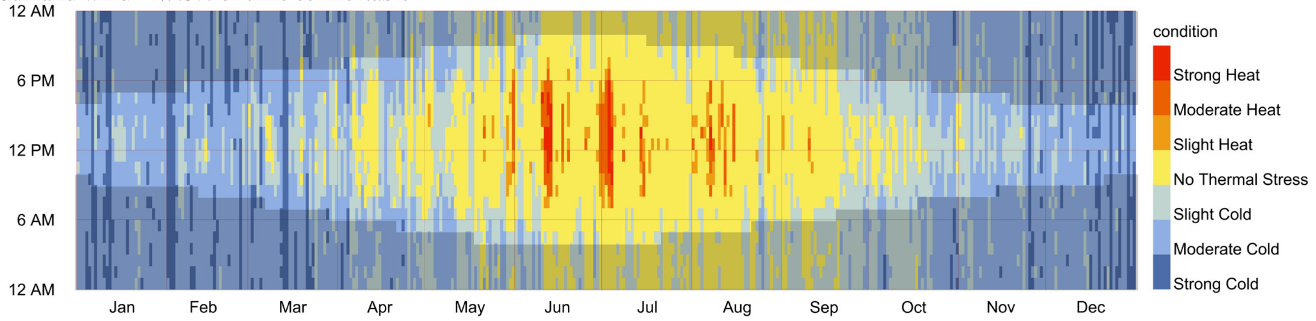


Fig. 36. Point of UTCI meassuring

UTCI (°C)	STRESS CATEGORY
UTCI > 46	Extreme heat stress
38 < UTCI < 46	Very strong heat stress
32 < UTCI < 38	Strong heat stress
26 < UTCI < 32	Moderate heat stress
9 < UTCI < 26	No thermal stress
0 < UTCI < 9	Slight cold stress
-13 < UTCI < 0	Moderate cold stress
-27 < UTCI < -13	Strong cold stress
-40 < UTCI < -27	Very strong cold stress
UTCI < -40	Extreme cold stress

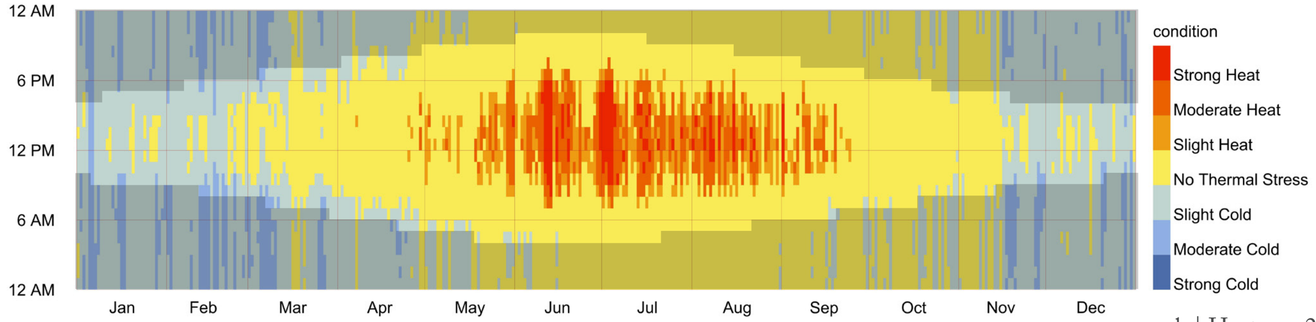
Table. 6. Table of UTCI

Sun and wind - 27.3% of time comfortable



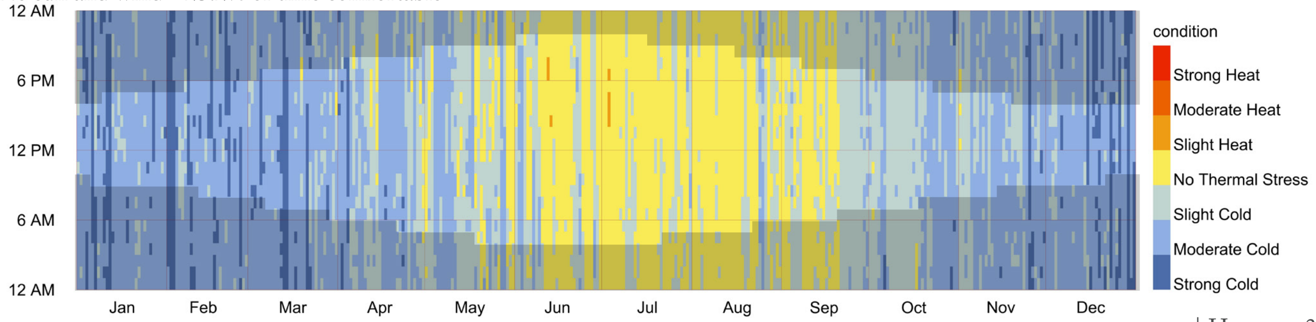
a | Heatmap 1

Sun and no wind - 45.5% of time comfortable



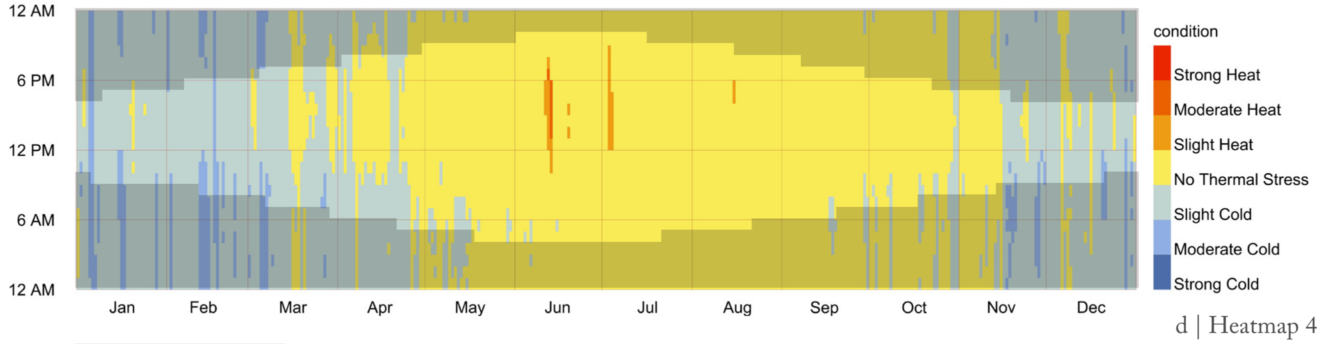
b | Heatmap 2

No sun and wind - 23.2% of time comfortable



c | Heatmap 3

No Sun and No wind - 58.9% of time comfortable



d | Heatmap 4

Night - time

Day - time

Fig. 37. UTCI | a-d

SUN AND SHADING MASK

Knowing the context and the movement of the sun enables a shadow study through time at any given location in the site. The sun diagram for Aalborg is merged with shading masks of the context.

The investigation is made at eye level for a person standing at ground level, 12m and 24m equal to 1 storey, three storeys or six storeys, to identify the differences if building in heights. The hourly sun analemmas demonstrate the varying position of the sun over time on successive days of a year, and the corresponding temperatures, see figure-of-eight curves in fig. 38-39. The figures illustrate that before and after 10.00-14.00, direct sun will be blocked by context buildings in the wintertime. However, a significant part of the contextual shading disappears when elevating the analysis level above ground level, accordantly to increasing the number of storeys.

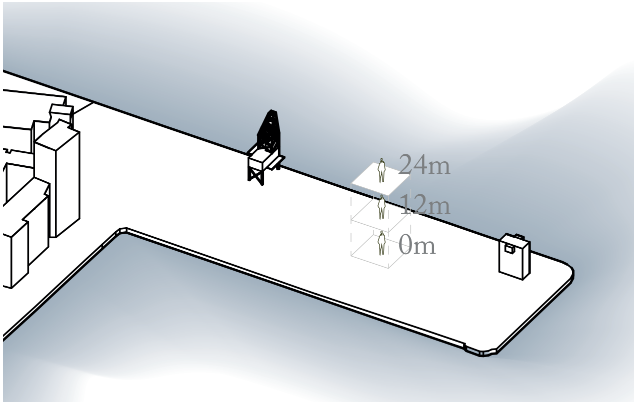
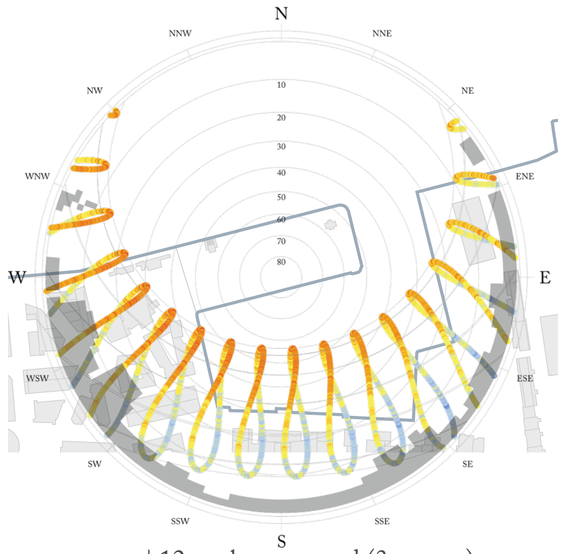
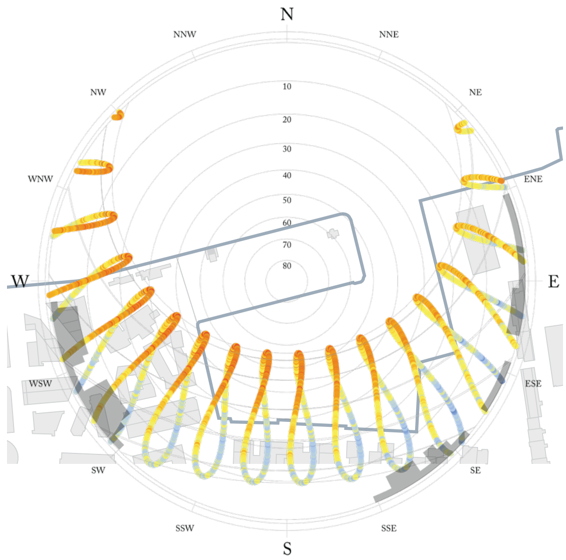


Fig. 38. Shadingmasks and sun paths | Analyses heights

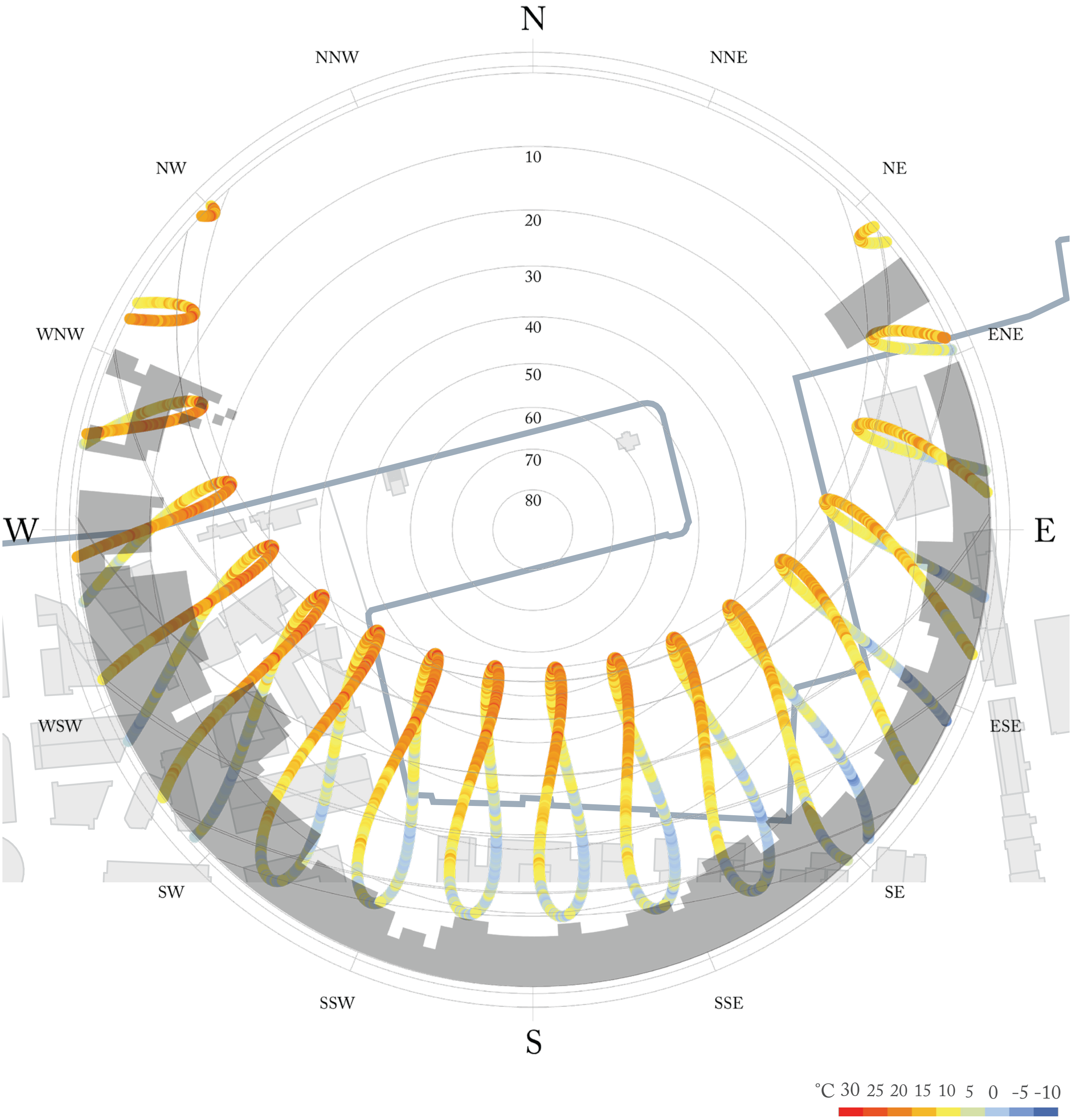


a | 12 m above ground (3 storeys)



b | 24 m above ground (6 storeys)

Fig. 39. Shadingmasks and sun paths | Dry bulb Temp. | a-c



c | 1,8 m above ground (Ground floor)

SUB CONCLUSION

The nature of the individual zones at the Pier must be invented by simultaneously considering the diversity in user groups, when designing a Spa House located in an upcoming park in Aalborg. The different and overlapping hours of activities are enhanced by the outdoor comfort, to which the different heights, orientations, and general shapes will be essential design parameters. The design should furthermore consider the overcast and windy weather conditions, especially in the winter half of the year, and therefore investigate how to integrate passive and active strategies to minimise the presumably extensive energy consumption of a spa.

Besides, the human scale, social interactions, and framing views will inform the design when recreating features from the cultural history and shaping a visual bridge to the future Stigsborg. The Pier will become a new node in Aalborg that merges a Spa House and informal outdoor spaces.

BUILDING

Ill. 6. Control Tower

STRATEGIES

Based on the climate and weather data for Aalborg, potential passive and active strategies for a building are derived from Climate Consultant based on the AHARE model, which might guide the design process of the Spa House (UCLA Energy Design Tools Group, n.d.), see fig. 40 and appendix I-II. The AHARE model is developed for American standards but follows principles close to the European standards, to which the results will be considered as an approximation.

In addition to an insulated compact building volume that integrates the mass/envelope ratio, various strategies could benefit the indoor comfort of a high-performance building in Denmark. However, the data outcome from Climate Consultants cannot directly be used for a Spa House since most of the facilities aim for an indoor environment that requires specific conditions that challenge the conventional understanding of indoor comfort. Therefore, some approximations are made to withdraw information useful for the building design of this project, such as specific needs for mechanical systems, the unorthodox distribution of internal heat gains, etc.

To achieve a desired atmosphere in specific spaces, the individual rooms most likely require different but steady conditions controlled by mechanical conditioning and ventilation systems. A passive natural ventilation strategy will be suitable for less restricted facilities, such as office spaces, where the perception of the outdoor conditions can be a quality, especially in the summer. Besides, the heating source will be floor heating to provide steady and uniform heat distribution and avoid cold contact surfaces for barefooted visitors.

Due to the Danish climate, heating will be the most prominent, to which additional heat gains become essential, e.g. internal heat gains and solar radiation. In the case of a Spa House, the internal heat gains consist of people, lights, mechanical equipment for heating water and saunas, or the like.

A way to store internal heat gain is to utilise the pools as water tanks. This help minimises the energy consumption caused by temperature differences of day and night, similar to the passive strategy of adding thermal mass. Water heating might be supplemented by solar panels such as thermal collectors to utilise renewable resources.

Passive solar heat gains harvest solar radiation through window openings to heat up the massive floor surfaces. Therefore, when shading direct sunlight, it must be considered how it compromises the need for solar heat gains in winter to mitigate overheating and glare.

A way to handle this delicate trade-off includes the consideration of the altitude and the azimuth of the sun when designing static shading. An alternative to static shading is the implementation of dynamic shading to adjust to seasonal differences. Those strategies will drive the design process of the Spa House, by zoning the building according to the thermal conditions and thereby differentiate which strategies are suitable for what functions or zones and thereby steer the process.

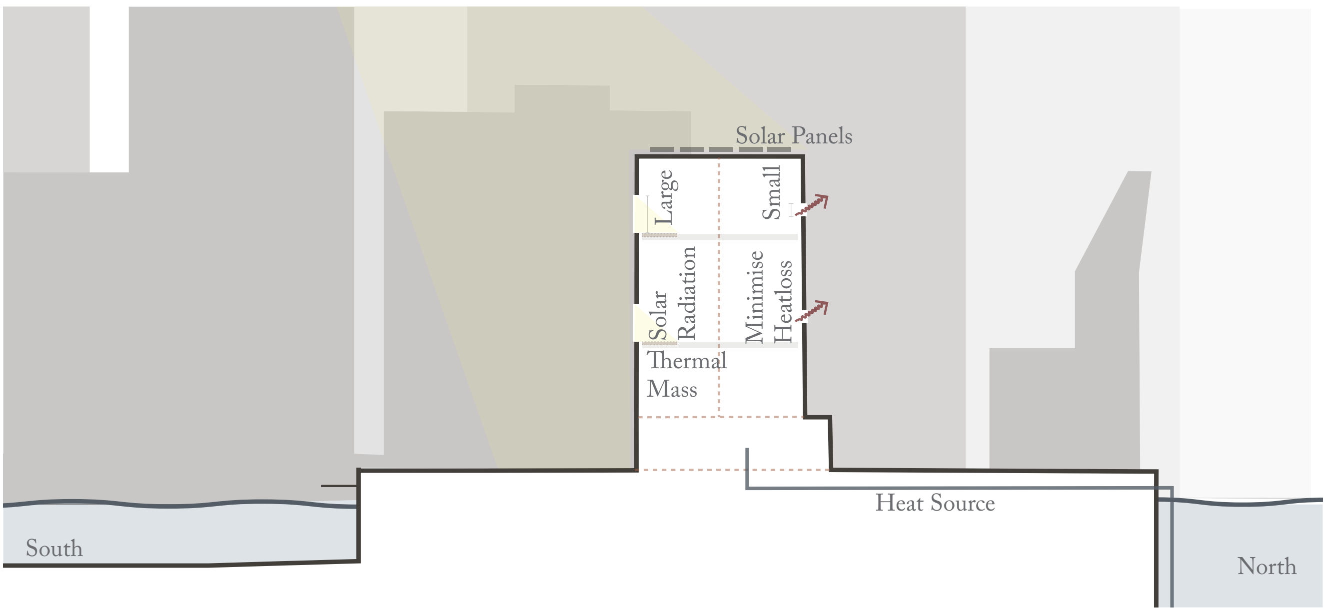


Fig. 40. Strategies

BUILDING REQUIREMENTS

When designing a Spa House, several building requirements inform the design process. Functions, sizes, and temperatures are based on cases and president studies and translated into the context of Aalborg. Thus, temperatures are corrected to fit the recommendations for swimming baths. For example, no hot pool should be more than 40 Celsius (Miljøstyrelsen, 2020).

The spa facilitates different pool experiences; chlorine and salt pools. The experience of salt pools is often combined with warm water, so the pools contribute to several nourishing effects; salt and minerals, which has positive effects on skin conditions, and the warm water for muscle tensions and gout, e.g., 12% salt and 37-celsius degrees (Læsø Kur, n.d.). Those pools assumably benefit from having a water supply system separate from the traditional chlorine pools.

The dimensions of systems for mechanical ventilation are estimated based on the sizes needed for conditioning an indoor swimming pool in Denmark (Danthermgroup, n.d.). Principles for air flows and additional systems are likewise estimated by standard solutions of similar facilities, e.g. saunas, snow sauna, etc.

Energy Frame

The energy frame can be increased for buildings or building sections with an increased need for lighting, ventilation, domestic hot water, and occupied hours or ceiling height. This energy supplement correlates to the calculated extra energy needed and is given for (Aggerholm, 2018):

» General lighting at 300 lux.
» Ventilation rate at 1,2 L/s/m^2 heated floor area in time of use.
» Hot water consumption at 100 l/m^2/yr.
» More than 45 hours of use per week.
» Ceiling heights above 4 meters.

For new buildings, the maximum allowed energy frame has a benchmark of 41 kWh/m^2/yr., excluding the correction related to the size of the building: 41,0 kWh/m^2/yr + 1000/area kWh/m^2/yr.

The benchmark for the Spa House, whiteout the additional energy allowance are thereby:

$$41{,}0 + \frac{1000}{A} = 41{,}0 + \frac{1000}{3000} = 41{,}25 \text{ kWh/m}^2\text{/yr.}$$

Low energy for conventional buildings other than housing units is: 33 kWh/m^2/yr. To balance the energy frame, 25 kWh/m^2/yr of electricity produced by renewable resources can be included (Aggerholm, 2018).

Because of the increased need for hot domestic water, ventilation rates and hours of use, the energy frame will go beyond this as a result of designing pools and saunas. One example of the extra energy supply is a building on 3200 m^2 constructed to facilitate indoor swimming, with an energy demand above 450 kWh/m^2/yr. The main categories for the additional energy supply are, in that case, related to heat and humidity, electricity for ventilation, and hot domestic water supply (Mørck et al., 2020).

Before adding active strategies, the energy demand should be minimised by utilising passive strategies, such as solar shading, passive solar gain in connection with thermal mass, insulation, and airtightness of the building envelope. These passive strategies decrease the energy consumption for mechanical intervention regarding the indoor climate. However, in neutral zones, the Spa House should aim to be below the benchmark to minimise the climate impact where it is possible.

Using principles from thermal autonomy, the Spa House is "...not just a building that is self-reliant but one that is calibrated to the climatic context." (Levitt, p. 2, 2013). Thermal autonomy allows occupants to experience and adapt to the seasonal changes inside the building, thereby extending the thermal comfort in the zones that aim for that. However, this is only applicable to the administrative building sections. In the Spa House, there needs to be a highly controlled indoor environment to create the desired experiences. Especially, the water and air temperature and humidity need to be controlled, which requires excessive amounts of energy for ventilation and heating.

The building location is already connected to the district heating grid, to which heat pumps can support the heating demand. A brine-to-water heat pump can utilise the fjord for heating pool water. An air-to-air heat pump can supply room heating and cooling. Another active strategy would be photovoltaics for electricity. However, if the Spa House in some periods manage to produce more energy than it consumes, it could be distributed in Aalborg as a small scale of the existing agreement between Aalborg Forsyning and Aalborg Portland (Aalborg Forsyning, n.d.). Surplus energy minimises the need for fossil fuels and creates an invisible connection between the Spa House and the city.

COMFORT CRITERIA FROM THE BUILDING REGULATIONS

The Spa House is about designing experiences. Therefore, the conventional comfort requirements are preserved for the facilities not directly related to the spa experience since designing for Alliesthesia often requires designing outside the comfort zone.

Visual/light

» Daylight: > 300 lux on 50% of the relevant floor area, 50% of the time (Trafik-, Bygge- og Boligstyrelsen, n.d. a).

Temperature

» Max 100 h > 26 °C.
» Max 25 h > 27 °C. (Trafik-, Bygge- og Boligstyrelsen, n.d. b)

Acoustics

» The desired reverberation times differs accordingly to the specific function as presented in the room program, table 7 (Trafik-, Bygge- og Boligstyrelsen, n.d. c ; Trafik-, Bygge- og Boligstyrelsen, n.d. d)

Ventilation

» Minimum 0,35 l/s/m² floor area in hours of use
» Maximum 1000 ppm CO_2 (Trafik-, Bygge- og Boligstyrelsen, n.d. e)

The ventilation rates are calculated by a handmade spreadsheet, using the standard procedure of air-flow rates for both CO_w-level and pollution. The calculations do not account for the additional chlorine content in the air. However, the results are compared with president studies of a Danish swimming facility to verify the missing information. The most critical case will drive the dimensioning.

The acoustics will be kept on a conceptual level to inform an environment, but this will not be elaborated or simulated further because of a limited time frame.

ROOM PROGRAMME

Administration/Staff

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Offices	1	100	to	125	3	125	25
Reception	1	50	to	65	3	65	2
Locker rooms	1	20	to	25	3	25	25
Break room	1	80	to	100	3	100	10

General

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Café w/ kitchen	1	150	to	200	3	200	10

Practical

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Cleaning room	5	5	to	10	3	25	0,2
Storage	5	20	to	30	3	150	1
Laundry	1	100	to	150	3	12	5
Toilets	5	40	to	50	3	250	1
Technical rooms	1	550	to	650	3	6	2

Informal

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Club room	1	30	to	35	3	35	10
Storage	1	10	to	15	3	15	1

Spa facilities

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Neutral zone	7	175	to	250	3,5	1750	15
Changing Rooms	40	5	to	10	3,5	400	40
Water tanks	1	500	to	600	3,5	600	1
Pool Experiences							
Cold	2	10	to	15	3	30	6
Flow	1	75	to	100	3,5	100	10
Hot	2	10	to	15	3,5	30	5
Half in/Half out	1	20	to	30	4	30	5
Saltwater	2	35	to	50	3,5	100	5
Showers	2	5	to	8	3,5	16	5
Room Experiences							
Massaging	5	18	to	21	3,5	105	4
Snow Sauna	1	10	to	15	3	15	5
Cold room	1	10	to	15	3	15	5
Sauna Experiences							
Finnish Sauna	1	20	to	35	3,5	35	5
Turkish Bath	1	40	to	50	6	50	5
Russian Banya	1	40	to	50	6	50	5
Infrared Sauna	1	20	to	25	3,5	25	5
Salt Sauna	1	20	to	25	3,5	25	5

Circulation

Room	Quantity	Area Range			Height	Total Area	Amount of People
Unit			[m2]		[m]	[m2]	[pers.pr.hr]
Hallways	1	159	to	199	4	198,75	10
Stairs	7	50	to	63	4	437,5	10
Elevator	7	8	to	8	4	56	1

ROOM PROGRAMME

Desired Temperatures		Types of active systems	Ventilation min. in Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
20 - 25	20 - 25	Heater and ventilator	429,70	1,07	Natural (Artificial supp.)	x > 300	0.6	Semi Private	Productive, Proffessional, Focused	30-50
20 - 25	20 - 25	Heater and ventilator	69,23	1,11	Natural (Artificial supp.)	x > 300	0.6	Public	Extrovert, Welcoming, Open	30-50
20 - 25	20 - 25	Heater and ventilator	361,54	1,85	Artificial	x > 300	0.8	Private	Practical, Introvert	30-50
20 - 25	20 - 25	Heater and ventilator	215,38	1,02	Natural (Artificial supp.)	x > 300	0.6	Semi Private	Casual, informal	30-50
Desired Temperatures		Ventilation Strategy	Ventilation min. In Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
20 - 25	20 - 25	Heater and ventilator	392,31	3,14	Natural (Artificial supp.)	x > 300	0.6	Public	Relaxed, refreshing, residence, longer residence	30-50
Desired Temperatures		Ventilation Strategy	Ventilation min. in Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
18-27	18-27	ventilator	22,31	1,07	Artificial	x > 100	0.8	Private	Practical	30-50
18-27	18-27	ventilator	92,31	1,11	Artificial	x > 100	0.8	Private	Practical	30-50
18-27	18-27	ventilator	153,85	1,85	Artificial	x > 100	0.8	Private	Practical	30-50
20 - 25	20 - 25	Heater and ventilator	169,23	1,02	Artificial	x > 100	0.6	Semi Public	Practical	30-50
18-27	18-27	ventilator	453,85	0,99	Artificial	x > 100	0.8	Private	Practical	30-50
Desired Temperatures		Types of active systems	Ventilation min. in Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
20 - 25	20 - 25	Heater and ventilator	176,92	74,81	Natural (Artificial supp.)	x > 300	0.6	Semi Public	Informal, gathering, sharing, extrovert	30-50
20 - 25	20 - 25	ventilator	23,08	2,77	Artificial	x > 100	0.8	Semi Private	Practical, Introvert	30-50
Desired Temperatures		Types of active systems	Ventilation min. in Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
25 - 30*	25 - 30	Heater and ventilator	346,15	1,42	Natural	x > 100	2	Semi Private	Relaxed, refreshing, residence, longer residence	30-50
25 - 30	25 - 30	Heater and ventilator	769,23	3,96	Artificial	x > 300	2	Private	Introvert, secure	30-50
20 - 25	20 - 25	Pumps, pipes, Heater, ventilator	169,23	0,87	Artificial	undf.	2	Private	Functional	N/A
15	15	Pumps, pipes, cooler, ventilator	69,23	4,15	Cold, artificial	x > 100	2	Semi public	Introvert, cold,	
34	34	Pumps, Heater, ventilator	165,38	2,27	Natural	x > 100	2	Semi private	Exploring, dimmed, guiding	40 - 60
40	40	Pipes, Heater, ventilator	61,54	3,16	warm, artificial	x > 200	2	Semi Public	Introvert, hot	40 - 60
34	34	Heater, ventilator/Natural	Outside	Outside	Natural	Natural	2	Semi Public	Contrasting, sequence of spatialities, extrovert, open, social, longer stays	N/A
32	32	Pipes, Heater, ventilator, salt	100,00	1,47	Natural	x > 300	2	Semi public	Open to the fjord, relaxing	40 - 60
varying	varying	Pipes ventilator	53,85	5,54	Artificial	x > 300	2	Private	Introvert, secure	40 - 60
23 - 25	24 - 25	Heater and ventilator*	115,38	1,32	Dimmed	x > 150	0.6	Private	Relaxing, intimate, self-reflecting	30 - 50*
-10 - -5	-10 - -5	EcoSnow 2.0, ventilator**	53,85	6,46	Bright	x > 300	0.6	Semi Private	Intimate, introvert, short stays, extremes (embraced?)	5 - 15*
10 - 15	10 - 15	Cooler, Ventilator*	53,85	6,46	Dimmed	x > 100	0.6	Semi Public	Extrovert, medium stay (surfaces contacts temp?)	10 - 15*
40 - 60*	41 - 60	Ventilator, Electric sauna heater*	61,54	3,16	Warm, natural	x > 300	0.6	Semi Public	Warm, extrovert, social, mulit-sensory, exposed (20min-60min)	10 - 15*
45 - 60*	45 - 60	Ventilator, Heating cables behind stone panels, steam generator *	53,85	3,23	Warm	x > 100	0.6	Semi Private	Warm, relaxing, steam cover	95 - 100*
60 - 85*	60 - 85	Ventilator, Heat stove *	53,85	3,23	Warm	x > 100	0.6	Semi Private	Hot, moist, extreme, self-awareness, (shorter stays?)	70 - 90*
32 - 35*	40 - 60	Ventilator, infrared lamps *	50,00	10,29	Red, artificial	x > 100	0.6	Private	Intimate, self-awareness ((min.10min-20min-max.60min)	20 - 35*
32 - 35*	40 - 60	Ventilator, heat stove*	50,00	9,00	Red, artificial	x > 100	0.6	Private	Intimate, self-awareness ((min.10min-20min-max.60min)	20 - 35*
Desired Temperatures		Types of active systems	Ventilation min. in Critical Senario		Light		Reverb DSE490	Private/public	Atmosphere	Humidity
Winter [°C]	Summer [°C]		Air flow [l/s]	Airchange [h^{-1}]	Aestetic value	Daylight factor [%]	[sec]			[%]
20 - 25	20 - 25	Heater, ventilator	276,15	1,56	Natural	x > 150	0.8	Semi Public	High, narrow, and dimmed light	30-50
20 - 25	20 - 25	Heater, ventilator	192,31	3,46	Natural	x > 150	0.8	Semi Public	High, narrow, and dimmed light	30-50
20 - 25	20 - 25	Heater, ventilator	17,69	5,31	Artificial	x > 150	0.8	Semi Public	Practical	30-50

* = (Cavanah and Global Wellness Institute, 2014)
** = (ArchiExpo, n.d.)

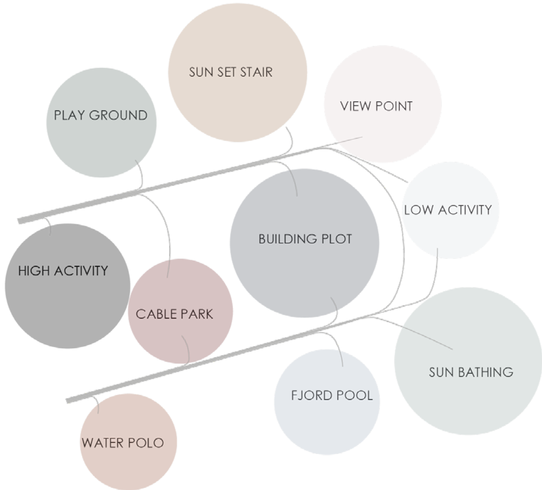
Table. 7. Room Programme | Data

FUNCTION DIAGRAMS - SITE

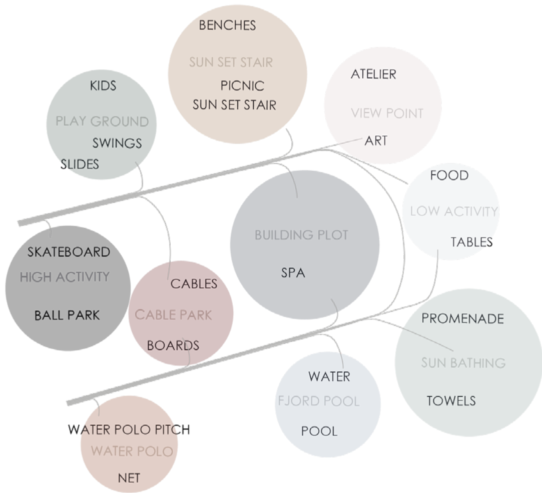
The flow of the Pier will have two main streets, which follow along the old train tracks and binds the flows together. As a gradient in activity level, the main paths connect different urban activities; the high activity to the west, near the arrival and Cable Park and low activity to the east. To the west, the Pier is occupied by flows and noise from a high activity level, and to the east, the Pier is calm, and a low pace is expected to happen.

The intention is to design for social alliesthesia.

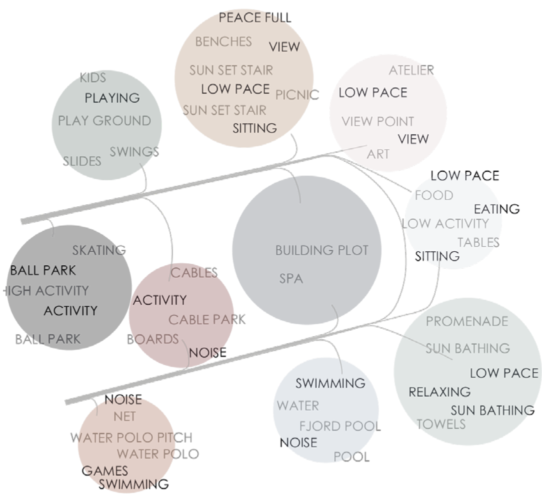
The illustrations in fig. 41 conceptualise the basic flow for the site without considering distances, orientation or size, but rather illustrate the activities and interconnectedness of the site. This will be elaborated on and detailed further in the design process.



a | General flow of the Pier categorised into initial zones.



b | Intended facilities for each zone emphasising facilities



c | Types of environmental properties at the Pier

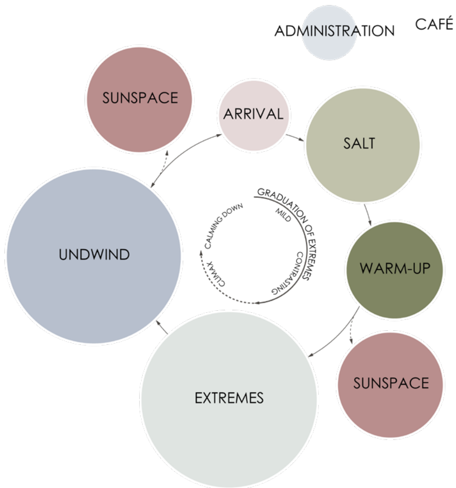
Fig. 41. Site function diagram | Flow | a-c

FUNCTION DIAGRAMS - BUILDING

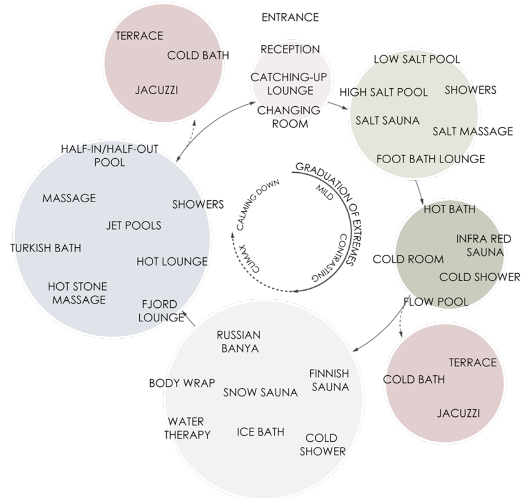
The flow of the Spa House assumably will be experienced circular, since entering and leaving through the lobby related to the changing rooms and storage of personal belongings in lockers. The illustration in fig. 42 of a conceptual flow demonstrates how to build up the extreme opposed gradually.

The intention is to incorporate outdoor areas in some way

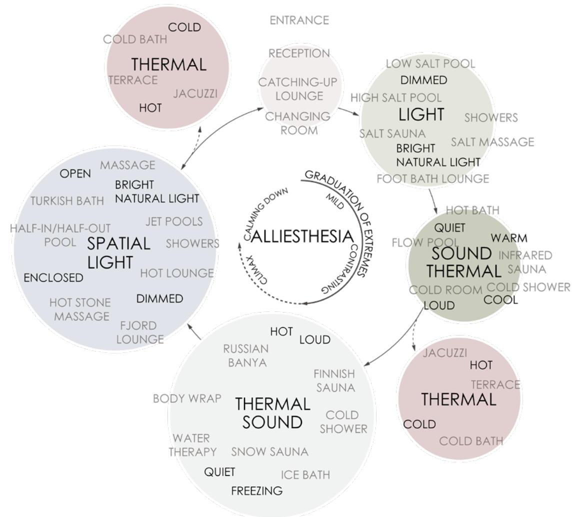
This abstract illustration does not consider distances, floors or subdivision of volumes. However, a need for mediation between zones and functions must be elaborated on in the further design process.



a | The general flow of the Spa House is categorised into initial zones.



b | Intended facilities for each zone emphasise contrasts and variations.



c | Types of alliesthesia and expected environmental properties.

Fig. 42. Building function diagram | Flow | a-c

PROBLEM

HYPOTHESIS

The hypothesis is that it is possible to integrate the phenomenological, poetic, and transient atmospheric dimension of architecture with the more pragmatic aspects of IEQ and construction of a Spa House in Aalborg using alliesthesia principles.

PROBLEM STATEMENT

How to use and extend alliesthesia principles to both shape and balance the qualitative and quantitative aspects of a high-performance Spa House, as well as to mediate different spatial and sensory experiences to functionally and socially activate a site in Aalborg?

VISION

To test the hypothesis and answer the problem statement requires integrating computational methods such as parametric design and building simulation into a performance-driven workflow to assess spatial and atmospheric qualities, and IEQ performance. Such workflow should enable the usage of local climate data and site context parameters to steer the design process towards designed sensory and spatial experiences, both onsite and in the building. Such experiences result from controlling the degrees of spatial, functional, and materiality contrast (e.g., light/darkness, high/low activity, outdoor/indoor, hot/cold, loud/quiet, rough/smooth).

GOALS & CRITERIAS

The goal is to:

Create a gathering point and give the Pier back to the city.

- By creating inclusive environments of different natures on the Pier that condenses multiple user groups and the informal structures that already inhabit Østre Havn.
  - By extending the iconic skyline of Aalborg with varying building heights as the city increases to the east.
  - By integrating urban spaces for the existing activities observed at Dok Øst; Cable Park, winter swimmers, strolls, and sunbathing as a minimum.
  - By designing for pedestrians as the main type of flow to lower the pace on site.

Embrace the identity of the cultural history of Østre Havn.

- By using the remaining industrial relics as guides to building placement height, and reintroduce a consistent flow of people at the Pier.
  - By preserving the existing control tower and green metal structure as a minimum.
  - By relating the height of the building to the context structures, to which the volume should be minimum four storeys.
  - By designing permanent facilities for Cable Park and their members.
  - By designing architecture that emphasises the heavy materials registered on-site, either by contrasts or by following the materiality of Østre Havn.

Design for alliesthesia.

- By reflecting the site strategy of high activity and low pace at the Pier through auditory and social graduation while aiming for environmental contrasts in the Spa House that create an explorative flow of experiences.
  - By contrasting thermal environments created by various room and water temperatures of both mild and extreme alliesthesia related to the psychrometric chart in fig. 6.
  - By creating visual differences between views and enclosed surfaces, or differentiating between bright and dark spaces, to reach a luminance contrast ratio above 1:10 in spaces intended to emphasise visual alliesthesia.
  - By utilising the contrast of single and double-height spaces and sectional connections between floors.
  - By creating spaces for a diverse user group.

Minimise the climatic impact.

- By designing with programmatic zoning while utilising local conditions for the production of energy, e.g. photovoltaics and heat pumps.
  - By designing for an energy frame of 41,25 kWh/m^2/yr for the building, excluding additionally energy demands for high room temperatures, domestic hot water, ventilation and lighting.
  - Reduce building notes by designing with passive means, such as solar shading, building envelope, passive heat etc.
  - By minimising the amount of build square meter to maximum 4000 m^2.
  - By creating zones for hot and cold experiences that reflect the distribution of solar radiation.

SUB CONCLUSION

Functions, sizes, and temperatures are inspired by presidential studies and corrected to fit the recommendations for swimming baths in Denmark, and the mechanical systems are estimated as standard solutions for conditioning a swimming pool. The energy frame should aim for 41 in the neutral zones, to which additional contribution is added for the special rooms of the Spa House.

Thermal autonomy will inspire the design by calibrating the building to the climatic context. For instance, utilising the fjord with a heat pump, heating water with thermal collectors, producing electricity with photovoltaics, etc. Besides, zoning the building according to the conditions of the individual functions might be beneficial for controlling the environment.

However, the comfort criteria will be challenged when designing for alliesthesia, as contrast in temperature, light, spatial, etc., is about contrasts outside the conventional requirements. This project is about designing experiences.

PROCESS

Ill. 7. Mooring anchor at Dok Øst

FUNDAMENTALS - INITIAL THOUGHTS

Initial studies of urban, site and building nature are executed by physical models in 1:500, focusing on the gesture created between the building and outdoor space, circulation flows, and spatial connections in the plan and section. The best qualities from each model are paired with one or more other models, to structure further development in the designs, as presented in fig. 43.

Vital strategies emerge as; either punctuating and ending the Pier, connecting and continuing the exiting urban flow by establishing a bridge or creating one or more volumes that separate the Pier into zones of different characters. To that end, scale, level of privacy, and mediation are influential dimensions of the site strategy, particularly while approaching the Spa House and building up the experience when arriving at the Pier. A critical question for most design proposals is; how close to the introvert Spa House the public is invited, and how to control the differentiation between paying spa visitors and visitors of the park.

If the public areas are not expected to be close to the building, the visitors might be guided by a defined path or multiple layers that allow glimpses of the Spa House and mediate the outdoor activities supported in the site strategy with the spa activities, as well as the different spa experiences inside the building.

The initial studies are generated along with consideration about what type of typology would be most suitable for the project site, see appendix III.

- **High Rise:** Leave space for the urban strategy, and more sun exposure in the winter when rising from the context shadow. The circulation takes up space but enables sectional connections.
- **Low, spread out:** Strong connection to outdoor spaces or courtyards and potential for skylights or big areas for solar panels. However, privacy might be a threat.
- **Detached:** Shifting from inside to outside might be experienced as less cohesion. The amount of surface implies a high heating demand. Besides, the occupant will be quite exposed when circulating.
- **Hybrid:** Besides combing the qualities of the three principles, the hybrid composes a skyline in agreement with the district plan for Østre Havn. However, spatial variations could inform the entire design

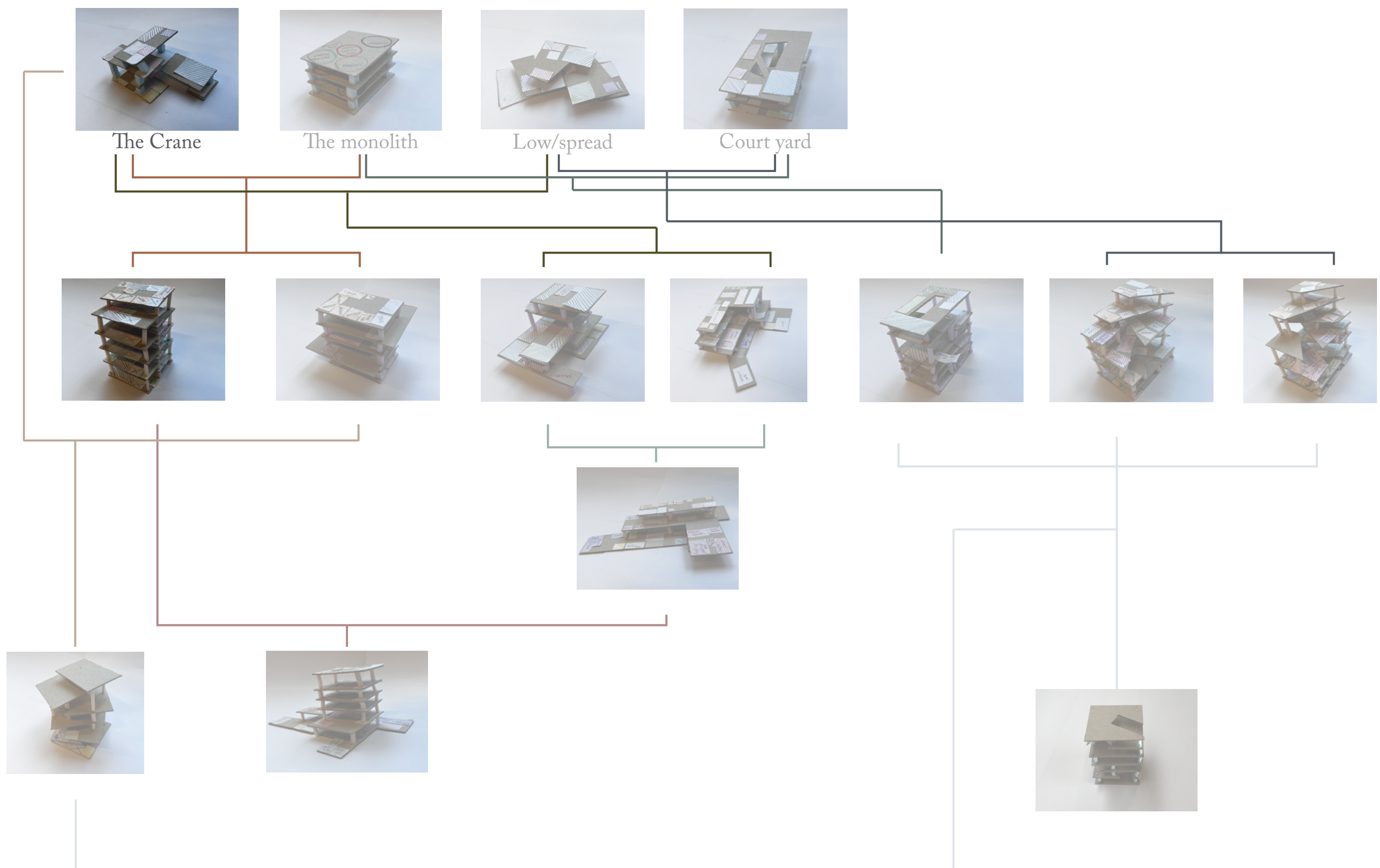


Fig. 43. Model Combinations

INITIAL MODELS

Psychical models in 1:200 investigate the human scale of the spatialities and approximated sizes of functions. The rooms start shaping an ambience when adding walls to the plateau models. For instance, some models create in-between spaces between enclosed rooms, as seen in fig. 44. The flow will then be guided by curiosity and exploration, unlike spaces where the entire floor is open with several experiences placed in the same room.

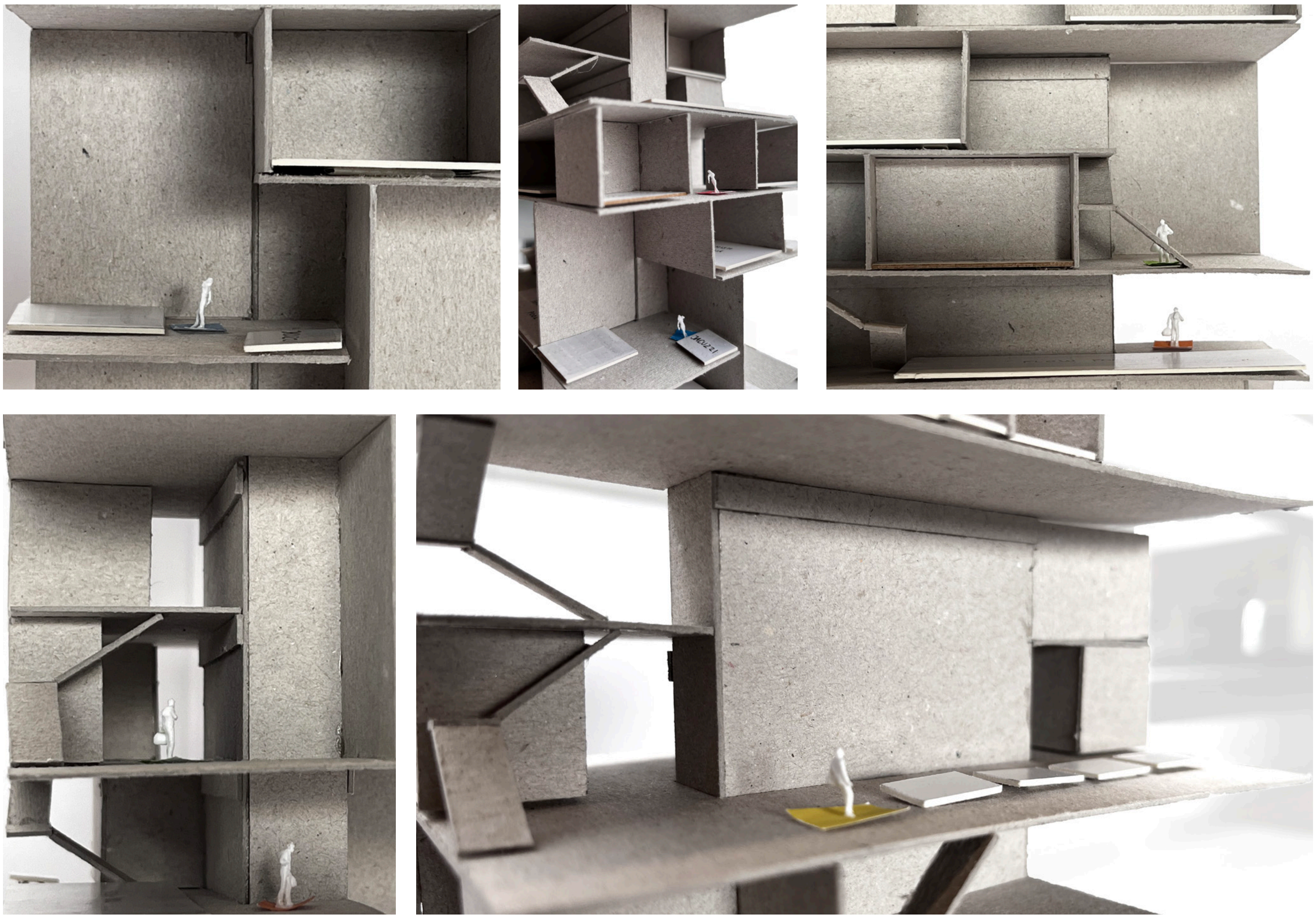
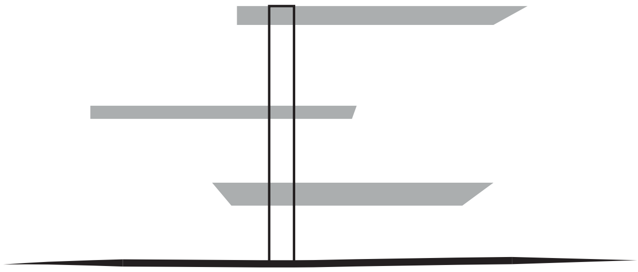


Fig. 44. Model pictures | Spatialities

POTENTIAL STRATEGIES

The Crane
One of the initial concepts is inspired by movable One of the initial concepts is inspired by movable structures and the game of balance, represented in the context by cranes and tracks, as seen in fig. 45. Floating, hovering or stacked platforms of the building bleed out to a potential park area with an extrovert expression, activating the Pier with a closer connection to Cable Park, who is located close to their cables.

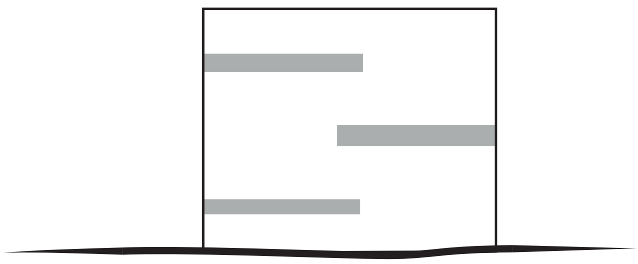
Inspired by cranes, the platforms could be connected by a core for technical and circulation purposes and allow sectional moments between floors. This design entails more surface unless the crane is seen as an internal structure with void spaces. However, the shifting platforms invite for outdoor areas in height, creating private sunspaces for the spa visitors. In this design, the structure might benefit from the industrial aesthetics of steel constructions.



a | The Crane

The Monolith
Another concept is inspired by the introvert and high-end expectations related to a spa experience. A monolithic expression of tall, opaque surfaces as a massive building with hidden openings and private plateaus. The monolith either recreates the old control tower at the end of the Pier,or acts as a separator of the park if placed in the middle. The slim volume minimises the footprint and gives space for a big public park area.

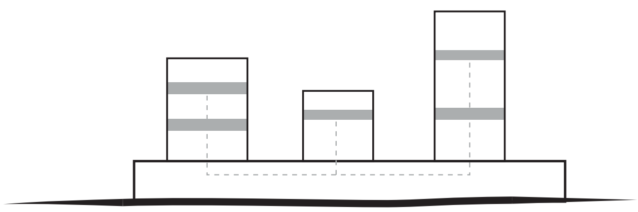
The compact shape of the monolith is flexible for circulation and technical installations, e.g., an elongated central core facilitating both purposes. This informs the structural system, as the core and the massive façade are loadbearing for the slaps.



b | The Monolith

The Mushrooms
By subdividing the monolith into several volumes, they acquire different natures according to the functions and experiences inside. Besides, this results in a lower scale than the previous concepts and several outdoor spaces to create a seamless transition between the plateau and the Pier.

The detached volumes are connected through a plateau as a hidden network between the different parts of the spa. This design might be differently flexible in circulation, cores and structural principles because of the dimension and scale.



c | The Mushrooms

Fig. 45. Building concepts | a - c

PROGRAMMATIC ZONES

The overall urban strategy is informed by an investigation of building placement in relation to the train tracks. The organisation in fig. 46 stages the old control tower and creates defined spaces on-site. All four strategies integrate Cable Park in the site strategy to condense the different user groups of Dok Øst, and connect the activities and spatial uses planned for the site.

Social alliesthesia
Social alliesthesia defines the gradient of separation or mediation between zones. This term is derived from the design of contrasts; in this case, the contrast or differences between social user groups, to enable different types of social interaction. Fig. 47 exemplifies which meetings are expected to happen between the various user groups on site.

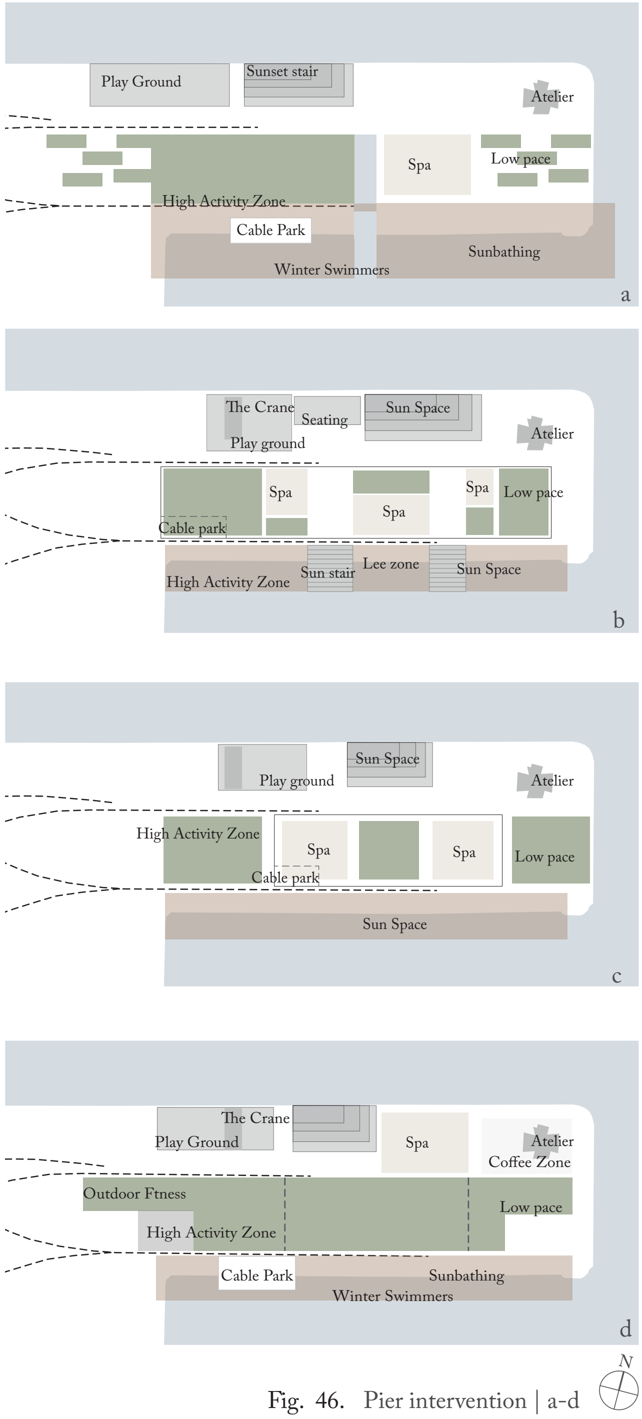


Fig. 46. Pier intervention | a-d

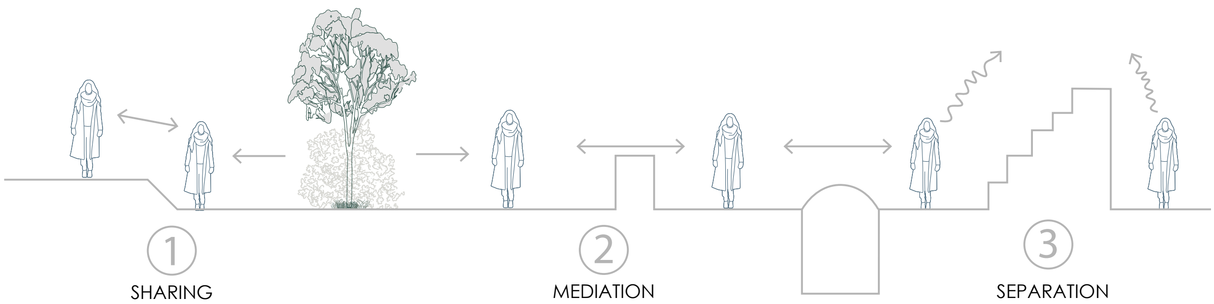
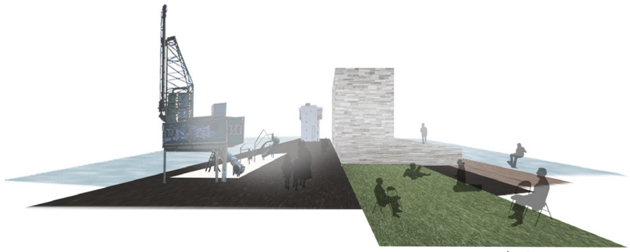


Fig. 47. Concept for social interactions

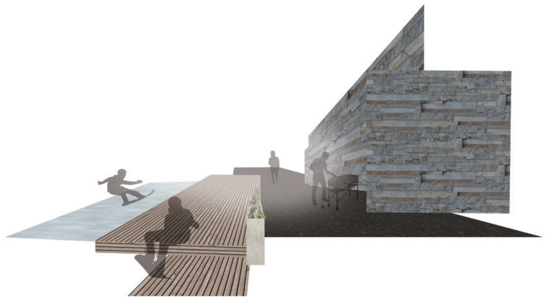
ZONING AND FLOW

Investigations of the site and its flow indicate and assist in further development of placement and size of the different functions. As fig. 48 demonstrates, the flow condenses at the site entrance and spreads along the train tracks.

The arrival at the site is wide open and unexploited, in contrast to the environment aimed to happen at the Pier, with several functions relating to the human scale, as conceptually illustrated in fig. 49.



Site atmosphere | Arrival



Site atmosphere | Cable Park

Fig. 49. Site atmosphere

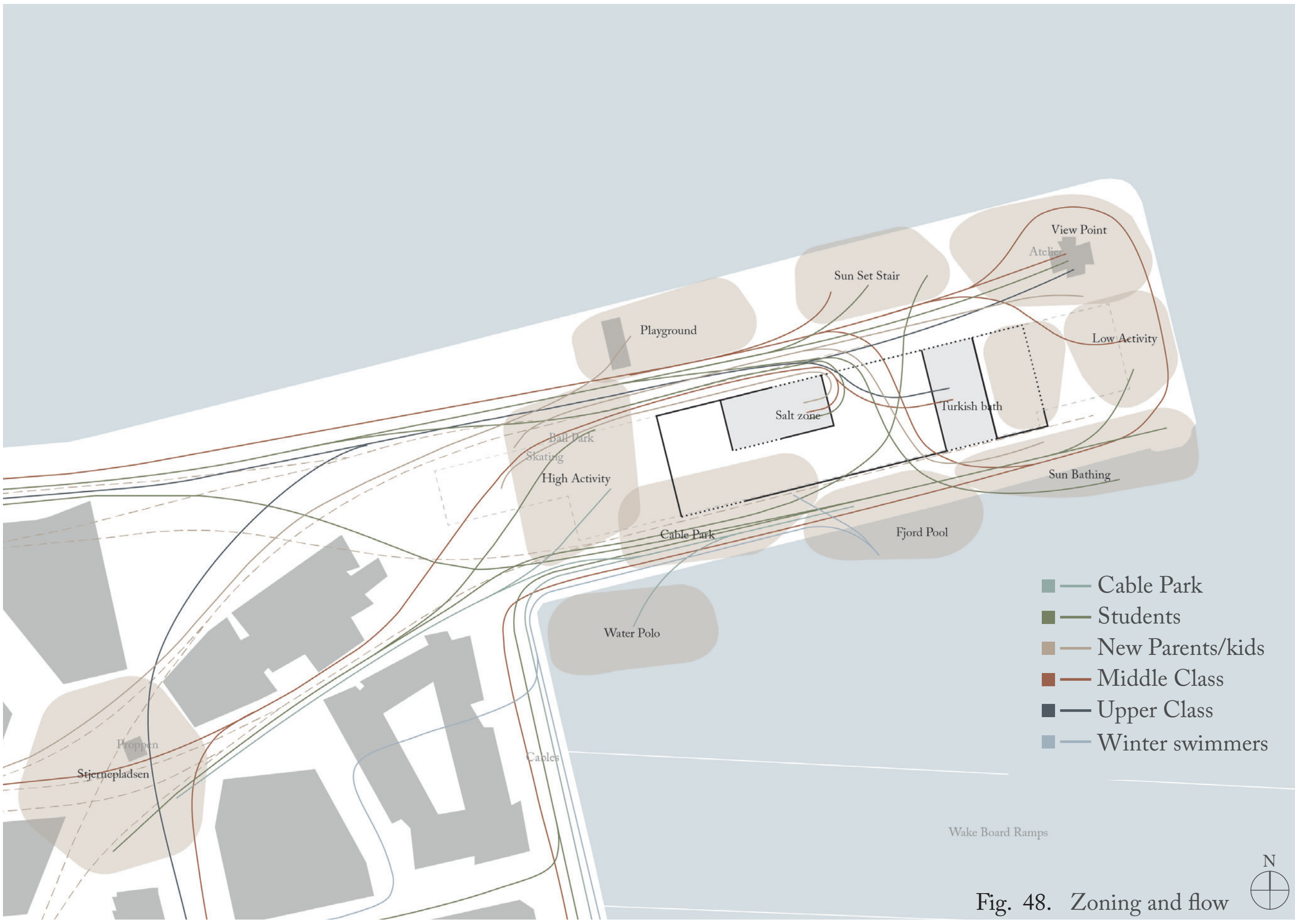


Fig. 48. Zoning and flow

The Towers

Qualities from both the crane, the monolith and the mushroom are merged into a concept that embraces the local history of Dok Øst. For example, an elongated volume that shapes outdoor spaces with an introverted expression and spatial connections inside the building.

The nature of the building is evolving with the facilitated experiences, in which the mediation of high activity and low pace is reflected. By shaping the plateau to follow the pre-existing train tracks and the footprint of the old factory, the volume is elongated to enhance the orientation of the Pier. To that end, the building mediates the heights of the two preserved and renovated relics on site.

When activating the entire Pier with the Spa House, the plateau acts as a mediator and enables different environments for dwellers not directly related to the spa facilities. Therefore, the plateau needs to mediate between user groups when condensing a diverse set of dwellers in the same place. Additionally, the period of use sometimes overlaps, as illustrated in fig. 50.

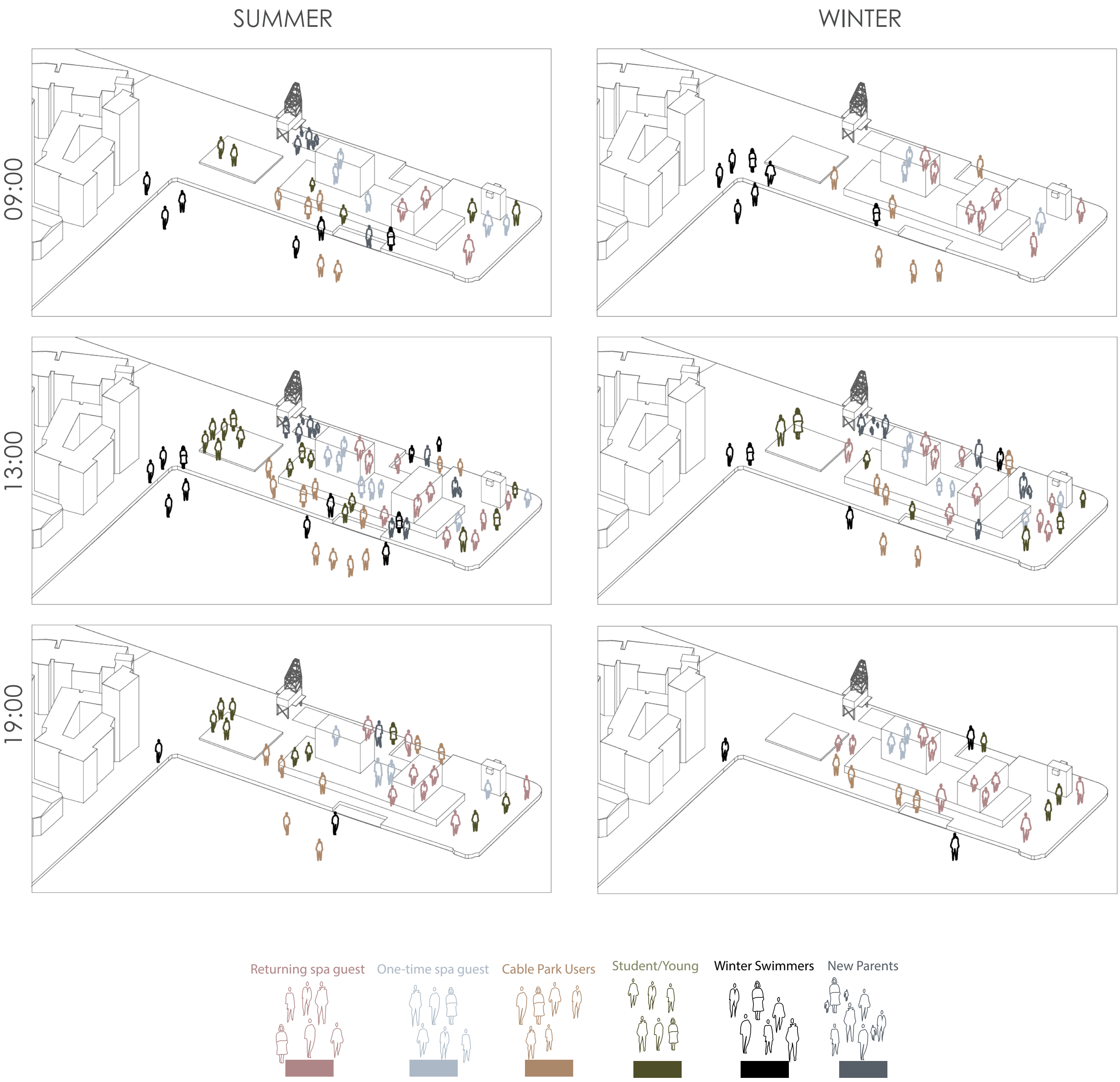


Fig. 50. User group | schedule

UTCI

The UTCI mapping in fig. 51-53 demonstrates the quality of outdoor spaces evaluated by radiation, wind speed, humidity and air temperature. To identify the potentials and limitations of different zones, the experienced comfort becomes paramount when investigating functions and user groups. The zones are set for areas intended for longer stays and ranked on an 11-step scale.

A transition space as point 1 has fewer requirements for the experienced thermal stress because of the short stay. Point 2 has the potential to be a sunspace for longer stays since the highlighted time slot is dominated by no thermal stress and moderate to strong wind. Such spaces potentially invite for a connection to water activities in Dok Øst.

The 3rd point is comfortable at noon in the hours from 11-13, creating a place for enjoying lunch, sunbathing, or other temporary stays in the middle of the day. In the opposed hours, point 4 has the potential to house social activities in the morning and evening time. For instance, a shared space for a small café, outdoor activities such as morning yoga, or the like, for the citizens nearby.

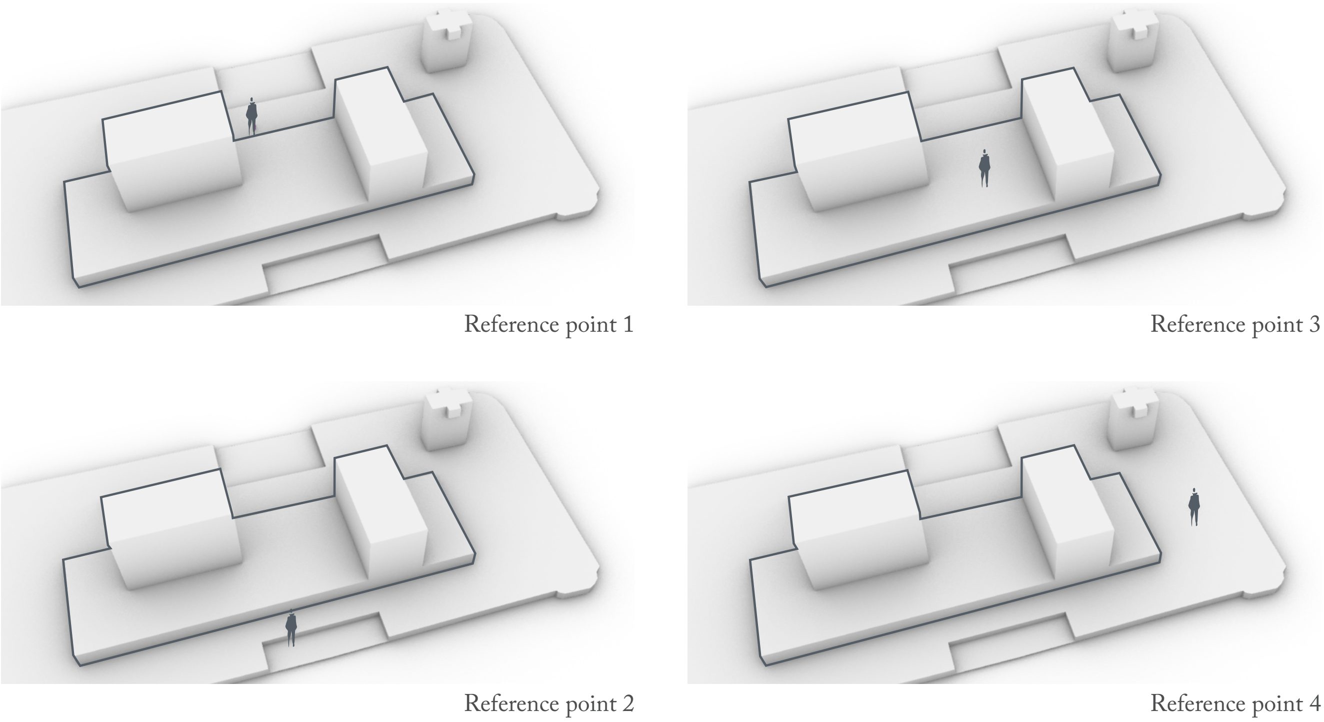


Fig. 51. UTCI | Reference points | 1-4

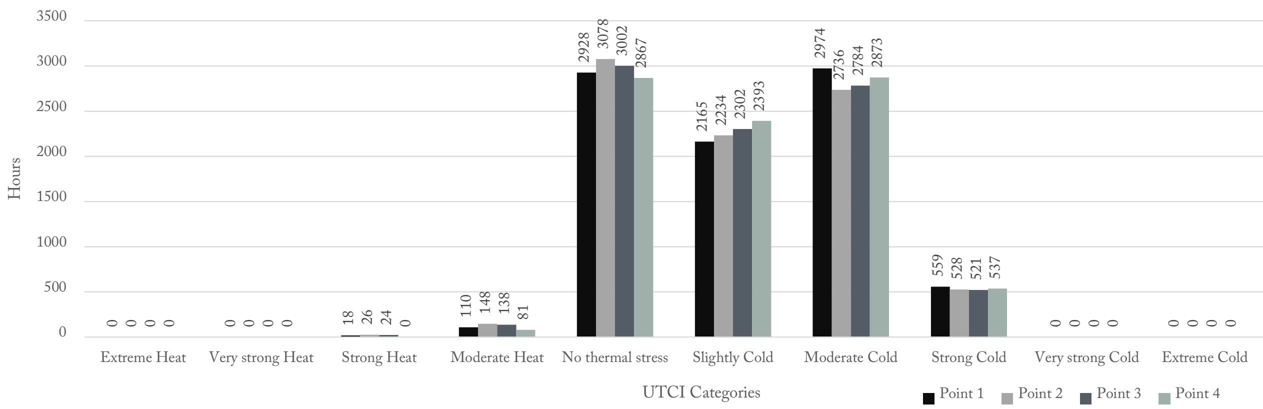
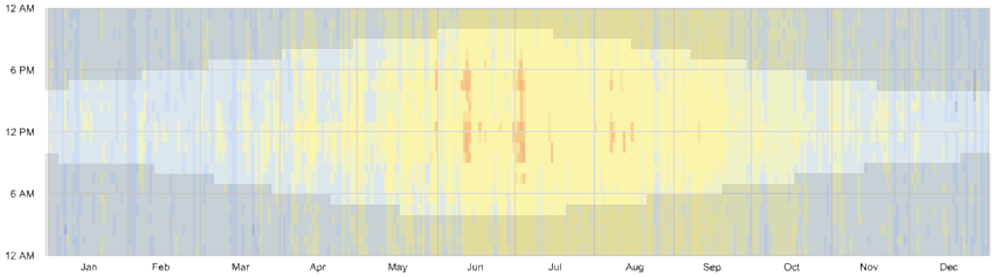
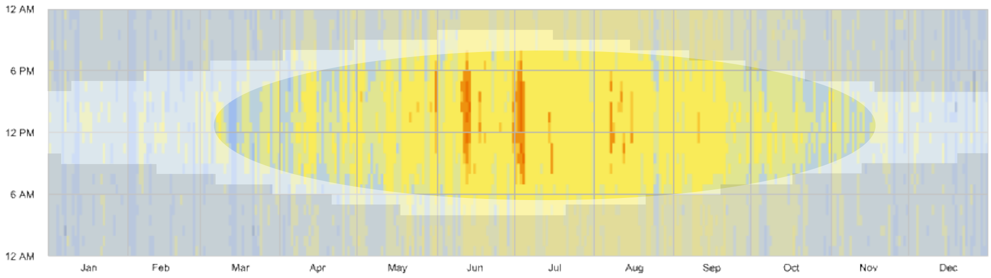


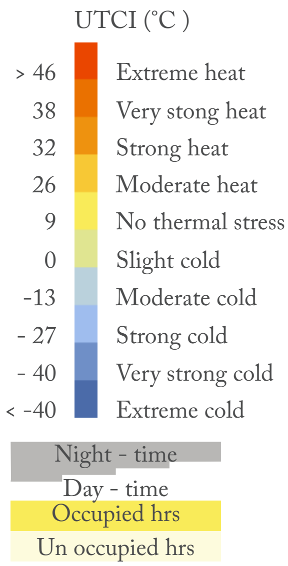
Fig. 52. UTCI | Occurrence of categories from reference points

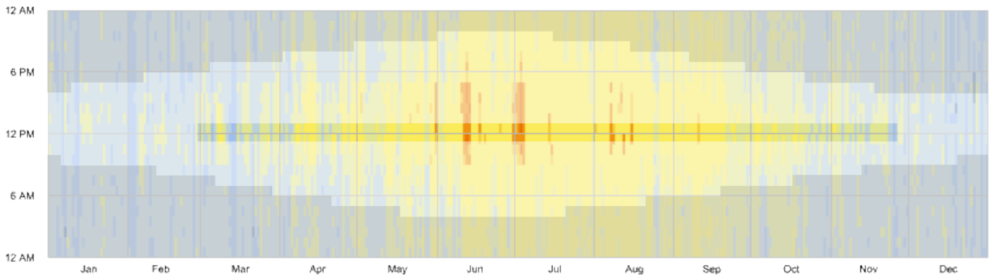


a | UTCI | Reference point 1



b | UTCI | Reference point 2





c | UTCI | Reference point 3

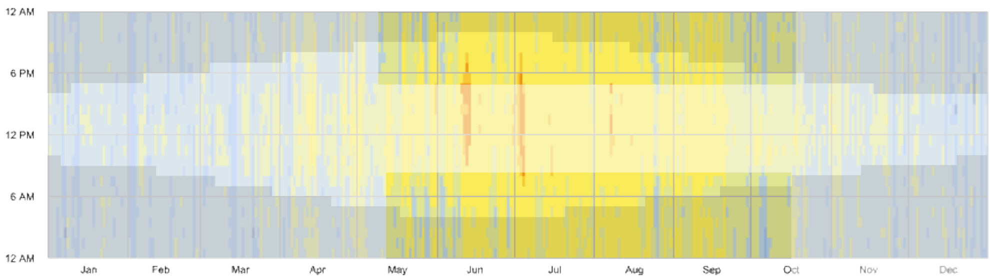


Fig. 53. UTCI | Heatmap 4 | a-d

d | UTCI | Reference point 4

MASSING

The correlation between site zoning, placement of functions and the climatic conditions points out various qualities that inform the nature of each outdoor space. Shading masks, radiation and UTCI investigation with the expected time frame and user group for each zone inform the design process.

Shading mask
The heights, dimensions and orientation inform the cohesion between volumes and the quality of outdoor spaces. Since the tallest volume is located to the west, to mediate the existing building heights on-site, the shaded space between the volumes is minimised by rotating the west volume. The west volume then blocks less for the sun and blocks instead the wind from the fjord, where no tall context building obstructs the wind, as illustrated in fig. 54.

Additionally, the shadings masks in fig. 56 guide the orientation and the proportions of sunspaces in height. To utilise the sun hours the most, the orientation must be facing the south-west, unless an outdoor space is intended to enhance a particular alliesthesia experience.

Radiation
The radiation mapping in fig. 55 maps how many hours of sunlight at the site. The areas south of the plateau are favourable for sunbathing and longer stays, to which there might be potential for distinguishing spaces for transition and for long stays. For instance, an additional zone close to the water housing the low pace activity. The spot in-between the buildings are intended for midday activities, such as the lunch break for the offices in the neighbourhood.

Furthermore, these mappings indicate which faces of the building photovoltaics or thermal collectors might be planned. However, if solar panels are to be visible, then integration must be considered to avoid compromising the desired architectural expression of the Spa House.

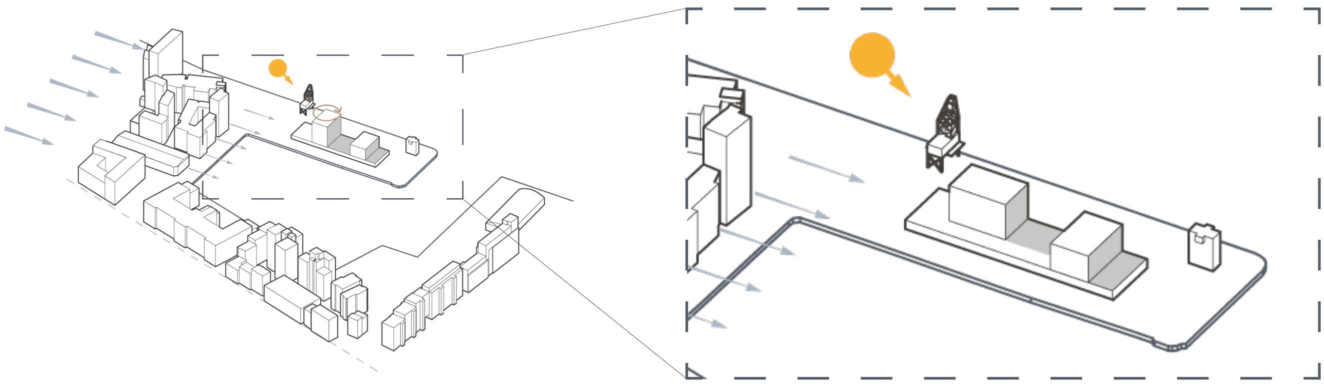


Fig. 54. Argumentation for building rotation

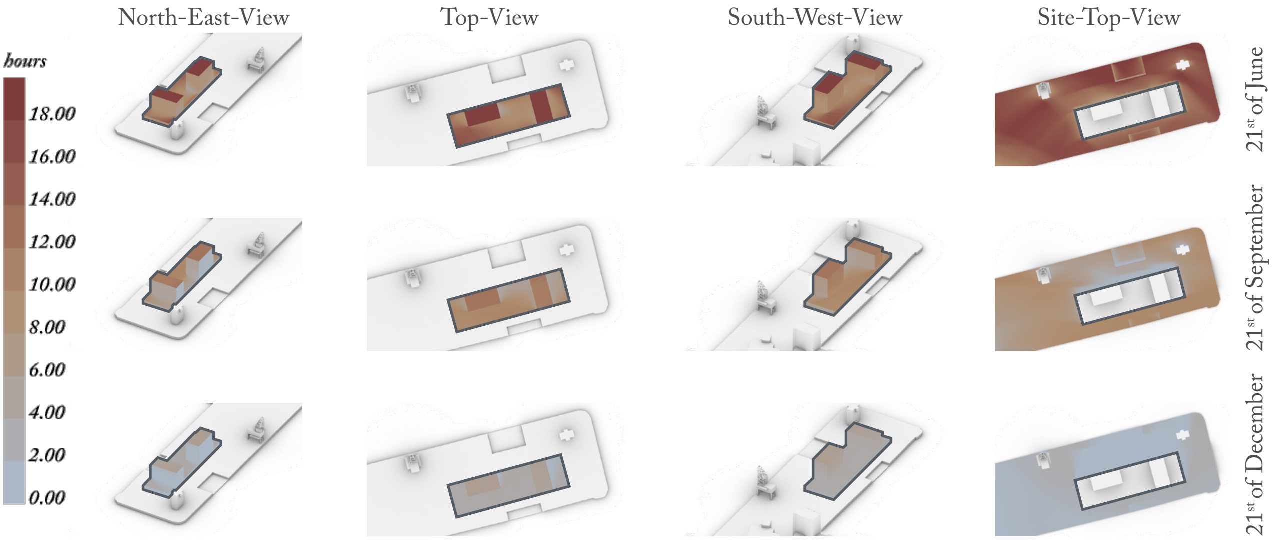


Fig. 55. Radiation mapping

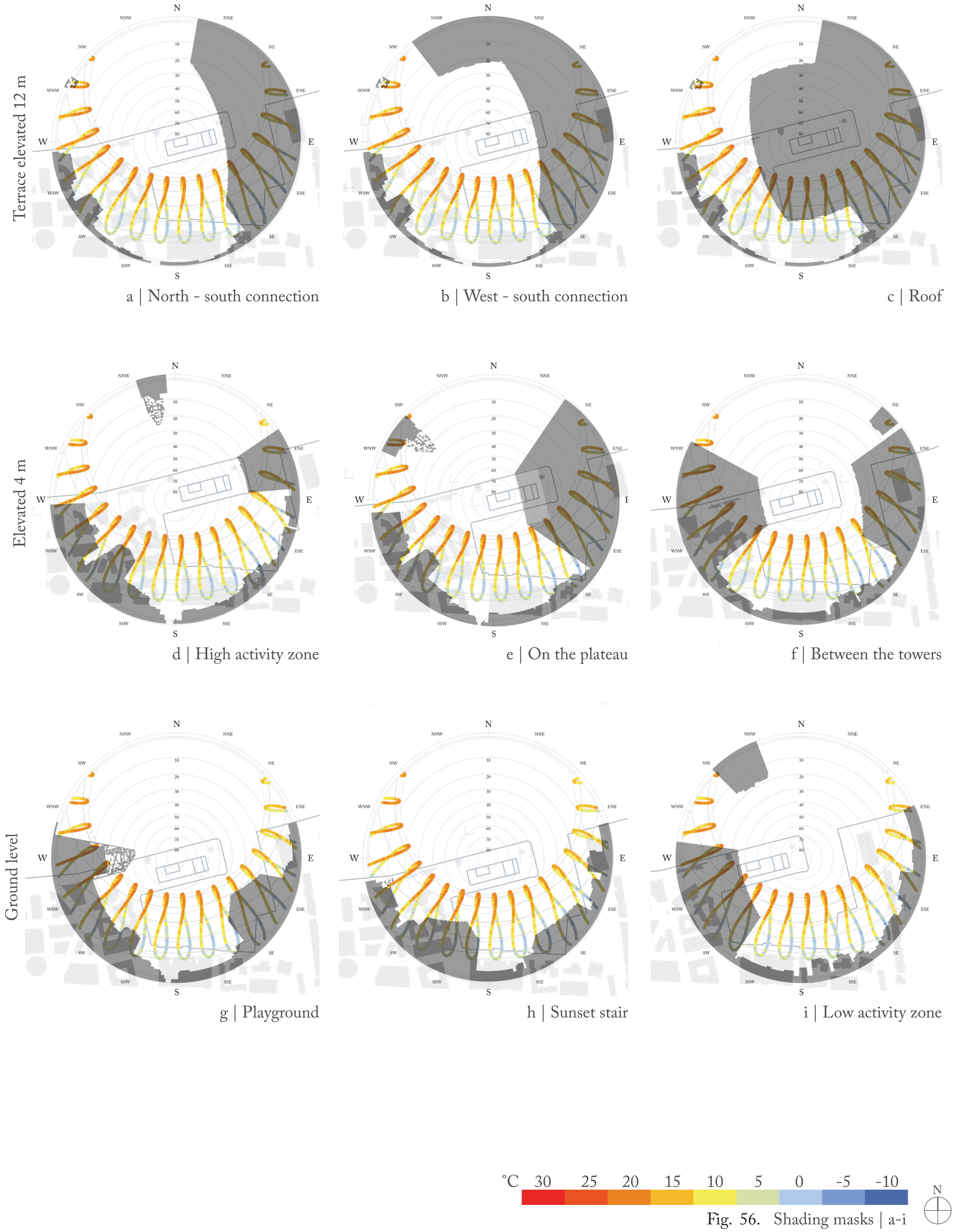


Fig. 56. Shading masks | a-i

STAIR

Stairs express a fluent connection between Pier and Plateau. Either by a peeling game with solid stairs that appears as the outer layer of the building, exemplified in fig. 58.a, or as a tectonic game as illustrated in fig. 58.d, from which plates bleed out, shaping the outdoor areas.

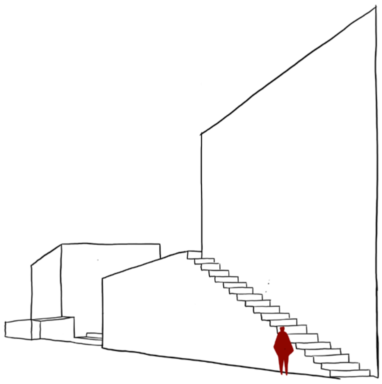
If the plateau aims to address the southern orientation in the daytime and the northern orientation in the evenings, a tectonic game of plates will be beneficial to embrace and extend the north-facing sunset zone at the Pier. The other game of one-flight stairs results in another experience when moving along the buildings. Therefore, a combination of the two might emphasise an exploring approach of the Pier.

ENTRANCE

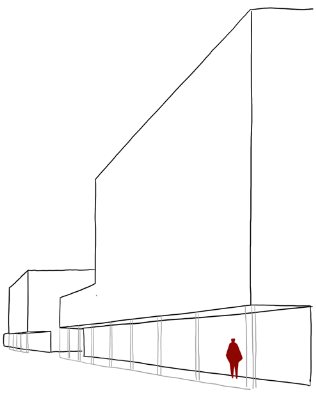
When entering the Spa House, the main door and the lobby sets the first impression of the Spa House.

The entrance floor can be framed in different ways, e.g. with an overhang as illustrated in fig. 58.d, a material change, or a shift in the façade such as extruding the lobby as in fig. 58.a, or by cantilevering the towers, illustrated in fig. 58.b. The orientation of a potential stair could frame the entrance and guide the flow, as in fig. 58.c. To that end, the consideration of both material combinations and structural systems are included simultaneously to enhance the potential of each strategy. One key reflection is whether the building volumes are flushed to the plateau or intentionally offset, based upon the internal function distribution.

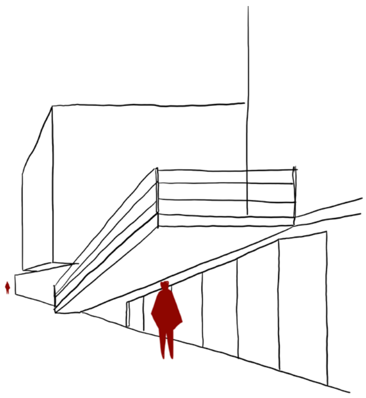
A double-height lobby permit glimpse of what happens when moving up into the building, enhancing sectional connections. Therefore, a tall door might state an extraordinary experience of entering the Spa House by the game of scale, pace and transition



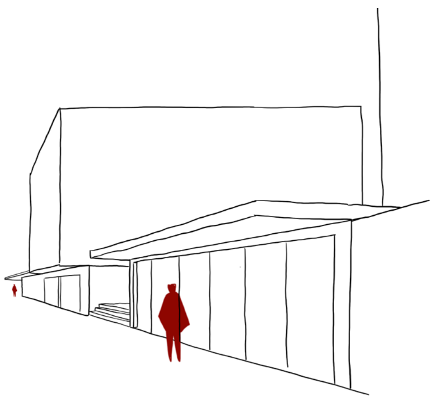
a | A one-flight stair highlights the extruded lobby and invites both urban dwellers and occupants of the Spa House to investigate the plateau.



b | An integrated passage inspired by the principle observed in the context, as a transition zone between building and Pier



c | A flipped one-flight stair obstructs the long views to highlight where to enter, by creating a natural corner for the entrance.



d | An overhang shelters the entrance door and communicates the differences in scale between Spa House and Urban spaces.

Fig. 57. Stair and entrance | a-d

FLOW AND CIRCULATION

The internal flows of the buildings are derived from connections and intended experiences between the individual rooms to enhance alliesthesia. Different strategies can elaborate on this; either connecting all functions with a common lounge as in fig. 59.a, a strictly guided flow that guides the experience through the Spa House as in fig. 59.c or 59.d or an exploring approach as illustrated in fig. 59.b that invites the occupants to explore their own sequence of experiences. The flow will be defined by the distribution and layout of either closed or open spaces or a combination of both, see fig. 60.

The stairs act as a natural mediator between extreme experiences, to which the design of the staircases turns out to be decisive for the flow; either including the main stair into the core to release free space in the floor plan, or to highlight the stairs as an experience when circulating between the facilities.

If the cores are not aligned with the facades, the cores and the stairs themselves have the potential to shape spaces and thereby create niches, integrated as a sequence of spatiality. However, this requires a floor large enough to embrace such concepts.

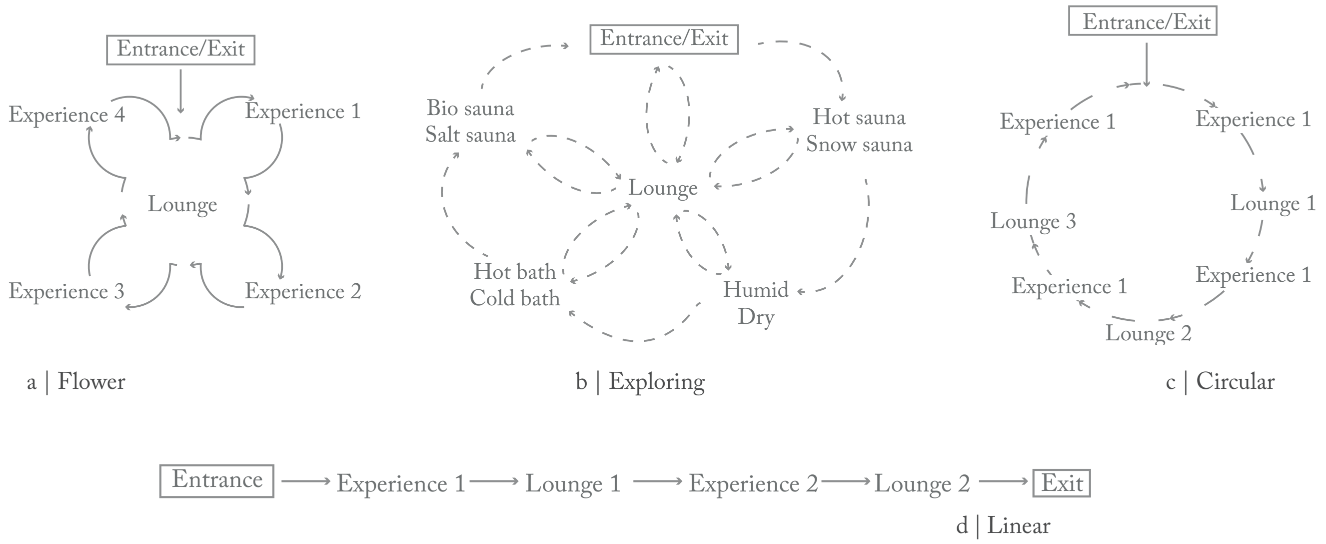


Fig. 58. Flow | Exploring

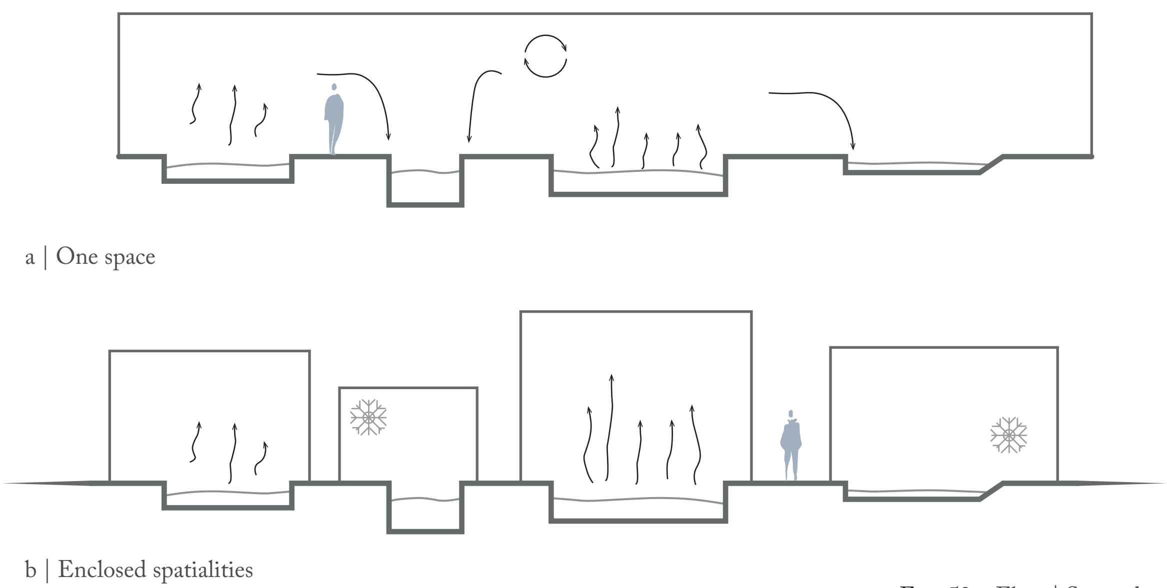


Fig. 59. Flow | Space distribution

SYSTEMS

The indoor environment of the spa facilities must be controlled by mechanical conditioning and ventilation systems. Because of the extreme experiences of contrasts, the air supply must be pre-conditioned in several rooms.

To minimise the pipework, respectively pools or saunas could be stacked or placed against each other in the plan, to which the distance to the technical cores must be considered. If the core is not centralised, an additional shaft enables shorter distances for air and water supply. This informs the flow of the buildings and the placement of functions.

Pipes and ceilings

The aesthetical dimension of the systems is considered in relation to the story of the Spa House. Visible pipes communicate transparency of the building design and the interconnection of the systems, which might be inspired by the industrial history of the Østre Havn. However, hidden pipes let all surfaces appear undisturbed, resulting in a neater expression.

A traditional drop ceiling could be a solution, especially if no sectional variation is intended, as illustrated in fig. 62. If instead placing the inlets and outlets of the rooms in the walls, the ceiling has greater freedom in terms of spatial variations. In that case, the two technical shafts contribute with flexibility related to the placement, see fig. 61. An increased wall thickness might be a gesture to the spatiality of the Spa House, creating niches or integrated furniture. However, reparations will be more comprehensive than working with either a drop ceiling or visible piping.

Air handling unit

Since most of the context buildings are taller than the Spa House, an air-handling-unit could be placed inside the building and not be visible on the roof, either at the top or ground floor. Additionally, the unit avoids being exposed to weather conditions and minimises the wear to which the lifetime will be extended. If placed on the ground floor, the enclosed technical room has the potential to promote introverted surfaces, where the urban dwellers get close to the building. To that end, the upper floor is prioritised for spa experiences and views of the fjord.

To minimise the gene from intake and exhaust air, those must be located where no outdoor spaces are interrupted, and distant to windows not intended to be fixed. Maybe integrated into the envelope.

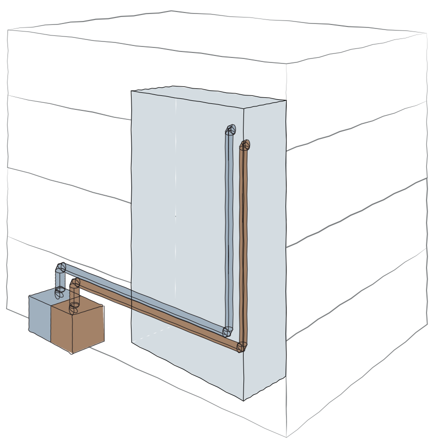


Fig. 60. Stacking of systems

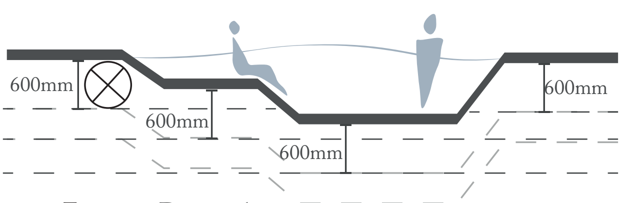
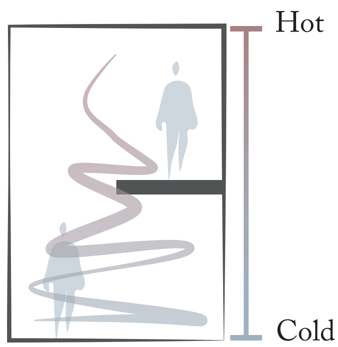
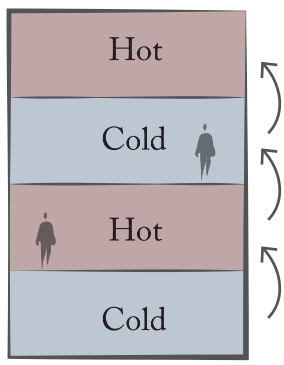


Fig. 61. Drop ceiling



a | Layering effect of cold and hot air create a temperature gradient.



b | Shifting from cold to hot rooms

Fig. 62. Connection between hot and cold

Extremes

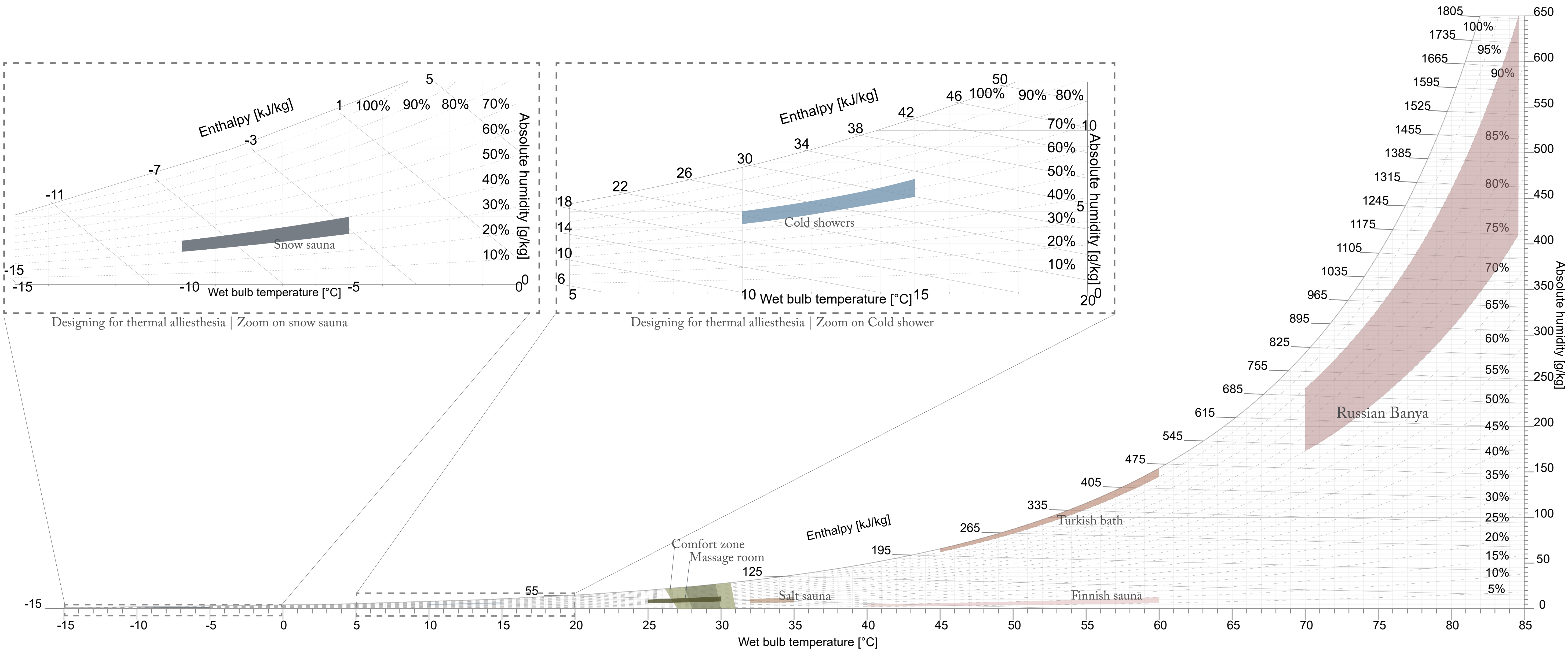
TThe final dimensioning of the system, pipes and air-handling unit will be up to a mechanical engineer to dimension, to which this project is derived from precedent studies of and producers of similar facilities. The dimensions of the main systems for mechanical ventilation are an estimate based on the sizes needed for conditioning an indoor swimming pool in Denmark (Danthermgroup, n.d.).

However, the extreme conditioning of saunas probably needs a separate system to supply heated air and control the humidity of the unique experiences. Each sauna will have an additional heating source, such as a stove with rocks to provide heat and steam, controlled in the individual room. Besides, the saunas benefit from having both air supply and extraction devices close to the floor, since the aim is to provide air circulation and preserve newly heated air inside the saunas (Spakompagniet, n.d.).

The snow sauna also has a separate system to provide snow inside, which should be placed less than 50 m from the room (ArchiExpo, n.d.). Therefore, the intention will be to place it directly related to the snow sauna.

The environmental conditions in spaces are essential when investigating perceived thermal alliesthesia for transitioning between spaces, such as the examples in fig. 63. The psychrometric chart is a crucial design tool to set the desired environmental properties for the thermal environment and the experienced sensation between spaces, see fig. 64.

Along with the circulation of the spa, a gradient of experienced alliesthesia should evolve from a conventional level of comfort to extreme thermal alliesthesia. The variation supports the intentional flow of slight perceived alliesthesia on the first floors by mild saunas and cold showers, and the extreme perceived alliesthesia on the top floor when moving between a Russian Banya and Snow Sauna.



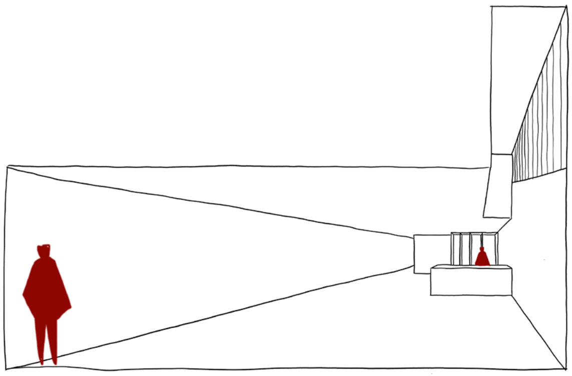
Designing for thermal alliesthesia | Zoom on snow sauna

Designing for thermal alliesthesia | Zoom on Cold shower

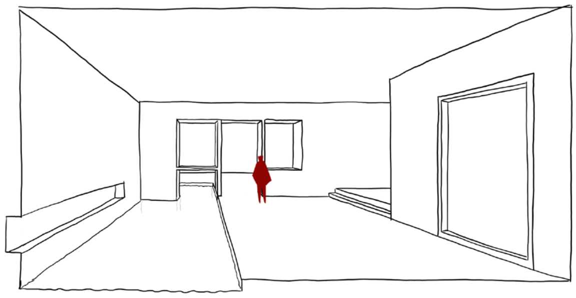
Fig. 63. Designing for thermal alliesthesia | Psychrometric chart

NATURE OF ROOMS

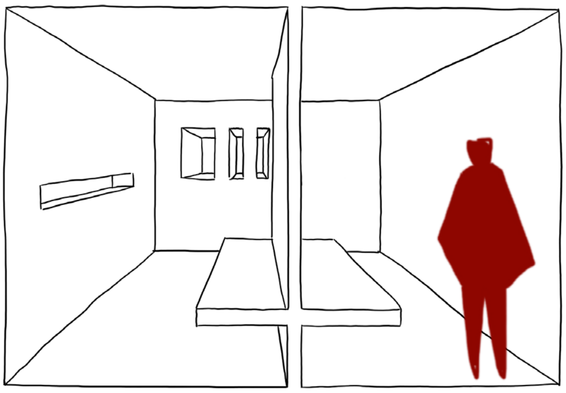
The placement of functions is supported by the nature of the individual rooms, reflecting the desired environment of each experience. Therefore, the distribution of functions is based upon which functions want to be in the facades and what functions permit a slightly secluded placement. For instance, the wish for openings related to the period of staying in the space. Pool areas for longer stays might benefit from a framed view as in fig. 64.d, unlike the short stays in a Russian Banya in fig. 64.e that by alliesthesia stresses the body as the most extreme facility in the Spa House, to which a view will be unnoticed.



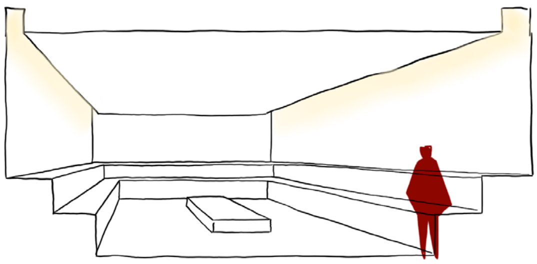
a | Lobby: Increased ceiling heights permit a sectional connection with glimpses of the circulation by the stair. The height and the shape of the ceiling are considered simultaneously with the potential it brings to the shape of the plateau above.



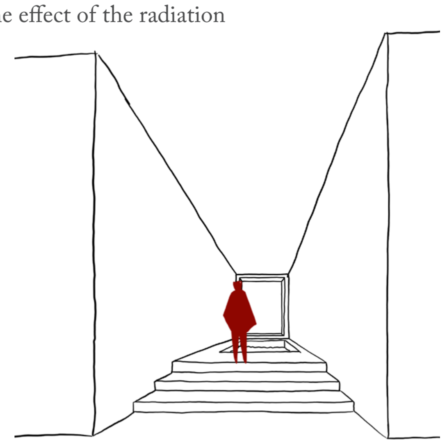
d | Half in, half out: An undisturbed movement between in and out with a narrow transition space. The energy loss minimises and creates contrasting spatiality before experiencing the open outdoor space. Additionally, a long low window frames a view from eye level when in the pool.



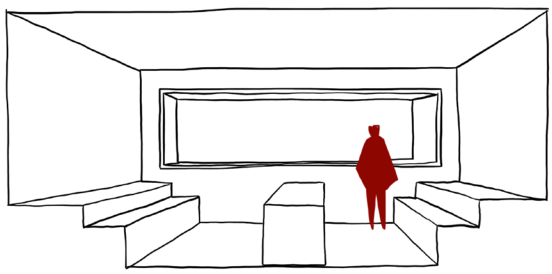
b | Infrared sauna: Small sauna for longer stays with no or controlled window openings. The infrared radiation is hidden in the walls, to which gaps in the surfaces are needed to maximise the effect of the radiation



e | Russian Banya: The hot and humid environment of the Banya might benefit from small openings to highlight the steam as a gesture of the space. However, the detail of the window must be carefully designed to avoid condensation because of the extreme temperature differences.



c | Cold pool/Jet pool: The void space between two enclosed rooms can create a defined space for a small pool, with surfaces framing a view. Steps emphasise changes in the environment, e.g. increasing the spatial dimensions and level of privacy.

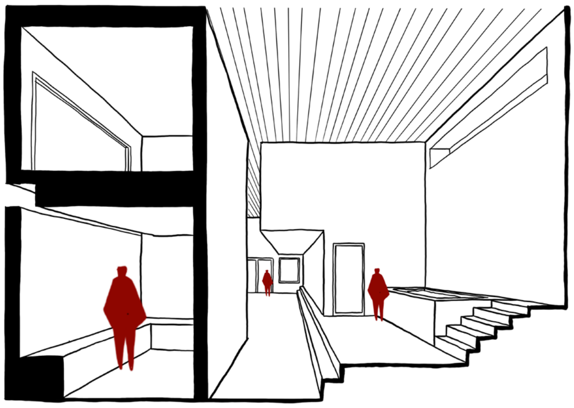


f | Finnish sauna: As the Finnish sauna houses longer stays and periodic sessions of sauna gus, a panorama window framing the context expands the sauna experience with a calming view, favourable facing the fjord.

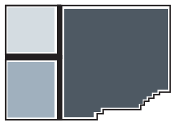
Fig. 64. Nature of rooms | a-f

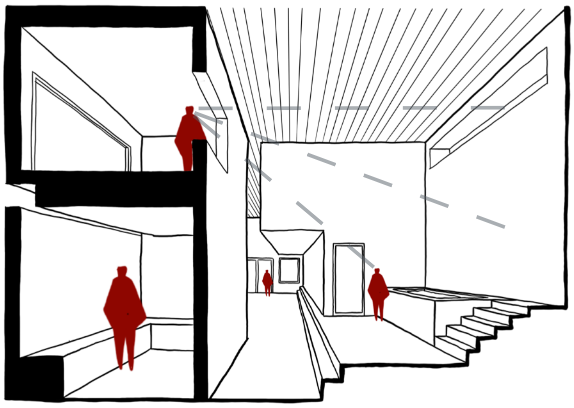
VOID SPACES

Connections between floors are sectional driven if working with double-height rooms and open floor plans, see fig. 65. Such a connection might be most beneficial in large spaces of the building, probably lounges or zones with open pools. However, internal openings or windows in rooms that are enclosed with strictly conditioned spaces allow visual connections between the spa facilities on different floors. Additionally, interior windows and different floor levels permit the opportunity to combine the usage of overhead light and views across the building, and thereby increase the experience of an opening in the envelope.

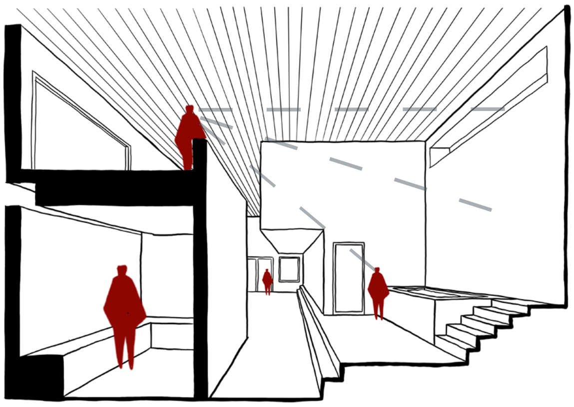


a | Self-contained rooms, enclosed and separate spaces with no internal connections.





b | Creating internal visual connections between floors but maintaining the distinction of functions.



c | The spaces blend together and make open spatiality and sectional connections.

Fig. 65. Void spaces| a-c

ATMOSPHERES

Materiality has a significant impact on the atmosphere of a space, to which surface properties help shape a desired environment. Therefore, abstract material investigations will guide the materiality of the Spa House. .

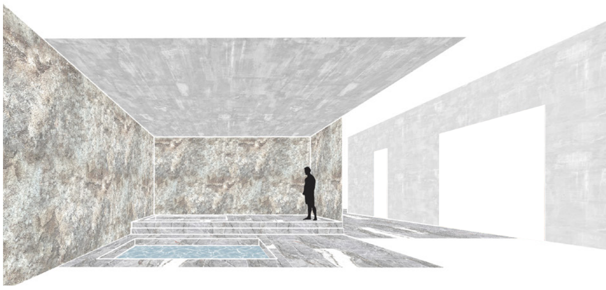
The buildings at Østre Havn is characterised by massive and heavy structures reflecting the previous industrial usage of the Pier. Besides, when designing a building for water, the heavy materials might be beneficial when shaping pools, since at least some of the surfaces assumable need to be concrete. Moreover, the floors need to be suitable for water, wet feet and high humidity. As demonstrated in fig. 66, some wall surfaces might be covered by other materials such as wood to create contrasts between the surfaces.

Surface material, finishes, and patterning contributes to aesthetical and technical qualities. For example, contact temperatures, heaviness, textures, and colour, from which contrasts and variations expand the environmental experience. It contributes to shaping a specific atmosphere in terms of use, tactility, and diffuse and direct light.

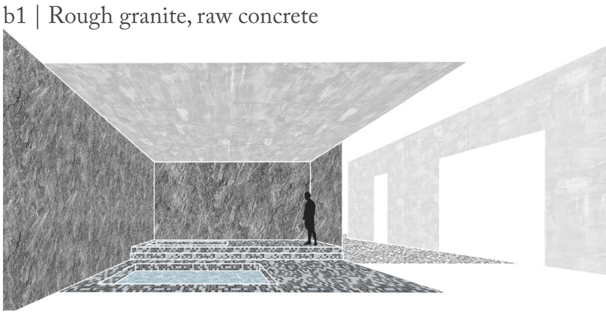
For instance, the wooden surfaces in saunas benefit from the low conductivity of wood, which is related to the contact temperature when operating with the high temperatures, and create a soft and warm surface for interactions. Such surfaces have the potential to contrast the heavy materials represented elsewhere. Another scenario, such as the pool areas, stresses the rough textures to enhance lighting and the depth created by shades. However, when considering the environmental impact of producing and transporting large stone surfaces, it becomes interesting to investigate the potential gestures of a locally produced material such as concrete. Some spaces might benefit from smooth massive surfaces, referring to an implicit concept of reflecting water when designing a Spa House. Fig. 67 visualises the gesture of stone. Additional visualisations are found in appendix IV.

The thermal mass can, in both cases, act as a heat sink in cold rooms. The texture or finish of the massive surfaces could serve as an indicator to guide the visitors, e.g., cohesion between zones or down-scale large surfaces.

a1 | Wood, smooth concrete

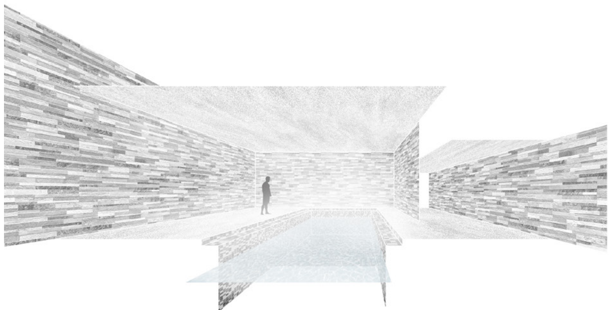


b1 | Rough granite, raw concrete

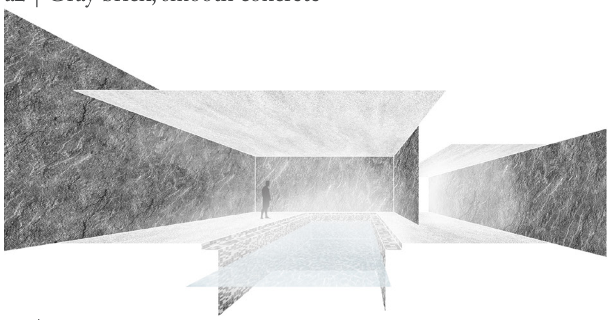


c1 | Black stone

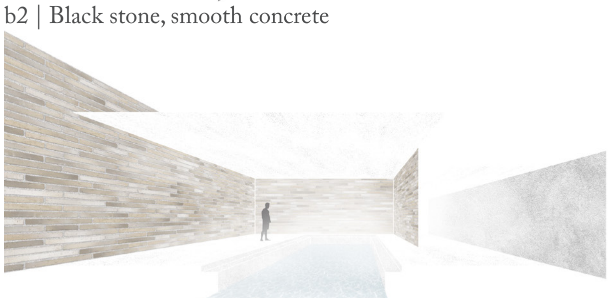
Fig. 66. Atmosphere | Room 1 | a1-c1



a2 | Gray brick, smooth concrete



b2 | Black stone, smooth concrete



c2 | Brown brick, smooth concrete

Fig. 67. Atmosphere | Room 2 | a-c

DAYLIGHT

The impact of openings and materiality in different rooms have a significant impact when designing an experience. A dark and textured material combined with small openings results in a cave-like atmosphere as in fig. 69.a. Fig. 69.c shows that white concrete surfaces reflect the light, to which the same room appears big and bright, resulting in an entirely different atmosphere. However, the shape of the openings is crucial to the design and the function of the room; either make a close connection to the outdoor environment, hide a window, frame a view, utilise light from raised openings without direct views, etc. Those principles should be mapped into the building to emphasise atmospheres and relations to the context by defining transparent and opaque surfaces. The entire investigation is found in appendix V.

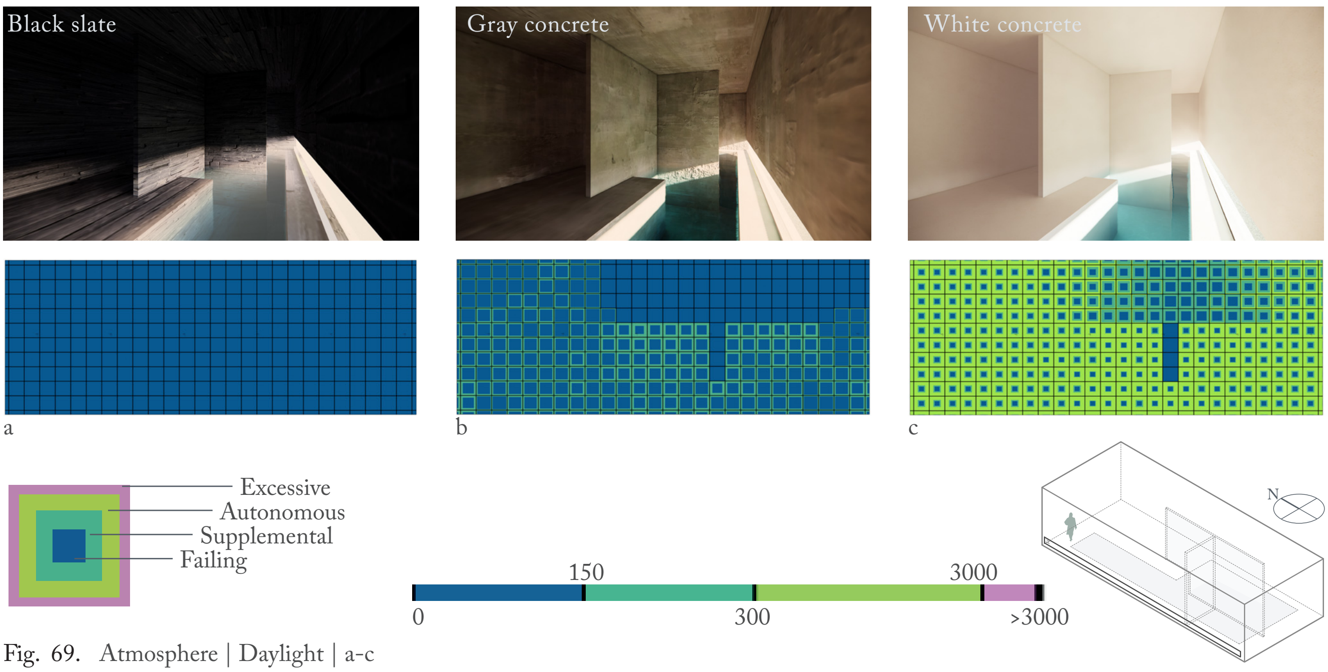


Fig. 69. Atmosphere | Daylight | a-c

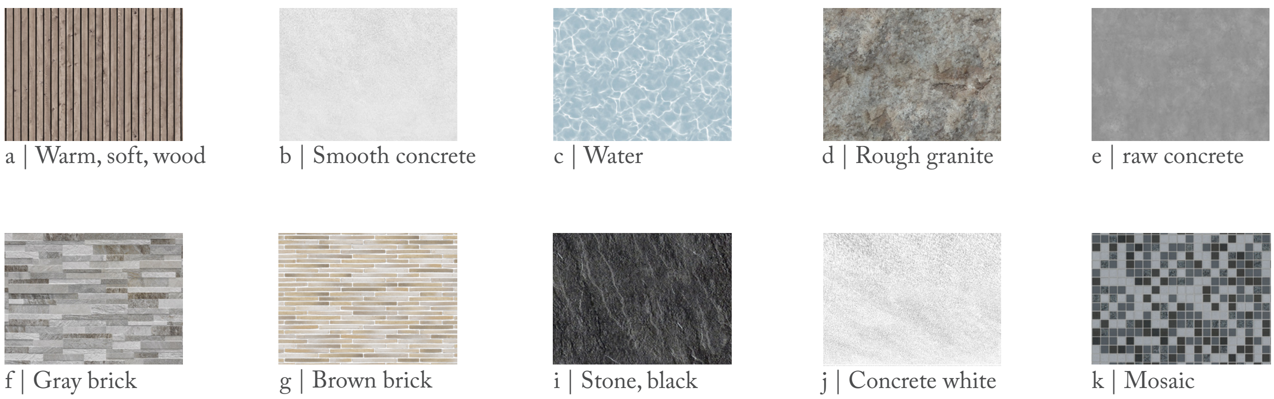


Fig. 68. Textures | a-k

The indoor environmental quality is vital for the long-term well-being of the employees in an office, to which the Danish building regulations present several minimum demands (Arbejdstilsynet, 2008). To that end, insulation thickness, daylight, and corresponding Energy Use Intensity (EUI) are vital aspects of the building design.

Office

A study of the EUI investigates the thickness of the Rockwool, to which an optimisation algorithm was used to evaluate the wall. The evaluation of the parameters is rated by: 10x+y, to which x: thickness [m] and y: EUI [kWh/m²/yr].

The formula simply priorities the parameter of a thin wall as the most important while still considering the EUI, implying that the insulation thickness should be approximately 350 mm. The fixed parameters are shown in table 8.

As seen in fig. 70-71, the heating demand decreases by 8% when going from 200mm to 300mm insulation, and only 2% from 300mm to 400 mm Rockwool. Therefore, the 300 mm is estimated to be the most efficient in this project, based on the evaluation criteria of a relatively slim wall.

	Investigation parameters
Set point temperature	Heating occurs at 20 °C Cooling occurs at 25 °C
Ventilation rate	In the room programme the air change has been defined to 429 l/s
Initial load	25 people who follow the schedule of being present from 7-16 and off-work at the weekend and holidays.
Systems	Ideal air system
Window area	15,2 m²
Wall	250mm Concrete xx mm of Rockwool 37 (Investigated parameter) 21 mm wood interior finish

Table. 8. Energy | Test specifications

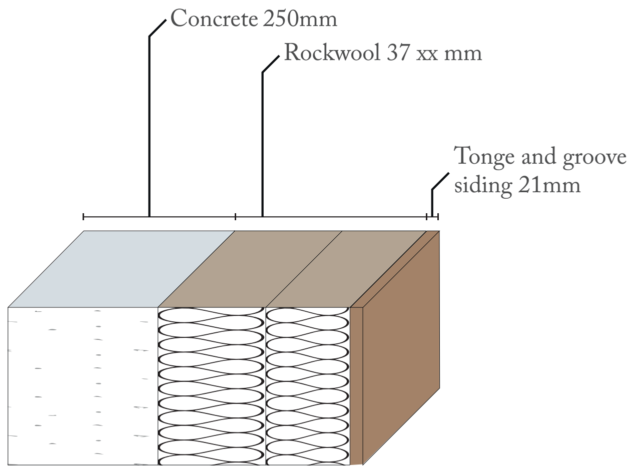


Fig. 70. Energy | Envelope neutral zone and office

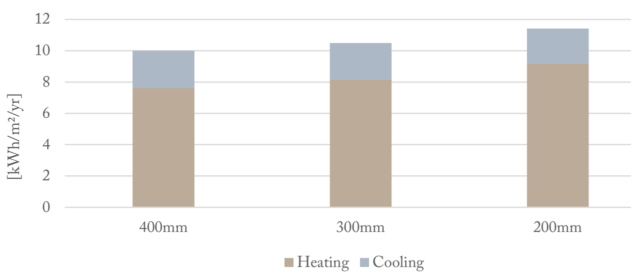


Fig. 71. Energy | Sensitivity diagram | Rockwool

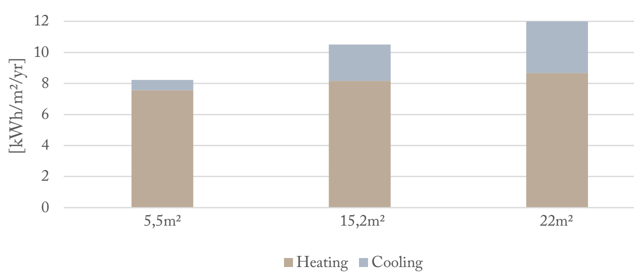


Fig. 72. Energy | Sensitivity diagram | Window area

Simultaneously, the windows are investigated to reach the specified 300 lux on 50% of the area, 50% of the time. Therefore, investigations of the window both imply daylight and EUI results, see fig. 72-73.

The first iteration, in fig. 72, with a 5,5 m^2 window area, has a low EUI, but the overall daylight factor is too low, and the energy demand for the 22m^2 gets too high. The simulation of a 15,2m^2 window for the offices is more suitable.

Fig. 74 compares different insulating materials, reaching a u-value of 0,87W/m^2K (Antonisen et al., 2021). The U-value is lower than the minimum requirement but states a tendency of the thicknesses, with a U-value similar to the energy-efficient houses presented in Komforthusene (Isover, 2010).

Kingspan has a low thermal conductivity, to which a minimal amount is needed to reach a low U-value. The downside is that it is very costly. However, Kingspan might be beneficial if it is strategically placed to insulate the saunas to reduce the wall thickness while maintaining sufficient insulating properties. To minimise the costs, the envelope could be insulated with Rockwool. A thick envelope can utilise the depth to create framed views or shading details in the wall.

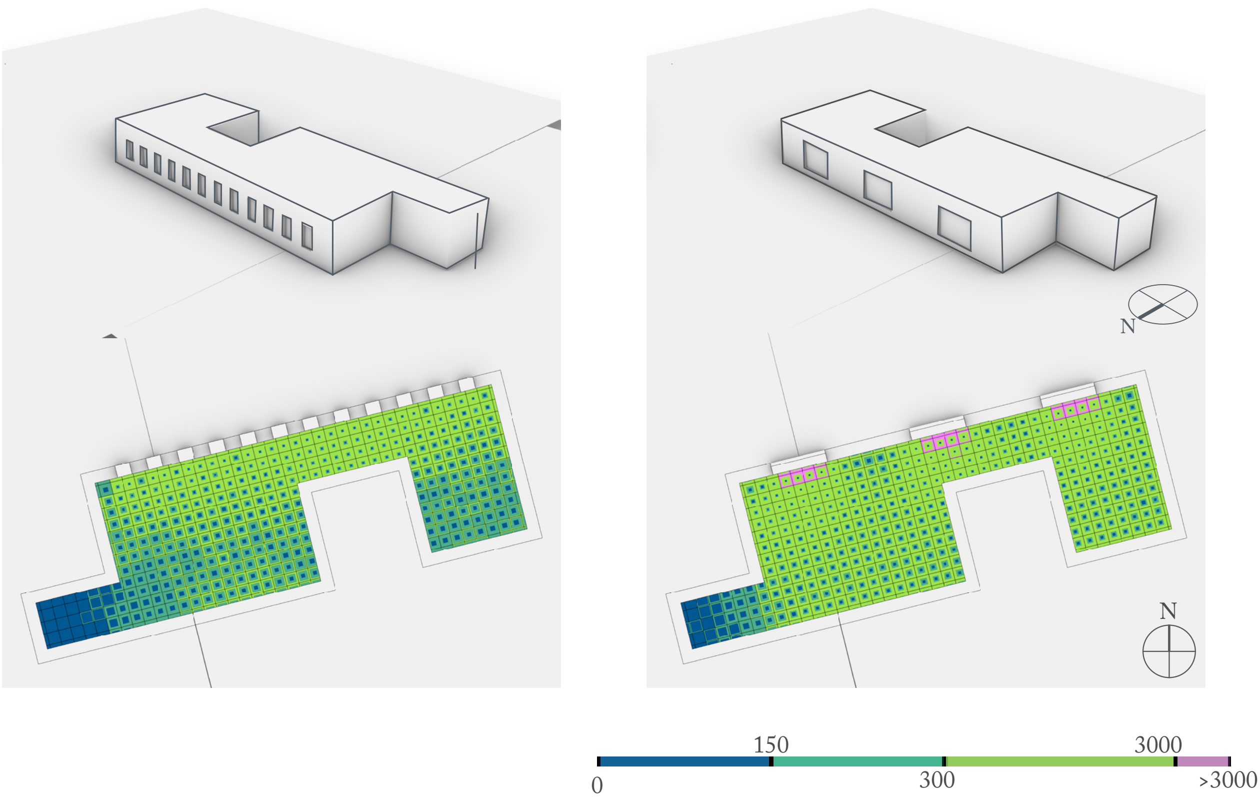


Fig. 73. Energy | Windows and daylight

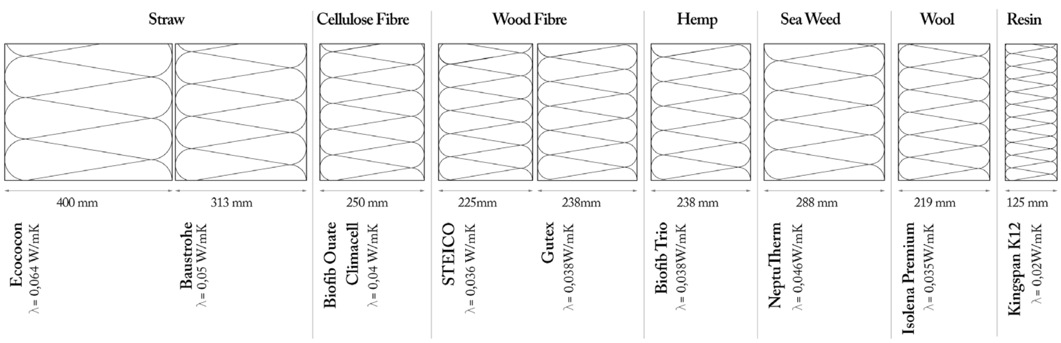


Fig. 74. Energy | Insulation study (Antonisen et al. 2021)

Spa

The placement of the different rooms is driven by the experience of alliesthesia, indoor conditions, thermal zoning, and energy. Warm saunas are placed to the south and cold rooms to the north because of the climatic conditions.

Window/wall ratios are tested for 20%, 40%, 60%, and 80% window areas, to which fig. 75-77 indicates that the energy needed for cooling is minimised when minimising the window area, but the heating demand rises. The different window expressions only result in minor impacts, to which the daylight and the atmosphere will be decisive, see fig. 76. Therefore, the energy simulations are bridged with daylight analyses. The entire investigation, including heatmaps, is found in appendix VI.

However, the orientation of the window openings matters. Therefore, the window/wall-ratio area for each direction is based on the simulation data from the first investigation, zones are defined in fig. 79.

- **Zone a:** Even a tiny window creates an excessive need for cooling and heating, as seen in fig. 78-79.
- **Zone b: A** minor challenge in cooling, but heating demand is similar. Therefore, a big window is beneficial for the daylight.
- **Zone c:** Small changes in both cooling and heating demand. The explanation might be that the zone is quite long and narrow in relation to the wall.
- **Zone d:** Overheating in summer and problems in winter. This might indicate that the façade needs a small or a low and narrow window.

	Investigation parameters
Set point temperature	Heating occurs at 20 ˚C Cooling occurs at 25 ˚C Varying at Set point investigation
Ventilation rate	In the room programme the air change has been defined to 346 l/s
Initial load	120 people spread out in the entire spa. Therefore, 15 people would approximately be at the top floor, following the schedule from 9-21.
Systems	Ideal air system
Window area	9,8 m^2 at setpoint investigation otherwise varying
Wall	250mm Concrete 280 mm of Rockwool 37 21 mm wood interior finish

Table. 9. Energy | Test specifications

An in-between zone can mediate between hot and cold functions to avoid condensation inside the construction. The simulation defines a mediation zone close to conventional indoor environmental conditions between the hot sauna to the south, and the snow sauna to the north. This zone creates a transition that minimises the instant experience, but the big contrasts between the two extremes will still enable strongly perceived alliesthesia. The top floor is estimated to be the most critical in terms of the amount of surface exposed to the outdoor.

In addition, the U-value and condensation risk of various wall compositions is investigated in Ubakus to ensure that the significant thermal differences are not causing condensation inside the construction, see appendix VII.

As a disclaimer, the software used for the simulation has difficulties modelling rooms with a setpoint temperature below 10˚C or above 70˚C. Therefore, these are modelled as with the conditions seen in table 9.

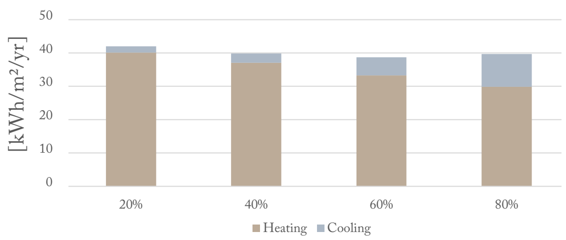


Fig. 75. Energy | Window/wall - ratio

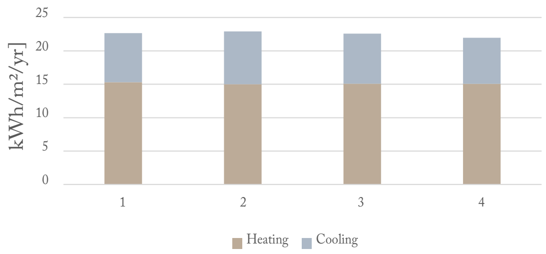


Fig. 76. Energy | Different expressions

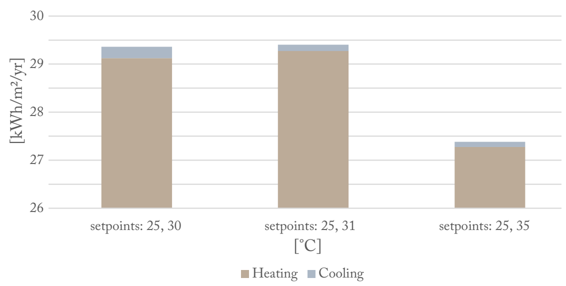


Fig. 77. Energy | Varying setpoints

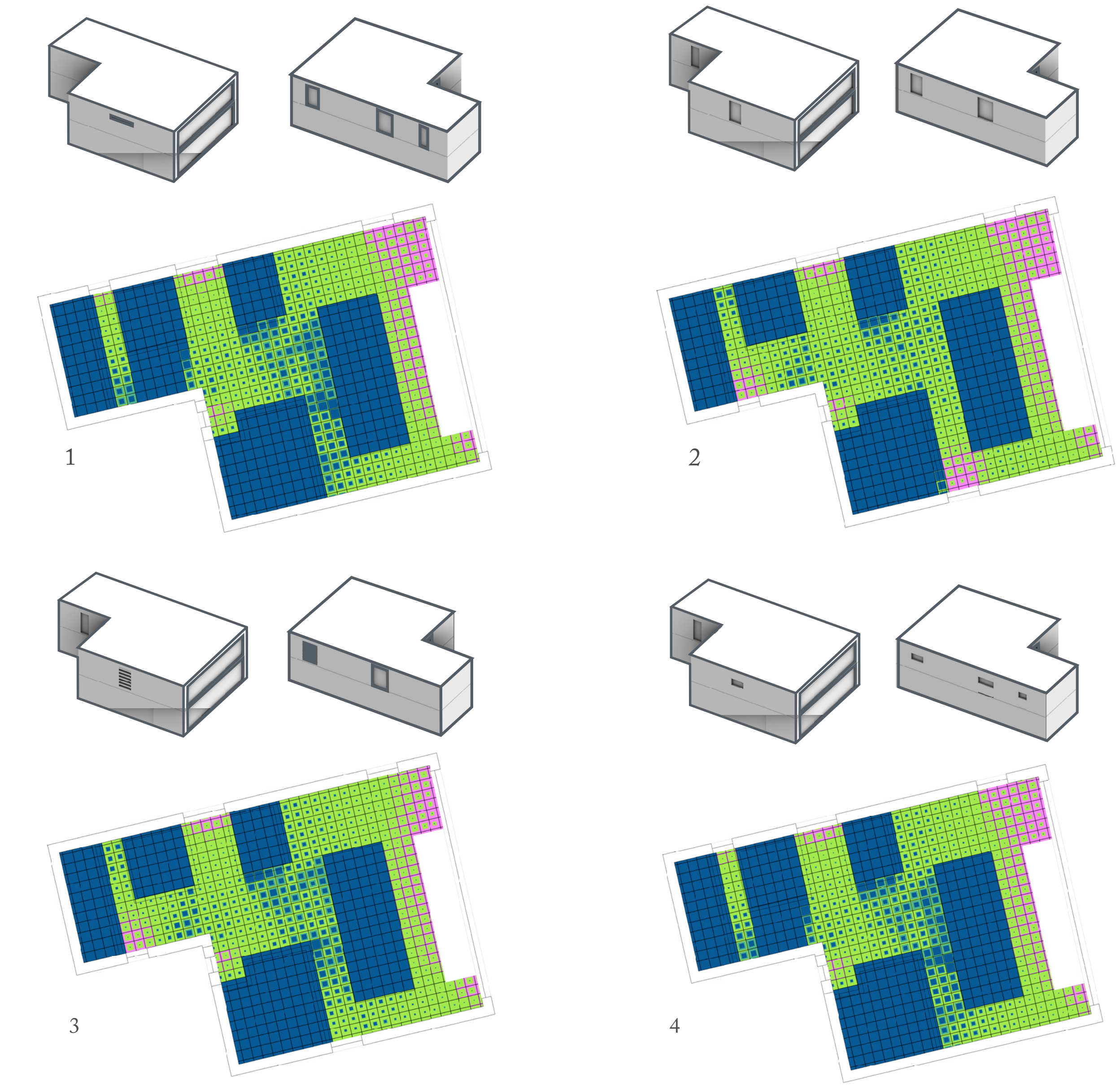
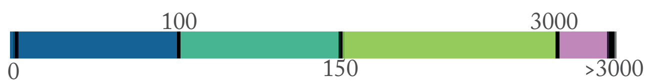


Fig. 78. Energy | Daylight diagram | a-d



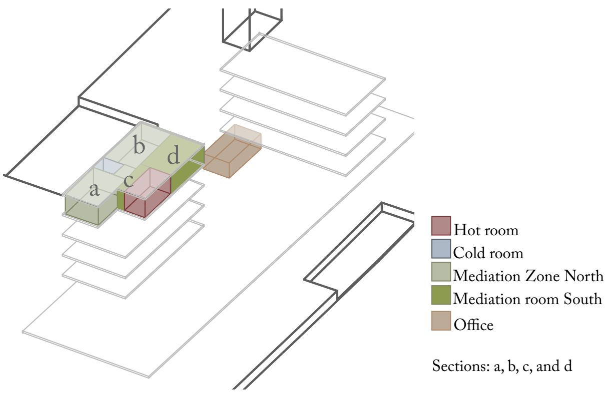


Fig. 79. Energy | Thermal zones

DESIGNING FOR VISUAL ALLIESTHESIA

The visual experience when transitioning from one room to another is investigated by visual alliesthesia. The contrast can be either view or no view, or by the contrast of light. The visual differences are studied by the Luminance contrast ratio (Lr) (Osterhaus, 2009):

$$Lr = \frac{E_{max}}{E_{min}}$$

- » Lr: Luminance contrast ratio
- » E_{min}: the lowest average level of lux
- » E_{max}: the face with the highest average level of lux

Frame:
he transition from one room to another is highlighting the experience by the use of light. The simulation investigates the transition between a dimmed room of 50 lux and a bright space. Different window constellations will result in different experienced glare when opening the door and leaving the room. The simulation runs for an overcast day, with a façade facing west. The dimmed room is covered in wood, and the other room is in concrete. When the transitioning happens, the minimum contrast ratio should be 1:10 to create a strong visual difference since the openings might not be in the direct line of sight.

The data is presented as a false-colour-rendering, illustrating the lux levels in cd/m². The investigation is paired with a render to communicate the atmosphere related to the data. Fig. 80-81 represent three situations made for September, and the complete analysis is found in appendix VIII.

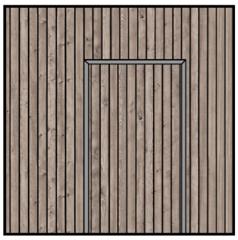
The test of the closed door indicates an average lux level of Emin=114cd/m², which means that the desired Lr of the window opening should be 1140cd/m² for a ratio 1:10 and 2280cd/m² for a ratio 1:20. The Lr of the respective windows are then:

$$\text{(b): } Lr = \frac{E_{max}}{E_{min}} = \frac{b}{a} = \frac{1634\ cd/m^2}{114\ cd/m^2} = 14{,}33$$

$$\text{(c): } Lr = \frac{E_{max}}{E_{min}} = \frac{c}{a} = \frac{1728\ cd/m^2}{114\ cd/m^2} = 15{,}16$$

$$\text{(d): } Lr = \frac{E_{max}}{E_{min}} = \frac{d}{a} = \frac{1889\ cd/m^2}{114\ cd/m^2} = 16{,}57$$

The created glare, in all cases, exceeds the threshold of 1:10. The bigger the window, the bigger Lr. However, the relation of glare achieved by increasing the size of the window further will not be worth it in this case, since the aim is to design visual differences more than create discomfort

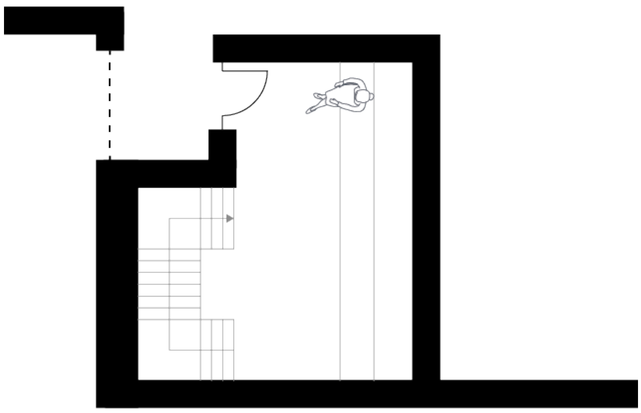


Test a: A simulation of a closed door.

Test b: A small window.

Test c: A high and narrow window

Test d: Replacing the entire wall with a window.



Context of simulation

Fig. 80. Test specifications

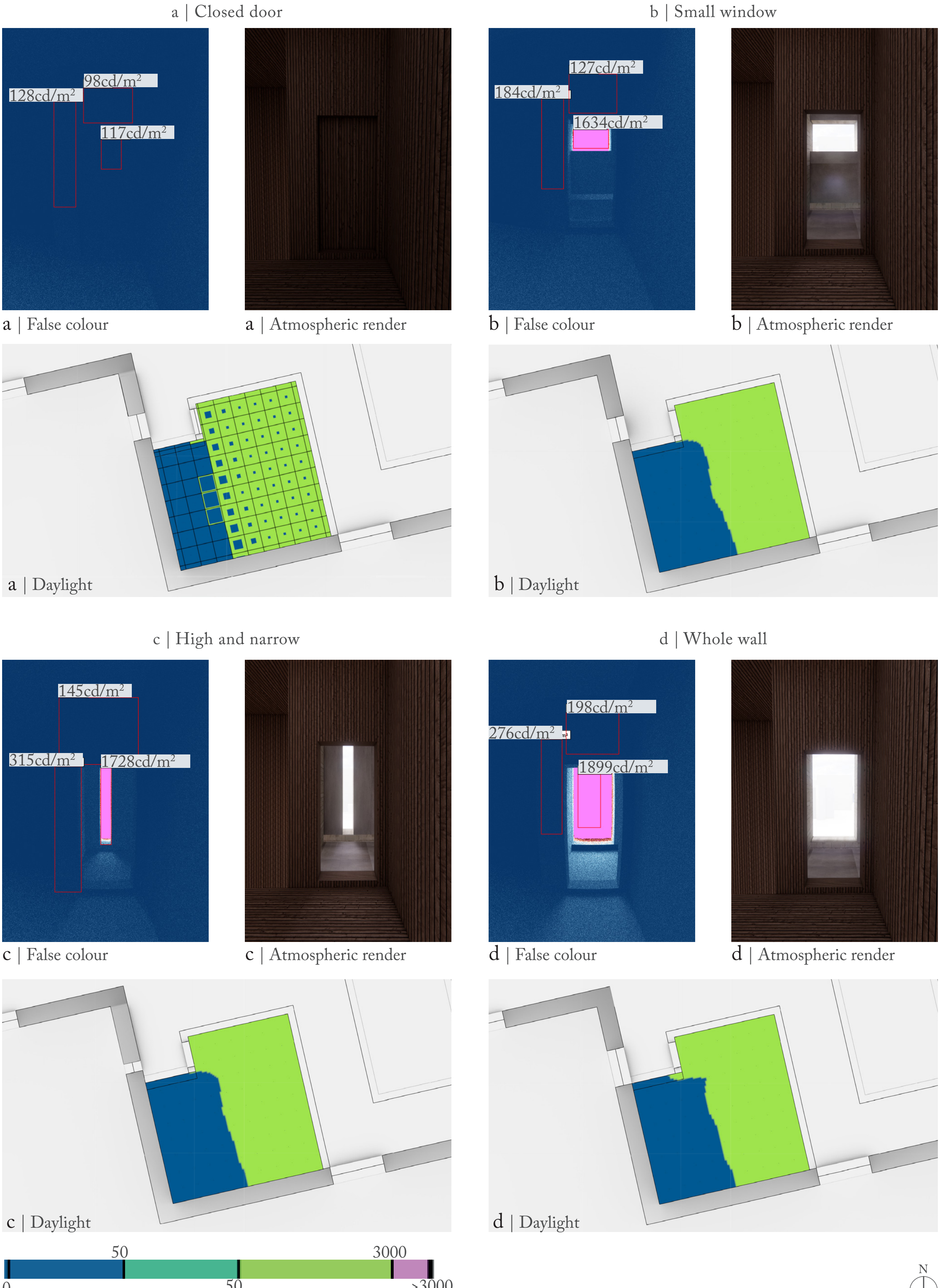


Fig. 81. False colour investigation

CONSTRUCTION PRINCIPLES

The Architect's Studio Companion: Rules of Thumb for Preliminary Design by Edward Allen and Joseph Iano is used to determine the structural system. As seen in fig. 83, three main structural systems are investigated; column and beam, wall and slab, and column and slab system. Each system requires a structural grid for placing columns or walls to ensure a straight load transfer to the foundation. The different structural systems have various deck thicknesses depending on the bay dimensions and construction material. The depth of the deck is essential for the room height, especially if ventilation ducts are placed in a drop ceiling. Fig. 82 shows different potential bay layouts on a 24 x 16 m footprint.

A deck of steel, glulam or precast concrete girders has the same depth when the span is 6 meters, as seen in fig. 84. As the span increases, a glulam construction achieves the smallest depths. However, a site-cast concrete slab can minimise the depth by 50 %, resulting in a lower floor-to-floor height. Another advantage of site-cast slabs is the possibility of casting the pools directly when constructing the building. Here the pools are integrated into the deck construction and allow for a seamless material transition between dry and wet zones in the Spa House.

If the plot area for the two volumes aims to be slim, it results in a relatively small bay width. Besides, if utilising the building cores as loadbearing structures, the span of the slab diminishes further and helps stabilise the structure.

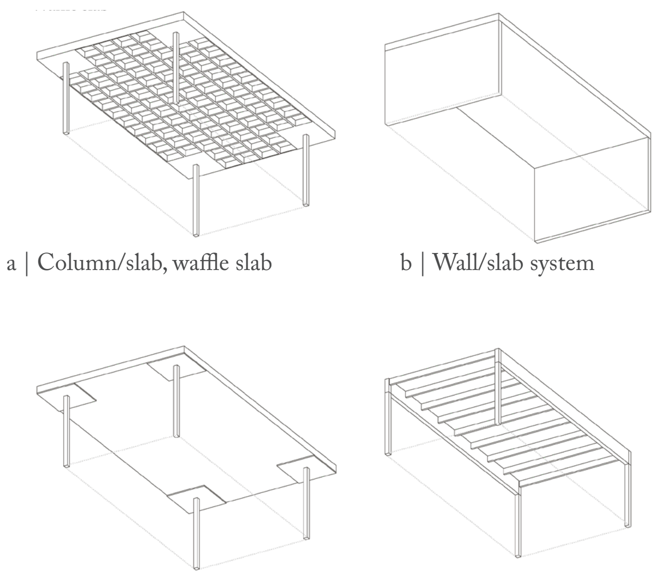
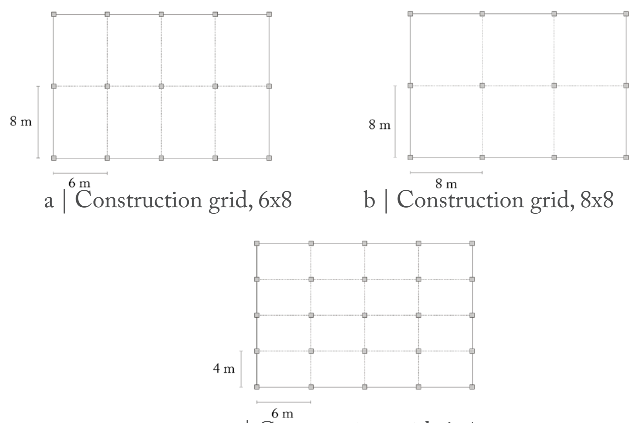

a | Column/slab, waffle slab
b | Wall/slab system
c | Column/slab, Two way flat slab
d | Column/beam

Fig. 82. Construction systems



a | Construction grid, 6x8
b | Construction grid, 8x8
c | Construction grid, 6x4

Fig. 83. Construction grid

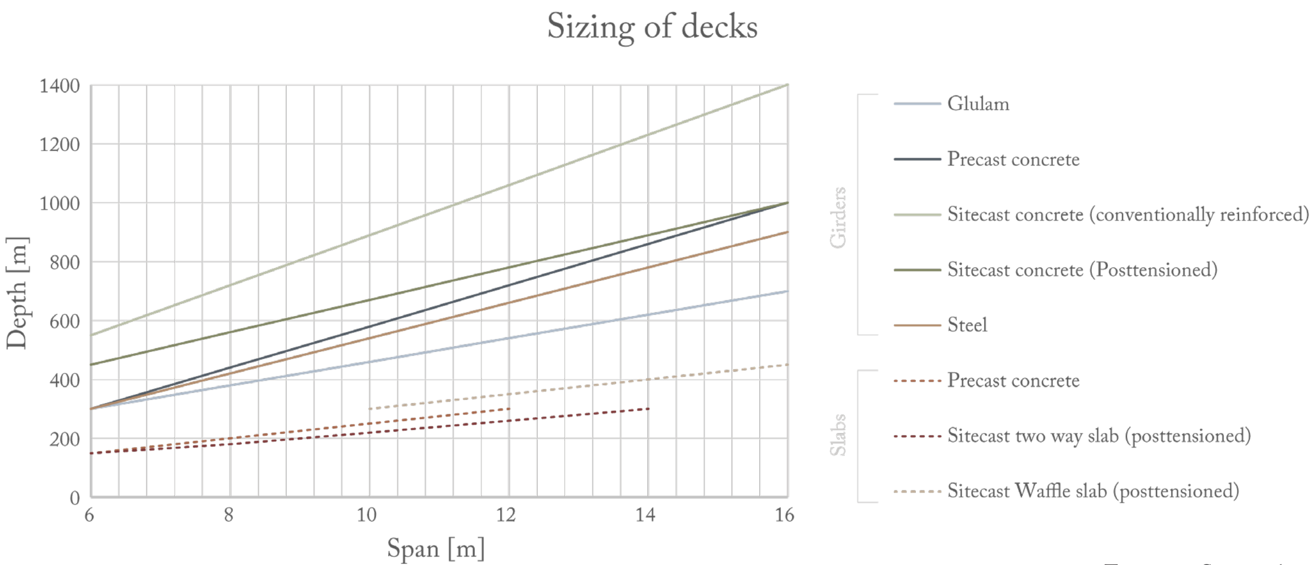


Fig. 84. Sizing chart

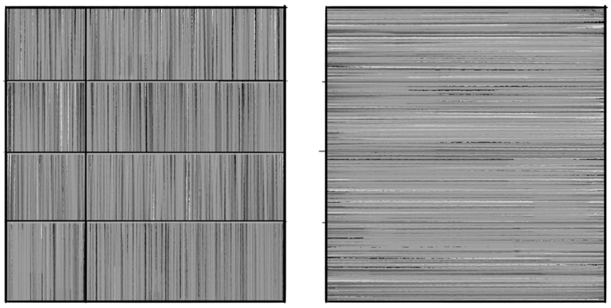
When designing a spa, privacy is a must. Therefore, a wall slab system can integrate the confining nature of a spa with the opaque expression of a wall slab system. Furthermore, concrete walls can add to the tactility of the building by utilising the mouldable properties of the material, see fig. 87. For precast elements, the visible surface of the concrete can be imprinted using different methods while it dries. However, when assembling the elements, a visible groove appears. Depending on the arrangement of the precast elements, the floors of the building become indexical in the façade, as shown in fig. 85. For a more coherent façade expression, sitecast concrete can be employed. Here the imprint from the cast used to create the facades can help generate a form-based narrative, where the surface texture plays an important role.

The massive appearance of concrete can also inform the tectonic aspects of the construction.

The Spa House consists of multiple enclosed functions, which could lead to a concept of stacked boxes, as illustrated in fig. 86. In this concept, the façades can either indicate the stacked interior layout or be a transparent element that displays the internal structure. Then the boxes dictate that the space between the boxes, the in-between spaces, is of a different nature than the space inside the boxes.

Another concept would be tapping into the modulable aspects of concrete. A massive block that gets carved into to create the different spatial experiences. This carving can be formed by stereotomy. Here the interior layout is more cave-like, where the spa guest is encouraged to investigate the different spatialities.

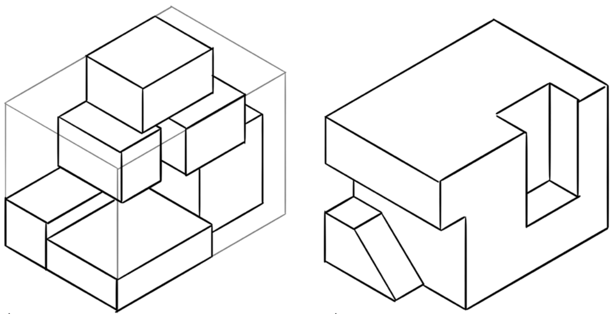
When constructing a spa in multiple storeys, one main challenge is to place pools above ground level. The water impacts the underlying construction by applying a relatively heavy load and the risk of extensive damage if leaking.



a | Expression of concrete vertical

b | Expression of concrete horizontal

Fig. 85. Concrete texturing



a | Stacking principle

b | Stereotomy principle

Fig. 86. Construstion expression

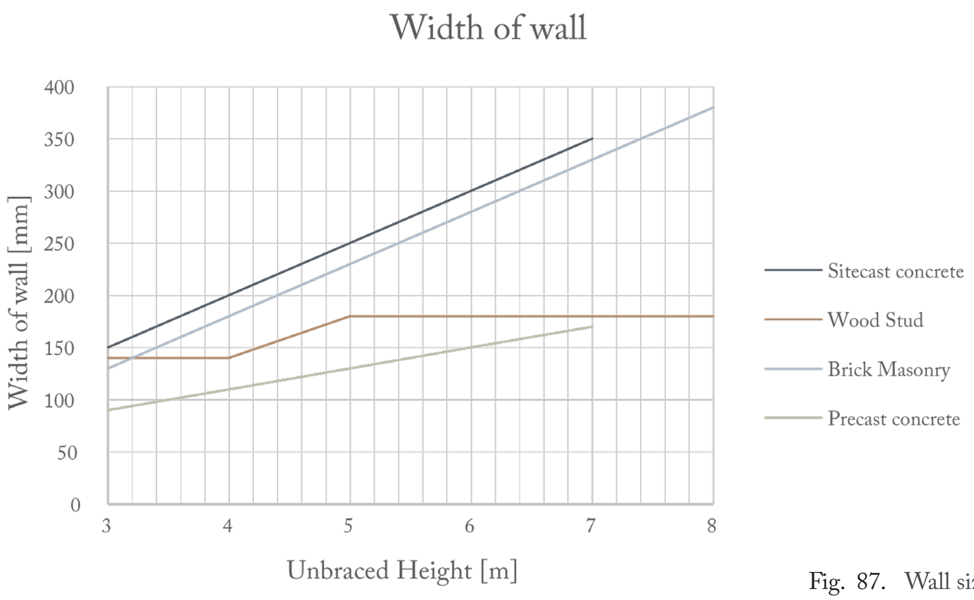


Fig. 87. Wall sizing chart

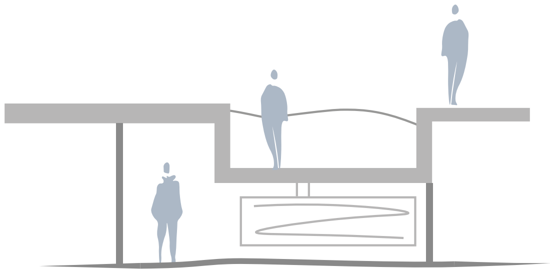
POOLS

When designing a multi-sensory spa, the pools must be integrated structurally. However, different solutions unfold different opportunities. One solution is by occupying the full area of the pool, on the storey below, which could be utilised for creating niches and room dividers but consumes a lot of area, illustrated in fig. 88.a. If instead increasing the thickness of the deck and thereby hiding the depth of the pools, as seen in fig. 88.c, the thickness can store technical equipment next to the individual pool to minimise the need for piping and heat losses. However, this method increases the height of the building.

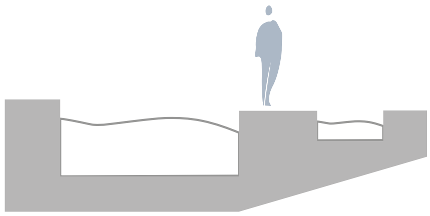
If pools are visible in both sections and by occupants on more than one floor, the pools can drop from the deck. To that end, a sloped pool floor results in spatial variations on the floor underneath, in terms of ceiling heights, as demonstrated in fig. 88.b. Such pools carved into the slab will be site-cast. Probably this will be suitable for big pools integrated into the floor. In this case, the occupant is stepping down into the water.

Investigations in Robot demonstrate in which bendings a site-cast pool slab needs the most material if simplifying the slab into a beam. The beam in Robot is drawn as a concrete slab with moment stiff joints. As fig. 89 shows, the first three iterations investigate the supports of the pool. In fig. 91 the shape of the beam is investigated. All investigations are made with a dead load of water in the pool and a live load of a person walking on the path next to it. The biggest cross-section will reflect the biggest bending moment when adding conceptual forces of construction, people and water in different depths, see fig. 90 and appendix IX. The aim is to minimise the thickness of the slab when less material is needed, while still reflecting the sloped gesture on the floor underneath. Drafty free body diagrams and crafty physical models demonstrate that all bends of the beam must be seen as moment stiff to avoid making a mechanism. The bending moment will be minimised with fixed joints, to which the slab assumably can be the thinnest. However, the aesthetics of the detailed joint must be considered in relation to the overall narrative of the Spa House.

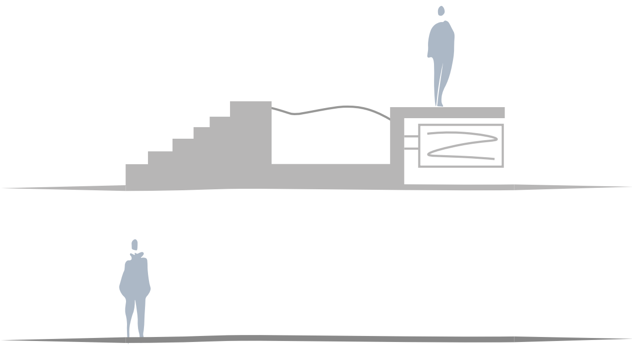
Some of the smaller pools might be above floor height, as in fig. 88.c, and thereby the occupant is stepping up into the water. When combining the two principles, it activates the body with ordinary horizontal and occasionally vertical movements when exploring the different environments.



a | Technical hallways underneath pools



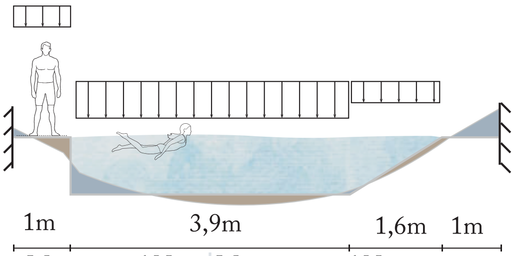
b | Pools carved in plateaus



c | Pools on top of floor

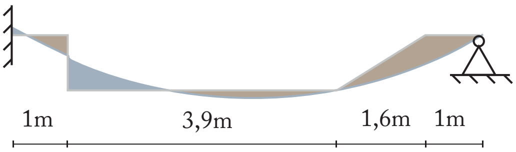
Fig. 88. Configuration of pools

Suppports



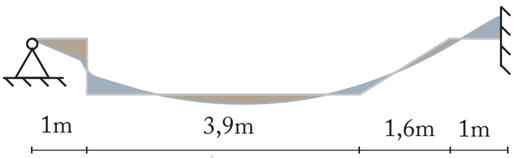
$M_{y,\,Max}$ 2,36 kNm | $M_{y,\,Min}$ =-3,68 kNm

a | Fixed, fixed



$M_{y,\,Max}$ =3,87 kNm | $M_{y,\,Min}$ =-4,47 kNm

b | Fixed, pinned



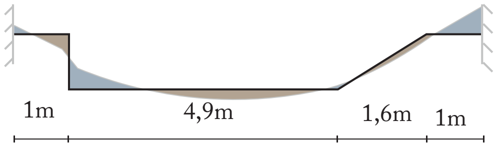
$M_{y,\,Max}$ =3,39 kNm | $M_{y,\,Min}$ =-3,61 kNm

c | Pinned, fixed

Fig. 89. Pools | Supports

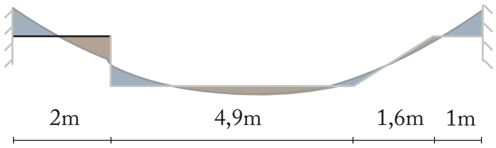
Fig. 90. Pools | Reinforcing weakpoints

Shape



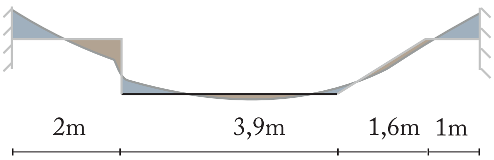
$M_{y,\,Max}$ =2,36 kNm | $M_{y,\,Min}$ =-3,68 kNm

a | Starting point



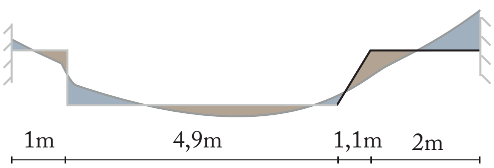
$M_{y,\,Max}$ =3,58 kNm | $M_{y,\,Min}$ =-3,96 kNm

b | Larger path



$M_{y,\,Max}$ =3,03 kNm | $M_{y,\,Min}$ =-4,12 kNm

c | Shorter pool



$M_{y,\,Max}$ =2,95 kNm | $M_{y,\,Min}$ =-5,28 kNm

d | Steeper incline

Fig. 91. Pools | spans | Steeper incline

SYNTHESIS

A key aspect of the elevations is the façade of the main stair, as it reflects the connection of the two volumes. A crucial parameter to investigate is the interior experience and the need for privacy when the occupant circulates between floors wearing robes or swimwear. In addition to the experiences, the dimensions and placement of windows are vital in relation to interfering with gridlines or continuing around corners.

The envelope investigated simultaneously with the energy simulations needs to be flipped, as demonstrated in fig. 92. The loadbearing wall was intentionally placed toward the exterior to enhance the gesture of textured surfaces from the casting process. However, placing the load-bearing columns in the façade limits the flexibility when designing windows, unless the structure is intended to be framed as an exception. Besides, the joint between a load-bearing facade and the site-cast slabs result in a thermal bridge that needs to be decreased.

By flipping the construction, as in fig. 93, the thermal bridge can be avoided. Additionally, the inner 15cm of the wall facing the interior can act as thermal mass and help stabilise the indoor environment. The texture from the cast will then be perceived when the occupants explore the spa experiences, as a previous model study demonstrates in fig. 94. However, the façade could be site-cast as a thinner surface to achieve a similar expression to the exterior. The façade must be tied to the inner wall for stabilisation, probably near the slabs.

The new wall construction aims to be similar to the one derived from the energy simulations in terms of U-value and thickness. Therefore, when increasing the thickness of the non-loadbearing wall, the amount of insulation decreases, implying a need for a material with lower conductivity.

Besides, the load-bearing structure is then protected from the weather and less exposed to abrasion. The flipped envelope as well creates more opportunities in terms of window details, if integrating gestures of long horizontal opening, with windows passing the columns.

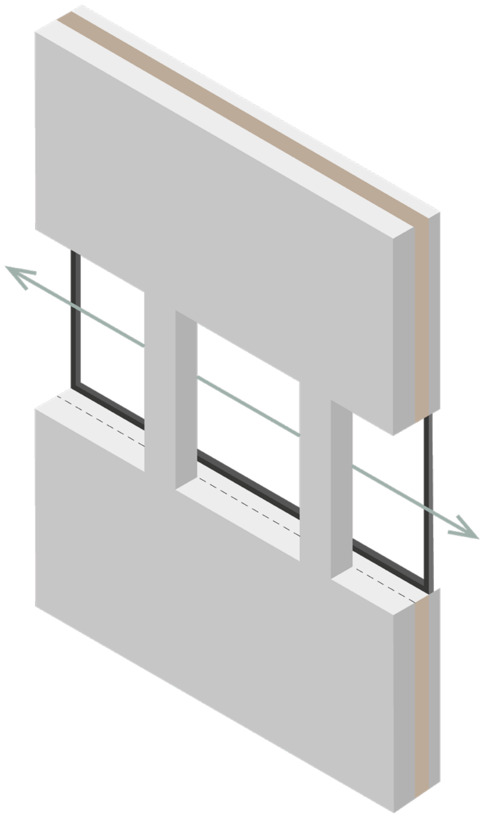
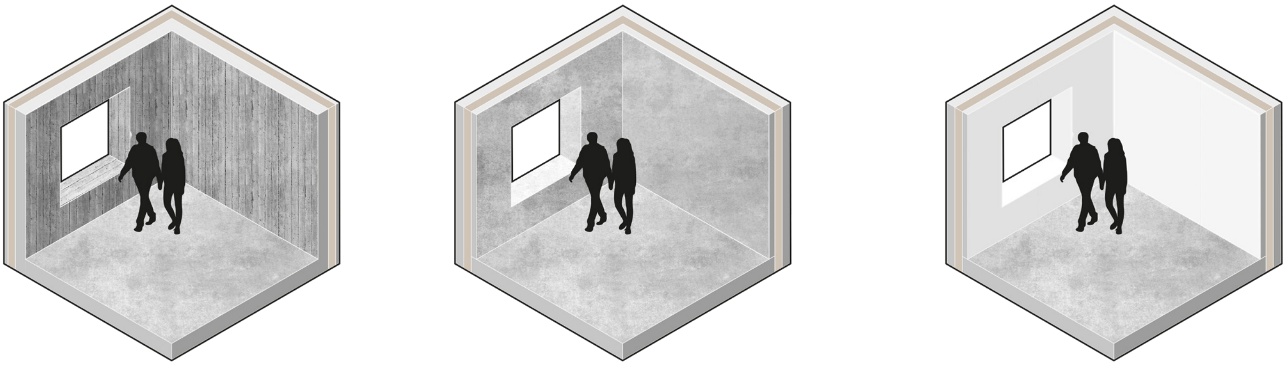


Fig. 92. Column in front of window



a | Concrete formwork b | Concrete smooth c | Gypsum

Fig. 93. Material investigation | a - c

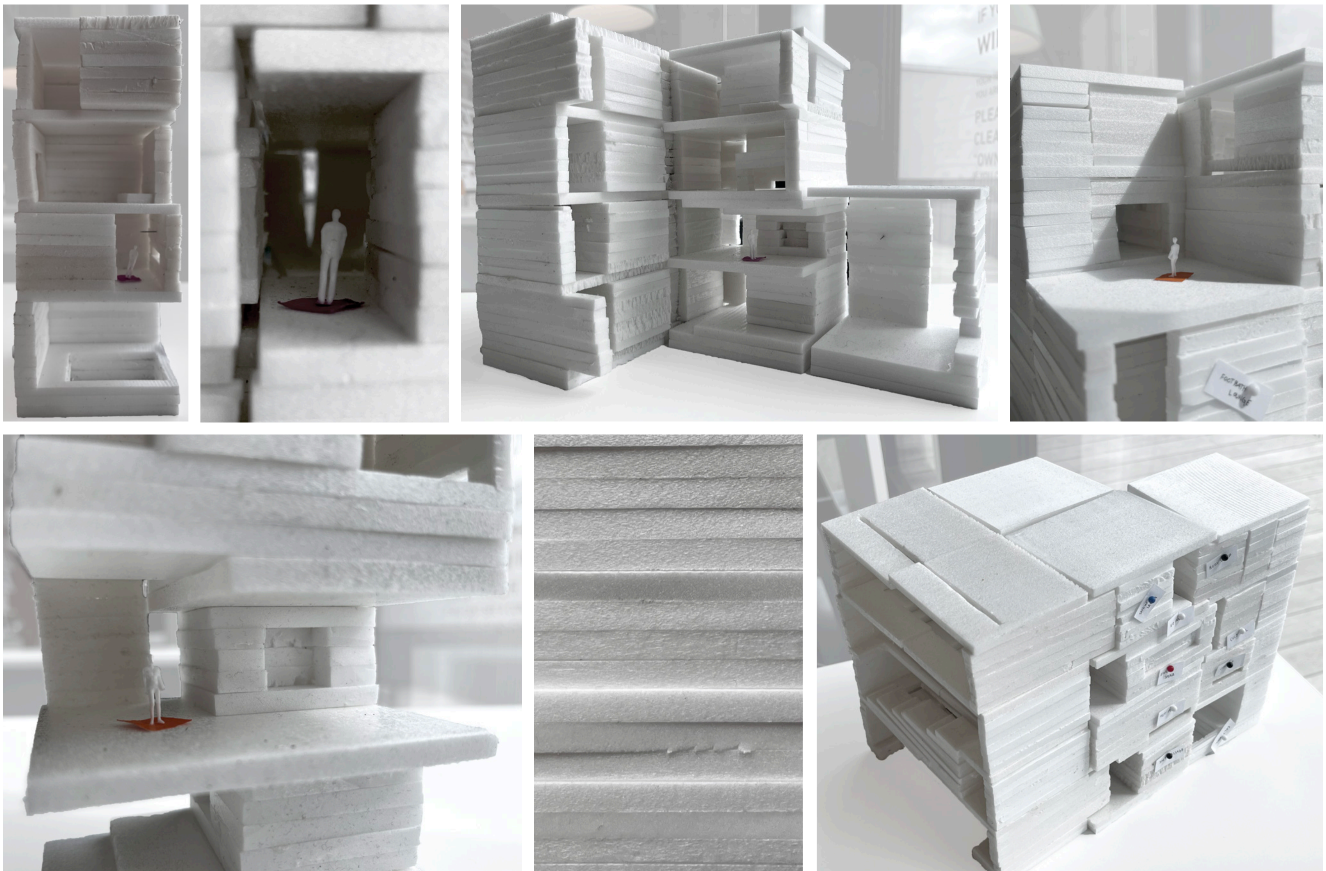


Fig. 94. Model study, collage

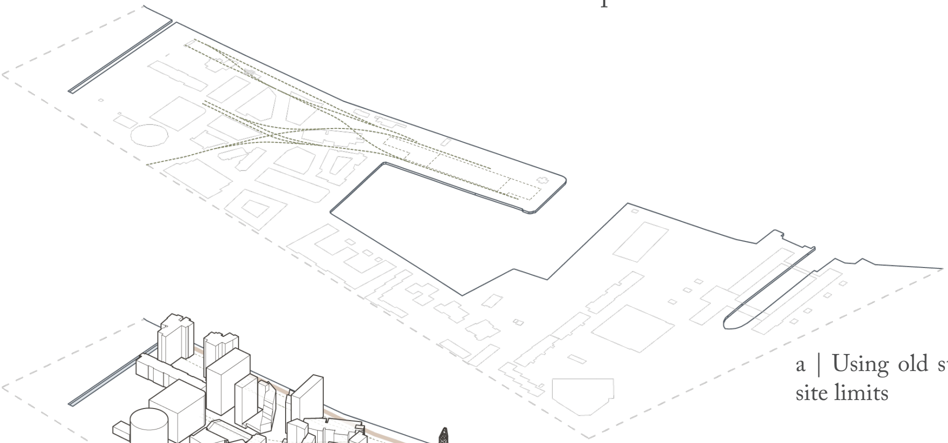
PRESENTATION

Ill. 8.   Spa House | Entrance

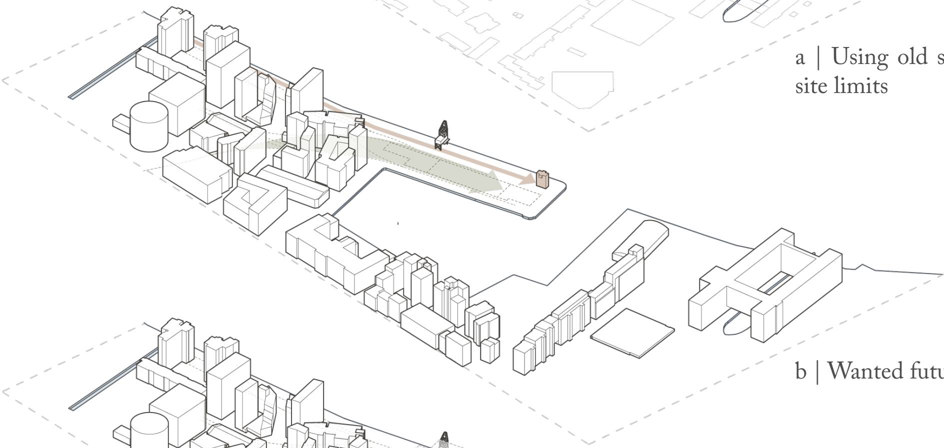
CONCEPT

The Pier is designed to recreate the pulsating presence of people. The aim is to shape spaces that both house the existing water activity happening at Dok Øst and free space for socialising, for the citizens of Aalborg.

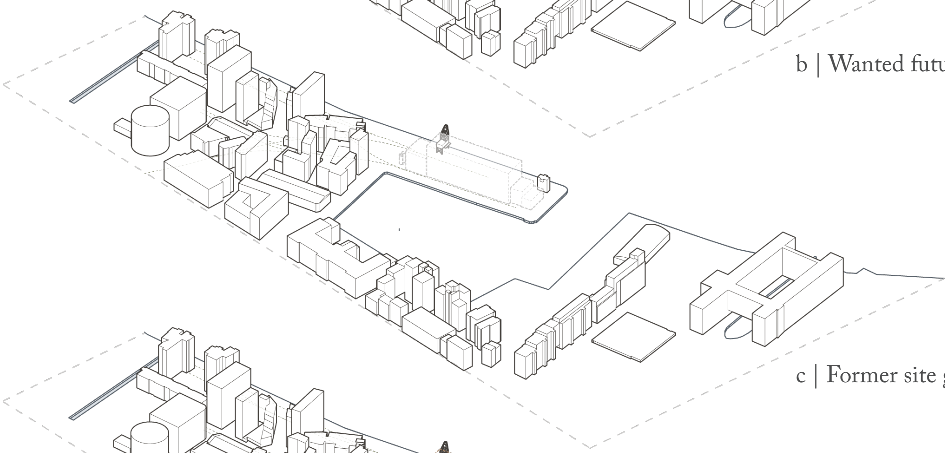
The Spa House is carved out from the solid inspired by the old factory previously located at the site. The carving creates void spaces in-between massive and enclosed volumes, giving shape to both exterior and interior spaces.



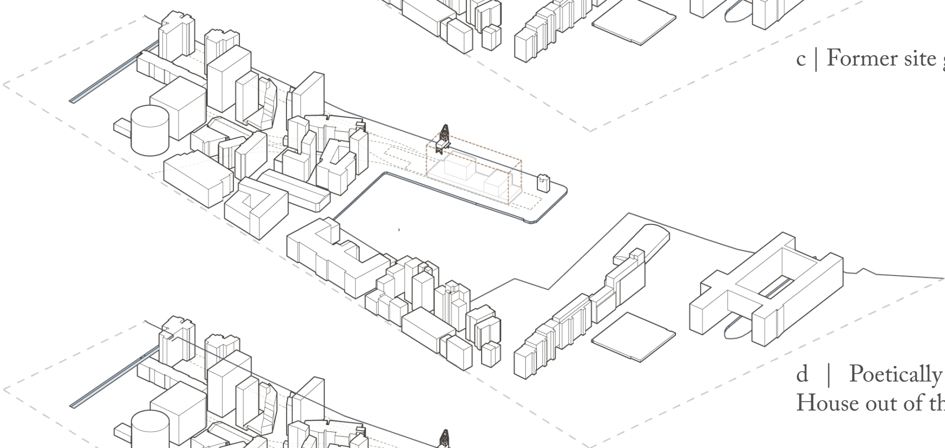
a | Using old structures to define site limits



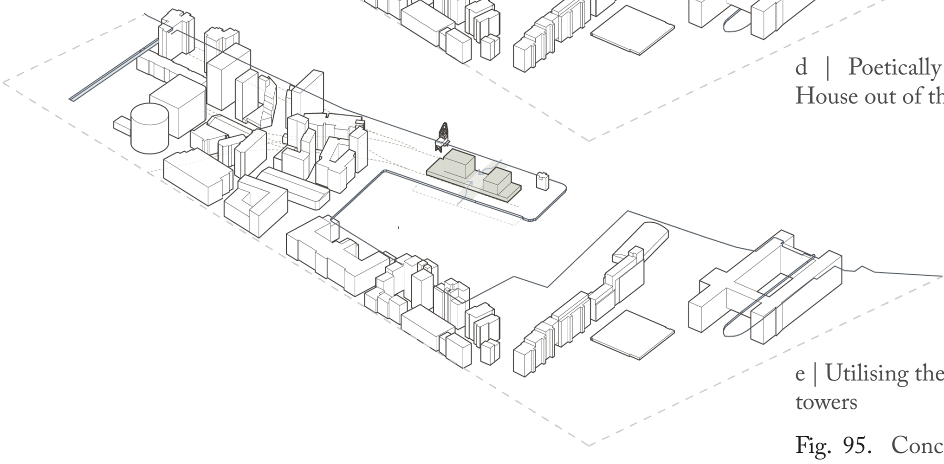
b | Wanted future flow



c | Former site geometries



d | Poetically carving the Spa House out of the old geometry.



e | Utilising the flows to define the towers

Fig. 95. Concept diagrams | a-e

MASTER PLAN 1:2000

The Pier is transformed into a park that aims to condense people of different backgrounds by complimenting the diversity in Aalborg, and utilising the potential of one of the last free spaces close to inner Aalborg.

1 | Site
2 | Stjernepladsen
3 | Office Building
4 | Fjordtrappen
5 | Beddingen
6 | The Machine Hall
7 | KMD
8 | Connection to Stigsborg
9 | Water Polo

Fig. 96. Master Plan | 1:2000

SITE PRINCIPLE

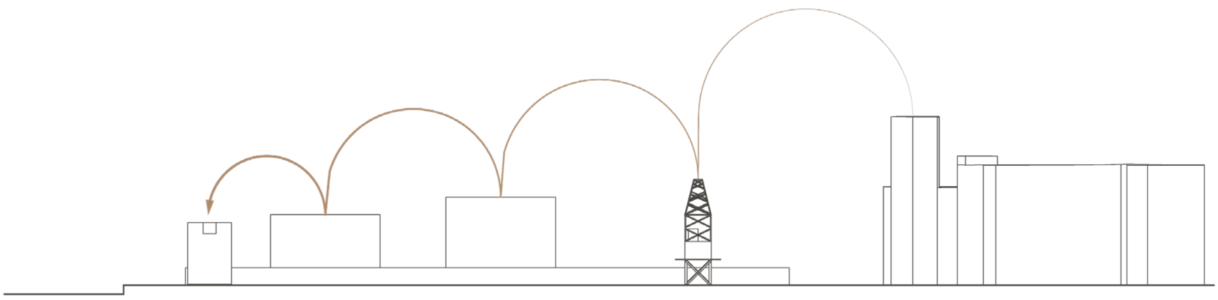
Ground floor
The entrance of the Spa House is oriented toward the main path to the north between the vertical volumes, from where the circulation splits into the two towers of different nature. The administration is facing north to emphasise the diffuse light, as opposed to the south façade that is closed toward sunbathing and Cable Park.

Siteplan
The main path frames the old control tower when arriving at the Pier from the Harbourfront. The renovated control tower is intended to house a showroom for the upcoming artists located in an informal atelier in the nearby context, communicating the industrial and cultural heritage and a viewpoint on top.

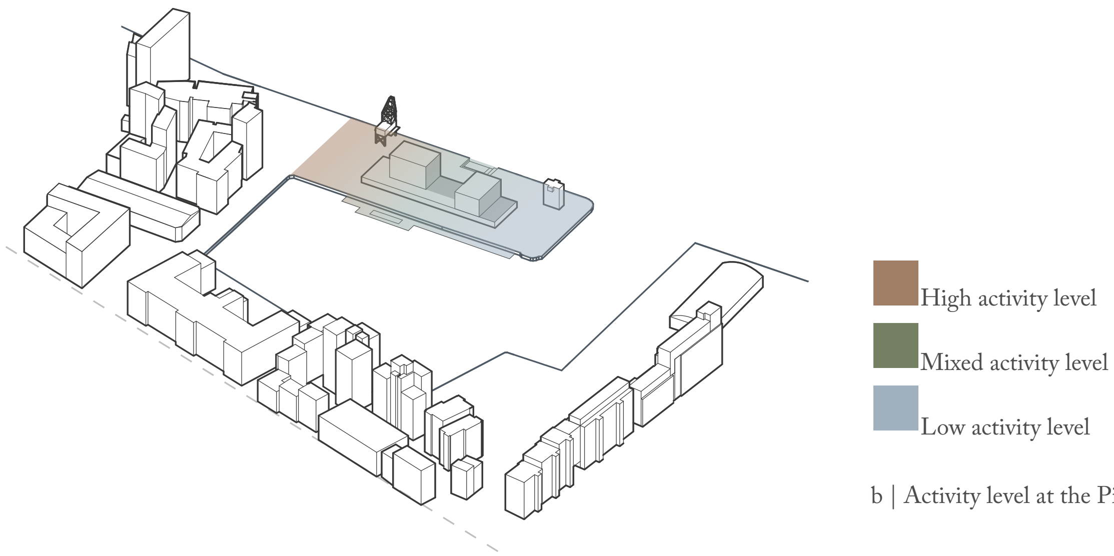
On the south side of the Pier, a wooden structure close to the water shapes a fjord pool for winter swimmers and sunbathers by following the design of the wood promenade existing at Dok Øst. A Café activates the ground floor to the east, supplying the visitors to both park and Spa House. The winter swimmers have access to a shared sauna in Cable Park's new club facilities near their cables.

The plateau shapes a landscape stair connecting the north and south side of the Pier. In the daytime, the plateau relates to the south with sun and water activities, and toward the north, watching the sunset in the evenings. Besides, the employees of the neighbouring offices are supplied with a sunspot for lunch, as a destination of their daily break-walks.

The other relic merges into a playground, inspired by the balance and movability of crane-like structures related to the high activity zone to the west.



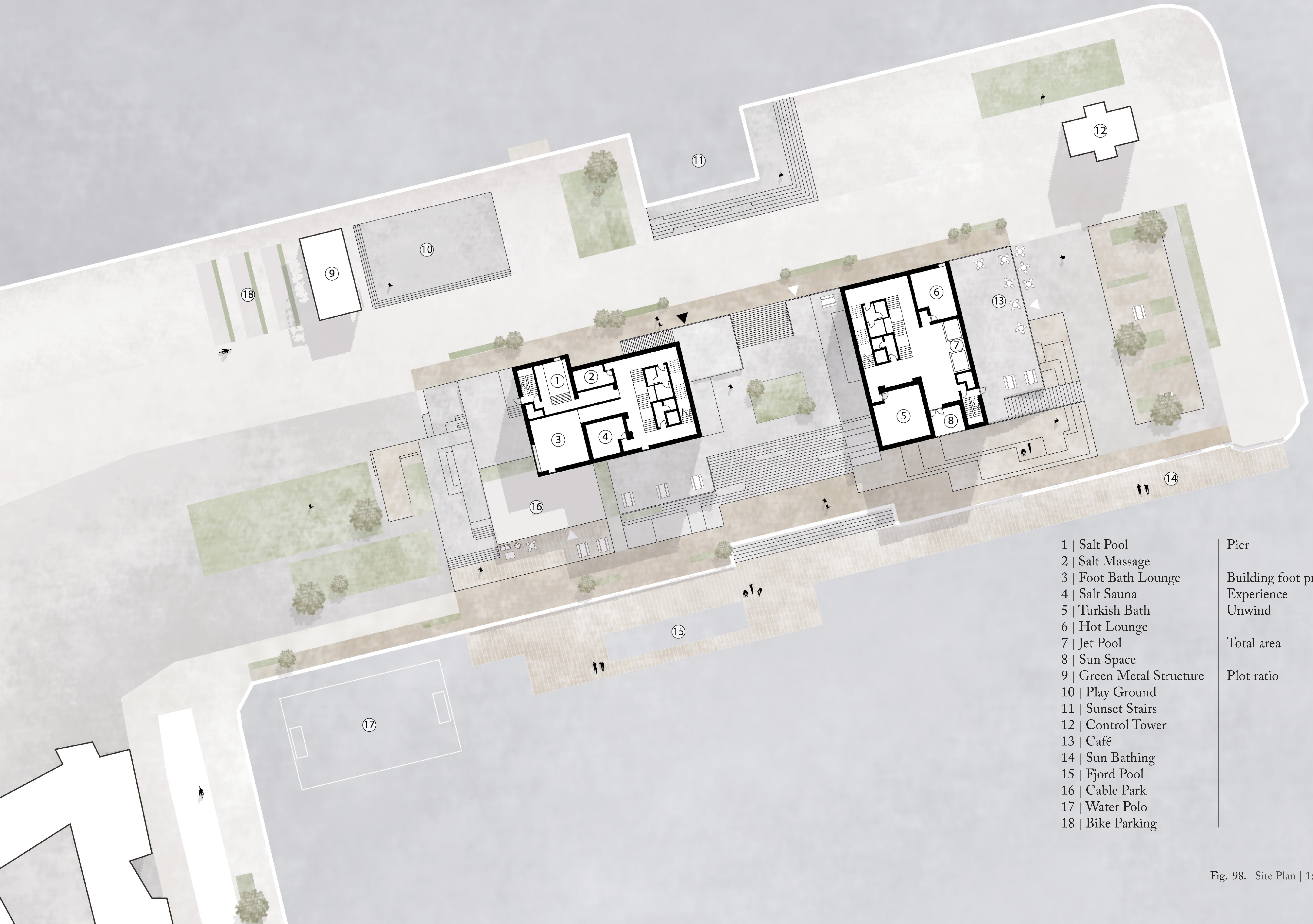
a | Gradinet of context



b | Activity level at the Pier

Fig. 97. Site diagrams | a-b

SITE PLAN 1:500



1 | Salt Pool
2 | Salt Massage
3 | Foot Bath Lounge
4 | Salt Sauna
5 | Turkish Bath
6 | Hot Lounge
7 | Jet Pool
8 | Sun Space
9 | Green Metal Structure
10 | Play Ground
11 | Sunset Stairs
12 | Control Tower
13 | Café
14 | Sun Bathing
15 | Fjord Pool
16 | Cable Park
17 | Water Polo
18 | Bike Parking

Pier	9947 m²
Building foot print	1625 m²
Experience	1352 m²
Unwind	1101 m²
Total area	4078 m²
Plot ratio	41 %

Fig. 98. Site Plan | 1:500

ARRIVAL

The redesigned Pier shapes environments for social activities by condensing several user groups, and thereby activating this part of the city. To that end, the site mediates between dwellers of the urban park and the occupants of the Spa House. The building houses the new spa experiences and facilitates the existing informal structures, in which the Spa House revives the historical, social water activities of Dok Øst.

The main door to the Spa House is framed by the carved stair that guides the dweller to a levelled spot to watch the sunset.

To extend the usage of the building, baby swimmers and new moms can utilise the hot pool in the morning, before the Spa House opens. Besides, the Spa House occasionally can host events at night for occupants who want to try out the most extreme conditions of the spa.

Ill. 9. Arrival

RADIATION

The hours of radiation indicate that the transformation of the Pier shapes outdoor environments that will be usable most of the year. For further details, see appendix X. Sunny surfaces at the Pier are utilised for more extended stays, and the shaded areas for transition spaces, as seen in fig. 99.

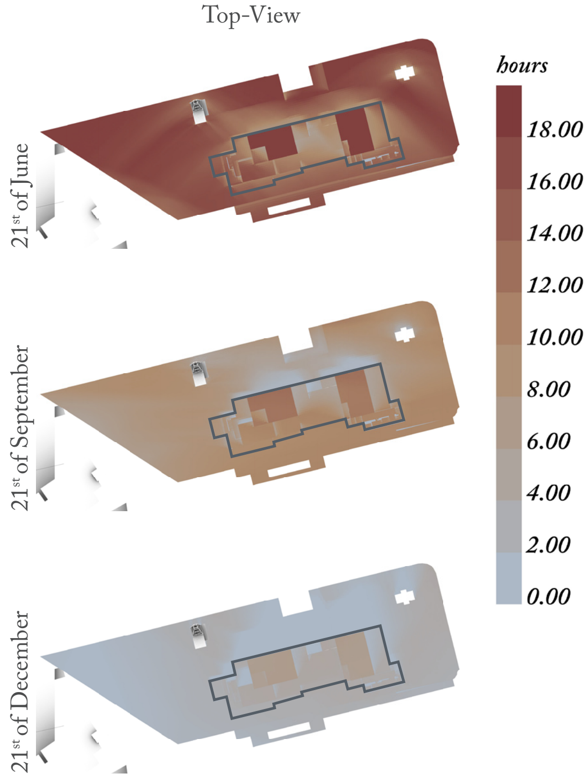
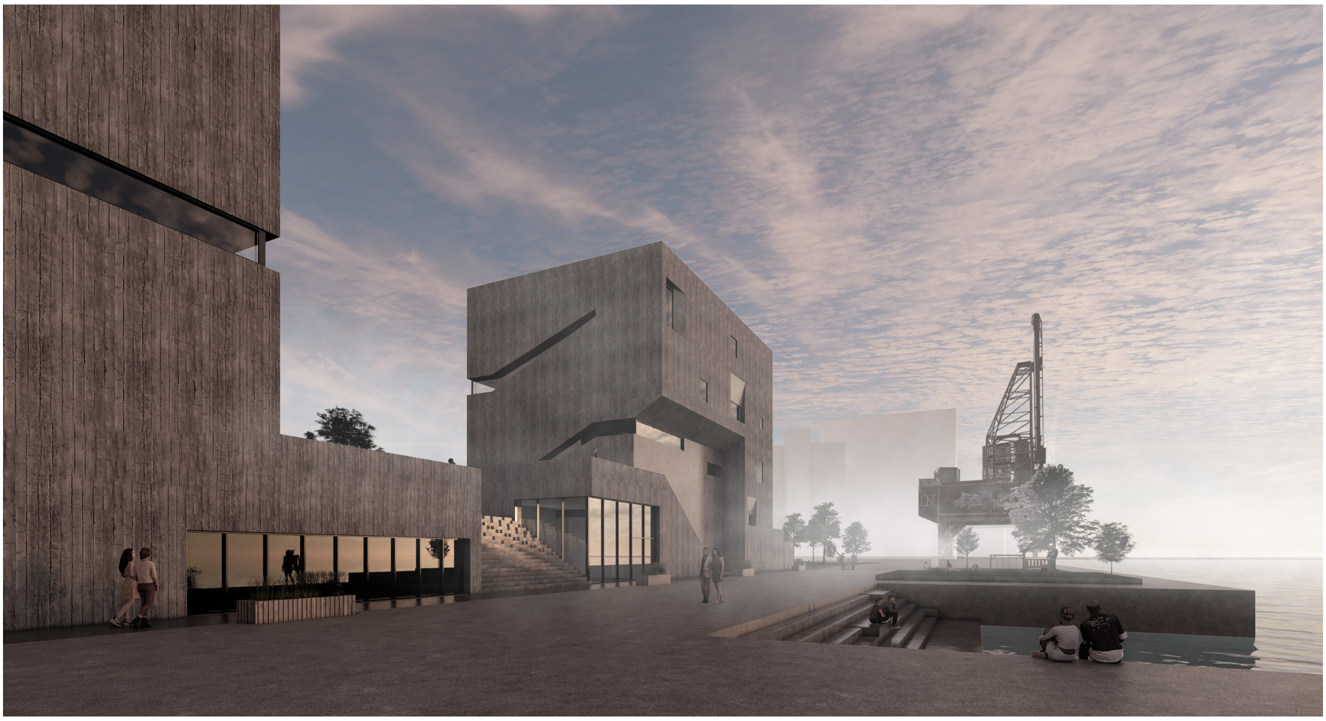


Fig. 99. Radiation mapping

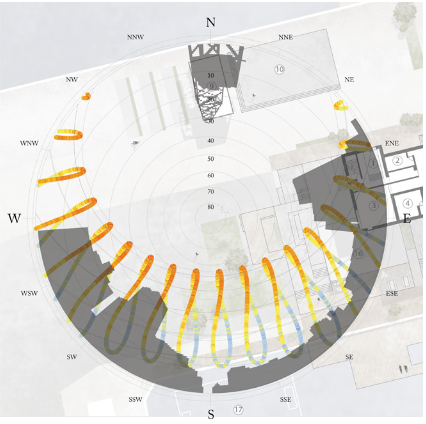


Ill. 10. View from the Control Tower

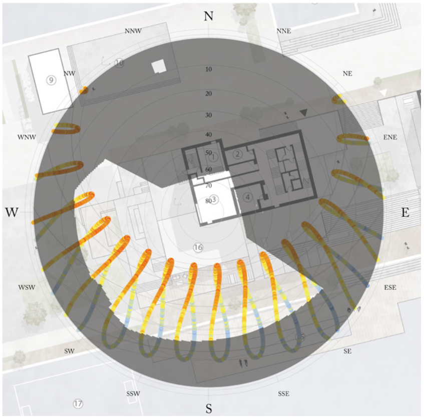
SHADING MASK

The various outdoor spaces facilitate social activities between the urban dwellers. The nature of each zone is addressed to planned activities and hours of use, which overlap and change throughout the day.

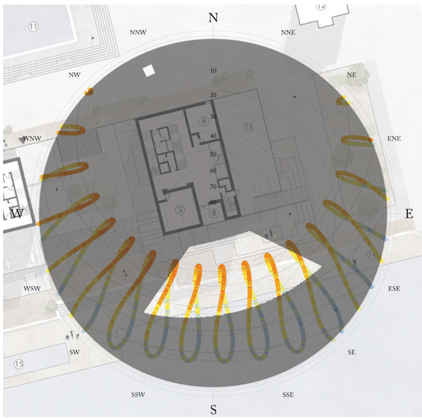
The shading masks illustrate hours of sunlight and underline what time of the day and year a place will be occupied and lit by direct light, see fig. 100.



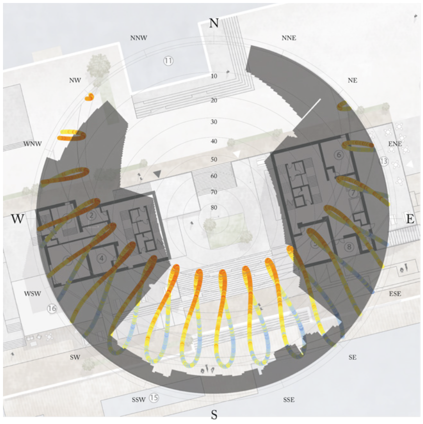
a | High activity zone



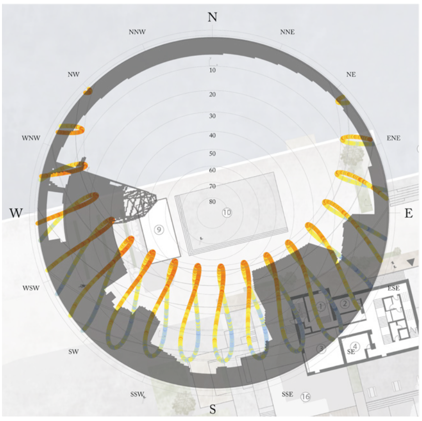
b | Terrace at west building



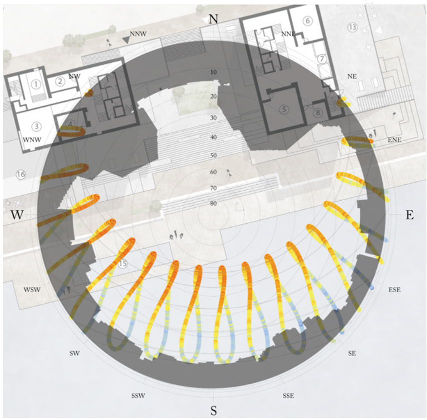
c | Terrace at east building



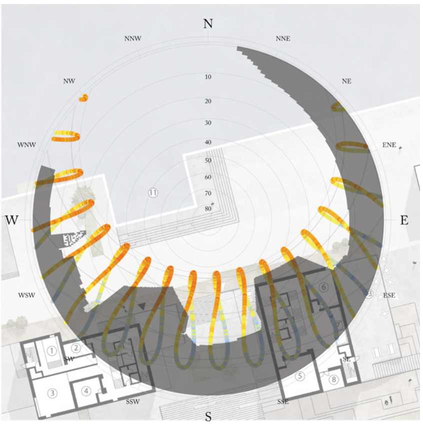
d | Between the towers



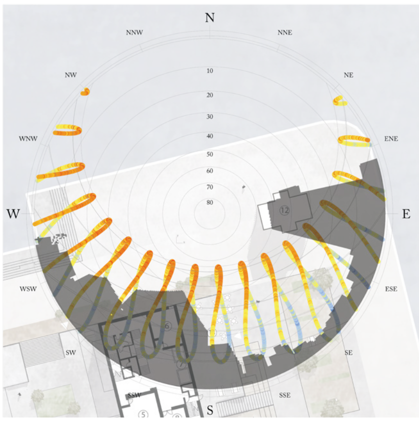
e | Playground



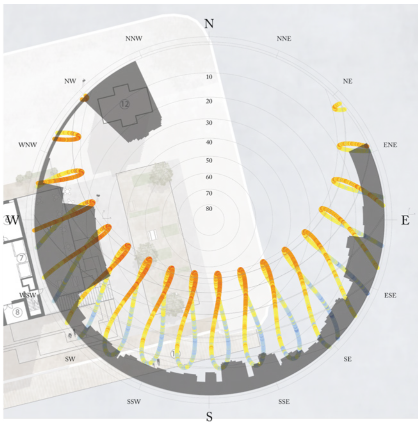
f | At the stair between the towers



g | Sunset stair



h | Next to the control tower



i | Low activity zone

°C 30 25 20 15 10 5 0 -5 -10

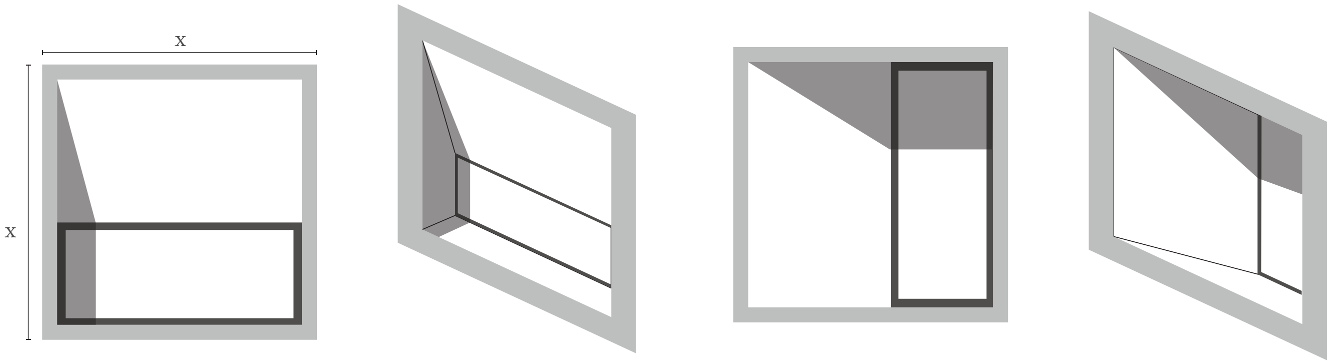
N

Fig. 100. Shading mask

FACADE CONCEPT

The placement of windows is based on the sectional distribution of functions and the individual experience intended for each room, including the need for natural daylight, views, or enclosed spaces. Daylight simulations are found in fig. 102.

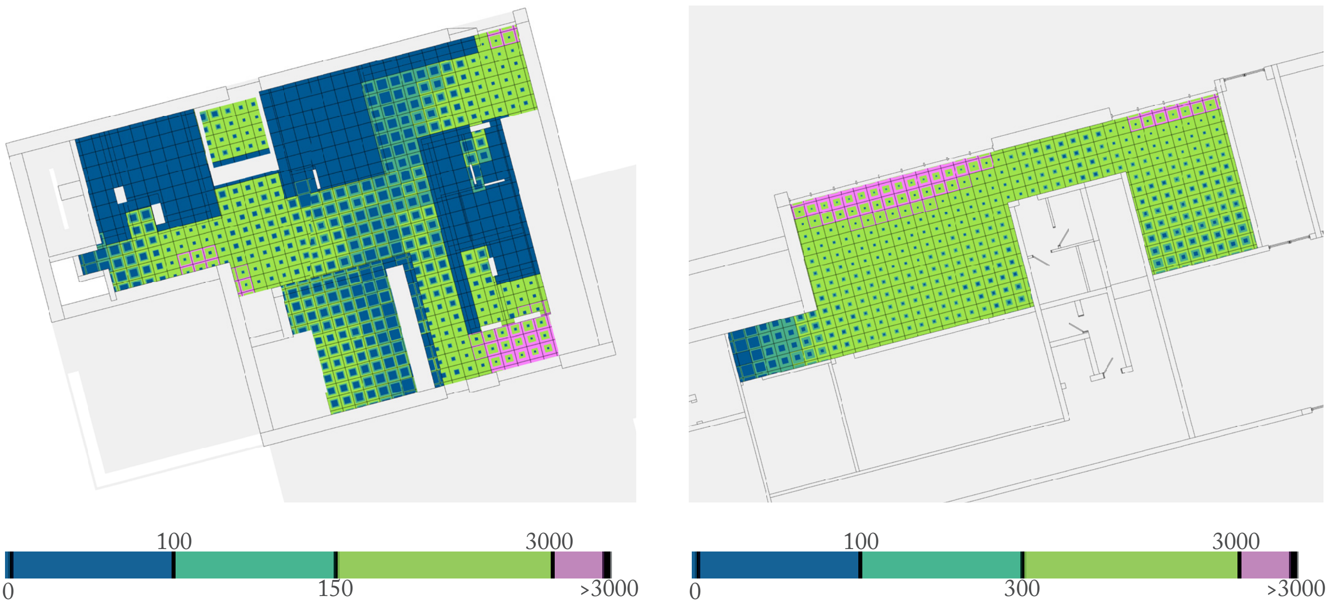
The quadratic window openings are read as one geometry in the façade, from which the opening inclines by chiselling to match the request of the interior experiences, as demonstrated in fig. 101. A slim aluminium frame encircles the windows almost invisibly. The aesthetics of the façade is a game of stereotomy and shadows, expressing the dense gesture of the architecture.



a | Vertical carving principle

b | Horizontal carving principle

Fig. 101. Window carving



a | Daylight, spa

b | Daylight, office

Fig. 102. Daylight

ELEVATIONS 1:500

The varying building height of the Spa House mediates the height of existing structures at Dok Øst. The massive concrete building shapes a landscape that extends the Pier to live in multiple levels.

The imprints left from the casting process are emphasised as a tectonic gesture of the facades. The carvings are processed differently, inspired by the chiselling methods of the art of sculpturing. The perceived contrast in textures visualises the narrative of the Spa House being carved from the past.

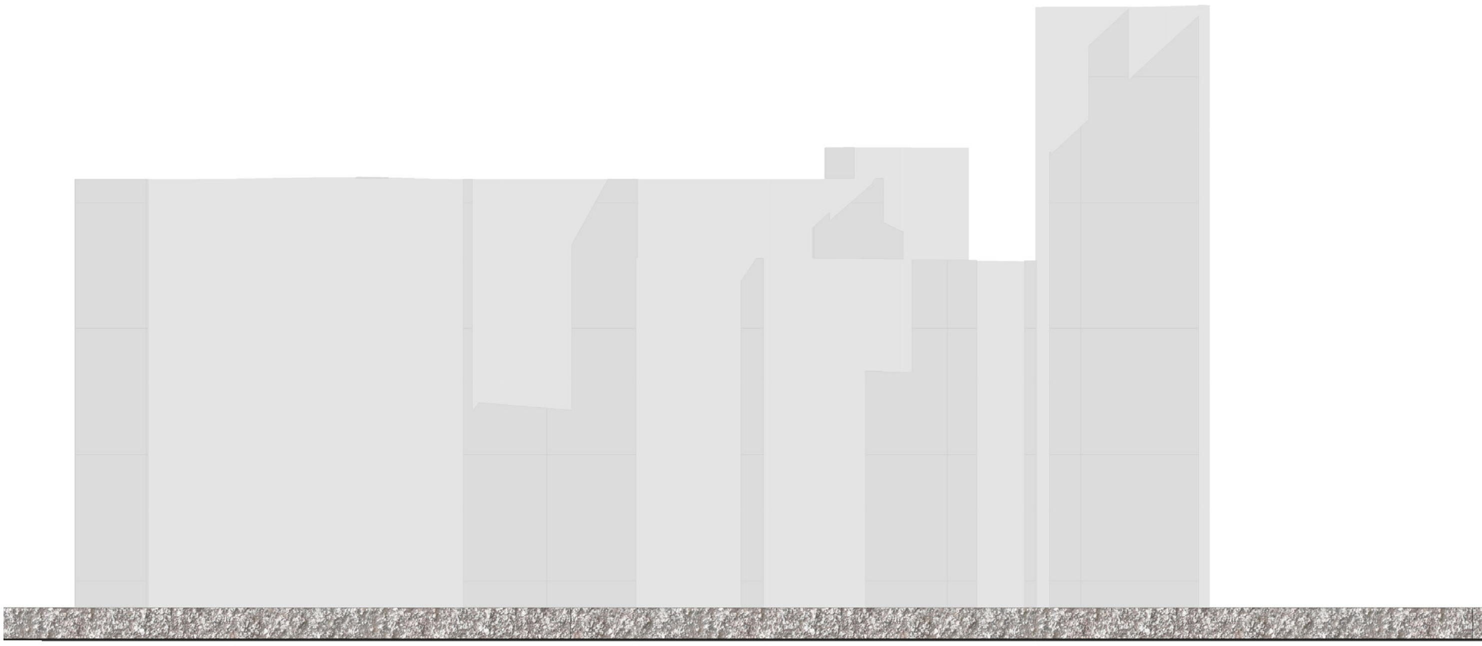

a | East tower, west elevation | 1:500

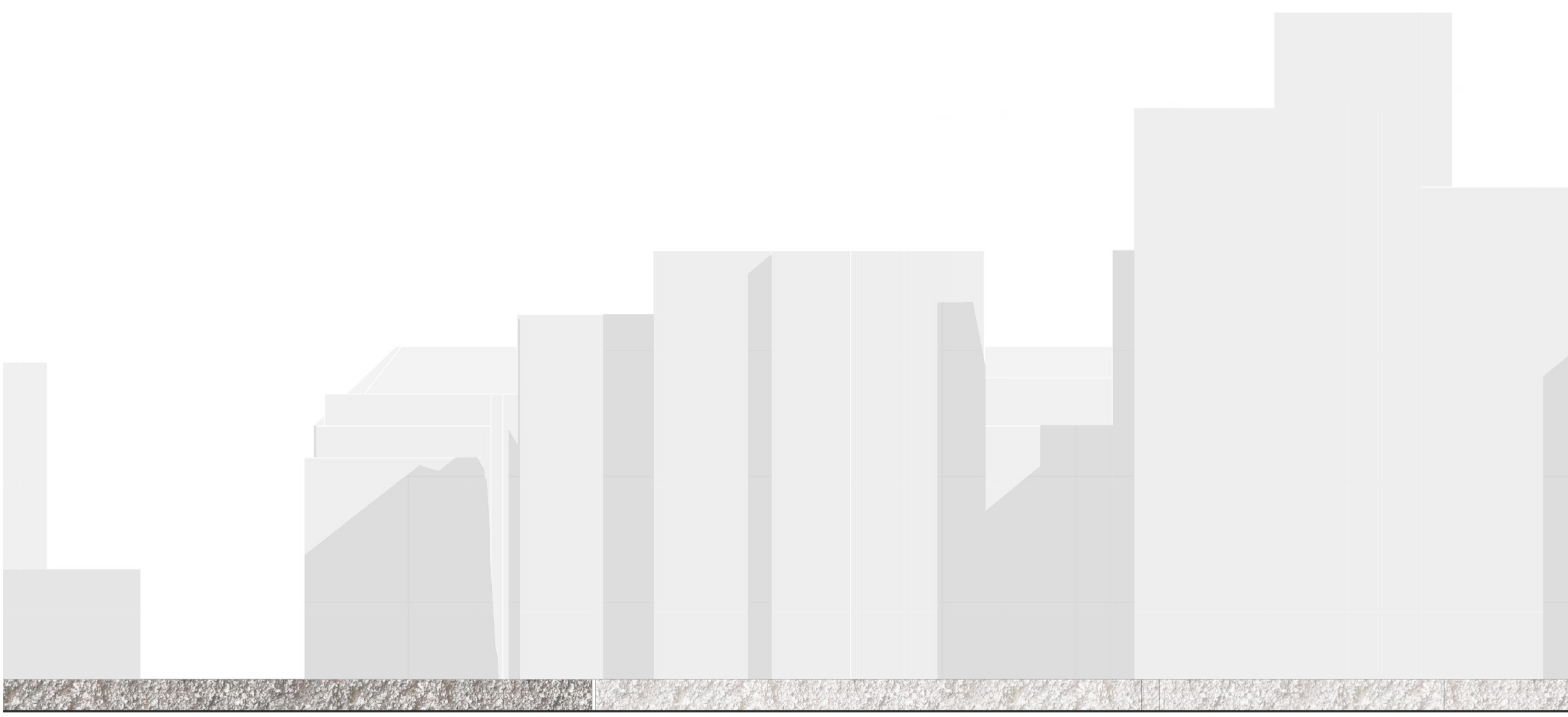

b | East tower, east elevation | 1:500

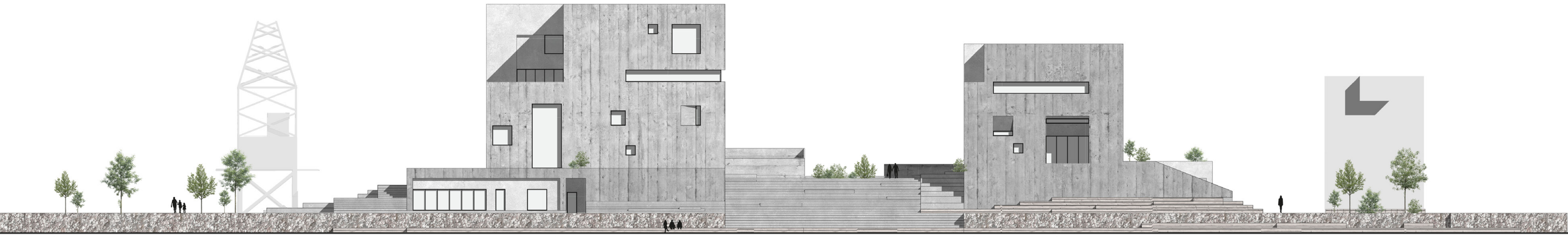

c | West tower, east elevation | 1:500


d | West tower, west elevation | 1:500

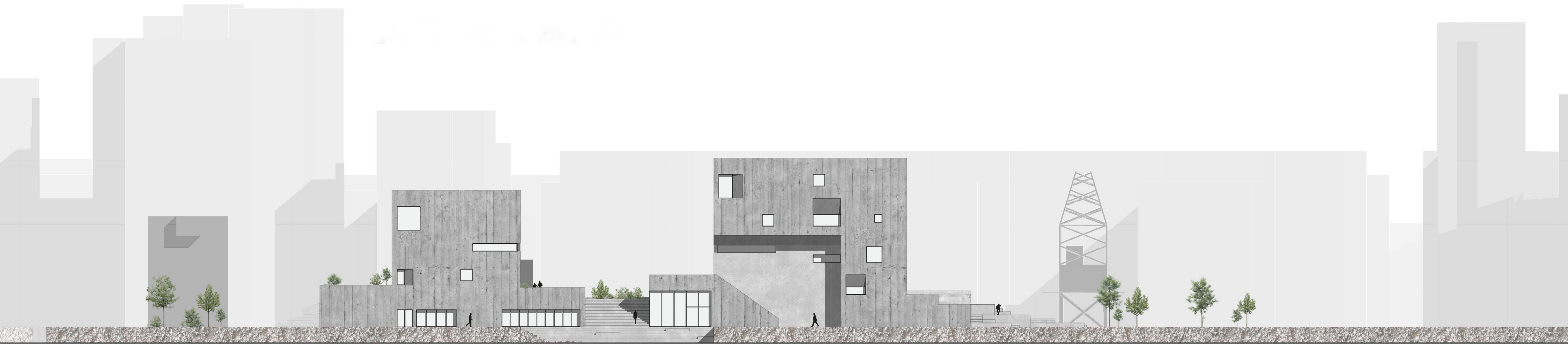
Fig. 103. Elevations







a | East-west elevation | 1:500



b | North - south elevation | 1:500 Fig. 104. Elevations

CIRCULATION

The circulation of both towers faces the open space in-between them as a connection that pulls the two volumes closer together. When entering a new floor, the stair carved out from the cores, occasionally provide views to the north to frame a view of the fjord.

The horizontal circulation connecting the stairs is hidden in the plateau, with a slit in the roof creating poetic filters of light to perceive when moving to the spa facilities, see fig. 105.

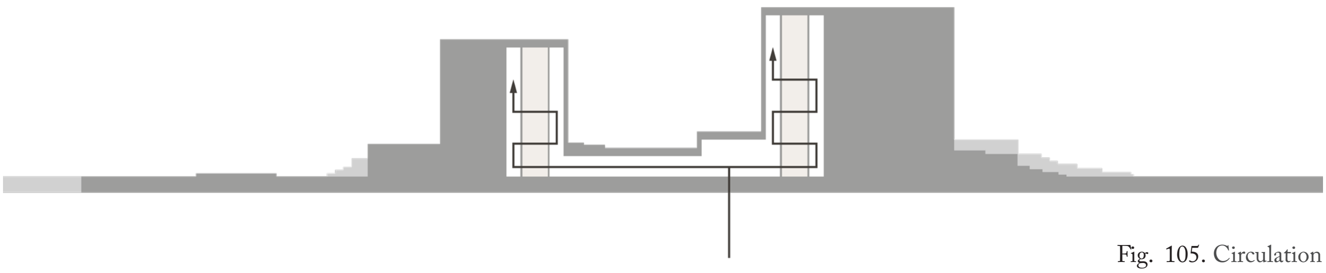


Fig. 105. Circulation

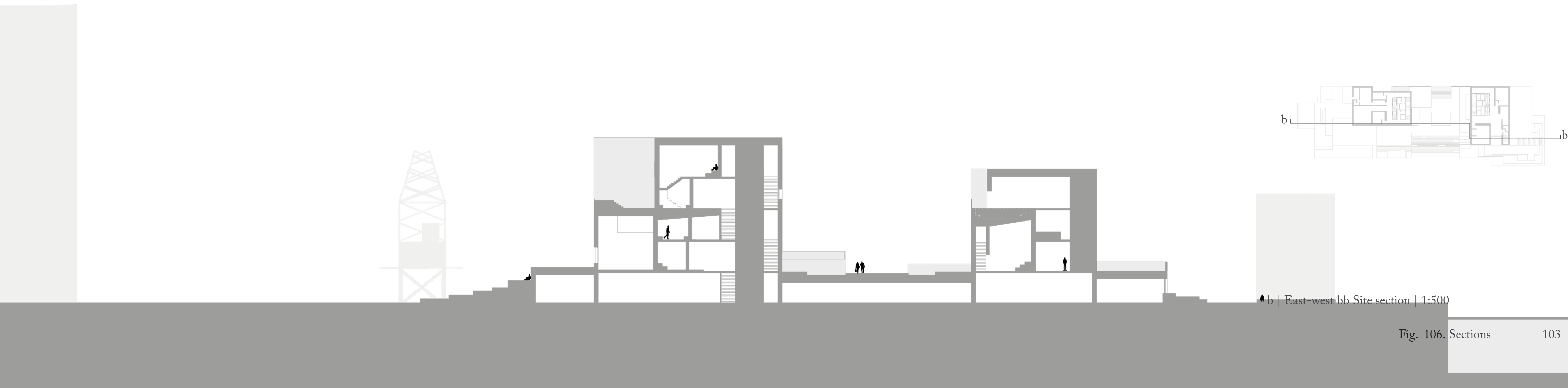
Ill. 11. Stair atmosphere

SECTIONS

When carving out the pools, the sloped ceiling underneath forms spatial alliesthesia when moving from a compressed section to an open space. The transparency when visualising the bottom of the pools communicates hints of what to expect on the next floor.

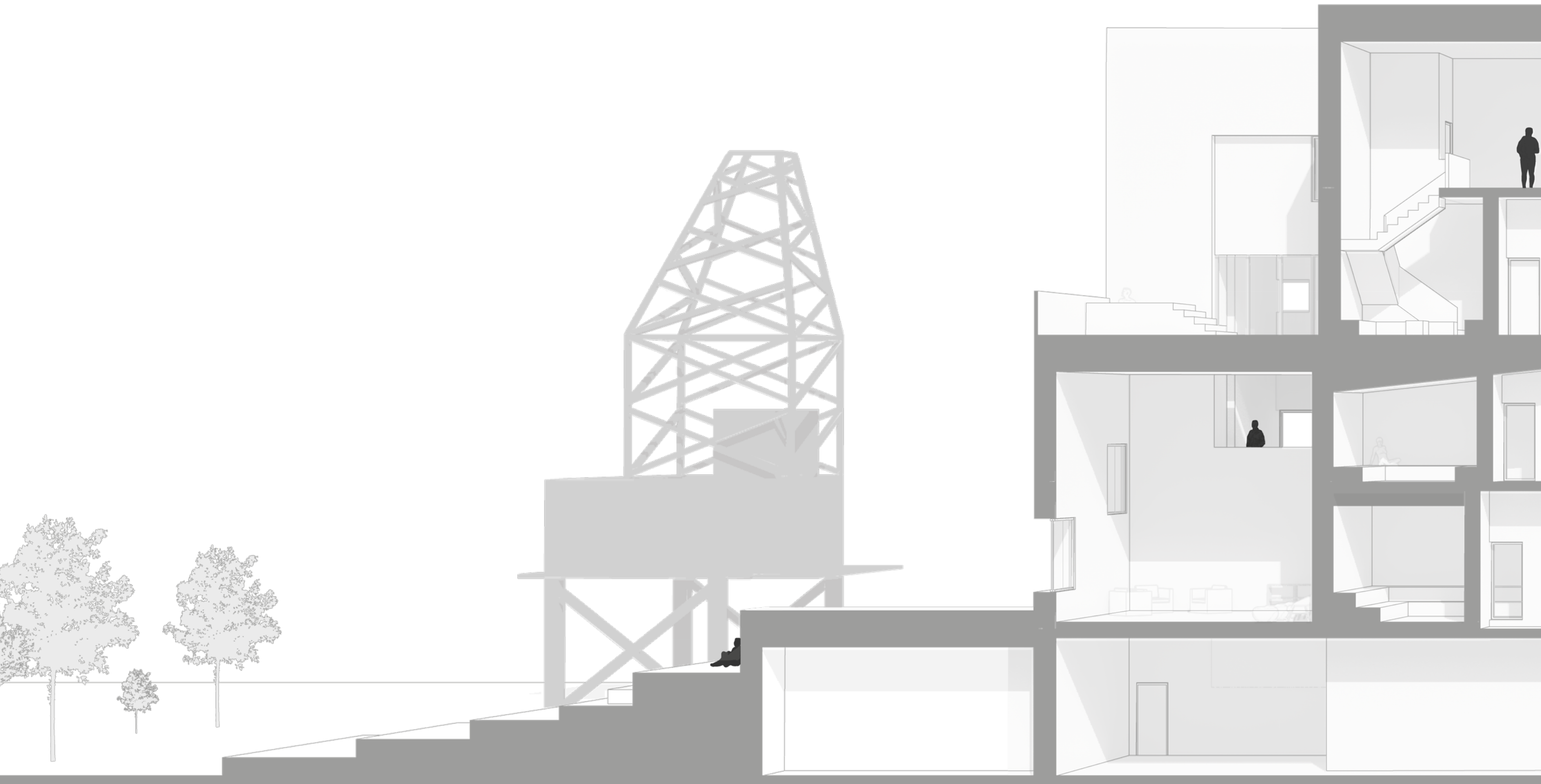
Glimpses or direct access between floors results in sectional connections that drive the curiosity for investigating the next step of the building, to which internal connections bind together the storeys of the Spa House.

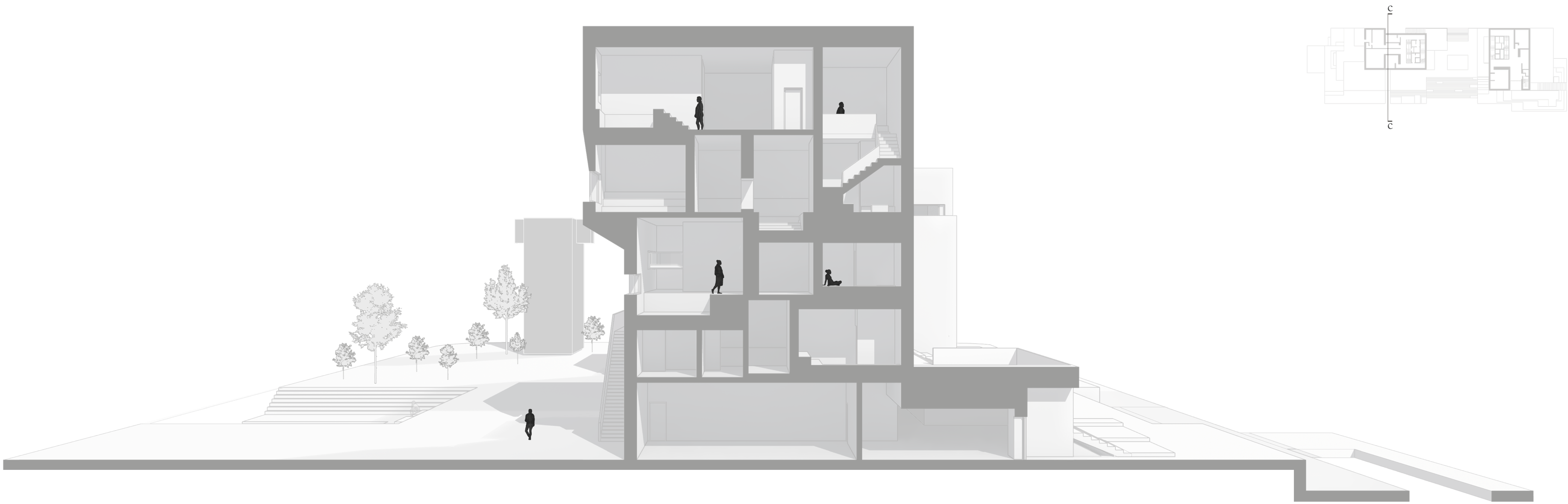
a | Section aa east tower | 1:200



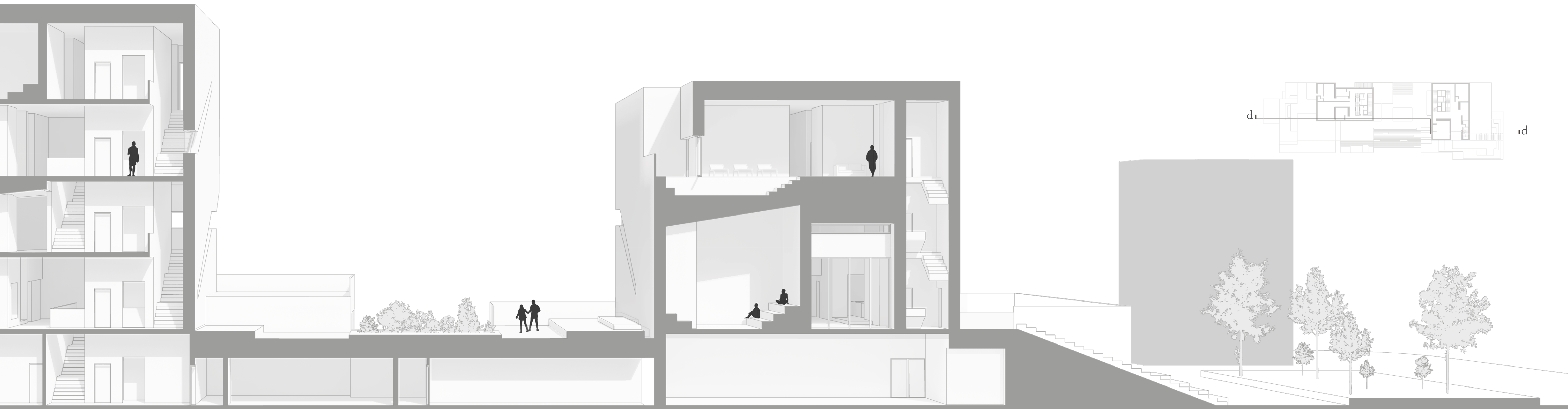
b | East-west bb Site section | 1:500

Fig. 106. Sections





a | North - south section cc west tower | 1:200



b | North - south Site section dd | 1:200

Fig. 107. Sections

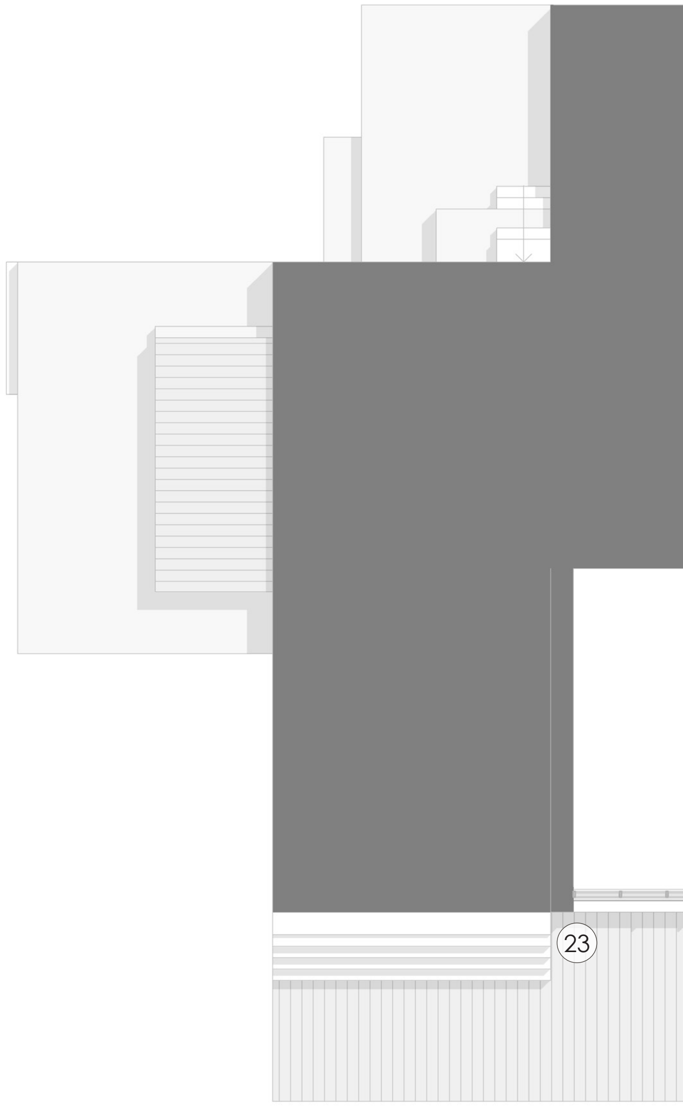
GROUND FLOOR

The explorative flow of the Spa House is shaped by carving out absents spaces from the massive volume. Integrated seating niches are carved into the walls of increased thickness. The void spaces and niches house pools and lounge areas with a more open character than the enclosed experience rooms.

Hidden doors emphasise the explorational flow. Instead of highlighting the doors, the small notches indicate a depth that nudges the occupants, and the aesthetical game of massive surfaces stays undisturbed.

The west volume houses the extreme perceived alliesthesia, with opposed environments close to each other on every floor to enhance the contrasts. The east volume provides less extreme alliesthesia and relaxing environments inviting for a slow pace.

1 | Elevator	| 3 m²
2 | Cleaning	| 5 m²
3 | Shaft	| 3 m²
4 | HC Toilet	| 5 m²
5 | Light Shaft	| 2 m²
6 | Toilet	| 4 m²
7 | Anteroom	| 4 m²
8 | Lobby and Reception	| 55 m²
9 | Changing Rooms	| 87 m²
10 | Offices	| 84 m²
11 | Stoage	| 30 m²
12 | Locker Rooms	| 21 m²
13 | Break Room	| 52 m²
14 | Technical Room	| 58 m²
15 | Kitchen	| 62 m²
16 | Café	| 102 m²
17 | Technical Room	| 300 m²
18 | Technical Room, Salt	| 50 m²
19 | Laundry	| 88 m²
20 | Cable Park Club Rooms	| 73 m²
21 | Entrance	| 9 m²
22 | Sauna	| 15 m²
23 | Outdoor Shower	| 5 m²



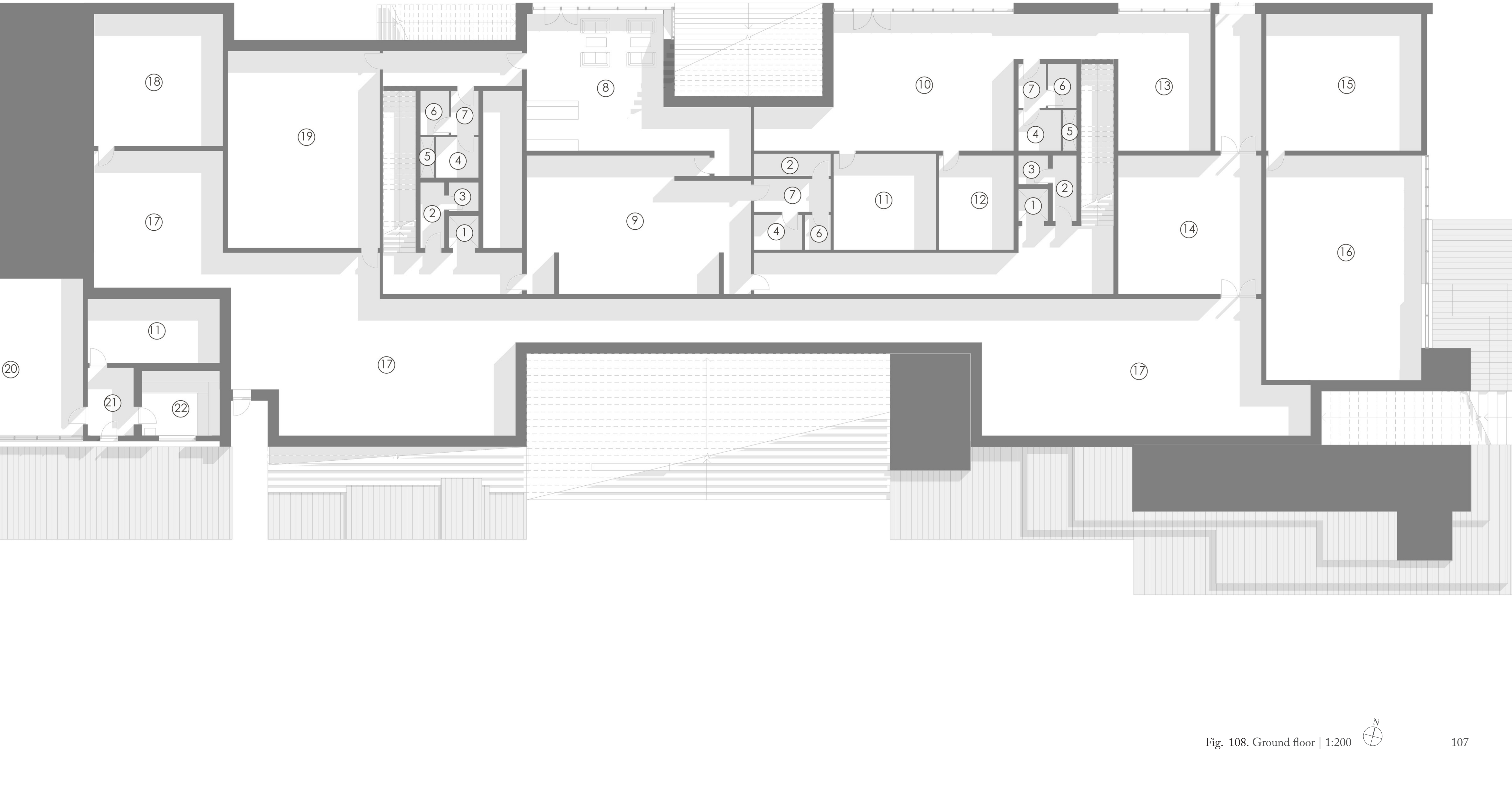


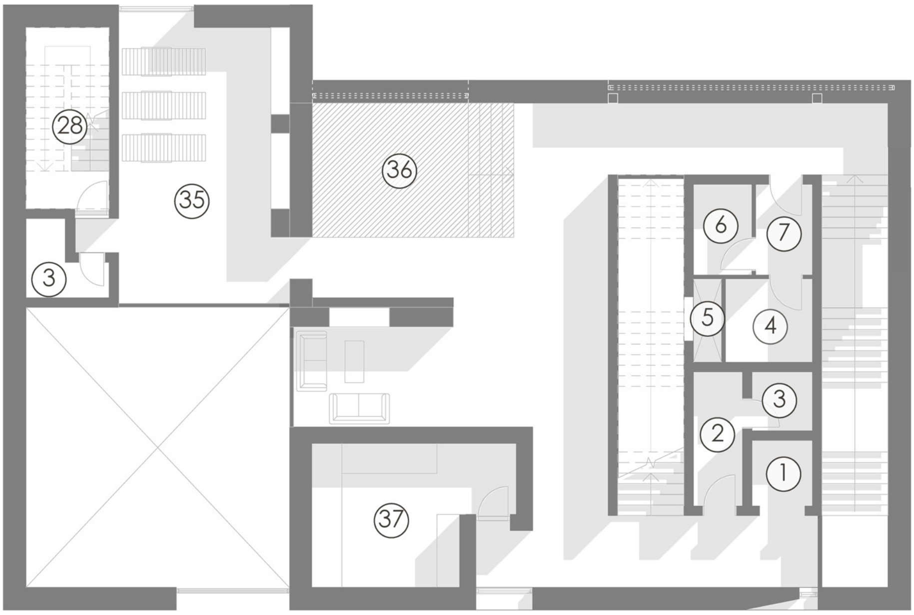
Fig. 108. Ground floor | 1:200

1ST FLOOR

1 | Elevator	| 3 m²
2 | Cleaning	| 5 m²
3 | Shaft	| 3 m²
4 | HC Toilet	| 5 m²
5 | Light Shaft	| 2 m²
6 | Toilet	| 4 m²
7 | Anteroom	| 4 m²
24 | Salt Pool	| 34 m²
25 | Salt Massage	| 15 m²
26 | Salt Sauna	| 24 m²
27 | Footbath Lounge	| 52 m²
28 | Fire Escape	| 11 m²
29 | Turkish Bath	| 49 m²
30 | Hot Lounge	| 35 m²
31 | Jet Pools	| 30 m²
32 | Sun Space	| 16 m²
33 | Cafe Dining Area	| 183 m²
34 | Cable Park Terrace	| 80 m²

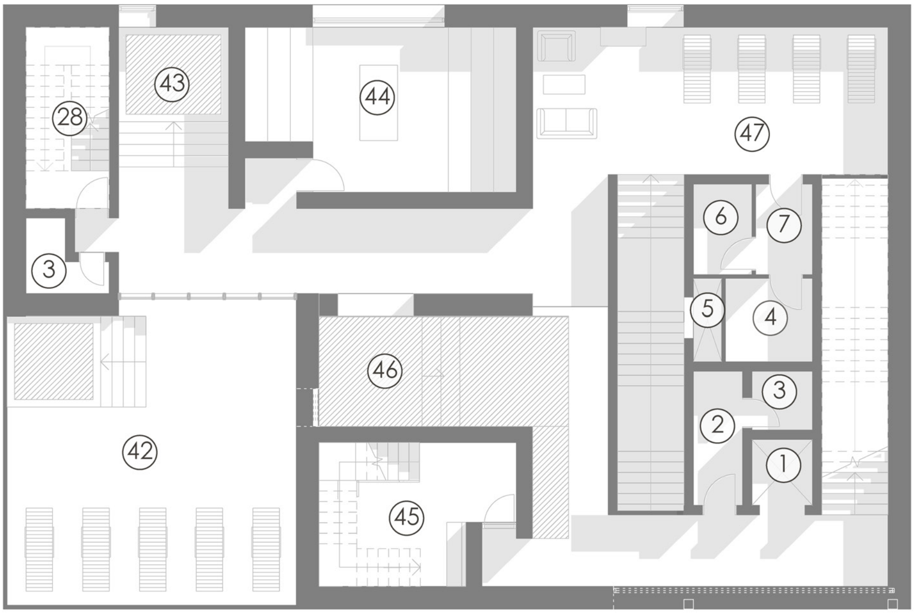
Fig. 109. 1st floor | 1:200

PLANS 2ND FLOOR



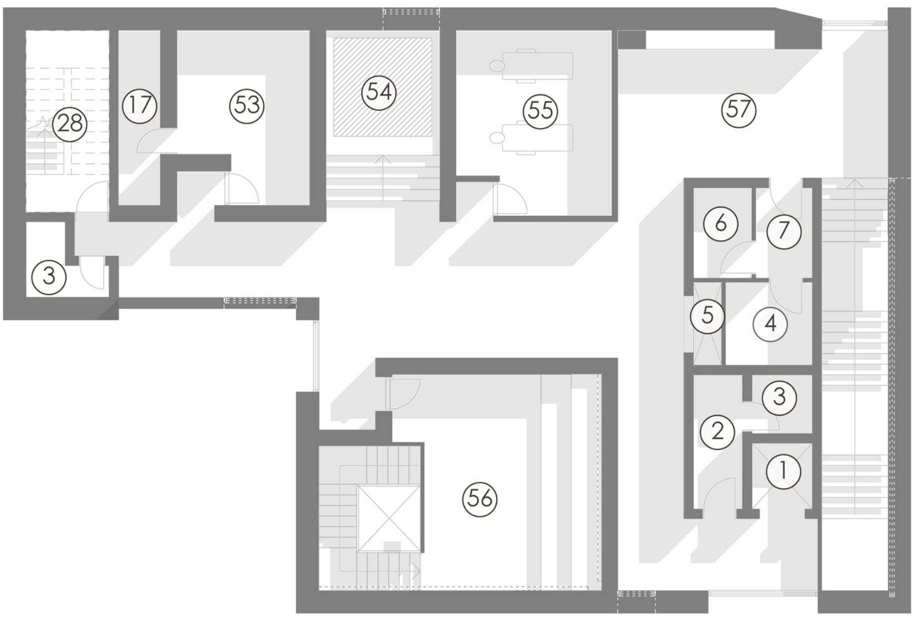
a | West tower 2nd floor | 1:200

PLANS 3RD FLOOR



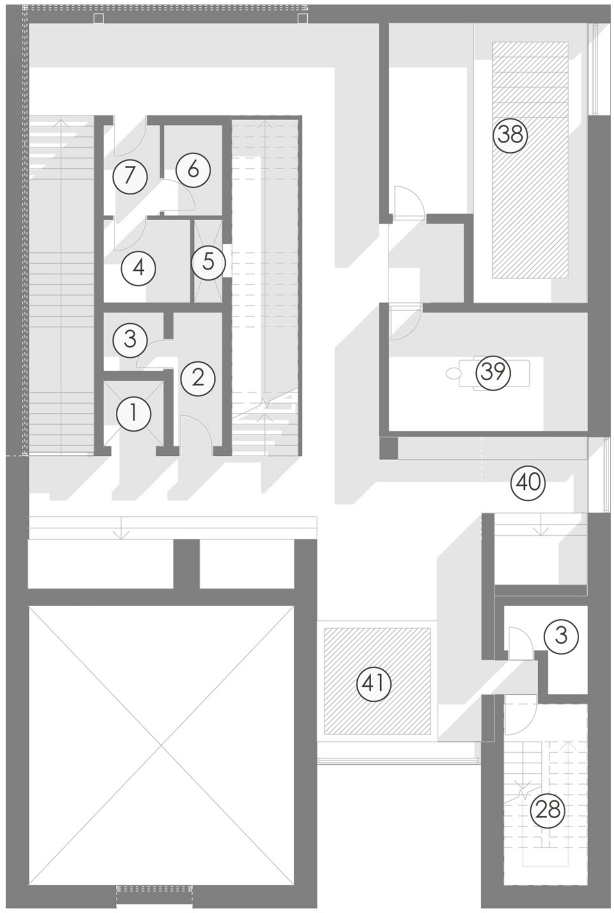
b | West tower 3rd floor | 1:200

PLANS 4TH FLOOR

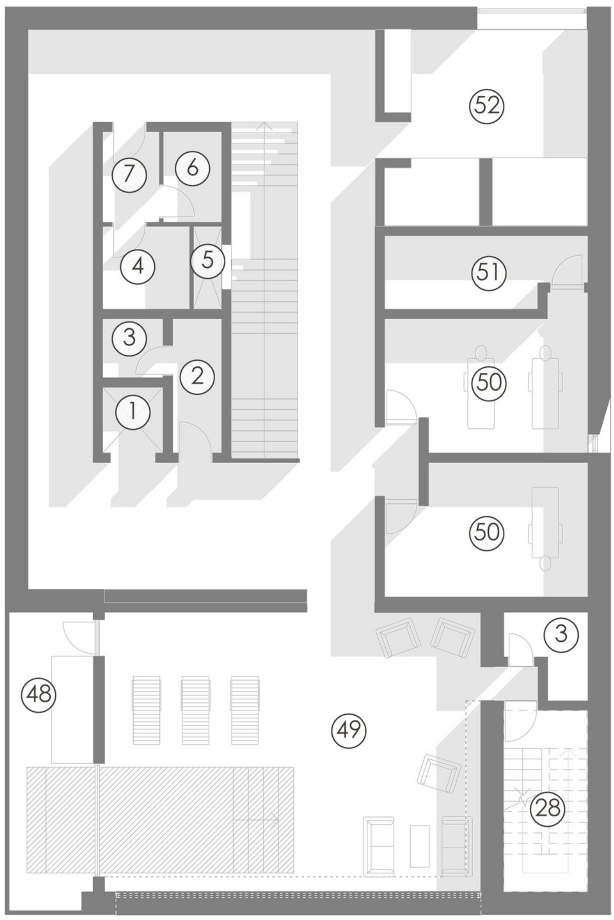


c | West tower 4th floor | 1:200

1 | Elevator	3 m^2
2 | Cleaning	5 m^2
3 | Shaft	3 m^2
4 | HC Toilet	5 m^2
5 | Light Shaft	2 m^2
6 | Toilet	4 m^2
7 | Anteroom	4 m^2
28 | Fire Escape	11 m^2
35 | Lounge	34 m^2
36 | Hot Pool	30 m^2
37 | Infrared Sauna	18 m^2
38 | Water Therapy	34 m^2
39 | Hot Stone Massage	17 m^2
40 | Niche	17 m^2
41 | Jet Pool	23 m^2
42 | Sun Space	59 m^2
43 | Cold Pool	14 m^2
44 | Finnish Sauna	29 m^2
45 | Russian Banya Low Part	18 m^2
46 | Flow Pool	26 m^2
47 | Lounge	37 m^2
48 | Sun Space	15 m^2
49 | Lounge	78 m^2
50 | Massage	37 m^2
51 | Storage	10 m^2
52 | Lounge	24 m^2
53 | Snow Sauna	14 m^2
54 | Ice Pool	15 m^2
55 | Body Wrap Massage	19 m^2
56 | Russian Banya High Part	40 m^2



d | East tower 2nd floor | 1:200



e | East tower 3rd floor | 1:200

Fig. 110. Plans 2nd - 4th floor | 1:200

N

CONSTRUCTION

The site-cast blade columns are integrated into the facades and enclosed spaces, to which the structural system is strategically hidden in room defining surfaces. The load-bearing cross-section is 250x250mm and follows a construction grid, from which the longest span of the two-way slabs is 8 m. The top floor has a longer span as no pools are located there, see fig. 111-112.

The main stair cantilevers from the load-bearing core because of the flexibility with a non-bearing facade when designing a horizontal window around a corner.

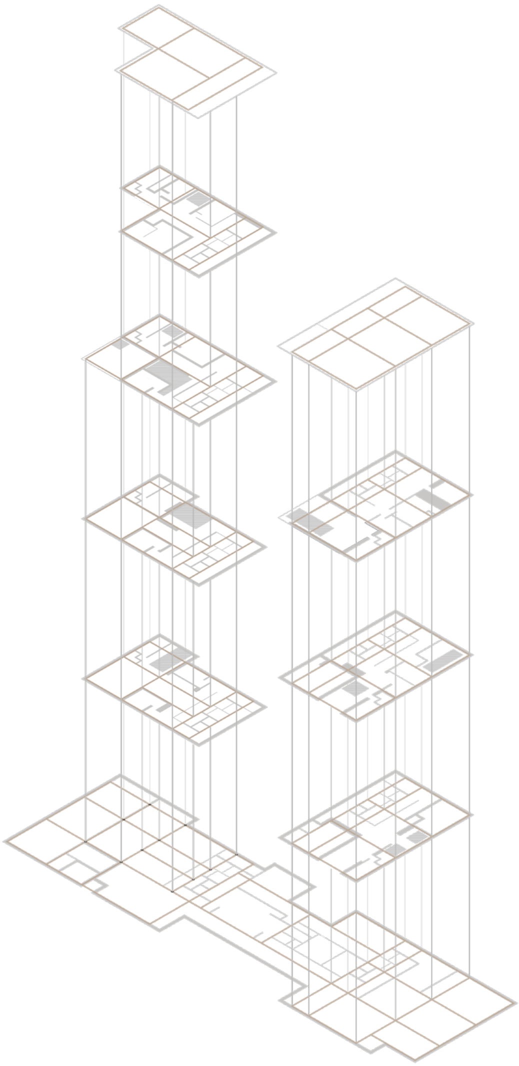


Fig. 111. Exploded construction grid

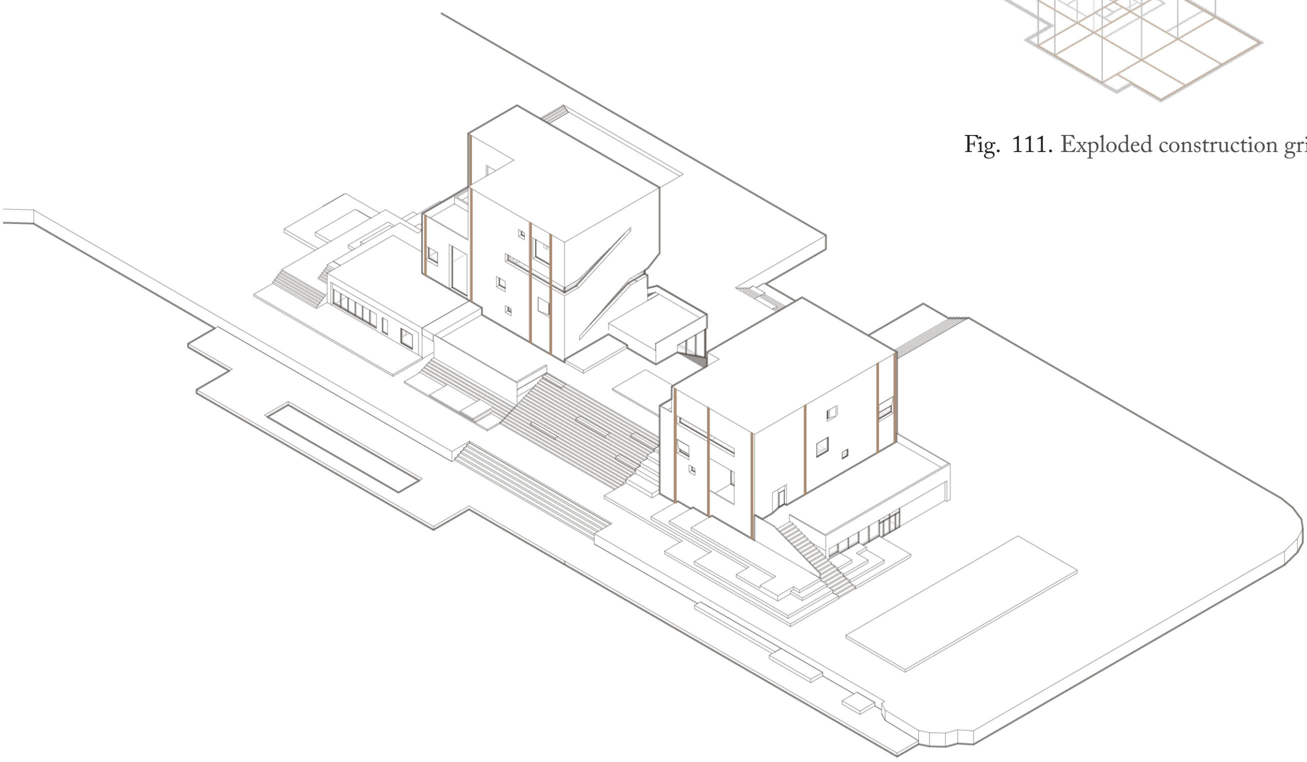


Fig. 112. Site-cast blade columns

SYSTEMS

Most mechanical systems are in the technical room at ground level, both ventilation system, cleaning and heating system for the pool water, and tanks for storage. However, some extreme rooms have additional machines integrated into the room. For instance, the steam generator for the Turkish Bath ensures more than 95% humidity all the time, or the device that produces snow in the snow sauna. Other saunas have an additional heat source visible in the room to which it is possible to create manually controlled experiences with steam and aromas, as demonstrated in fig. 113.

A mechanical engineer will develop further specifications.

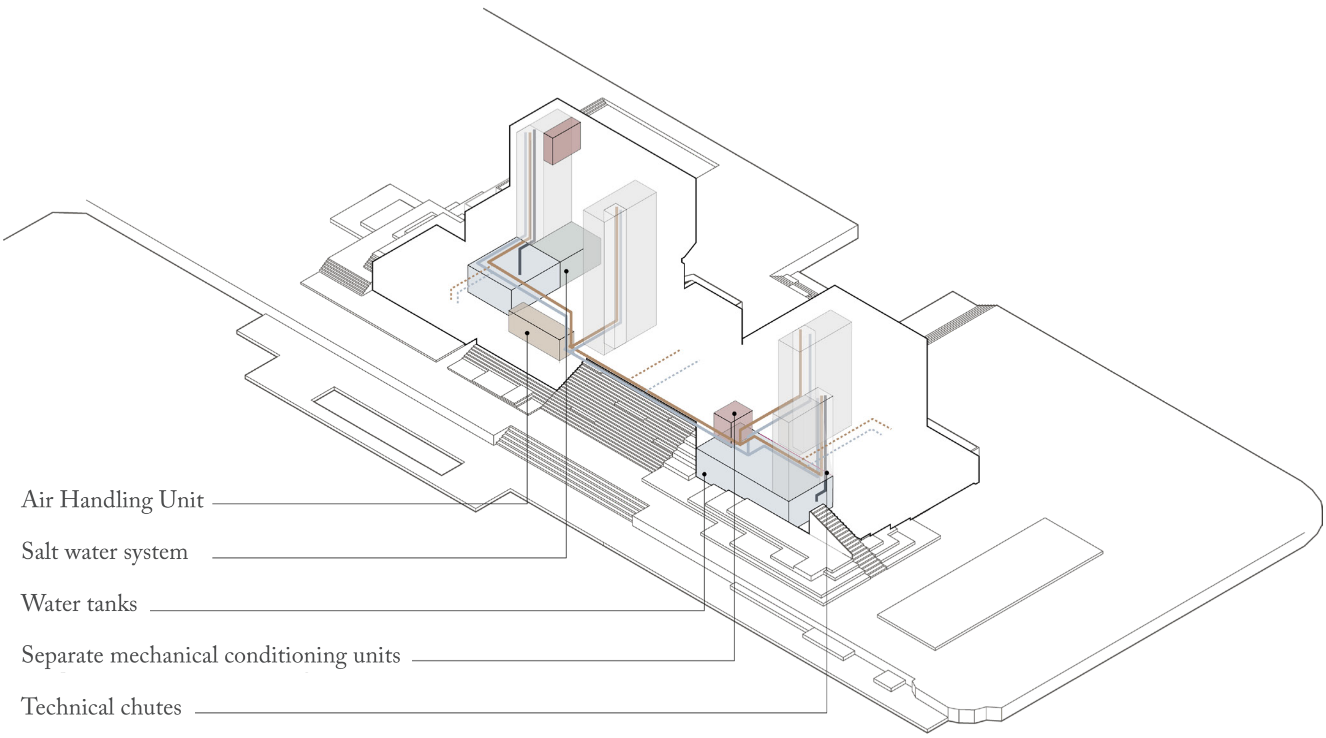


Fig. 113. Mechanical conditioning

SALT POOL

The indoor environmental qualities of the Spa House are enhanced by thermal, visual, and spatial alliesthesia. Besides, materiality, textures, and lights state the aesthetic and poetic appearance of the spa. The atmospheres follow the narrative of carving out spaces, shaping niches and sculpturing the volume. The cavy expression of monolithic surfaces leads to an explorational flow when occupants move between spa experiences.

The Spa House is from the president studies, estimated to house approximately 40 new visitors every hour of the opening hours 10-22. The occupants are assumed to stay a minimum of 3 hours.

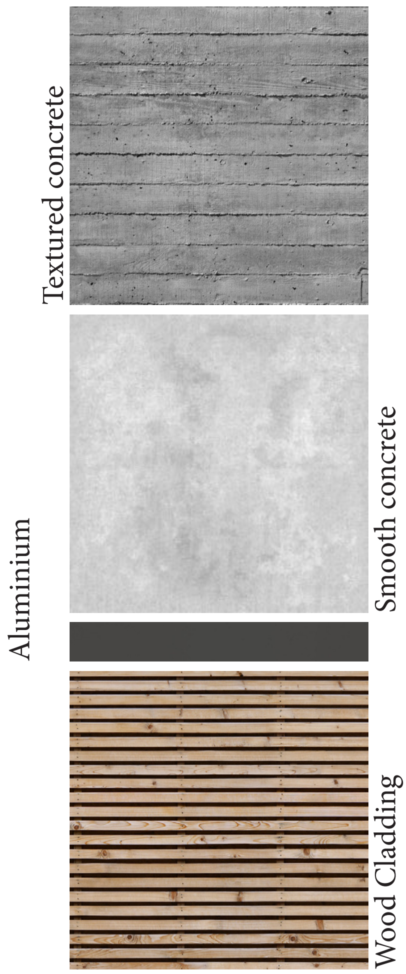

Ill. 12. Salt Pool

DETAIL

The exterior texture is imprinted from the vertical wooden planks from the formwork, see fig. 114. Since the loadbearing inner wall and the façade are cast at once, the inner wooden surface stays inside the envelope, to which a cheaper solution can be used, such as wood boards. The soft mineral wool is filled in continuously while constructing the formwork, see fig. 115.

The walls are cast in several steps because of the dimensions of the building. However, the aim is to minimise the visual differences in the cast, to make the surface appear as one mass. In small window openings, the thickness of the envelope frames a view by the enclosing surfaces.

A general ceiling height of 3700 mm creates a spatial quality to pools and lounges since the functions request more space than conventional buildings. The extreme rooms are extra insulated to control the hot conditions, which lowers the ceiling height. However, the sauna still requires seatings in more than one level since the sauna experience's intensity varies according to the seating height.



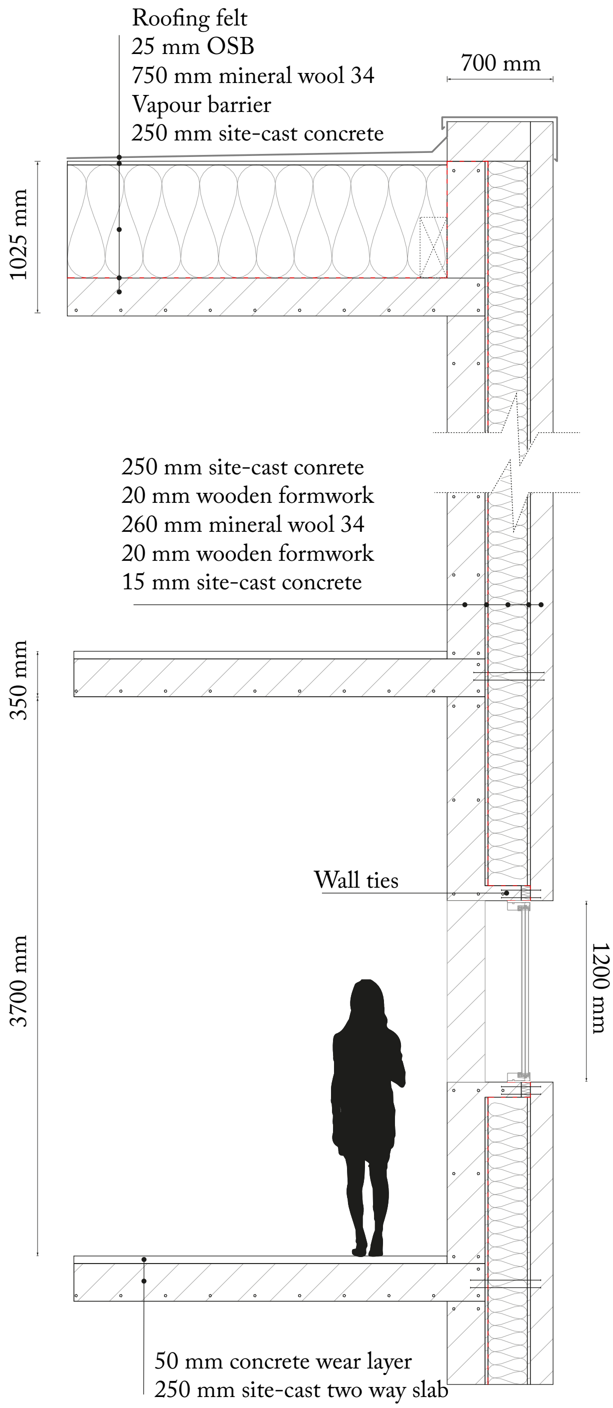


Fig. 114. Material board

Fig. 115. Envelope detail 1:50

The neutral spaces of the Spa House are below 33 kWh/m^2/yr as the benchmark for conventional low energy buildings. The ambience of the spaces is essential for the experiences of the building, which compromises the energy consumption. However, the high energy demand will be balanced or lowered with energy produced by renewable resources, as discussed in fig. 40.

Office
The office aims to balance energy optimisation and well-being. The offices have big windows, with a little overheating in certain seasons, although the room faces a nice view of the fjord. The space gets enough natural daylight to illuminate the office with minimal artificial light. The temperature inside ranges between 20˚C and 25˚C, leading to the energy consumption presented in table 13.

Window
TThe windows are strategically related to extrovert spaces, such as the office and break room, and shielding for introverted hallway and transition space. The high windows can naturally ventilate the offices by one-sided ventilation. The specifications of the windows are to find in table 11.

Spa
Table 12 presents the energy consumption for a neutral zone on the top floor. The data is assumed to be a valid guideline for the other floors, with only minor tweaks. Extreme rooms conditioned from -10˚C to 80˚C are insulated by Kingspan vacuum panels. However, in the simulation, inner walls facing those rooms are defined as adiabatic.

Window
The fixed window openings in the spa facilities focus on shaping gestures, to which the openings are strictly controlled in the carvings mediating between the exterior and interior dimensions.

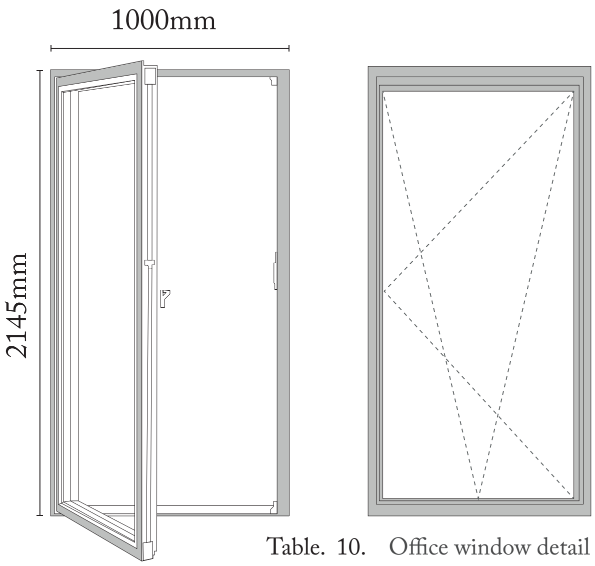


Table. 10. Office window detail

Velux Window	
U-value [W/m^2*K]	0.8
G-value	0.74

Table. 11. Window specifications

	Office	Spa
Heating [kWh/m^2/yr]	12,022	29,125
Cooling [kWh/m^2/yr]	4,368	0,237
EUI [kWh/m^2/yr]	16,390	29,472

Table. 12. Energy consumption

	Office	Spa
Set point temperature	Heating occurs at 20 ˚C Cooling occurs at 25 ˚C	Heating occurs at 25 ˚C Cooling occurs at 30 ˚C
Ventilation rate	From the room programme: 429 l/s	From the room programme: 346 l/s
Initial load	25 people who follow the schedule of being present from 7-16 and off-work at the weekend and holidays.	120 people spread out in the entire spa. Therefore, 15 people would approximately be at the top floor, following the schedule from 9-21.
Systems	Ideal air system	Ideal air system
Natural ventilation	A window will open when the inside temperature is above 26˚C and the outside temperature is above 18˚C	N/A

Table. 13. Systems definition

Ill. 13. Seen from south

EPILOGUE

Ill. 14. TheCrane

CONCLUSION

This Master Thesis exemplifies a design driven by alliesthesia, with a main focus on the environmental qualities of thermal, visual, spatial and social alliesthesia.

The Spa House shapes visual and sensory experiences by integrating the phenomenological and poetic dimensions of architecture into a Performance-based design. Computational tools and performance-driven design methods inform the evolving environments. For instance, when investigating interconnections between window opening, material, daylight and atmosphere, or how to minimise the energy demand related to the envelope. To that end, the simulations generate feedback for the design to attain the goals for energy. The two investigations start bridging the gap between the quantitative and qualitative dimensions of the architecture. Thus, the bridge gets further strengthened by integrating other indoor environmental parameters, such as those mapped in the psychrometric charts, when designing experiences.

In the investigation of how to bridge the gap between quantitative and qualitative dimensions of architecture, the thermal and visual alliesthesia has steered the design the most. Computational simulations and mapped environmental conditions have informed the final design proposal and its evolving environments with spaces of different nature. The introduced spatial and social alliesthesia is complicated to measure and is therefore based on expected experiences and use when designing spaces.

The conceptual principles of acoustic alliesthesia inform the urban strategy and overall programming of the building. However, this should be investigated further in relation to the experience to support the desired atmosphere.

The design is based on a programmatic approach of zonings horizontal and vertical, interior and exterior. The indoor environment merges and incorporates flow, mechanical conditioning and structural principles in a tectonic concept following the narrative of carving. The tectonic gestures of the main stair being carved into the core, the chiselled window details, and the textured surfaces tell the story of a stereotomic Spa House. To that end, the architecture combines aesthetics, durability and convenience into the narrative of the building. The stereotomy and sectional connections are utilised to improve spatial alliesthesia.

The stereotomic game in the exterior shapes and mediates spaces between the diversity in dwellers. The transformation of the Pier creates environments for gathering, condensing a wide range of user groups and social activities, to which social alliesthesia is intended to happen in one of the last free spaces close to the inner city of Aalborg.

The social sustainably benefits from the new gathering place and contra balances some of the challenging aspects of the economical and environmental sustainability of a Spa House. However, environmental sustainability is attempted to be met by minimising the energy demand in non-extreme areas and utilising passive and active means such as photovoltaics, thermal collectors, and a heat pump connected to the Fjord. To that end, a potential surplus could feed into the heat grid of the Aalborg, favourable to connecting the Spa House and the city.

In sum, it is possible to combine and integrate the phenomenological dimension of architecture with the pragmatic aspects of IEQ metrics. An integration that creates a place that offers the possibility to explore both unique physiological and psychological experiences. By applying principles of thermal, visual, social, spatial, and audible alliesthesia it is possible to create transient, multisensory spaces that impact people in specific ways, is indeed a way to create Evolving Environments.

Ill. 15. Niches

REFLECTION

Alliesthesia
This Thesis is driven by contrasts and extent the understanding of alliesthesia, and ways to mediate between the opposites. Considerations about how the design might mediate too much between the extreme experiences could be challenged by placing the contrasting environments even closer. For instance, stronger thermal alliesthesia is perceived if placing an ice pool inside the Russian Banya instead of having a mediation space in-between. However, the temperatures will counteract and require a high level of detailing in the technical dimension.

The various principles of alliesthesia support each other to shape a desired atmosphere and merge different layers of the environment. For example, visual alliesthesia has the potential to mark a transition beyond the thermal differences. To that end, the acoustic and spatial alliesthesia enhance the nature of the spaces further as the environment evolves. For instance, moving from an open, bright space of comfort with people talking to a small, dimmed room of cold heat stress, with a high reverberation time indicating a low pace.

However, the false-colour simulation measures the luminance-contrast-ratio for glare to create an indication of visual contrast. In future work, it must be evaluated where, when and to what extent the data is used to inform the design. The contrast-ratio must be balanced with visualisations to ensure utilising the qualities of the contrasts, more than creating discomfort. Therefore, it will be interesting to continue mapping daylight and visual alliesthesia to identify tendencies of alliesthesia based on drafty renders and analysis of lux. For instance, false-colour renders of several rooms, e.g. communicating and linking how a dimmed room of 50 lux is experienced as opposed to a space of 100 lux, 200 lux, 500 lux, etc., and how that helps designing atmospheres.

Besides, the bridging between the phenomenological dimensions and predictions by simulations would be elaborated on, both in terms of acoustical potentials to shape a desired environment; absorbing, diffusing, scattering or directing soundwaves. Additionally, studies of reverberation times and surface materials will be interesting to manipulate the sound experiences, and how different types of alliesthesia are combining indoor environmental qualities. The acoustical behaviour will be interesting to investigate when shaping and dimensioning rooms. For example, the double-height space in the footbath lounge, a small niche as the ice pool, or the void space by the flow pool, which is expected to be the loudest environment in the Spa House. In spaces with sloped ceilings, the soundwaves will be redirected because of the angle, which might be simulated in a program such as Pachyderm Acoustics to indicate the potential impact on the surrounding areas.

However, the spatial gesture of the sloped ceiling forms a sequence of variating spatiality, as one example of spatial alliesthesia. To that end, a research paper from Aalborg University 2020 exemplifies how the body and the brain unseparately explore spaces resulting from previous, present and future environments (Djebbara, 2020). Such a time aspect of moving between environments is reflected in the Spa House, but could be integrated further to communicate shifts in pace, activity, transitioning, etc. For example, by introducing half storeys, which assumably supports the narrative of the carving game. Those gestures emphasise a Spa House of several floors and further elaboration on creating additional sectional connections and interior heights.

Building
A Spa House in 5 storeys needs a strong focus on the structural system and loads from pools, as well as waterproofing since leeks assumably cause massive damages to the floors and facilities underneath. All pools could be placed on the ground floor to minimise the amount of water in height. However, this goes against the tall context buildings implying a tall Spa House unless the pool facilities are replaced with other experience rooms, such as cold rooms, sensory saunas, specific types of massage, jacuzzies, and showers, etc. that require less water.

Both experience rooms and pools increase the energy demand significantly by extreme temperatures and the special need for domestic hot water. Those environments are demanding for the need of energy, both related to climatic impact and the costs of operating. If more time, it would be relevant to estimate the total energy demand of the building, investigate how and where to optimise the design, to emphasise sustainability to a greater extent. This will, as a minimum, require detailing of the facilities needed for cleaning and storing water, an approximation of the mechanical conditioning systems and their energy consumptions, to which mechanical engineering assistance will be required.

However, the quantitative investigation of energy presented in this project is made in the spaces estimated to be representative for the building, excluding the extreme rooms, because of the limitations of the simulation software. If the project period were extended one month, the goal-oriented design would be implemented to a greater extent. The windows assumably would benefit from being informed by something specific to guide the facades and not alone focusing on the interior qualities.

In addition to the costs of operating the Spa House, expensive solutions, such as vacuum panels and site-casting add to the material cost of the project. However, these solutions emphasise a specific gesture and obtain desired environments and atmospheres. If, instead, working with prefabricated wall elements, the façade would be indexical by the jointing between elements and not read as one volume. Nevertheless, standard prefabricated elements assumably lower the price of the construction phase and potentially result in a Spa House that is more reachable for everyone. The tectonic game will then be something else.

Evolving project

The project evolved over time, to which the project scope changed throughout the process. Nevertheless, this evolving helped improve the design and arguing for the environments shaped at the Pier, both interior and exterior. If the project period were extended, the next step would be to refine the indoor environmental qualities in line with the intended scope. The focus would be to continue bridging between the computational data and poetic dimensions of the evolving environments.

The methods of simulations and investigation on how to design with alliesthesia will in other projects assumably be adjusted to be closer to the comfort criteria because of the usage, e.g., housing or offices. However, contrasts in light and spatiality could be integrated into every type of project. For instance, to indicate spaces not intended for stayings by guiding the occupants elsewhere with lights. This could as well guide social alliesthesia.

The requirements to sound make it challenging to integrate acoustic alliesthesia. Therefore, other projects probably must be of a sudden size and nature to let the differences be noticeable. For example, cultural projects such as a museum or a church.

Thermal alliesthesia of less extreme conditions can potentially emphasise the adaptive comfort model, which should be even more integrated into future buildings to minimise the climate impact (Lichtenbelt, 2022).

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Fig. 7, section of the eye - Own illustration based on:
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Fig. 6 and 63, psychrometric chart – Own illustration, based on data from:
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APPENDIX

Ill. 16. View at along the fjord

APPENDIX I: STRATEGIES

Passive and active strategies are derived from the climate and weather data for Aalborg by Climate Consultant (UCLA Energy Design Tools Group, n.d.). The graph demonstrates how an office building could be designed to accommodate the AHARE model, developed for American standards.

The Adaptive Comfort Model can help ensure comfort for 254 hours a year. This strategy requires action from the occupants, which should fit the function of the room. Besides, there will probably be a need for solar shading 112 hours a year.

The European standards are estimated to be comparable to ASHARE, to which the results will be considered as an approximation.

Passive	4,4%	1 Comfort - ASHRAE Handbook 2005 model (383hrs)
	1,3%	2 Sun shading of windows (112hrs)
	0,5%	3 High thermal masss (43hrs)
	0%	4 High thermal mass night flush (0hrs)
	0%	5 Direct evaporative cooling (0hrs)
	0%	6 Two-stage evaporative cooling (0hrs)
	2,9%	7 Adaptive comfort ventilation (254 hrs)
	0%	8 Fan-forved ventilation cooling (0hrs)
	28,6%	9 Internal heat gain (0hrs)
	0%	10 Passive solar direct gain low mass (0hrs)
	11,4%	11 passive solar direct gain high mass (0hrs)
	0%	12 Wind protection of outdoor spaces (0hrs)
Active	0%	13 Humidification only (0hrs)
	0%	14 Dehumidfication only (0hrs)
	0%	15 Cooling, add dehumidfication if needed (0hrs)
	59,6%	16 Heating, add humidfication if needed (5221 hrs)
	99,9%	Comfortable hours using selected strategies (8747 out of 8760hrs)

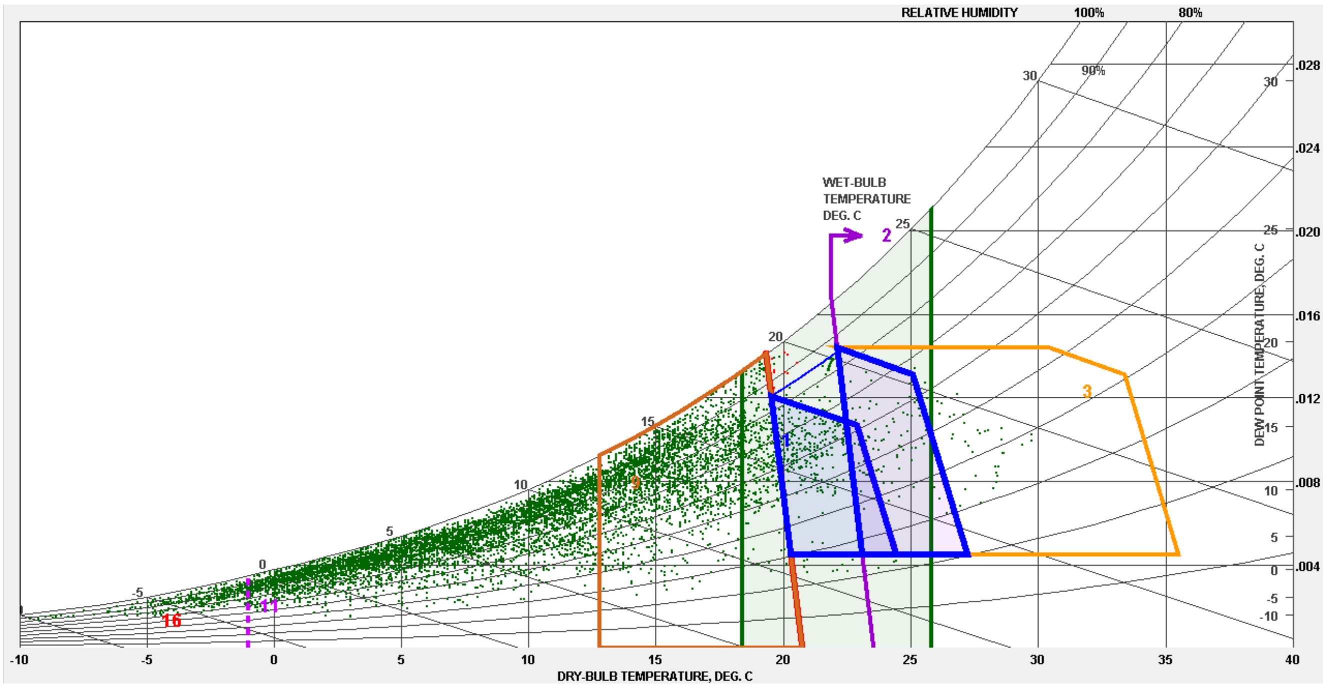


Fig. 116. Psychrometric chart

APPENDIX II: SOLAR SHADING

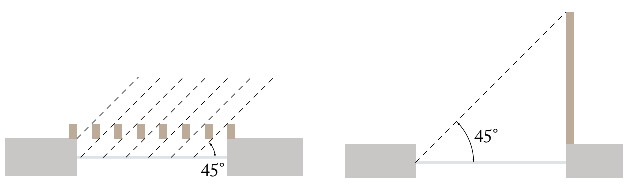
Based on weather data for Aalborg, an investigation in Climate Consultant identifies critical tendencies for overheating, to derive potential strategies for the Spa House (UCLA Energy Design Tools Group, n.d.).

The outdoor temperature can help estimate if shading is needed during different periods of the year. If solar shading is required in the case of overheating, the most efficient shading angles are related to the shape and placement of the shading and the orientation of the window.

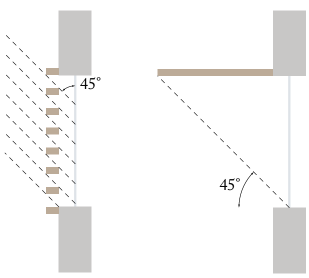
The shading investigation illustrates what kind of shading is needed in the different directions and how many critical hours of sunlight are shaded. For instance, a south-facing window is efficiently shaded using an overhang, but the most critical orientation is west, as the low sunlight enters the window. In such cases, fins are an opportunity as a static shading device, but the size of an effective fin can be inadequate. However, the fin can be divided into smaller fins covering the window opening if maintaining the same horizontal shading angle, and thereby utilising the shading to gain privacy.

	East		South		West		North	
	Jun-Dec	Dec-Jun	Jun-Dec	Dec-Jun	Jun-Dec	Dec-Jun	Jun-Dec	Dec-Jun
Warm/hot > 27 °C (shade needed)	4 h exposed 5 h shaded	8 h exposed 10 h shaded	0 h exposed 9 h shaded	0 h exposed 18 h shaded	0 h exposed 9 h shaded	2 h exposed 16 h shaded	2 h exposed 7 h shaded	0 h exposed 18 h shaded
Comfort > 20 °C (shade helps)	88 h exposed 155 h shaded	43 h exposed 43 h shaded	16 h exposed 227 h shaded	0 h exposed 86 h shaded	15 h exposed 228 h shaded	13 h exposed 73 h shaded	38 h exposed 205 h shaded	2 h exposed 84 h shaded
Cool/cold < 20 °C (sun needed)	334 h exposed 1540 h shaded	375 h exposed 1630 h shaded	1012 h exposed 862 h shaded	1003 h exposed 1002 h shaded	531 h exposed 1343 h shaded	535 h exposed 1470 h shaded	144 h exposed 1730 h shaded	177 h exposed 1828 h shaded

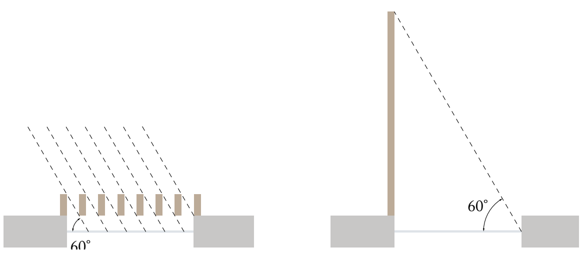
Table. 14. Exposed and shaded hrs



a | Finns | HSA | East



b | Overhang | HSA | South



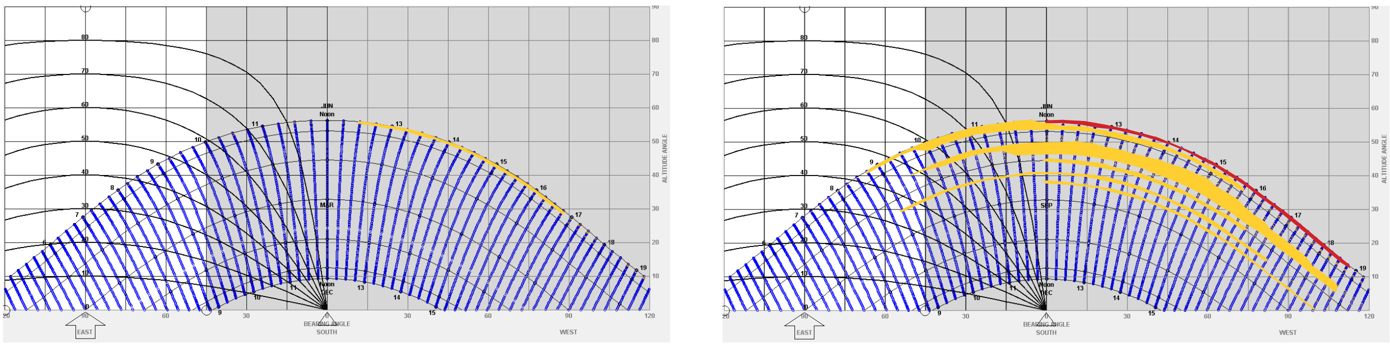
c | Finns | HSA | West

d | No Overhang | HSA | North

Fig. 117. HSA and VSA | a-d

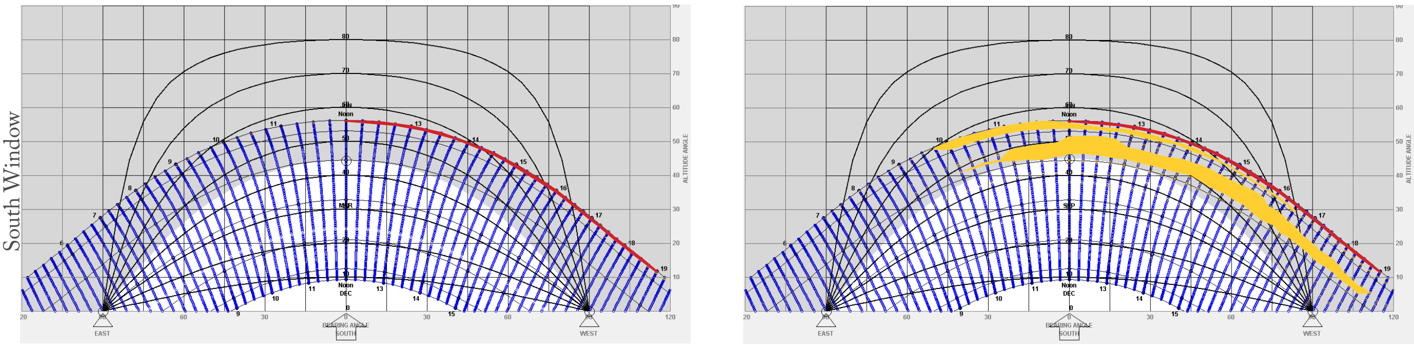
21. Jun - 21. Dec | 21. Dec - 21. Jun

East Window



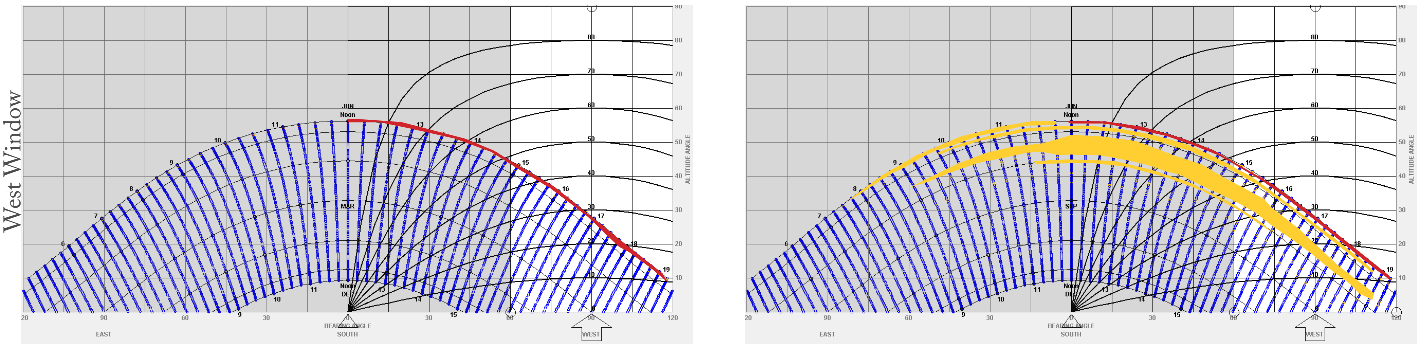
a | Shading mask for finn horizontal shading angle (HSA) optimisation

South Window



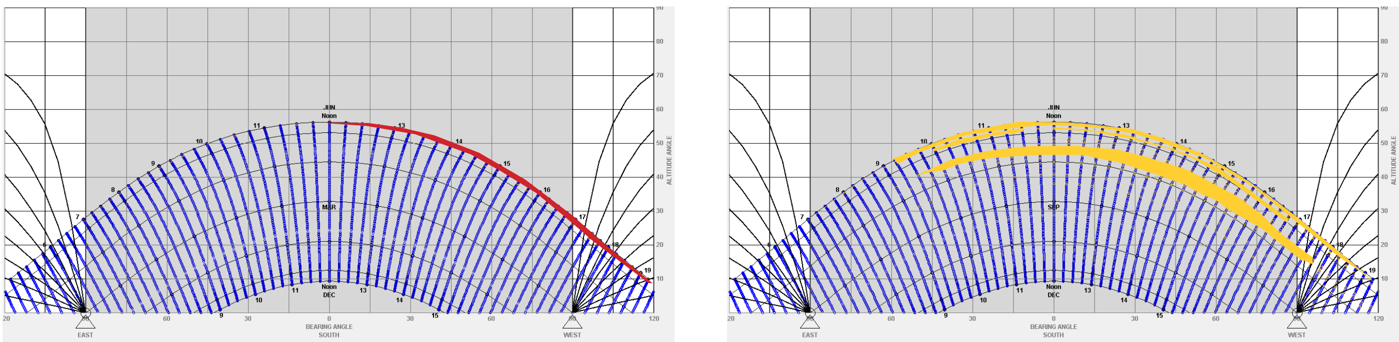
b | Shading mask for overhang vertical shading angle (VSA) optimisation

West Window



c | Shading mask for finn HSA optimisation

North Window



d | Shading mask for overhang VSA optimisation

Not in shade In shade

Fig. 118. Shading maske for overhang and finn shading angle optimisation | a-d

APPENDIX III: INITIAL DESIGN

The design process started by defining the nature of the building. Here, the functional and spatial definition of the words extrovert/introvert and private/public became essential when designing a spa house. To illustrate the spatial interpretation of the terms, different sauna layouts and placements were investigated. The nature of the building also determines its form and placement on the Pier. Here it became important to determine the nature of the urban environment in relation to the building. Especially, how the placement influences the flow of people while the form allows for people to interact with the building e.g. green spaces, courtyards, public ground floors, etc.

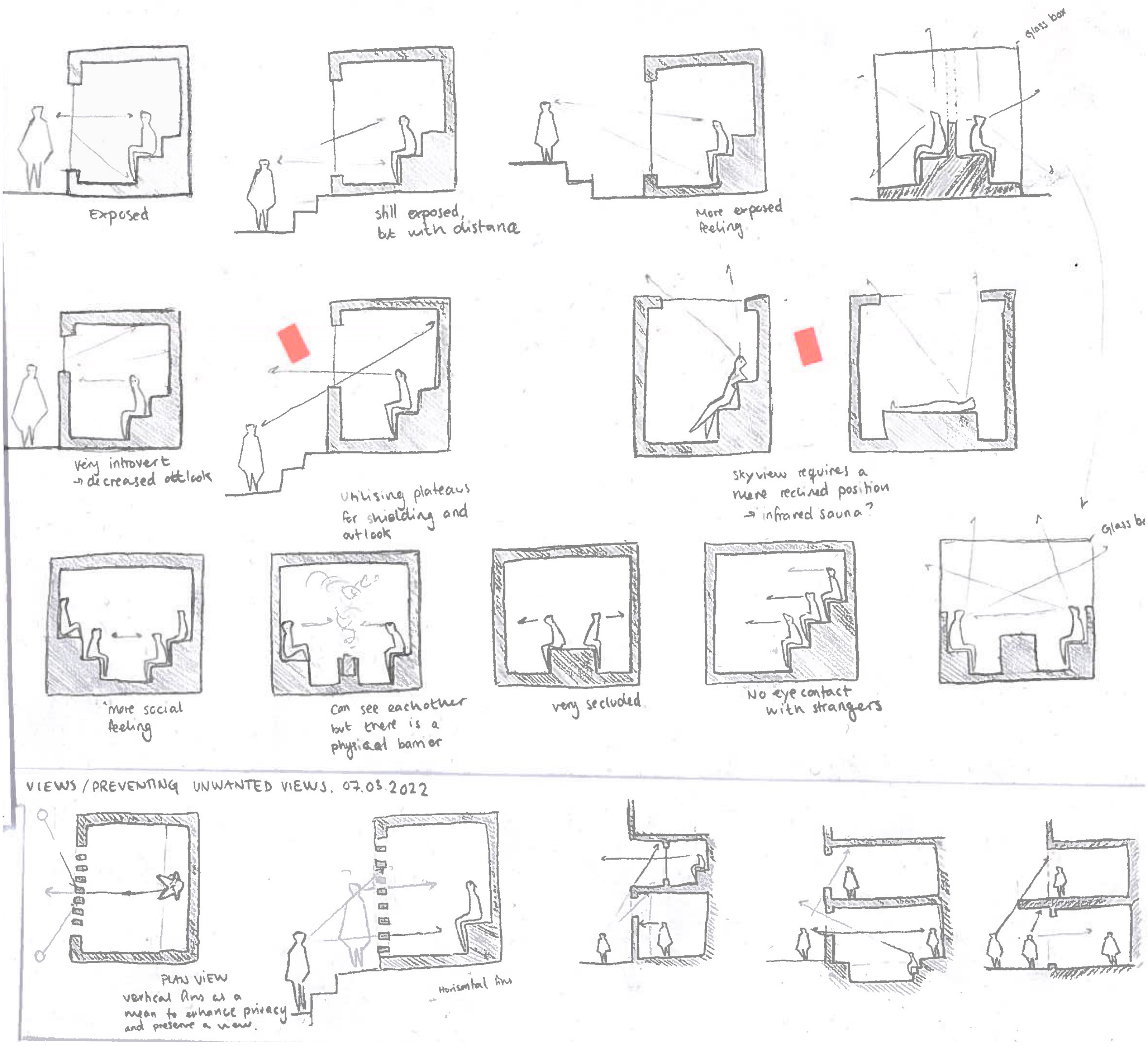


Fig. 120. Windows and interactions studies

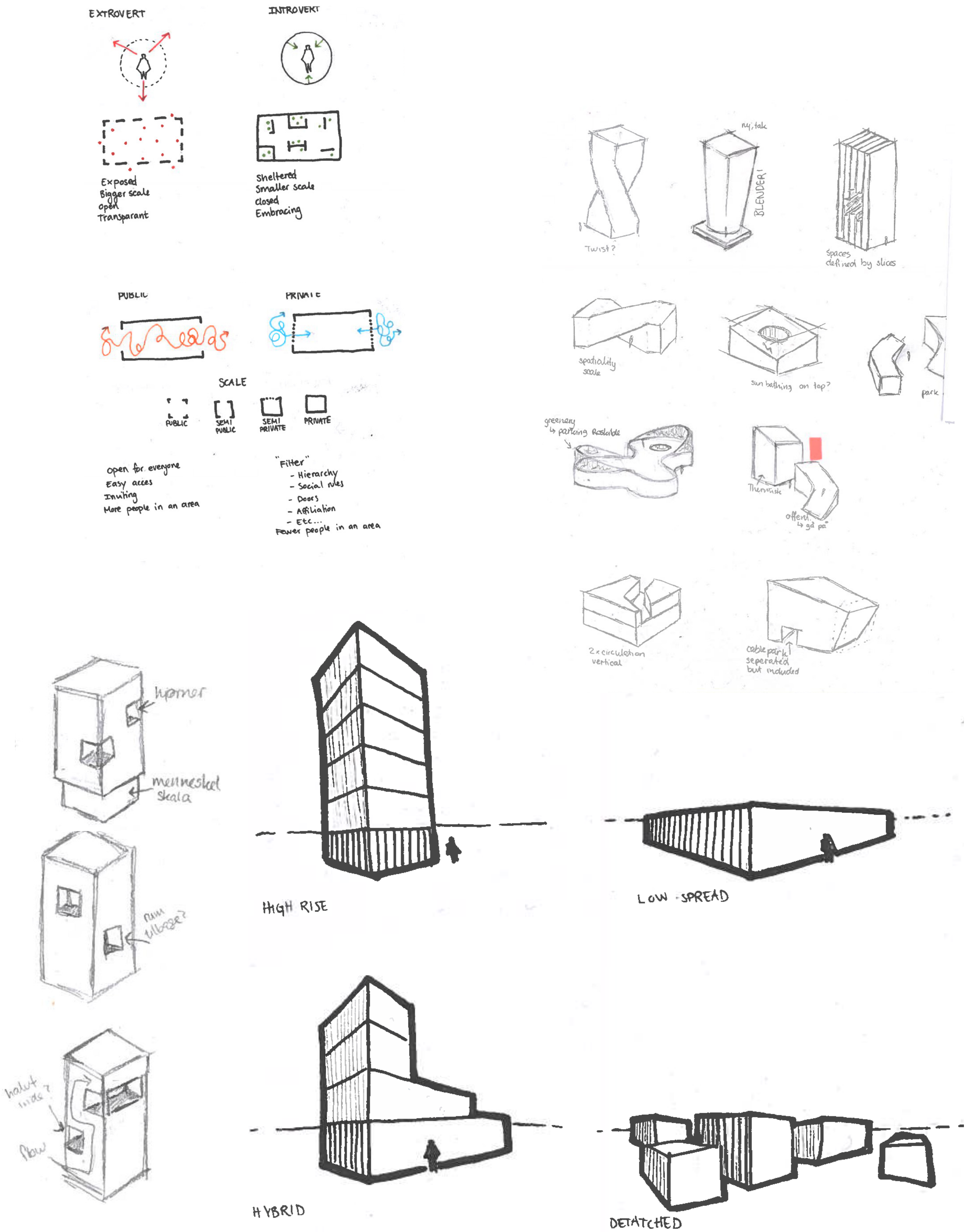


Fig. 121. Initial massing studies

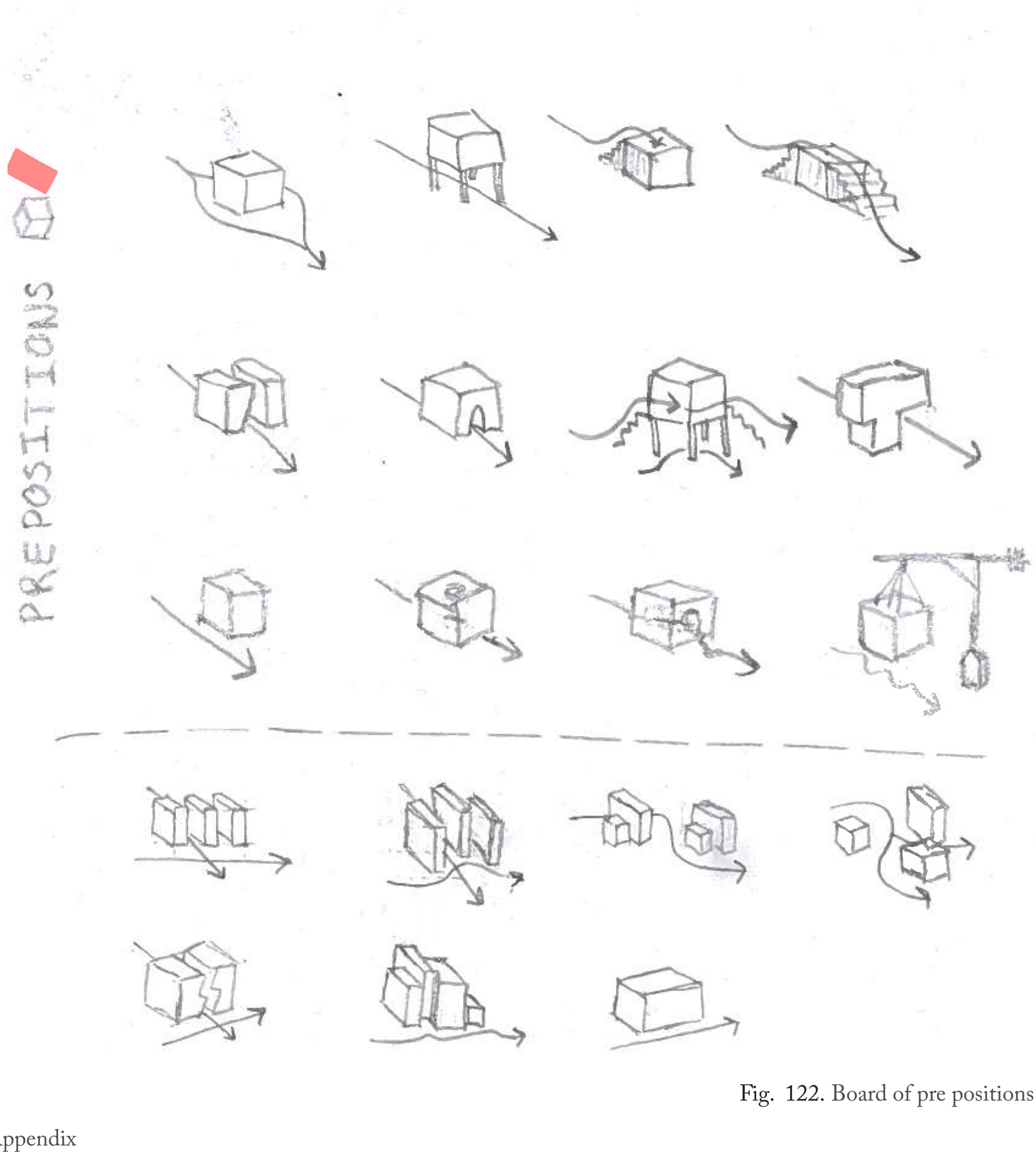


Fig. 122. Board of pre positions

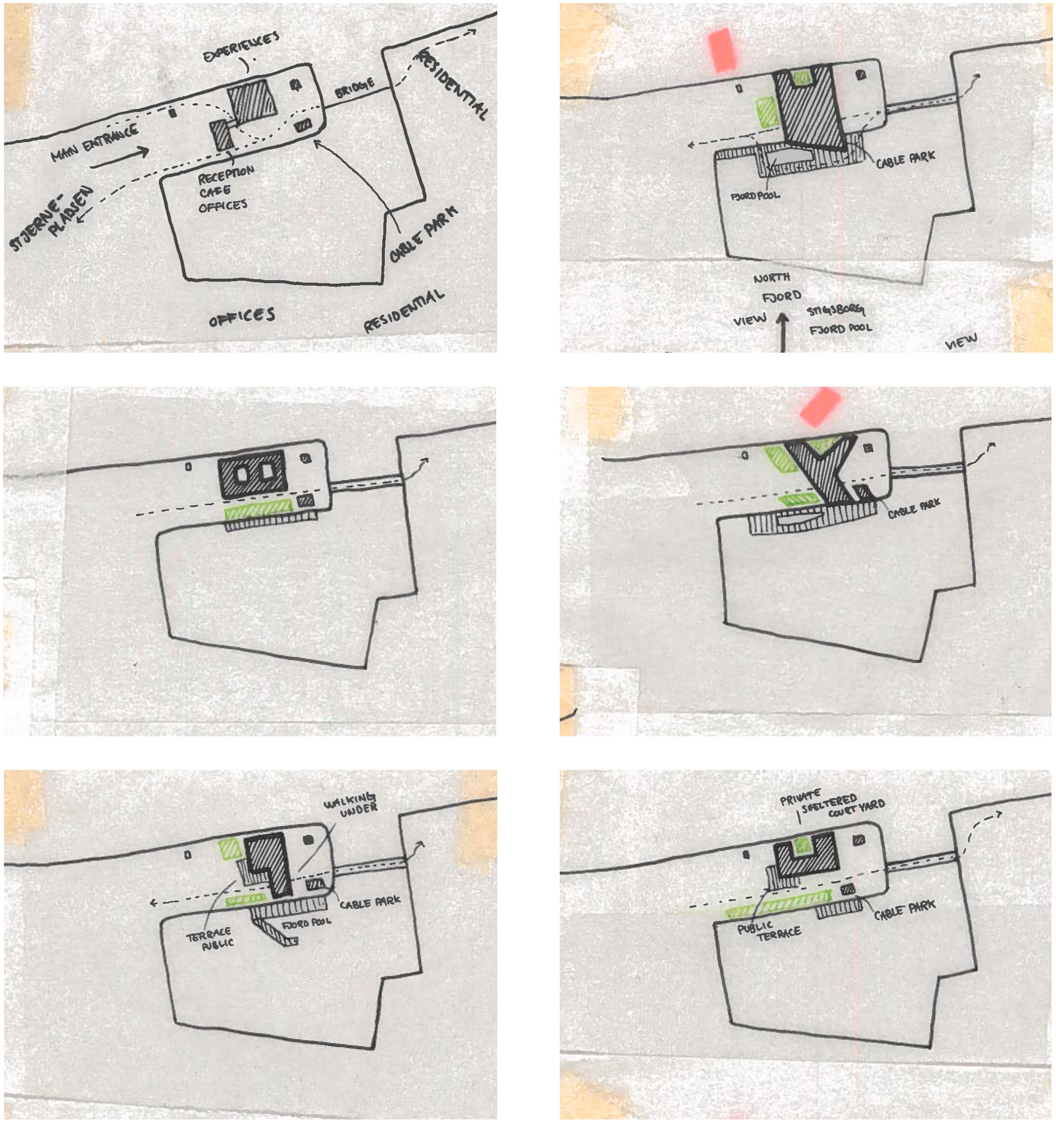


Fig. 123. Initial Urban strategies

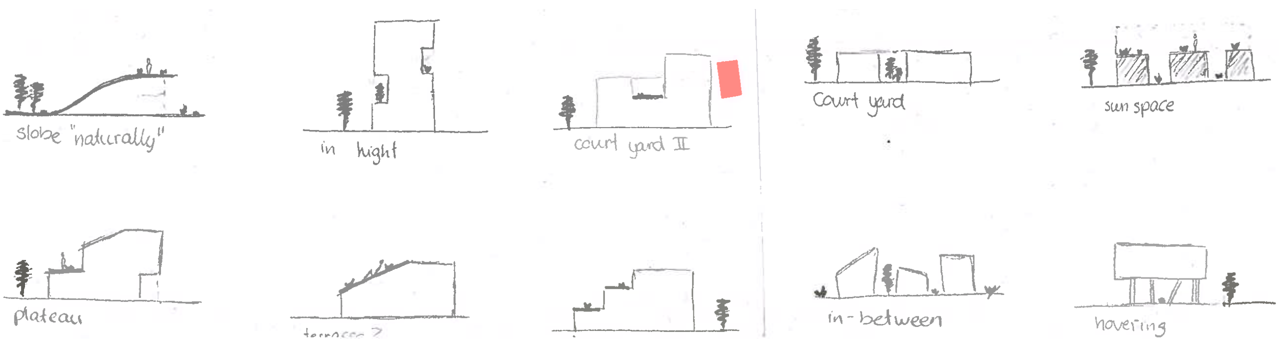
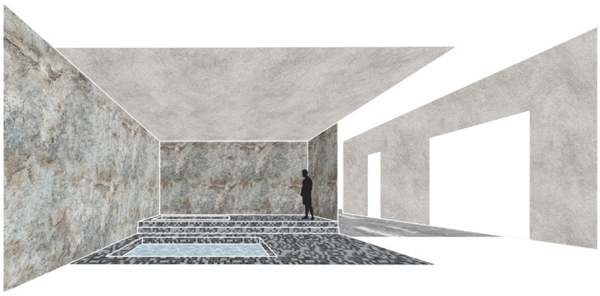


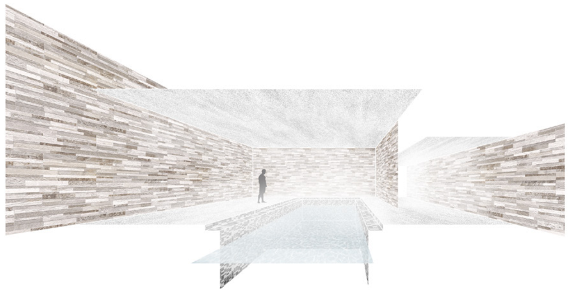
Fig. 124. Urban structures and human scale

APPENDIX IV: ATMOSPHERES AND MATERIALS

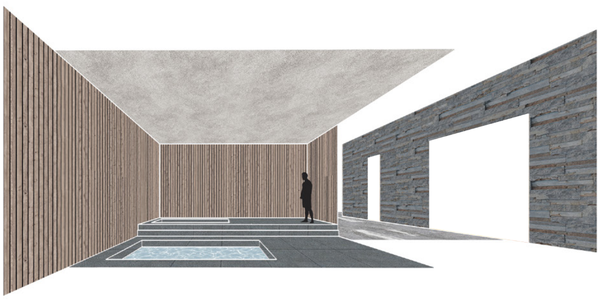
The poetic dimension of the interior has been explored through material collages. Here the colour, texture and mass all affect the atmospheric experience of the room.



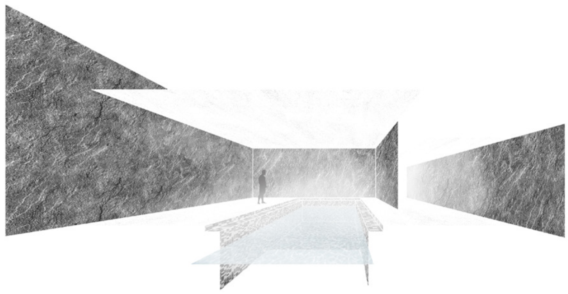
a | Room 1 | Marble(smooth, reflecting), Mosaic (pattern), Concrete(smooth)



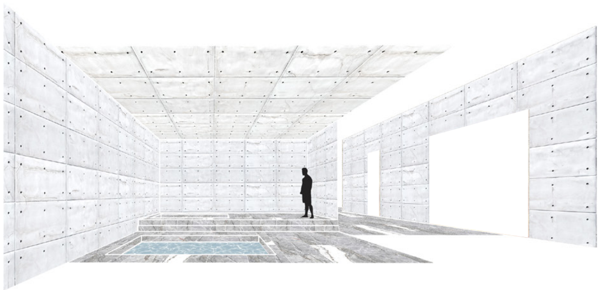
d | Room 2 | Brick(variation), Stone(White)



b | Room 1 | Wood(warm, soft), Concrete(smooth), Brick(patterning)



e | Room 2 | Stone(textured, dark, rough, nature), Stone(White)



c | Room 1 | Concrete (site-cast)

Fig. 125. Atmosphere and materials

APPENDIX V: DAYLIGHT, WINDOWS, MATERIALS - ANALYSIS SPACE

A study of visual alliesthesia considers atmosphere and amount of daylight in relation to different materiality, orientation, and configurations of windows. The various constellations vary from black slate to concrete, single room height to double room height. The visualisations demonstrate different placements and sizes of the investigation windows. For every constellation, a test is made for the window facing north, east, west, and south.

SKYLIGHTS

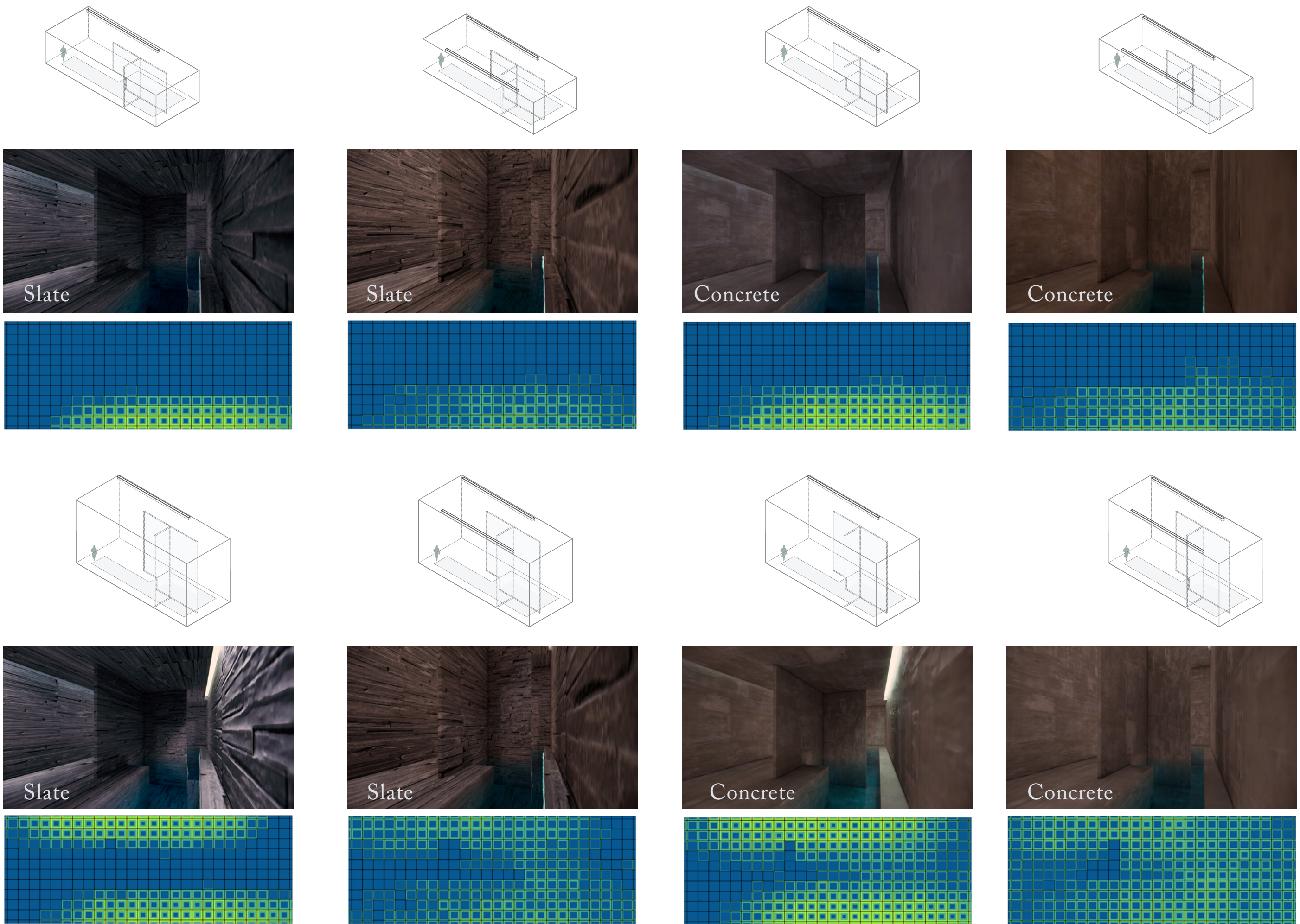


Fig. 126. Daylight | Skylights

The windows with north orientation

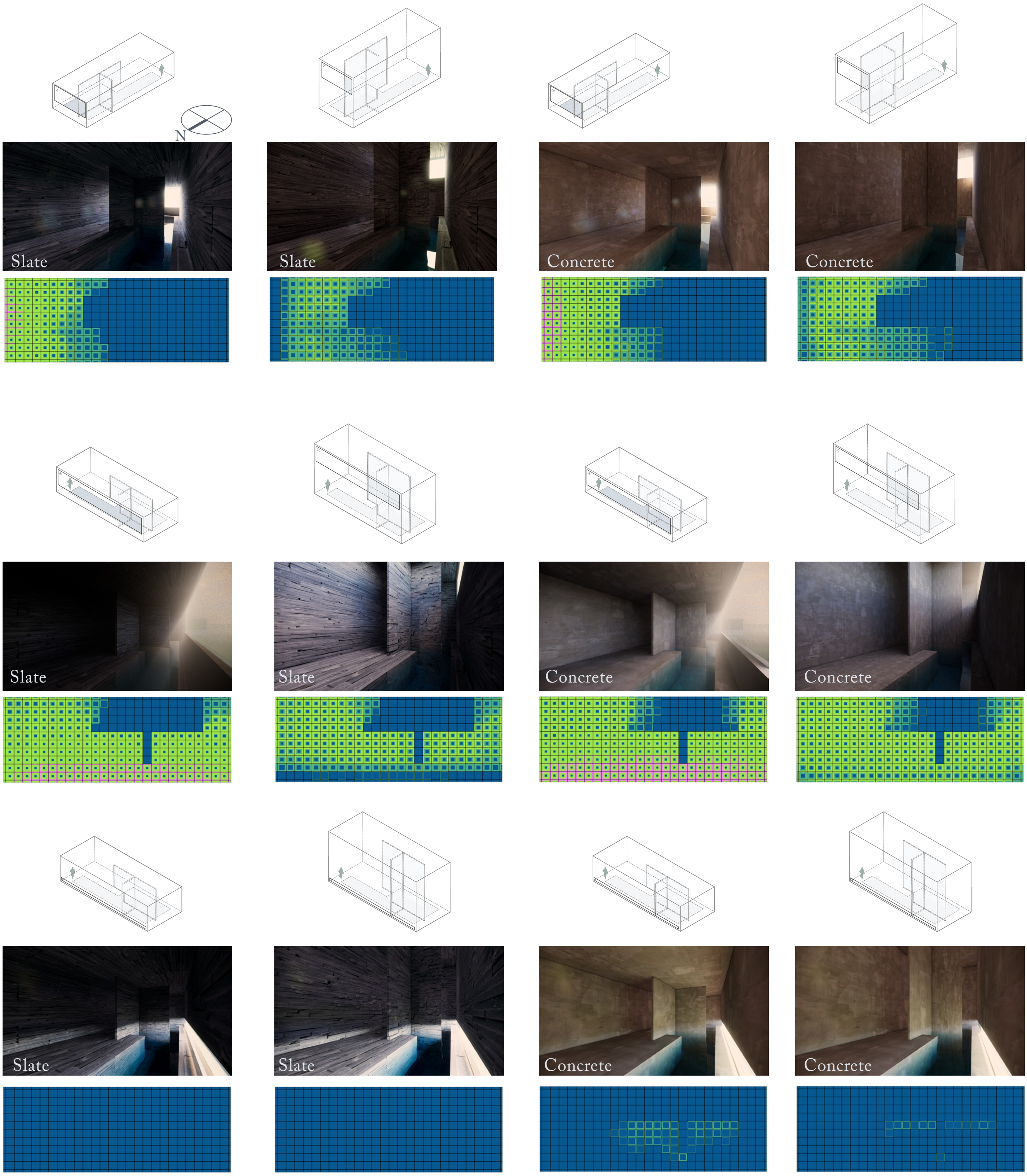


Fig. 127. Daylight | Orientation | North

The windows with west orientation

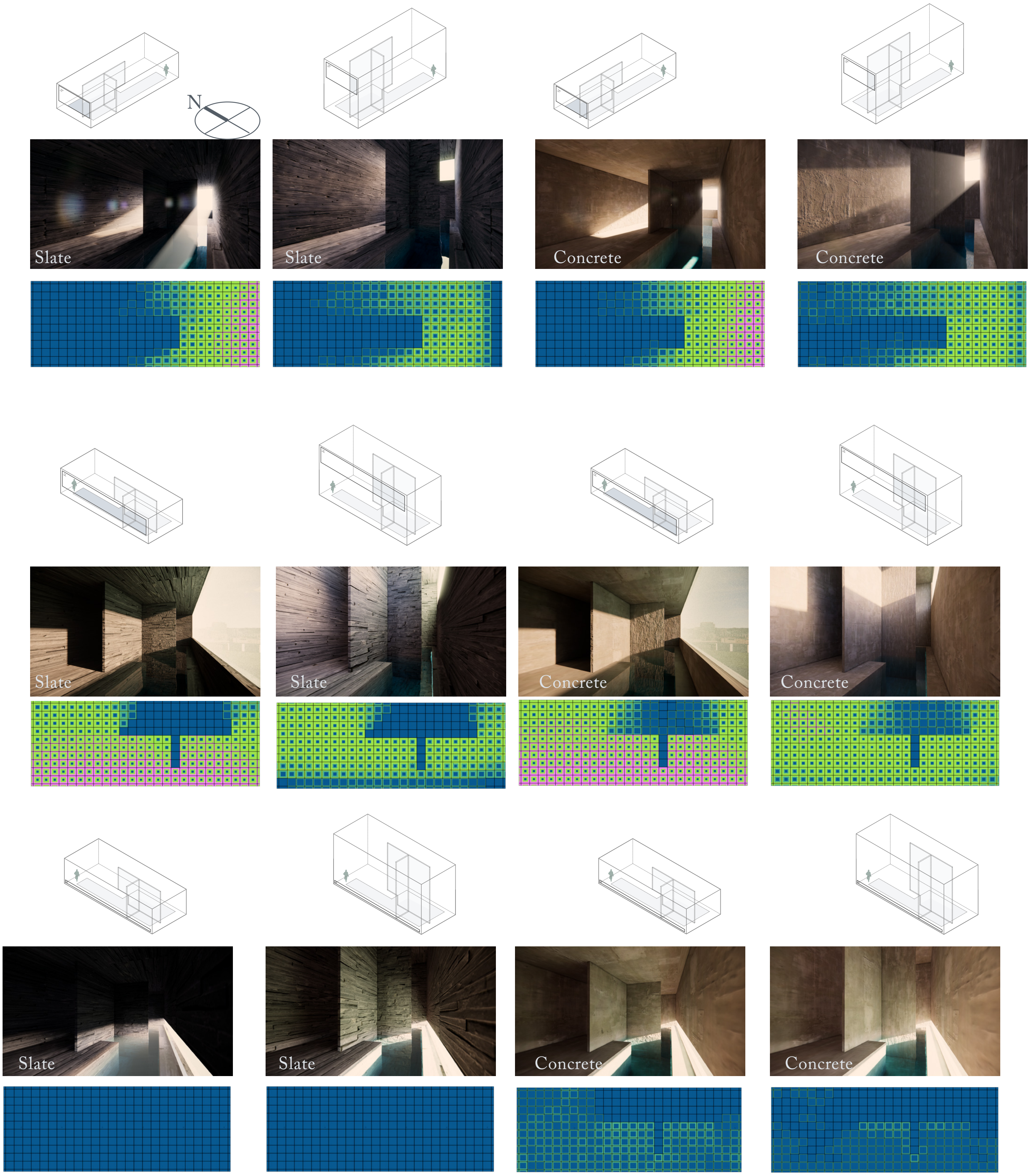


Fig. 128. Daylight | Orientation | West

The windows with south orientation

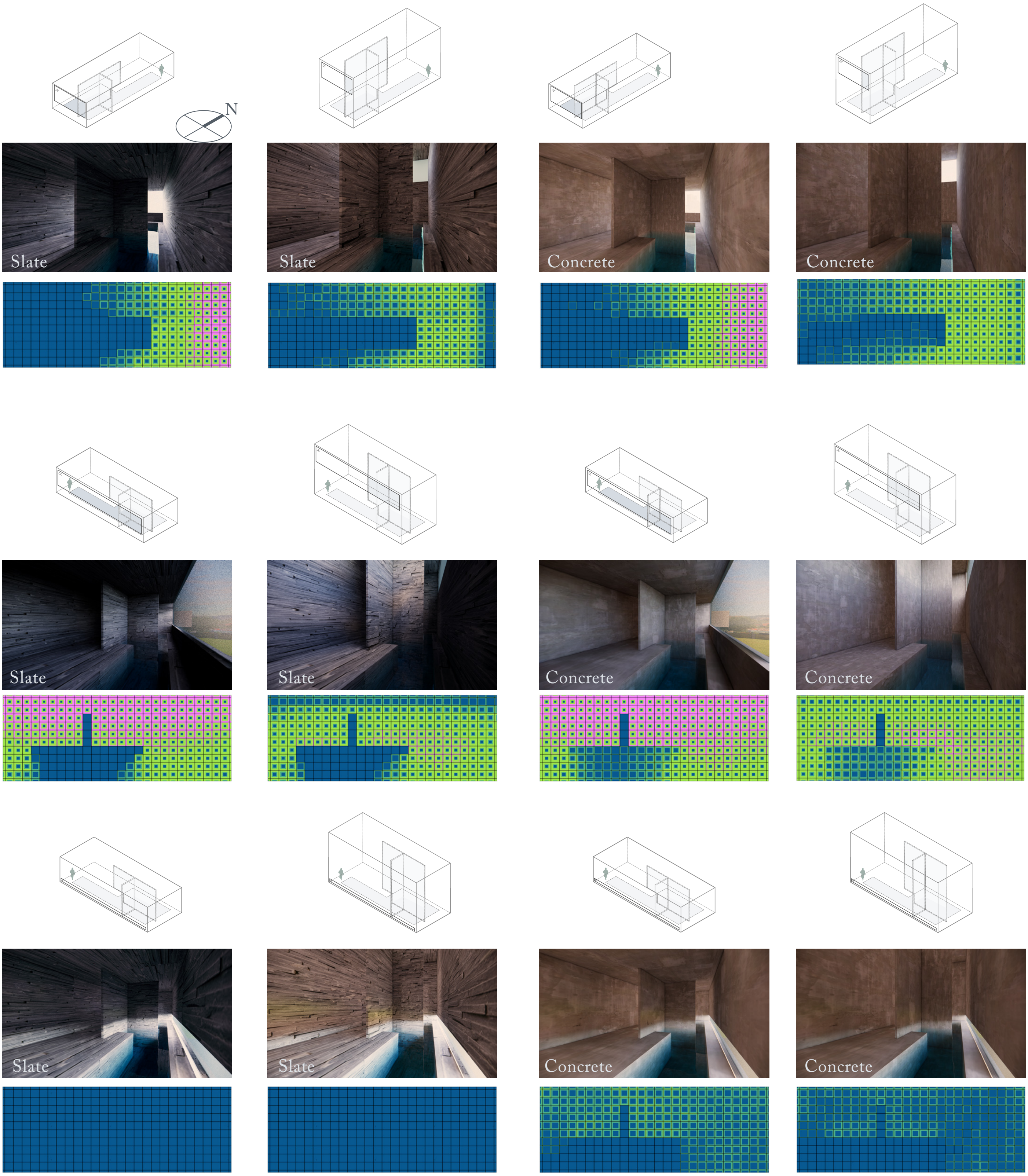


Fig. 129. Daylight | Orientation | South

The windows with east orientation

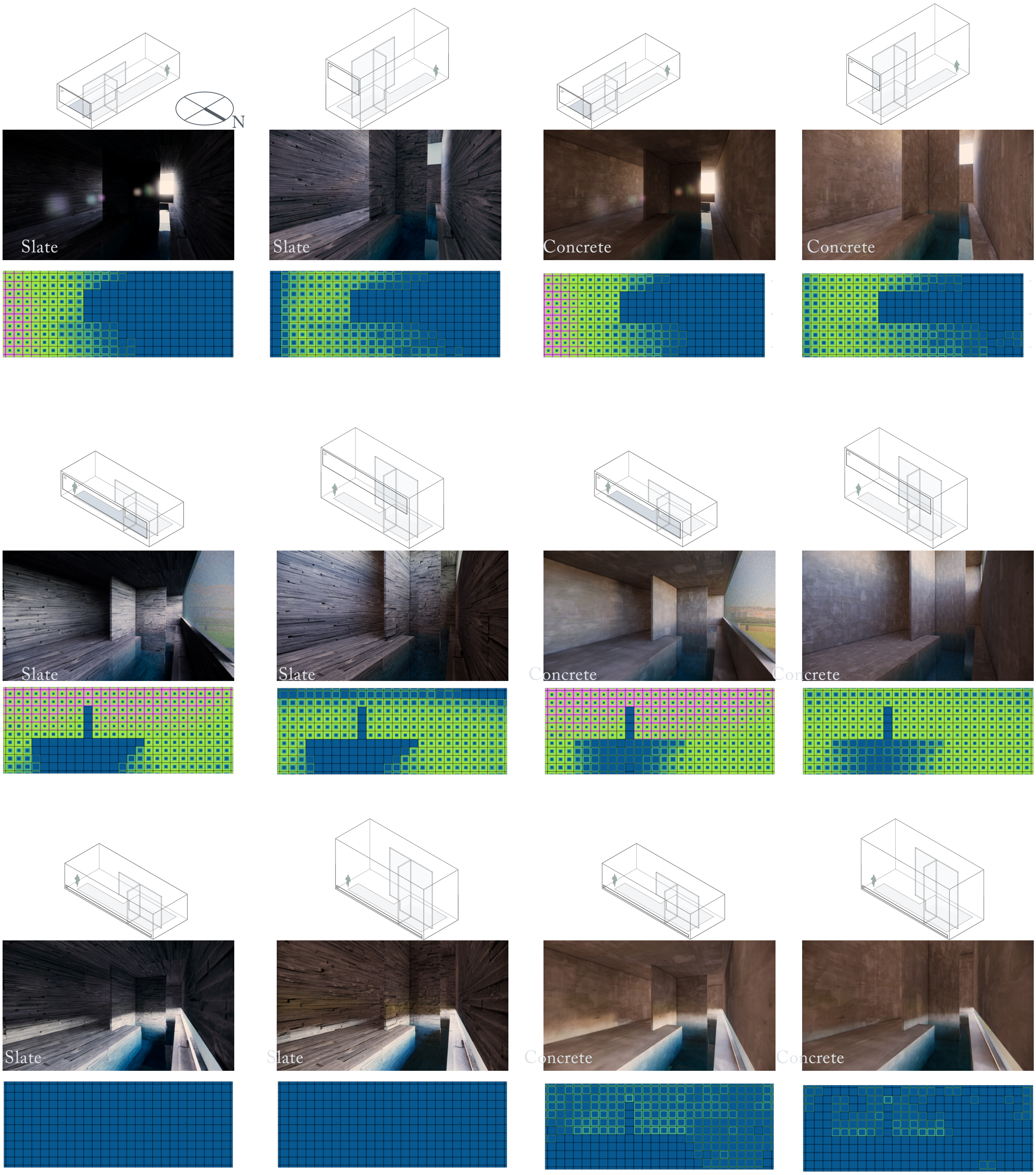


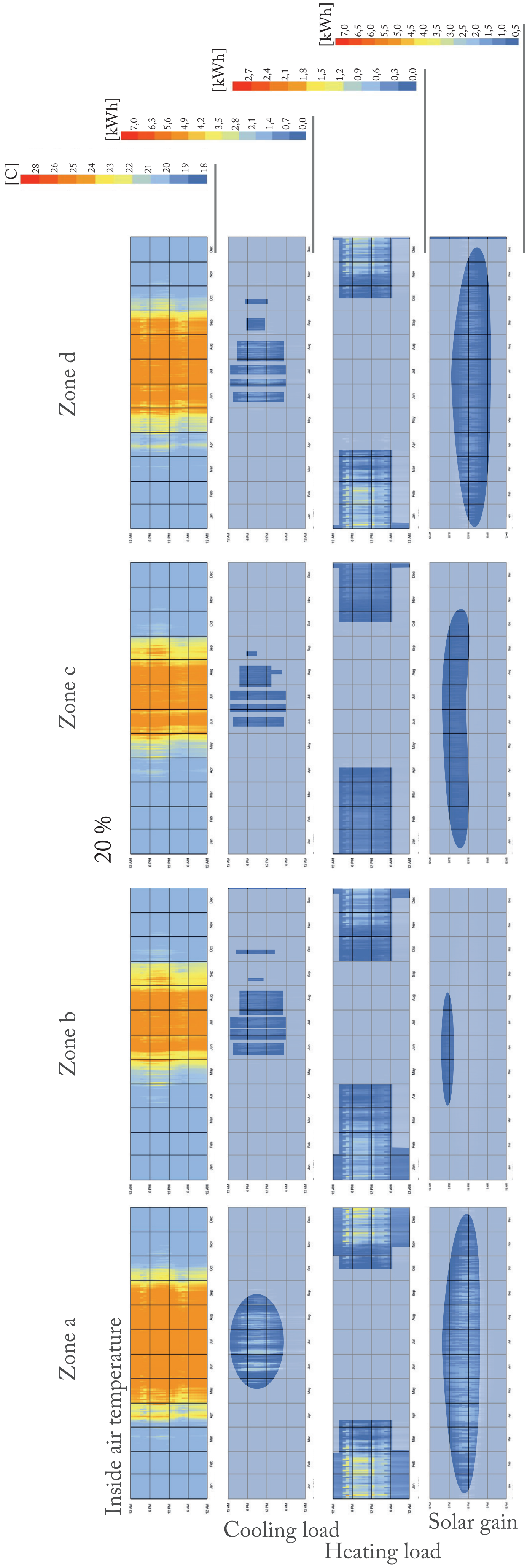
Fig. 130. Daylight | Orientation | East

APPENDIX VI: ENERGY - WINDOWS

Initial investigations of the windows state whether the window area should aim to be minimised or enlarged. Therefore, a study of the wall-window ratio of 20%, 40%, 60%, and 80% generated in Rhino/grasshopper and Honeybee set some guidelines for the window design. The heatmaps visualises the impact from the various sizes according to what zone they are placed in.

Zones with high heating and cooling demands require smaller windows, unlike a situation with much heating but no cooling, which requires big windows. From this initial study, the windows are placed in different constellations throughout the design process.

In the concept of carving, an overhang does not follow the narrative, to which it is not simulated. Instead, the frame placement in the wall becomes interesting to investigate.



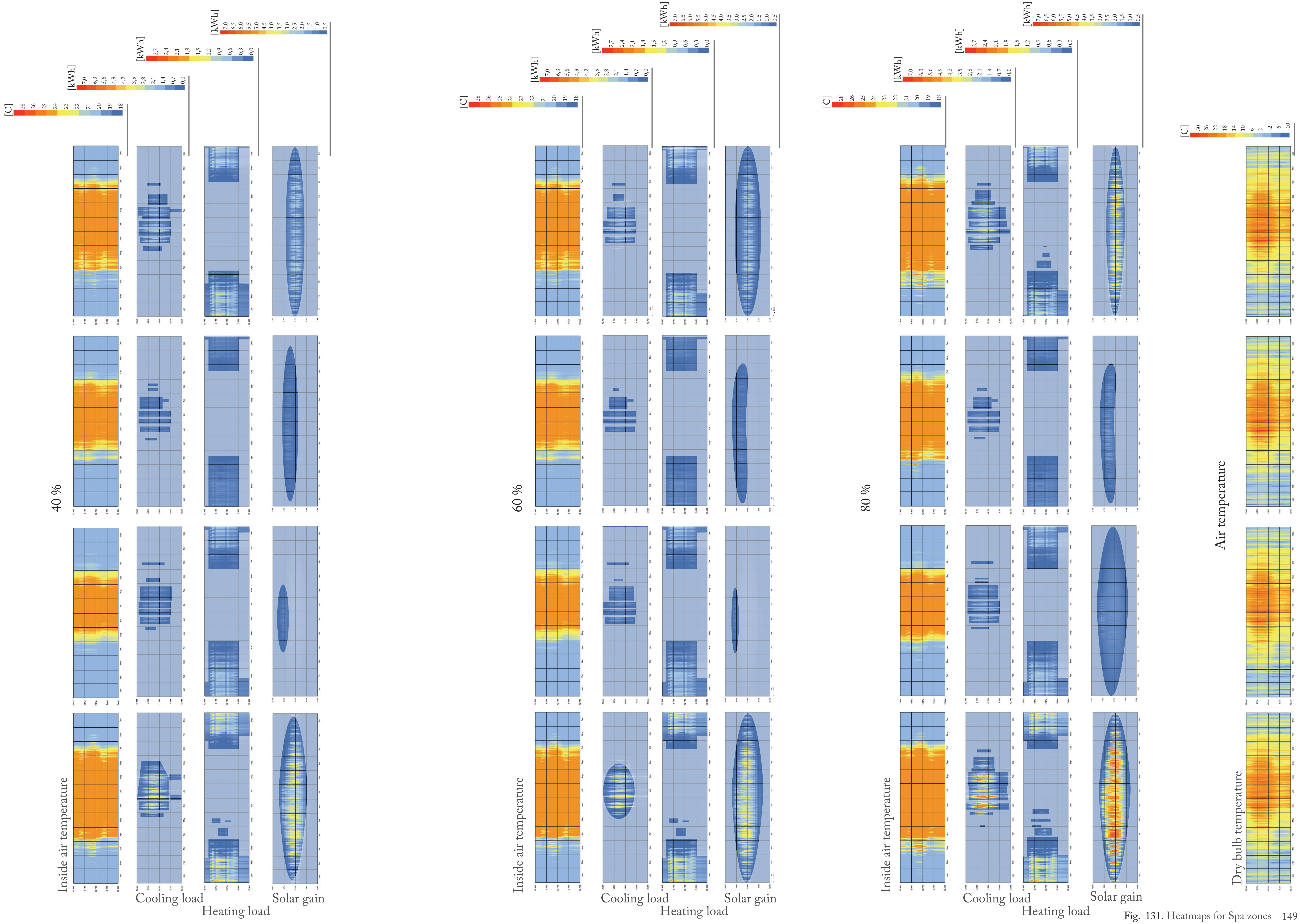
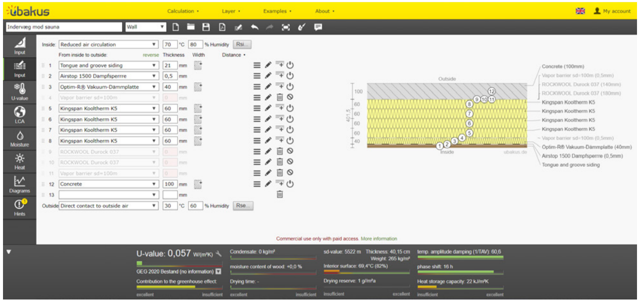


Fig. 131. Heatmaps for Spa zones

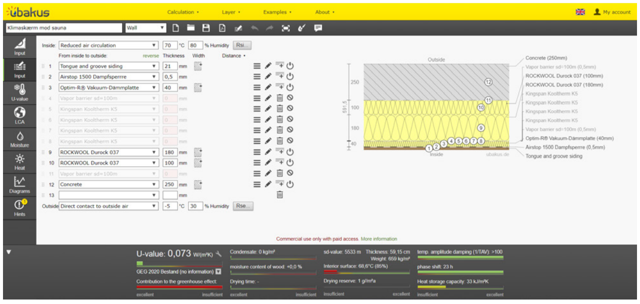
APPENDIX VII: ENERGY UBAKUS

Ubakus investigations demonstrate the U-values and condensation risks of different compositions because of the significant differences in temperature and humidity in several rooms. A vapour barrier is needed to avoid condensation inside the construction.

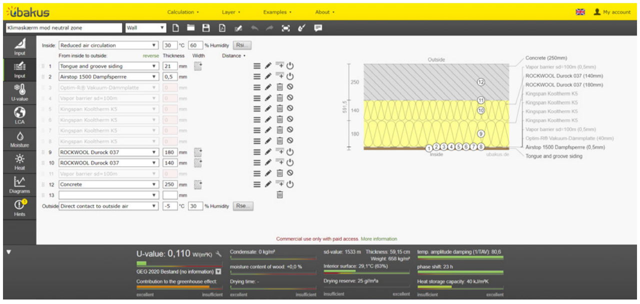
Tests of Kingspan, Kingspan Vacuum panels, Rockwool 37, mineral wool 34 state that more than one solution is needed concerning the functions. The saunas are the most critical.



a | Wall investigations | Innerwall sauna

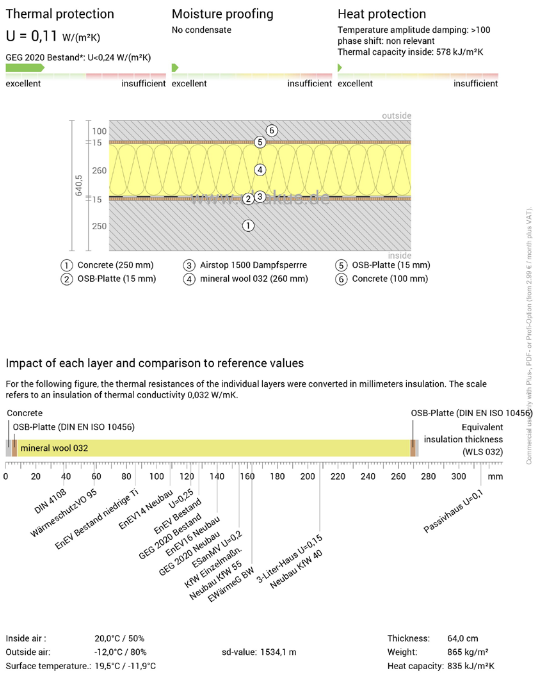


b | Wall investigations | Envelope sauna

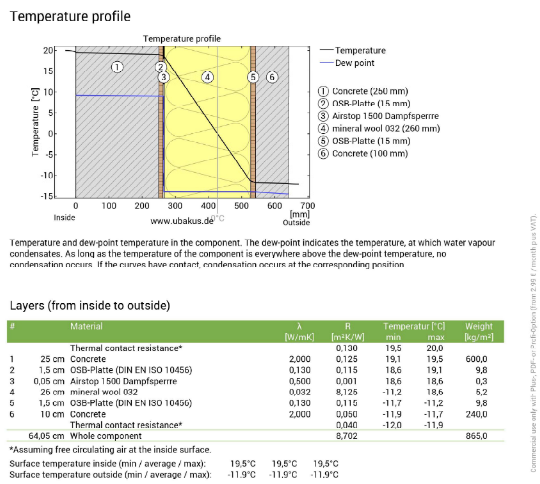


c | Wall investigations | Envelope to neutral zone

Fig. 132. Wall investigations | Ubakus



a | Wall investigations | Thermal protection



Temperature profile

Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

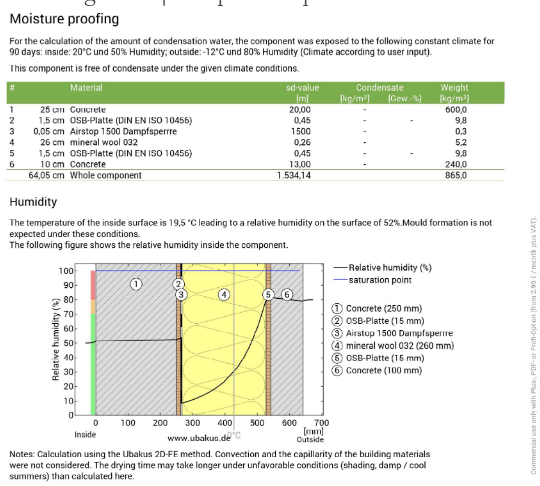
#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,5	20,0	
1	25 cm	Concrete	2,000	0,125	19,1	19,5	600,0
2	1,5 cm	OSB-Platte (DIN EN ISO 10456)	0,130	0,115	18,6	19,1	9,8
3	0,05 cm	Airstop 1500 Dampfsperrre	0,500	0,001	18,6	18,6	0,3
4	26 cm	mineral wool 032	0,032	8,125	-11,2	18,6	5,2
5	1,5 cm	OSB-Platte (DIN EN ISO 10456)	0,130	0,115	-11,7	-11,2	9,8
6	10 cm	Concrete	2,000	0,050	-11,9	-11,7	240,0
		Thermal contact resistance*		0,040	-12,0	-11,9	
	64,05 cm	Whole component		8,702			865,0

*Assuming free circulating air at the inside surface.

Surface temperature inside (min / average / max): 19,5°C 19,5°C 19,5°C

Surface temperature outside (min / average / max): -11,9°C -11,9°C -11,9°C

b | Wall investigations | Temperature profile



Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: -12°C und 80% Humidity (Climate according to user input).

This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	25 cm	Concrete	20,00	-		600,0
2	1,5 cm	OSB-Platte (DIN EN ISO 10456)	0,45	-	-	9,8
3	0,05 cm	Airstop 1500 Dampfsperrre	1500	-		0,3
4	26 cm	mineral wool 032	0,26	-		5,2
5	1,5 cm	OSB-Platte (DIN EN ISO 10456)	0,45	-	-	9,8
6	10 cm	Concrete	13,00	-		240,0
	64,05 cm	Whole component	1.534,14			865,0

Humidity

The temperature of the inside surface is 19,5 °C leading to a relative humidity on the surface of 52%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.

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

c | Wall investigations | Moisture Proofing

Fig. 133. Wall investigations | Ubakus

The expanded investigation of visual alliesthesia is made for June, September, and December to discover the seasonal differences. The false-colour render indicates that the ratio will be possible all year but in different intensities.

The low lux level in the dark space results in extreme ratios in December since entering a bright room. However, if increasing the lux level in the dark area with supplementing artificial light, the ratio will be controllable.

a1 | Closed door | 21/06
b1 | Small window | 21/06
a2 | Closed door | 21/09
b2 | Small window | 21/09
a3 | Closed door | 21/12
b3 | Small window | 21/12

$$(b_x):Lr = \frac{E_{x,\,max}}{E_{x,\,min}} = \frac{b_{x,\,average,\,window}}{a_{x,\,average}}$$

$$(c_x):Lr = \frac{E_{x,\,max}}{E_{x,\,min}} = \frac{c_{x,\,average,\,window}}{a_{x,\,average}}$$

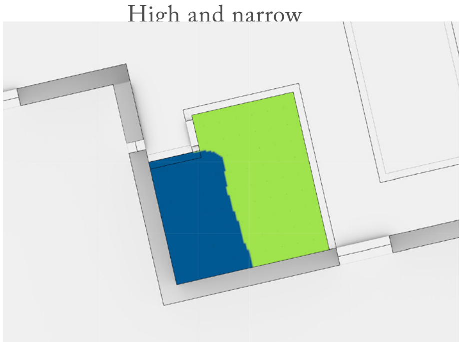
$$(d_x):Lr = \frac{E_{x,\,max}}{E_{x,\,min}} = \frac{d_{x,\,average,\,window}}{a_{x,\,average}}$$

Fig. 134. Formular for Lr

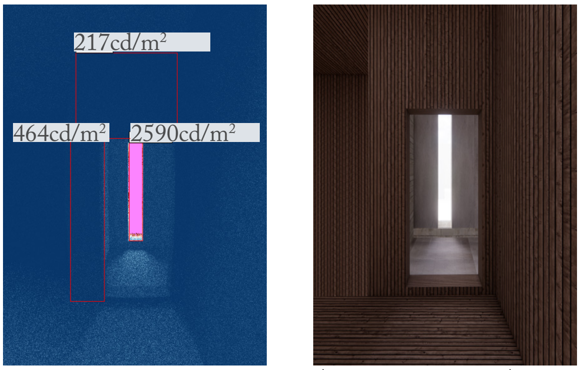
$Lr = \frac{E_{max}}{E_{min}}$	Closed door (a)	Small window (b)	High and narrow (c)	Whole wall (d)
21/06	N/A	21.201	22.473	24.711
21/09	N/A	14.291	15.114	16.069
21/12	N/A	1093.040	1299.716	1269.886

Table. 15. Contrast ratios

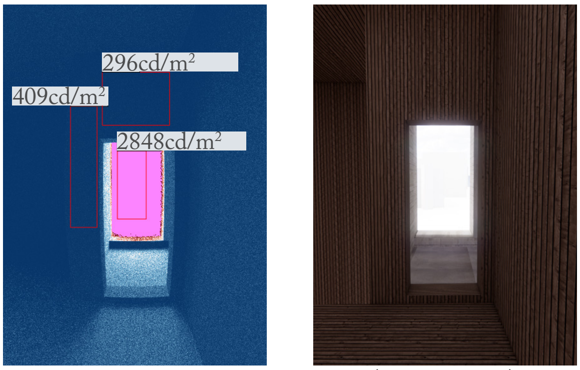
High and narrow



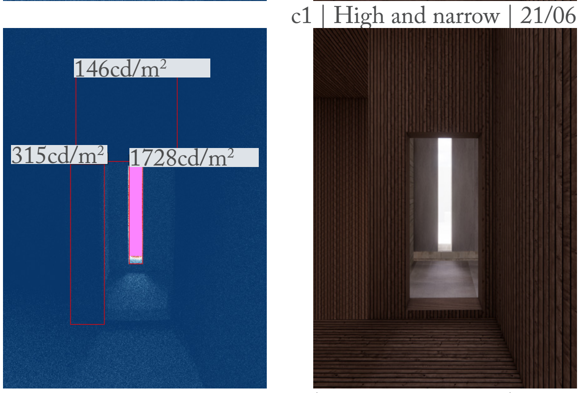
Whole wall



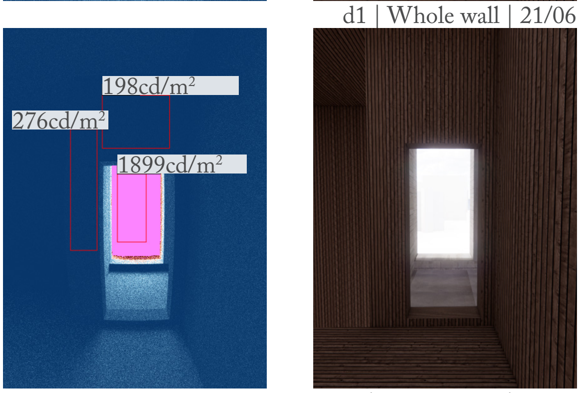
c1 | High and narrow | 21/06



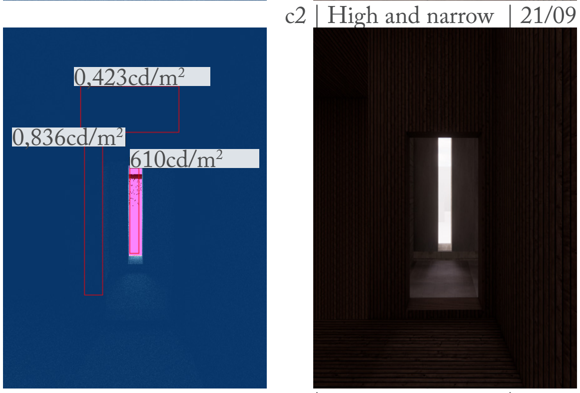
d1 | Whole wall | 21/06



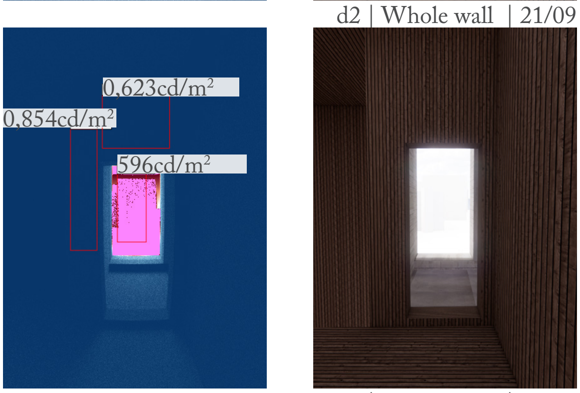
c2 | High and narrow | 21/09



d2 | Whole wall | 21/09



c3 | High and narrow | 21/12



d3 | Whole wall | 21/12

Fig. 135. Visual alliesthesia investigation

APPENDIX IX: POOL ROBOT

In an investigation in Robot, the site-cast pool slab is based on the bending moment. The assumptions for the study concern the material properties of concrete (C30/C35), a roughly estimated dead load of water, and live load of people passing by next to the pool.

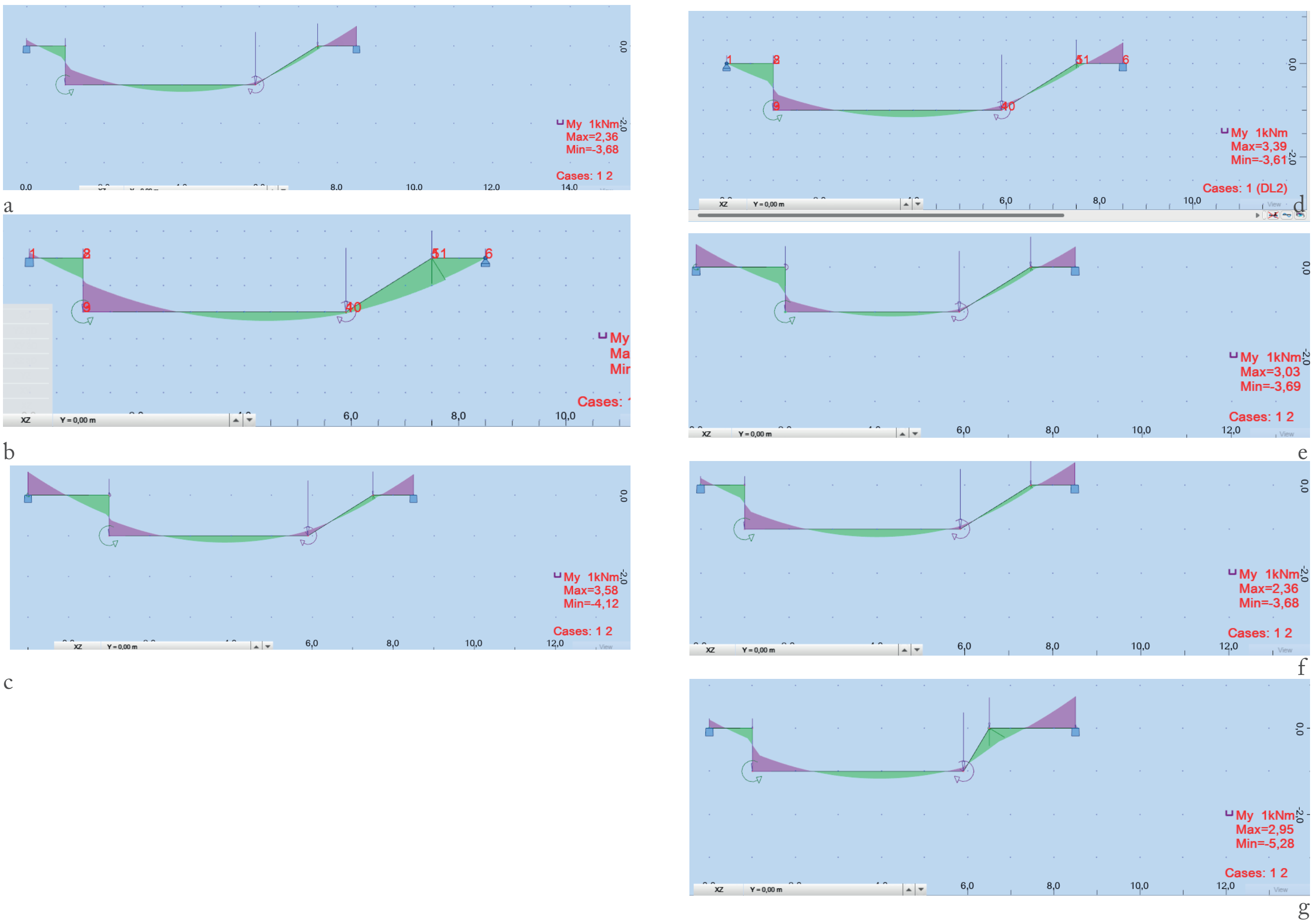


Fig. 136. Robot investigations | a - g

APPENDIX X: RADIATION

A radiation analysis shows the number of sunlight hours on the Pier and Spa House. Here the urban park has multiple sunlit spaces throughout the day and seasons. Furthermore, the facades receive a great amount of radiation, which creates bright interior spaces. Direct sunlight affects the transient atmospheres of the different indoor environments throughout the day and year.

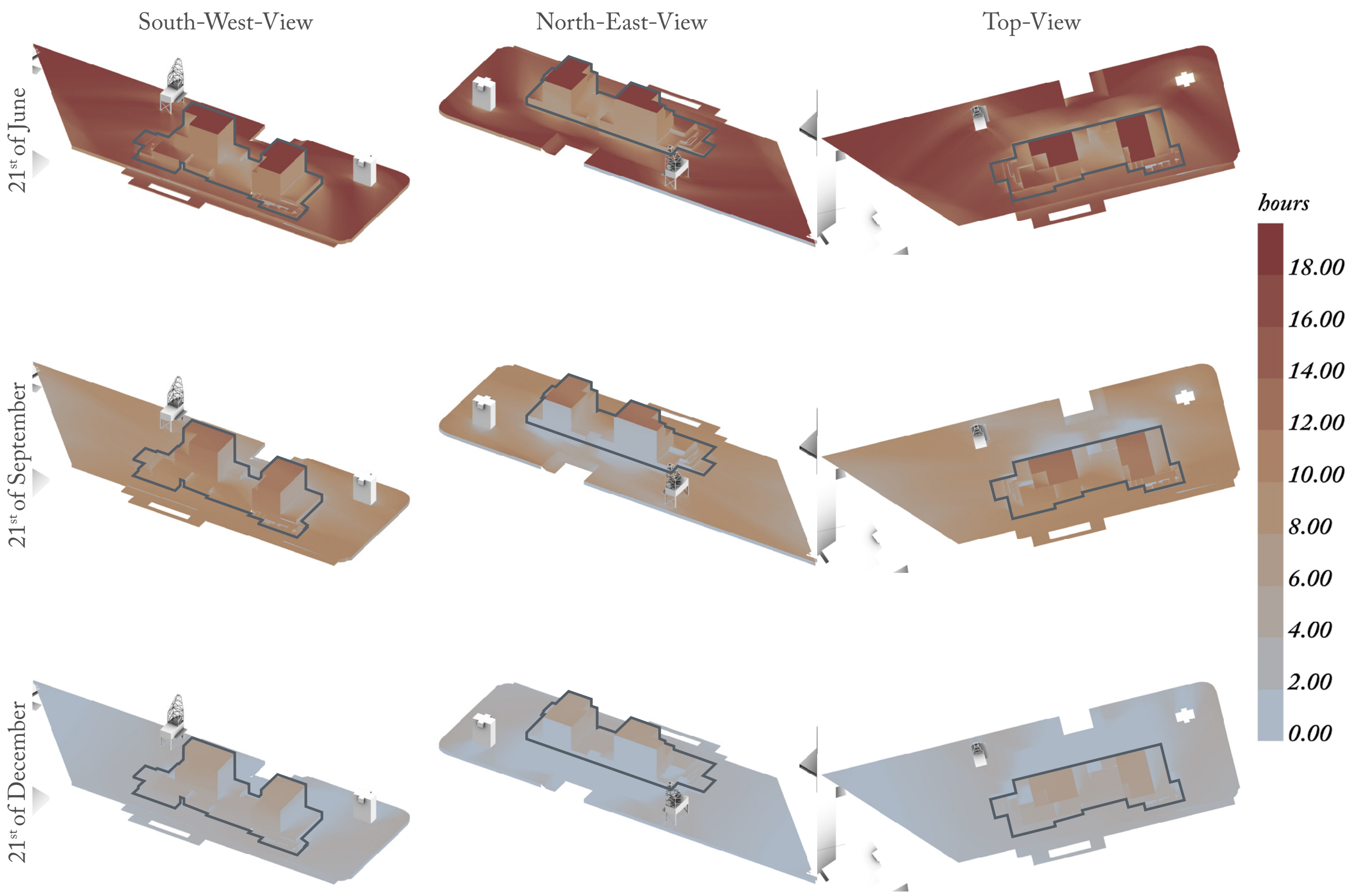


Fig. 137. Radiation mapping

ILLUSTRATIONS

Fig. 116, psychrometric chart, screenshot from Climate Consultants:
UCLA Energy Design Tools Group. n.d. Climate Consultant 6.0 (version 6.0). English. The University of California.

Fig. 118, shading, , screenshot from Climate Consultants:

UCLA Energy Design Tools Group. n.d. Climate Consultant 6.0 (version 6.0). English. The University of California.

Fig. 132 -133, Ubakus, screenshot from Ubakus:
U-value calculator | ubakus.com (n.d.). Available at: https://www.ubakus.com/en/r-value-calculator/ (Accessed: 23 May 2022).