Ariake Arena / 有明アリーナ

Booklet / ブックレット

Group 19 - MSc04 - ARC / グループ19 - マスター - 建築

Ill. 1: Render of structure

Abstract

This thesis describes to development and design of a new Olympic Volleyball Arena. Revolving around the forthcoming Olympic games in Tokyo 2020, this thesis seeks to discuss, and give a solution to how to design large scale sport architecture in the ambiance of the Olympic games as well as in a local context.

The Ariake Arena will during the Olympic games host indoor volleyball and basketball for the Paralympics. After the games, it will still be used for national and international Volleyball matches, and will also function as a local gymnasium.

To challenge the general typology and aesthetic of sport architecture, the project is rooted in the traditional tectonic theory of Gottfried Semper. Using Sempers elements of architecture as an understanding of architecture, has led to a design with a clear distinction between the elements, which in relation to each other create a functional architecture.

The new Ariake Arena will be a recreational hotspot for the Ariake area, offering a waterfront, park areas, shops, a local gymnasium and centrally a main hall capable of hosting 15.000 spectators.

Title

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Main supervisor:
Claus Kristensen
Architect MAA
Associate Professor

Technical supervisor:
Dario Parigi
Associate Professor

Frederik Peter Kæmsgaard

Morten Lydiksen

Reader's guide

This booklet consists of first an introduction to the project and afterwards a total of five chapters.

The introduction includes formalia and an introduction to the project theme and initiating problem. The first chapter of the booklet contains the methodology used for the project. Second chapter contains all relevant analysis and some preliminary studies, which created the foundation for the design process and further work with the project. Third chapter is the design process, which thoroughly through xx phases explains how the project design has developed. Fourth chapter is the presentation of the final design including visualizations, drawings, diagrams and texts. Lastly the fifth chapter contains an overall conclusion and reflection on the project and process. Following this, an appendix and afterwards references and illustrations list are found.

All referencing to literature is done according to the Harvard method. Attached to the booklet there is a drawing folder containing presentation drawings in larger formats.

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Introduction

This thesis seeks to address the challenges of large-scale sport events, as the Olympics, where weeklong events demands new venues, housing, infrastructure etc. to host athletes and millions of spectators.

Being one of the world's biggest sporting events, the Olympic games is known to draw people together from all over the world to celebrate the human spirit. The games can provide a unique opportunity for host cities to capture attention from around the world, deliver positive change to the community and the given city's reputation.

Throughout history as well as today many new buildings and areas has been erected for the sake of the Olympics, always being a large investment economic, social as well as environmental for the host cities. Unfortunately, in many cases the overall planning of new Olympic venues and urban areas has failed to ensure a sustainable legacy and lacks integration with nearby neighborhoods and post-game users, resulting in empty and abandoned venues which never has succeeded to become a successful part of the city fabric.

Revolving around the forthcoming Olympic games in Tokyo 2020 this thesis seeks to discuss, and give a solution to these issues by addressing the overall planning of new stadiums and then afterwards to design one of the future Tokyo venues, the Ariake Arena, which during the Olympic games will host indoor volleyball and basketball for the Paralympics.

Under the Olympics, Ariake Arena will be home to extraordinary achievements and not only to Japanese traditions, but be an international stadium for all cultures present at the games. The stadium is decided to host up to 15,000 spectators and after the games being transformed into a public gymnasium.

To design a sustainable stadium the venue should not only be seen in the two-week span of the Olympics, but also in the span of its post-game function, where its function and architecture should inspire the local community, reflect its environment and context of a Tokyo neighborhood.

Rooted in the integrated design process (IDP) as primary methodology the thesis will through a holistic approach combine different tools of architecture, planning and engineering. The thesis will develop from analysis of earlier Olympics games and Japanese architecture and culture in both a more historical as present context. The project will use and discuss tectonics in the ambient of Japanese building culture and tradition, as well as focus on the social aspects of sport architecture and how to ensure this when planning and building new stadiums.

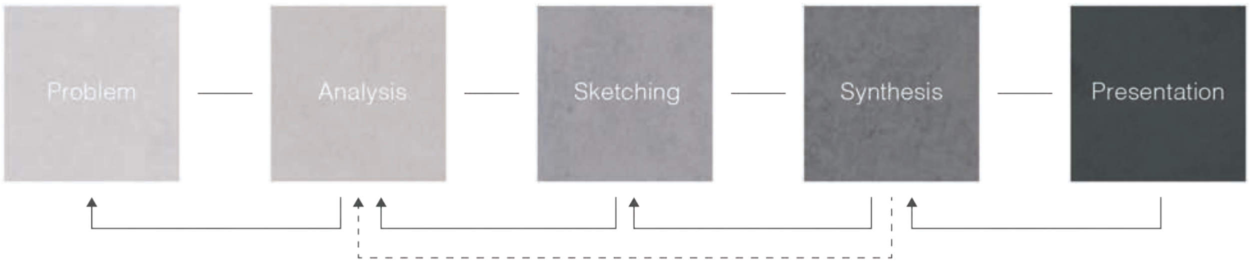
Ill. 2: Japan to Tokyo

01

Methodology

方法論

The first chapter of this booklet presents the overall methodology which will be applied in the project. The chapter consist of first the fundamental approach of the project being the integrated design process and afterwards a tectonic discussion leading to the tectonic approach of the project.



Ill. 3: Integrated design process

Integrated Design Process

As the fundamental approach of this project the integrated design process (IDP) has been incorporated in the problem based learning method, to ensure a holistic approach combining both architectural and engineering tools as equal parameters throughout the project. Competencies from both professions was from the very beginning of the project implemented and executed through the didactic learning model (PBL), concerning group work and realistic problems. (Knudstrup, 2004)

The approach secures that both disciplines was a part of the project and included in every phase of the integrated design process. The phases are described in the following.

Problem
The first phase of the integrated design process (IDP) is about formulating and defining the problem and/or idea for the project. For this project, the initial idea was developed around the forthcoming summer Olympics in Tokyo 2020, where several new stadiums now are being designed and built. Throughout and in recent years, where a larger focus on sustainability is present, there is always discussions about how to make large scale architecture and most important how to secure either a future use or easy dismantling and transformation into something else. These discussions initiated the work of this thesis.

Analysis
The second phase is about sourcing and analysing all material necessary for beginning the design process. This could be mappings, various site-analysis, climatic considerations, technical requirements and local plan or city strategies for the given site. In this case, it was central to define a program and demands for the arena, because not all of the actual material for the Ariake Arena was public. Because of the site being far away, it was important through mappings, site analysis and digital tools to understand the site and context. At the same time, it was important to start understanding and analysing sport architecture in a general manner, but also to understand the Olympics and learn from

previous events. This phase led to a vision and a program which was central for the next phases.

Sketching
In the third phase of the integrated design process, the professional knowledge and competencies of architects and engineers are combined and used simultaneously in order to accommodate the demands of the project. Different tools and medias was used. In this early phases analog methods as sketching and physical models were important, but quickly computational modelling was begun and parametric tools were important to generate geometries on the basis on functional demands. This was due to the scale of the arena, but also quite clear demands to seating, sight, size of competitions area etc., made it quicker to work digital. Technical tools as acoustical simulation software Pachyderm and final element modelling software Robot Structural Analysis, was early included to verify and work simultaneously with sketching, modelling and designing of the arena.

Synthesis
In the synthesis phase the building finds its final form according the problem, analysis and design criteria from previously phases. For the arena, an architectural and structural concept was created at the midterm review, and this became central for the early synthesis phases and rest of the design process.
The final detailing of architectural, functional and technical parameters clarified how to finalize and conduct the concept into a building design.

Presentation
In the last phase of the integrated design process all previous phases and final building design thoroughly described and illustrated.
(Knudstrup, 2004)

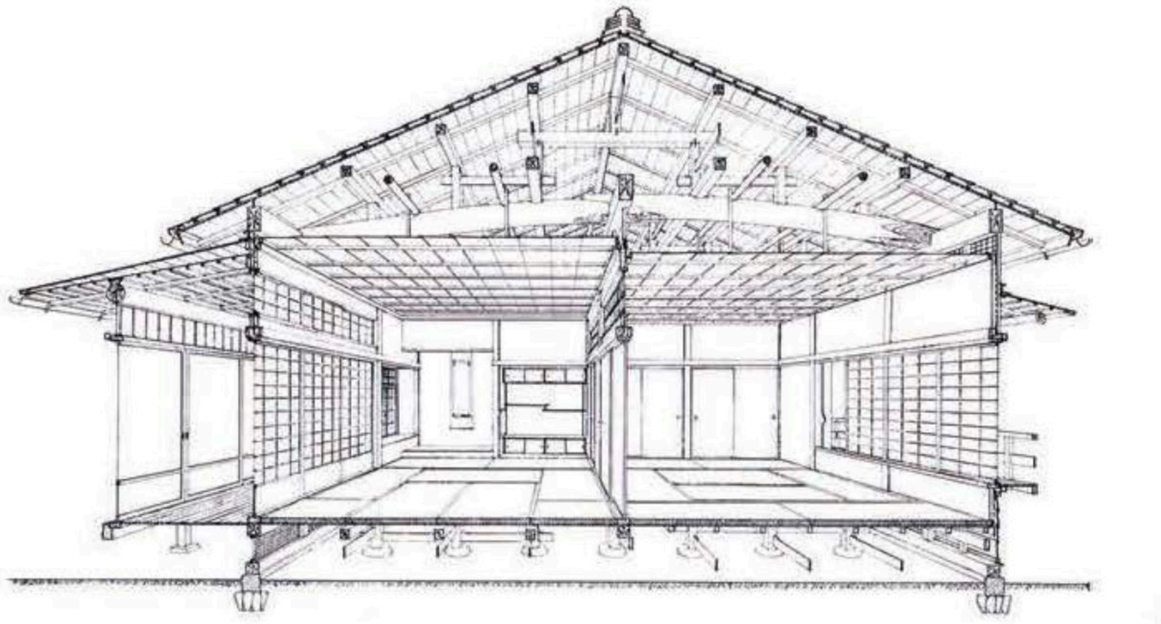
Tectonic approach

How to approach the designing of sport and stadium architecture? The vast scale of such a building typology, might demand another understanding of tectonics? First step should be to decide a tectonic approach and perception of architecture in order to develop a coherent design. But where to start?

To understand the basic elements of architecture, one could start with German architect and theorist Gottfried Semper. Semper is well-known for his work and search of understanding the origins of architecture. In his work Semper theorized a universal understanding of architecture based on an anthropologian view and analysis of the elements of indigenous primitive structures. Based on these findings Semper distilled the four elements of architecture, present in all buildings despite of typology and style; The earthwork, the hearth, the framework/roof and the lightweight enclosing membrane. (Frampton, 1995)

The first element is the “Earthwork”, which can be described as the mount or foundation on which the structure lies. The second element is the “Hearth”, which Semper describes as the sacred focus around which the building took form and shape. The third element is “The framework/roof” that be the structure from which the space is created. The last element is the lightweight enclosing membrane, which from ancient time should be just a fabric, and according to semper only when needing extra functions, something else. (Frampton, 1995)
On the basis on these four elements, Semper used a further classification for the building craft into the tectonics of the frame and the stereotomics of the earthwork. This creates a distinction between lightweight structures in wood from heavyweight structure built of stone, or in today reinforced concrete and emphasize a difference between these two in a tectonic sense. (Frampton, 1995)

In the theory of Semper there is no difference in the general elements of architecture in terms of where it’s from. The universality of these “rules” makes it an understanding applicable everywhere in the world. Central for both the theory of Semper as well



Ill. 4: Section of traditional japanese house

as later architects practising a tectonic approach which can be seen as an extension of Semper, have been inspired by other cultures than necessarily only their own. For instance, if one should understand Semper according to Japanese architecture, he used the traditional Japanese house as object for his theory and quite clearly the four elements can be identified in that construct. The house on ill. 4 displays this. Standing on foundation pillows, the earthwork. With its large roof, the framework, creating shelter and lastly with the light sliding doors, the enclosing membrane, layering the building with thin fabrics. All traditional Japanese is based on the system of the Tatami mat, which act as flooring and a multifunctional piece of furniture. A tatami mat measures approximately 90 x 180 centimetres, and from small houses to large temples, this modular size is used.

One could suggest a parallel between the systematization of the four elements of Semper, and the traditional elements of Japanese architecture, seen both in religious as well as domestic architecture. This clear functionality and place for the different elements shrive for simplicity and honesty in architecture and its aesthetic language.

This project bounds in a tectonic perception of dividing and staging the different elements of a building. Hereby, the elements which are connected structurally and in terms of functionality will be seen as one, while other elements will be seen as another. Such an approach should simplify the architectural language and make a building easier to perceive.

Japanese building culture

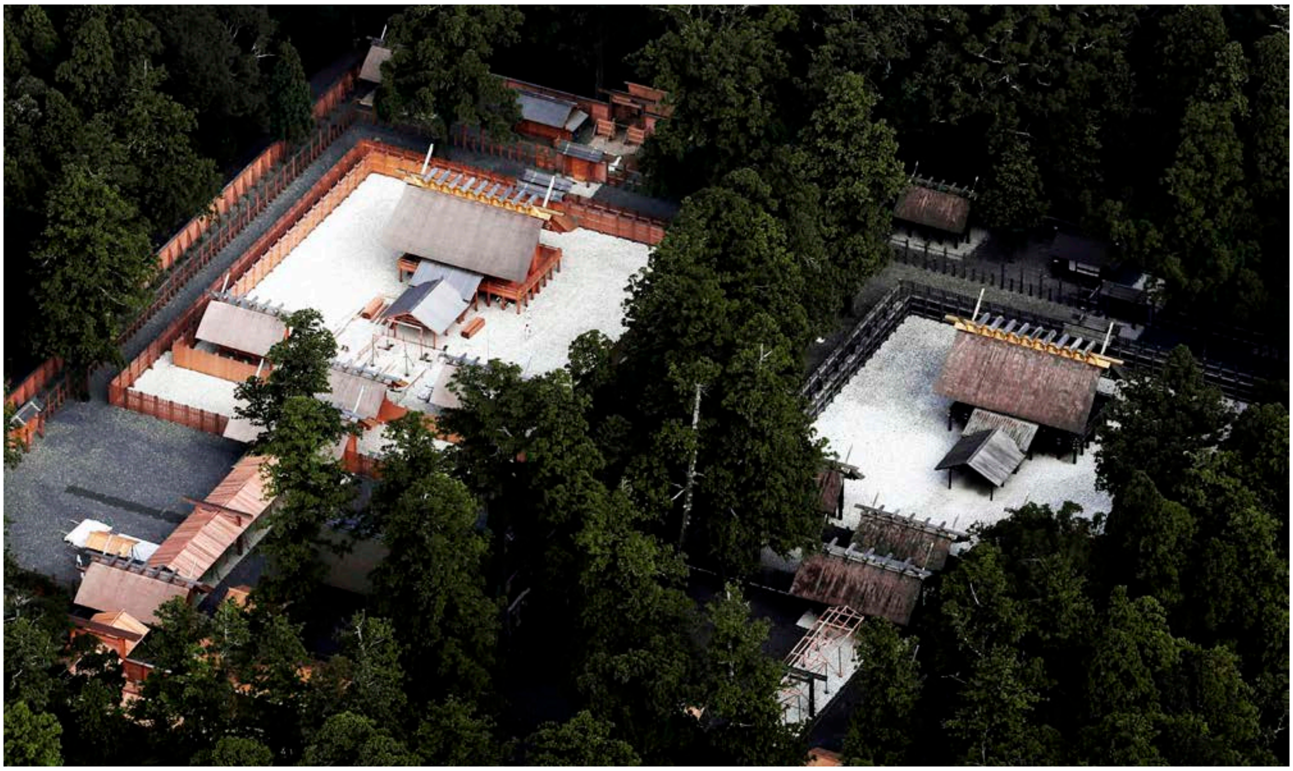
If one looks beyond the international and cross-national event of the Summer Olympics, the Ariake Arena will be built in a Japanese city in a Japanese cultural context. The “Semperian” elements of architecture are easily translatable in Japanese buildings, but how does Japanese people understand and relate to design and buildings?

To continue from the previous text on tectonics, Semper also tried to distinguish his theory according to culture and context of the building. Semper’s theory on tectonics was rooted in the science of ethnography, and in this context, the circular life perception of Japan, as seen in Buddhism, leaves a different perception of buildings. Kenneth Frampton states in his book on studies in tectonic culture; *“Japanese building and place-making practices seem to have been interconnected throughout history. Thus, to a greater degree perhaps than in other cultures, metalinguistic forms and spatio-temporal rhythms are bound up with the act of building in Japan. That this culture is quite literally woven throughout is further substantiated by the dovetailing interrelationship of every conceivable element in the traditional Japanese house, from the standard tatami mat of woven rice straw construction to the kyo-ma and inka-ma method of modular building.”* (Frampton, 1995)

This perception of impermanence is further elaborated and argued in the article ”Makeshift: Some reflections on Japanese design sensibility”, by Sarah Chaplin. She argues through the notion of Makeshift, that in Japanese culture *”…things are never fully designed, but are always in a state of being designed”*. (Chaplin, 2005)

From observations in architecture, literature, diet, product design, graphics and urbanism Chaplin draws a connection through these different subjects to the idea and embracement of the impermanent and the makeshift, in Japanese culture.

An example on this is the Shinto temple at Ise in Japan (see ill. 5) which every 20 year is reconstructed, displaying the Japanese tradition of venerating the sacredness of the site whether of the built, which usually is the case in Western society. Furthermore, this ritual rebuilding of the temple means that every time it is rebuilt minor differences in term of wood



Ill. 5: Shinto shrine of Ise

use, techniques and maybe minor details occur, which make and change the temple every 20 year. One could say the temple is always *"in the state of being designed."*
Also, the history of Japan has acquired a dynamic, fluid and impermanent people, where first of all the nature of Japan offering strong seismic powers as well as the many fires which devastated cities in close intervals. This adaption to those realities can be seen in the traditional Japanese houses which through simple wood structures, quickly could be rebuilt. (Chaplin, 2005)

In a more contemporary context Chaplin quotes and work of Japanese architects. First Chaplin addresses the renowned Tange-protegé Arata Isozaki which in a interview said: *"Architecture is not the fixing of images; in the design process we have to realise that architecture is always growing or decaying … materialisation is the beginning of a new life, and if the lives of buildings move in the same direction that people do, they will surely encounter change and eventually their end"*. (Chaplin, 2005)
For architect Toyo Ito his architecture should be *"capable of mastering the now"*. (Chaplin, 2005) This can often be seen in his work with light and materials which are capable of mediating and emitting light.

So fundamentally one could say that the understanding of the impermanent and makeshift is different between western and Japanese culture. Where it in the west is negative and an error, it is a part of Japanese culture, everyday life and belief as something admirable, special and beautiful.
In the context of the Olympics, the notion of impermanence is also present, because the whole construct and event of the Olympics is impermanent. Only lasting a few weeks, before the Olympic flame is passed on to the next host. But the impermanence of the Olympic is also what makes it spectacular. It is a way of displaying the abilities and current state of the world as it is now, a way of promoting the host country in its own current ambition. Should the architecture also take part in this impermanence and be a current display of, in this case, Japanese culture and modernity today?

02

Analysis 分析

The second chapter consist of several analysis and preliminary studies. The chapter will introduce the project theme and all the relevant material which lay the foundation for the development of the design.

Ill. 6: Athens Olympic stadium

Ill. 7: Athens Softball stadium

The Olympics in retroperspective

The Olympics is an international sports event held every fourth year, where athletes from all over the world meet to compete in different competitions. The Olympics originated in ancient Greece 3000 years ago as a celebration to the Greek mythology and honor the Greek god Zeus. Since then inspired and evolved into what is known as the Modern Olympics, founded by Pierre de Coubertin and held for the first time in Athens, Greece 1896 with the idea of celebrating humanity and gather the world to overcome national disputes in the name of sports and spirit.

The Olympics are known to be the world's biggest sporting event, both in summer and winter and followed by the Paralympics more than 200 countries are represented to compete in more than 70 different sports disciplines. All in the spirit of promoting world peace through fair and equal competition. (Olympic charter, 2016) The Olympics and their host cities capture worldwide attention, specially the summer Olympics are known to gather more than 500.000 foreign travellers and watched by half of the world's total population and have around 10,500 athletes competing. (People, 2016)
Circumstances which demands careful and long-term planning in advanced.

It's a great responsibility to be appointed host city for the Olympic movement. An opportunity for the host city to promote and showcase the celebration of the human spirit and leave a positive inheritance for a sustainable development that will ensure legacy, which is fundamental for the Olympic movement. The Olympics contributes to everything from public health, national spirit, new developments, urban transformation to tourism and even social improvement.
In other words, the Olympic games can create a characteristic set of environmental, social and economic legacies that can change a community and a nation forever (Tomlinson, 2016). However, hosting the Olympic games can have lasting consequences in many different ways, which in some cases has failed to ensure a sustainable venue legacy.

By looking at the different Olympic cities, their strategies, what they bring and leave behind from an architectural standpoint it's possible to see how venues have left a negative or positive legacy behind. Architectural historian Even Smith Wergland argues in his article "When icons cruble: The troubled legacy of Olympic design", (Wergland, 2012). That legacy rests quite heavily on the fate of the arenas', whatever successes are achieved in other fields: *"The architectural centrepieces play a crucial role in deciding between failure and success when design legacy is concerned"*. (Wergland, 2012)

Athens Olympics
The 2004 Olympics in Athens was a strong reference to the narrative of antiquity offering a special cultural symbolism and identification for the greek people and the world. The Olympic work that specially boosted the public traffic network and the city's transportation infrastructure improved the living standard of Athens considerably. However, the Olympic project have turnout to be far bigger than

Ill. 8: Aquatic stadium during OL

Ill. 9: Aquatic stadium after OL

the Greek society could afford. Athens has in Allan Tomlinson, professor in social history and sociology of sport, opinion failed to increase urban green spaces and enhance the waterfront to its full potential (Tomlinson, 2016). Many sports venues were constructed of heavy permanent structures and particularly sports like badminton, softball, baseball and others with no athletic tradition in Greece in which were known that they only would be used once and not considered as temporary structure or flexible for reconstruction into new use like conference centres, cultural spaces or commercial areas. (Tomlinson, 2016). Overall it is clear the positive of the Athens Olympics are seriously overshadowed to be the negatives, within a context of an abandoned Olympic site. (Tomlinson, 2016)

London Olympics

London Olympics 2012 showed that long-term advanced planning with a great emphasis on sustainability, accessibility and strong visionary leadership and close cooperation with government officials delivered a positive driver for Olympic legacy. (Rogge, 2013) A long time vision of redevelopment of an industrial wasteland in London proved to be the perfect and great investment for the London Olympics. Reborn as Queen Elizabeth Olympic Park in a prone area of London delivered a new urban living life to the city area with Vedant parkland, new homes, a medical clinic, a school, hiking and cycling trails, almost 180 thousand square meters of entertainment and retail areas, plus the remaining Olympic sports venues that is open for the local community. For example, the Aquatic centre showed its transformation character: designed for the use after the Olympics, to benefit the public as a community swimming pool. Under the Olympics, seating tiers was added to the sides and constructed in a light flexible structure that made it possible to strip back to original after the games was over and allow light to enter the space, which was blocked by the tier under the games. The centre today proves it self to be a world-class facility where elite and everyday swimmers can train side by side. Also, The Olympic stadium was built for an afterwards reconstruction so West Ham United (Premier league Football team) could move in and share the stadium with UK Athletics. Overall the London Olympics was a success, with venues in use and the Olympics Park as a catalyst for engaging and create a positive remembered legacy.
(Tomlinson, 2016)

So, these two different cases show us legacy planning is one of the most important aspects for The International Olympic committee when working with the host cities. Transferring knowledge from other cities is an important factor, but also sensitive to local specifications: because you can't automatically bring the effective outcome in cross-cultural context. The Olympic games provides the cities with a unique opportunity for innovation and redevelopment of new areas and improve the urban living life. For the future Summer Olympics of Tokyo 2020 how are the pre-game strategy and ambition?

Ill. 10: Diagram of OL 2020 strategy

The Olympics Tokyo 2020

Tokyo won the bid for 2020 Olympics with a very committed vision to bring innovation and inspiration into one of the most forward thinking cities in the world. Combining the power of the Olympic and Paralympic games with Japanese values for the younger generation and sharing the dream and hope of sport was the main massage. (Tomlinson, 2016).

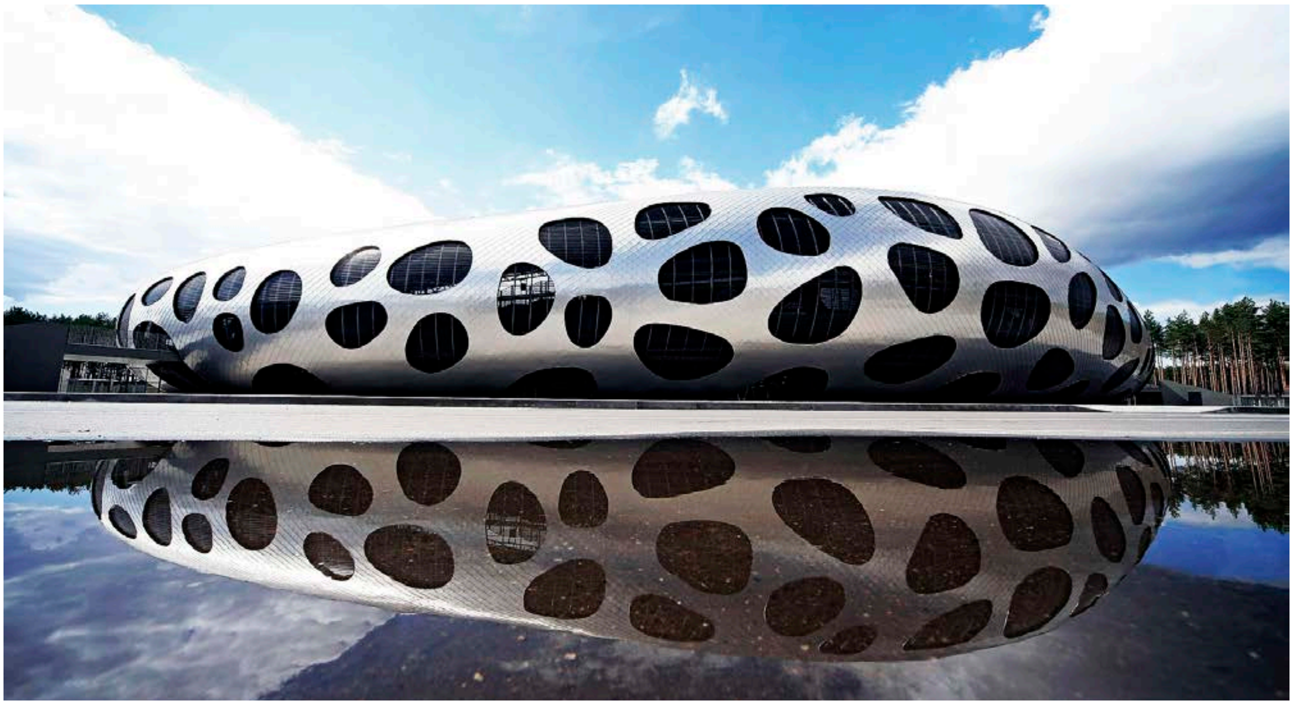
The last time Japan hosted the Olympics was with the Tokyo Olympics in 1964, which transformed Japan completely with newly developed infrastructure and venues still in use today. Building on that legacy the concept of the future Tokyo Olympics 2020 is to bring a positive transformation to the world through three main concepts:

1. "*Striving for your personal best (Achieving personal best)"*: aiming towards achieving personal best in different fields concerning sport, culture, education and technology. Adopt technologies from the world and implement them into competition venues and in operating the games.
2. "*Accepting one another (Unity in Diversity)"*: Accepting and respecting the differences across nations and cultures, with sports as a driver for people to engage actively in the development that happens across Tokyo.
3. "*Passing on legacy for the future (Connecting to tomorrow)"*: Remembering the Tokyo games and facilities continue to be cherished and used as a symbol of Tokyo 2020 legacy.

(The Tokyo Organising Committee, 2015)

At the Tokyo Olympics 2020, the concept relies on dividing the venues in two headlines – the heritage zone and the Tokyo bay zone. The heritage zone honouring and reusing the Olympic venues from 1964 as well as other existing venues in Tokyo, while the Tokyo bay zone will consist of new venues and be a dynamo for developing Tokyo as a waterfront city. In a way linking the past with the future of the city. In the centre and intersection of these two zones the athletics' village will be placed, and during the games host athletes and officials. (See ill. 10). Afterwards these will be sold and rented as apartments, supplying the Tokyo bay with many new residents. From the athletes' village, most of the venues are accessible within 30 minutes. For new venues; location and transportation services are important to ensure that athletes can perform and to maximize the experience for visitors. For all the new stadiums in the Tokyo Bay it is expected to rely almost entirely on public transportation.
(The Tokyo Organising Committee, 2015)

The 2020 games in Tokyo seem to be well-organized and post-game plans have been arranged for all venues and structures. But is this in align with the future trends of sport arenas?



Ill. 11: Borisov Arena

Future trends for sport architecture?

As this project seeks to design a sports arena capable of accommodating the future needs, one should ask; What are the current trends of sport architecture and culture?
In modern society sport culture and events seems to be more and more important, and events as the Olympics or World Championships keep attracting vast numbers of spectators. As Anna Martovitskaya, chief editor for architectural bureau SPEECH, states “In modern society, urbanisation is dramatically increasing the importance of sport and physical culture is difficult to overestimate. This is almost the most effective way to diversify and energise the depressingly monotonous lifestyle of the modern citizen.” (Wimmer, 2016) The modern stadium is according to Martovitskaya an important agency in daily life. But more concise how does new arenas adapt to these circumstances?

Rod Sheard, founder and senior principal at architectural firm Populus, envisions in a fictive conceptual project called Arena 2020 several guidelines for future sport architecture. Central for the project is that the arena becomes a “nucleus for urban regeneration and revitalisation.” (Sheard, 2001). Sheard stresses the importance of the arena becoming a part of the city fabric, which in a complex of urban public areas, event spaces, retail, commercial and accommodation-facilities can serve both the arena but also the city. These functions, Sheard envisions as buildings and spaces bordering the arena, and believes by placing arenas central in city neighbourhoods these can be create a new vitality. This can be seen in contradiction to many stadiums built in the peripheral areas, isolated from the city centres.
Bruce Miller, another principal at Populus, recently published a future concept for a soccer-stadium called “Urban Park”, in many ways similar to the one of Rod Sheard. With the same agenda of blurring the lines between stadium and city, Miller envisions the pitch being a public park when not in use for sport events. By opening up the stadium and working with a moveable pitch, a park landscape can become a natural part of the city allowing a larger palette of activities, and most important a public space for the neighbourhood. A similar perception as the one of Sheard and Miller is shared by Martovitskaya which addresses multifunctionality as also concerning an arena not exclusively being reserved for large professional events, but also allowing the public to use the arenas, through local training facilities and club sports. Martovitskaya exemplifies this through the Borisov Arena in Barysaw, which holds a 3000 square meter public zone in the lower level of the arena, with restaurants, bowling alleys, a fitness centre and more. Martovitskaya also address the importance of the architectural coherence with the context and how the outside space of the arena is treated.

Summing up, one could suggest that the future and current trends of sport architecture is first of all to address its context to a larger extent. To take the role as an urban recreational area for the city and give the possibility of more informal activities not necessarily only connected to sport.

Ill. 12: Tokyo with view towards the Bay Area

The Tokyo Bay

The overall strategy for the Summer Olympics in Tokyo involves the Tokyo Bay Area and concentrates all the new constructions of stadiums and the Olympic village in this area. For the city, the Olympic event is seen as a tool and dynamo for developing Tokyo as a waterfront city. But what is the history and identity of this central Tokyo area and what shapes the area today?

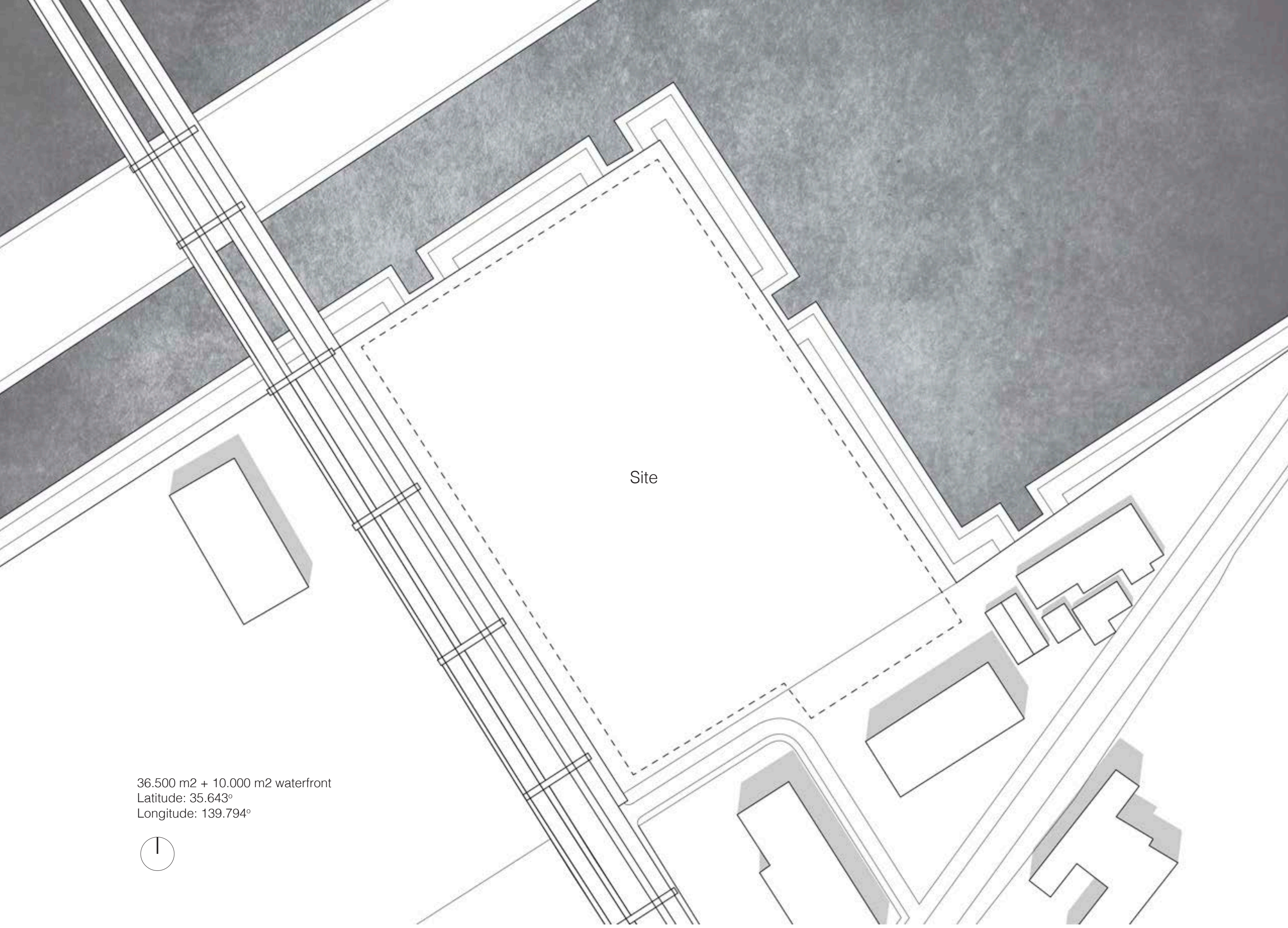
For many decades ideas of expanding Tokyo into the vast Tokyo Bay have been present, but in the mid 20th century when the rapidly growth of Tokyo demanded alternative city planning, young architects, artist and politicians began envisioning a city on the water. Historically the Tokyo Bay was an important place for fishing and aquaculture, sourcing Tokyo with food, but from the early 20th century as the industrialization of Tokyo increased these professions slowly vanished. From 1945 to 1960 the population of Tokyo grew from 3,5 million to 9,5 million people, and the 922 square kilometre large Bay became a possible way of resolving the 622 square kilometre city of Tokyo's problems with housing, offices etc. Modernists as Kenzo Tange and Metabolists as Kisho Kurokawa and Kiyonori Kikutake envisioned different masterplans for Tokyo and the Tokyo Bay area during the 1960s. Through visionary plans, they tried to solve not only the population pressure on the city, but also the lack of ambitious city planning after the Edo earthquake of 1855 and the later devastation of the city in World War II. At the time 25-year old Kurokawa stated in 1959, while presenting his Tokyo Plan: "New cities need a visual pattern. I'd like to propose a human pattern for this project. Tokyo is currently sticking its butt out into Tokyo Bay. It should place its eyes, mouth, and ears there instead, to interact with the rest of the world." (Koolhaas, 2011)

The many visionary plans were never executed and the development of the Tokyo Bay have since been without an overall strategy like the masterplans of the 1960s, but less organized developments of reclaiming land and constructing artificial islands.

The bay today is the largest industrial area in Japan and hosts several large ports as; Port of Yokohama, Port of Chiba, Port of Tokyo, Port of Kawasaki, Port of Yokosuka and Port of Kisarazu, which ranks as the busiest ports in Japan, but also in the Asia-Pacific Region. (Wikipedia, 2017)

One could argue that Tokyo still today to some extent is sticking out its butt as Kurokawa believed in 1959, having the waterfront as an industrial area instead of a recreational area. But hopefully the building strategies of the Summer Olympics can change this, and give back the bay to the people of Tokyo.

Ill. 13: The Tokyo Bay



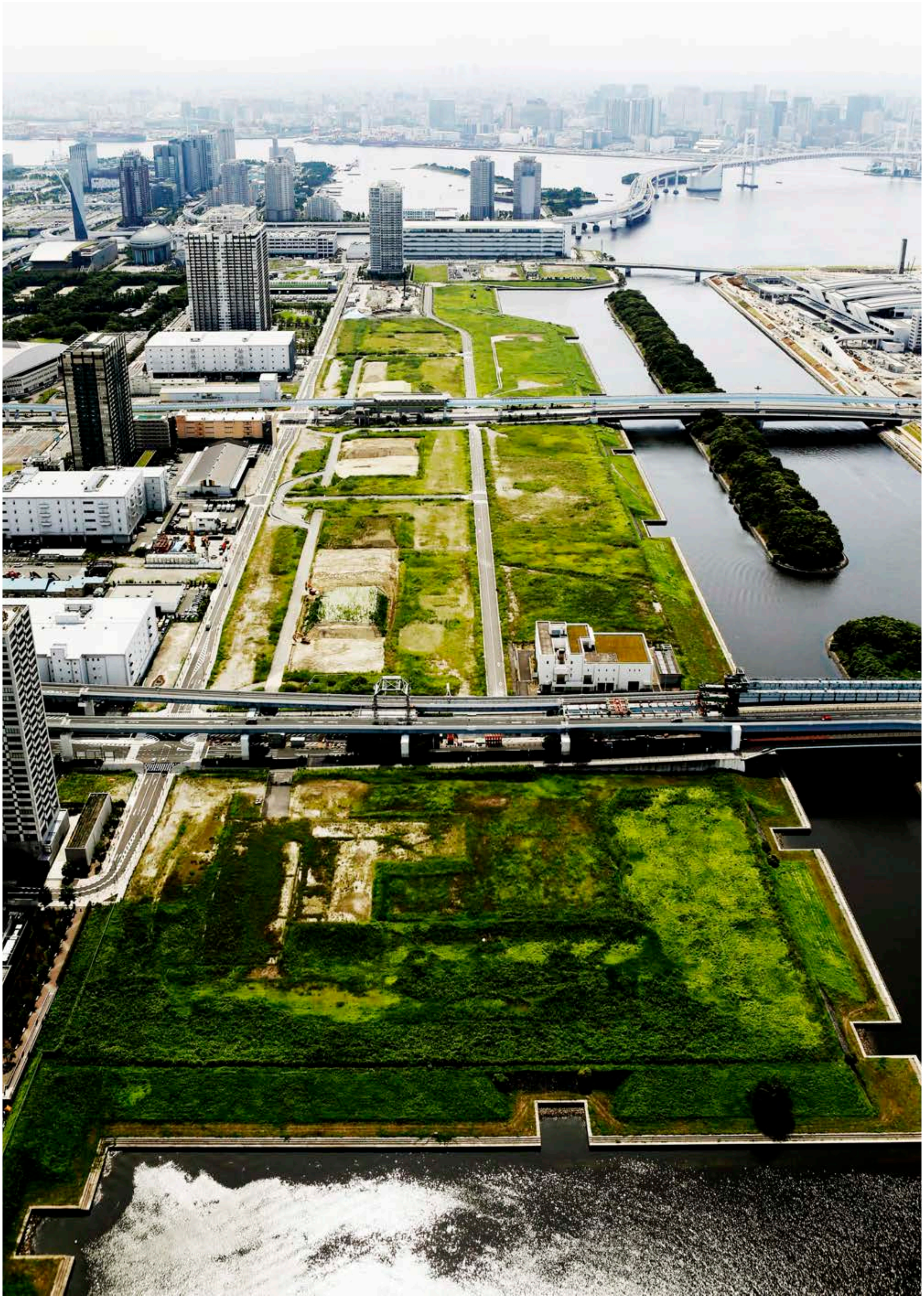
Ill. 14: Site 1:2500

Site

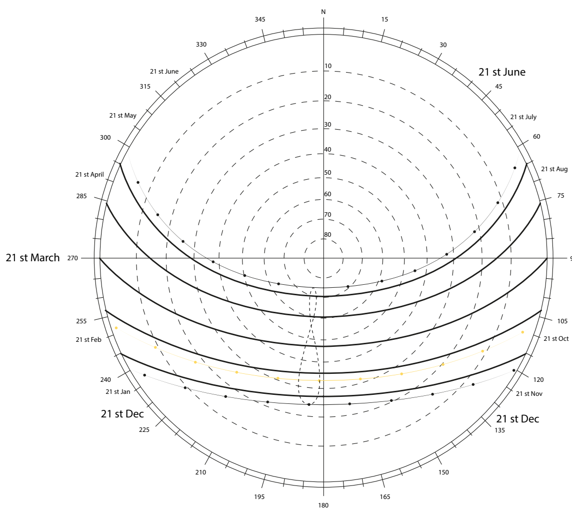
The project site is located in the Ariake area, which is part of the new modern Tokyo bay zone. At present the area is relative undeveloped peninsula, with grassy dooba. The building site is placed in beautiful green open surroundings with the river bay surrounding the north faced edges. A smaller highway to the southwest, which also serves pedestrians in different vertical levels, defines the site into a quite large rectangle of 36.500 square meters. For the project the area along the waterfront will be included in the site, which adds approximately 10.000 m2 to the total area.

With in a walking distance of 15 min five rail stations are located. Shin-Toyosu station is located to the north west side with a distance of 800 m and Ariake Station located directly south with a distance of 1.3 km. Other stations are: Shinonome Station, Kokusai-Tenjilo station, Ariake-tennis no-mori station and Shijon-Mae station. It's a desired to create a better public served transportation system for the area, so the distance to the new Ariake arena and the other Venues for the Olympics are within shorter walking distance.

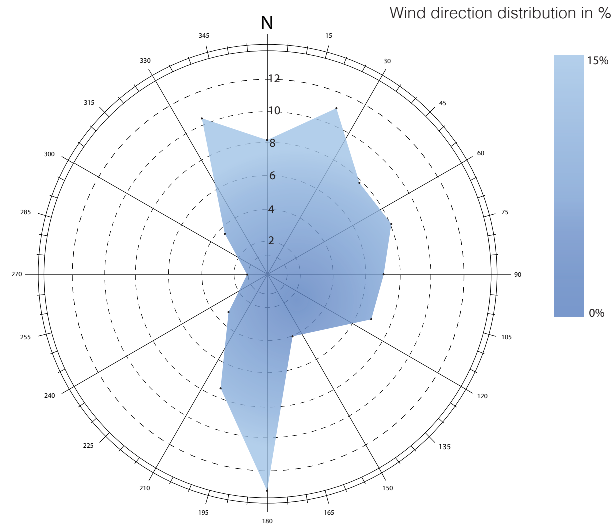
The area is mostly surrounded by large-scale buildings like: high raises, commercial and office building in a relative open and modern urban development compered to the denser central areas in Tokyo like Shibuya.



Ill. 15: Aerial view of site seen from north-east



Ill. 16: Sun diagram



Ill. 17: Wind during all year

Climate

In the following the climatic conditions in Tokyo will be investigated. Tokyo is placed in a humid subtropical climate zone and has four distinct seasons. The summer months are wet followed by hot and humid weather, while winter generally tend to be dry and mild with a bit of snow and cool spells. The surrounding ocean helps temper most severe weather, which is why Tokyo typically is known for a very moderate weather. (Japan-guide, 2017)

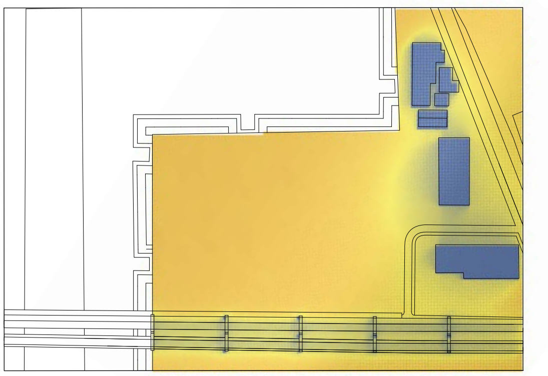
Wind

Being on the ocean side of the pacific, Tokyo is susceptible, September can be a tough month with typhoon's ramparting the city, and lots of rain following. (Japan Talk, 2017) Throughout the year, most of the wind comes from the north side, but a heavy wind pressure is also located direct south. (Windfinder, 2017) This should be considered throughout the design process, due to the orientation, shape of the building and the structural forces.

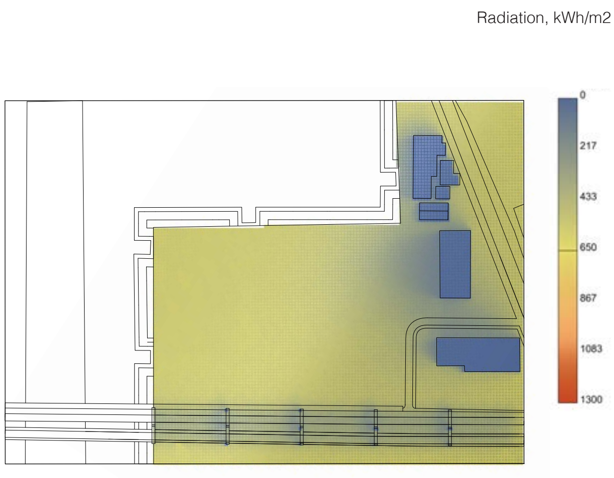
Sun

The amount of sunlight does not change much throughout the year in Tokyo. Even with winter being shorter than summer days, you can actually find some of the sunniest days in the winter season. Compared to June and September, where you have less sun hours because of the rainy season. (Weather and Climate, 2017)

However, from the sun radiation analysis on illus-



Ill. 18: Sun radiation summer



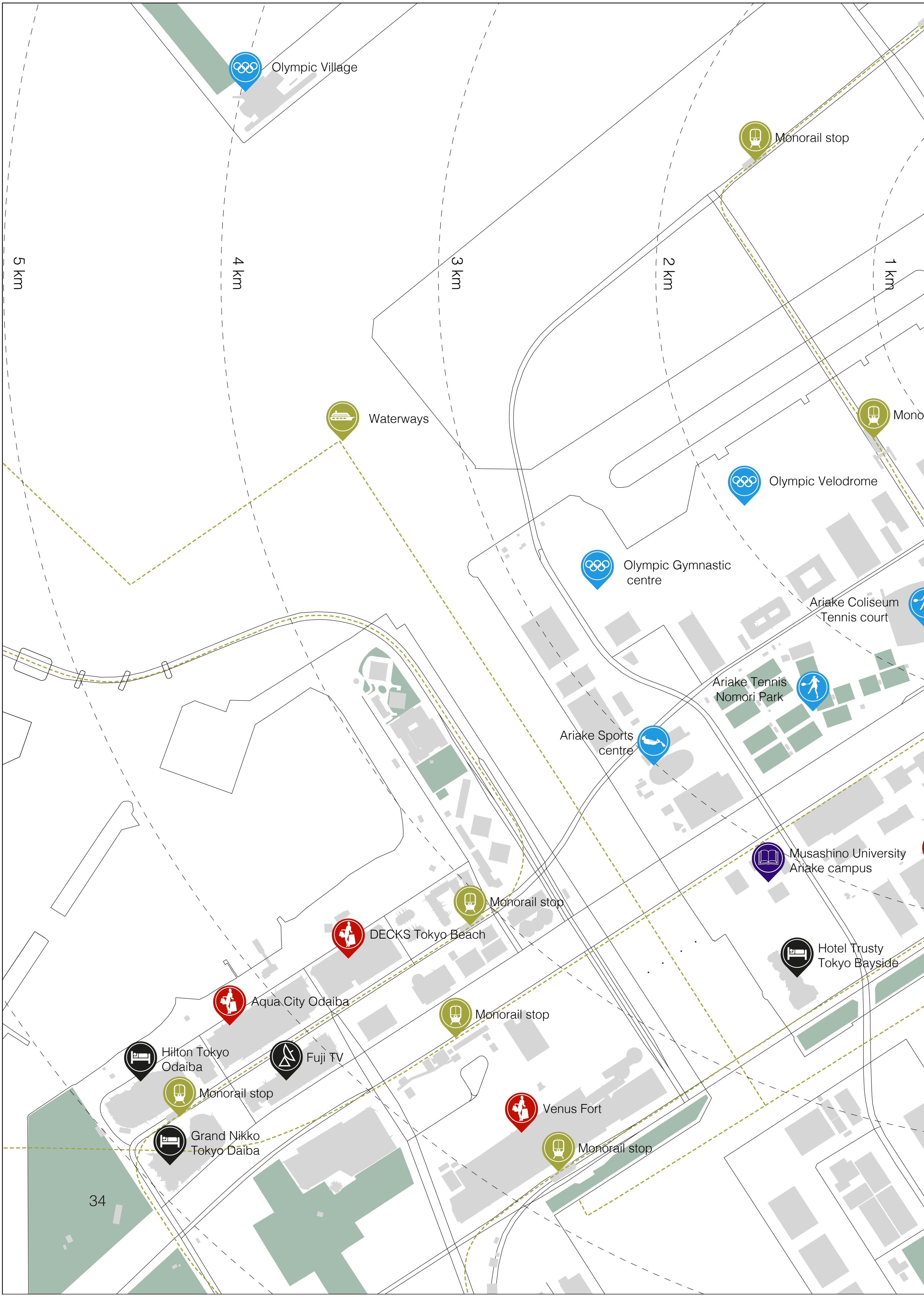
Ill. 19: Sun radiation winter

tration 18 and 19, the conditions for the site have been analysed in summer and winter. The results show that there is much sun allowed onto the site at both seasons and the tall buildings south-east of the site does only to a small extent allow shadow onto the site.

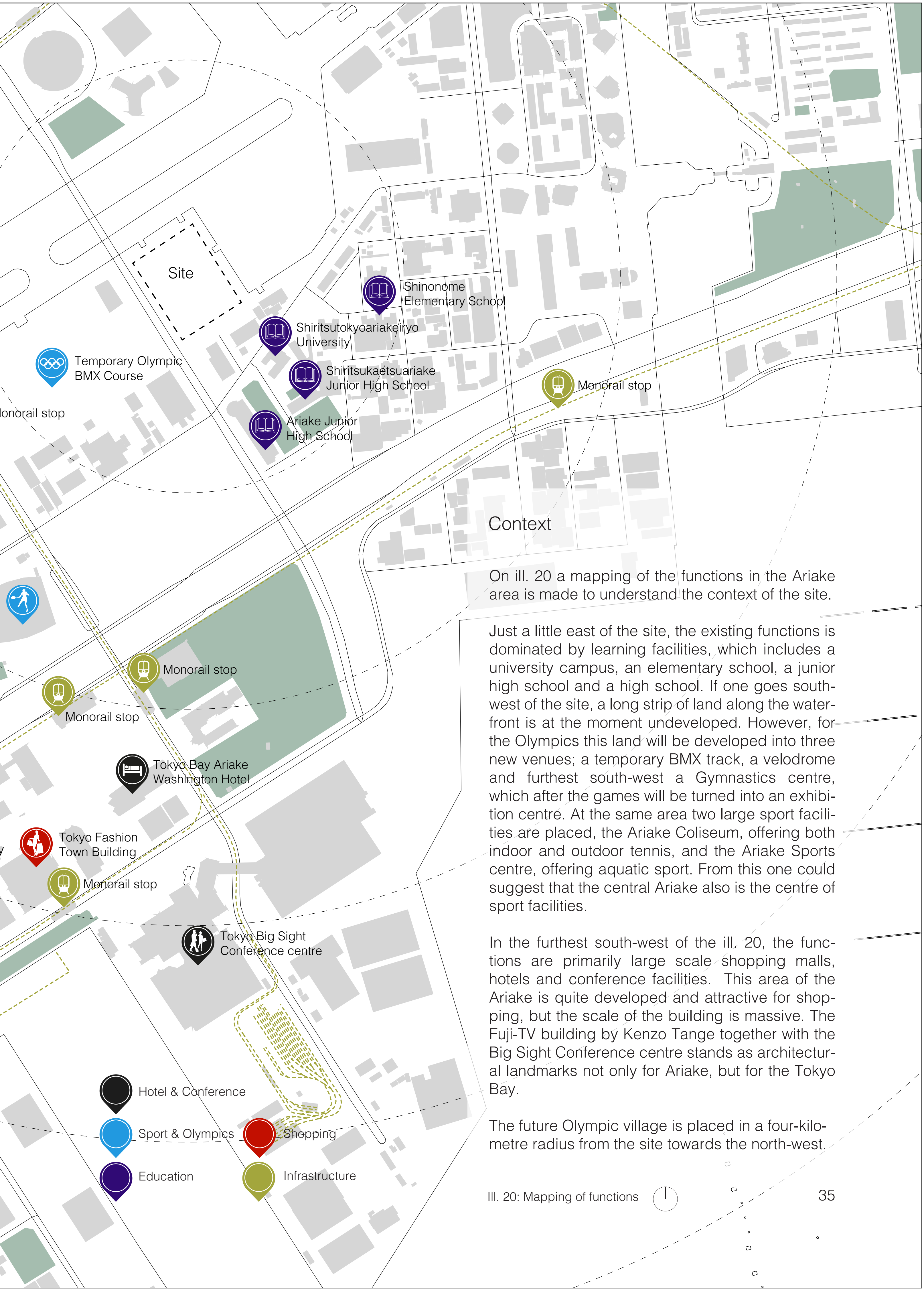
Earthquake

Japan is in one of the world's most active seismic and volcanic zones and has a notorious earthquake history with over 1500 earthquake strike every year. (Japan-guide, 2017) Usually the Earthquakes in the Tokyo region are measured at shindo four or lower on the shindo scale (Seismic Intensity), which are considered to be mild and weak. While 7 and above rarely occurs have caused significant casualties and damage to its surroundings. (Real estate-Tokyo, 2017)

With high intense forces from the earthquakes affecting buildings it is necessary to consider when constructing. But due to the short time frame of this project, seismic forces will not be adressed or calculated.



Olympic Village
Monorail stop
5 km
4 km
3 km
2 km
1 km
Waterways
Olympic Velodrome
Olympic Gymnastic
centre
Ariake Coliseum
Tennis court
Ariake Tennis
Nomori Park
Ariake Sports
centre
Musashino University
Ariake campus
Monorail stop
DECKS Tokyo Beach
Hotel Trusty
Tokyo Bayside
Aqua City Odaiba
Monorail stop
Hilton Tokyo
Odaiba
Fuji TV
Monorail stop
Grand Nikko
Tokyo Daiba
Venus Fort
Monorail stop



Ill. 20: Mapping of functions

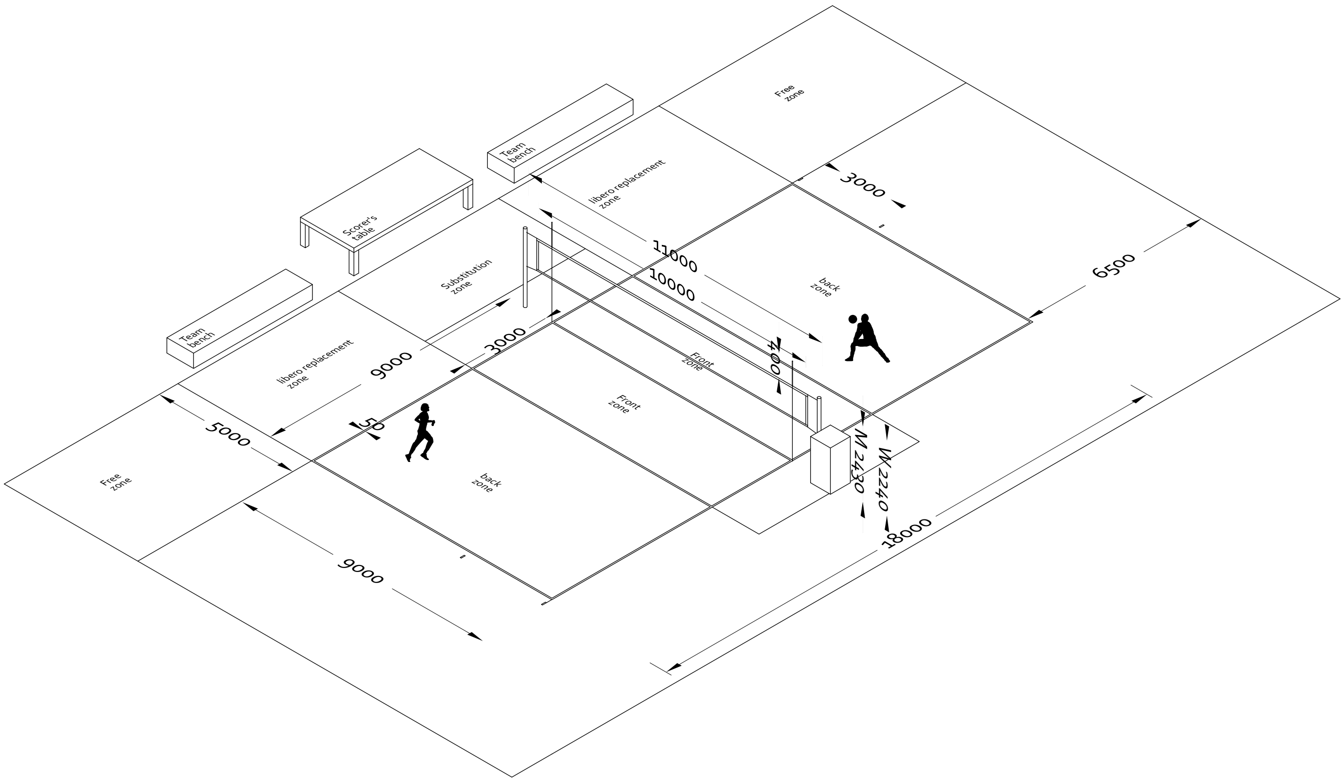
Context

On ill. 20 a mapping of the functions in the Ariake area is made to understand the context of the site.

Just a little east of the site, the existing functions is dominated by learning facilities, which includes a university campus, an elementary school, a junior high school and a high school. If one goes south-west of the site, a long strip of land along the waterfront is at the moment undeveloped. However, for the Olympics this land will be developed into three new venues; a temporary BMX track, a velodrome and furthest south-west a Gymnastics centre, which after the games will be turned into an exhibition centre. At the same area two large sport facilities are placed, the Ariake Coliseum, offering both indoor and outdoor tennis, and the Ariake Sports centre, offering aquatic sport. From this one could suggest that the central Ariake also is the centre of sport facilities.

In the furthest south-west of the ill. 20, the functions are primarily large scale shopping malls, hotels and conference facilities. This area of the Ariake is quite developed and attractive for shopping, but the scale of the building is massive. The Fuji-TV building by Kenzo Tange together with the Big Sight Conference centre stands as architectural landmarks not only for Ariake, but for the Tokyo Bay.

The future Olympic village is placed in a four-kilometre radius from the site towards the north-west.



Ill. 21: Volleyball field dimensions

Volleyball

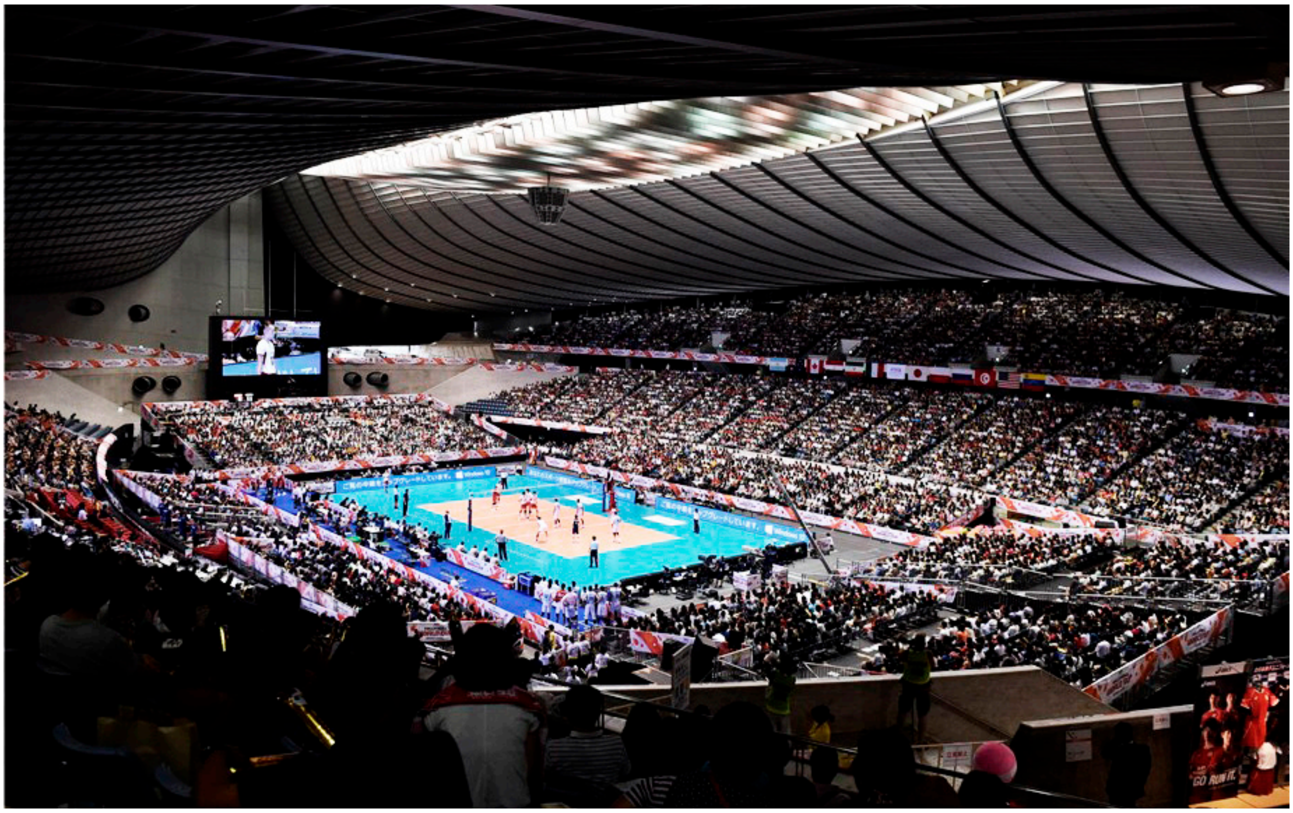
The game of Volleyball was invented in 1895, in the United States by William Morgan and has since become one of the world's most popular sports with more than 200 countries regular participating and competing in the sport.

The nature and purpose of volleyball was to encourage in teamwork, group coordination and communication with less physical contact, than basketball. The game is explosive, fast and exiting for both athletes and spectators and exhibits the best of ability, creativity, aesthetics and spirit.

The objective is to send the ball over the net while causing the ball to land in your opponent's court while preventing it from landing in your own. Each team is allowed a limit of 3 touches on the ball before it needs to return. The game is put into play with a serve and continues until the ball is grounded on the court, where a team fails to return the ball properly or goes out. A full match is won by the team that wins three sets first and each set is won by the team which first scores 25 points, but only won with a two point minimum lead.

The team consists of 14 players, one coach, two assistance coaches and one team therapist. Volleyball is played by two teams of 6 players on a court divided by a net with a height of 2.43 m for men and 2.24 m for women.

The court is a rectangle measuring 18 x 9 m surrounded by a free zone in which is free from any obstructions and from the playing surface it shall measure a minimum height of 12.5 m.
The playing surface must be flat, horizontal and uniform with a light colored wooden or synesthetic surface. For indoor qualities and comfortable aspects temperature in the main hall shall not be below 16 Celsius and maximum 25 Celsius. Measured 1m above the playing surfaces the playing areas lighting should be 1000-1500 lux.
(Federation international de Volleyball, 2014)



Ill. 22: Volleyball match at the Yoyogi National Staidum

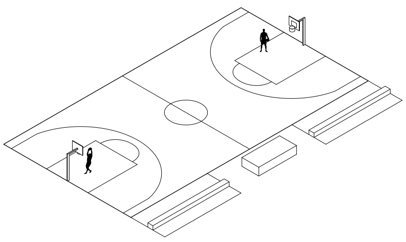
Volleyball in Japan

What is the current situation for Volleyball in Japan? Is it possible to justify a new arena primarily dedicated to the sport with a capacity of 15.000 spectators? A size sports venue which in a Danish context only is possible for sports as Handball or Football and through a multipurpose programming as Jyske Bank Boksen in Herning or the new Royal Arena in Copenhagen.

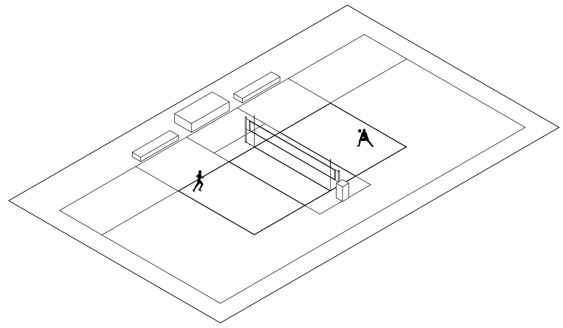
But different from Denmark, it seems like Japan has a passion for Volleyball, if the host statistics is taken into consideration. For instance, Japan have been hosting the FIVB Men's and Women's World Cup every four year since 1977, hosting the FIVB women's world championship in 1967, 1998, 2006, 2010 and in 2018, hosting the FIVB Men's World Championship in 1998 and 2006 and finally the World League in 1990. (Wikipedia, 2017)

According to sports journalist Christopher Johnson the Japanese media has during the last years succeeded in making Volleyball one of the most popular spectator sports in the country, showing national as well as international Volleyball matches on prime-time television. Network stations as TBS has created a hype and show around Volleyball, leading to evening matches can gather around 11.000 fans at the Yoyogi National Stadium in Tokyo.
(New York Times, 2013)

So apparently, Volleyball enjoy popularity in Japan, but also an overall growing interest for attending matches. The FIVB analysed and compared the total attendance at the world cup Japan 2011 with the world cup 2015, also in Japan, and concluded an overall increase of spectators - for women as much as 25,4 % more spectators than the 2011 World cup.
(Federation Internationale de Volleyball, 2015)



Ill. 23: Basketball court, 28 x 15 meters according to IWBF standards



Ill. 24: Volleyball competition area, 40 x 25 meters according to FIVB international standards.

Building program

The building program of the new Ariake Arena is developed on the basis of several different stakeholders. Since most information of the future Arena and the exact demands from the client and developer still is secret, the program is based on firstly the official demands and regulations of FIVB (International Volleyball Federation) for olympics events, regulations of IWBF (International Wheelchair Basketball Federation), standard regulations and estimates for stadium architecture, and then the published information about the future Ariake Arena, gathered from Tokyo municipality and the different stakeholders within the olympic organizers.

From the organizers and developers the future of Ariake Arena is already planned. During the Olympic games it will host Volleyball, afterwards during the Paralympic games it will host Wheelchair Basketball and lastly after these events of summer 2020, the Arena will take part as a local gymnasium and arena for the national volley league.
The future purposes of the arena is therefore quite similar according to the demands of building functions. Ill. 23 and 24 shows the size of a volleyball field and the size of a basketball field, which indicates an almost similar demand in terms of size for both games.

The vast spectator capacity of the arena should during the function of a local gymnasium be more than enough and some degree of downscaling will be incorporated, but as a arena for the national volley league, and possibly also international competitions, there is a demand for spectator capacities similar to the Olympics. Together with Volleyball becoming a more popular spectator sport in Japan which, as previously mentioned on page xx, can gather large crowds, in order to secure a future relevance of the arena, it should be capable accommodate these types of events.

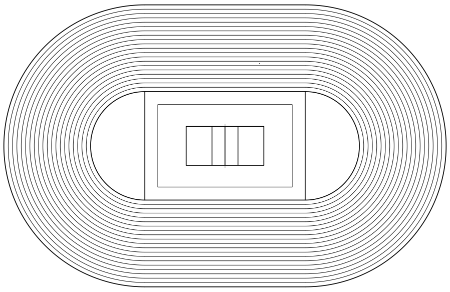
Ill. 25, shows the building program of Ariake Arena and will be a guideline for the design process.

Function	*Number*	*Size m2 (Each)*	*Size total m2*
Competition area (Volley) (Main hall)	1	1000	1000
Warming-up area (Secondary hall)	2	360	720
Team changing room	4	30	120
Referee changing room	2	20	40
First aid section	1	25	25
Doping control section (3 rooms)	1	40	40
Technical video facilities	1	18	18
Press room	1	150	150
Press lounge, cafeteria, restrooms	1	250	250
Working rooms (Main hall) (5 rooms)	1	152	152
Press delegate's room	1	20	20
Official photographer's room	1	20	20
Secretariat and statistics room (Main hall)	1	50	50
Reception rooms (Main hall)	3	20	60
Foyer	1	1000	1000
Cloakroom	1	100	100
Cleaning & maintenance	5	50	250
Info, tickets, administration	1	200	200
Vendor	8	15	120
Bar	2	100	200
Toilet facilities (0,01 per spectator)	150	2	300
Spectator seats (Of which 2300 is flexible)	15000	0,4	6000
Storage	5	100	500

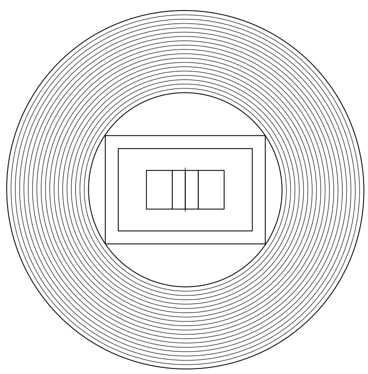
Ill. 25: Building program


YAMAHA
PC USEFUL
2F アウトレット
OUTLET
HAMADA
OUTLET
2F アウトレット
コーナー
アースニクス
センサーの
浜田電機
オートメの
ハマダ
TSUKUMO
Transcend
GIGABYTE
24H
DVD・ビデオ鑑賞

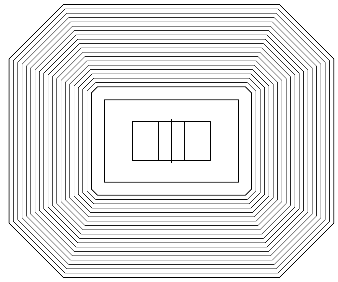
Ill. 26: Street in Tokyo



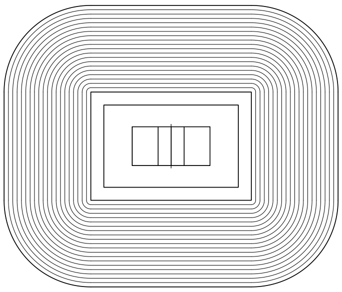
1. Oval



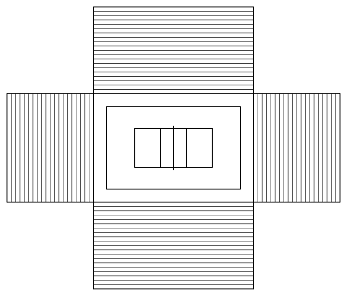
2. Circle



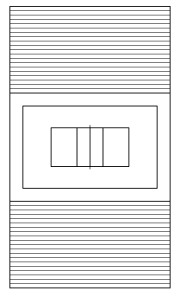
3. Polygon



4. Rounded rectangle



5. Rectangle with open corners



6. Double-sided open rectangle

Ill. 27: Building footprint analysis

Building Footprint

A stadiums footprint and floorplan, like all architecture, is a product of many considerations such as site, regulations, capacity etc. But stadiums always being venues of big events, in this case Volleyball, the general seating arrangement of the building is important to considerate from the very beginning of the project. In order to understand and analyze the usual typologies used in stadiums, 6 general footprint and seating situations will in the following be discussed.

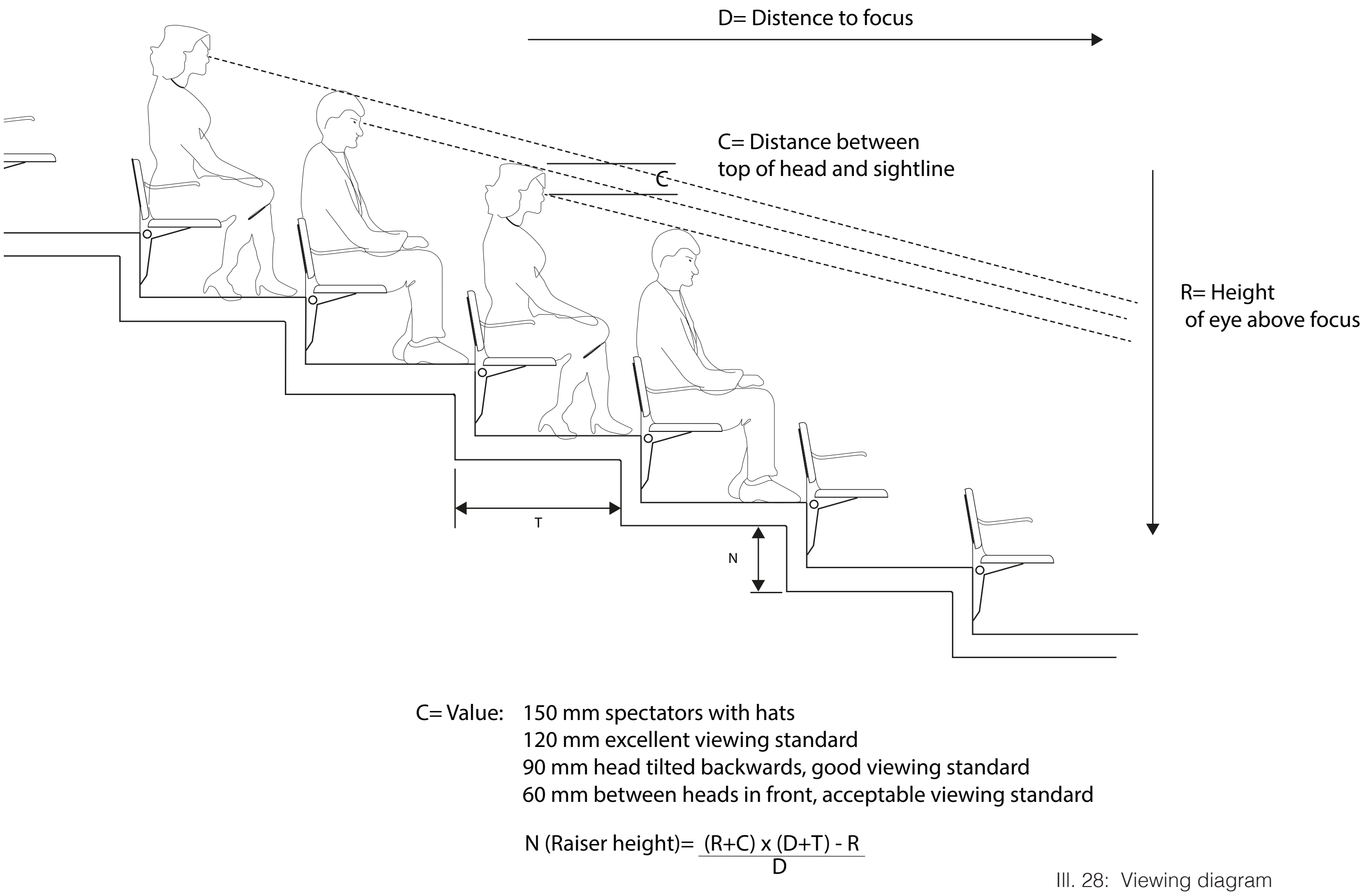
The oval (example 1) is typically used for athletic stadiums because of the shape fitting a running track. In case of volleyball, basketball, football etc, sports with rectangular playing area, this shape releases problematic space on both ends of the field. This results in spectators seated on the short side have longer distance and worse view of the game and players.

The circular shape (example 2) are geometrically bound in a center point, this will also apply for the sight line of the spectators which will be in the center of the stadium. Whether this is positive depends on the sport, but in the case of volleyball where the center is the net, it could be an advantage because most of the action and play revolves around the center and net of the game.

The polygon and rounded rectangle (example 3 and 4) are very suitable for football and, for instance volleyball, because of the proximately to the playing area, giving excellent view and good distance to the game for all spectators.

The rectangle with open corners and double-sided open rectangle (example 5 and 6) consist of a simpler geometry, and by having separate elements it can offer detachable, scalable and movable elements in terms of the separated seating sections.

The typologies of example 1-4 consists of a continuous seating arrangement which gives coherent and more intense atmosphere and the often desired “pressure cooker” effect. Example 5-6 on the other hand offer through a rectangular form fractured seating areas, where the coherence and social synergy between spectators in some cases gets lost.



Ill. 28: Viewing diagram

Viewing

Spectators viewing conditions depend on different factors such as viewing distance (That you aren't too far away from the action), sightlines (are you able to see past or over the heads of the people in front of you), the sight needs to be led and focused towards the event and not having columns, beam and other barriers that can obstruct your eyesight
.
To create the best viewing experience, so spectators can keep track of the game. Because volleyball, as well as basketball, are above waist sports the focal point is placed on the field and raised 600-900 mm where sightlines are drawn from the height of the spectator's eye to the vocal point. The variable is referred to as the C value. This will change the N value dimension and where the tier becomes steeper for every row of seats. Typically for safety requirements the stands are between 35-42 degrees. To avoid columns and other barriers that will obstruct the spectator's eyesight, long-span trusses or cantilevered structures are used to deal with this technical challenging issue. For comfort, spectator seating the ideal minimum dimensions are 475-500 mm wide and 760-800 mm for the treads deepness (T Value) so the seated spectators have enough room for their knees and people are able to pass and get to their seats. For other safety, comfort and fire features the number of seats in every row, placed between the aisles should not exceed 28 seats pr. row. (Sports Architecture, Rod Sheard, 2001)

Countries and cultures have different perception of how the game of volleyball should be viewed. Ariake arena will also for the Paralympics host wheelchair basketball which is why the vocal point is determined from a basketball playing surface, it is larger than a volleyball playing surface and will automatically create better sightlines for the spectators.

With these aspects in mind together with the previous analyzes of volleyball and its popularity in Japan, the conclusion is that the at Ariake Arena Volleyball should be watched with these dimensions; 500 mm for the seating width, 800 mm for the deepness of the threads, 120 mm c-value for excellent viewing in lower tier and 150 mm for upper tier.

Acoustics of sports architecture

Hearing is a central sense for humans to perceive space as well as interaction with other human beings. When designing any type of architecture, the soundscape of that given building is an important parameter in the overall experience and performance of the building. For large buildings such as an arena a good acoustic solution is vital for creating a useable building. But how should the acoustic performance of a stadium be?

The sense of hearing defines the word acoustics. It is a way of having knowledge about the physical aspects of sound. Sound is an energy characterized as a motion of vibration in fluids and gases, like water and air, known per definition as a "medium". Its vibrations from a source like banging on a drum that force the air around it to vibrate, in which we call sound waves. The sound spreads in all directions by pulling and pushing the air back and forth in alternating patterns. (Long, 2006). Sound waves lose its energy over further movement and appear different to the listener whether it is high or low frequencies. The movement of the sound waves in a room can be controlled in three different ways: It can be reflected (bounced of a surface), diffused (divides the energy) and absorbed (convert the waves into heat energy). All depending on the configuration and the materials it encounters. (Long, 2006)

Early examples on knowledge of acoustics, can be seen in ancient Greek architecture where it was implemented in outdoor amphitheatres. Built on a steeply sloped hillside as a semicircle construction of stone steps orientated towards a vocal point on the stage improved the intelligibility of the human voice to reach the whole audience. (Long, 2006)

In modern large spaces, such as sports arenas, often there is generation of echoes, background noise that reduce the sound quality and blurs the different sounds. This is damaging for the enjoyment and experience for spectators, but also problematic for the athletes performing, which is why excellent acoustic solutions are critical for the experience of the space. For sports events, a rather longer reverberation time and a high level of focus on speech intelligibility is necessary to produce a more alive atmosphere and make sure the communication between athletes is possible. This will emphasize the emotions and intensity among spectators and athletes, and also be able to enhance the home team's momentum throughout a game. Following acoustic properties are recommended; reverberation time of 2.1 – 2.5 seconds and a speech intelligibility of minimum 0.7. (L-acoustics, 2017) (Bradette, 2013)

Unfortunately, the optimal acoustic demands of a sport arena can almost be characterized as a paradox. As volleyball being a sport with much communication between players, it is important that this is possible. Still as a spectator you would like to understand this communication. At the same time the athletes should feel the momentum and cheer from the spectators, but not too much because this can disturb their communication with their team. For this project, it will be central to find a balance between these demands.

Case: Palazzetto dello Sport

The Palazzetto dello Sport is an indoor arena designed for the 1960 summer olympics in Rome. Designed by architect Annibale Vitellozzi together with structural engineer Pier Luigi Nervi the arena stands still as an impressive architectural and structural accomplishment.

Pier Luigi Nervi was a pioneer of his time and used throughout his career reinforced concrete to create not only large spans and heights, but also to create imaginative and beautiful structural systems capable of accommodating strict functional as well as economical demands. So when designing a new indoor arena Pier Luigi Nervi could be a place to start and learn, in this case exemplified through the Palazzetto dello Sport, one of four structures Nervi was responsible for as a part of the Olympics.

The arena was designed for hosting primarily basketball where it had the capacity of 3.500 seated spectators. Furthermore, it was intended for boxing and wrestling where it was capable of hosting 5.600 spectators. Today it is still in use for basketball as well as volleyball matches. (Patrick Kunkel, 2015)

Architecturally one can say that the building consists of two main elements; a base which is partly buried and a thin concrete shell or roof which almost is hovering above the base - only connected by a glass ribbon. In terms of materiality these two elements are also different, the base being clad in red bricks and glass and the roof being in light grey concrete.

The plan of the Palazzetto is completely circular, but in the seating arrangement, the circular stadium typology merges with the rounded rectangle typology making the plan more effective in term of space, but also securing closer distance between the game and the spectators, resulting in an overall more intimate sport experience. Functions such as changings facilities, first aid etc. are placed underneath the seating sections. Unusual for indoor arenas, the Palazzetto dello Sport, takes in much natural light from the previously mentioned glass ribbon. As a result the arena is naturally well lit during daytime, and as a spectator making it easier to navigate inside.

The main structure of the arena is the thin shell concrete roof spanning almost 60 meters, releasing column-free space underneath for seating and basketball pitch. The shell can be seen as a spherical vault consisting of 1620 prefabricated elements of only 19 different types. Structurally the shell is working as both a concrete shell dome and as a gridshell structure, since the stability is created both by a membrane as well as a series of Rib-arches. (Iori & Poretti, 2015) Thereby the structure is capable of both tension and compression.
The forces applied on the shell are led from the ribbons of the roof down to the ground through 36 y-shaped flying buttress placed along the perimeter of the circular arena holding down the structure.

The overall curvature and "cassettes" of the roof are presumably also beneficial in term of acoustics and through this varied surface, standing waves and therefore echo should be reduced.

The tectonics embedded in the Palazzetto dello Sport displays a complete synergy between the functional needs, the structural and aesthetic. In the Palazzetto the structure of the roof becomes the main ornament and aesthetic element of the building.

Ill. 29: Inside Palazzetto dello Sport

Ill. 30: Exterior Palazzetto dello Sport

Case: Yoyogi national stadium

The Yoyogi National Gymnasia was designed by Kenzo Tange for the 1964 Summer Olympics in Tokyo, and became the embodiment and symbol of the modern post-war Japan.

Like many Japanese architects at that time Tange had questions about the relationship between tradition and modernity. But as an architect Tange found a way of translating the western modernism into a Japanese context and understanding – the Yoyogi National Gymnasias can be seen as an example of that.

The complex Tange designed consist of two sculptural stadiums connected by a central axis, which accommodate the stadiums with infrastructure, training facilities, administration and canteen. The complex is situated in the large Yoyogi park in the central Tokyo district of Shibuya, which is a vital recreational area for the city.

During the Summer Olympics of 1964 the large stadium (1st Gymnasia) was hosting swimming and diving with a capacity of approximately 13.500 spectators and the small stadium (2nd Gymnasia) hosted basketball with a capacity of 5.000 spectators. (*Architectures: Les Gymnases Olympiques de Yoyogi,* 2006)

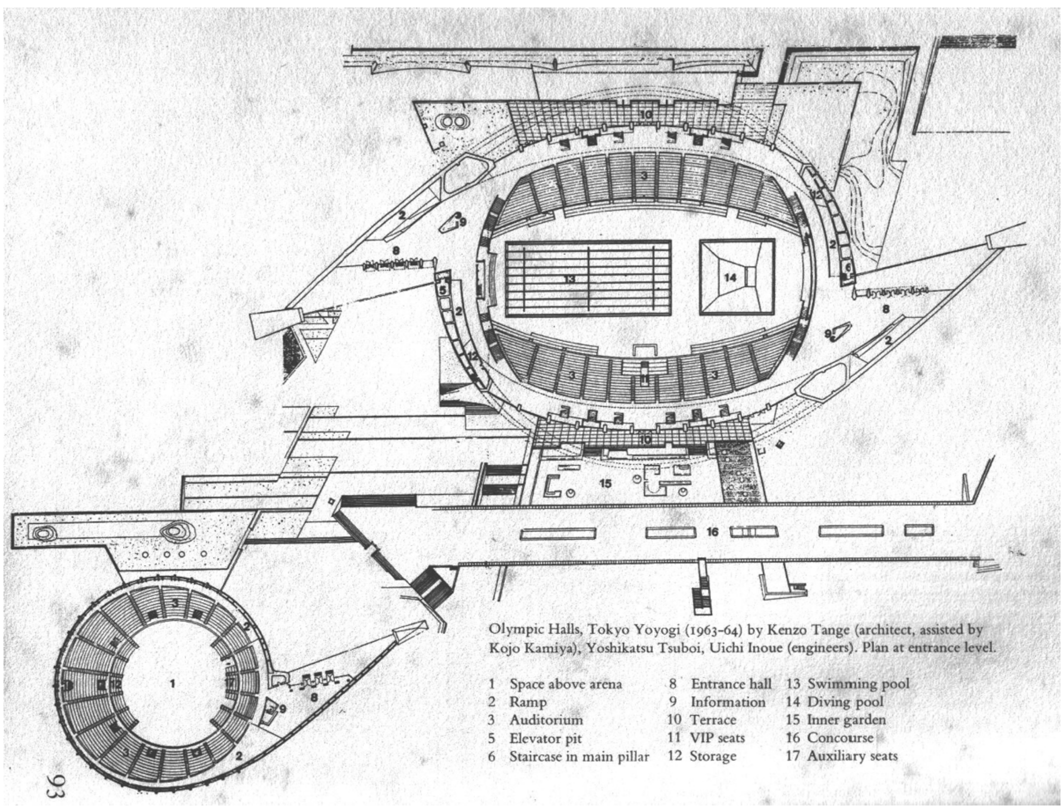
The distinctive and sculptural form of the two gymnasia are a result of the same structural system. For the design Tange adapted a structural principle mainly found in suspension bridges, which consist of pilings and cables which hold up a roadway. At the large stadium two steel cables anchored in concrete pass through the top of two concrete masts, supporting the weight of the roof rather than the one of a roadway. At the small stadium, a single steel cable is twisted around a concrete mast creating a circular formed roof.

The concave structure of the roofs at the large gymnasia, almost forming two leafs, results in a smaller interior volume which essentially means less air in the stadium to heat and an improvement of the acoustics. The central space between the two steel cables, Tange made into a large skylight, which illuminates the entire arena. The structure allows in the large gymnasia for 120 meter in width and 125 meter long span without any columns or posts – securing free view for all spectators. (*Architectures: Les Gymnases Olympiques de Yoyogi,* 2006)

Along the concrete facades of the gymnasiums concrete stables creates the façade rhythm and link the roof with the floor – the transition and element where the metal of the roof and concrete meet. At both stadiums, the base is smaller than the roof, which gives lightness and an idea of motion to the building, which seems like it is almost hovering above the landscape.

From the basis of the same structural principle Tange succeeded in creating two very different poetic forms, representing a structural expressionism. For the visitor, all the structural tensions are expressed, one could say that the form translates the construction requirements. The gymnasia's represented a new architectural identity of Japan and was, among other works, a basis of the Metabolist movement, but still the architecture was deeply rooted in a Japanese cultural context. For instance, the shape of the roof references the Shinto Shrines and the detail in which the large concrete mast and steel cables meet also references the details of Shrine architecture.

Ill. 31: Aerial photo of Yoyogi stadiums



Ill. 32: Plan of both stadiums

Conclusion on Analysis

The analysis made for the project has given an insight in the Olympics as an institution and how previous games have happened. It has given an understanding of the site, its context and the climatic conditions in Tokyo. Furthermore, the game of Volleyball has been investigated to give an understanding of the sport, its conditions and its popularity. It has given a better understanding of the architecture of Japan, as well of sports architecture in general.

It is clear that in order to make a successful stadium or arena for an event such as the Olympics, its central to have a vision and strategy for how the building should be integrated in its surrounding neighbourhood and how it shall be used after the event. For this project, there is already a vision for the future use and therefore the project should respond to that, but also try to make it even more attractive and useable in the future.

The site is located with direct exposure to the water at the northwest-northeast sides of the site. This gives opportunities to use the proximity for different recreational purposes. The area is still an area in development, and if it is compared to other more developed Tokyo neighbourhoods, quite open still. Therefore, it is important to keep in mind that the area in a few years will be denser and have a different urban structure and needs.

The weather of the bay area offers main wind directions from north-east and south, which should be taken into consideration. The site has a quite even sun radiation and only at the north-eastern corner is shadows from nearby buildings influential. The rainy season of Japan should be taken into consideration when designing the outdoor areas, so the site can offer sheltered spaces from rain.

To make an arena capable of facilitating the game of Volleyball it is important to have an unobstructed view from every seat at the arena. This means that the structural system of the roof should be capable of handling large spans without columns. In addition to this, the design of the seating bowl should provide optimal c-values from all seats. Another architectural consideration should be at acoustics. The acoustic of an arena is important for the atmosphere, but also for the ability to follow the game and the athletes to communicate. The design will try to have an acoustical performance capable of accommodating that.

The future strategy of the arena of being still a Volleyball arena after the games, together with the popularity of the sport in Japan, gives the possibility of creating an arena specifically designed for the sport. But to increase the functionality the arena should also could host sports which can fit at the dimensions of the volleyball competition area. The core program according to FIVB and IWBF regulations should be followed, but the vision of making the stadium an attractive public dynamo, should create a more dynamic program including different public functions, which can make the area useable for different activities, not only bound to Volleyball.

The design of the Ariake arena should showcase Tokyo at the Olympics, but it should also be an arena designed for Japan. The first international and afterwards more national situation of the arena should be translated into the design, which respects and understands Japanese design values, while also pointing towards a new understanding of it.

TECHNICAL	No columns in the seating bowl, which in any way can obstruct the view to the playing field.
	The acoustic performance of the arena should reach the recommended values of; reverberation time of 2.1 – 2.5 seconds and a speech intelligibility of minimum 0.7.
FUNCTIONAL	Mixed program capable of activating the site at different times and for different activities, not necessarily only connected to sport or volleyball.
	Accommodate the requirements of the core program according to FIVB and IWBF regulations
	Optimal C-value of 120 mm and above from all seats.
	Playing field is capable of hosting volleyball and basketball matches.
AESTHETICAL	Establish a clear identity for the arena supporting the arenas role as a Olympic venue, but equally important as an arena designed for its neighbourhood.

Ill. 33: Design criteria's

Vision

The vision of this project is to create a sports arena which structure honour Japanese design sensibility and unites technical, aesthetical and functional aspects into an architecture capable of staging large athletic accomplishments.

A success criteria for the Arena is to create a stadium possible of facilitating volleyball and other sports being played there in best way possible, so the architecture of the stadium ensures not only a high level of functionality, but also a high level of architectural quality. Therefore, the aesthetics and atmosphere of the stadium should also encourage to visits and use beside the large sport events.

The new arena should not only be a representative of Tokyo at the 2020 Summer Olympics, but also a dynamo of the future development of the Tokyo Bay Area of Ariake. It should be an attractive recreational area to visit and invite people to use the Arena.

The Ariake Arena should ensure an Olympic Legacy, being a standstill shot of Japan showing the architectural and cultural abilities, but also ensure a constant relevance and functionality for the neighbourhood, city and country.

03

Design process

設計プロセス

The third chapter explains and presents the design process of this project. Through text and illustrations, the different phases of the design development will be explained, from the first sketches to the last simulations and detailing.

PART ONE		PART TWO	
PHASE 1	PHASE 2	PHASE 3	PHASE 4
Sketching Modelling Parametric model Acoustical analysis	Sketching 3d model Concept Structural concept Midterm	Sketching 3d model Structural analysis	Detailing Final calculations & simulations

Ill. 34: Design process diagram

Introduction to Design Process

In this chapter, the design process of the project will be explained in a fairly chronological order. The process is divided into four phases, two phases before the midterm review and two phases afterwards.

This introduction will introduce the main themes of the different phases and briefly how different architectural- and technical tools have been integrated and used throughout the design development.

The two first phases of the design process tried to materialize and understand the results of the analyse phase according to the design. Therefor sketching and physical modelling was central at these phases, but because of the vast scale and complexity of the project, digital tools was already from the first phase used because of their efficiency. 3d- and parametric modelling was quick to use according to seating bowl investigations and acoustical simulation software pachyderm was used to investigate the influence of the bowl geometry on the acoustic performance of an arena. At the end of the second phase, an architectural and structural concept was developed and presented for the midterm review. The two last phases focused on developing and refining those ideas into the final building design.

From the third phase, Final element software, Robot, was an essential tool for structural calculations, in order to understand the potentials and capacities of the system. This phase is dominated by the interplay between these structural calculations and functional and aesthetical demands and visions.

The fourth and final phase of the design process is the final synthesis phase and here the different aspects of the design joins together and final calculations and simulations are done.

Phase 1

PART ONE		PART TWO	
PHASE 1	PHASE 2	PHASE 3	PHASE 4
Sketching Modelling Parametric model Acoustical analysis	Sketching 3d model Concept Structural concept Midterm	Sketching 3d model Structural analysis	Detailing Final calculations & simulations

The first phase of the design process was open and stretched around many different aspects. Based on the extensive previous analysis and some preliminary studies, the work in this phase sought out to start understanding the criteria, demands and visions of the analysis phase into a design context. Because of the large scale of the project, this phase operates already on several different levels.

Programme & Flow

Functionality and logistics are two essential key areas when designing large sport facilities. In this first phase of the design process the programme and the disposition of functions according to flow was investigated and processed.

In a arena as the one being designed, there are many different flows according to the different stakeholders. Some of these should during professional events, be quite seperated in order not to disturb the game and athletes.

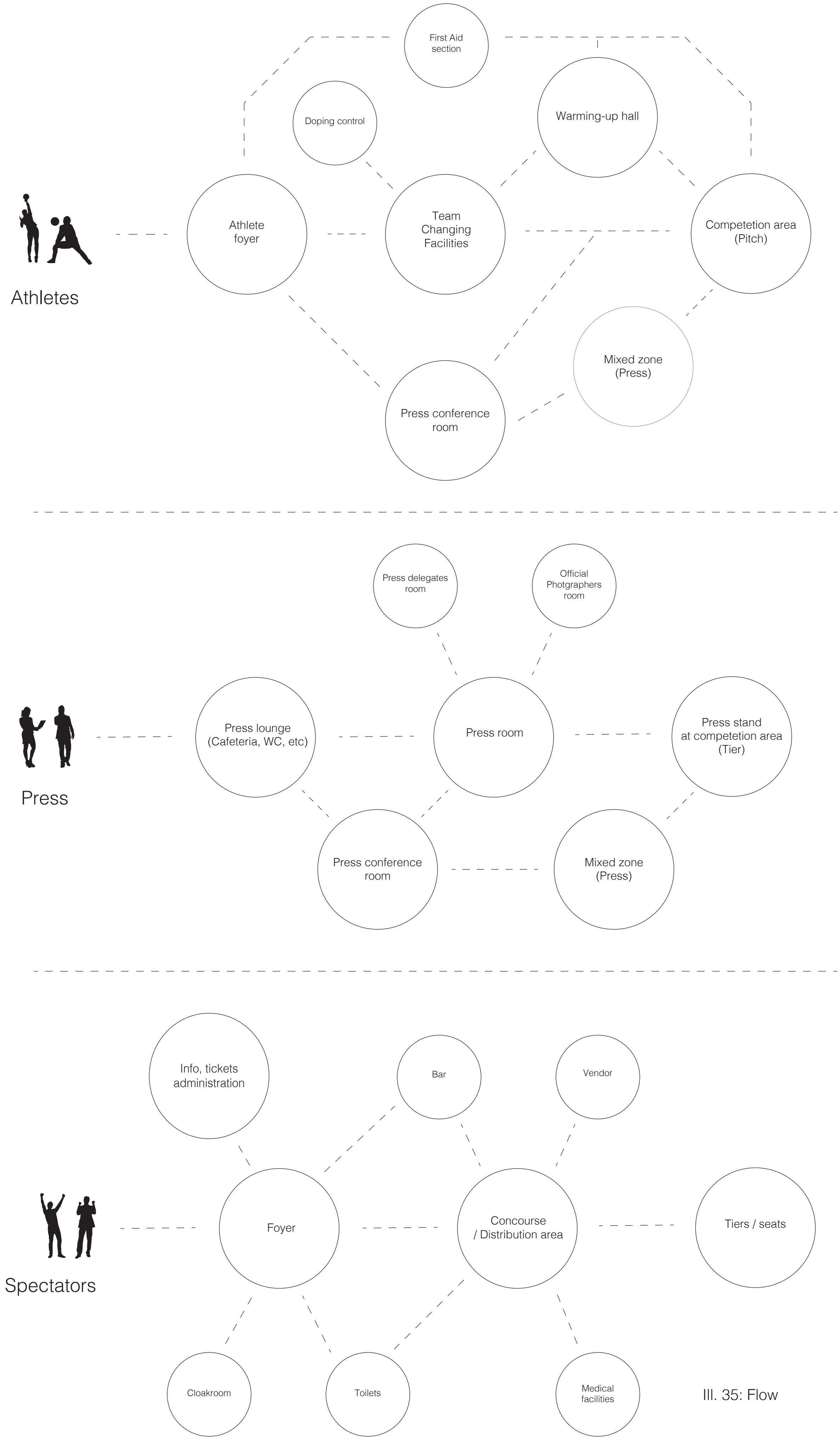
The building programme (See page 39) have been divided among three main operators, athletes, press and spectators, in order to determine which operator use which part of the programme and how these should be interconnected. Illustration xx shows this.

The three flows should be seperated, in particular the flow of the athletes should be foreclosed for media and fans. The mixed-zone and conference room (see ill. 35) should be accessible for athletes but wth seperate entrances between press and athletes.

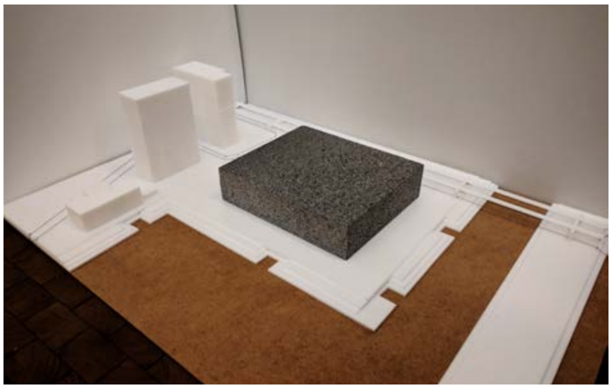
For the spectator flow its central that the way from the tier to exit is simple and intuative. Still different offers as bars, vendors and toilet facilities should be close to the spectator. On ill. 35 the idea is the use a foyer and concourse as distribution areas and in connection to these other facilities are interconnected.

Lastly, the three flows have different entries, the athletes a foyer, the press have a lounge and the spectators have foyers. Hereby the flow is seperated already before entering the building.

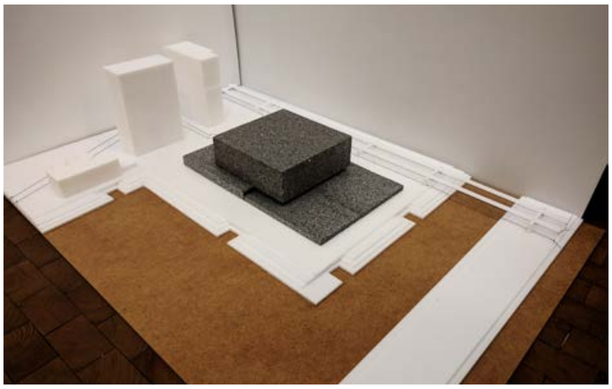
This analysis created the base for later work with plan and organization solutions.


First Aid section
Doping control
Warming-up hall
Athlete foyer
Team Changing Facilities
Competetion area (Pitch)
Athletes
Mixed zone (Press)
Press conference room
Press delegates room
Official Photgraphers room
Press lounge (Cafeteria, WC, etc)
Press room
Press stand at competetion area (Tier)
Press
Press conference room
Mixed zone (Press)
Info, tickets administration
Bar
Vendor
Foyer
Concourse / Distribution area
Tiers / seats
Spectators
Cloakroom
Toilets
Medical facilities

Ill. 35: Flow

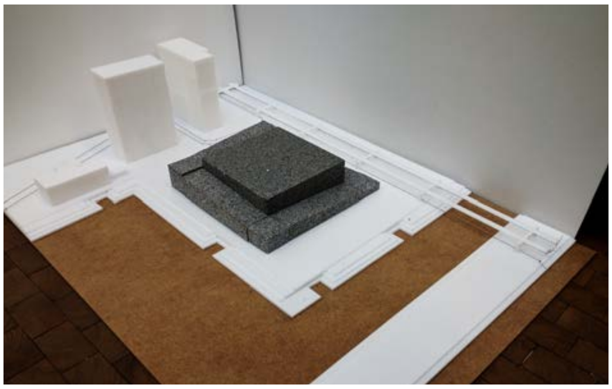


Ill. 36



Ill. 38

Ill. 37



Ill. 39

Volumestudies

As an initial investigation, this volume study in physical models sought out to understand size and scale according to the site. In the following four of the models will be discussed.

On ill. 36 we see a simplified model of the volume of the arena which will be built. 25.000 m2 and 35 meters tall, the vastness of the building occupies almost the entire site. The model give some space along the volume and still makes it possible to make for instance a recreational waterfront, but larger plazas or parks are not possible.

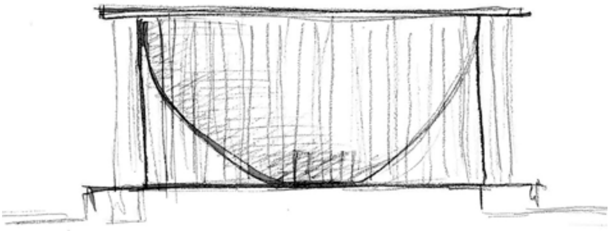
On ill. 37 an oval shaped volume almost similar in size of the previous. Still a big volume occupying much of the site, but the rounded corners, frees room for natural space generations at these areas. The shape seems more dynamic, and the scale of the context makes the height and or volume not seem unnatural in those settings. The volume should generally be higher than the elevated highway towards west.

The volumes necessary for the arena are quite big as the illustrations on this page indicate. So, in response the model on ill. 38 tries to break down the arena in several volumes. Here the lower volumes act as podiums, while a volume situated on top could be the seating bowl. Hereby a more dynamic volume is achieved, and the different surfaces or roofs could have different functions and recreational purposes.

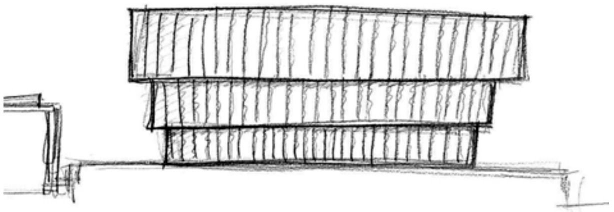
The last ill. 39 shows a different interpretation of the previous idea of podiums. Here a central volume is bordered by a large ramp, making it possible to claim the building and enter at various levels of the building from the outside. Hereby the roof of the building could become a park or urban plaza.

From these volume studies, in particular the idea on podiums and breaking down the building in several volumes was further and later investigated.

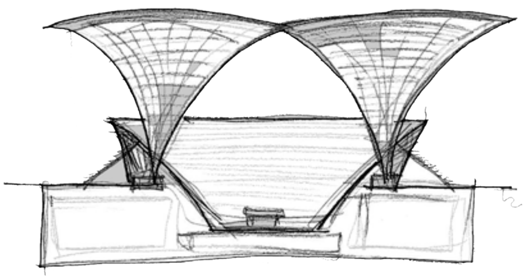
Ill. 40



Ill. 42



Ill. 41



Ill. 43

Initial sketching

In the first phase of the design process, sketching was used as a quick way of generating ideas. After the previous work with simple volume studies in model, the following investigation, sought out to work with different concepts through sketching.

On ill. 40 a quite expressive shape is drawn. Here the shell and the shape of the volume become expressive, not necessarily exploiting anything about the interior or function of the building.

On ill. 41, three circular shapes are stacked on top of each other, with the smallest in the bottom and gradually the diameter of circle increases the further is goes up. Through a simple geometric concept a dynamic shape is developed, which could follow the curvature of the seating bowl.

On ill. 42, the composition of the idea consists of a base and a separated seating bowl which are covered by two shell-like structures. Where the two previous sketches work with idea of externally perceiving the building as a complete volume, as one shape, the idea of ill. 42 is more to decompose the arena in its different parts and functions, and there through having simpler shapes.

On ill. 43, the sketch consists of three compositional elements; a large roof and a bowl-shaped volume which is wrapped by some type of semi-transparent surface. As ill. 42, this sketch works with the idea of separating the elements of the arena and simplifying the geometry.

This investigation was very free and quick, but gave an opportunity to discuss and try different shapes and concepts. At this point it was clear that in order to start designed and working with the geometry of the arena, the seating bowl and its design needed to be further investigated in order to understand the interior dimensions and there through what the skin and shape of the building should comply.

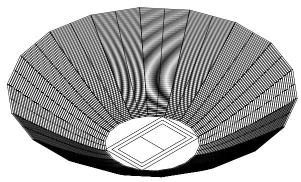
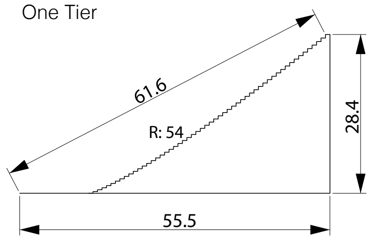
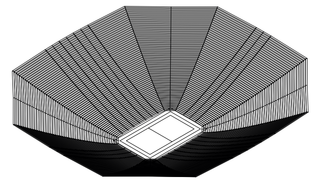
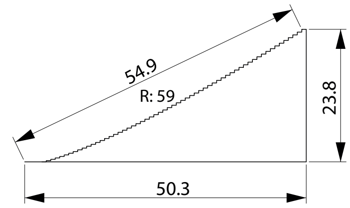
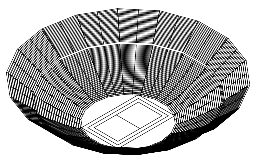
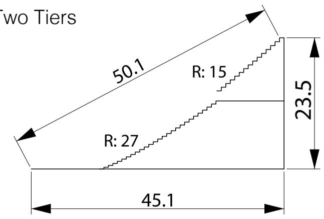
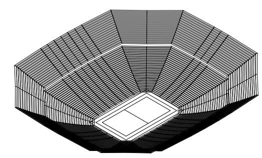
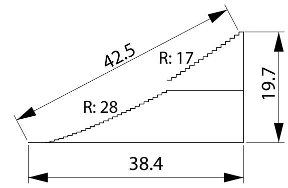
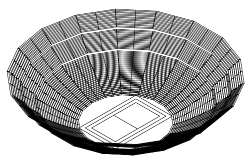
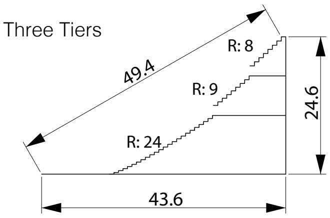
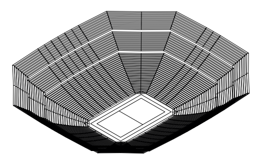
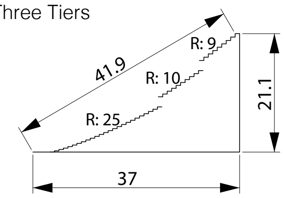
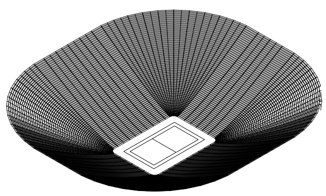
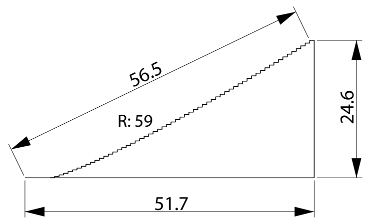
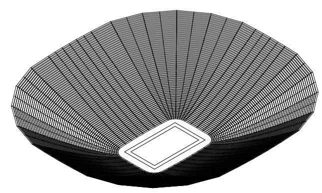
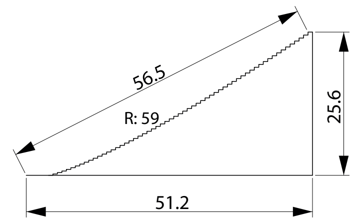
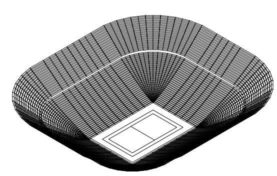
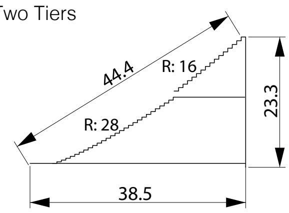
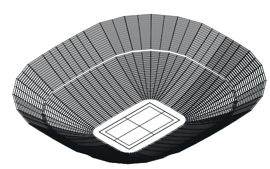
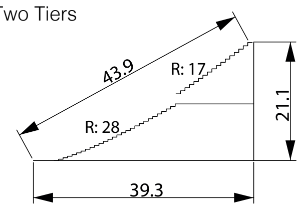
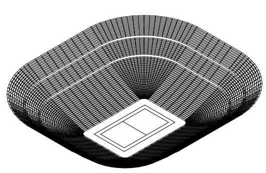
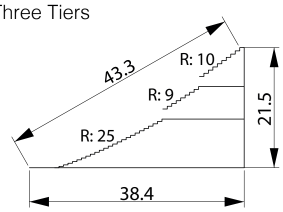
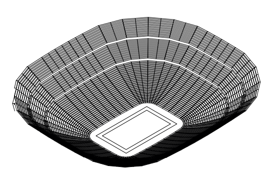
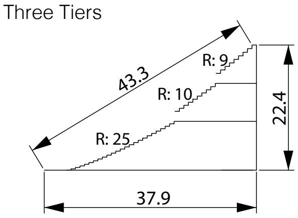
The seating bowl

This phase worked from the beginning on mainly two scales. One being the overall master plan and volume studies, while the other one was the opposite working inside out. The seating bowl is the largest element of the building and the geometry and configuration is essential for the design of the arena. Since the ambition of this project is to design an arena capable of accommodating big sport events and facilitate great atmospheric experience with the sport. The bowl design is therefor a central element and very important factor for the design of the arena.
To understand the optimum distance from the last row of spectators to action, also called the viewing distance. Specialist and theoretical ideas of the human perception are researched.
Based on the stadium typologies shown in previous chapter (See page 42) the investigation focused on several parameters such as sight C-values), proximity to the field, height of bowl and acoustic performance.

With the amount of 15,000 spectators; four bowl typologies are compared by the number of tiers, which refer to how many levels of spectators placed above one another. The three tiers are; Single-tier, double-tier and triple tier.

Through this study, it is important that spectators are brought as close to the action as possible so an interaction between spectator and the game is present. Danish Architect Jan Gehl talks about human interaction as something everyone seeks towards. *"Eyesight: Although vision is a long range-sense, humans need to get relatively close to perceive details, atmosphere and facial expression"* (Livet mellem husene, 2000). While Gehl mainly operates within an urban scale, his studies in how people recognize each other is relevant because of the scale of the arena. According to Gehl at 80 meters distance you can register sex, age, while it's impossible to see who the person is.
At 50 meters, you begin to recognize people. At 20 meters, you see nuance: facial features and hairstyle, this is where the experience of the person gets interesting. At 7 meters, you can contact others, start conversations and other senses complement our sight with emotions and moods. And finally, at 3 meters, ordinary conversations, intensity and experience are enhanced. (Livet mellem husene, 2000). With this in mind the seating bowls on ill. 44 is analysed.

A single tier design is usually the best in terms of accessing and exiting a arena, but with the large amount of spectators it issues a long distance from the last row to the focal point of the playing field. Here the double and triple tier show significant improvement by allowing the curvature of the tiers to become steeper while still allowing optimal C-values. The circle shaped bowl allows optimum cohesion by surrounding and directing the spectators towards the playing field compared to the more edgy polygon bowl but shows the best results in distance to the playing field. The rounded rectangle and the curved rounded rectangle are very similar, and create almost the same result in terms of distance, but the curved rounded rectangle bowl geometry concentrate the seats in a better position towards the field.

Isometric view	Distance to back row	Isometric view	Distance to back row
Circle  Spectators: 15,038	One Tier  C-Value: 120mm	Curved Polygon  Spectators: 15,254	One Tier  C-Value: 120mm
Circle  Spectators: 15,010	Two Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm	Curved Polygon  Spectators: 15,040	Two Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm
Circle  Spectators: 15,029	Three Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm, Tier 3: 150 mm	Curved Polygon  Spectators: 15,022	Three Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm, Tier 3: 150 mm
Rounded Rectangle  Spectators: 15,034	One Tier  C-Value: 120mm	Curved - Rounded Rectangle  Spectators: 15,072	One Tier  C-Value: 120mm
Rounded Rectangle  Spectators: 15,020	Two Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm	Curved - Rounded Rectangle  Spectators: 15,018	Two Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm
Rounded Rectangle  Spectators: 15,025	Three Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm, Tier 3: 150 mm	Curved - Rounded Rectangle  Spectators: 15,018	Three Tiers  C-Value Tier 1: 120 mm, Tier 2: 150 mm, Tier 3: 150 mm

Ill. 44: Seating bowl investigation

Acoustical investigation

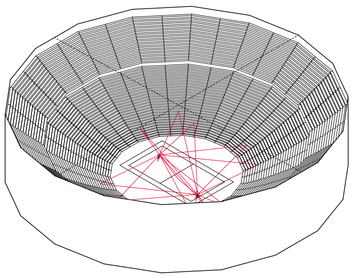
In order to verify and begin understanding the bowls geometries influence on the acoustics of the arena, three of the bowls from previous bowl investigation were analysed in acoustic-simulation software, Pachyderm. The bowls analysed was the circular bowl, rounded rectangular bowl and polygon shaped bowl.

Pachyderm has been used to measure two acoustical characteristics, the reverberation time (T30) and speech intelligibility (D50). The three simulations have been conducted in the same way and with the same material settings in order to make the only variable the geometry of the bowl. The set-up for the simulation has been following: Spectators to athletes and athletes to athletes. For the first, position of source and receiver was a midlevel placement to central competition area and a man shouting from the tiers. For the second, position of source and receiver was at the competition area, end corner to end corner to understand player to player communication.

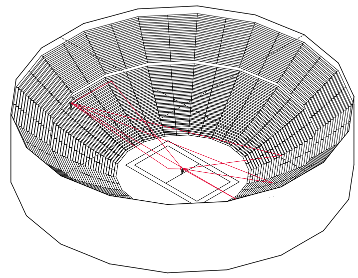
In speech intelligibility from spectators to athletes the circle and the rounded rectangle turned out to be the two most efficient bowls where the polygon bowl significantly would need improvements.
For reverberation time the circle bowl creates a high reverberation time in the 500 hz and 4000 hz range where Polygon bowl comes out just a little better reverberation time than the rounded Rectangle. The rounded rectangle and polygon shape shows they both have good performance in different frequencies.

With an overall view of the three bowl: The rounded rectangle shows good results, and together with the results of the previous bowl analysis, is therefore the bowl which the project proceeds with. The aim is to reach a minimum of 70% in speech intelligibility and a reverberation time with in 2.1-2.4 second, so further improvements is necessary. Optimal distribution of sound reflection is necessary as well as elimination of echoes. Parameters to improve would be highly absorptive finishing material and diffusion surfaces are required to eliminate detrimental reflection.

Athletes to Athletes

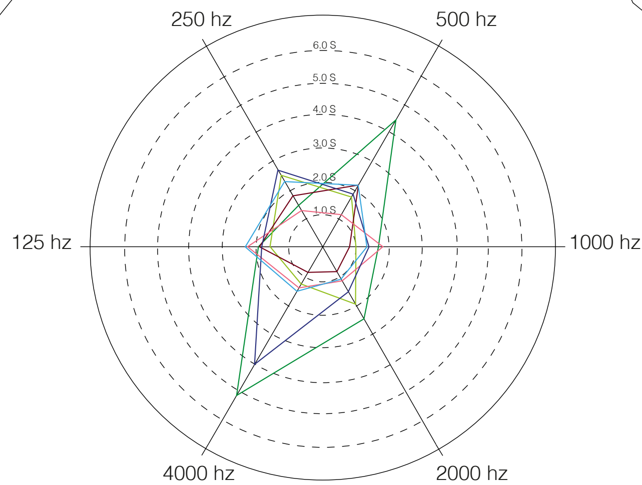


Spectators to Athletes

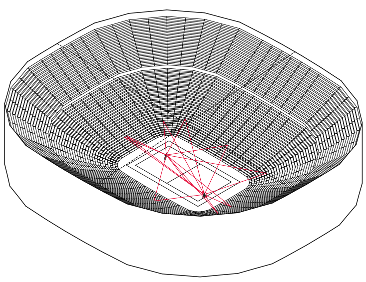


Circle

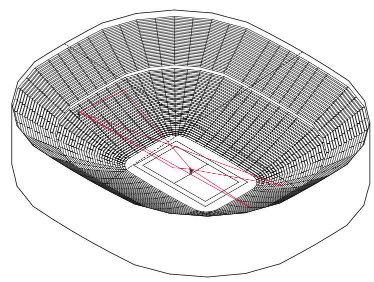
Reverberation time: T-30



Athletes to Athletes

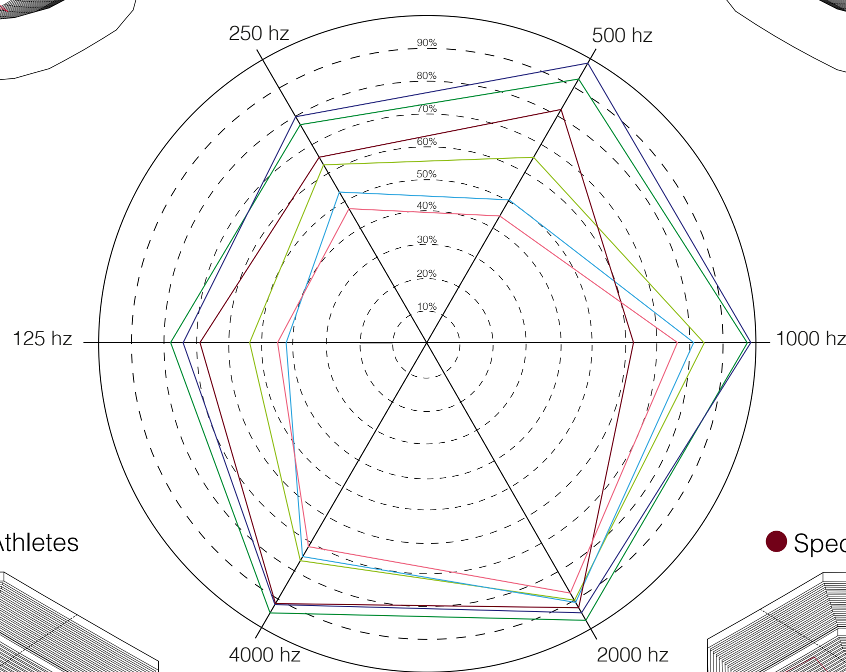


Spectators to Athletes

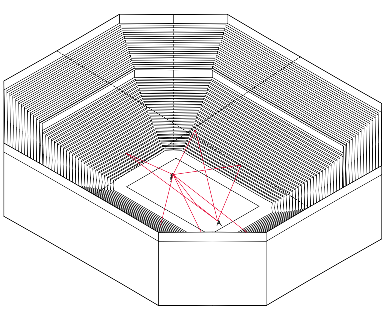


Round Rectangle

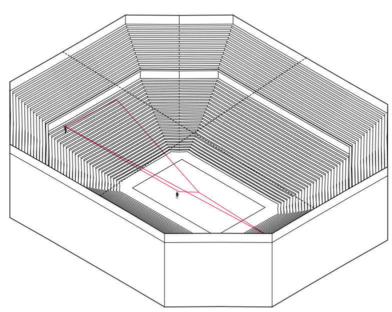
Speech intelligibility: D-50



Athletes to Athletes



Spectators to Athletes



Polygon

Ill. 45: Acoustical investigation

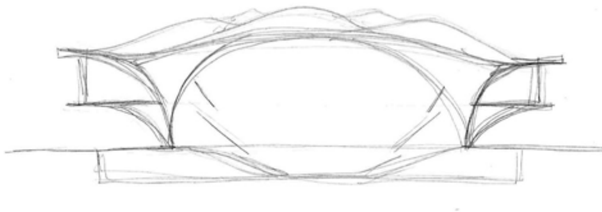
Conclusion on Phase 1

The studies conducted in the first phase of the design process gave an understanding of how to organize the layout of the functions according to three main users, the spectators, the athletes and the press. The sketching and volume studies was very freely, but started a discussion and development of how a design of the arena could be. The investigation of seating bowl typologies and the following initial acoustical investigation made the different bowls comparable based on the demands and criteria for the Ariake Arena. This gave the project an overarching interior seating bowl design, which made it possible to start working on plan-layout, but also gave an understanding of the actual size and scale of the arena according to the capacity of 15.000 spectators.

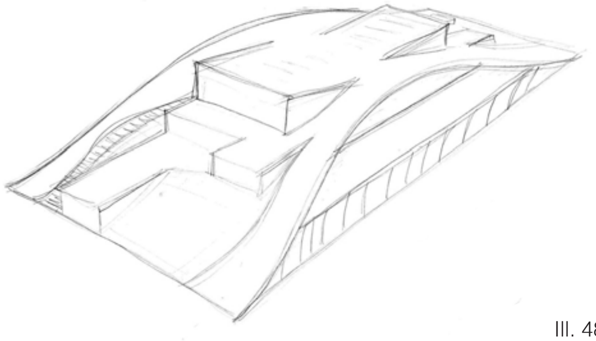
Phase 2

PART ONE		PART TWO	
PHASE 1	PHASE 2	PHASE 3	PHASE 4
Sketching Modelling Parametric model Acoustical analysis	Sketching 3d model Concept Structural concept Midterm	Sketching 3d model Structural analysis	Detailing Final calculations & simulations

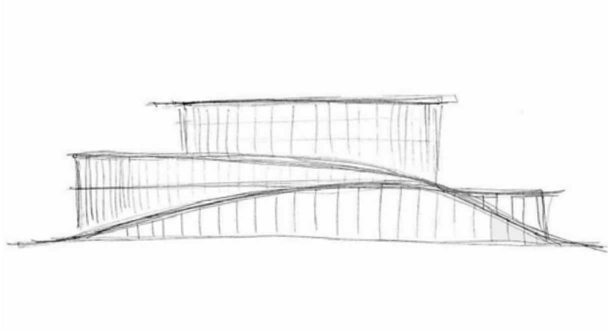
With the discoveries of the first phase in mind, the second phase of the design process was about developing a building- and site concept. The definition of a seating bowl made it possible to sketch more precisely and understand an approximately dimension of the arena. The second phase ends with the midterm review.



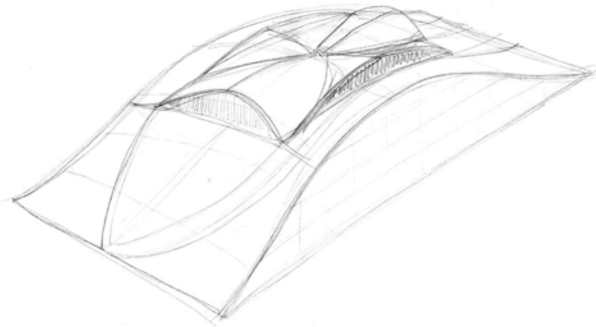
Ill. 46



Ill. 48



Ill. 47



Ill. 49

Concept development

With the previous phase working with the seating bowl and interior proportions of the arena, this phase sought to develop a concept able of combining this with the idea of creating an urban dynamo with quality outside space and room of different activities.

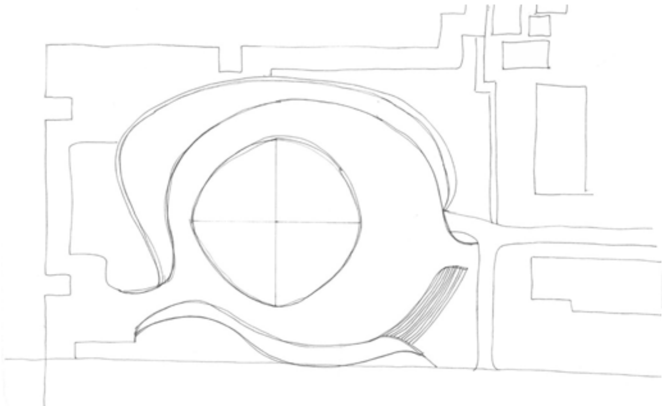
At this point in the process the ideas of breaking down the building in different volumes, working with levels and podiums and highlighting the different elements of the building was central for the design development.

On ill. 46 a sectional sketch shows a building with a hilly landscape on top. Together with ill. 47-49 these illustrate a concept developed at this stage, about seeing the arena as a piece of artificial landscape, a hill. Hereby the idea of working with podiums and urban recreational spaces are taken to an extreme.

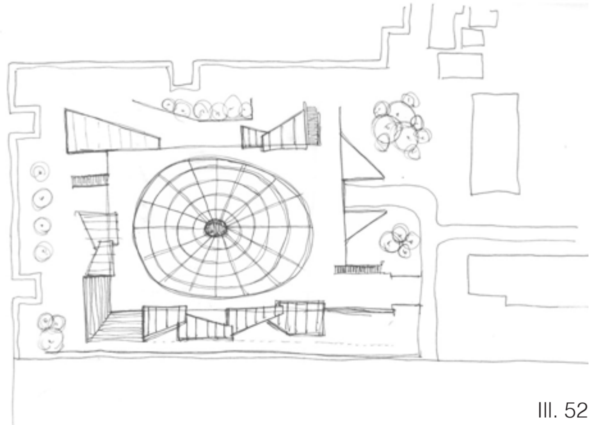
On ill. 47 several volumes are creating this urban landscape, but the buildings are more pronounced than previous idea. Hereby different terraces and levels are created on the roof.

The isometric drawings of ill. 48 and ill. 49 works with a walkable roof, while the two other facades reveal the building and gives access to sunlight. In relation to the idea of creating an urban dynamo for recreational purposes, this concept of placing the building under or in relation to a hilly urban landscape is sympathetic. But with the size of the interior seating bowl and site, unless the building is placed many levels underground, the inclination of the slope will be difficult to use and for some difficult to access.

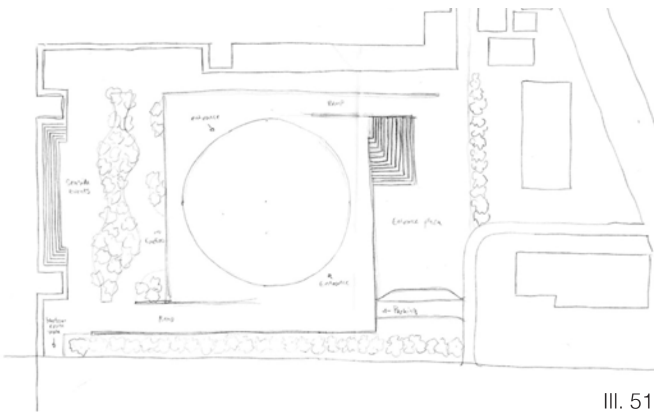
This idea was set aside, and working with podiums instead was central for the next sketches. On ill.



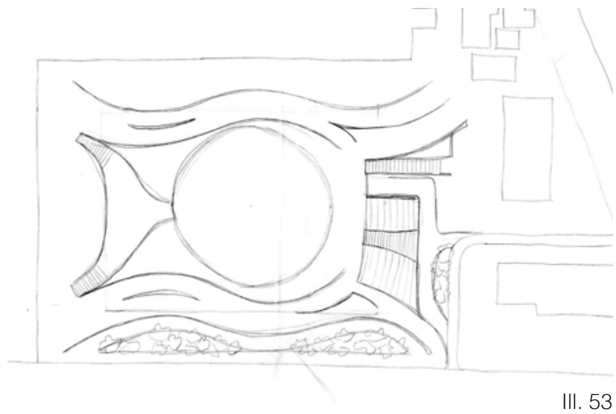
Ill. 50



Ill. 52



Ill. 51



Ill. 53

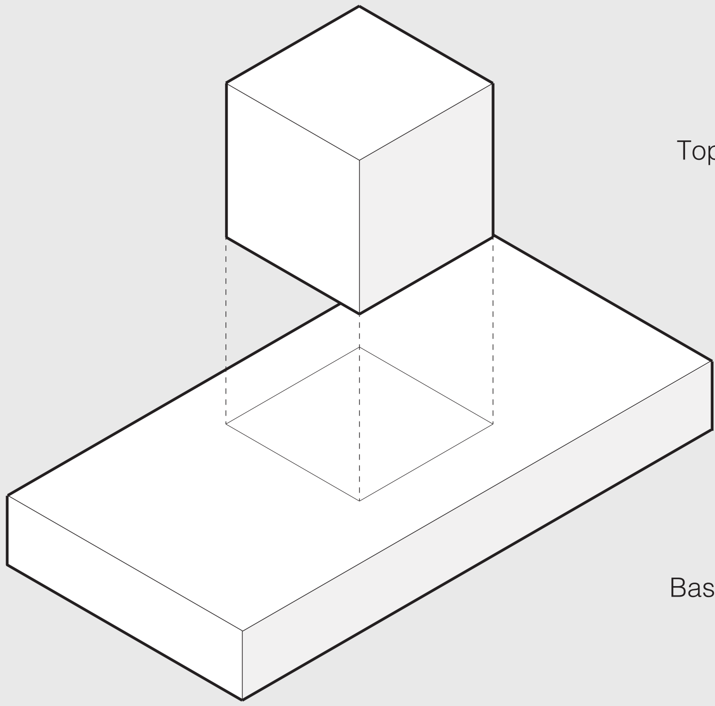
50 several circular shapes creates three levels with the top of arena sticking out as the highest placed. A large entrance to the podium is placed at the south-west end and another at the north-western end of the site.

On ill. 51 the sketch works with a more clean geometry than the previous. Here two elements are placed, a square base with a ramp at the southern and the northern side of the shape, and a circular top. Despite the simplicity, the clean shapes together with the ramps creates a dynamic, quite effortless, and also an order of the site.

On ill. 52, a organization and geometry similar to sketch 51, is added with a number of triangular smaller volumes. The intention here is to create space for shops, restaurants, sheltered spaces along the ramps leading to the arena. Hereby a small city of functions is created around the arena, creating a dense area of activities, almost as with urban structure known from medieval city centres. This is also another way of staging to act of arriving at the arena, making it an experience.

The last sketch shown in this phase, ill. 53, combines different aspects of the last three sketches in a more fluid and dynamic shape. Here the shape of the different volumes and podiums are appearing to be cut out of the same shape.

These last sketches became central for the development of the actual architectural concept for the arena. Working with podiums, ramps and several levels is efficient in breaking down the scale of the building, but also creating and defining different urban areas around the building.



Ill. 54: Concept

Concept

The concept of this project is to create a new stadium which foremost will be an urban intervention and regenerate the Ariake Neighbourhood as an attractive recreational hotspot in human scale. The Ariake Arena as a complex will be multifunctional by allowing space for restaurants, shops, office, and centrally, public outdoor spaces, which often is a scarcity in metropolis, in close connection to the arena, making the area active and interesting also when no games are played.

Secondly the actual stadium will be monofunctional in terms of the pit, which is designed for giving the best possible experience of Volleyball and similar sports, but multifunctional in terms of designing the arena also capable of accommodating public use as a gymnasium.

The concept can be seen in three strategies:

1. Urban dynamo.
2. Allowing the public in.
3. Best possible architecture for Volley ball.

Ill. 55

Ill. 57

Ill. 56

Ill. 58

Structural concept

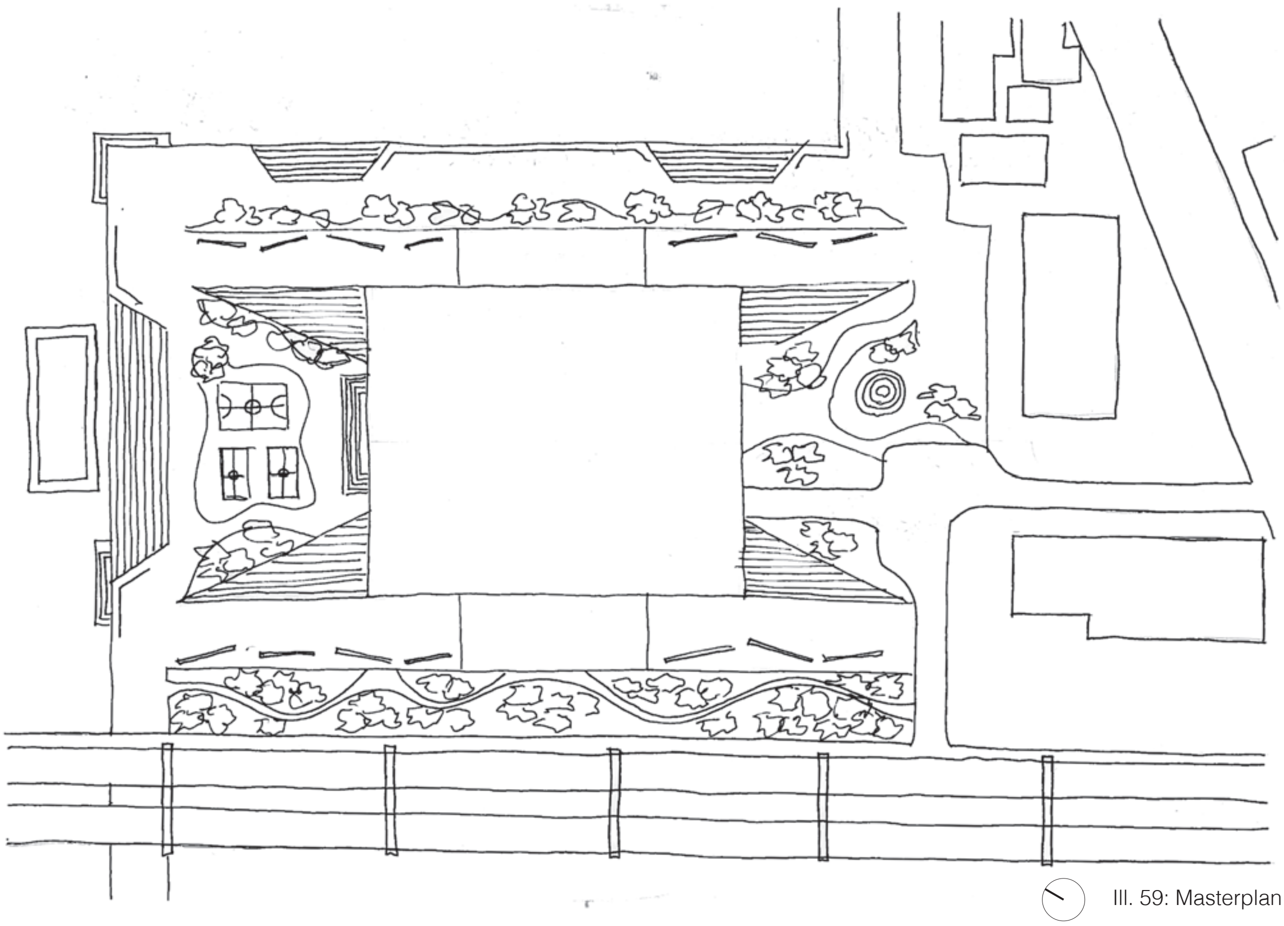
With the choice of a seating bowl typology, a development of a vision for the masterplan and an overall concept for the stadium, the criteria's, demands and role of the structure begin to take shape. Therefore, the next part of design process started as an investigation on which structural system and concept that could accommodate both the more tangible requirements, should as acoustics and spans, but also the vision of creating an arena rooted in Japanese tradition and culture.

The acoustic investigation suggest that we need a roof capable of absorb and diffuse the sound to achieve a lower reverberation time. At the same time the structure should be able of spanning 100 meters in order to avoid any columns in the seating bowl.

At this point in the process, the idea of doing a wooden construction is prevailing. This is because of the tendencies for the Tokyo Olympics about sustainability and also the Olympics Stadium by Japanese architect Kengo Kuma will be done entirely in Wood. But also because of the vast tradition of Wood work in Japan. So, this was the base for investigating different structural systems.

The before mentioned Kengo Kuma stadium (ill. 55) will structurally be of a wooden grid truss system and consist of large elements. But for the concept of a "top" or almost a crown for the building the idea of an additive and parametric structural system is interesting. The illustration 56-58 shows different examples of this. Illustration 56 is a wooden structure in Sevilla, called Metropol Parasol, consisting of vertical wood plates intersected in 1,5x1,5 m grid, ensuring rigidity. The impressive scale and shape of the structure demands a lot of special elements, since not two are the same. But as a system capable of large spans and could work acoustically as the project requires. On illustration 57 and 58 we see two different examples of additive wood structure which as a system is quite traditional in a Japanese context. They both rely on the concept of stacking elements according to where the most forces run. Hereby a very simple system, not relying much on one joint, but having a better distribution of forces and in smaller scale examples can be built without specialized elements or joints.

As a structural principle, the structure on ill. 58, became subject for further investigation to see the potential in larger scale.



Ill. 59: Masterplan

Midterm

For the design development, the midterm review forced the design to be formulated and illustrated quickly. For the process the pressure of presenting the current design, made it necessarily to address many different aspects of the design simultaneously. Also, this design seeks to embody the concept together with the structural concept for the first time.

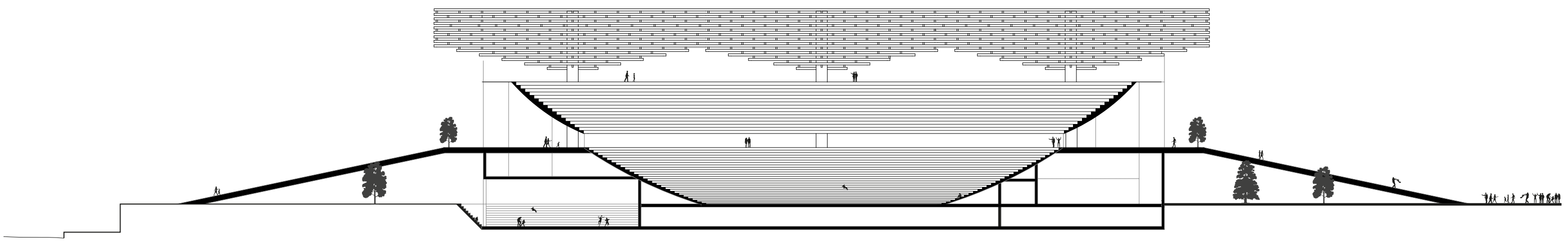
The design presented and illustrated on 59-61, seeks to shape the concept of a bottom, acting as an urban landscape, and a top gesturing the arena, which uses the structural system, as a crown.

The masterplan on illustration 59 shows how the arena is centrally placed with the square roof. Two ramps and podiums on both side of the square connects the ground with the entrance to the seating bowl, which is in the middle of the bowl. (see ill. 60) On the northwest side and the southeast side of the building two urban plazas are created. The southeast plaza is thought as an entrance to the area, here heavy transport can arrive and access the parking basement and large crowds can gather before entering the arena. The northwest plaza is thought as an active area for outdoor sports and is closely connected to the recreational waterfront.

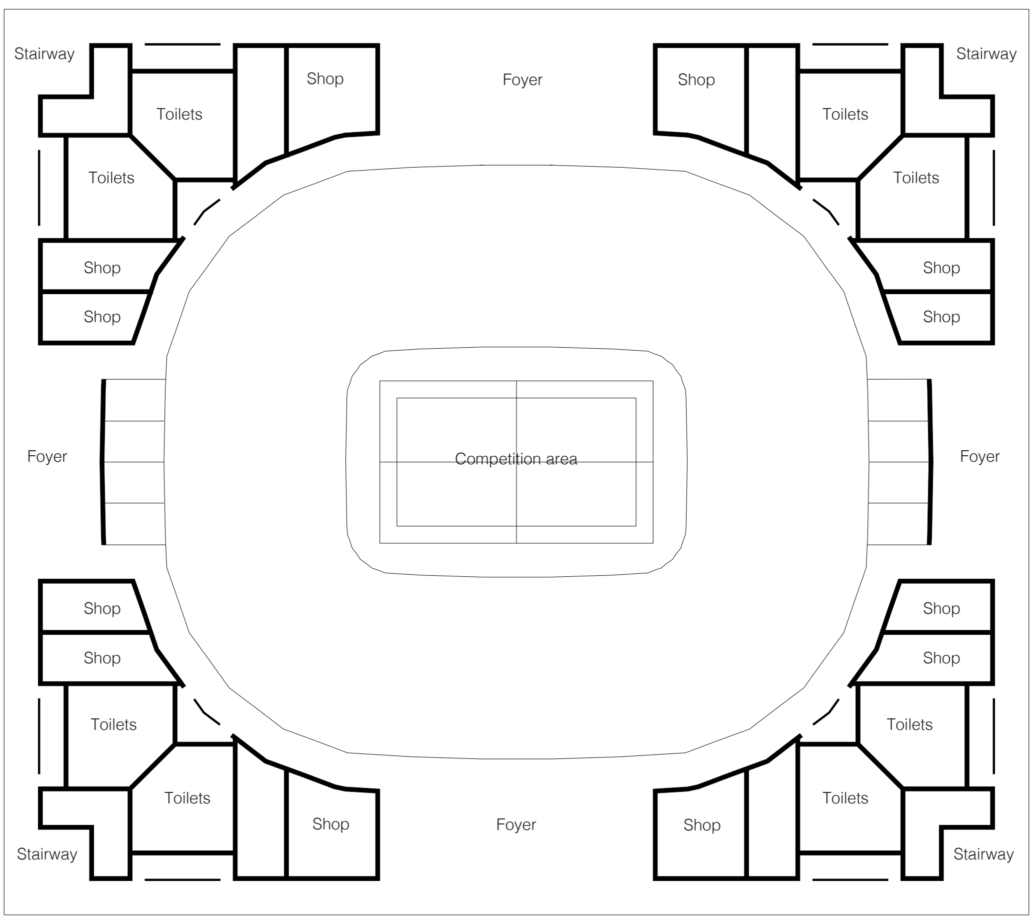
The site has a pedestrian and bicycle connection under the highway towards west, and this will be an important connection to the site for softer traffic both during the games and after. Following this, the design of the masterplan also offers a waterfront capable of seating, water activities etc.

On illustration 61 the entry-level plan is displayed. Here the ideas from the flow investigation of spectators on page 59 is interpreted by creating two foyers which naturally becomes the concourse, offering vendors, bar, ticket sales etc. Two main flows for the spectator are the concourse and the passage following along the façade of the building. From here the corners of the arena, which serve the vertical flow can be reached. Another main idea behind the distribution of the plan is to create views not only to the field, but also towards the city and outside under breaks or when no games are played. This transparency should not only encourage city views, but also make it possible for passer-by's the get a glimpse of what is happening inside.

The design at the midterm-review became central for the further redevelopment of the design and concept.



Ill. 60: Section



Ill. 61: Concourse plan

Conclusion on Phase 2

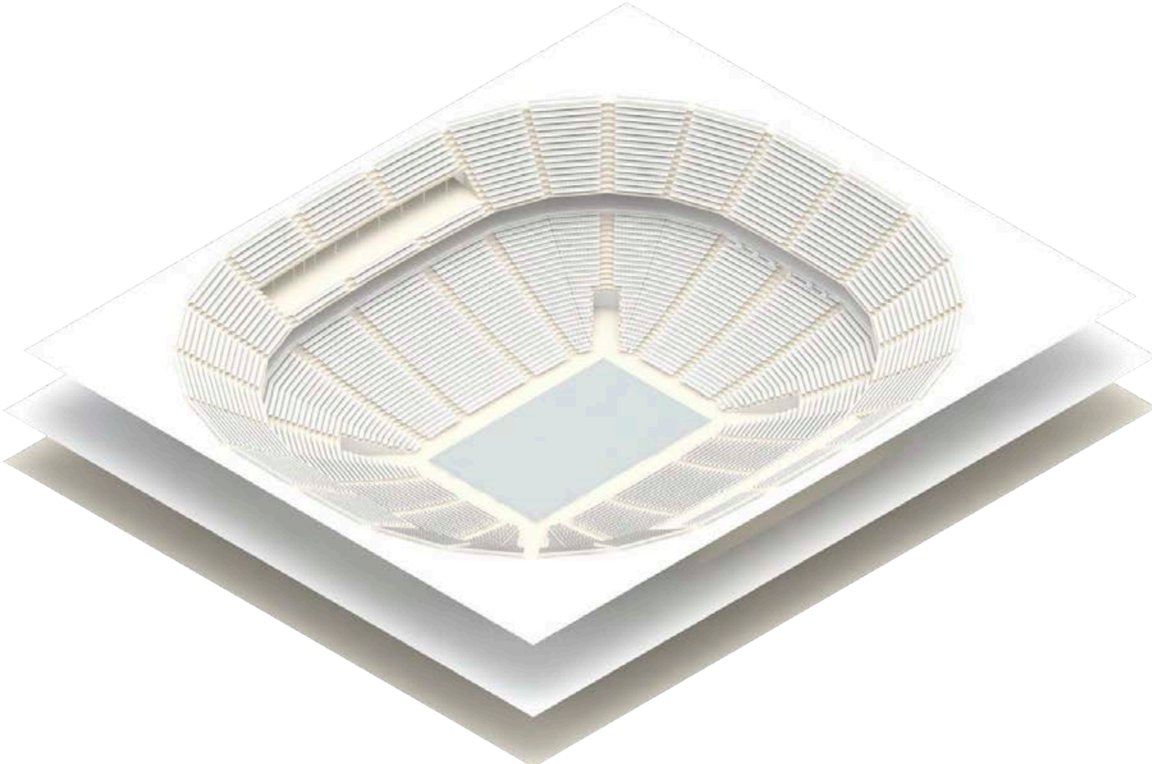
The second phase worked with sketching and concept development, and together with the mid-term review it demanded the group to visualize the thoughts and concepts. The sketching further investigated the idea of podiums and split levels of the Arena, an idea which was generated in previous phase. Eventually this laid the foundation for the overall architectural concept, working with a base, an urban landscape, together with a top, which was the actual arena.

This phase also developed a structural concept, which with the tectonic understanding and the different technical demands in mind, showed potential for the Ariake Arena. To sum up, the phase generated a lot of central ideas for the project, and created the need for many future iterations.

Phase 3

PART ONE		PART TWO	
PHASE 1	PHASE 2	PHASE 3	PHASE 4
Sketching Modelling Parametric model Acoustical analysis	Sketching 3d model Concept Structural concept Midterm	Sketching 3d model Structural analysis	Detailing Final calculations & simulations

With a concept for the building, the site and the structural system in hand, the third phase of the design process sought out to further investigate this in both functional, aesthetical and technical manners.



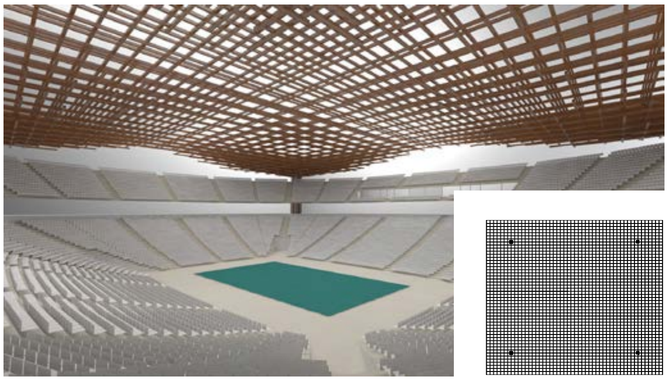
Ill. 62

Plan & flow

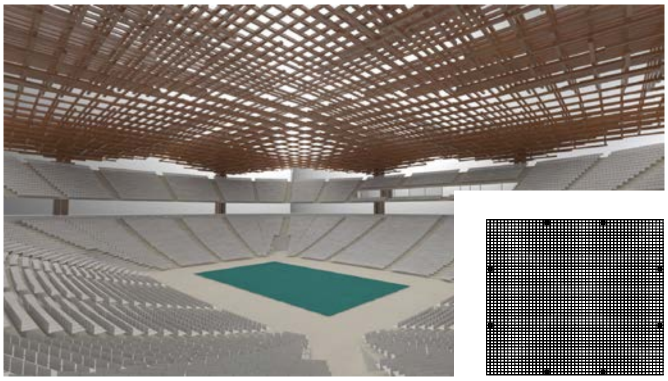
Until this point in the design process the plan have been on diagrammatic level. In this phase, the seating bowl and plan are further detailed according accessibility, functions, movement of spectators and regulations as fire, logistic and safety. The two-tier design of the bowl allows an open concourse design in between the tiers. The concourse will work as the main entrance, create 360-degree view of the playing field, easy traffic movement, keeps fans connected through out the game and creates an ideal platform for concession stands, restrooms and merchandise. This will allow spectator to have visual sightlines back to the action, while they for example buy food.

For the seating bowl; A more detailed scheme of how spectators arrive to their seats are applied, by adding clear continuing ails up through the two tiers and according to our past research from page 43. Openings that allow access to the ground level there usually athletes and officials operate from are cut into the bowl in each corner to create symmetry. VIP, press boxes for officials are cut into the upper bowls, which allows them some of the best seats in the arena.

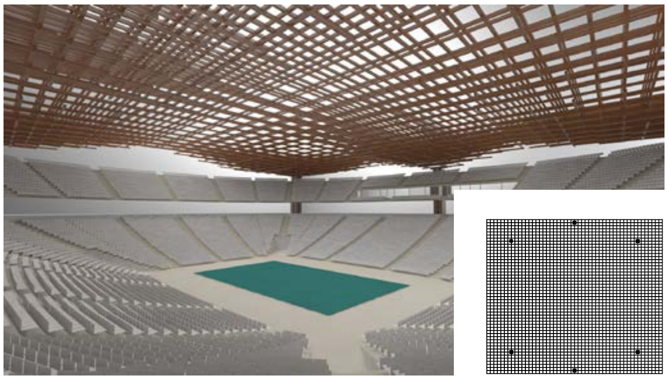
This further detailing of the interior changed the layout of floors, height of the building and the necessary span of the roof among other things.



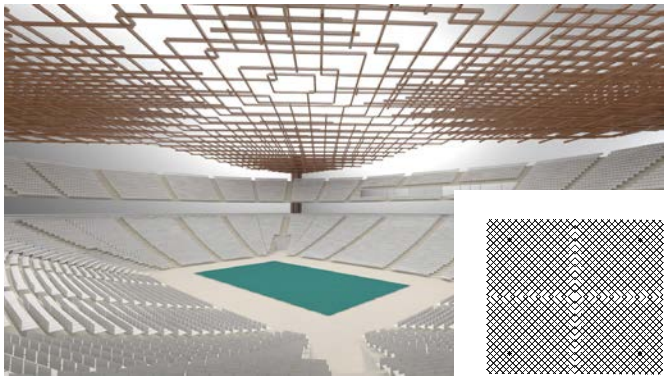
Ill. 63



Ill. 65



Ill. 64



Ill. 66

Structural investigation

The structural concept which was created and visualized for the midterm review, is still on an early stage. In the following, the potentials of the structural principle were further investigated through a number of different variations. This investigation was conducted according to the functionality and aesthetic values of the structure.

The structure is generated from the same grid, but by placing the columns and thereby how the structure expands and in how many steps.

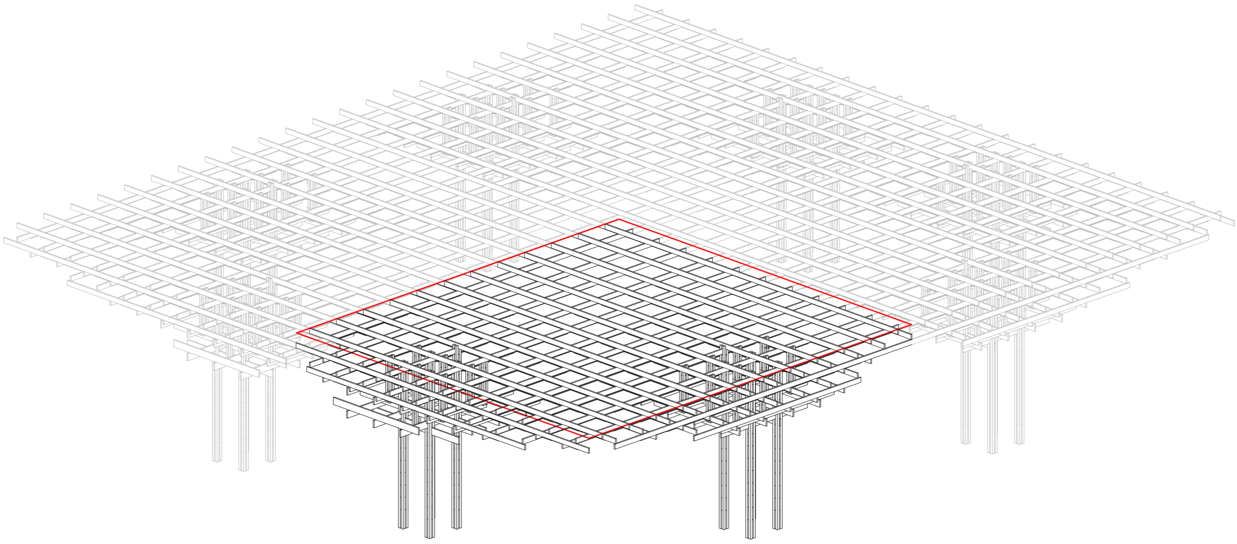
On ill. 63 there is one columns in each corner of the arena, resulting in long spans between the columns. In this cases, the columns will be at the same area as the vertical flow cores, and therefore the structure and the flow will follow each other.

On ill. 64 six columns, three on each side, follows the curvature of the seating bowl. This results in more arches and an overall denser grid. By having longer spans on each short side of the seating bowl, a sense of direction is created.

On ill. 65 a total of eight columns are placed. At each side of the seating bowl two columns are placed, creating eight arches, but different from the previous illustrations leaves the corners without a column. This makes the structure lighter in the corners and breaks away from the very defined overall square. Structurally this gives smaller spans than the previous variations and possibly a stronger structure. In terms of functionality this makes the spaces larger and higher where you enter the top level from the stairs and elevators in the corners.

On ill. 66 the direction of the grid is rotated 45 degrees and as the first illustration in this investigation, there is a column in each corner. At the outside of the structure the effect is interesting, but will also result in larger spans because of the diagonal direction of the grid.

The investigation shows the plasticity and many possibilities of the structural principle. For the next iterations, the system of ill. 65 is further investigated.



Ill. 67: Section of structure

Initial structural calculation

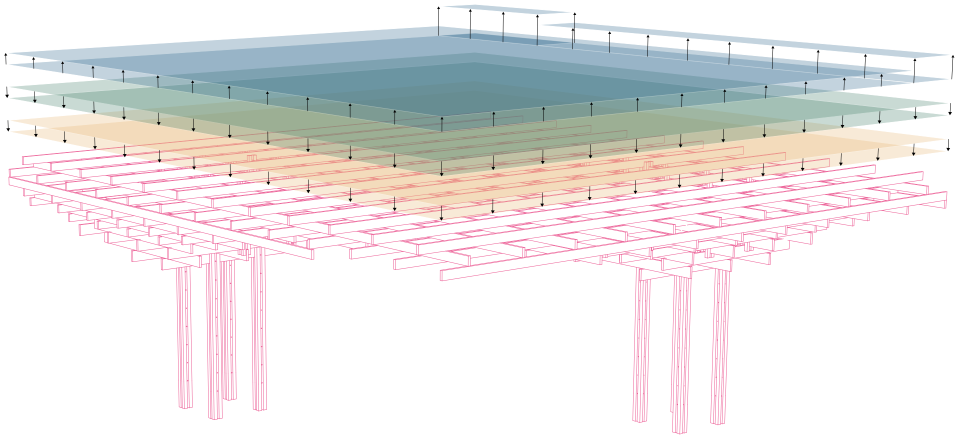
Can it hold? That's the central questions since this structural system has not previous been used or seen in a large scale or in this specific constellation. As previous mentioned, this principle has been translated into a structure working as a system with several columns.

From the previous aesthetical and functional studies (See page 77), this investigation start to analyze how the structure behaves with applied loads.

Since the structural system consists of a large number of elements and the scale of the entire structure will challenge the FEM software, but also make it more complex to work and adapt the system, it is chosen to calculate and investigate one fourth of the structural system. The section consists of 2 columns and a total span of 55x60m. The idea for the system is that, despite the individual parts are assymetrical and have large cantilevers, by connecting several parts, the structure will works as a system by stabilizing itself.
So, for the section that is investigated supports are added the beams that will meet up the next section. The system is divided into a large number of segments that is defined by every time elements meet.

Inspired from a traditional Japanese cantilever structure: the system consists of stacked beams stepping down to 2 main base columns. Distributing the forces from the top, down to the meeting point of the columns. For each layer of steps up through the system the beams are rotated and offset.

The geometry of the structural system is modelled and generated from a Grasshopper script combined with curves from rhino and exported from



Ill. 68: Loads on structure

grasshopper to Robot SA for calculations through Grasshopper plug-in, Gh2Robot.

The entire structure is made and calculated as Glulam. Glulam is chosen because of the potential large element dimensions, but also for its strength.

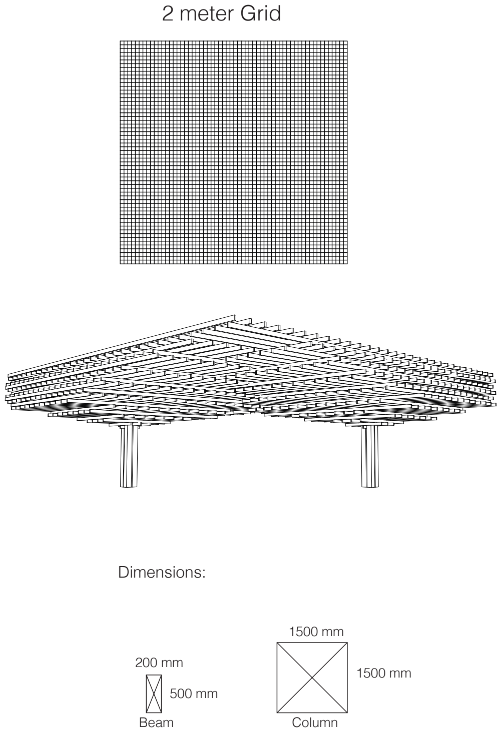
Loads
In order to begin calculating and understand how the structure will behave, the loads affecting the structure has been calculated. (See ill. 68).
For the load calculation see appendix 3.

The loads affecting the system are a self-load from the light roof ontop of the structure, ia snow load and a wind load. The wind load is quite high compared to the other loads.

Since the facade its selfbearing and enclosed the wooden roof structure, the calculations does not include lateral loads.
All loads are calculated to a line load that fits the structural systems grid length. Loads applied for the final structural system, 5-meter grid size calculated into line loads;
The wind loads will affect the roof and structure in three loads zones, resulting in;
Wind load 1: -6.041 kN/m, Wind load 2: -10.356 kN/m and Wind load 3: -15.53 kN/m.

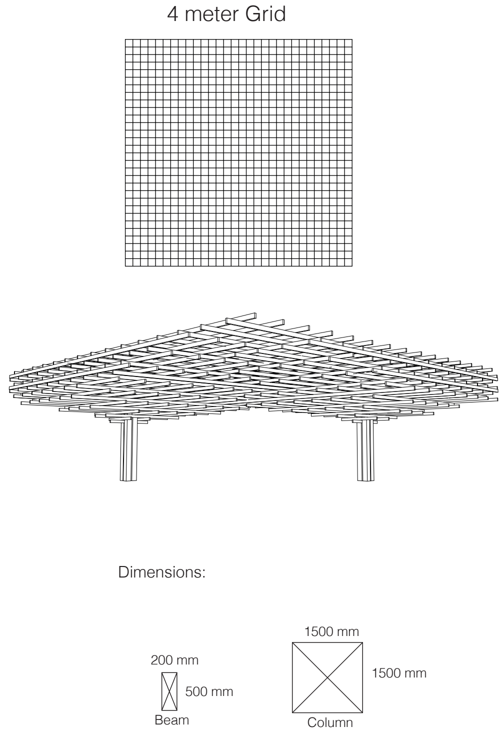
Snow load: 1,38 kN/m
Self-load from the roof: 3,5 kN/m
Structure Self Load

This is the foundation and basis for the following structural investigations.



Steps (Height): 18
Element amount: 1378
Ratio above 0.99 (%): 82

Ill. 69



Steps (Height): 18
Element amount: 5033
Ratio above 0.99 (%): 39

Ill. 70

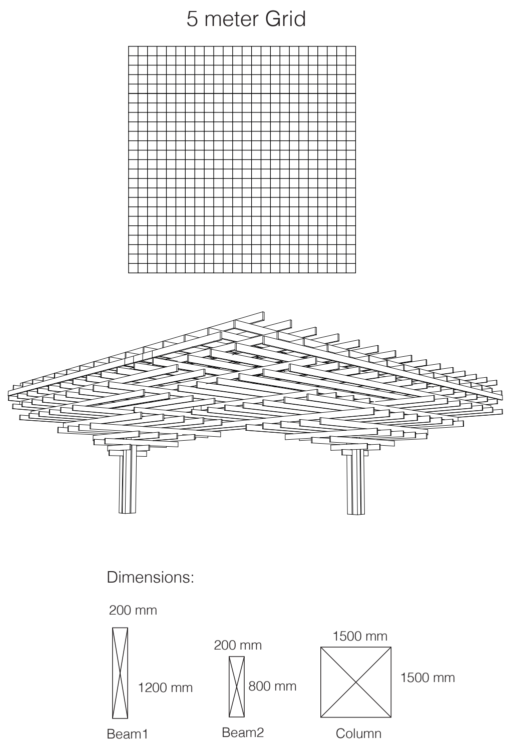
Structural investigation: Grid-size

The ill. 69-72, shows experiments with four different types of grid sizes. For each investigation the illustrations indicate; steps in height, dimensions, element amount and percentage of elements above 0.99 in ratio, in order to compared the results to one another.

The two first iterations, ill. 69 and 70, the only difference is the grid sizes. Shifting from a 2-meter grid (Distance between beams in same layer) to a 4-meter grid minimizes naturally the element use by half the amount and create a much higher percentage of beams that hold.

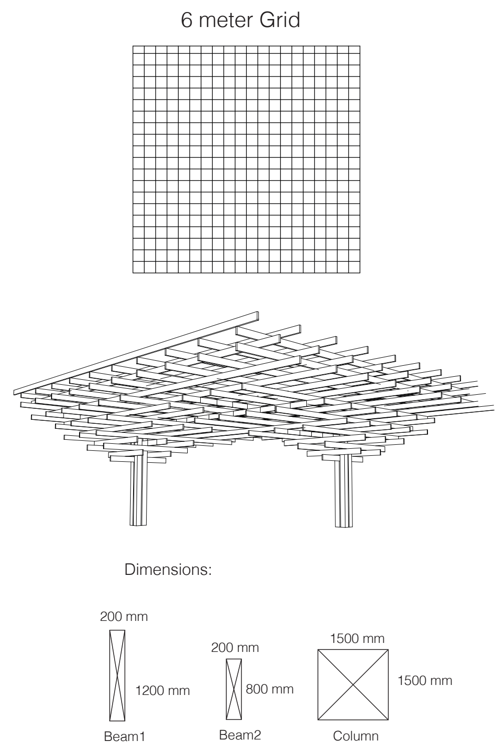
The analysis shows that the self-load of the structure is the main problem and especially the beams centred around the columns are main issue, because all forces leds through them. Also the beams connecting to the next “section” of the structure are affected, and for the two first iterations it shows that they aren’t strong enough to hold the stress from the supporting points.

For the next two iterations, ill. 71 and 72, the grid size was increased to a 5 meter and a 6 meter grid and with a gradient dimensioning of the beams, so stronger beams are applied, especially around the



Steps (Height): 14
Beam 1: 4 steps
Beam 2 10 steps
Element amount: 3039
Ratio above 0.99 (%): 19

Ill. 71



Steps (Height): 14
Beam 1: 4 steps
Beam 2 10 steps
Element amount: 1448
Ratio above 0.99 (%): 32

Ill. 72

centre of the columns and where most stress travel.

Where increasing the grid size from a 2-meter grid to 4-meter grid improved the structure, this iteration shows that the 5-meter grid size system in this constellation works better than the 4-meter grid, but the 6-meter grid performs worse than the 5-meter grid. Therefor, the 5-meter grid structurally distributes the forces better through the steps than the larger grid of 6 meter.

Self-weight is the main problem and it is central to create a balance between the dimensions of the beam members and the amount of elements, so it still withstands the applied forces from the calculated loads, and itself.

The 5-meter grid size in combination with a gradiation of beam dimensions was further analyzed in the following investigations.

Ill. 73

Ill. 74

Facade

Throughout the entire design process the facade and external appearance of the building has been processed and discussed. But first in this phase of the design process, the work of plan, structure and sections has been advanced enough, to further detail and work with the facade.

The building concept of working with a top or "crown" with the structural roof system being the main ornamentation of the building, suggest a role of the facade of facilitating the view and understanding of the roof, and therefor also being a structural self-bearing membrane - a separate element. But how should it be done, should it be completely transparent, with some kind of rhythm or something third? This following investigation tries to process that, here illustrated through four examples.

On ill. 73 the façade is vertically divided in 5 meter intervals, which originates from the plan grid. Two horizontal lines runs along the façade, where the two upper levels are. Aesthetically, this gives a high level of verticality to the façade and makes it seem tall in relation to its width. The vertical and horizontal façade lines are here emphasized in the same degree.

On ill. 74 the façade is also from the concrete base and up completely transparent as the ill. 73, but here the concept is to make the joints and connections between the glass elements invisible and there through have a clean transparent surface. According to the idea of the façade being invisible and only facilitating the view inside, this is an extreme response to that. At the same time the idea is

Ill. 75

Ill. 76

that the façade should be a separate element and therefor also independent structurally. This notion is difficult to achieve without any larger columns present.

On ill. 75, the façade works with two concrete bounds horizontally on the façade. Here the bottom and the top of the building begins to appear united. Conceptually this creates a strong design feature, but clashes with the roof structure, which now appears as an extra element and not the main element of the façade.

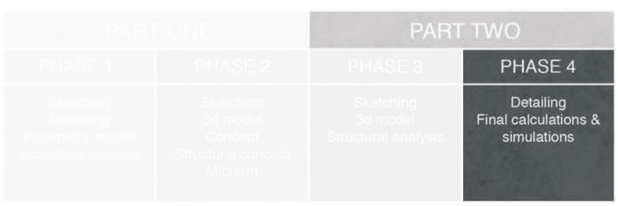
The last façade, ill. 76, goes back to the concept of ill. 73, and uses slender columns to create a rhythm and hierarchy in the façade. Here a column per 10 meter in the façade, makes the perception of the building proportions better, and by adding an extra horizontal line, the façade gets a human scale.

In order to further process the façade design, its central at this point to understand how large the eventual structural columns in the façade potentially would be. Based on the load calculations of appendix 3, an estimate calculation was made in Robot SA for a column supporting 200 m2 glass façade. For the worst area of the building with a dominate lateral wind load, a number of calculations in the software indicated that a HEA 700 steel profile, measuring 300 mm x 690 mm was capable of withstanding these loads. Therefor the concept of ill. 76 was decided to be further processed.

Conclusion on Phase 3

The third phase redeveloped and connected the different aspects of the project into the same concept. The seating bowl and flow was further processed and refined. The structural concept was according to aesthetic and functional considerations interesting for the concept and the arena, but the structural principle which previously never been used in this scale or typology, was more difficult to approach and solve than first anticipated. However, by looking at a section of the structure it became more feasible and the investigations in this phase analysed different aspects of the system.

Phase 4



The final phase of the design process consisted of iterations of many different aspects of the project according to each other, so the final detailing of interior and exterior elements could happen. The structural system was further processed and developed at this stage and this phase includes the final calculations and an acoustical simulation.

Structural dimensioning

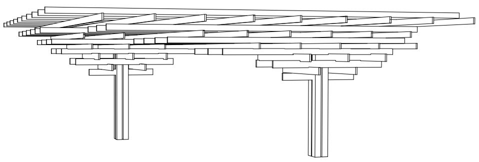
For the next investigation, knowledge from the previous calculations are taking into account by minimizing the self-weight by having less steps in height, different degrees of cantilever at each layer and a more gradient system of beam dimensioning.

By minimizing the steps of the system and changing the gradient of the element dimensions the self-load drops dramatically. The structure on ill. 77 and 78, show how it is possible to improve the structures stability by going from 11 steps in height to 12. Hereby the structure gets more rigid by having more layers and more element to distribute the forces, but the increased self-weight still creates an issue around the two bottom columns.

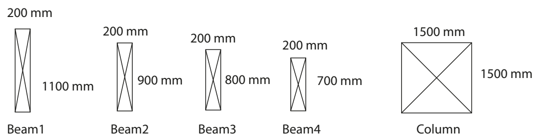
The problem is that all forces are eventually led through the lowest beam and down the column. Therefore the next iteration include more columns, so more beams can distribution the forces down more places.
At ill. 79 two extra columns are added, so the they work two and two. This improves the system, but not sufficient. Therefore the next calculation, ill. 80, includes a total of eight columns, working four and four. This distributes the forces more equally to the mid-centred beam segments and generate less stress around the columns and reduce the maximum ratio and number of elements that will break to a small minimum.

Adding more columns will at this point ruin the two-base system. So for the final phase, stabilizing columns are placed into the grid of the structure to distribute the forces even further. Ill. 81 shows a more random and uneven placement of the stabilizing columns, which show remarkable results. But by organizing the stabilizers, see ill. 82, more evenly the stress around the main 8 columns decreases. Only 0.3 percent is an issue and results with maximum ratio of 1.25. This stresses the importance of the structure, to archieve a good physical balance in order to work efficient.

This is only a small amount of all the different structural systems that has been investigated and calculated in robot. Dimensions of the beams has thought the whole process been big factor and especially the last simulations with the stabilizing columns improved with small steps. Both increasing and decreasing of the beam elements.

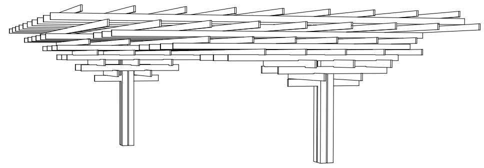


Dimensions:

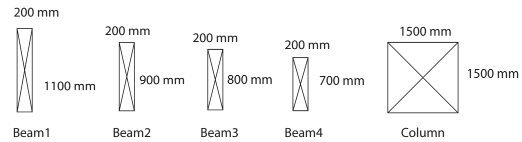


Grid Size: 5 m
Total Steps (Height): 11
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 5 steps
Beam 4: 1 Step
Element amount: 1310
Ratio above 0.99 (%): 14

Ill. 77

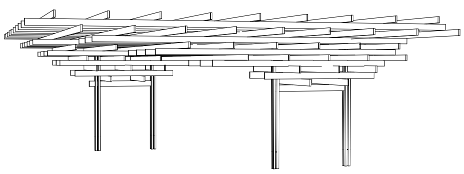


Dimensions:



Grid Size: 5 m
Total Steps (Height): 12
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 6 steps
Beam 4: 1 Step
Element amount: 1591
Ratio above 0.99 (%): 11

Ill. 78



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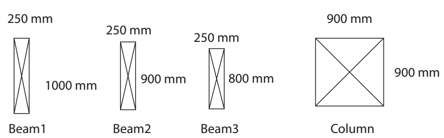
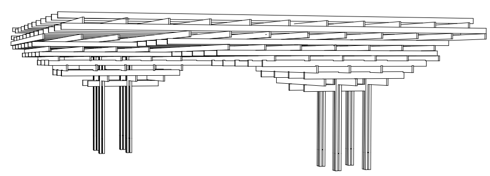


Grid Size: 5 m
Total Steps (Height): 12
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 7 steps
Columns: 4
Element amount: 1628
Ratio above 0.99 (%): 7

Ill. 79



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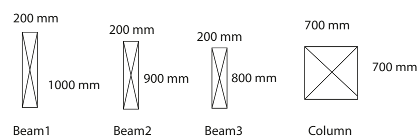
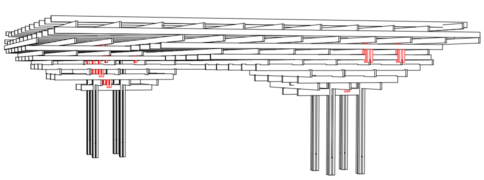


Grid Size: 5 m
Total Steps (Height): 13
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 7 steps¨
Columns: 8
Element amount: 2064
Ratio above 0.99 (%): 3.3

Ill. 80



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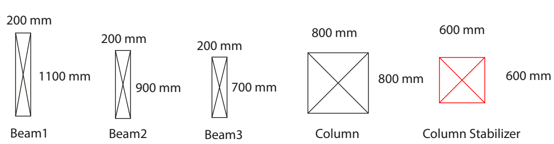
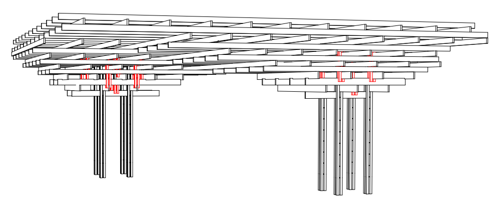
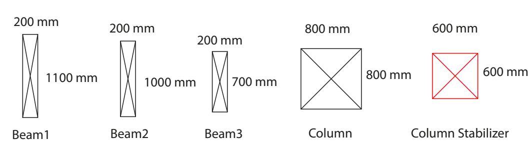


Grid Size: 5 m
Total Steps (Height): 13
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 7 steps
Columns: 4
Stabilizers: 9
Element amount: 2345
Ratio above 0.99 (%): 1.2

Ill. 81

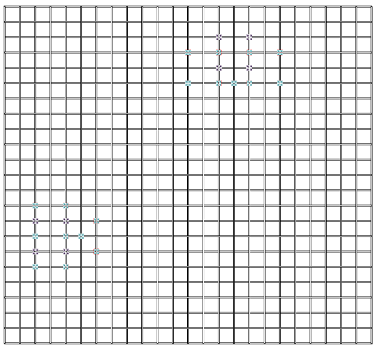


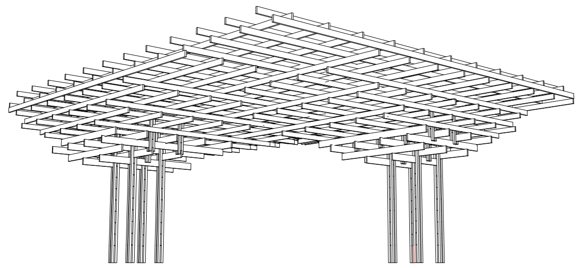
Dimensions:



Grid Size: 5 m
Total Steps (Height): 13
Beam 1: 4 steps
Beam 2: 1 step
Beam 3: 7 steps¨
Columns: 8
Stabilizers: 15
Element amount: 2422
Ratio above 0.99 (%): 0.2

Ill. 82





Ill. 83

Final structural dimensioning

Based on the structure of ill. 82, the last iterations focused on locally inforcing the few beam segments which still continued failed.

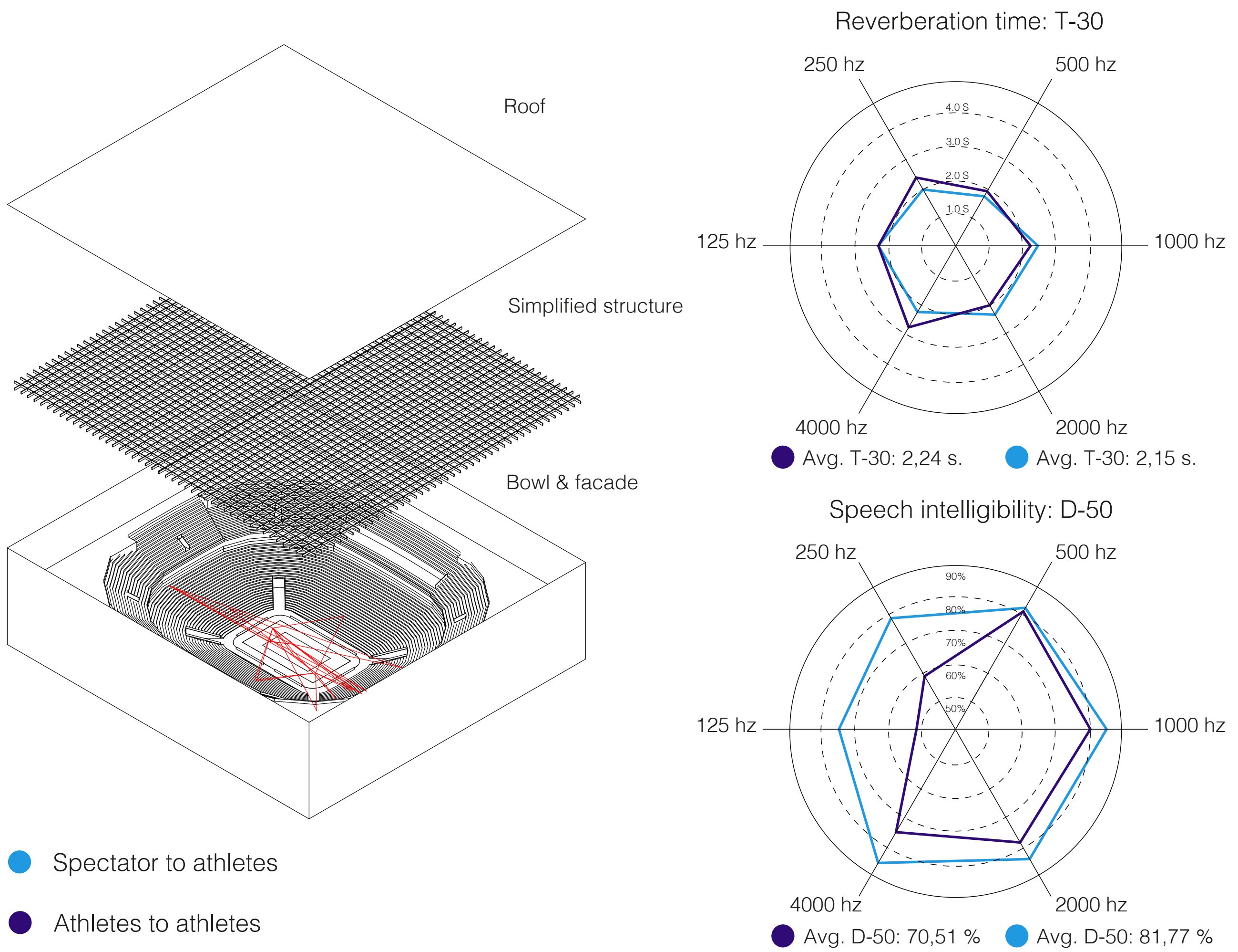
For the final structural system, see ill. 83, the whole system works with no segment above 0.99 in ratio. 10 beam segments are dimensioned individually to allow the ratio to decrease.

This should be further improved, so less difference in the beam size would be present. But this proves that the structure can hold, and the structural principle can be implemented into large-scale buildings where long spans are needed to keep the comfort and user experience intact.

Final acoustical simulations

As mentioned earlier, the acoustics is an important factor for the spectator and athlete experience in any sporting event. Therefore, throughout the design process acoustical solutions has been considered.
For example, is the idea behind choosing the structural system also because of its potential good acoustical performance, that would absorb and diffuse the sound waves up through the stacked beam grid. The placement of the columns, cutting slightly into the shape of the bowl, absorbs and reflects the circulation of the sound. It is important to find the right balance between absorption, reflection and diffusing to reach the desired acoustical goals (See page 51).

For the final phase, the Ariake arena is tested again in Pachyderm acoustical simulation software with the same positions as earlier in spectator-to-athlete



Ill. 84

and athlete-to-athlete. Because of the complexity of the geometry and structure the acoustical model is simplified so pachyderm is able to simulate the acoustical performance. The structure has in this case been defined as a 2.5 m grid in the height of 700mm and located 5 meter under the roof. Because of the simplification, the calculations are generated with 5000 rays, which provides more accurate results.

The different surfaces and elements in the acoustical simulation has been given a material. The floor is a combination of linoleum on concrete and wood, interior concourse walls are concrete, wall openings for spectators and athletes are acoustical diffusers (Schroeder Diffusers), railings and façade is glass, defined more specifically as large panel glass and regular size glass, structure is wood and roof is acoustical absorbed panels (troldtekt). The seating bowl is defined as upholstered seats with audience.

The final bowl simulation showed improving results both for reverberation time and speech intelligibility (see ill. 84). The structural system, installed openings and the column cuts helps the sound waves to be diffuse and spread more equally and prevents the sound to circulate around within the bowl. Small adjustments of the material have been adjusted to reach results within range of the design criteria's.

More simulations throughout the design process could have helped reach a better result especially with the speech intelligibility for athletes to athletes, but due to the challenges with the structural system, fewer simulations was made. It is also worth mentioning that pachyderm acoustics does not handle large volumes as sports arena very well, which sometimes gives different results without making any changes. Therefor results are a more overall understanding of the arenas acoustical abilities.

Conclusion on Phase 4

The final phase of the design process consisted of many iterations because of the high level of complexity and synergy between the different elements of the building design at this stage.

The last iterations on the structure refined the concept aesthetically and eventually also structurally. This final acoustical simulation indicated that the initial thoughts about the acoustical benefits with the structural system, was somewhat true. The reverberation time and speech intelligibility was approved in comparison to previous studies.

The outcome of this final phase was the final building design, which in the next chapter will be further explained and presented.

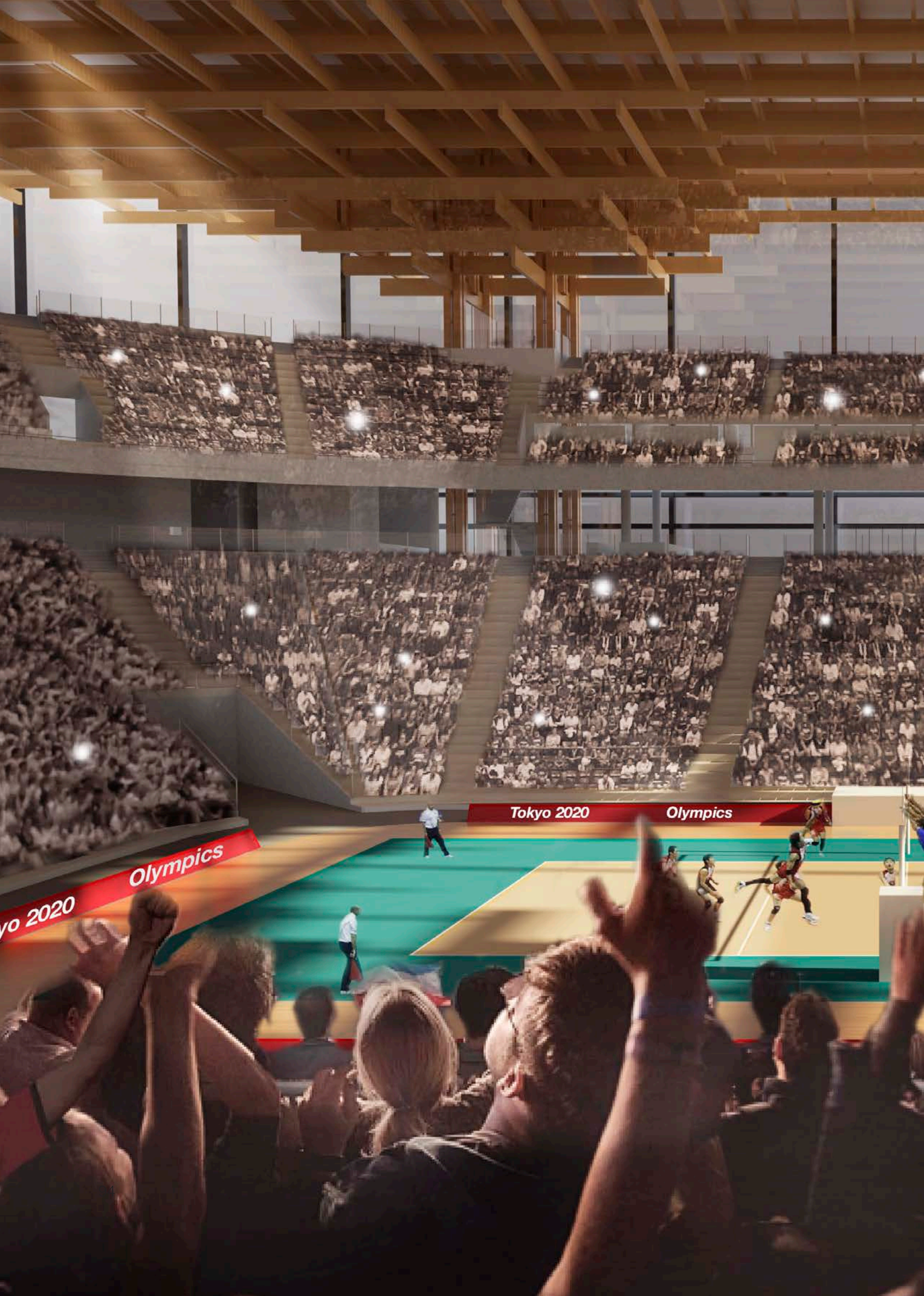
04

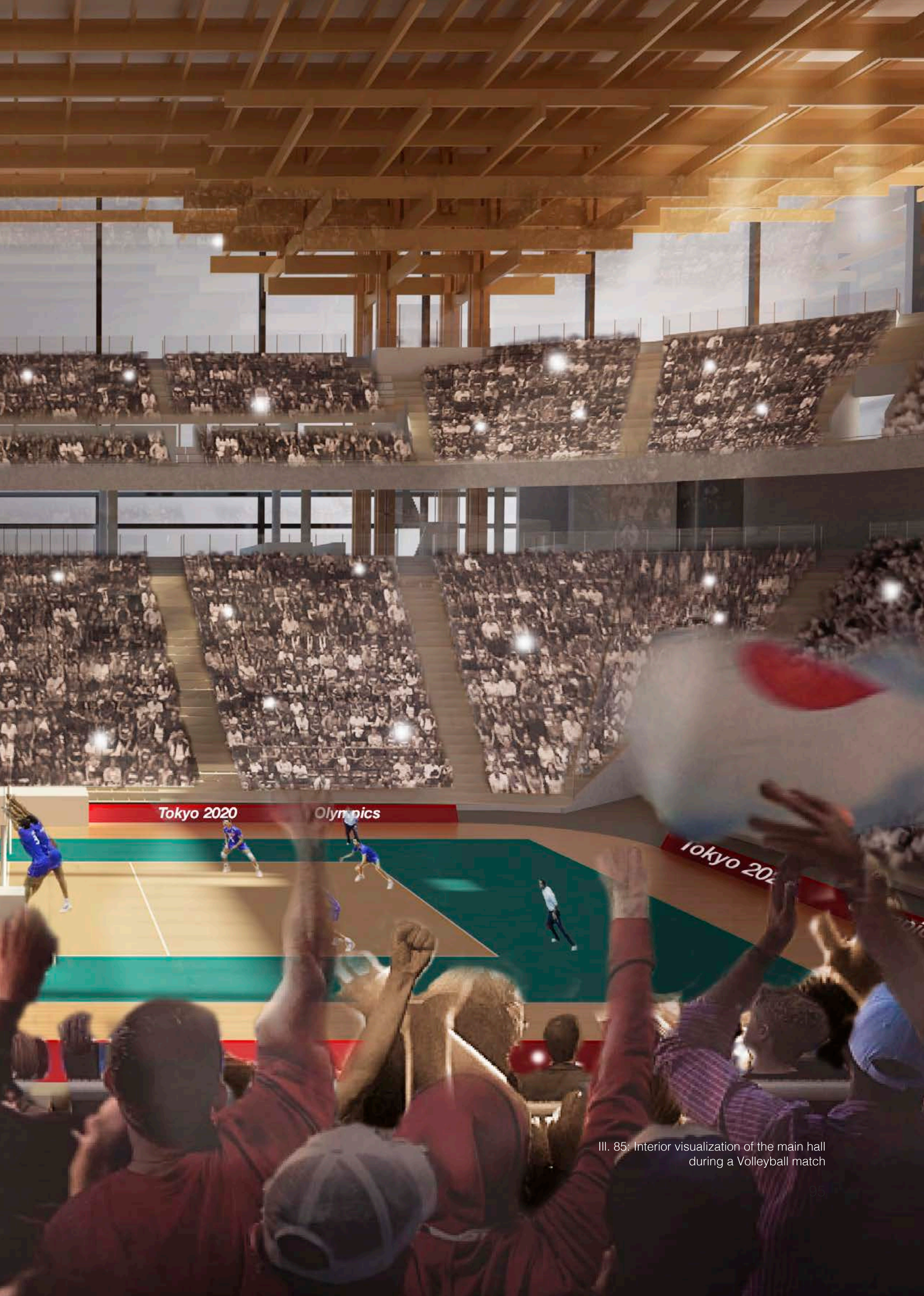
Presentation

プレゼンテーション

The fourth chapter will continue from the last chapter and present the final building through text, diagrams and illustrations.

Attached to the booklet a drawing folder contains presentation drawings in larger formats.


Tokyo 2020
Olympics
Tokyo 2020
Olympics



Ill. 85: Interior visualization of the main hall
during a Volleyball match

Ariake Arena

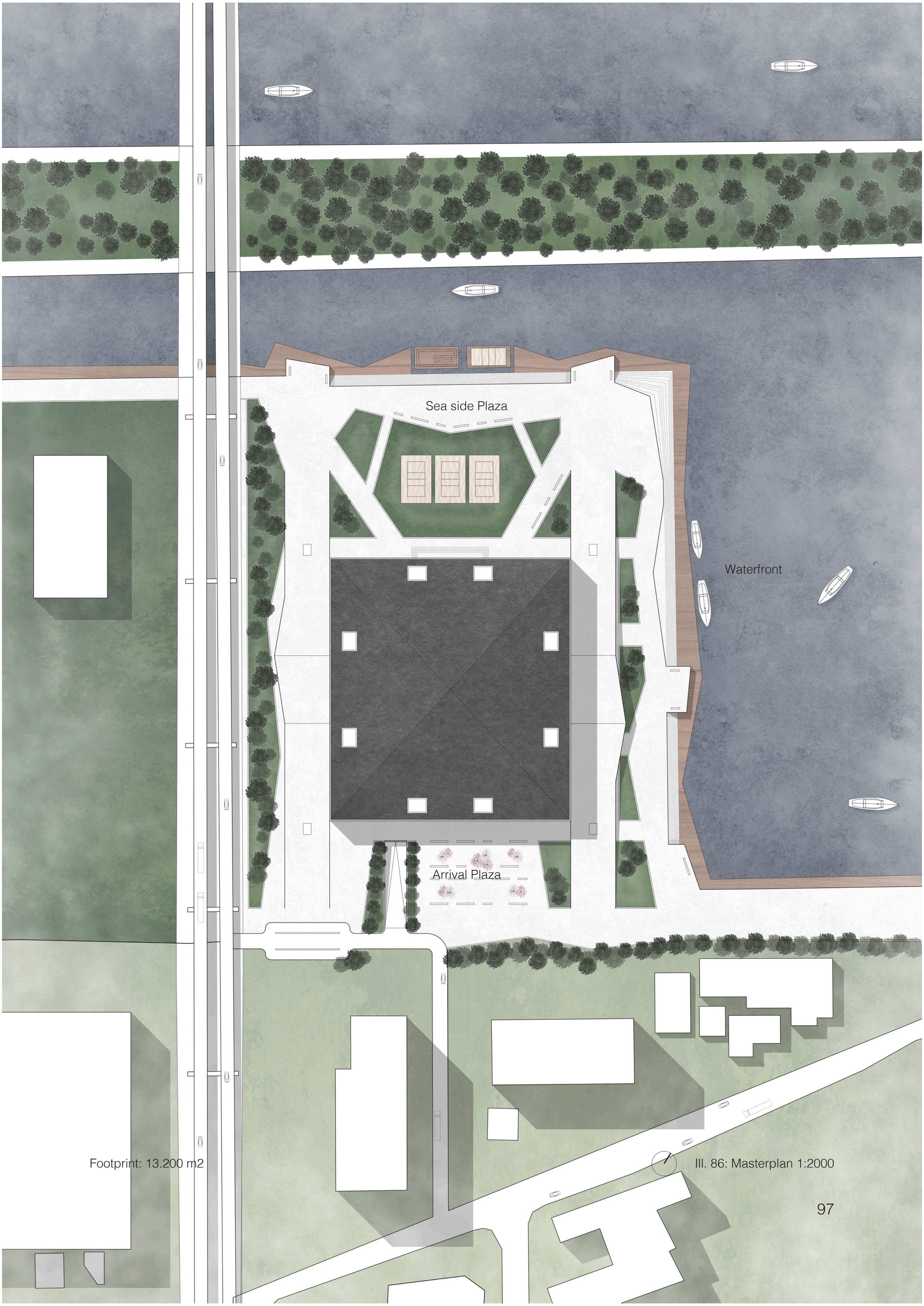
The Ariake Arena is not only an arena, but as well an area which should improve urban life of the Tokyo Bay in different ways. The urban landscape around the arena is inviting, offering several different opportunities for activities or just a quick break from daily life. The arena itself is centrally placed on the site bordered by the two ramps on the south-west and north-east side of the building. This naturally creates two plazas on each side, the arrival plaza and the sea side plaza.

Arrival plaza
The arrival plaza is placed on the south to south-east side of the arena and is the natural arrival place for people arriving with both public and private infrastructure. The plaza offers direct entrance to the public functions at ground level as well as the different internal stairs and elevators.

Sea side plaza
Where the arrival plaza is more formal and designed for flow and accommodating large crowds, the sea side plaza is an active area of the site offering beach volley courts, green zones, seating and a close connection to the waterfront.

Waterfront
The ambition of the project is to create a waterfront accessible for soft infrastructure at this part of the Ariake area. Therefore, the idea is that the layout of the project site should be applied further along the waterfront.
The waterfront operates with different levels offering different types of proximity and interaction with the water.

The ramps
The two ramps offers a progression into the arena, making it possible for the visitor to climb up to the entry level. Underneath the ramps there is a colonnade supporting the ramp, but the intension of these is also to provide the area with sheltered space. The climate of Japan and the Tokyo area offer quite unstable weather conditions, which in summer can be very wet. During these periods the colonnades underneath the ramps together with the public functions of the ground level can be space for events such as food markets, music performances, flea markets etc.



Ill. 86: Masterplan 1:2000

Plan layout

The program and layout of the Ariake Arena offers both optimal settings for professional sport events and community sport and associations, but also events and activities not bound only to sport.

Ground level +0
The ground level of the Arena, can be seen as the buildings machinery but also a public floor. The plan offer functions for both athletes, press, officials, employees and locals.

At the northern part of the building the professional athletes have a zone separated from other users of the building. This includes an athletes lounge, changing facilities, kitchen, doping testing- and first aid functions, and a direct access to the parking basement, warm-up areas and the competition field.

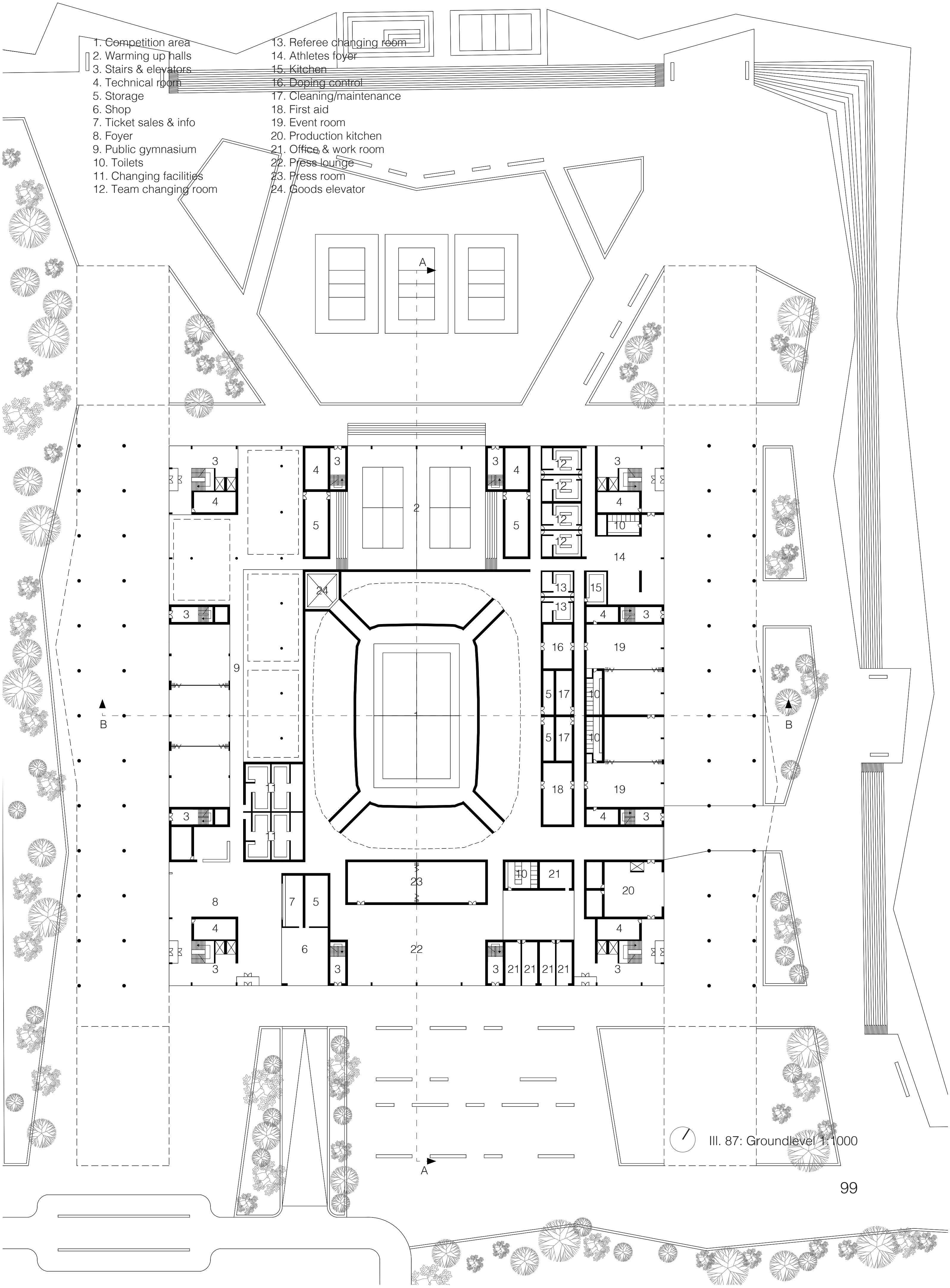
Along the north-eastern part of the building two large rooms offer space for local associations and events as conferences or parties. Directly in connection to these, a large production kitchen supplies the entire building, including the concessions stands on the levels above.

At the south-eastern part of the building, administrative-, and during events, press functions are placed in connection with the Arrival plaza. Here offices, press lounge and press conference rooms are placed.

At the south-western part of the building several public functions are placed. An information desk, in connection to a merchandise shop and ticket sales. Here, also a large public gymnasium is located which both can use the different halls intended for professional use, but also have several rooms and areas inclusively for the gymnasia, making it possible to use this simultaneously with events in the main hall.

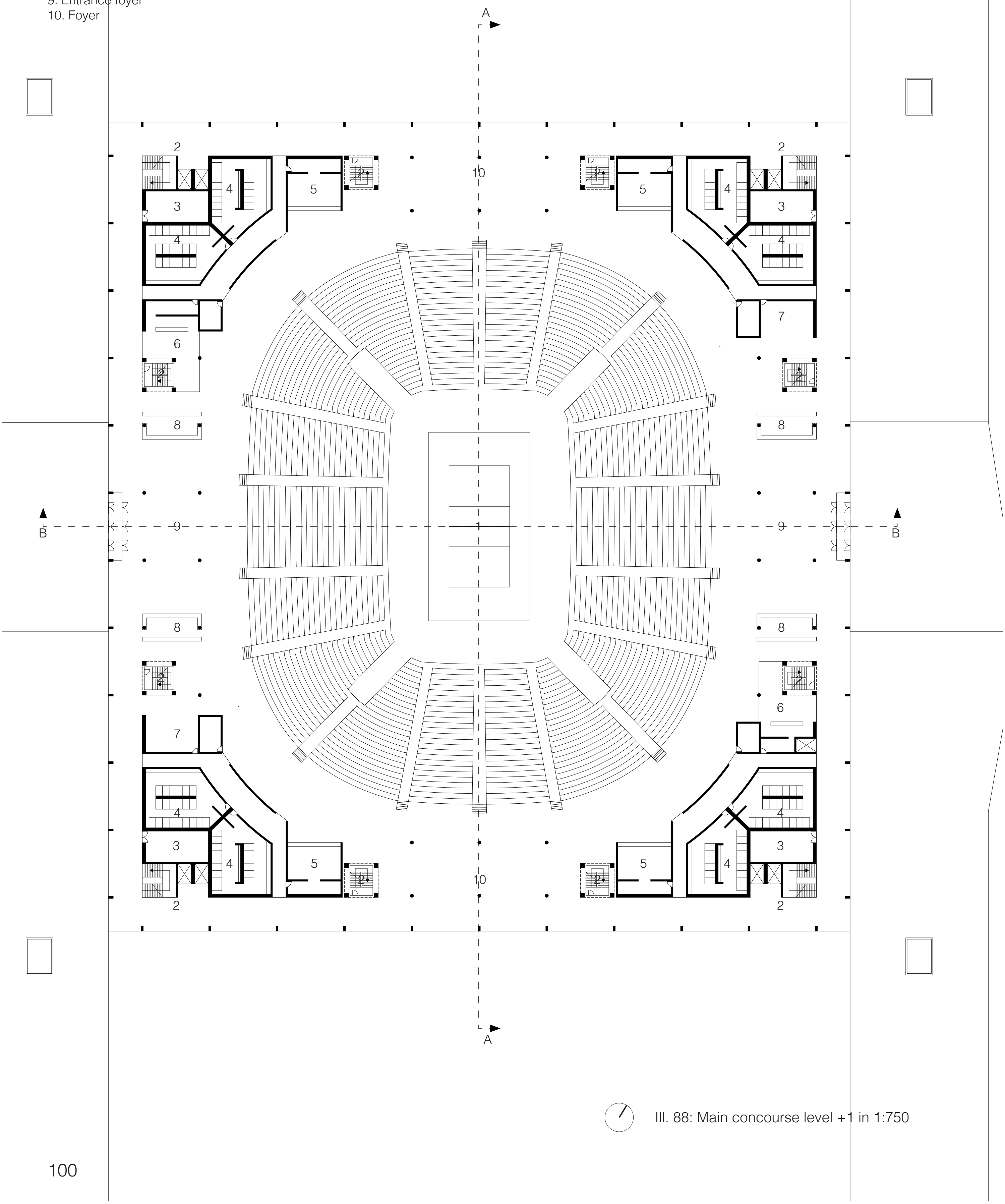
Main concourse level +1
The surface of the ramps evolves into the main course level which offers several foyer areas, concession stands, information desks, wardrobes, shops and toilets. The passage ways and foyers are dimensioned so many spectators and visitors can stay before, during and after events.

Upper concourse level +2
The upper concourse level is arranged similar to the level beneath and offers also concession stands and toilet facilities. Furthermore, a VIP lounge is placed on the long side of the seating bowl containing a closed foyer, bar and eight private lounges. On the opposite side of the seating bowl a similar area is reserved for press and officials. Here reporters and commentators have excellent view to the match.



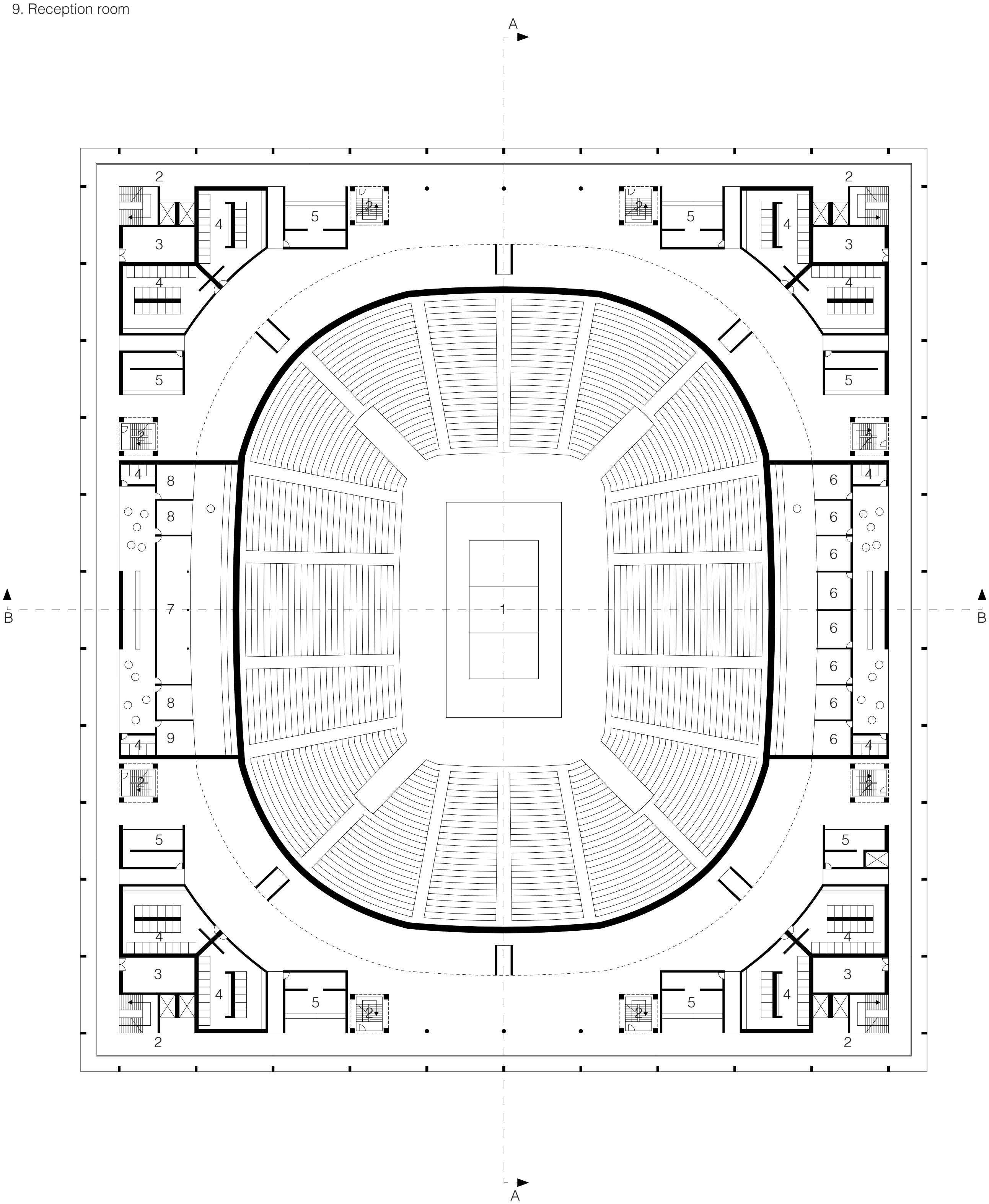
Ill. 87: Groundlevel 1:1000

1. Competition area
2. Stairs & elevators
3. Technical & service room
4. Toilets
5. Concession stand
6. Shop
7. Cloarkroom
8. Information & bar
9. Entrance foyer
10. Foyer



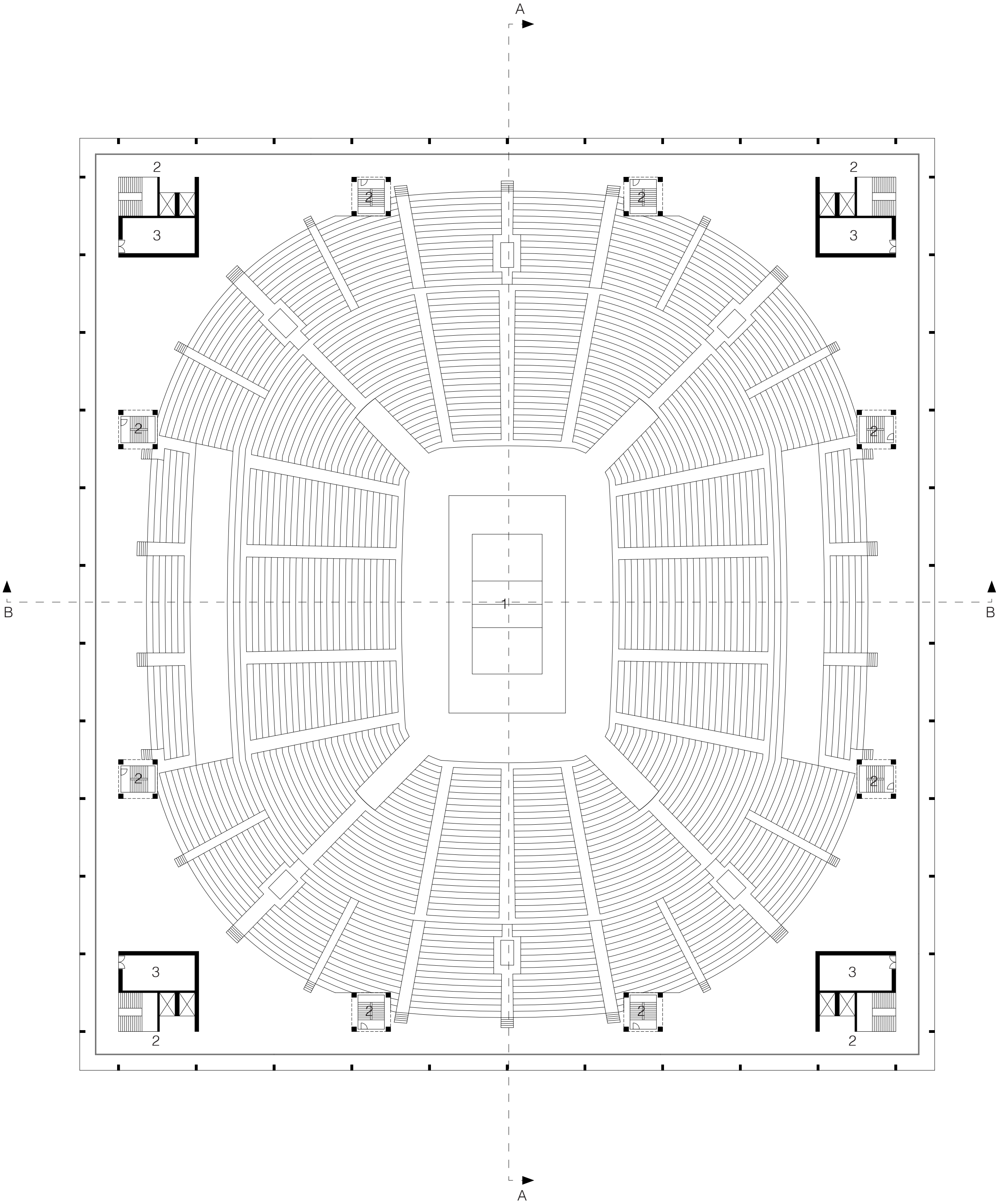
Ill. 88: Main concourse level +1 in 1:750

1. Competition area
2. Stairs & elevators
3. Technical & service room
4. Toilets
5. Concession stand
6. VIP lounge
7. Press lounge
8. Statistics & secretariat room
9. Reception room



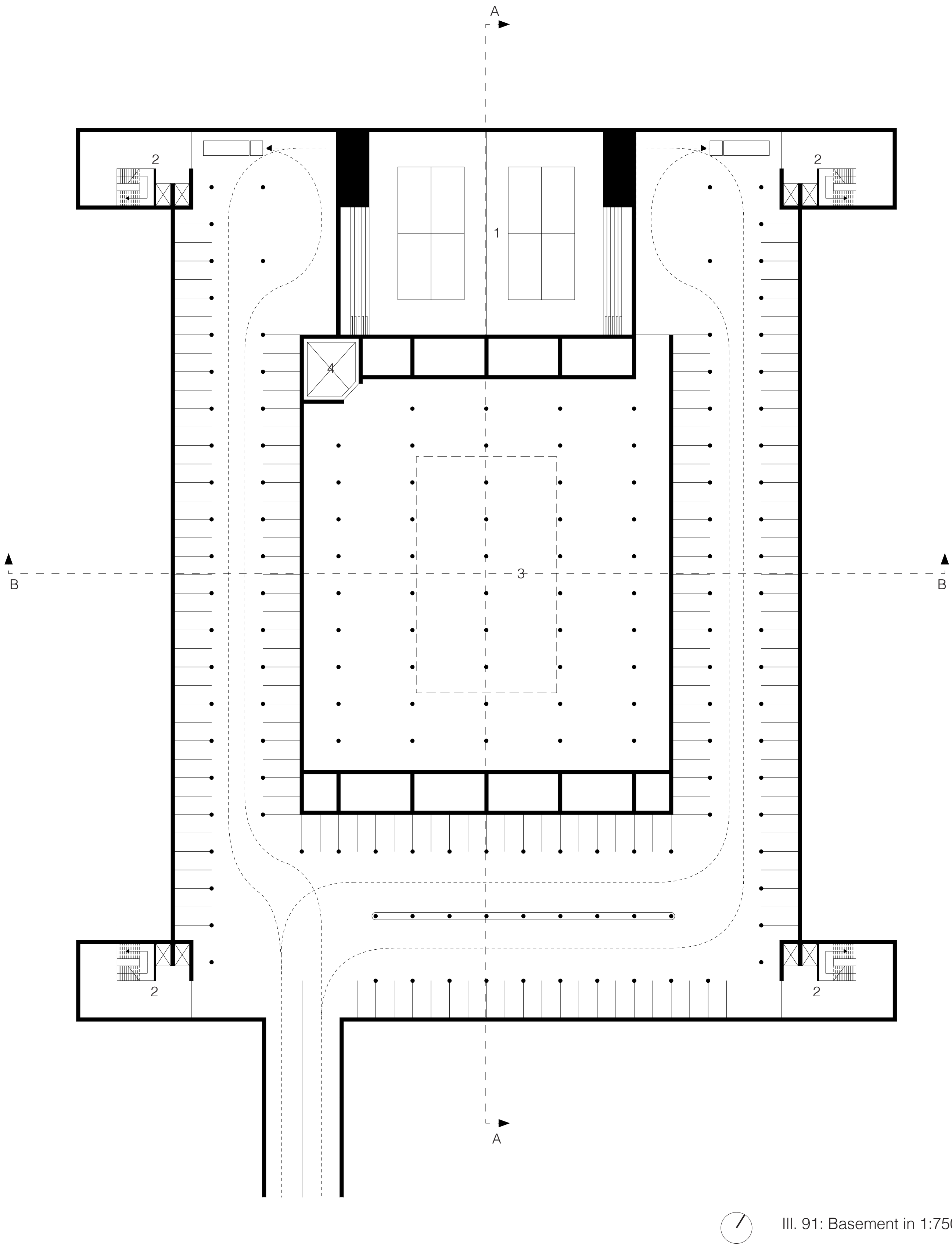
Ill. 89: Upper concourse level +2 in 1:750

1. Competition area
2. Stairs & elevators
3. Technical & service room

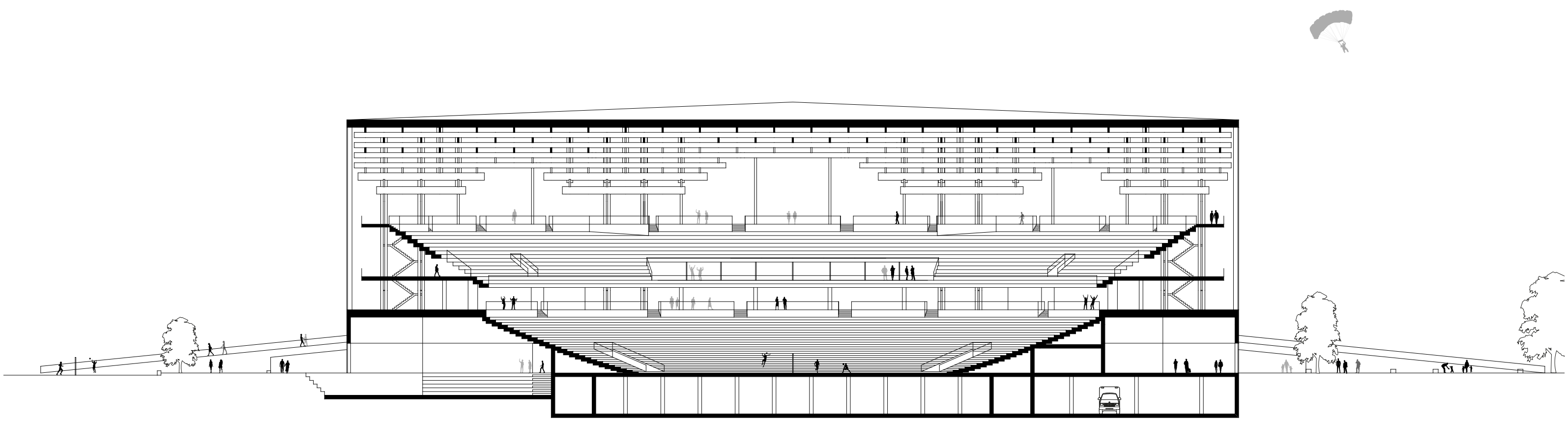


Ill. 90x: Level +3 in 1:750

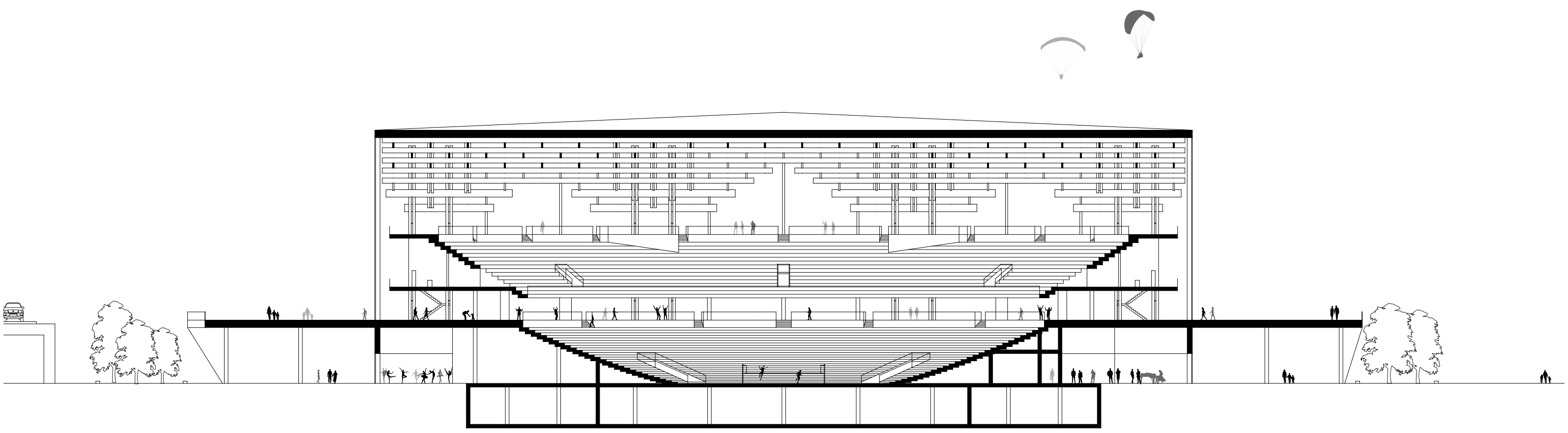
1. Warming-up hall
2. Stairs & elevators
3. Storage
4. Goods elevator



Ill. 91: Basement in 1:750



Ill. 92: Section AA in 1:1000



Ill. 92: Section BB in 1:1000

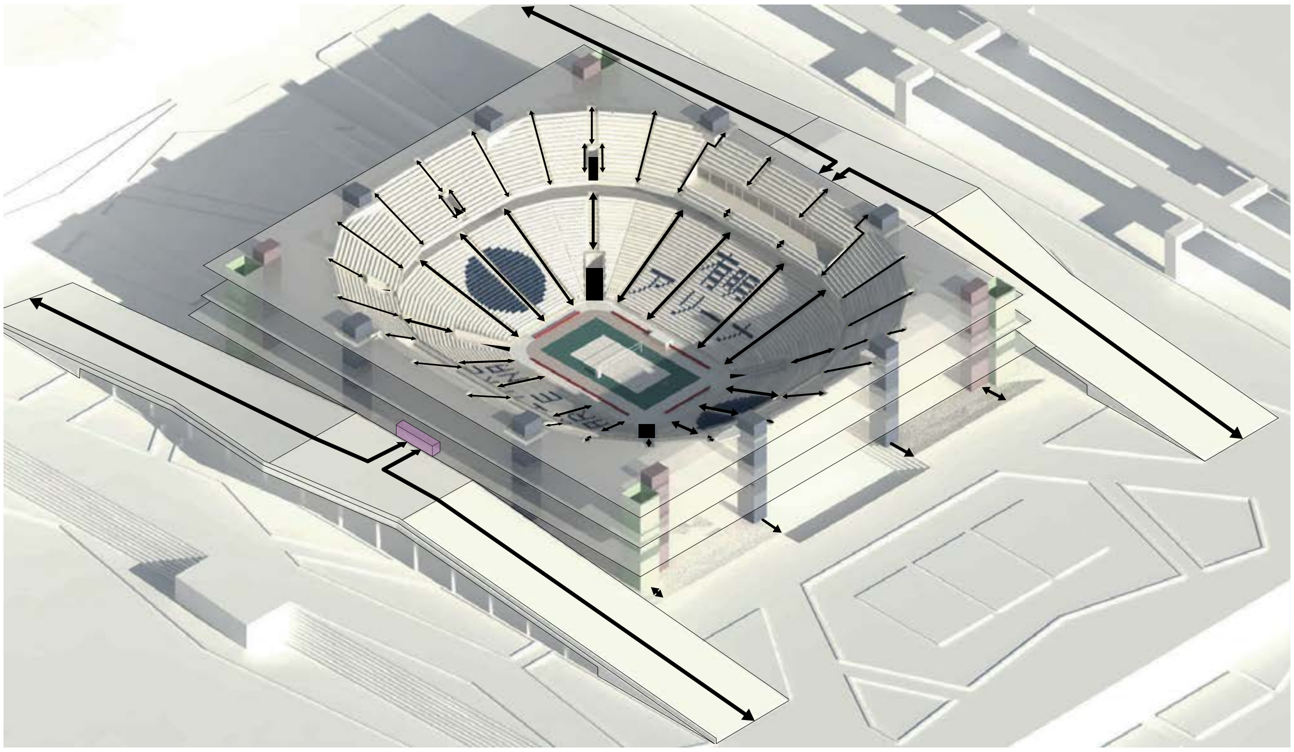
Ill. 94: Exterior visualization of the Ariake Arena seen from north


Ill. 95: Facade south-east 1:1000


Ill. 96: Facade south-west 1:1000

Ill. 97: Facade north-west 1:1000

Ill. 98: Facade north-east 1:1000



Ill. 99: Flow diagram

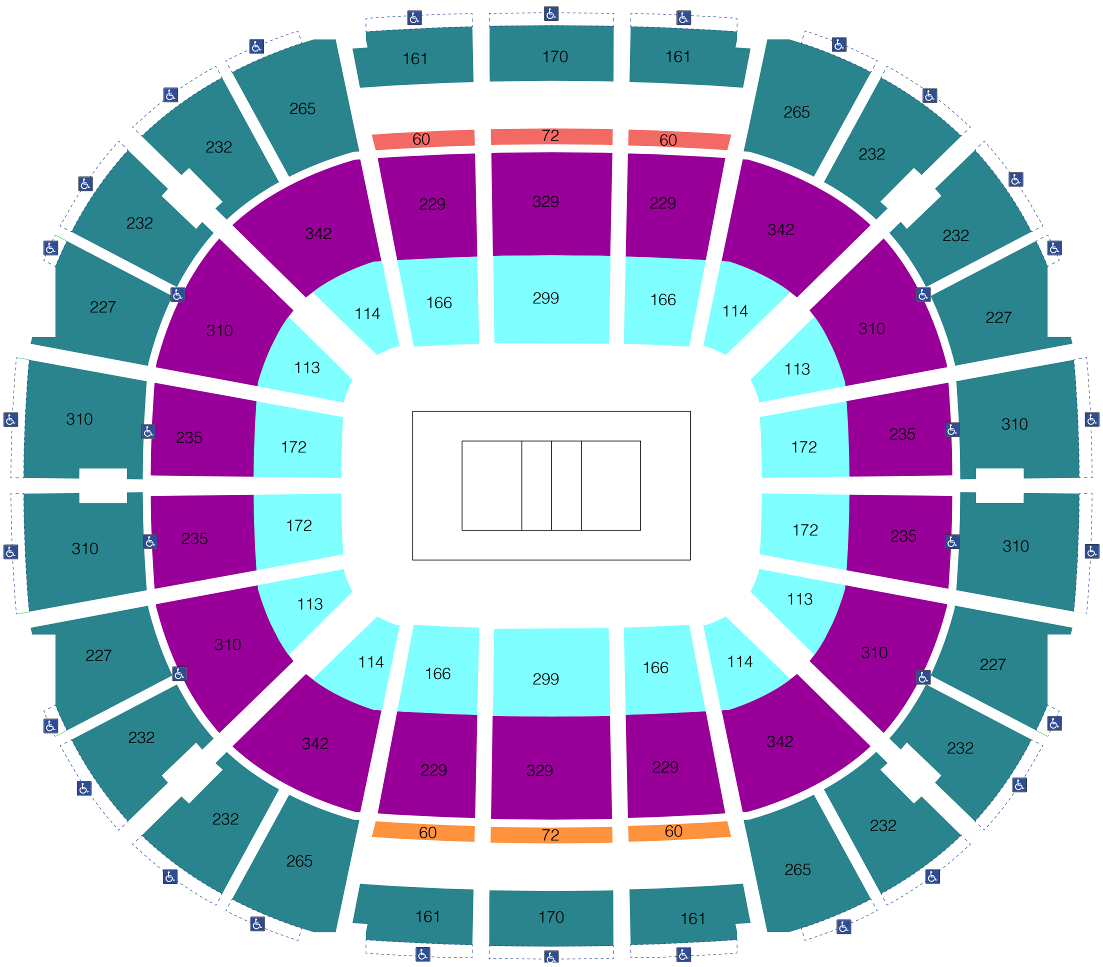
Flow

The building operates with a rational plan layout to make it intuitive to navigate and understand the building. On the level +2, +3 and +4 where spectators will move at events, the plan layout works with a complete symmetry.

From basement to top level the vertical flow is placed at each corner of the building, where a large stairway and two elevators is placed. Furthermore, at each of the total eight structural columns from the wooden roof structure there is located stairs which as well connects all floor. In connection with the vertical flow cores, concession stands and toilets are placed on level +1 and +2.

On the horizontal direction, the flow starts at the ground level where from the ramps to the main concourse at level +1 makes it possible to enter the building without using stairs or elevators. On the +1 and +2 level concourses, the flow is dividing into two main flows. Around the seating bowl the main flow for people entering the tiers runs unobstructed all around the bowl. The other flow is running all along the façade of the building, making it possible quickly to use the vertical cores.

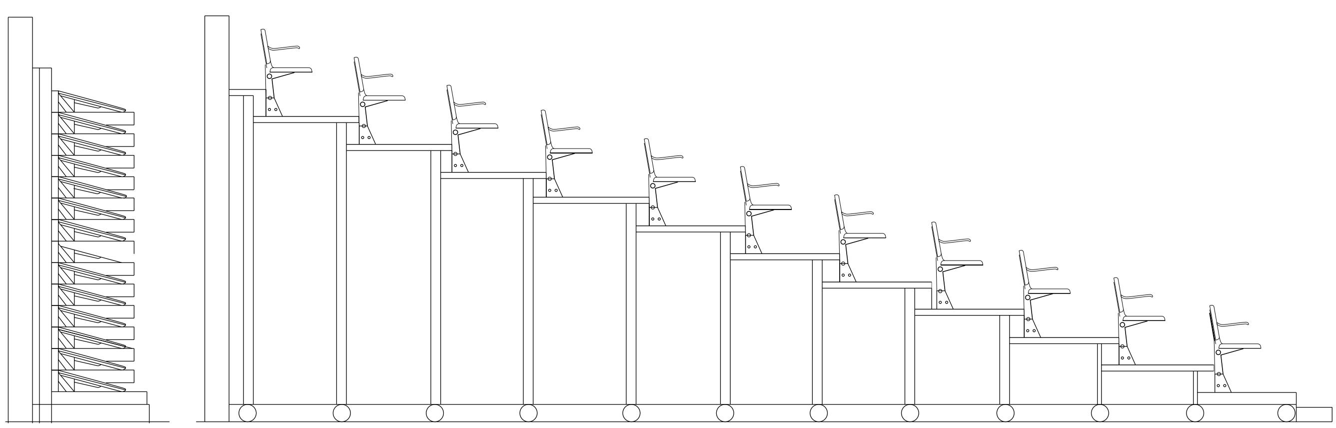
The seating tiers have a maximum of 28 seats to an aisle, ensuring comfort for the spectators, but also makes it quick to exit and access.
Ill. 100 shows how the seats are distributed in the seating bowl.



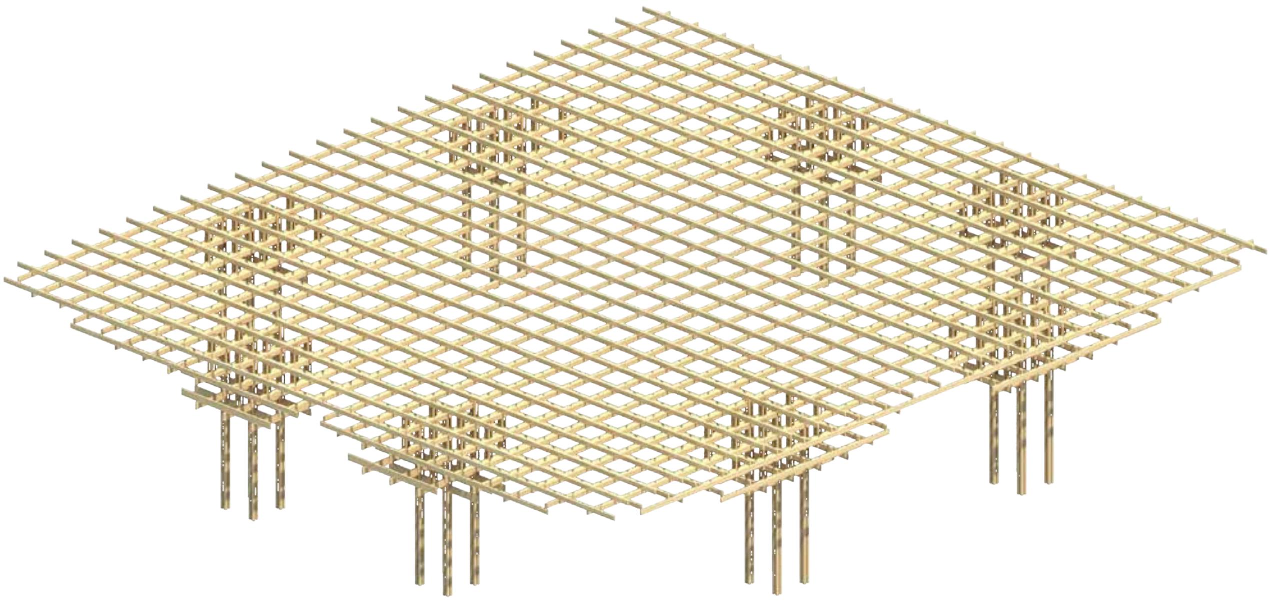
- Flexible seating (2858 seats)
- Main Tier (5114 seats)
- Upper Tier (6048 seats)
- Press & Official (192 seats)
- HANDICAP (404 seats)
- VIP (192 seats)

Total amount of seats: 14808

Ill. 100: Spectator seating map



Ill. 101: Flexible seating system



Ill. 102: Isometric rendering of the structure

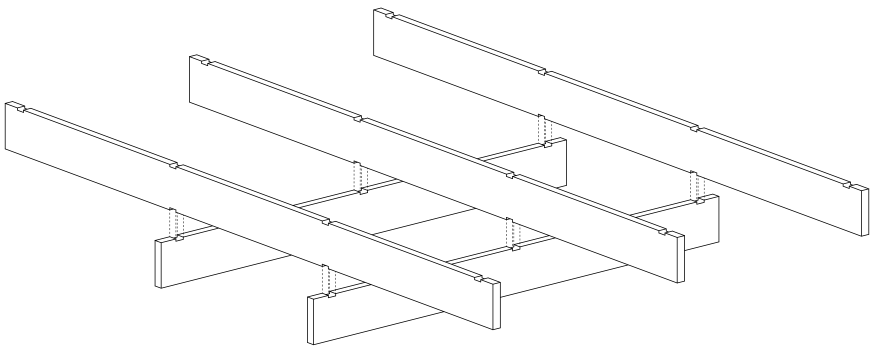
Structural design

The building can be seen in three separated structural parts.

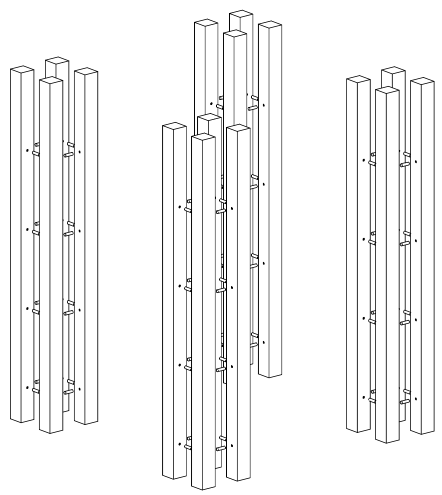
The ground evolving into the ramps and bottom of the building is made in reinforced concrete creating a strong structural system capable of withstanding the extensive live loads during events, the seating bowl as well as the weight of the top and roof of the building.

The top on the other hand is made completely in wood, more precisely glulam gl32h. Only supporting it self and the roof, the system stands as the main ornamentation of the arena, but also providing acoustical diffusion and absorption. The structure measures a total of 108 x 118 meters and are supported by eight sets of four columns. The stacked beams have a total of 13 layers.

Lastly the top of the building is covered by a self-supporting glass façade separated from the wooden structure within. The glass façade is sheltering and withstanding the building from the strong winds occurring at the side.



Beams



Column

Ill. 103: Detailing of joints

Materials

The choice of materials follow the overall building concept, the structural design and the tectonic perception of this project.

As mentioned on previous page in the “Structural Design” text, the three different structural compositions of the building use different materials. These materials stand out without any covering to enhance and remove any lines between the structural elements and the decorative elements.

The concrete used for the ramps, seating bowl and bottom walls of the building will be in a dark grey fine concrete adding a contrast to the light roof structure and enhance the concept of a “heavy” bottom.
The flooring is done in polished concrete, except at the competition area which will be a coral and teal coloured Taraflex flooring with a wooden subfloor. This is a product approved by the FIVB for international competitions.

The choice of these materials for the flooring and internal walls is also due to their durability. Since the building will be subject to many visitors and therefore much wear and tear, it is important that the material can withstand this.
The roof structure made entirely out of a light glulam wood (see ill. 104) will add a warmth to the arena and through light intakes from roof and the façade, a play on shadows and light will enhance the colour, appearance and depth of the structure.

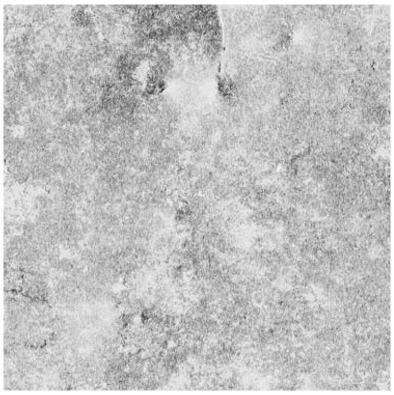
The façade consisting mainly of glass will add much transparency to the building creating a natural well-lit interior but also adding a strong visual connection to the neighbourhood and Tokyo bay. The slender columns of the façade are made in dark steel.

The seats of the stadium are an important aesthetic and atmospherically factor. For the arena, the considerations have been that the colour of the seats should not be too loud, but still not anonymous and the solution has been to use mainly white seats with the name of the arena written in blue seats.

Shading & screening
The large glass facades allow a well-lit interior, which for some events during daytime can be undesirable and inconvenient for athletes and performers. To accommodate this two strategies has been applied on the façade. The first is using Glass solutions Priva-Lite, which through electric current transforms the glass surface from clear to opaque. Hereby the interior will still receive light, but direct sun light will be avoided. Second strategy is more low-tech, offering curtains that are attached at the façade columns. This can completely black out the arena.

Ill. 104x: Glulam

Ill. 107: Stell



Ill. 105: Concrete

Ill. 108: Priva-Lite Glass

Ill. 106: Taraflex flooring

Ill. 109: Seat colour

Fire

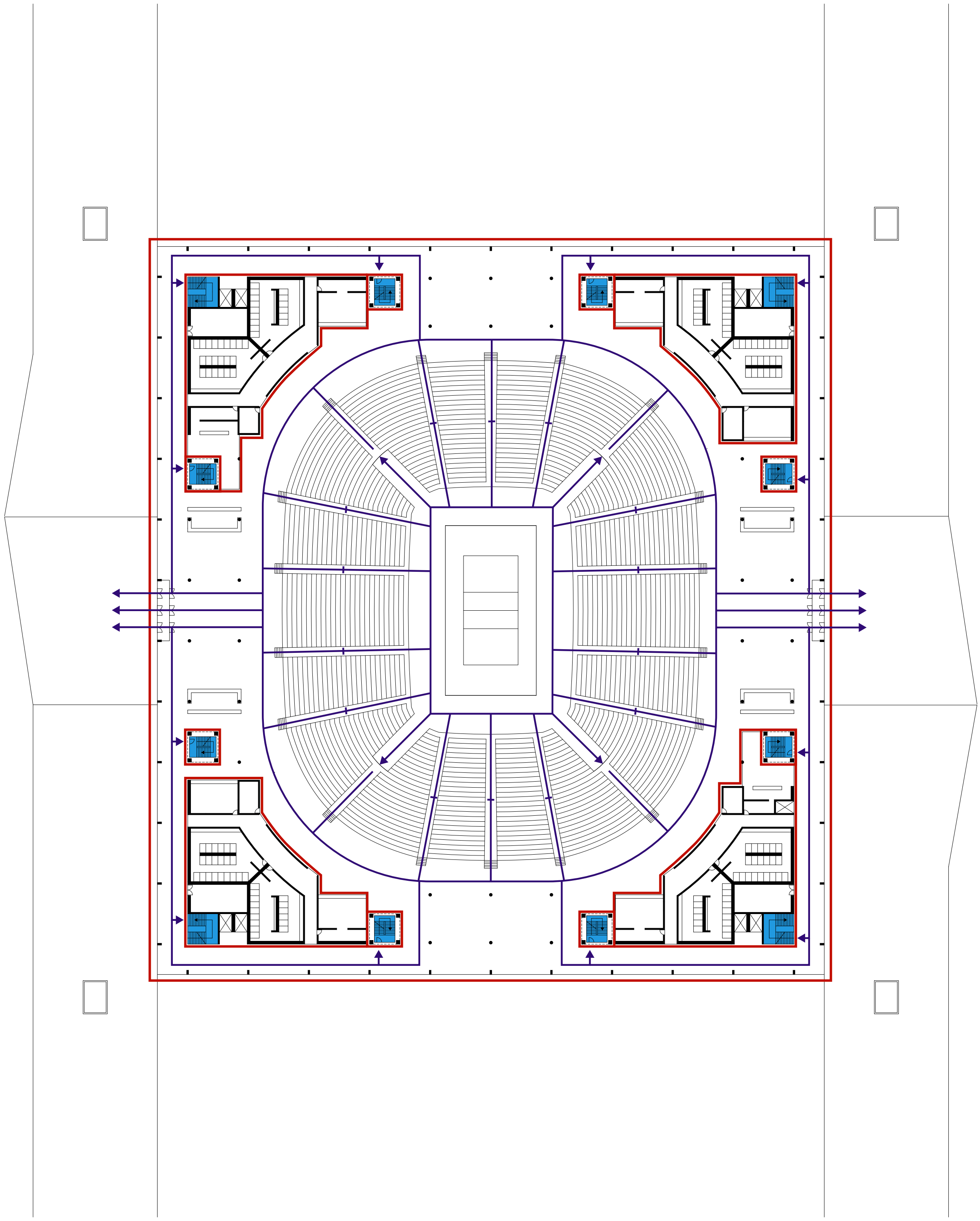
Due to the function, size and materiality of the Ariake Arena, measures according to fire is taken into consideration.

A large wooden construction is often seen as an easy subject to fire. But the wooden construction is made entire out of Glulam, which because of its high content of glue makes it quite resistant to fire. In case of fire, the outer layer of the glulam member will char, stopping the further burning of the inside of the member. The un-carbonized part of the member will therefore still have it load bearing capacity. (Lilleheden, 2017)

Furthermore, the highest consequence class, CC3, has been used for load combinations and therefore the dimensioning of the bearing wooden structure. This means that the structure is dimensioned to withstand cases of emergency, and therefore in case of fire, this structure is presumable still capable of holding in the duration of 30 or 60 minutes, so the building can be evacuated. To verify this an actual fire verification according to material and time of fire could be made.

The illustration 110 shows a fire escape plan and division of fire cells of level +1. Same principle is applied on the different floors. Eight of the total twelve stairs located on each level is individual fire cells. These are because of their central placement and because of aesthetic reasons made completely in glass, from Danish firm Triplan, at all levels except ground floor level. This solution is certified as EI 60. (Triplan, 2017)
The other fire cells are certified as REI 60, with fire resistant doors which automatically closes in case of emergency.

Not only for the comfort of the spectators, have each row of the seating bowl been split, so never no more the 28 seats go without an aisle on each side. This is also in cases of emergency, people can quickly access the aisles and be led out of the building.

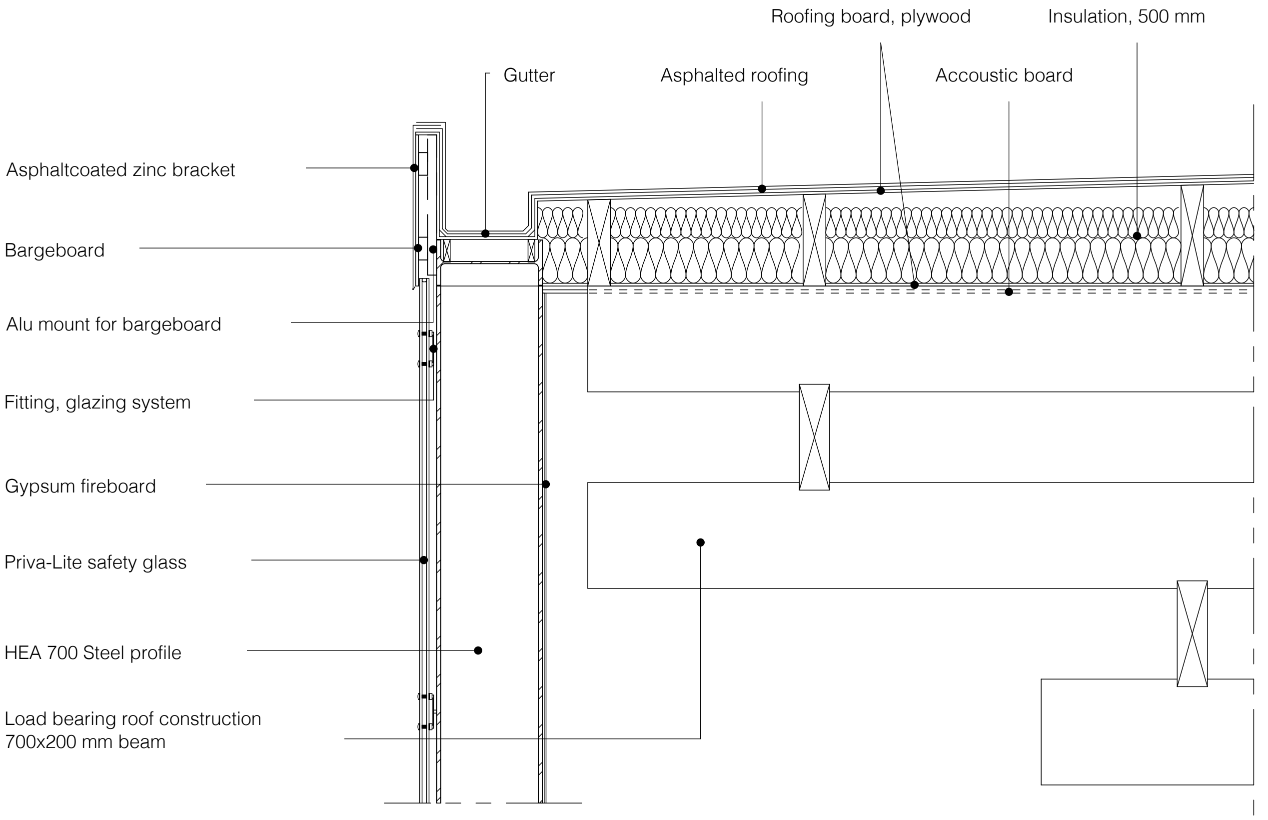


Fire cell

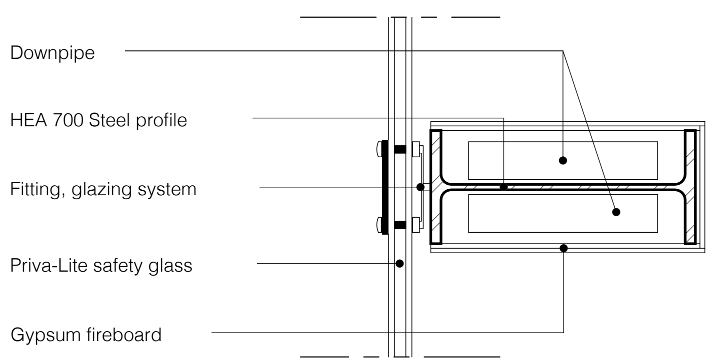
Escape route

Escape route vertical

Ill. 110: Fire escape plan 1:1000



Ill. 111: Detail of facade-roof 1:50



Ill. 112: Section of a facade column 1:20

05

Final

最後の

The fifth and final chapter of this booklet contains the project conclusion and a reflection upon the project in terms of final building, the process and the group work. Lastly, this chapter includes literature and illustration list as well as an appendix.

Conclusion

In order to rethink what a new sport arena should be capable of, analysis and discussions on the Olympics, sport architecture in general, cases, architectural theory together with architectural and technical investigations have generated the design for the future Ariake Arena in Tokyo.

To challenge the general typology and aesthetic of sport architecture, the project is rooted in the traditional tectonic theory of Gottfried Semper. Using Sempers elements of architecture as an understanding of architecture, has led to a design with a clear distinction between the elements, which in relation to each other create a functional architecture. The elements of Semper is pronounced in the final design. The "Earthwork" being the ramps and ground level made in concrete, creating the base of the building. The "Framework" being the wooden structure defining and sheltering the space of the arena. The enclosing membrane being the transparent self-bearing glass façade. Lastly, one could suggest that "The hearth" is the center of the arena, the competition area, where the events take place. The design seeks to continue and rethink Japanese wooden architecture, by adapting a structural principle common in various traditional roof structures and which at present time have been used by Japanese architect Kengo Kuma, and then translate this into a different scale of architecture. This translation evolves and changes that principle into a new type of expression, displaying a modern interpretation of a Japanese architecture. And exactly seeking to create a building design with a clear national character is central for this project.

Because despite the Olympics being an international event, the new Ariake Arena should display Tokyo and Japan, as the Yoyogi national stadium did in 1964, at present time.

The design is based in two main functional intentions. The first being to design a venue capable of giving an excellent experience of Volleyball in term of sight, acoustic and ambiance, while not comprising the architectural quality. The other intention has been based in perceiving the arena throughout the project as not only a place for Volleyball, but also a place for the neighbourhood and city. This has been done by incorporating several public functions in the ground level of the arena, and by creating space for outdoor stay and activities. Furthermore, by creating an arena of high architectural and functional quality, it may boost the interest and popularity of Volleyball, and during the Olympic games through the architecture of the arena, set more focus on the sport.

Even though there is a strategy for what this stadium should become after the Olympics, it is very difficult to predict the future. Maybe in 10, 20 or 30 years the reality of the sport, the fans or Tokyo is completely different. In those cases, structures like this should encourage to transformation, instead of them becoming unused symbols of the past. By working with a program which encourage to different activities, creating an area capable of hosting different events and with an interior main hall capable of hosting different sports, the Ariake Arena should stay relevant and useable.

Reflection

Problem based learning and group work in the ambiance of a master thesis is somewhat different from previous semester projects first of all because of the scale of groups. The dynamic and efficiency of a group is reduced because of fewer members included in the group. The design process has in this case been both easier as well as a more difficult than when previously working with more people in a group. Easier because it is quicker to obtain a consensus about where this project should go and because fewer minds have to be convinced when taking new decisions. At the same time, more difficult because it forces the group members to individually generate more ideas and be more critical about their own work. More obvious is an increased workload per person, in this case when designing in a scale building, without any previous experience.

The process concerning the development of the structural design turned out somewhat different from what expected. The translation from the structural principle into the situation of the arena, evolved the quite simple structure into a very fluid and complicated structural system.
A mistake was to try to grasp the entire system from the beginning of the process, and therefor working with very large and complex structures before fully understanding the plasticity and structural performance of the system. Instead it would have been easier and more efficient to begin investigating the structural principle in a more universal way before implementing it into a larger system. Nevertheless, this project being a master thesis, the many iterations was possible and in the end very insightful and interesting to investigate and translate a structural principle into a very different typology and function than what previously have been done. In relation hereby one could argue that this project does not include and discuss many different structural solutions. This is also to some extent true, but it was decided to focus on one structural principal in order to challenge and develop to principle according to the project. This would not have been possible to

achieve all these iterations if many other systems also should have been granted same attention.

From the beginning of the project, acoustics was found important in order to create a good atmosphere and experience of the arena. Several investigations have been made, but it was intended to work more simultaneously with Robot SA and Pachyderm in order to create iterations bound in the interplay between the dimensioning and size of the structural grid, beams and etc. with how the acoustics was affected. But within this timeframe and with the size and complexity of the structure, it has not been possible to analyse this precisely in Pachyderm. Through simplifications of the geometry it was possible to make an overall estimation of the final arena's acoustical performance.

The design of the Ariake Arena is to some extent very conceptual and strict in how the architecture is formulated and executed. In terms of feasibility this would in later stages of an actual construction, result in some changes. The large glazed facades might in terms of energy consumption and indoor climate be problematic. Furthermore, this is also a result of the vast scale of the building, which has demanded this thesis to focus on some elements more than others. Working with a tectonic approach and developing a structure capable of its function and rooted in its contexts was central for this project. Furthermore, developing an interior seating bowl and creating optimal conditions for the building to function as a Volleyball arena was to same extent important, as discussing and working with the arena as a public area. On the other hand, many other elements of the Ariake Arena is still at this stage only processed to a small extent and much more detailing could be needed.

Content of Appendix

Appendix 1: Conversion with Norman Friedman from Populous

This is an email correspondence between the authors of this thesis-project and Norman Friedman at the american architectural firm Populous.

Email with questions:

Hey Sherri.

Hope everything is well.

We have been working intensely on our thesis the last month, and come across some question we hope you can help us anwser?

We want to create an arena that is specific created for sporting events, that will enhance the intimacy between athletes and spectators.
For indoor volleyball/basketball arena's:

What is the preferred configuration for the bowl footprint and why?

What is the preferred C-value and how is it best to watch the sport? (steep rakes, in a more perspective view, so you feel like you are on top of the game or is a lowered rake for a more direct view) we know it's probably a subjective view, do to culture and other factors, but what's your experience?

Is it possible to maybe get some studies from different arena's of the C-value you firm have made? or if you know what the value is in different arena's some we can compare them our selfs?

What is the wished acoustical reverberation time in arena's like this and what type of design solutions do you create to make sure the ¨alive¨ feel is kept throughout the whole game?

Hope you can help or can put us in contact with someone that can?

Also I haven't ben able to connect with John Shreve yet. We would very much like to get in contact with him and here his thoughts.

We do not hope the question takes to much of your time.

Regards
Morten Lydiksen

Reply from Norman Friedman

Hi Morten:

Sherri asked if I would help out with your question. I personally have only used a c value of 2.25". Often the c value is higher than this because the seating bowl is connecting 2 points. The Ballpark at St George in Staten Island NY had 12" constant tread rises, which was steeper than necessary, because the bowl connected a street level above, to the waterfront below. On renovations I have used lower c-values also. In basketball, which is an above the waist sport, we would raise the focal point up to 2 or 3'. The c-value might still be 2.25", but if you were to lower the focal point to the sideline on the court, it would be less than that. In discussing it with some of our arena guys, they said they virtually always use a higher c values in premium locations. In the T-Mobile Arena in Las Vegas, the club seats and loge boxes had improved c values for improved sightlines.

I think different people have different ideas about the best viewing location. Generally for basketball, the most expensive seats are on the court. As you go up the bowl, its important to have a good view over the people in front, but I don't think we deliberately make bowls steeper for improved perspective. Generally, the closer to the court the better. I had an athletic director on Georgia Tech's McCamish Pavilion renovation say he wanted to show that the distance of the nose to the court was improved.

I attached a couple of sheets out of ESPN's book that describes their preferred sightlines. I was surprised that ESPN, in the book considers 2.25" was poor. I also attached below the US DOJ (Department of Justice) description of required c-value for wheelchair patrons.

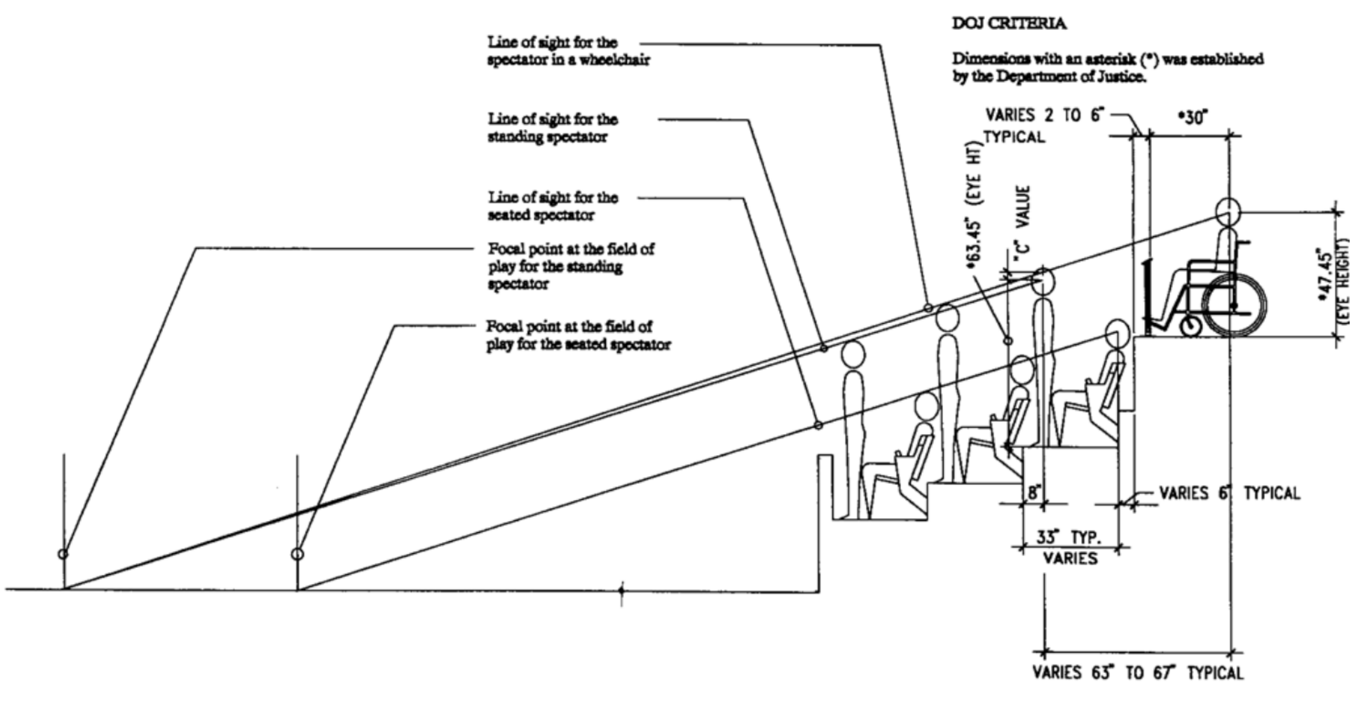
The best configuration for basketball and volleyball would probably be to design to for basketball, and the smaller volleyball court will have better sightlines since the court is further from the front row. I tossed I a university of Central Florida, Mizzou and Rhode Island plans if they help you. The first riser is usually 11-12’ from the basketball sideline, allowing press, players, and 2 rows of court seats.

As far as acoustics go, there is usually an acoustic treatment on walls or lapidaries hung from ceiling to absorb sound. While loudness is good for an exciting event, it can’t compromise the ability to hear the audio system.

Good luck, let me know if this helps.

Thanks,
Norman

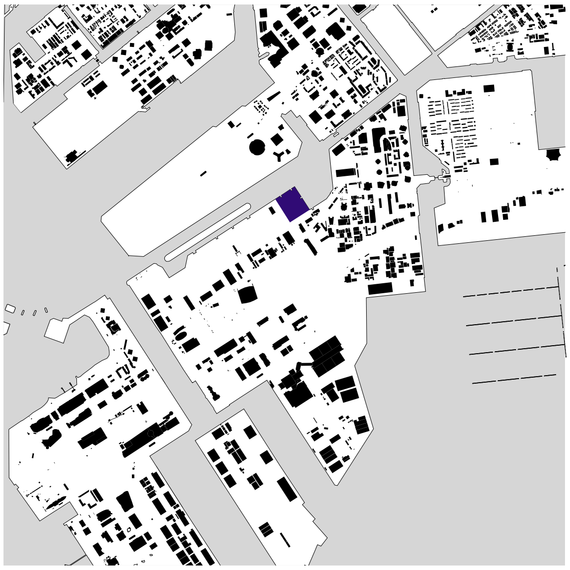
Norman Friedman AIA PE LEEDap
ASSOCIATE PRINCIPAL



Ill. 113: Illustration sent by Norman Friedman

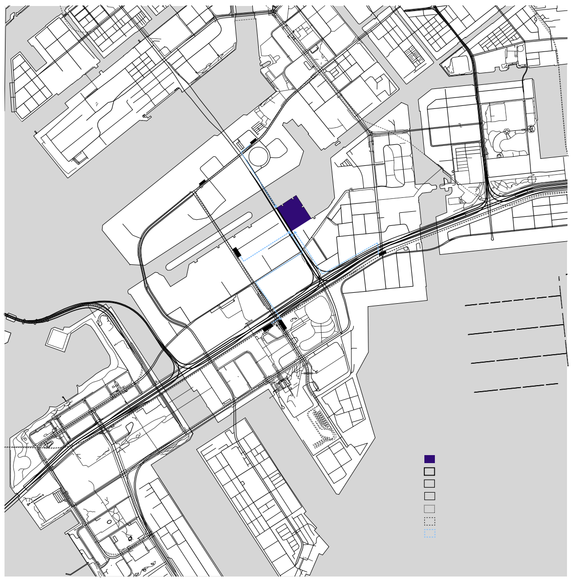
Appendix 2: Mapping

This appendix display three mappings; figure ground, green / blue and infrastructure. These were part of the initial analysis of the site and context.



Ill. 114: Figure ground

Ill. 115: Green / Blue



Ill. 116: Infrastructure

Appendix 3: Load calculations

The following calculations are made to understand the general actions on the structure so it's possible to determine whether the structure can hold and dimension the structural elements in correspondence thereto. The load calculations are done for the wooden roof structure.
The calculation of the different loads and load combination is done according to current advice of Eurocode. In addition, hereto, values for snow and wind loads are sourced specifically for the Kanto Region and Tokyo.

Consequence class
As the building height exceeds 12 meter above terrain and the roof structure operates with large spans, together with the use of building as a place of large gatherings and many people the building will be in the highest consequence class, CC3. (Eurocode 0, table B.1)

Self-weight
The estimated self-weight of the structure is calculated in software Robot Structural Analysis by following equation:

$$G_{self-weight\_structure} = mass(mm^3) * density\ (\frac{kg}{m^3})$$

The self-weight of the on top laying roof membrane is calculated by using estimated values from table 2 in "Last og Sikkerhed" concerning a roof structure consisting of trusses and light roofing:

$$G_{selfweight\_roof} = 0{,}7\ kN/m^2$$

Live load
As the building will be a large arena for primarily sport events it will be in category C, but since these load calculations concerns the structure supporting the roof, no live load will be present.

Snow load
The snow load is calculated by using following formula:

$$s = \mu_i\, c_e\, c_t\, s_k$$

$\mu_i = Roof\ shape\ coefficient$
$C_e = Exposure\ coefficient$
$C_t = Thermal\ coefficient$
$S_k = Characteristic\ value\ of\ the\ ground\ snow\ load\ for\ the\ relevant\ altitude$

Since the structure is operating with an almost flat roof, the roof slope coefficient will be for slopes which complies with $0° \leq a \leq 30°$, therefor:

$$\mu_i = 0{,}8$$

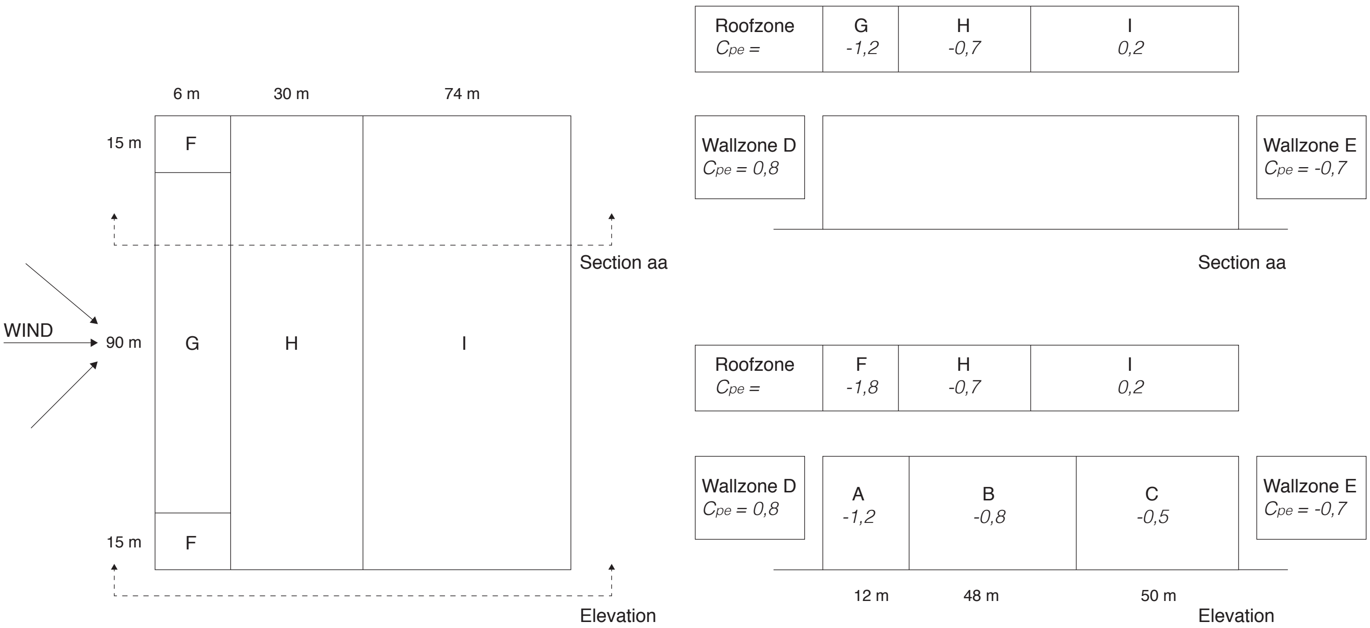
The exposure coefficient depends on the surrounding topography as well as the size of the construction. Even though the nearby context includes much higher buildings, the site is open toward the water from two side making the area quite windswept. Therefor following exposure coefficient is chosen:

$$C_e = 0{,}8$$

Some skylights will be included in the roof, which potentially could reduce the thermal factor, but for the calculation the thermal factor is set to:

$$C_t = 1$$

The characteristic value of the ground snow load



Ill. 117: Pressure coefficients

for the relevant altitude is sourced through a publication concerning The Architectural Institute of Japans recommendations for Loads on Buildings. Herein a chapter for snow loads determines that based on a 100-year return period the annual maximum snow load for the site in Tokyo is:

$$s_k = 0{,}42\ kN/m^2$$

The snow load is estimated to be:

$$s = 0{,}8 * 0{,}8 * 1 * 0{,}42 \frac{kN}{m^2} = 0{,}268\ kN/m^2$$

Wind load

The wind load is calculated through following formula:

$$w_e = q_p(z_e) * c_{pe}$$

$q_p(z_e) = Peak\ velocity\ pressure$

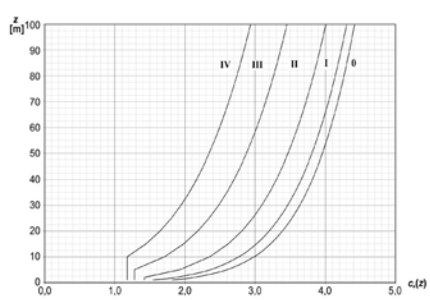
$z_e = reference\ height\ for\ the\ external\ pressure$

$c_{pe} = pressure\ coefficient\ for\ the\ external\ pressure$

First the peak velocity pressure will be calculated by following formula:

$$q_p\ (z_e)\ =\ c_e\ (z_e)\ * 0.613\ *\ vb^2$$

To do so, the exposure factor, $c_e\ (z_e)$, needs to be calculated first. By knowing the height of our building, 30 m, and the terrain category, which is set to category 5 because of its location in an area with tall buildings, following figure makes it possible to read the exposure factor.



$$vb = 38\ m/s$$

Next the basic wind velocity is found. Again, the recommendations of The Architectural Institute of Japan are used to find the basic wind velocity for Tokyo area:

$$c_e\ (z_e) = 1{,}95$$

Now the peak velocity pressure can be calculated:

$$q_p\ (z_e) = 1{,}95 * 0{,}613 * 38^2 =\ 1726\ N/m^2 \approx 1{,}726\ kN/m^2$$

On illustration 117, the c_{pe} is calculated for the different surfaces of the building.

Load combination

$$\sum \gamma_{G,j} G_{k,j} \text{"} + \text{"} \gamma_{G,1} Q_{k,1} \text{"} + \text{"} \sum \gamma_{Q,i} \psi_{0,j} Q_{k.i}$$

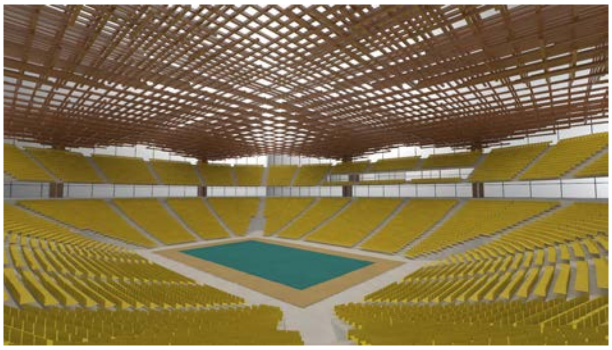
$$K_{Fi} * \gamma_{G,j,sup} * G_{k,j,sup} + K_{Fi} * \gamma_{Q,1} * Q_{k,1} + K_{Fi} * \gamma_{Q,1} * \psi_{o,i} * Q_{k,j}$$

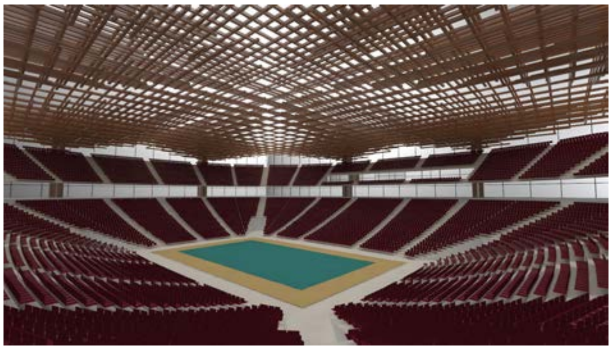
Since the snow load is quite low, the following will be an example calculated with dominating wind load, which means that the snow load will be zero:

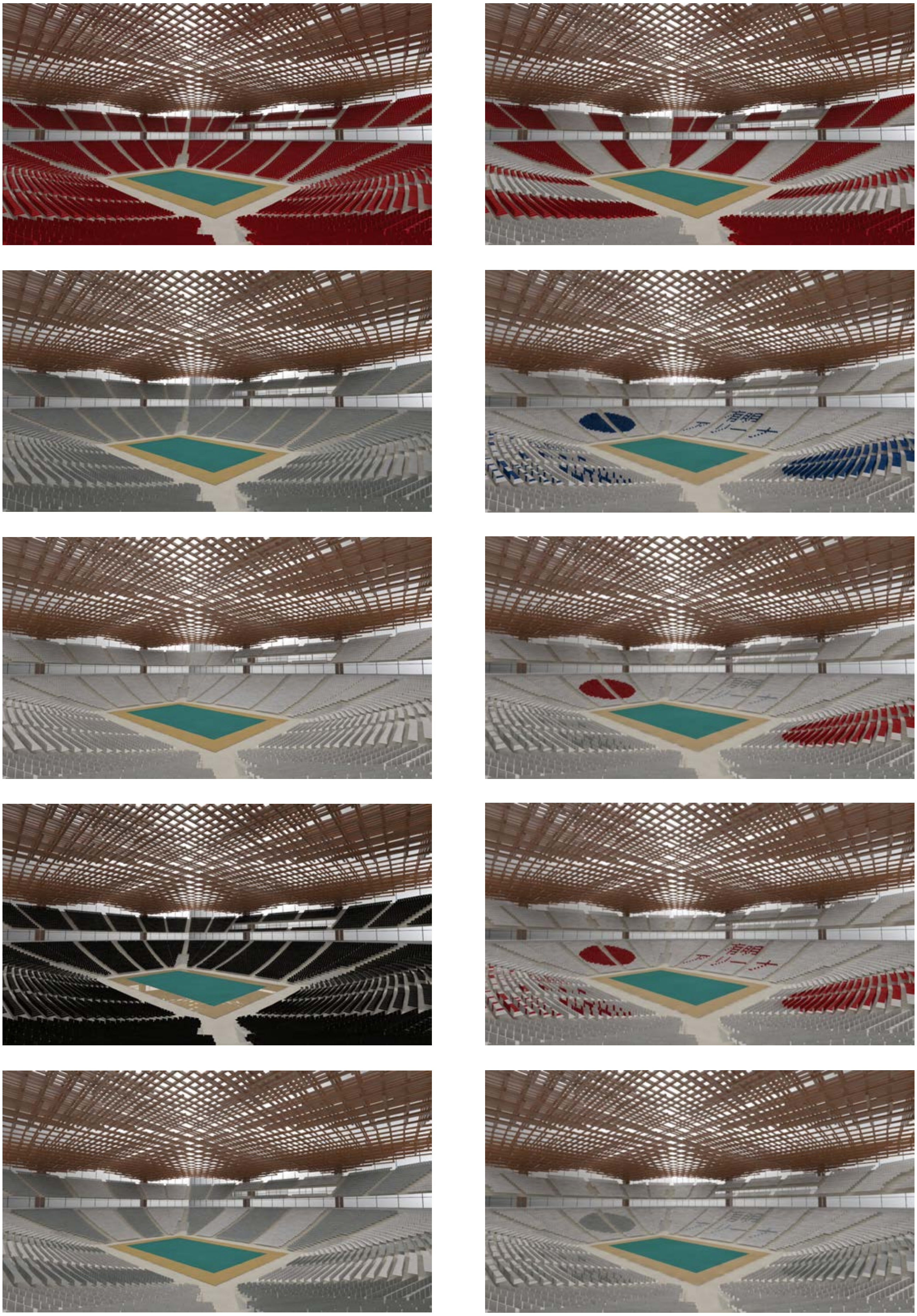
$$1{,}1 * 1 * G_{selfweight} + 1{,}1 * 1{,}5 * Q_{wind} + 1{,}1 * 0 * Q_{snow}$$

Appendix 4: Seat colour

This appendix display a number of different variations of seat colours and patterns.



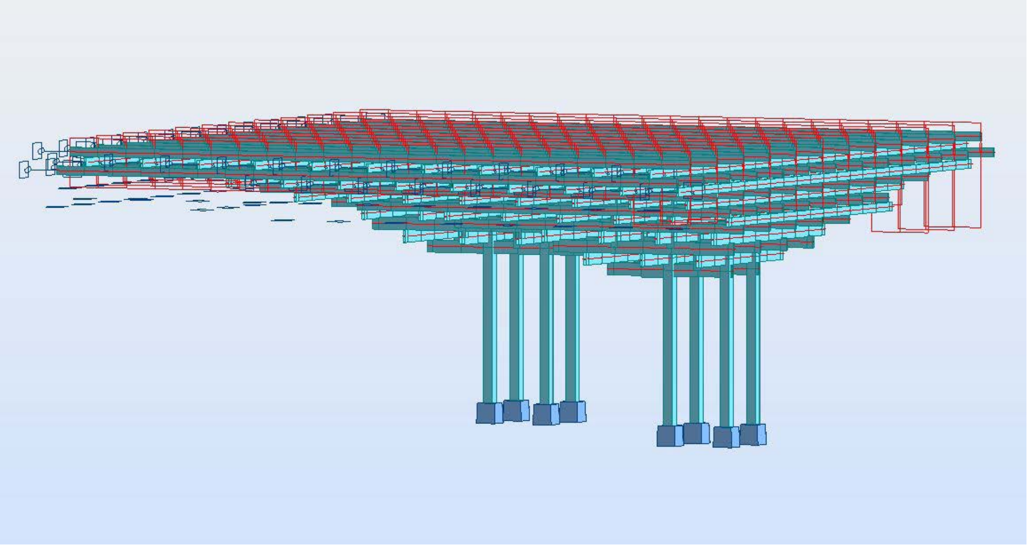




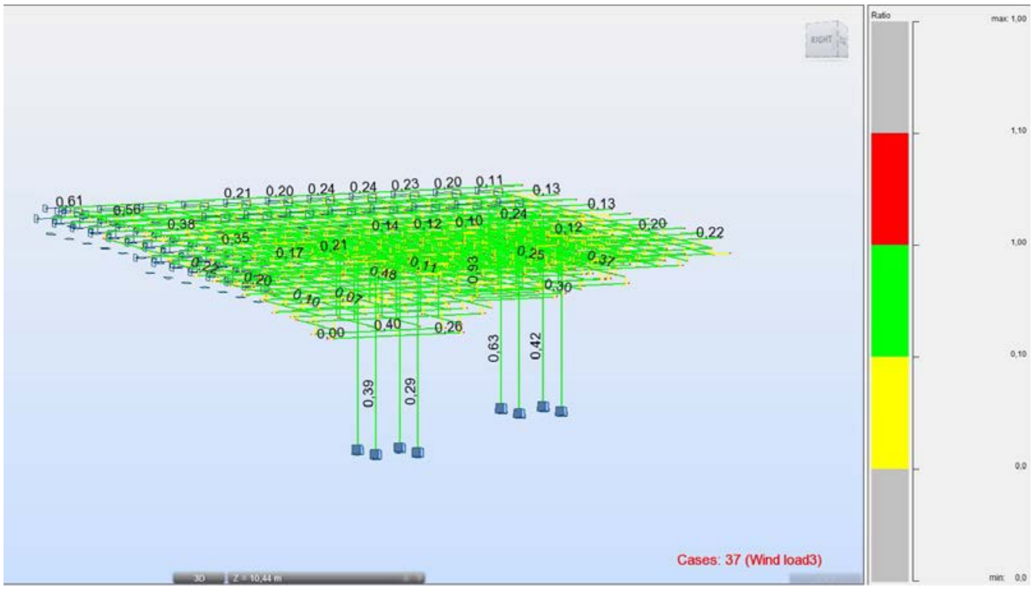
Ill. 118: Seat colours

Appendix 5: Robot SA

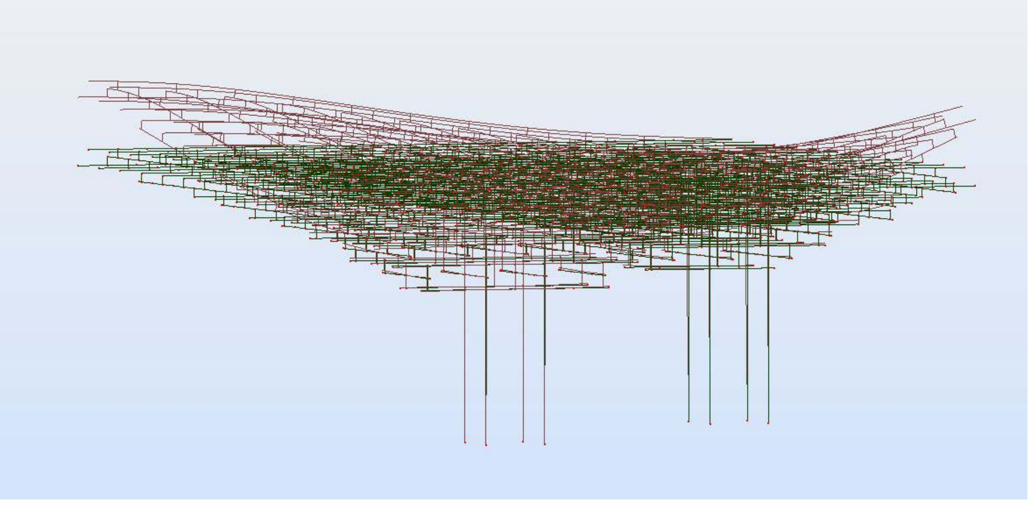
This appendix display three illustrations from Robot SA of the final structure and calculation.



Ill. 119: Loads are applied



Ill. 120: Utilization



Ill. 121: Maximum displacement: 100 mm

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Illustrations

Ill. 1 -3: Own illustrations

Ill. 4: Illustration taken from: Frampton, Kenneth. (1995), *Studies in Tectonic Culture.* The MIT Press.

Ill. 5: Picture taken from: http://www.japantimes.co.jp/wp-content/uploads/2013/09/yv20130926w1a.jpg

Ill. 6: Picturen taken from: http://www.justluxe.com/travel/luxury-vacations/feature-1964176.php

Ill. 7: Picture taken from: http://www.news.com.au/sport/more-sports/athens-olympic-site-in-ruins-10-years-on-from-2004-games/news-story/be7db5728f668c45b6048477be116445

Ill. 8: Picture taken from: https://www.flickr.com/photos/belowred/7349358544

Ill. 9: Picture taken from: http://www.bbc.com/news/magazine-29503711

Ill. 10: Illustration taken from: http://hidetoyagi.com/?p=1667

Ill. 11: Picture taken from: http://www.archdaily.mx/mx/763740/video-estadio-de-futbol-arena-borisov-ofis-arhitekti

Ill. 12-14: Own illustrations

Ill. 15: http://www.japantimes.co.jp/news/2016/09/28/national/costs-scrutinizing-panel-looks-pare-three-2020-tokyo-olympics-venues/

Ill. 16-21: Own Illustrations

Ill. 22: Picture taken from: http://www.fivb.org/en/volleyball/viewPressRelease.asp?No=58749&Language=en

Ill. 23-28: Own illustrations

Ill. 29: Picture taken from: http://www.architravel.com/architravel/building/palazzetto-dello-sport/

Ill. 30: Picture taken from: http://openbuildings.com/buildings/palazzetto-dello-sport-profile-2396

Ill. 31: Picture taken from: http://www.japantimes.co.jp/sports/2014/10/10/olympics/olympic-construction-transformed-tokyo/#.WLSgzhCrkdV

Ill. 32: Picture taken from: http://archeyes.com/national-gymnasium-for-tokyo-olympics-kenzo-tange/

Ill. 33-54: Own Illustrations

Ill. 55: Picture taken from: http://wtop.com/wp-content/uploads/2015/12/Japan-Olympic-Tokyo-2020-Stadium7.jpeg

Ill. 56: Picture taken from: http://modamoda.info/wp-content/uploads/2017/01/sevilja2.jpg

Ill. 57: Picture taken from: https://thedesignsociety.files.wordpress.com/2013/02/kengo-kuma-disassembly-wood-cafe-kureon-5.jpeg

Ill. 58: Picture taken from: http://images.adsttc.com/media/images/5004/e403/28ba/0d4e/8d00/0c0e/slideshow/stringio.jpg?1413994783

Ill. 59-103: Own Illustrations

Ill. 104: Picture taken from: http://www.istockphoto.com/dk/photo/nature-wood-background-gm496061922-

78338015?esource=SEO_GIS_CDN_Redirect

Ill. 105: Picture taken from: http://valleysinthevinyl.com/wp-content/uploads/2012/08/SimpleWhiteGrunge_featured-800x390.jpg

Ill. 106: Own Illustration

Ill. 107: Picture taken from: https://static1.squarespace.com/static/5787c6c82994ca7e8499335c/t/5787d8b72994ca7e849a135a/1468524435157/primalunabg.jpg?format=1500w

Ill. 108: Picture taken from: http://glassolutions.dk/da/produkter/priva-lite

Ill. 109-112: Own Illustrations

Ill. 113: Illustration sent by Norman Friedman of Popolous.

Ill. 114-121: Own Illustrations