Saimaa University of Applied Sciences
Technology, Lappeenranta
Double Degree Bachelor Program in Civil and Construction Engineering
Civil Engineering

Stepan Svintsov

Study of urban designs and planning for pedestrian bridges and overpasses

Bachelor’s Thesis 2019

Abstract
Stepan Svintsov
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Instructors: Lecturer Eija Hauska-Mertanen, Saimaa University of Applied Sciences;
Managing Director: Ekaterina Zlotnikova, Stroyproekt Engineering Group

The aim of the study was to explore and analyse planning, design and other solutions for the pedestrian bridges and overpasses in the urban areas, which would improve their efficiency and social value.

The data for this thesis was collected from the analysis of the already existing structures in different urban areas, national building standards and requirements and literature concerning this topic.

As a result of this thesis main ideas and requirements for the increase of the social value of the pedestrian bridges and overpasses were formulated. Three bridge designs were made to show possible implementations of these ideas. Bridge designs represent the implementation of the ideas in different cases (different span length and surroundings). Same concepts can be used for the overpasses. Alternative projects for the three existing structures were made as well.

Keywords: urban design, bridges, public space

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1 Introduction

Big cities attract more and more people nowadays, which is proven by multiple researches, carried out in the different regions of the world (Florida 2018 pp. 14-38). This tendency leads to the increased construction rates in the urban areas due to the rapid growth of population. It creates a high demand for comfortable and high quality infrastructure as well as available public spaces.

Presence of public spaces coming in a form of urban open spaces (areas that are not covered by cars or buildings and accessible for people) and vehicle-free pedestrian routes is crucial for modern cities, which is proven by many works, and experience gathered in city planning in recent decades (Wooley 2003, p. 3-4). Lack of spaces available for using as a public space or green zones is a big problem for many modern big cities. It is especially true when talking about historical city centres in heritage cities all around the world. Usually these centre areas are densely populated and most of the buildings are considered as historical heritage and therefore cannot be demolished and even if they can be, the price of the land is very high. These factors create a situation when almost no plots of land are available to create new public spaces. There are different ways to solve this problem. Some of them are already implemented in such cities as New York, London, Moscow, Portland etc. Ground floors of big office and residential buildings, abandoned industrial buildings, underground spaces can be used for this purpose. One possible solution is to use space provided by the newly constructed or renovated infrastructure such as pedestrian bridges and overpasses for this purpose. Such structures, however, can be expensive which might make them a heavy financial burden for the client and, therefore, considered ineffective. As a result, these structures can not rely purely on the good planning and need to seek other ways to increase their social value as well. For these bridges and overpasses, same as for other urban structures social value is based on lesser costs, better quality, faster designing and construction processes, more effective use of materials, better durability and less maintenance needed during the lifecycle.

This thesis investigates designs and planning used for pedestrian bridges and overpasses in the densely populated urban areas around the world which make them functional not only as an important part of the city infrastructure but also as a recreational area, business area or a tourist attraction. Ways to increase the social value of the structures are also explored. The main ideas on which designs and planning of the already existing structures are based are analysed. Different materials that are possible to use in the pedestrian bridge construction are compared and their properties are evaluated. Governmental requirements (Eurocodes and Russian SPs (Rules of Construction)) concerning this type of structures are analysed. Possibilities of implementation of BIM (Building Information Modelling) tools are explored. Suggestions of possible designs for the new and already existing structures are made based on these studies.

2 Study of existing structures

In this chapter public demand for public spaces located on pedestrian bridges and overpasses is evaluated. Five structures constructed in different cities are analyzed. Conclusions about necessary requirements in design and planning are based on this analysis and study of the papers and books regarding this issue.

2.1 Public demand

There is no doubt that open public spaces in form of urban open spaces have great importance for the people who live in the urban areas (Wooley 2003, p. 2). Although evaluating public demand for the certain public spaces can be difficult since there are no statistics, questionings or official reports, which can provide such information for most of the structures.

In this thesis public demand for structures analysed in this chapter is roughly estimated by correlation between the amount of tagged pictures from the chosen public spaces published since the year of opening to the city population and annual amount of tourists which will be compared to the amount of tagged pictures from cities' iconic sights. Such approach when social media is used as a main source of information is a simpler and a cheaper way to conduct this kind of research (Hyung 2018 pp. 69-70).

Suggestion is made that same people can publish same pictures with the same tags on different social networks so only one social network will be taken into account in this thesis. The chosen social network is “Instagram” since it is the easiest one to get the required data from. Information about population is gathered from such open sources as United States Census Bureau website and Undata (made by the United Nations) website. Information about tourists is gathered from the local mass-media sources such as mos.ru website for Moscow, ngi.org.uk for Newcastle, northstarmeetingsgroup.com for New York. Such tags were used: #highline, #highlinenyc, #highlinepark, #highlineparknyc, #highlinenewyork, #nychighline for High Line park, #zaryadyebridge, #zaryadyepier, #зарядьемост, #зарядьепарящиймост for Cantiliver bridge in Zaryadye park, #bagrationbridge, #moscowcitybridge, #мостбагратион, #мостбагратиона for Bagration bridge, #gatesheadbridge, #gatesheadmillenniumbridge, #gatesheadmileniumbridge for Gateshead Millennium bridge.

Gathered information is presented in Table 1:

Table 1. Public demand evaluation

Name	Pictures (public space)/opening year	Pictures (iconic sight) (iconic sight)	City population	Tourists
High Line Park	92,83k/2009	3500k(Empire State Building)	8,384m (2012)	65,2m (2018)
Cantilever bridge in Zaryadye park	2,46k/2017	1000k (Kremlin)	11,92m (2012)	23m (2018)
Bagration bridge	5,51k/1997	1000k(Kremlin)	11,92m (2012)	23m (2018)
Gateshead Millennium bridge	5,36k/2001	74,2k(Tyne bridge)	0,268m (2011)	17,3m (2018)

The results of the public demand evaluation show that most of the chosen public spaces are quite popular among the public and got a lot of attention in the short time following their opening. However, there is a significant difference in attention between some of them that can not be explained only by differences in city population and annual amount of tourists visiting. The cause of this difference is explored further in this chapter.

2.2 High Line Park (New York, USA)

High Line Park was constructed in New York City in the USA in 2009 in West Chelsea, Meatpacking, and Midtown West districts in the western part of midtown Manhattan. Manhattan is a densely populated area in the centre of the city which serves as a main place of business and culture as well as a residential area with lots of multi-storey apartment buildings concentrated on a relatively small area. The park was inspired by the similar project of Coulee Verte Rene-Dumont in Paris. The layout of the High Line Park and its location at the map of New York are presented with Figures 2.1 and 2.2 respectively.

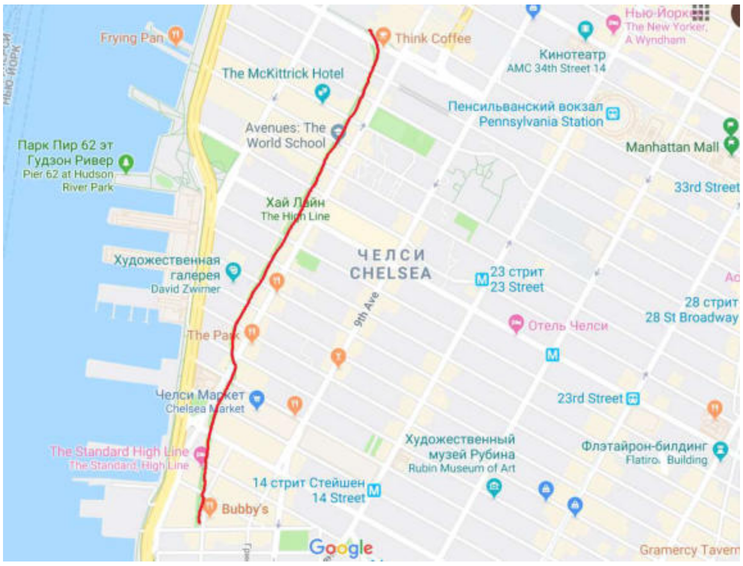

Figure 2.1 Layout of the High Line Park (original image from Google Maps)

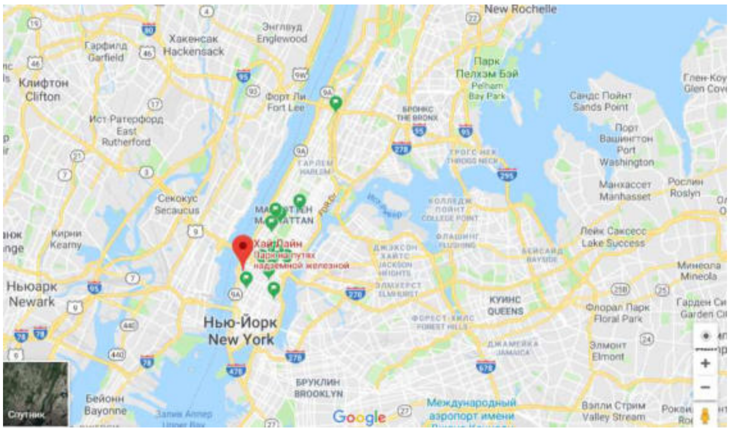

Figure 2.2 Location of the High Line Park on the map of New York City (original image from Google Maps)

Construction of High Line Park was a renovation project during which a park area located above the street level on the overpass with old unused rail line was created. Soon after its opening High Line Park gained iconic status and became one of the most famous landmarks in the city, it is praised by the press, politicians and the general public (Broder 2012 p. 245).

High Line Park is 2.3 kilometers long with varying width in different parts of the structure. The overpass of an old rail line is mostly made of steel structures. Steel beams are supported by the steel columns, which are supported by the ground based foundations. Steel beams are mostly covered by concrete slabs creating the space of the overpass. The look of the structure is presented in Figure 2.3.

Figure 2.3 Look of the typical span of High Line Park from 10th Avenue (photo by the author)

As it was mentioned before, High Line Park became an important place in every-day life of local population. The main reason for that is the way space provided by this structure is used. Lots of trees, grass and other kinds of vegetation are planted through all of its length. It provides a severely needed green area in the densely populated mid-town Manhattan which used to be an industrial part of the city therefore no publically available parks or gardens were originally planned. Conveniently located benches provide places for rest to the city inhabitants and tourists (Figure 2.4). Some sightseeing areas were created as well which allow people to enjoy views of the streets of New York (Figure 2.5).

Figure 2.4 Vegetation and benches at High Line Park (photo by the author)

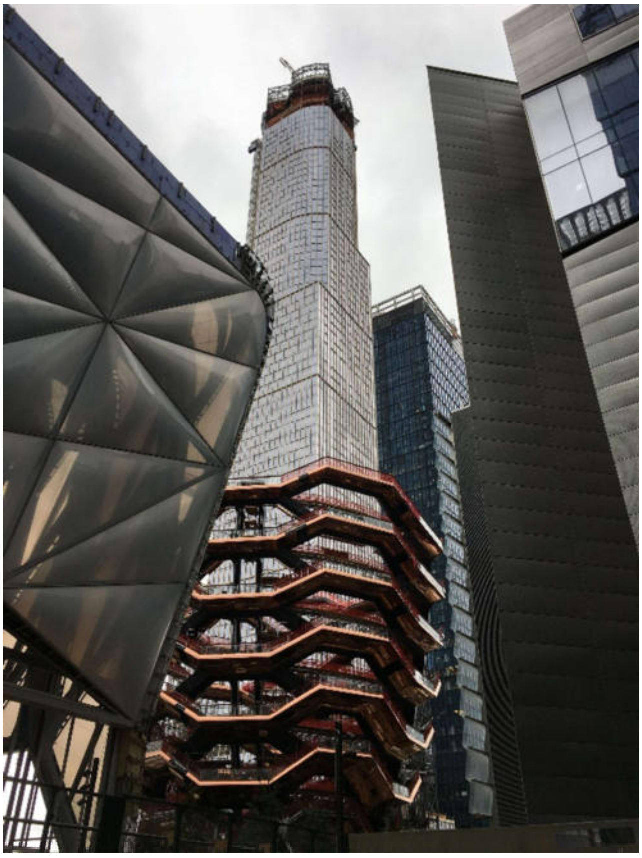

Figure 2.5 View at Hudson Yards from High Line Park (photo by the author)

High Line Park provides space for observation of some legal street art on the firewalls of surrounding buildings as well as it serves as a location for the other pieces of art such as statues and installations located in the park itself. Examples of street art are presented in Figures 2.6-2.7. High Line Park also provides places for the small businesses and attracts more investments to the part of the city where it is located (Cropp 2011 p.1; Broder 2012 pp.249-250).

Figure 2.6 Legal street art at High Line Park (photo by the author)

Figure 2.7 Statue at High Line Park (photo by the author)

The overpass lost its initial infrastructural value since the rail line is not in use anymore. However, it provides a vehicle-free route for pedestrians which can be accessed from the different points consisting of stairs as well as elevators for disabled people. The access points are shown in Figure 2.8 where black dots stand for the stair access, the elevator sign for the elevator access and the disabled sign for the ramp access.

Figure 2.8 Scheme of High Line Park access points (image from Wikipedia)

2.3 Cantilever Bridge in Zaryadye Park and Bagration Bridge (Moscow, Russia)

Cantilever Bridge is located in the centre of Moscow in the beginning of Varvarka street in the recently constructed Zaryadye park. It is also known as “The Flying bridge” because of its unusual design. It was opened for public at the same time as Zaryadye park itself in 2017. The layout of the Cantilever Bridge and its location at the map of Moscow are presented with Figures 2.9 and 2.10 respectively.

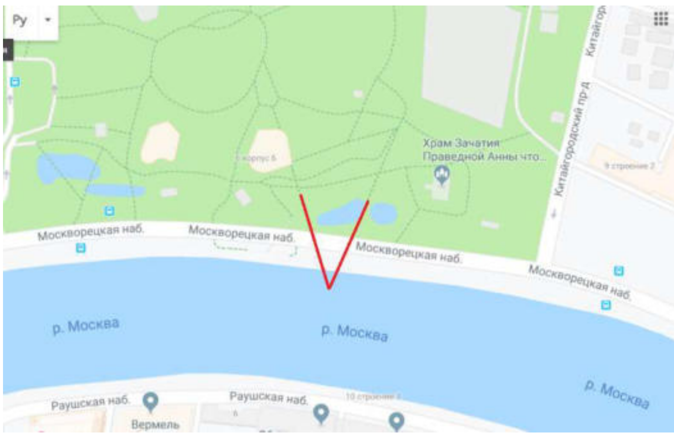

Figure 2.9 Layout of the Cantilever Bridge (original image from Google Maps)

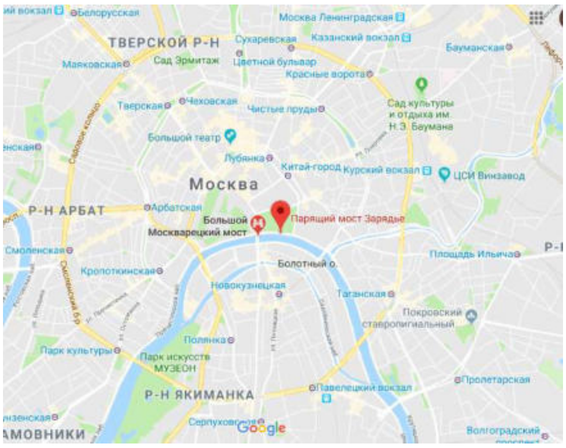

Figure 2.10 Location of the Cantilever Bridge (original image from Google Maps)

It is a new bridge. The park was constructed on the plot of land where all of the old buildings were demolished. Cantilever Bridge serves as one of the main attractions in the park and is popular especially among tourists who go to the bridge's observation point to see views of Moskva river, Kremlin and Raushevskaya embankment.

Bridge structures are made from the prestressed concrete elements, steel was used for decorations and the walking area is made from the wooden planks. The bridge has a cantilever system which means supports are only located on the one side of the structure. The view of the bridge is shown in Figure 2.11.

Figure 2.11 Cantiliver Bridge in Zaryadye Park (image from mos-holidays.ru)

Cantilever Bridge has no infrastructural value since it does not connect river banks. Its main purpose is to serve as a tourist attraction by providing a unique sightseeing area in the city center. Its popularity, however, attracts more people to the park which has a number of businesses running inside.

There are no resting areas or vegetation located on the bridge itself, however, in this case it does not seem necessary since it is located in the park which provides all of these. Therefore, only two relatively narrow passes leading to a wider open sightseeing area are available for the people. The view of the bridge model from the top is shown in Figure 2.12.

Figure 2.12 View on the model of the Cantiliver Bridge from the top (image from moslenta.ru)

Bagration bridge is located near the Moscow City district which serves as a business center of the city since its skyscrapers host a number of offices of big companies. It connects Krasnopresninskaya embankment and Taras Shevchenko embankment crossing the Moskva river. The construction was completed in 1997. The layout and location of the Bagration Bridge are shown in Figures 2.13 and 2.14 respectively.

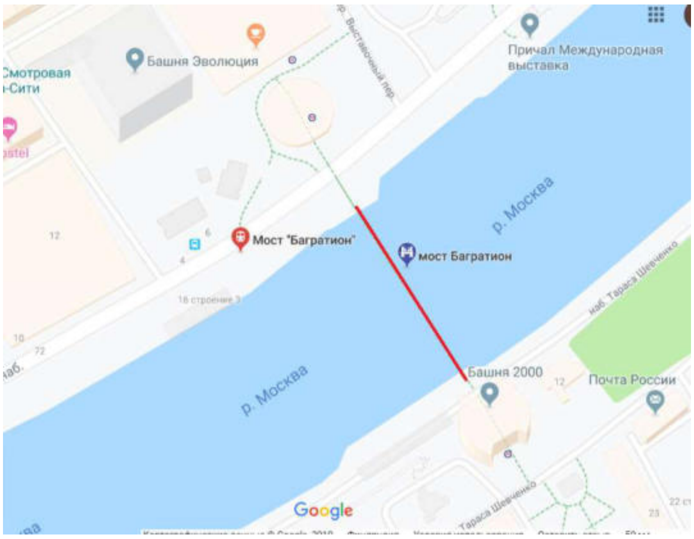

Figure 2.13 Layout of the Bagration Bridge (original image from Google Maps)

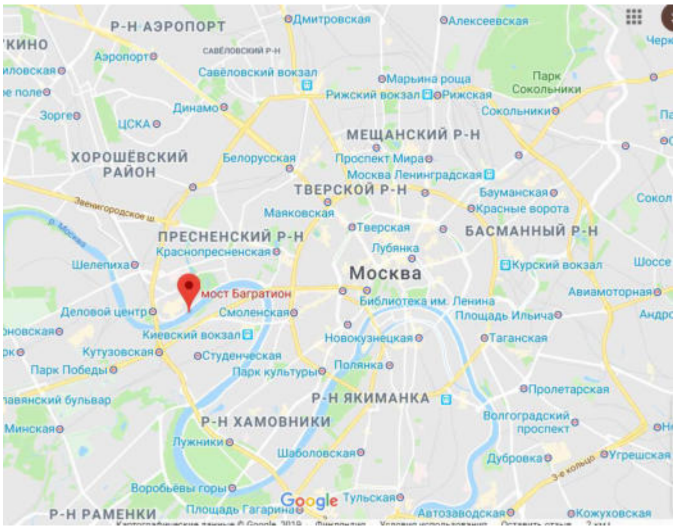

Figure 2.14 Location of the Bagration Bridge (original image from Google Maps)

The load-bearing construction of Bagration Bridge is made of steel framework. The bridge is 214 meters long with the longest span being 147 meters long. Spans are 16 meters wide. It is a two-level structure with the roof and walls where the first level is a walkway with travolators installed on both sides of the span, glass walls which provide a view over Moskva river and both embankments. The second level serves as a mall area and many shops are located in the central part of the span. The glass walls of the second level as well as a special observation point provide sightseeing opportunities. The view of the Bagration Bridge from the Taras Shevchenko embankment is shown in Figure 2.15.

Figure 2.15 View of the Bagration Bridge (photo by the author)

Wide span allows Bagration Bridge to host some small businesses, glass walls and observation point make it an attractive place for sightseeing. At the same time the bridge still manages to fulfill its infrastructural purpose by allowing people to cross the river from the busy business district of Moscow City to the mostly residential district of Dorogomilovo with a fast and vehicle-free route. The view of the Bagration Bridge from the inside is shown in Figure 2.16.

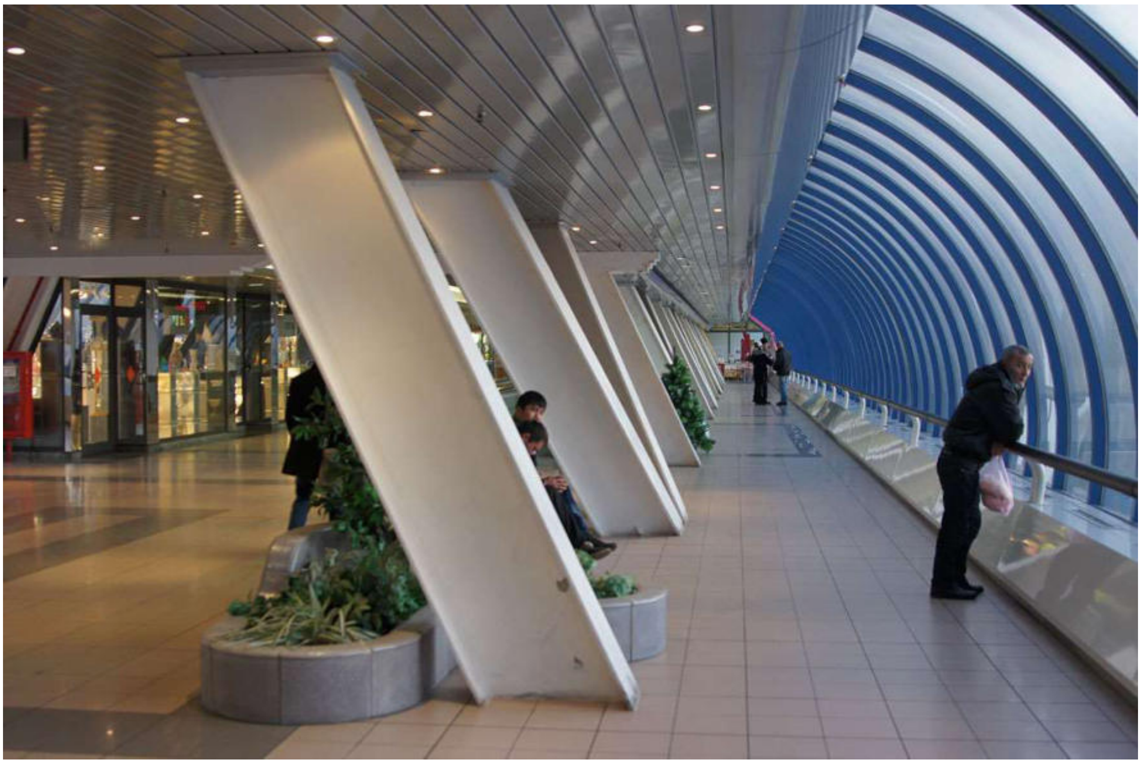

Figure 2.16 View of the Bagration Bridge from the inside (image from travel.wmouse.ru)

2.4 Gateshead Millennium Bridge (Newcastle upon Tyne, UK)

Gateshead Millennium Bridge was constructed in 2001. It is located in the central area of Newcastle upon Tyne near the Baltic Art Centre crossing the river Tyne. It is one of the fifteen bridges crossing the river in the city area. The layout and location of the Gateshead Millenium Bridge are shown in Figures 2.17 and 2.18 respectively.

Figure 2.17 Layout of the Gateshead Millenium Bridge (original image from Google Maps)

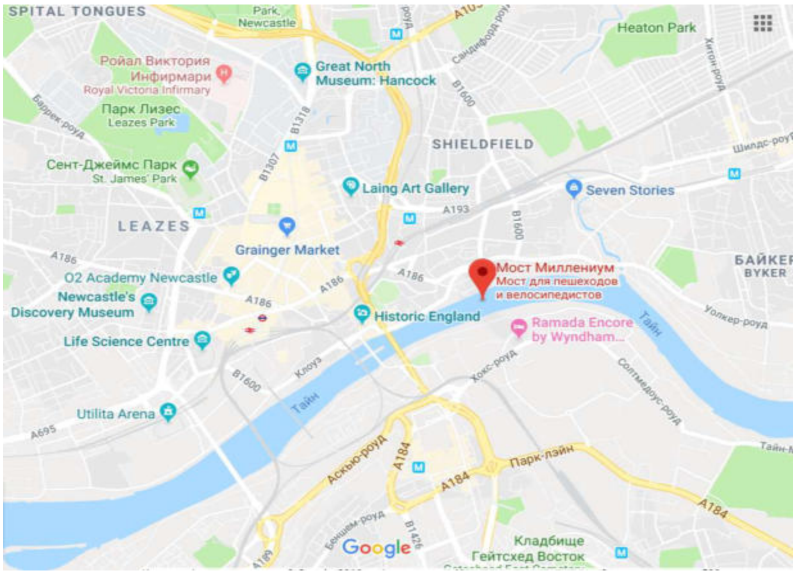

Figure 2.18 Location of the Gateshead Millenium Bridge (original image from Google Maps)

Gateshead Millennium Bridge is the first in the world tilt bridge which means that instead of lifting up or moving horizontally a span or a part of the span to let the ships pass it tilts on the side creating a big enough clearance gauge. The bridge in the tilted position is shown in Figure 2.19. The tower, cables and span of Gateshead Millennium Bridge are made of steel, piers are made of concrete. The view of the Gateshead Millenium Bridge from the sightseeing point at the top of the Baltic Center for Contemporary Art is shown in Figure 2.20.

Figure 2.19 Gateshead Millenium Bridge in the tilted position (Wikipedia)

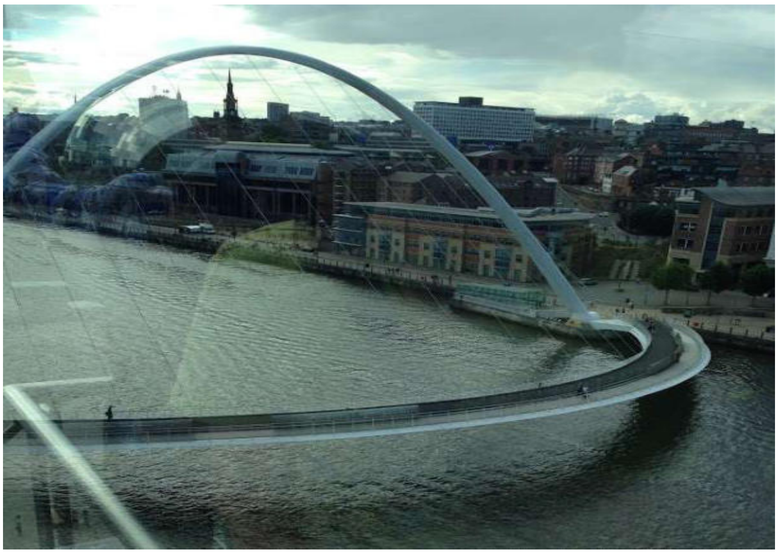

Figure 2.20 View at the Gateshead Millenium Bridge (photo by the author)

The bridge serves as a pedestrian and bike route in the cultural and business center of the city of Newcastle providing a shorter route between two busy districts of Gateshead in the South and Jesmond in the North without the need to use an automobile. Automobile Tyne Bridge is located further down the river.

Gateshead Millenium Bridge is usually praised for its unusual design and energy efficient tilting mechanism and self-cleaning system (Rhodes 2011). However, it also became one of the most popular tourist attractions in Newcastle in the years following its opening. Such popularity is probably a result of bridge’s international fame as well as its good location between two of the most visited central districts of the city where many other tourist attractions and landmarks are located.

Space provided by the 8-meter-wide curved bridge span fulfills its infrastructural purpose by hosting a pedestrian and a bike route separated from each other with a small fence and some benches. However, the bridge also serves as a sightseeing point providing a scenic view over the river Tyne and its embankments as well as it is a sight itself attracting more people to the area and rising the value of the surrounding land and businesses. The view of the Gateshead Millenium Bridge from the Tyne embankment is shown in Figure 2.21.

Figure 2.21 View of the Gateshead Milleium Bridge from the Tyne embankment (image from traveltriangle.com)

2.5 Overpass in Tufeleva Roscha Park (Moscow, Russia)

Tufeleva Roscha also known as ZIL Park is a public space constructed in the fast developing Danilovsky district of Moscow in 2018. It is made in public-art style in the old industrial zone and supposed to become an important recreational place for the inhabitants of the newly constructed multi-storey apartment buildings in the district. It makes its purpose and location similar to the High Line Park in New York City. However, the approach to the construction of the overpass in the ZIL park was different from the one in New York. The layout and location of the overpass at the ZIL park are shown in Figures 2.22 and 2.23 respectively.

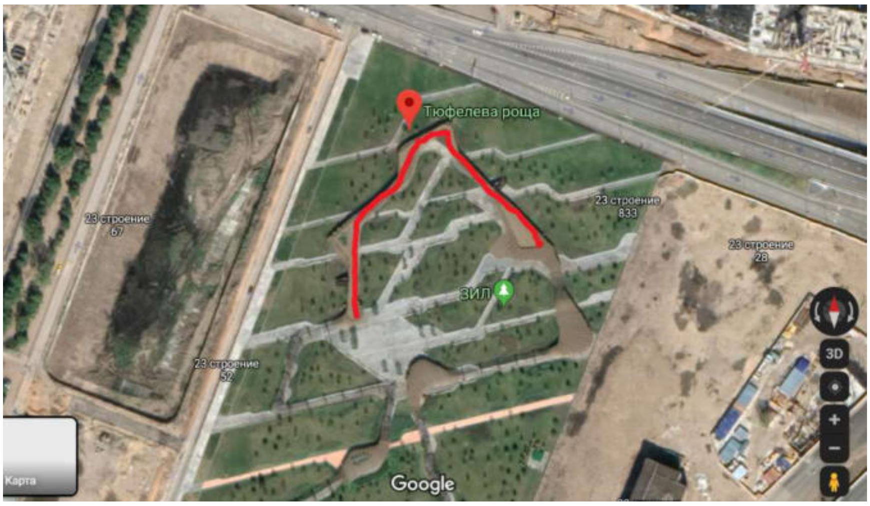

Figure 2.22 Layout of the overpass at ZIL Park (original image from Google Maps)

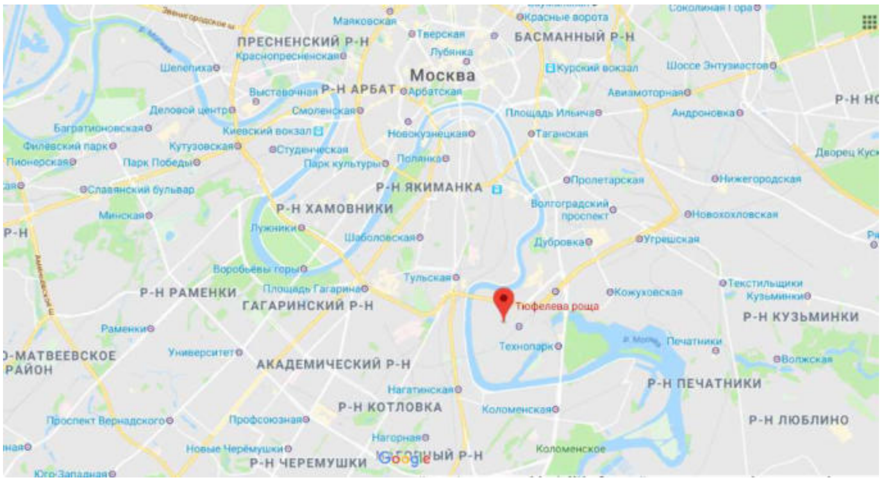

Figure 2.23 Location of the ZIL Park overpass (original image from Google Maps)

One of the most notable sights of the park is a 1.3 kilometre long pergola part of which serves as an overpass. Its architectural qualities are praised in the local media and municipal government website (Complex of the Urban Planning Policy and Construction of Moscow 2019). Indeed, it might serve as an important sight in the newly constructed public space. However, this overpass has no infrastructural or public function since the space of its spans is empty and the overpass itself leads nowhere and is not even closed in a circle, which would create an alternative walking route in the park. There are multiple access points to the overpass located in the park but all of them are presented in the form of narrow stairs which makes the structure inaccessible for the wheelchair users and people with the strollers. The spans of the overpass are narrow and host nothing apart from some safety features such as safety railings. Only a few people go on top of the overpass to see the sights from above and the structure while still being beautiful seems at the same time empty and useless. The views on the overpass and pergola are shown in Figures 2.24-2.26.

Figure 2.24 Overpass at ZIL Park (image from otzyv.ru)

Figure 2.25 Model of the overpass at ZIL Park (image from otzyv.ru)

Figure 2.26 Pergola at ZIL Park (image from estate.ria.ru)

The reason for it might be that it has nothing to offer to the visitors of the park apart from some sights. The overpass at ZIL Park can serve as an example of the structure where space provided by the spans is used ineffectively.

2.6 Analysis of the structures

The four structures chosen for this chapter have proven to be a success in creating a public space or significantly increasing the value of the already existing ones by becoming a centre of attention inside them or strongly improving their infrastructural qualities. Therefore, some ideas gathered from their designs and planning can be implemented in the other projects that are trying to achieve the same goal – effective use of the space provided by the spans of the pedestrian or cyclist bridges and overpasses.

Such design and planning ideas can be borrowed from these structures: Barrier-free environment should be created to ensure everyone is able to use the created public space and a piece of infrastructure. Different kinds of vegetation such as trees, grass, flowers and bushes can be located on the spans to create a comfortable park-like environment which is of high demand in the overpopulated areas with high land prices. Places for rest such as benches, street chairs, deck chairs and other pieces of publically available street furniture should be placed in the area to create a more comfortable recreational space. Sightseeing decks or observation points should be created if they provide a good view to make the space more attractive for tourists and the structure itself should have some interesting architectural solutions for the same purpose. Such solutions would be especially beneficial in cases similar to the overpass in ZIL park since it is located far from the main points of attraction in the city. Therefore, the amount of visitors will increase but not to the state where the structure would become uncomfortable to use. For the structures that are located in more busy urban areas solutions that would increase the amount of visitors should be implemented with extra care since due to the limited space provided by the span such structures can easily become overcrowded and partly lose their infrastructural value.

Small business areas should be located near the structure or at the structure to increase its commercial value. It is good if a structure also serves as an important piece of infrastructure and provides a safe, comfortable, car-free route for pedestrians, cyclists or both. Some space can be used as an area for publically available art to make the space more interesting to the people. Art installations can be temporary and can change over time to keep the public interested. The location of the structure is important which means that there has to be a high demand for a public space and a piece of infrastructure in the area. The space should be open which means that there should be no automobiles, trains or tall buildings on it or too close to it if it is possible to make it feel more like a safe and peaceful park area.

In general, to increase the social value of the structure it should be made more satisfying in three main ways: as a piece of the infrastructure, as a public space and as an object that has a positive effect on the local economy.

3 Materials

One of the main goals of the urban design, especially, in the case of the pedestrian and cyclist infrastructure is to increase the social value of the structure. It can not be achieved just with the effective use of the space provided by the structure. It also has to come from better, more environmental friendly and effective materials, which will increase the social value of the structure by reducing the damage done to the nature.

This chapter explores loads for calculations and requirements for pedestrian bridges and overpasses from such standards as SP (Rules of Construction) and Eurocode that are used for construction of the new structures to see if the same designs and materials can be implemented in different regions of the world. Values from SP represent requirements of standards from the ex-Soviet countries and Eurocode represents the requirements of the western countries. This chapter also takes a look on different materials which can be used for pedestrian bridges and overpasses construction.

Same materials and systems that are used for automobile, railway and mixed-purpose bridges can be used for the pedestrian bridges as well. However temporary loads on such structures are significantly lower (SP 2011 p.43; Eurocode 2003 p.59). Because of that, load-bearing requirements are not that high, which can be used to implement more architecturally interesting design solutions, wider spans can be used which would provide additional space that can be used as a public space, construction of the new structures on top of existing bridges and overpasses after renovation and change of purpose also becomes possible.

According to the SP temporary equally distributed vertical load from pedestrian and cyclist movement if there is no automobile or railway movement on the structure - $q_{fk} = 4\ \mathrm{kN/m^2 (kPa)}$. In Eurocode $q_{fk} = 5\ \mathrm{kN/m^2 (kPa)}$. In Eurocode concentrated load Q_{fwk} is also mentioned. $Q_{fwk} = 10\ \mathrm{kN}$ for the square surface with sides that are 0,1 meter long. However, these concentrated loads are only taken into account for the local effects. There are also loads from accidental situations such as resonance, collisions etc. mentioned both in Eurocode and SP. Constant loads from the weight of the structure and loads from the service vehicles that might be used at some point of the structures' lifecycle should also be taken into account. Service vehicle loads are calculated as a concentrated load from just one vehicle unlike usual distributed or concentrated loads from multiple sources that are used in the automobile and railway bridges.

There is a small difference between the q_{fk} values in the different standards but this difference is insignificant and does not affect design solutions dramatically but all the other loads seem to depend heavily on the structures' location and the structure itself without any significant differences in calculation standards. This means that relatively the same design decisions can be implemented in different regions of the world and structures from the first chapter can be used as examples everywhere. It means that in this chapter more attention can be paid to the architectural and planning aspects and not the structural qualities of the materials.

Traditional materials such as wood, stone, steel and concrete can be used for the bridge construction as well as relatively uncommon materials such as aluminum, glass and carbon or glass reinforced plastics (CRP and GRP). When choosing a material for a bridge it is important to think about four aspects. First, the structure has to be safe, which means material has to have required load-bearing capacity and they have to be durable enough to take the load without meeting any of two limit states. Second, they have to meet the architectural requirements for a specific construction case since usually it is not allowed by the law to build a massive hi-tech looking structure made of glass in the historical center of an old city. Third, they have to be as environmental friendly as possible. And last, they do not have to require too much maintenance during their lifecycle because it can significantly increase the cost of the structure use over the years and can become a heavy burden for its owner. Also as little material as possible should be used for construction to lower the price of the structure, its weight and therefore make it as efficient as possible (Keil 2013, p. 27).

There are many examples of use of conventional materials for the bridge construction and building standards describing and regulating construction of steel and reinforced concrete structures quite well. Therefore, this chapter will focus more on less commonly used materials such as wood, aluminum, glass, CRP and GRP and will describe possibilities of their use.

Wood is a traditional material that has been used for all types of structures for many centuries. However, with the introduction of industrially produced steel and reinforced concrete wood started to play a secondary role in construction. In Russia, for example, wood is considered a material that can be used for temporary bridges only. However, nowadays more and more permanent wooden structures start to appear all around the world. Especially it is the case in the Northern European countries rich with wooden resources. Vihintasalmi Bridge made mainly from wood can serve as an example of such a structure. This bridge won some awards and has been praised for its unique structure. Vihintasalmi Bridge is shown in Figures 3.1-3.2. These examples together with the increasing production of glue laminated timber as well as other timber products mark the renaissance of the wood as a construction material.

Figure 3.1 Vihintasalmi Bridge (image from woodarchitecture.fi)

Figure 3.2 Vihintasalmi Bridge span (image from woodarchitecture.fi)

Wood and timber products with correct protection are durable enough to be used for secondary or even primary support structures in bridges (Keil 2013, p. 28). Also wood is an environmental friendly and renewable material, which makes it a good choice for construction of the pedestrian bridges.

Pure aluminum is not used as a construction material. However, aluminum with the addition of the alloying elements becomes a lightweight construction material with strength similar to the strength of steel but way lower stiffness, which leads to bigger deformations under the load, and limits the use of the aluminum in the load-bearing constructions. For example, a long aluminum beam has a high chance of achieving high deflections, which would lead to the reaching of the first limit state, which is not acceptable. It has such advantages as good material efficiency, stability and low maintenance requirements and these qualities are good for construction of any structure. It also has a significant advantage over steel in the cold environment that makes the steel brittle but only makes aluminum stronger increasing its tensile strength, which is the most important property for the bridge beam since it usually, has to face bending load. However, aluminum is expensive compared to steel and its production requires lots of energy which causes some ecological damage and makes aluminum not quite an environmental friendly material. It can still be used in the different parts of the structure as supports or covers for the surfaces but extra caution in evaluation is required when aluminum is chosen as a primary material for the structure. An example of a bridge made primarily from aluminum is shown in Figure 3.3.

Figure 3.3 Aluminum bridge (image from aluminiumimsider.com)

Glass is not usually used in the supporting or any load-bearing structures because even though it has comparatively high theoretical tensile and compression strengths it does not perform well in the actual structures. That is so because of the possible defects that often occur during the manufacturing and transportation of glass and because of the natural causes. These defects lead to the dramatic decrease of the real glass strengths, especially compressive strength compared to the theoretical values (GOST 32281.1-2013). Such defects also make glasses' bending resistance very low and make it impossible to use in the spans, which are more than 5 meters long (Keil 2013, p.31). Low compression strength means that glass can not be used in any vertical supporting structures as well. Still glass can be used in combination with steel, for surface covers and for non-load-bearing parts of the structure, for example railings.

Carbon reinforced plastic (CRP) and Glass reinforced plastic (GRP) are relatively new materials. Plastic in CRP and GRP is reinforced by the glass or carbon fiber, which leads to a very high tensile strength of the final material (up to 2400 N/mm^2) which makes elements made out of such materials strong, durable, and therefore suitable for use in the load-bearing parts of the structure. They do not require lots of maintenance during their lifecycle and can withstand harsh weather conditions. These composite materials are also relatively lightweight. Those qualities could make them one of the best options for the construction of the new structures, however, they are expensive when compared to the traditional materials and not always easy to get since there are not so many companies producing such materials for construction. Environmental friendliness is also an issue with such materials because their production like the production of aluminum requires lots of energy and depends heavily on the use of chemicals. CRP and GRP can still be used when they are available and a lightweight load-bearing construction is needed but these materials probably would not be the best option for the most of the projects. CRP and GRP are shown in Figures 3.4 and 3.5 respectively. However, the look of the material might differ depending on the type of plastic and amount of reinforcing fibers. The bridge in Fredrikstad constructed mainly from CRP is shown in Figure 3.6.

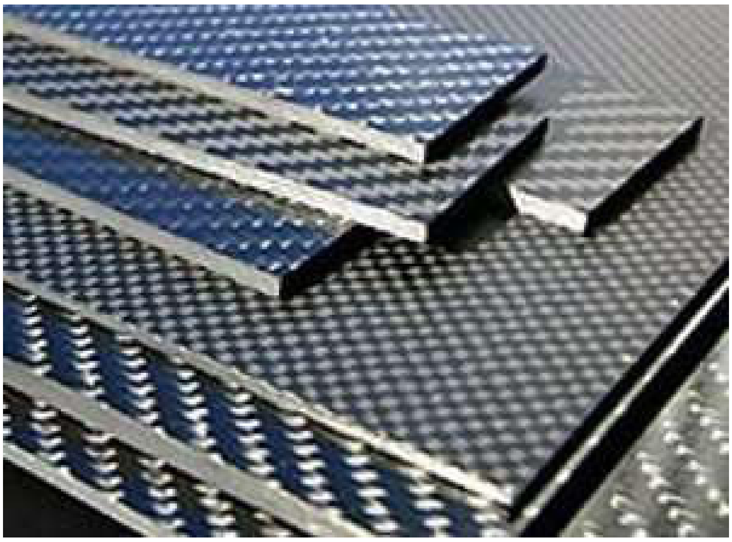

Figure 3.4 Carbon reinforced plastic (CRP) (image from industrialnetwork.com)

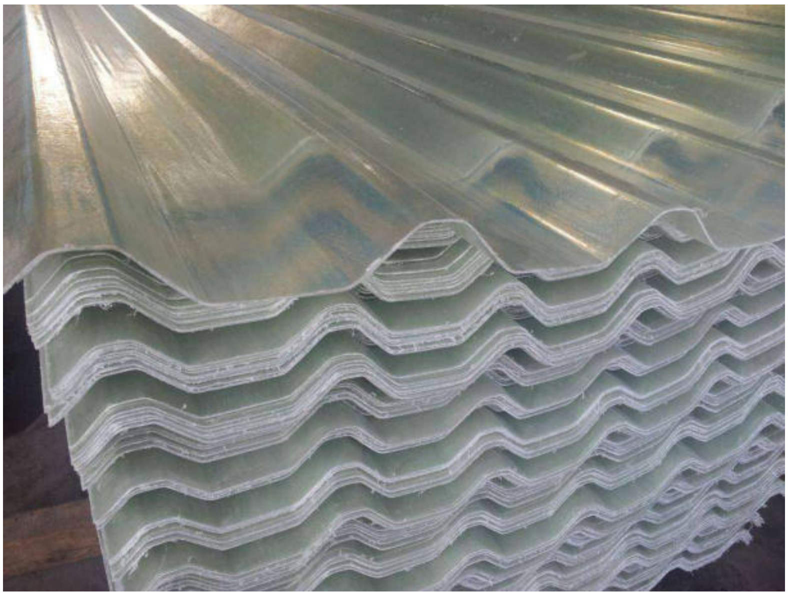

Figure 3.5 Glass reinforced plastic (GRP) (image from ecplaza.net)

Figure 3.6 Bridge in Fredrikstad made from CRP (image from Keil 2013, p.86)

Judging by the information presented above non-traditional materials have some unique properties and can be useful in the construction of the bridges and overpasses but those materials should be chosen with extra caution since all of them have their downsides which sometimes can take precedence of their good qualities. The only exception is wood which is not a new material but was not used as much as before during the last century after the invention of the steel-reinforced concrete and start of the mass industrial production of steel elements. Qualities of modern timber products allow it to be used in the construction of almost any structures but wood is still not the ultimate solution because wood production is not that well developed in many regions of the world and can be improperly organized which might lead to the destruction of the forests which can result in a big ecological disaster.

Conform materials like reinforced concrete and steel allow to construct spans ranging from a few meters up to 4800 meters. Reinforced concrete is inexpensive to produce and it is widely produced for construction almost everywhere. It can come in form of pre-made elements, which increases construction speed, or it can be made on-site to save money from the transportation of the elements. Concrete can be either pre-stressed or non-pre-stressed depending on the situation. Pre-stressed concrete allows to cover longer spans and carry bigger loads by reducing the bending stress of the beams and preventing cracks. Steel can be used in the bridge construction in form of cables or steel elements. Steel elements can serve as a basis for many different bridges systems such as arches, frames, cable-stayed bridges etc. Typical steel and concrete bridges are shown in Figures 3.7 and 3.8 respectively. Steel is more expensive to use in construction than the reinforced concrete but it is a better option when an element has to deal with high levels of the tensile stress since concrete is only good at holding under the compression stress. Industrial production of either steel or concrete is as almost any other industrial production not completely environmental friendly but it requires less energy than the production of aluminum or composite materials. These materials still have their limitations and there are some examples of the structures where they were used improperly, for example, Alexandr Nevsky Bridge in St Petersburg where a continuous span made of pre-stressed concrete requires a lot of difficult and expensive maintenance. Luzhnecky Metro-bridge in Moscow that hosts several railway lines and a metro station, which went far beyond the construction budget due to the improper use of the concrete structures can serve as the other example. However, if no special requirements for the structure are given and if non-conventional materials are not easily available in the region of construction it is better to choose either concrete or steel depending on the situation. Wood can also be a good option in many cases.

Figure 3.7 Typical steel bridge (image from hoyletanner.com)

Figure 3.8 Typical concrete bridge (image from nationalconcretebridge.com)

Figure 3.9 Alexandr Nevsky Bridge (image from Wikipedia)

Figure 3.10 Luzhnecky Metro-bridge (image from Wikipedia)

Stone that is considered to be one of the traditional materials for bridge construction was not taken into account in this chapter because nowadays it is used very rarely. It can cause problems with supply since there are not so many companies providing stone processed specifically for construction. The other problem is that there are no standards describing construction of the stone bridges, this can lead to the unexpected problems with the structure during the construction or during its lifecycle. A stone bridge is shown in Figure 3.11.

Figure 3.11 Stone bridge at Pakenham (image from Wikipedia)

Comparison of the load-bearing capabilities of different materials can be done as a comparison of their tensile and compressive strengths. Resistance to bending and shear force stress are also important for the bridge construction but since these as well as some other properties vary greatly from one type of the same material to another and are not provided for some of the materials at all they would not be taken into account in this comparison. This simplification seems to be possible since the goal is to compare materials and not to calculate a load-bearing capability of a certain structure. Values for the comparison (except for CRP and GRP) are taken from SPs and GOSTs. However, they are similar in both of the standards. Qualities of CRP and GRP are taken from the manufacturer websites. The approximate values of these two qualities are presented in Table 2. The values are obtained from the standard test specimen for each material.

Table 2. Comparison of material strength

Material	Compressive strength (MPa)	Tensile strength (MPa)	Extra notes
Wood	4.5-50	6-120	Anisotropic material
Aluminum	-	310	Low stiffness
Glass	1	7	-
CRP	160-240	80-585	-
GRP	200-230	70-230	-
Concrete	7.5-80	0.85-2.75	-
Rebars (for concrete)	-	240-500 (1500)	-
Steel	380-490	380-600	-

It is important to mention that wood characteristics vary greatly and depend on the type of wood and the way the load is transferred to the structure. Load can be transferred to the wooden element along the fibers of the wood or perpendicular to the fibers. Wood gives up to ten times better results when the load is transferred to the wooden element along the fibers. Type of wooden product also makes a difference. Glue laminated timber (GL) and glue laminated veneer (LVL) (the best numbers being from the LVL) show significantly better strength qualities than logs or sawn timber. LVL and GL beams are shown in Figures 3.12 and 3.13 respectively. In these figures the direction of the fibers in the different layers of the materials can be seen. However, the direction of the fibers in LVL can be different depending on the type of the LVL.

Figure 3.12 Glue laminated veneer (LVL) (image from metsawood.com)

Figure 3.13 Glue laminated timber (GL) (image from perthtimberco.com)

Values for concrete also vary due to the different types of concrete. In this table the lowest numbers come from the B10 concrete and the highest from the B60. It is also worth noticing that only reinforced concrete is used in the load-bearing elements therefore the values for the tensile and bending strength of the reinforced concrete come mostly from the rebars. The maximum achievable tensile strength of the rebars is with the prestressed concrete where anchored thick steel cables act as reinforcement – it is given in the brackets.

Steel values depend on the type and diameter of the steel profile. Therefore, they also vary, although not as much as concrete or wood. Only the types of steel that are used in construction were taken into account. The theoretical strength of steel can be up to 6000 MPa.

For CRP and GRP the difference was in the total volume of carbon or glass fibers in the material. The tensile strength of pure carbon fibers can get up to 3500 MPa and the strength of glass fiber up to 3400 MPa so the more fibers there are in the material the stronger it gets. However, carbon or glass reinforced plastic can not be made purely out of the fibers which lead to the significant reduction of the strength making CRP and GRP strength qualities comparable to the more conventional materials like steel or reinforced concrete.

The results presented in Table 2 when compared to the loads given in the beginning of this chapter show that theoretically all of the materials can be used for the construction of the load-bearing structures if used correctly. Not all of them are, however, equally effective. Glass can not be used in the elements that might face any compressive stress because of its small compressive strength as well. However, all of the materials analyzed in this chapter are suitable for use in the bridge structures if their qualities are evaluated correctly and the suitable system is chosen for the structure. Therefore, other qualities of the materials should also be taken into account.

Another important quality for the materials for the bridge and overpass structures is weight to volume ratio – density. It should be taken into account since the load that the bridge supporting structures have to carry consists not only of the temporary loads but also of the constant loads, which are coming from the weight of the bridge elements. Therefore, the lower the constant loads the less load-bearing capability is required from the supporting structures. Low density means that material is lightweight and a big volume of such a material would not weigh too much. Consequently, materials with the lower density are preferable to use in the bridge structures. The density of the materials is presented in Table 3.

Table 3. Density of the materials

Material	Density (kg/m3)
Wood	300-1330
Aluminum	2700
Glass	2400-2800
CRP	1800-2000
GRP	910-1200
Concrete	2400 (without rebars)
Steel	8050

Analyzing the qualities presented in Table 3 it can be stated that wood and GRP have the lowest density. However, it should be mentioned that the types of wood with the lowest density values do not have good load-bearing qualities. Steel has the highest density out of all materials but it is largely compensated by its load-bearing capabilities. CRP and GRP show relatively good results in both load-bearing capabilities and density value.

As it was mentioned in the beginning of this chapter, the chosen material should be also environmental friendly, easy in maintenance, efficient and not too difficult or expensive to obtain. Therefore, materials should be compared in these categories as well. The results of the full analysis of the materials are presented in Table 4.

Table 4. Comparison of the materials

Material	Environmental friendly	Locally produced (usually) or can be easily ordered and delivered	Suitable for load-bearing structures	Easy in maintenance
Wood	+	+	+	+/-
Aluminum	-	+/-	+	+
Glass	-	+/-	+/-	+
CRP/GRP	-	-	+	+
Concrete	-	+	+	+/-
Steel	-	+	+	+/-

In Table 4 materials are compared in the four categories that can give the general idea about the material cost, environmental friendliness, efficiency and load-bearing capabilities. Environmental friendliness depends on such qualities of the material as renewability, production energy consumption and pollution caused by the production. None of the materials except for wood show good results in the environmental friendliness when these criteria are used for comparison.

Local production or easy delivery means that there are a lot of companies producing this material for construction, therefore, it can be easily ordered from a trusted supplier for a price close to the market price and delivered on time with the use of equipment suitable for the transportation of the elements made of such material.

Suitability for the load-bearing structures depends on material strengths and possibility of its use in the span or supporting structures. Maintenance easiness stands for how much effort is required to prevent possible damages to the elements made of such material and repair damages that have already occurred.

Judging by the material qualities from Table 4 wood seems to be the best material for the construction of the pedestrian bridges and overpasses. However, it is important to remember that wood has lots of limitations when compared to reinforced concrete and steel, for example with the maximum span length. Wood anisotropy might also become an issue in some cases and it creates some further limitations for the use of wood. For example, beams made out of round or sawn timber can not be long because load in this case comes perpendicular to the fibers. LVL, however, partly resolves this problem by providing timber materials where fibers can go in the opposite directions in different layers. Architectural qualities of wood might not be suitable for some landscapes but usually they fit well with the other buildings and structures. Therefore, wood and timber products can be used when it is possible but other materials should be considered as well.

4 Requirements

This chapter explores general requirements to pedestrian bridges such as safety and capacity requirements etc. There are no strong ties to any national or international standards in this chapter but some references would be made to the German DIN (Deutsches Institut für Normung) and European EN (European norm) standards since they are the most commonly used in the referred literature.

This paper sets study of the possibilities of creating of a public space on the bridge as its goal but bridge is still a piece of infrastructure and usually it has to function as such or at least it is good to make it so for the reason that it will increase the social value of the structure. In addition, created public spaces and infrastructure should be as comfortable and safe for people to use as possible.

Any bridge or overpass should meet obvious load-bearing requirements, natural effects resistance requirements (loads from the wind, water streams, vibration resistance) and impact resistance requirements (loads from collisions) that are responsible for structure integrity. Those are explained with a great degree of precision in all of the national standards and many studies. The bridge structure, however, has to meet requirements for span width, clearance gauge, requirements for comfortable use as well as, of course, safety requirements. Those are also explained in the national standards but the values and information given there are usually more suitable for use in the automobile, railway or mixed-traffic bridges with only brief notices about the pedestrian structures. This lack of information can lead to the creation of usable structures that are, nevertheless, uncomfortable for cyclists and pedestrians.

Loads for pedestrian bridges and overpasses established by such standards as SP and Eurocode were briefly explored in the previous chapter of this paper. Therefore, they would not be repeated here. Natural and impact loads would not be explored either since they vary greatly depending on the location and design of the structure. However, these loads should be still always taken into account.

DIN 18-024-1 prescribes the minimum width of a barrier-free route in the public spaces of 2 to 3 meters (Keil 2013, p.9). In some other countries, for example, in Great Britain the minimum required width for pedestrian bridges can be smaller because they do not take necessity of creating a barrier-free environment into account. Therefore, numbers from DIN 19-024-1 can be used as the minimum span width when designing a pedestrian bridge or overpass. However, width of the bridge span depends not only on its use as a piece of infrastructure but is also defined by the density and type of traffic so in case of creating a public space it has to be as big as possible taking other designs and urban planning as well as project budget into account.

Clearance gauge is defined by the bridge's location. It has to be big enough to allow water and ground transport to pass under the bridge or an overpass. It is an issue to be considered when the structure is constructed over the river or a bay where ship route is located, over the railway or over the automobile road or highway. Sometimes clearance gauge requirement can significantly affect the choice of the bridge system and, as a result, choice of materials and architectural properties. The minimum clearance gauge for pedestrian bridges is 2.5 meters, 4.5-4.7 meters for the roads and highways with the automobile traffic (Keil 2013 p.12). For railway transport, it is the same as the usual clearance gauge used on the railway lines, which is 5.5 meters (GOST 9238-83). However, it might differ a little based on the national railway traffic standards and local conditions, for example, speed limit for the certain railway line. For the water routes, the type of the water transport used and the annual changes in the water level define the needed clearance gauge.

Access and layout requirements are based on the principle of creating the shortest route from one place to another. Following this principles is important to create not just a usable structure but also a valuable piece of infrastructure. Access paths, therefore, should be as short and as convenient as possible and route layout is supposed to be flowing or even straight to avoid sharp corners that may be hazardous and lead to accidents, especially for cyclists. However, curvature and width requirements are not as strict as in the vehicle or railway traffic bridges and overpasses because of the relatively slow speeds of pedestrians and cyclists.

Design of a specific structure that would provide access to the bridge is needed when edges of the bridge are located above the ground level. For the pedestrian bridge those structures can come in three forms: ramps, stairs, lifts. Ramps can be a comfortable access structure. Nevertheless, according to DIN 18024-1 the inclination of the ramp is supposed to be less than 6% and for the ramps that are longer than 6 meters an intermediate landing is required. The scheme of a ramp is shown in Figure 4.1. Such ramps can become too long because of this inclination limit. Stairs can be used as an alternative that occupies less space and also provides a quicker route to the structure. However, if the access point consists exclusively of stairs, the wheelchair users and other people who for some reasons cannot use stairs would not be able to use the access point and the structure will not become a barrier-free environment, which will lead to a significant decrease of its social and infrastructural value. This problem can be solved by creating both stairs and the ramp. It will solve the problem with the route length but such an access point will occupy even more space. Another solution is creation of one or multiple lifts. They occupy less space than a ramp but their construction and maintenance are notably more expensive than those of a ramp. If combined with stairs lifts can create a barrier-free environment in the areas where space is limited. However, using lifts exclusively will result in high maintenance cost and might lead to the appearance of lines at the access points.

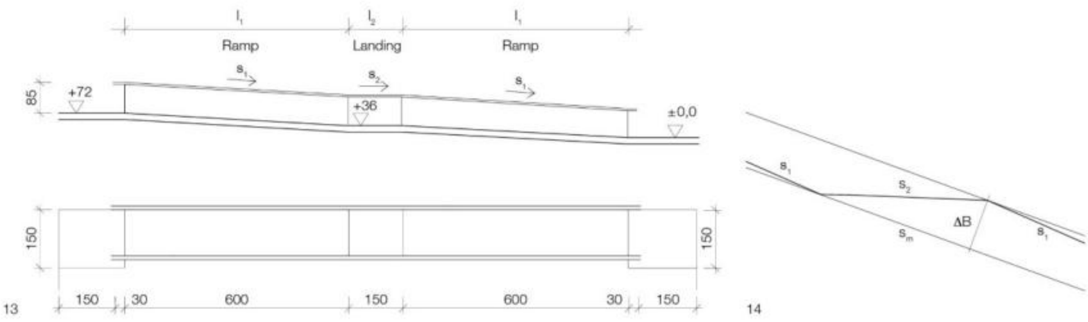

Figure 4.1 Scheme of the ramp (image from Keil 2013, p.13)

Safety requirements are important in all types of structures. Bridges and overpasses are not an exception. Except for the structure collapse that can only be prevented with the correct risk evaluation, good designing and construction as well as maintenance, the main danger coming from a bridge or an overpass is the danger of falling since these structures are elevated above the ground level. Therefore, railings might be one of the most crucial safety features for the bridge and should separate all of the pedestrian and cyclists routes from the edges of the bridge. Correctly installed railings are usually enough to prevent accidental falls from the structure. Railings also provide guidance, which is important to make the created route comfortable for the people. However, railings are not enough to prevent purposeful jumps so if the span of the bridge or an overpass is located high above the ground prevention barriers or nets might be needed to prevent suicides. An example of a prevention net is shown in Figure 4.2.

Figure 4.2 Prevention net at the bridge (image from jakob.com)

A barrier separating cyclist traffic from the pedestrian traffic might prevent possible accidents especially if there are any dangerous turns located on the structure. However, since the speeds of both cyclist and pedestrian traffic are low and there is no car traffic on the structure such barriers are not necessary.

All of the other safety equipment is used during the maintenance. Such pieces of safety equipment as safety pillars, extra safety railings etc. can be located on the structure if some works on the high and open surfaces should be done during the maintenance.

The other requirements are supposed to provide comfortable use of the structure and seem to be international. Those are drainage, lighting and surface requirements.

Drainage is necessary if the bridge is open and, therefore, exposed to such natural conditions as rain and snow. It is needed to remove the rainwater or the water from the melting snow from the surface. To achieve this, a gradient of no less than 2% should be created in the longitudinal direction and 1.5-2.5% in the transverse direction. Drainage wells can be located behind the abutments with the slopes leading to them by the edges of the bridge span. Direct drainage can be created from the intermediate supports or the spans of the structure. However, direct drainage might be an unacceptable solution for the overpasses since the area underneath the structure is usually also used. As for the bridges, direct drainage from the spans is not considered the best solution and is rarely approved by the authorities since the use of the uncontrolled drainage is prohibited because of the use of de-icing salt on the walking surfaces in winter (Keil 2013, p. 72).

Lighting is crucial for any structure that is supposed to be used not only in the daytime but also during the twilight in the morning and in the evening and at night. Pedestrian structures should be well lighted for several reasons: to ensure safe use of the structure, to increase the subjective feeling of safety of the users and to highlight architectural properties of the structure in the dark. Bridges and overpasses can be lighted either indirectly from the light sources located nearby that are not part of the structure or from the light sources located directly at the structure. Lighting of the structure might become a complicated task since often there are many variables and many possible solutions for every case. DIN EN 13201 dedicated to the street lighting sets lighting classes for the structures with the different types of traffic. Those classes range from S1 to S7 and prescribe a certain horizontal intensity of illumination required for the certain structure. S-classes from DIN are comparable to the A-classes that are used by the most of the European countries. However, A-classes use the hemispherical luminance and not the horizontal one and only consist of six classes instead of seven. Correct lighting of the pedestrian structure is very important since it directly affects many crucial aspects of its use, especially, if the structure serves not only as a piece of infrastructure but also as a public space. Therefore, enough attention should be paid to the lighting if the goal is to create a structure with the high social value.

To create a deck that would be comfortable for its users a right surface cover should be chosen. Usually the bridge structure predetermines the use of the certain materials as the surface covers. Decks are not an exception to the other surfaces and their cover strongly relies on the primary bridge materials. When a deck cover needs to be chosen several aspects should be taken into account.

These aspects can be roughly divided into practical and aesthetical. Practical aspects are: the usage of the deck, required abrasion-resistance, mass of the walkway slabs or plates. Aesthetical aspects are: colour, transparency and texture.

Deck covers can be chosen from the wide range of materials. The most common materials will be mentioned below. Concrete slabs or steel plates are often used and do not necessarily require any additional coating. However, concrete surfaces need to be roughened to make them more slip-resistant, the same can be achieved for the steel surfaces with the thin layer synthetic coating that would also protect such surfaces from corrosion. Synthetic coatings can be used on the concrete surfaces as well. They are usually resin-based and, therefore, can be coloured in any colour and almost any shade. Asphalt, traditionally, can also serve as a coating. It can be used instead of the synthetic coatings. Glass and stone can be used for the bridge decks construction. They usually do not need any extra coatings and are used uncovered since such materials are usually chosen for their unique aesthetical properties. Glass should be used with the extra caution because of its unusual qualities.

Wood can serve as a good surface cover. However, it has to be used carefully as well, because of some unique properties. No longitudinal planks should be used on the decks where any non-motorized wheeled transport will be used since wheels can get stuck in the gaps that will appear between the planks during the drying of the wet wood, which is likely to cause accidents. In addition, wood should be primarily used in the well-ventilated areas or at the open bridges since otherwise, it would not dry properly and the rot will appear shortly. Anti-slip measures might also be necessary for the wooden covers because wet wood can be relatively slippery. Luckily, those measures can be easily implemented with the use of the same synthetic coatings as with the steel and concrete or with the change of the wood surface texture.

5 Possibilities of BIM use in urban bridge designing and planning

This chapter explores BIM (Building Information Modelling) tools that can be used for the pedestrian bridges and overpasses designing, erection, maintenance and renovation. Different software is briefly compared. Programs suitable for use during the design, construction and maintenance phases are found.

BIM technologies that involve 3D modelling are becoming more and more widespread in all branches of the construction industry but still many blueprints are done in the CAD software such as AutoCAD. That is especially true for the infrastructural projects because of the special requirements to the modelling software. However, more and more companies start to implement BIM tools in their everyday design and construction work. Modelling and calculation software is always used for big and complex projects such as long-span cable-stayed bridges but it is becoming more and more attractive for the use in the smaller projects as well. BIM makes work of engineers and designers more effective as well as they help to provide on-date and precise information to the contractors at the construction site. BIM technologies can be used not only during design and construction phases but also during the whole lifecycle of the structure for monitoring and maintenance tasks. Overall, they increase the efficiency of work of all of the parties involved. This increase of efficiency leads to the reduction of time required for the design and construction works, lesser costs, better, more unusual and complex solutions in architectural and structural designs which increase the social value of the final structure and as it was stated in the beginning of this paper, increase of the social value is one of the goals of the urban bridge design. Therefore, such tool as BIM and its capabilities should be explored.

BIM tools in the bridge construction can be used during all phases of the structure lifecycle. Therefore, adequate software should be chosen for each one of these phases or one program should be suitable to use for all of them.

There is some BIM software designed specifically to model bridge structures. However, most of the bridge design software is expensive and can only be purchased by the relatively big companies who more or less rely on the infrastructural projects. Many of the other modelling and calculation programs are suitable for creating bridge models as well. Although, they are not that easy to use for such purposes. For example, Autodesk Revit theoretically allows its user to create almost any structure with additional possibility of easily exporting it to Autodesk Robot for the load calculations. However, its interface unless modified is not very suitable for modelling of a bridge or any other piece of infrastructure. The other problem of Revit is that it lacks simple tools for creation of common bridge elements, although, these elements can still be created with the use of masses and other functions of Revit. The same problems occur with the use of standard version of Tekla Structures and other more house-like structures oriented software. However, the version of Tekla Structures modified for bridge modelling provides a better working environment and allows to export structural models to Sofistic and other calculation and analysis software. Therefore, it is still possible to use not specialized software for bridge modelling, especially, since there are modifications for some of them that solve most of the problems. However, because of the limitations of these programs they might be less effective than the specialized software. Another problem that is typical for such software is the integration of models with the road models, which is crucial since bridges and overpasses are usually a part of a bigger infrastructural project.

All of the BIM tools designed specifically for the bridge design have their own strengths and weaknesses as well. Therefore, software should be chosen after the adequate analysis of its qualities and specific needs of the current model and needs of the project as a whole. However, most of them have some similar ideas implemented in them. One of them is the calculation method: all of the bridge modelling software which can be used for calculations relies on the finite-element method (FEA) for calculation which basically means splitting a structure into small simple parts and calculating load transfers between them. Although, the similar theoretical ideas are behind all of the calculation software not all of the programs are equally good for modelling and calculating all types of bridges.

Comparison of the most popular bridge modelling software is presented in Table 4. Software used for calculations and analysis only such as Sofistic as well as purely architectural software is not presented in the following table. FEA software not designed specifically for the bridge modelling such as SAP2000, ANSYS or Abaqus are not presented either.

Table 5. Software for bridge modelling

Name	Developer	Capabilities
Tekla Structures (bridge modification)	Trimble	• Precise structural models • Automatically created lists of quantities • Updates for existing models • Import of models to the other programs for calculations and analysis • Clash checks
OpenBridge Designer (OpenBridge Modeler with additional programs)	Bentley	• Combines modelling, analysis and design tools • Possibility to create physical and analytical models • Construction management tools • Data sharing tools • Tools for detailed modelling of elements

		• Easy to make modifications to existing models • Clash checks • Integration of models and LandXML, DGN files • 3D Visualization tools • Real-time traffic simulations
Midas CIM	Midas	• Precise structural models • Possibility to cre-ate physical and analytical model • Bills of materials auto generation • Auto generation of cross-sections • Integration with Midas Civil and Midas FEA for analysis and cal-culations

All of the software mentioned in the table can be used for the structural modeling of the bridges and most of them have calculation capabilities as well. However, as it was said before strong and weak sides of the software differ. Therefore, software should be chosen depending on the project needs. For example, the bridge version of the Tekla Structures is probably the easiest for the structural modelling but makes more sense to use if one of the compatible calculation programs is available. The official website of Bentley states that OpenBridge Designer is not a single program for modelling but a package of integrated software which includes OpenBridge Modeler for bridge structural modelling as well as analytical software such as LEAP Bridge Concrete and LEAP Bridge Steel that can be used for the precise designing and analysis of the concrete and steel bridge structures respectively. This package provides tools for every stage of the modelling process and all of the details as well as tools for calculations and analysis. A similar situation appears with Midas CIM since it is integrated with the other Midas software such as Midas Civil, which can be used for calculation and analysis of the bridge structures, and Midas FEA developed for the detailed analysis of the bridge elements and connections. The difference between the OpenBridge Designer and Midas CIM is that, although integrated with the Midas CIM, Midas Civil and Midas FEA are not part of the software package coming with the Midas CIM and have to be purchased and installed separately. As it was mentioned before any of the modeling software presented in the table as well as other programs for the bridge modelling can be used for all of the structural models needed in most of the cases if a specific one is not available. Interfaces of the Tekla Structures, Midas CIM and Bentley OpenBridge Modeler are shown in Figures 5.1-5.3 respectively. These Figures will allow to visually highlight the fact that the design process might slightly differ in the different software while being generally the same since the same ideas and methods serve as a foundation for all of the modelling software.

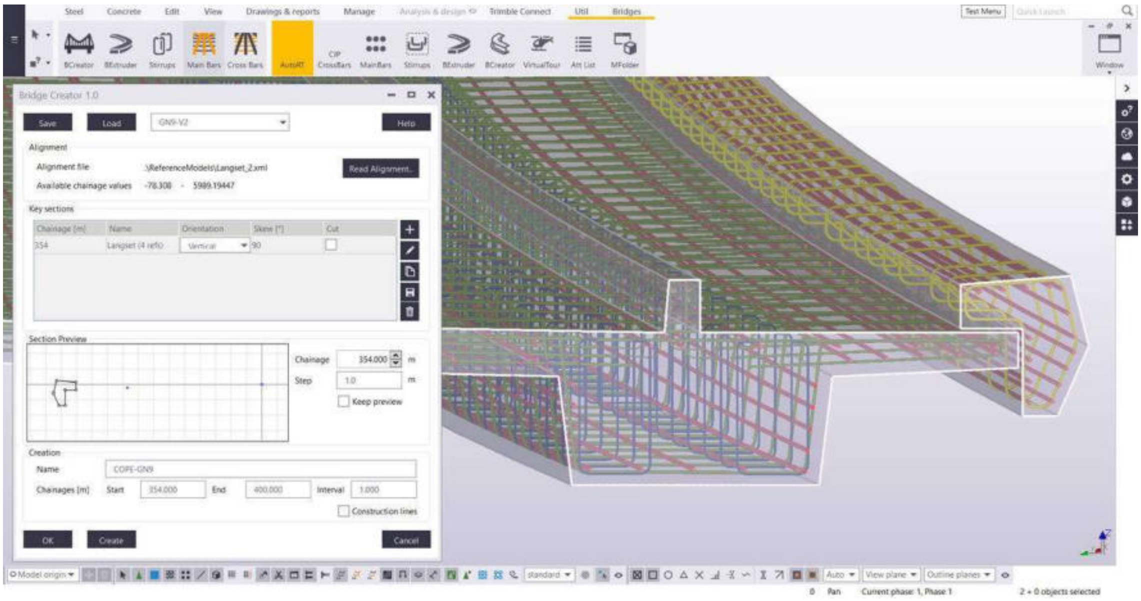

Figure 5.1 Tekla Structures interface with a bridge model example (image from tekla.com)

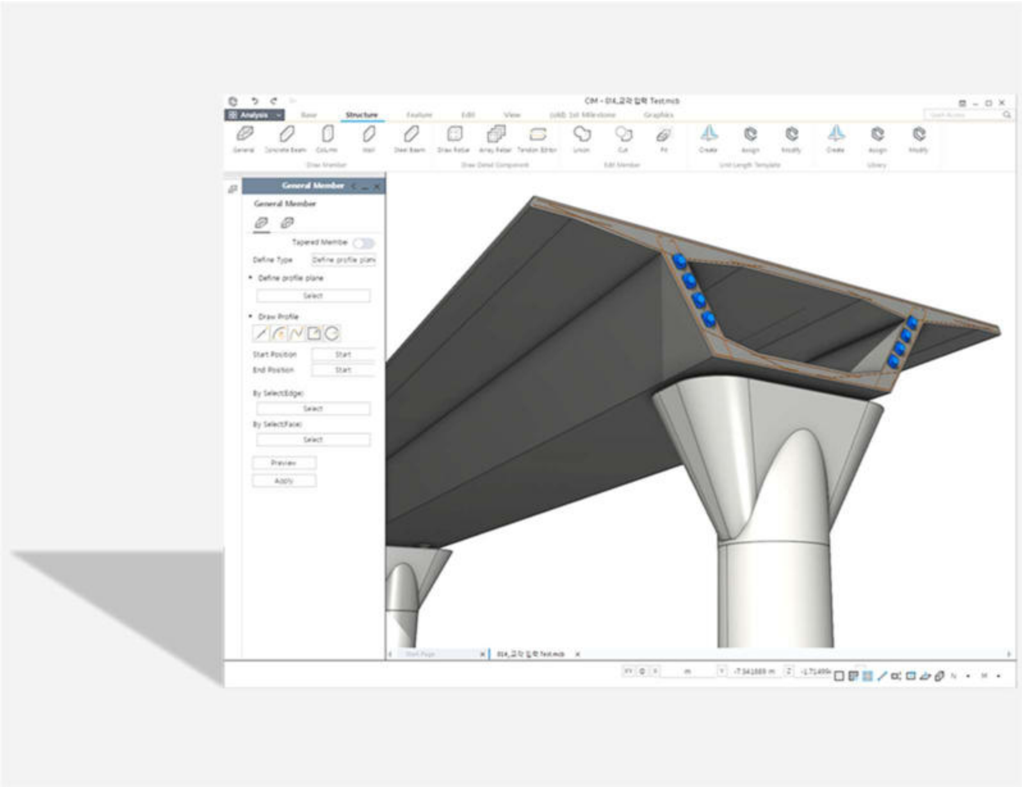

Figure 5.2 Midas CIM interface with a bridge model example (image from midasoft.com)

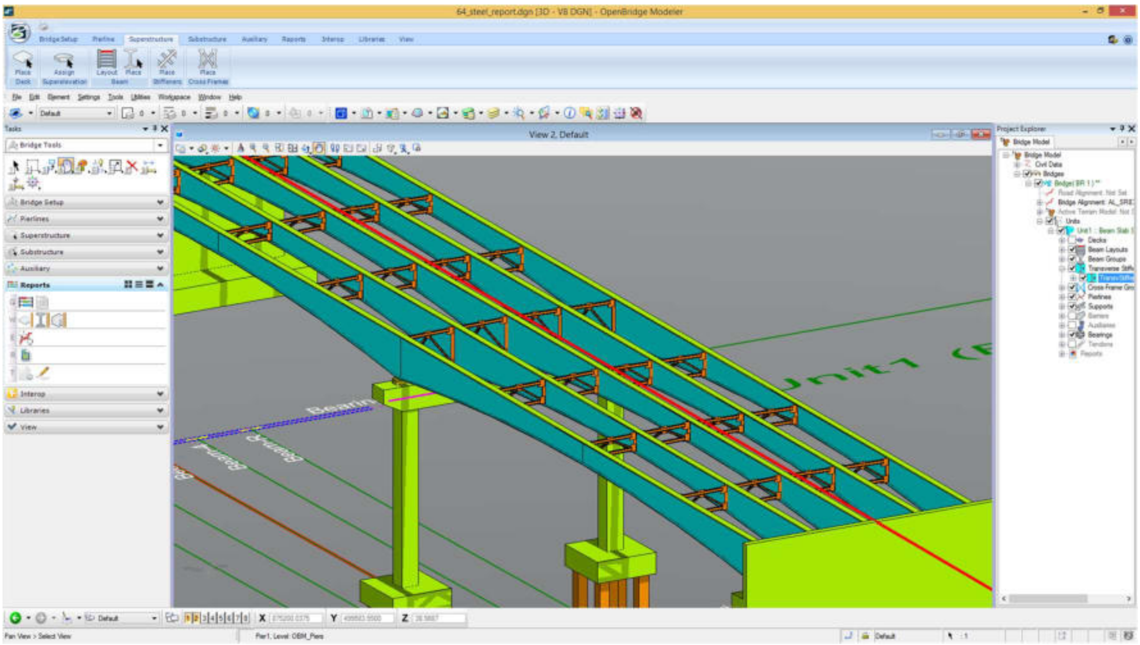

Figure 5.3 Bentley OpenBridge Modeler interface with a bridge model example (image from communities.bentley.com)

Models created with the use of the software mentioned above are supposed to be made during the design phase. Models themselves and the drawings created from them can be used during the construction phase to access the design information and to update the existing models for the further development of the as-built model that can be released when the structure is finished if it is required. If made according to the Common BIM requirements (COBIM) they can be accessed on-site with the use of any IFC format compatible programs and applications. Such as Solibri Model Viewer or Tekla BIMSight that can be used with the PC and Tekla Field, ENDbim BIM Viewer or similar that can be used with a smartphone or a tablet. Most of this software is free and capabilities of these programs are similar so there is no need to choose one program to provide access to model from the design office and from the construction site. Information needed for the maintenance phase can also be easily provided if an as-built model is made during the construction. However, none of the programs mentioned above except for OpenBridge Designer provide possibilities for the construction management. It might not be that big of a problem if only a single structure is constructed or renovated but if the structure is a part of a larger infrastructural project serious organizational and planning difficulties might occur with the use of conventional management methods. Therefore, some management tools created specifically for the infrastructural projects can be used in such cases. One of such tools is Infrakit.

Infrakit is a software developed by the international team in Europe. It is becoming a more and more widespread tool in the infrastructure construction. Infrakit is a cloud service for the project management. According to the developer official website Infrakit allows to achieve faster project completion with better quality and lower costs which is what is needed for the increase of the social value of the final structure as it was stated before.

Except for the cloud service itself, Infrakit consists of a program and multiple applications to be used with PCs and mobile devices. These programs and applications provide access to the information from the different devices. The main two of those programs are Infrakit OFFICE and Infrakit FIELD. Infrakit OFFICE is a PC program, which provides a view of the project progress, quality control, machine-controlled tools such as excavators and as-built points from the office. Infrakit FIELD is an app, which provides access to all of the project data such as drawings, models, geological information on site. It also allows to take geo-referenced photos to update information on construction progress. Other apps provide tools for machine control and tracking. The structure of the Infrakit software package is shown in Figure 5.4.

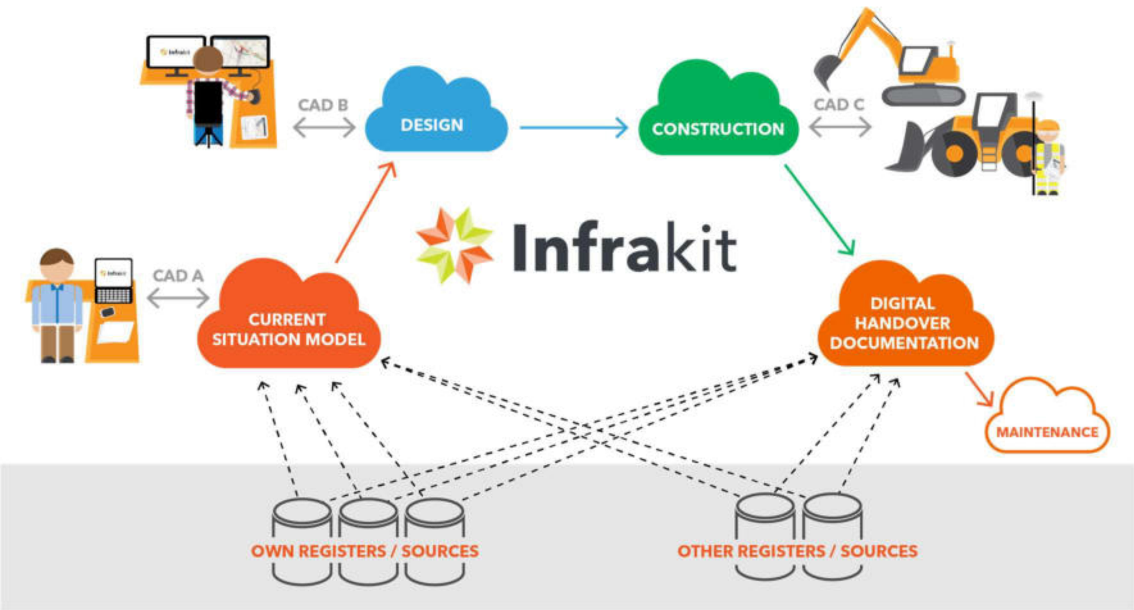

Figure 5.4 Infrakit software package structure (image from infrakit.com)

There are of course other construction management software and cloud services created for the information sharing similar to Infrakit in many aspects such as BIM360 by Autodesk, 1C Construction by 1C and many others. These services can be used for the similar scheduling and information sharing tasks. However, they do not provide applications for the distance machine control, tracking and other tasks that are more crucial for the long linear objects. However, for urban construction of pedestrian bridges and overpasses management software is not crucial and any available program can be used since the linear distances are relatively short. Nevertheless, choice of the modelling software is still important for such kind of structures.

Some additional software that is not used for the modelling directly can also be used during the surveys and some specific aspects of the design phase. For example, Plaxis can be used for geological calculations, which are crucial for the bridge supports and abutments. However, such a software is usually used for one type of calculations exclusively, therefore, it should be chosen according to the specific needs of the structure or a project and design company experience.

BIM provides some great tools for the design and construction processes improvement for any structures and pedestrian bridges and overpasses are not an exception. These improvements lead to the reduced costs, reduced design and construction time and better quality of the final structures, which of course increases the social value of the structure. However, BIM solutions have their flaws. The most notable one is the lack of the international standards approved in most of the countries. There are some attempts to standardize BIM such as COBIM requirements as well as other Buildingsmart initiatives, which might become a foundation for the one set of standards approved by all of the governments and standardization institutions all around the world. Although, currently it is not possible and many countries do not have any approved standards and requirements for BIM software and models at all and others only broadly cover this aspect. The situation seems similar with such construction standards as Eurocodes and SP but the difference in construction standards usually does not become a big issue since even when the international team is working on the project the set of standards is always chosen based on the project location, which dictates subject to which law the project is. In addition, companies working abroad are usually co-operating with one or multiple local companies that can provide all of the necessary information. It is not that simple with BIM because international cooperation is required in the most cases of BIM use and it is not always easy to achieve. Since most of the companies providing necessary software are located in only a few countries their products are only subjects to the law of the country where they are developed and internationally adopted standards, as it was mentioned, are not yet completely agreed on. Therefore, developers have to certify their software in every country where they want to operate which creates unnecessary difficulties and delays. The other problem caused by the same factors is the data exchange between parties from the different countries or even different companies using non-identical software. However, this problem is mostly solved by the introduction of the IFC and LandXML data formats suitable for most of the software. Nevertheless, in many counties there are still no official governmental requirements that would make utilization of these formats obligatory. In addition, use of BIM technologies requires participation of high-skilled professionals in multiple positions such as, for example, BIM coordinator and it is a common situation when such specialists can only be found abroad. Familiarizing these specialists with the national construction and BIM standards might become a waste of valuable time and will reduce the social value increase coming from the use of the BIM tools.

In conclusion, BIM software provides some great opportunities for the increase of the social value of the structures but its effect can become even greater with the improvement of the international cooperation and development of international BIM requirements approved all around the world. However, it should not stop the use of BIM in the urban pedestrian bridge and overpass projects since the implementation of such tools will result in the increase of the social value of the structures.

6 Designs

In this chapter drawings for the three pedestrian bridges will be made which will contain possibilities for implementation of the ideas for public spaces on bridges and overpasses from Chapter 2, design and materials found in Chapter 3 and will meet the requirements described in Chapter 4 of this paper.

Bridges are located over the three different rivers with different widths therefore the lengths of the structures differ. Architectural and structural properties of the bridges vary as well to represent different cases in which such structures can be used.

The first design is a concrete cable-stayed bridge with the total span length of 103 meters (with abutments). The second design is a three-pinned arch-bridge made of glue laminated timber with the total span length of 28 meters (with abutments). The third design is a curved two-level bridge that consists out of concrete supporting structures and steel framework, which creates two levels of the bridge. The spans and the ramps of the third bridge cover the distance of 62 meters.

All of the designs are preliminary and do not show the structures in a great detail. Many necessary but smaller systems such as the drainage system are not shown on the blueprints since they are not crucial for the stated goal of this chapter. However, these details and systems are very important for the designs of the real structures.

6.1 Design 1 – Cable-stayed bridge

Drawings of the bridge are presented in Appendix 1 of this thesis.

The system of the bridge should be chosen considering the materials, loads and architectural requirements of its location therefore a cable-stayed bridge is chosen in the first case since this system suits most of the urban landscapes well as it can be seen with the examples of the Erasmus bridge in Rotterdam, Brooklyn and Manhattan bridges in New York, Lazarevsky bridge in St Petersburg and many others. Cable-stayed systems also allow to cover longer distances with spans whithout creation of the additional supports which are costly to construct in the deep areas of big rivers. It also allows to preserve a water transport route mostly unaffected. Abutments that are not covered by the ground are used in this design for the same purpose. As a result, such a design allows to save the routes of the water transport in the river mostly unharmed and creates an interesting new sight in the urban landscape. However, such design might not be the best choice for the historical districts since high pylons usually become architectural dominant in their surroundings and might ruin some iconic sights and architectural identity of the district.

The main materials chosen for the first bridge are reinforced concrete (spans, pylon, abutments and foundations), steel (cables, railings, railing poles), glass (railings on the sightseeing deck at the span level, cover of the upper sightseeing deck at the top of the pylon) and sawn timber (surface covers). Most of the chosen materials are traditional for the bridge construction because new materials as it was explained in Chapter 3 are usually only reasonable to use in the very specific projects and should be chosen with extra caution. Since this design serves more as an example of the implementation of the ideas for creation of a public space on the spans of the bridge or an overpass than an actual design of a new structure its location and information about the region are not available and, therefore, need and possibility of use of the new materials can not be properly evaluated. Wood that also showed good results in compresence with the other materials is not chosen for the load-bearing elements because of the bridge system – cable to beam connections might become an issue in that case because such connections are not at all widespread. Therefore, such connections might cause difficulties both during the design and construction phases.

The space of the span is shared between the pedestrian route, vegetation area and the two-lane bike route. The widened sightseeing deck is located on both sides of the bridge near the pylon providing more space for pedestrians and allowing them to calmly enjoy the sight from the bridge span with lesser chance of forming a crowd. The wider space of the sightseeing deck at the side of the bike route is used to provide space for the bike parking and a resting area for the cyclists. The pedestrian area occupies 6-9 meters of the 20-meter wide span. The bike route is 5 meters wide and is split in two lanes. The pedestrian and bike routes are separated by the green area with the trees and smaller vegetation. Benches are located in the widened parts of the pedestrian route going deeper in the vegetation area. Garbage bins are located near the benches with the interval ranging from 9 to 18 meters. Garbage bins consist of three sections for the trash separation for the future recycling. At the bottom of the pylon a deck is created with the cast-in-situ concrete and timber panels. This deck provides access to the water and can serve as an area for different temporary structures and furnishings. For example, some deck chairs can provide additional resting space for the people. Stairs leading to the lower deck are located near the pylon on the pedestrian side. On the side of the cyclist route stairs are combined with the ramp to make transportation of the bike to the lower deck easier. Another bike parking is located at the lower deck as well. An elevator installed in the middle part of the pylon provides access to the lower deck for the disabled people. The same elevator is used to transport the people from the span level to the second sightseeing deck located at the top of the pylon.

The bridge connects two pedestrian zones. Two buildings that can be rented out by the small businesses are located near the bridge access points. Since the structure will attract people as a public space businesses located in those buildings are more likely to succeed and can cover some of the construction costs over time with the money from the rent.

The span is not elevated above the ground level therefore, there is no need in creation of any special structures such as ramps or elevators for the access points. However, vegetation area from the bridge is continued on the shore to create the visual unity of the space.

6.2 Design 2 – Three-pinned arch bridge

Drawings of the bridge are presented in Appendix 2 of this thesis.

Since the river in the second case is only 25 meters wide, it can be crossed with a single span. A three-pinned arch structure without a tie made of GL is used to cover the needed distance. A wooden deck is located above the arch to create a surface with the inclination of 6% acceptable for the barrier-free environment. The span of the bridge is 6 meters wide.

Railings are made of glass connected to the timber poles with the steel gusset plates. Connections between the bridge elements are supposed to be made of wooden nogs in some cases: deck to the railing poles, and glue in other: deck to the GL load-bearing arch, but if the calculations would show that the load on connections would be too high they can be easily replaced with the steel or composite nogs during the construction phase. However, probably it would not be necessary since the railing poles only carry the constant loads from their own weight and the weight from the glass railings located between them which can easily be held by the wooden nogs especially since this constant load is vertical and mostly transfers to the deck through the bottom part of the pole and not through the nog intself. It leads to the situation where nogs connecting railing poles and deck only have to be able to hold horizontal loads from the possible impact, which is low due to the fact that the bridge is supposed to be used by the pedestrians and cyclists exclusively and nothing can cause a collision with the strong impact going to the structure.

Similar to the first design the space of the span of this bridge is split between three areas. However, planning is different due to the noticeably smaller size of the structure.

No separate cyclist route is created due to the small span width. However, some space can be reserved for the cyclist traffic in one of the areas if it is necessary. Two pedestrian routes both 2.25 meters wide are separated by the green area with small vegetation such as bushes. Lanterns are located around the green area. No additional structures are created as in the first design therefore this bridge mainly fulfills the infrastructural purpose. However, benches are created near the green area to provide places for people to rest and garbage bins with the separated trash collection are located at the space of the span.

The main advantage of this design is that almost all of the elements are made of wood or wood products which as it was proven in Chapter 3 of this thesis is one of the best materials for the construction of the such structures since it is renewable, eco-friendly and at the same time has some good load-bearing and durability qualities.

6.3 Design 3 – Curved two-level bridge

Drawings of the bridge are presented in Appendix 3 of this thesis.

A 70 meter long (with the ramps) curved two-level bridge is designed to cross the third river, which is 50 meters wide. The system of the spans of this structure is a framework on the two supports. However, the framework is curved horizontally and both levels provided by the structure of the framework are used for either pedestrian or cyclist traffic. The structure is elevated above the ground level of the paths located at the river bank. Access to the structure both for the cyclists and for the pedestrians is provided by the ramps with the inclination of 6%.

The first level is located inside the framework and is mainly used for the pedestrian traffic and public space creation. The second level serves as a two-lane bike route. Ramps leading to the different levels of the bridge are connected to the pedestrian and cyclist routes located in the different levels at the embankment as well. Such a separation insures safety and comfort of the pedestrians since cyclist traffic does not cross their route minimizing the risk of the accidents.

Supports of the bridge are made out of the reinforced cast-in-situ concrete as well as foundations. The framework and the ramps is made of steel. However, lighter composite materials such as CRP can be used if they are available to increase the material efficiency and make the future maintenance of the structure easier. GRP can be used as well, however, as it is shown in Table 2 its strength is lower than the one of steel so the structure elements made of GRP might be even thicker than the similar ones made of steel. Nevertheless, the weight of GRP elements is still going to be lower which will result in the lesser constant loads from the weight of the structure on the bridge supports. Traditional asphalt cover is used for the surface of the bike route. Surface covers for the pedestrian route and public space vary depending on the area. However, the route itself is covered with the thin concrete slabs to create a flat surface comfortable for walking.

Lanterns for the top level of the bridge are located in the top part of the supports. Lanterns for the bottom level are located inside the framework.

Requirements to the curvature of the pedestrian bridges were explored in Chapter 4 and it was found out that the curvature of the pedestrian and cyclist structures can be much higher than the curvature of the structures with the vehicle traffic. In fact, almost nothing regulates the curvature of the pedestrian or cyclist bridge unless it leads to the appearance of the sharp corners that may be hazardous since they block the view for the users of the structure, which might result in collisions.

The curvature of the designed bridge is high but no sharp corners are created. In addition, only the top open level is used for cyclist traffic which is the most likely to suffer from the possible hazardous turns and corners due to their relatively high speed. At the top level of the structure nothing blocks the view on the road except for the top parts of the supports therefore the curvature of the bridge does not create any additional dangers for the cyclist traffic.

The first level is divided into four areas: pedestrian route itself, which provides a passage from the one end of the structure to the other, business area where a small café or a street-food restaurant as well as a small shop can be located, green area with some vegetation and a restaurant area with some tables and chairs combined with the sightseeing deck. Pedestrian route is 5 meters wide to provide enough space for any of its potential users. Green area occupies space of 100 m^2. It is covered with grass and small bushes and can be used for the instalment of the temporary furnishings, which would provide additional rest area for the people. Plants can get enough light from the sun through the glass covered framework wall or from the lanterns that can be installed inside. The business area occupies the same amount of space as the green area at the other side of the bridge. The restaurant area and the sightseeing deck are located between them. Benches and garbage bins are installed at the opposing side of the span.

7 Legal restrictions

Most of the implemented solutions seem simple and possibly obvious, especially, for the pedestrian structures. However, many of the existing structures do not implement any of such ideas, which leads to the situation where they can only be used as a piece of infrastructure, sometimes not even a high-quality one. Therefore, they only achieve one of the three main goals stated in Chapter 2. This chapter will try to explore if the national building laws and general approach to the construction stated by the laws of the different countries are the main reason behind different quality of the urban designs and planning of the pedestrian infrastructure and public spaces. Comparison of the different national building laws is based on the suggestion that the difference between them might be significant.

Some laws that regulate construction differ from one country to another. Construction requirements are not an exception. As it was briefly mentioned in Chapter 4, however similar, requirements to the structural qualities and planning may noticeably differ even in the strongly bounded European countries. Architectural, social and economic requirements to the new bridges and overpasses differ even more widely and can depend not on the national construction requirements and standards exclusively but also on the requirements prescribed by the local governments, for example, municipalities. However, the most general approach to the construction in the different countries will be analysed in this chapter.

Diversity in the documents regulating construction and in the approaches of the local governments might lead to the situation where some countries as well as some certain cities and regions are more successful in creating good urban environments for their population. This diversity, of course, would affect all of the construction industry. Bridges and overpasses are not an exception. That might be the reason why in some urban areas great attention is paid to the effective use of the spans of the bridges and overpasses as well as to the increase of the social value of these structures and in others it is not.

Further in this chapter Finnish urban building legislations that might concern bridges and overpasses as well as construction projects in general will be compared to the similar legislations used in the Russian Federation. This comparison would not give precise answers on how to change these legislations in such a way to create more effective structures with the higher social value, however, it will help to find some restrictions that might be caused by the legislations in one of these countries. Such comparison can be done between almost any countries. Although, it makes more sense when the approach to the construction in these countries is different but the climatic and geographical conditions are similar. That is so with Finland and Russia. The main differences in the construction between the two countries lay in the scale of the projects, priorities and preferred materials. The climate of the North-West part of Russia and Southern Finland is, however, the same.

As it was found out in Chapter 3 calculations and loads for the overpass and bridge structures differ insignificantly, therefore, the following comparison can be dedicated more to the general requirements to the structures and the priorities set or not set by the existing legislations.

Search of the official documents that would standardize and regulate planning and effective use of the individual type of structures showed that the government in both of the countries does not directly regulate these aspects. There are almost no legislations concerning pedestrian bridges and overpasses exclusively as well. These structures are usually only mentioned in the other standards and requirements concerning bridges as one of the types of bridges. Therefore, the most broad documents concerning the building process in the countries were chosen for the comparison. Even if such documents would not provide any possible differences that might directly affect construction of the pedestrian infrastructure and the public spaces in the urban areas they might highlight more general and theoretical differences in building. Bridges and overpasses are part of the infrastructure and, therefore, are indirectly mentioned in the Building codes that regulate construction and land use in general as such.

According to the website of the Ministry of Environment of Finland the most important legislation controlling the land use, spatial planning and construction in Finland is The Land use and Building Act. Based on this information it will be chosen for the comparison. It will be compared to the The City Building Code of Russian Federation which is the most similar document to the Land use and Building Act of Finland in the Russian Federation.

It might not seem obvious to use The City Building Code which mainly regulates planning and construction in the urban areas and mostly concerns planning and construction of the residential buildings and their surroundings for comparison.

However, since the topic of this thesis is focused on the study of the urban structures and since pedestrian infrastructure has the greatest importance in the densely populated urban areas it is suggested that this document can be used. Both documents regulate the building industry broadly and mostly provide general information about the approach to the different aspects of building in the country.

Both The Land use and Building Act of Finland and The City Building Code of Russian Federation are relatively large documents when compared to the most of the other acts, codes and standards that regulate building processes. However, a significant part of both documents is dedicated to the precise description of the parties involved in the processes, relations between these parties among themselves and the authorities, necessary documents that should be produced at the different stages of the project lifecycle, legal issues that concern the land use etc. Most of these sections differ insignificantly if at all and do not seem to directly affect the quality of the structures concentrating more on the legal aspect of building. They do not contain any straightforward guidelines for the construction or planning either. Comparison between these part of the document seems pointless considering the goal of the chapter and the fact that these two documents were chosen for their broad coverage of the building processes. Therefore, a suggestion is made that the most important parts of these documents that would provide the most suitable information concerning the stated goal are the parts where the most general information and the main principles of construction are stated.

The first chapters of both the City Building Code of Russian Federation and the Land use and Building Act of Finland are named Key points and General provisions respectively.

There are 5 articles in Chapter 1 of The City Building Code. Article 1 briefly covers the main terms that are considered crucial for the planning and construction and are used in the following document. Article 2 of the City Building Code is named “The main principles of law of the city building” and states the main goals of the building process. Article 3 is dedicated to the documents that regulate building. Article 4 describes relations between the parties that are involved in the building process and are regulated by the following document. Article 5 describes very briefly the parties and authorities that act in the building process and sets the procedure of the participatory building that is supposed to ensure that people can take part in the planning and design works.

Most of the articles give the most general information that is described in greater detail in the following chapters of The City Building Code of Russian Federation. Article 2, however, seems to provide the information that is needed for the comparison of the general approach to building in the country since it describes the main principles of building that should serve as a foundation for all of the decisions concerning planning, design, construction, maintenance and demolition of the structures.

The main principles stated in Article 2 are: building should result in the integrated and sustainable territory development based on the planning; economical, ecological and social factors should be taken into account; barrier-free environment should be created; building should be based on the documents that regulate planning; citizens and citizen unions should be able to participate in the city building activities; authorities are responsible for the high quality of building; safety must be insured; environmental and ecological requirements should be taken into consideration; historical heritage must be preserved. These principles seem to set the goal in the creation of the high quality public environment, however, they still have to be compared to the Finnish building principles.

The first chapter of The Land use and Building Act of Finland is divided into 16 sections. Sections are named different from the articles of the Russian City Building Code but cover similar issues.

According to the website of the Ministry of Environment of Finland Land use and Building Act sets creation of the high quality living environments, ecological economical and cultural development and participation of the population in the open planning process as its goal. The same statements are repeated in Section 1 of the Act. Sections 5 and 12 also give some general building principles. These sections are named “Objective in land use planning” and “Objectives of building guidance” respectively.

Section 5 declares such objectives of the land planning as: creation of the safe, pleasant, socially functional and healthy environment which provides for the needs of the various population groups; economical community structure and land use; protection of the built environmental and cultural values; environmental protection; provident use of resources, functionality of communities and good building; favorable business conditions; availability of services; appropriate traffic system, especially, for public transport and non-motorized traffic.

Section 12 sets three objectives of the building guidance: creation of the socially functional and aesthetically pleasing good living environment that has to be safe and pleasant; building should be based on the sustainable and economical approaches that are socially and economically viable and maintain cultural values; planned and continuous maintenance of the built environment.

On the first sight, the main principles stated in The City Building Code of Russian Federation and The Land use and Building Act of Finland seem to be similar and to promote the same goals and values. However, some differences that might affect the approach to building can be found when these two documents are compared.

First, The Land use and Building Act unlike the City Building Code clearly states the priority of the public transport and non-motorized vehicles over the motorized traffic. What may seem like an unimportant clarification might in fact significantly affect the approach to the infrastructural planning in the urban environment. The difference between the cities which preferred motorized traffic and the cities that chose non-motorized, public and pedestrian as their priority can be seen clearly. A street with vehicle traffic priority is shown at the Figure 7.1. Streets with the public transport priority that also has a relatively wide pavement and a bike lane is shown in Figures 7.2 and 7.3. Urban areas, especially, big cities that prioritize public and pedestrian traffic show better and more sustainable development (Banister, 2005 p.7). Better development of the city districts rises the demand for the good quality of the urban environment and public spaces which forces local authorities to find solutions for the creation of such spaces. Therefore, this priority mentioned in The Land use and Building Act might affects the creation of the pedestrian infrastructure and effectiveness of designs and planning of the structures.

Figure 7.1 Street with the vehicle traffic priority (image from bicycling.com)

Figure 7.2 Street with the public transport and pedestrian traffic priority (image from straitstimes.com)

Figure 7.3 Wide street with the public transport and pedestrian traffic priority (image from tfgm.com)

Second, necessity to care about the functionality of the communities and good building are also proclaimed directly in The Land use and Building Act and are not stated in the City Building Code. Lack of need to create functional communities might lead to the decrease of effort put in the creation of the infrastructure and the public space both of which affect the functionality of the communities and the quality of living. Good building principle affects all of the structures constructed and pieces of urban pedestrian infrastructure are not an exception. Therefore, this principle may also result in the difference in the quality of the urban environment and the social value and effectiveness of the structures included in it.

All of the other principles proclaimed by both documents are mostly the same and, therefore, probably do not cause significant differences in the approach to building in two countries. No difference is likely caused by the calculation methods and general requirements to the design and construction either since they usually only differ insignificantly from one country to another.

In conclusion, different quality of the urban environment, infrastructure and effective planning and design of the structures might be to some extent caused by the laws regulating construction in the different countries but are more likely to be caused by the other reasons such as differences in the budgets, involvement of the general public and local authority control.

8 Alternative projects

In this chapter three existing structures or standardized structure types will be explored. Ideas for their improvement or alternative designs will be suggested. The structures located in the Russian Federation are chosen since they are the easiest to get the needed information for and relatively often lack effective and socially valuable planning and design solutions, therefore, need improvement.

All of the designs in this chapter are preliminary and only highlight the general ideas for the improvement of the structures or alternative designs.

8.1 Case 1 – Yahtenniy Bridge

Yahtenniy Bridge is the longest pedestrian bridge in St Petersburg, Russia. It is located in the northern part of the city and crosses Big Nevka river and it connects the new stadium on Krestovsky island with the 300 Hundred Years Park in the Primorskiy district. The bridge is a 940 meters long structure made mainly of reinforced concrete. The spans are 17 meters wide. The clearance gauge under the main span is 16 meters in height which allows most of the ships to pass under the bridge. The main materials used for the bridge construction are reinforced concrete and steel. Yahtenniy Bridge layout is shown in Figure 8.1.

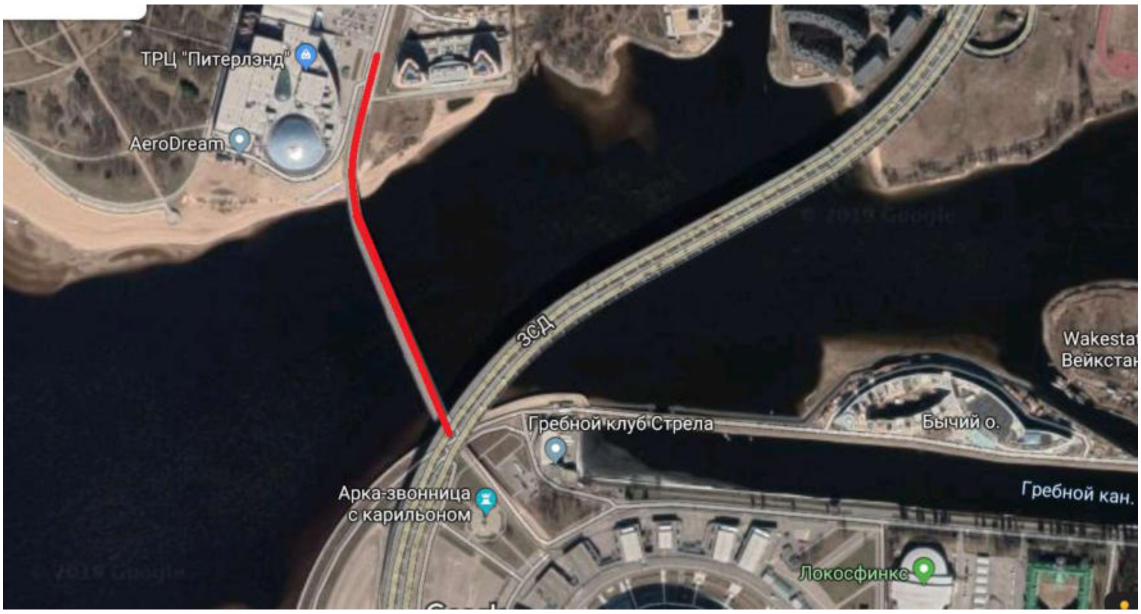

Figure 8.1 Layout of the Yahtenniy Bridge (original image from Google Maps)

The spans of the Yahtenniy Bridge are divided between the pedestrian and cyclist routes. One of the pedestrian sections is wide enough to be used by the service vehicles as well. The sections are separated by the barriers. The sections are wide enough to meet the width requirements from Chapter 3: cyclist section - 3.5 metres, service vehicle and pedestrian section – 9 meters, pedestrian section – 2,25 meters.

The bridge is architecturally integrated in its surroundings. In addition, it has an important infrastructural purpose since it is the only way that allows to get to the mainland from Krestovsky island from the stadium area on foot or by bike. Yahtenniy Bridge became a popular landmark shortly after its construction. However, it has serious planning problems. The main two problems of the bridge are ineffective use of the wide span area and complicated access layout. These two problems can be solved with the ideas stated in Chapter 2. The view of the Yahtenniy bridge is shown in Figure 8.2.

Figure 8.2 View at the Yahtenniy Bridge from the Krestovsky Island embankment (photo by the author)

As it was mentioned before, the span of the Yahtenniy Bridge is divided into three sections separated by barriers: pedestrian section, service vehicle section and cyclist section. This division seems reasonable since it allows all types of traffic to have its own separated route unless the actual use of the spans is analysed. The usual use of the span area is shown in Figure 8.3. It can be easily noticed that the cyclist route is used by the pedestrians and because of this cyclists often use the service vehicle section to ride across the bridge, therefore, creating a potentially dangerous situation since the risk of an accident with the pedestrians and other cyclists is higher at the wider open space without any road markings. Such problems with the use of the routes might be caused by the poorly planned bridge access for two reasons: the division between the sections is unclear at the access points since there are no signs highlighting the right way for the each type of traffic, both pedestrian and cyclist routes are not well planned and located at the bridge access points. The second reason needs some clarification. One access point is located near the “Gazprom Arena” stadium. It is the biggest stadium in St Petersburg and many large-scale events such as concerts, football matches etc. are held there. For this reason, the stadium itself and the area around it are considered an extra security zone that requires restrictions on the access to the area. Therefore, the bridge is cut off from the main pedestrian and cyclist routes by the multiple fences that surround the stadium and Novokrestovskaya metro station located nearby. The fenced area has multiple exits but they are located far from the bridge access points. Approximately 25 minutes of walking is needed to get from the nearest exit to the bridge and this route has neither a cyclist section nor any road signs showing the right way for the different types of traffic. The access point at the other side of the river connected to the Yahtennaya street does not have any signs or cyclist routes either. However, it is does not create such serious problems since unlike the opposite site it is not cut off by the fences. As it was found out in the previous chapter of this paper, the main sets of laws that regulate building would not lead to the creation of such a poorly planned area, however, requirements of the authorities on security intervene the initial planning, therefore, creating an infrastructure that is uncomfortable to use.

Figure 8.3 Planning of the span of Yahtenniy Bridge (photo by the author)

Figure 8.4 Improper use of the cyclist route (on the right) (photo by the author)

During the bidding phase an alternative project was developed. The location of the structure was the same, however, the system of the bridge and the planning differed significantly. The alternative project was a two-storey bridge with the huge recreational area located at the second level when the first level was supposed to be used to fulfil the infrastructural purpose. Wide pedestrian and bike routes should have been located there as well as a set of travolators to increase the speed of the pedestrian movement, which could be helpful after the events at the nearby stadium when the people flow in the area significantly increases. However, in the end the cheapest and the most simple bridge system was chosen due to the limited time reserved for construction. The choice was probably also affected by the financial side of the project. The model of the alternative project is shown in Figure 8.5.

Figure 8.5 Architectural model of the alternative project (image is provided by Stroyproekt Engineering Group)

The proposed solution is presented in Appendix 4 of this thesis and does not suggest a creation of the new bridge structure since such a project was already developed as an alternative project. The layout of the bridge and, therefore, its connections to the land is not changed since they seem to be reasonable. However, the fences on the Krestovsky island side of the bridge should be removed or replaced with the other structure that would allow a faster and an easier access to the bridge. Continuous cyclist routes that would connect to the existing one at the bridge should be constructed on both sides.

The structure of the existing bridge is not changed, however, the second level and the accesses to the second level are added. The second level supporting structures are made of steel beams and columns that are covered by the concrete slabs. These structures are connected to the supports through the original bridge span elements. The panels that can be made out of glass to create a more modern look of the bridge cover the second level supporting structures. The first level of the structure is planned similar to the existing planning of the bridge, however, some changes are made. Barriers between the sections are replaced with the supports of the second level which make the routes clear but allow the access from one section to another through the arches located all through the bridge length. The middle section that is reserved for the service vehicle traffic is divided between the wide pedestrian route and the commercial area where temporary structures that can host small businesses can be located. These temporary structures should be easily removable to allow service vehicles to pass when it is necessary. On the opposite side of the middle section travolators are installed to provide a faster way for the pedestrians to cross the river. People with low mobility can also use those travolators as the simplest way to cross the bridge.

The second level can be accessed from both sides of the bridge by the stairs or the elevators. The span of the second level is divided into three sections two of which are 2.5 meters wide pedestrian sightseeing decks that provide the view on the river, stadium and the Finland gulf. The middle section of the bridge is 7.6 meters wide and is covered with ground. It is reserved for the area with the wild vegetation parts of which can be cleared for the creation of the recreational areas.

Such changes in the bridge structure and planning would result in the significant increase of its social value. Clear division of the routes on the first level will allow cyclists and pedestrians to move safely. However, unlike barriers, the second level supporting structure would allow cyclists and pedestrians from the smaller section to get to the commercial area located in the middle of the span. The commercial area itself would provide development for the district since it will allow small businesses to rent places with high density pedestrian traffic. Sightseeing decks would help to improve the tourist flow in the area by providing a unique view on the new and rapidly developing city district. The wild vegetation area on the second level will provide a pleasant green environment, which is crucial for the urban areas with the high levels of the noise and fumes pollution.

Drawings for the Yahtenniy Bridge modification do not show planning of the spans with the same degree of precision as the drawings of the structures from Chapter 6 of this paper since the scale of the bridge is noticeably larger. However, they give the general idea about the suggested improvements.

8.2 Case 2 – Typical pedestrian crossing overpass

When a typical pedestrian crossing that is located at the same level with the pavement and the road can not be constructed for some reason underground crossing or an overpass crossing must be constructed. For the large highways and wide avenues at the outskirts of the cities overpass crossings are usually constructed in the Russian Federation as well as in many other countries. The simplest and the cheapest typical design is usually chosen for such structures. However, the social value and efficiency of such structures is low since they are only used as a part of the pedestrian infrastructure and do not offer anything more than that to the end users. Even this purpose is not always fulfilled on the satisfying level since barrier-free environment sometimes is not created correctly. Typical pedestrian overpasses are shown in Figures 8.6-8.8. Such overpass crossings are only constructed in the places with the high-demand for pedestrian crossings, therefore, they are used by many pedestrians on the daily basis and improvement of such structures would affect a significant amount of people.

Figure 8.6 Typical pedestrian overpass crossing at the highway (photo by the author)

Figure 8.7 Typical pedestrian overpass crossing at the wide street in the urban area (image from news.rambler.com)

Figure 8.8 Typical pedestrian overpass crossing at the highway with long ramps (image from rosavtodor.ru)

The suggested overpass pedestrian crossing is presented in Appendix 5 and is one of the possible options for such structures. It relies on the suggestion that most of the densely populated areas located near the highways or large avenues lack green areas such as parks and gardens, therefore, all of the possibilities for the improvement of this situation should be taken. Different materials can be used for such overpasses depending on the length of the span. Typical steel and concrete elements that are usually produced for such structures can be used with the slight modifications made. However, GL or LVL beams and supporting structures can be constructed in some cases to raise the social value of the structure by using a renewable material. Foundations of the overpass depend on the geological condition of the area where the structure is located.

The suggested overpass consists of the span and the two access points. The access points provide access to the span with the stairs and the elevator. They also host a small maintenance area where the control panels of the elevators and the electricity control panels can be located as well as some equipment needed for the maintenance of the structure. The access points also create public bike parkings that can be used by the people.

The span of the overpass is divided between the pedestrian route and vegetation area. However, division is unclear and parts of the vegetation areas that are located by the sides of the pedestrian route are supposed to be covered by the short grass only and can be used for walking as well. The span is open at the top to allow the sunlight to pass to the vegetation. From the sides the span is protected from the traffic noises by the noise barriers. Noise barriers themselves are partly covered by the solar panels that are supposed to provide power to the lanterns of the overpass and to the local electricity network if extra energy is produced. The location of the solar panels on the noise barriers that are raised above the ground at the 6-8 meter height is not equally effective in all of the possible cases. However, further the structure is located north the more light comes at the correct angle to hit the solar panels during the day. Orientation of the structure also makes a difference. The best orientation is achieved when the sides of the span are facing east and west. Rain water is collected through the drainage system and is used to water the ground with the vegetation.

Such a pedestrian overpass is supposed to be self-sufficient in terms of the energy use. It will also improve the quality of the pedestrian infrastructure in the area and will provide a more comfortable environment to the users.

Drawings only show one possible design of such a structure. Certain elements and solar panels implementation can vary depending on the specific case.

8.3 Case 3 – Circle overpass pedestrian crossing

Circle pedestrian overpass is located in the southern part of St Petersburg at the large intersection between the Budapeshtskaya street and Slavy avenue. Since the vehicle traffic on both of the roads is intense a decision to construct an overpass crossing was made. However, the constructed structure coming in a form of the steel circle overpass is not satisfying and could use the valuable space provided by such a structure more effectively both as a piece of infrastructure and as a public space. The existing structure is shown in Figures 8.9-8.11.

Figure 8.9 View on the circle overpass from above (image from ok-inform.ru)

Figure 8.10 View on the circle overpass from the corner of the Budapeshtskaya street (image from kanoner.com)

Figure 8.11 View from the span of the circle overpass (image from sptoday.ru)

The suggested alternative design to the existing circle overpass is presented in Appendix 6. This design does not change the main idea of the circle overpass but the structure, nevertheless, is changed significantly.

Public transport stops that are located nearby and the high amount of multi-storey residential buildings in the area ensure a big pedestrian flow through the overpass especially in the morning and evening hours since that is the time most of the people commute to their workplaces. Therefore, the structure can host some commercial and recreational areas that could be used by those people.

The alternative circle overpass is made out of the steel elements. Supports are located on the pavements with the foundations covered by the pavement surface. Foundations can be either ground or pile based depending on the geological conditions of the area. Pedestrian routes that cross the overpass diagonally as well as the outer route are made of steel. The areas between them are covered with the concrete slabs which serve as a foundation for the structures on top of the overpass and transfer the load to the ground supports.

The access points are located at the pavement at all four sides of the intersection. They all consist of the stairs and elevators. Ramps that serve as an access to the existing structure take too much of the pavement space and are rarely used, therefore, the ramps are not used in the alternative design.

The routes of the overpass are not limited to the ones going around in a circle. Diagonal routes provide a shortcut for the people crossing the intersection in the diagonal direction.

The areas between the routes are shared between the two commercial areas and two recreational areas. The commercial areas consist of two levels. The first level is at the same height with the overpass. The second level is located 7.4 meters above the overpass surface. The first level of the commercial areas is provided to the businesses. The second levels are given to the small restaurants and open terraces. The recreational green areas host vegetation as well as some benches and places for the temporary art installations.

Drainage and some other smaller systems are not shown on the drawings since no specific detailed drawings are made. Such systems can be executed in the standard manner typical to the other overpasses and bridges. For the drainage system it means an 0.02 inclination of the surface cover from the structure center with the drainage wells located near the edge.

The alternative structure would have a much higher social value than the existing one since it would satisfy the needs of the users better both as a piece of infrastructure and a public space. Commercial areas would improve the local economic development. Recreational areas would provide a much needed comfortable green resting areas.

9 Summary

In the time when densely populated urban areas become more and more popular places to live and, therefore, attract an ever-growing number of new inhabitants from the suburban areas and smaller cities the effort should be put by the local authorities and landowners to make those urban areas as comfortable and effective as possible. Creation of public spaces and pedestrian infrastructure is crucial for achieving this goal. Certain designs and planning solutions for the pedestrian bridges and overpasses can solve both of these problems. As this paper shows, such structures can be constructed and are proven to be effective in many urban areas around the world. Therefore, pedestrian bridges and overpasses with additional functions should be considered as an alternative to the other options when a decision is made on creation of a public space or a pedestrian route, especially, since there are no serious restrictions in the building laws concerning the use of these structures in such a manner.

Created structures should have as high social value as possible, which means that they have to be effective. As little waste as possible should be produced during the construction, use and demolition of the structure. In addition, maximal material efficiency would serve to the benefit of the structure. The materials should also be chosen considering their environmental friendliness and aesthetical properties. Timber seems to be a good choice for the smaller bridges and overpasses. CRP and GRP might also be worth to consider if they are available. However, more conventional materials are still more suitable in some cases.

New technologies and approach to building such as BIM should be implemented at all of the project stages, when it is possible, to make the overall process more effective and, therefore, increase the social value of the structure by reducing the construction time, amount of the resources spent and the quality of the final structure.

Simple planning solutions as well as complex designs might serve for the purpose of the effective use of the pedestrian bridges and overpasses and the creation of the comfortable public spaces at their spans and surrounding areas. Such structures might not be the ultimate solution for the lack of land and other problems that the urban areas are facing but they can certainly help to improve the current situation and increase the quality of living in such areas.

10 Conclusion

This thesis covers many aspects of the urban pedestrian bridge and overpass designing and planning. It also explores different ways to increase the social value of such structures. However, the covered topics only provide the most general information and the most general ideas. They, of course, have to be explored further and in much greater detail to be used in the actual projects. More existing structures that are proven to be successful should be analysed to find better planning and design solutions. Other options of the pedestrian and cyclist infrastructure cration in the urban areas as well as the options for the public space creation should be explored and compared to the one chosen for this paper.

The possible benefit from the creation of such pieces of the pedestrian and cyclist infrastructure should be evaluated both in general and in every certain case. Alternative options should always be considered as well. However, as this paper shows there are neither legal nor technical restrictions to put such designs and planning ideas in use to improve the quality of living in the urban areas. Therefore, they might be a good solution for some areas.

List of Figures

List of Tables

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Bridge system scheme

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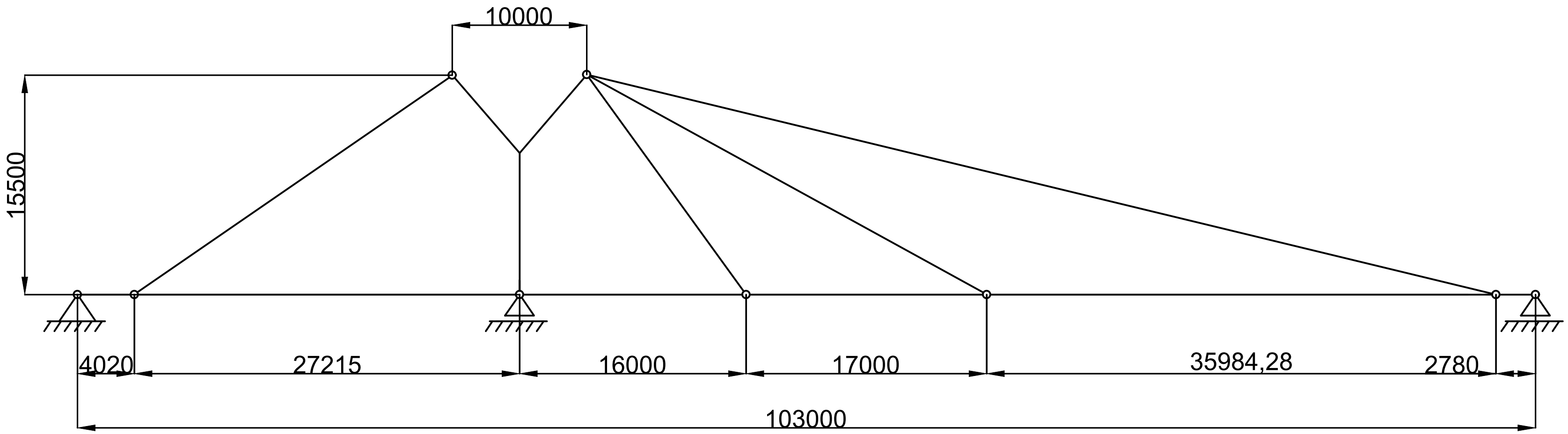

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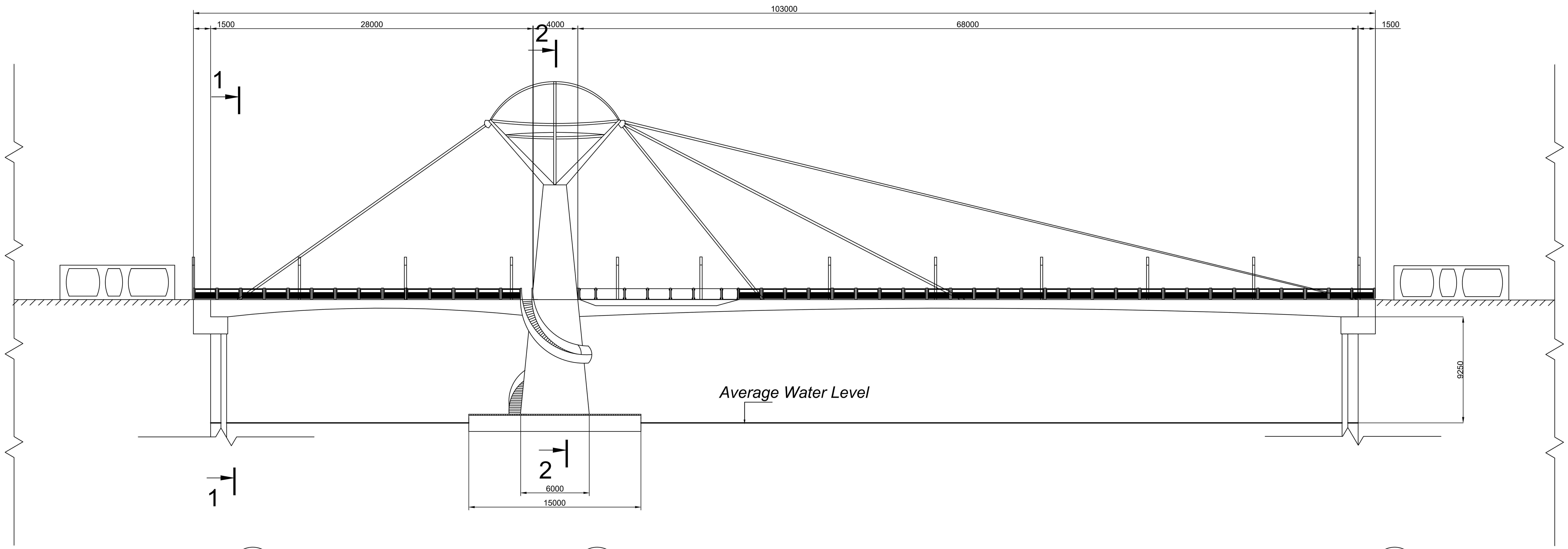

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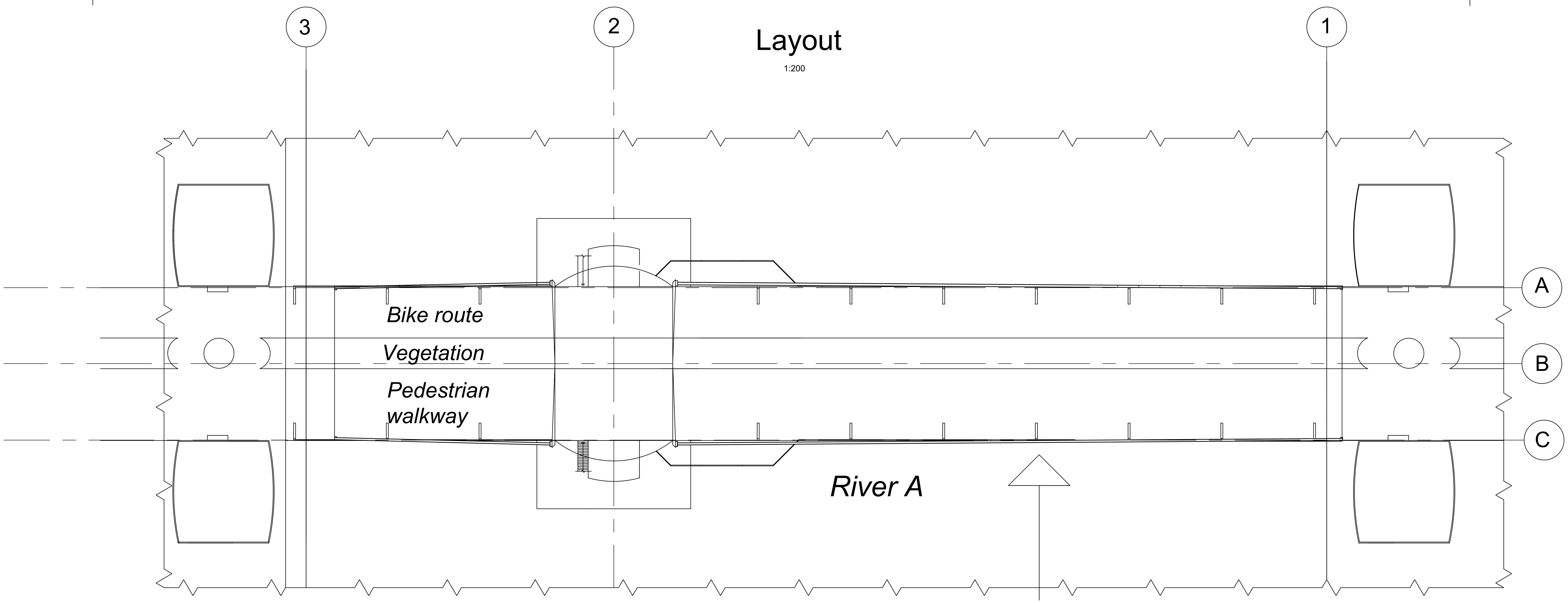

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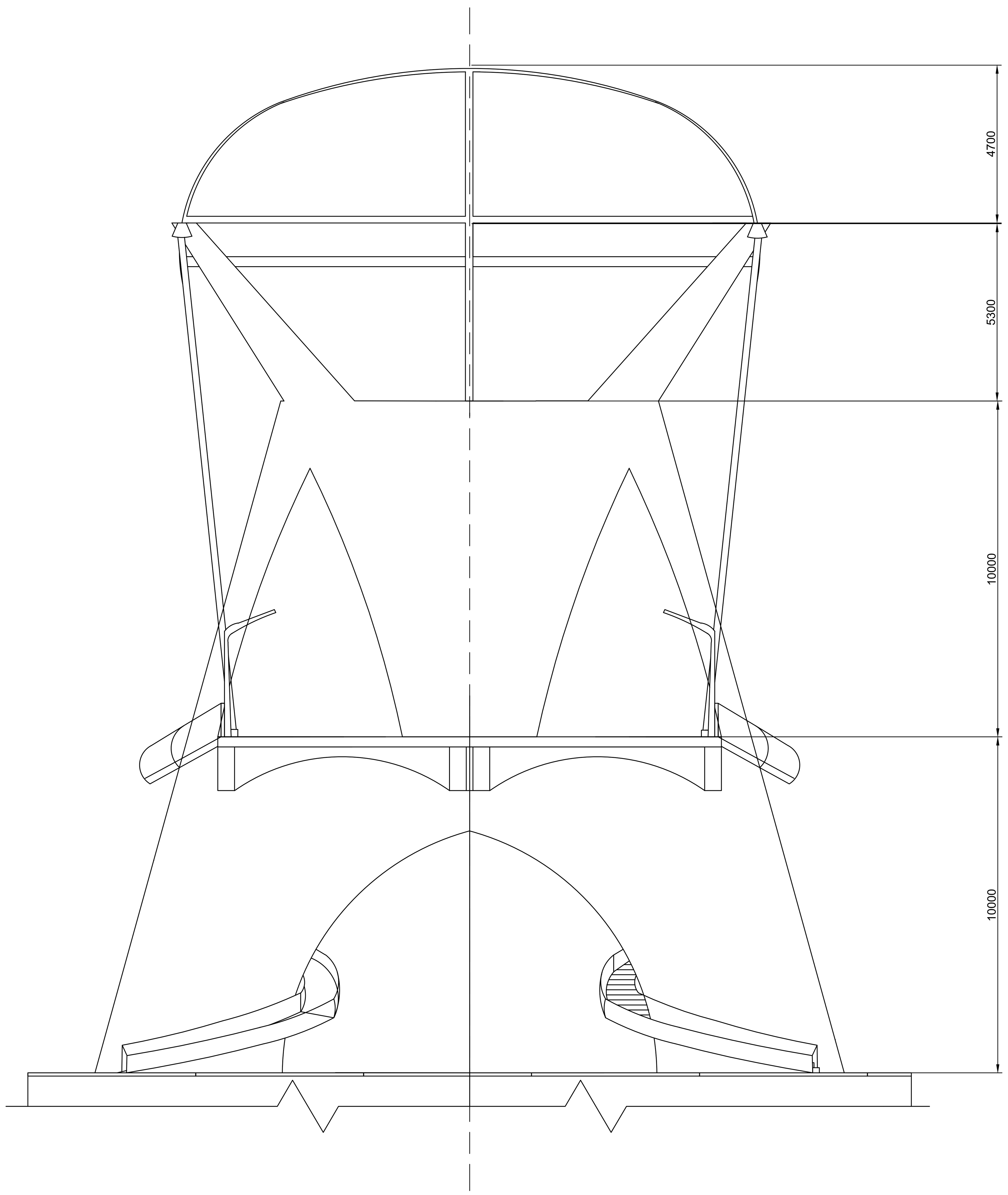

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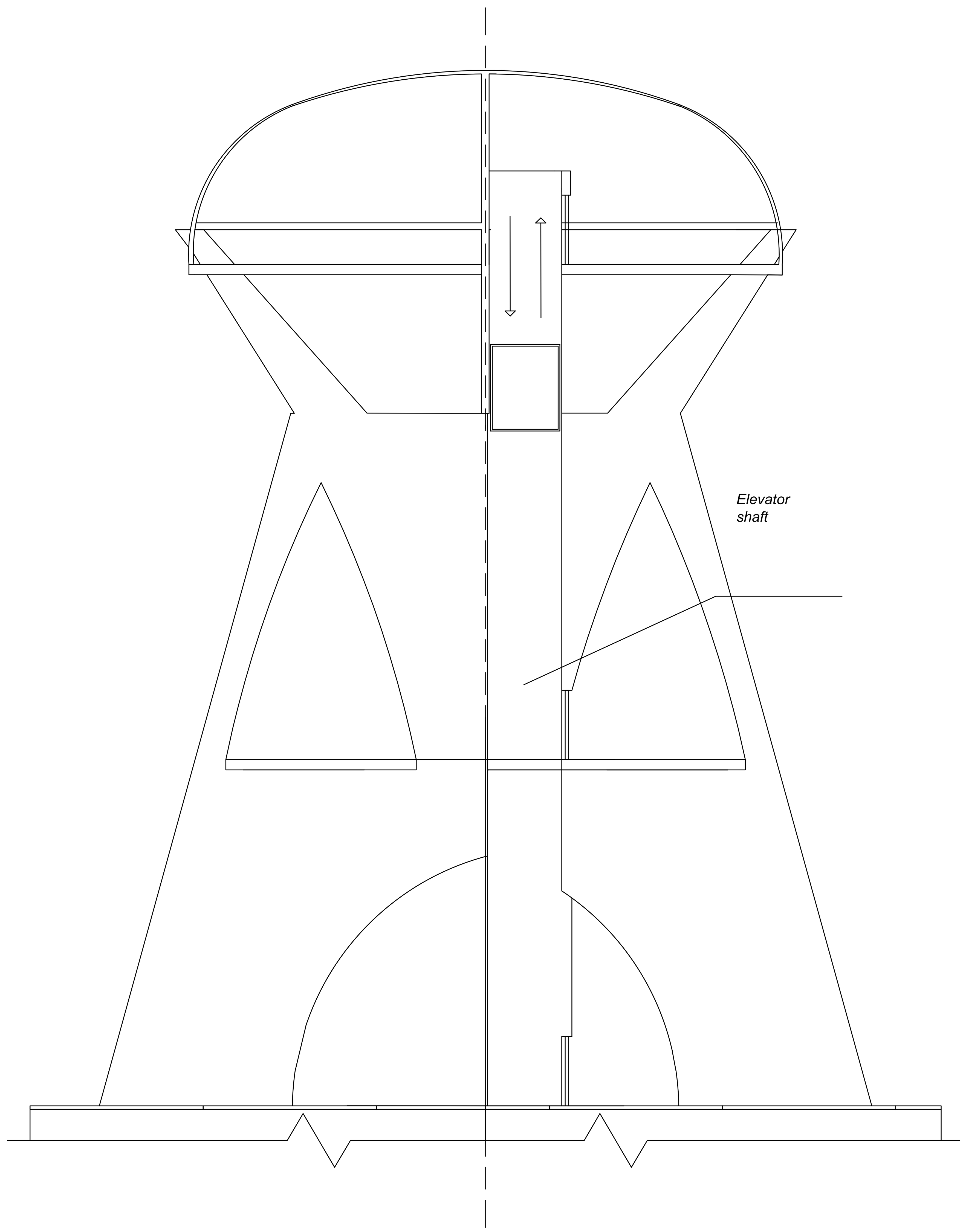

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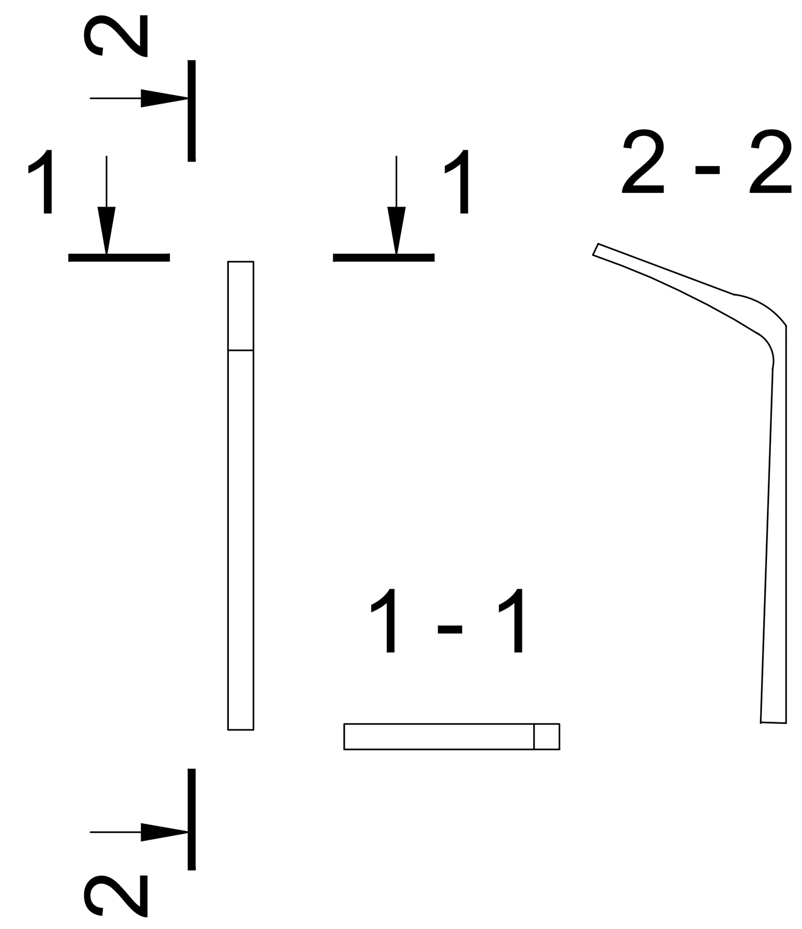

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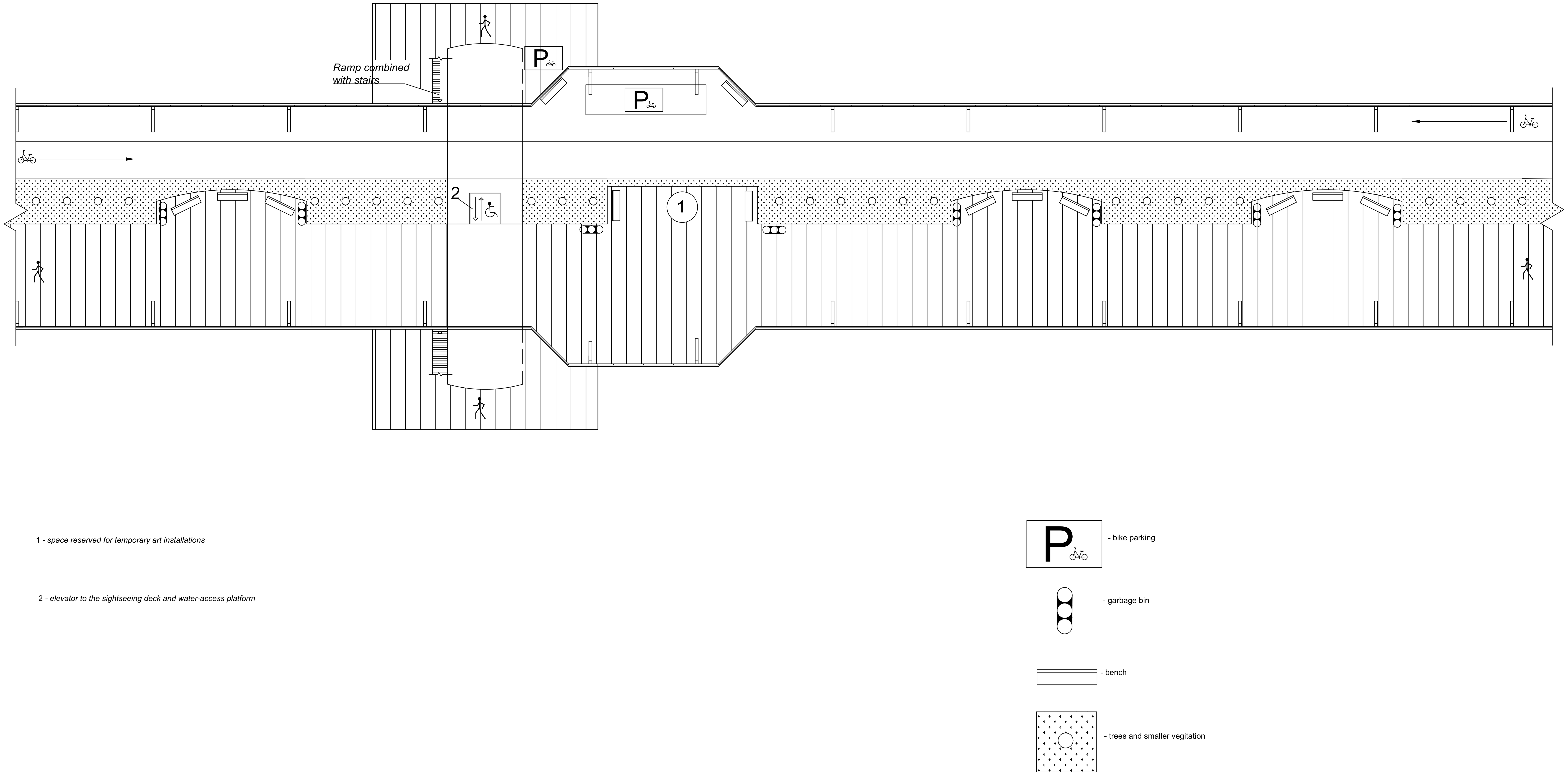

1 - *space reserved for temporary art installations*

2 - *elevator to the sightseeing deck and water-access platform*

Facade

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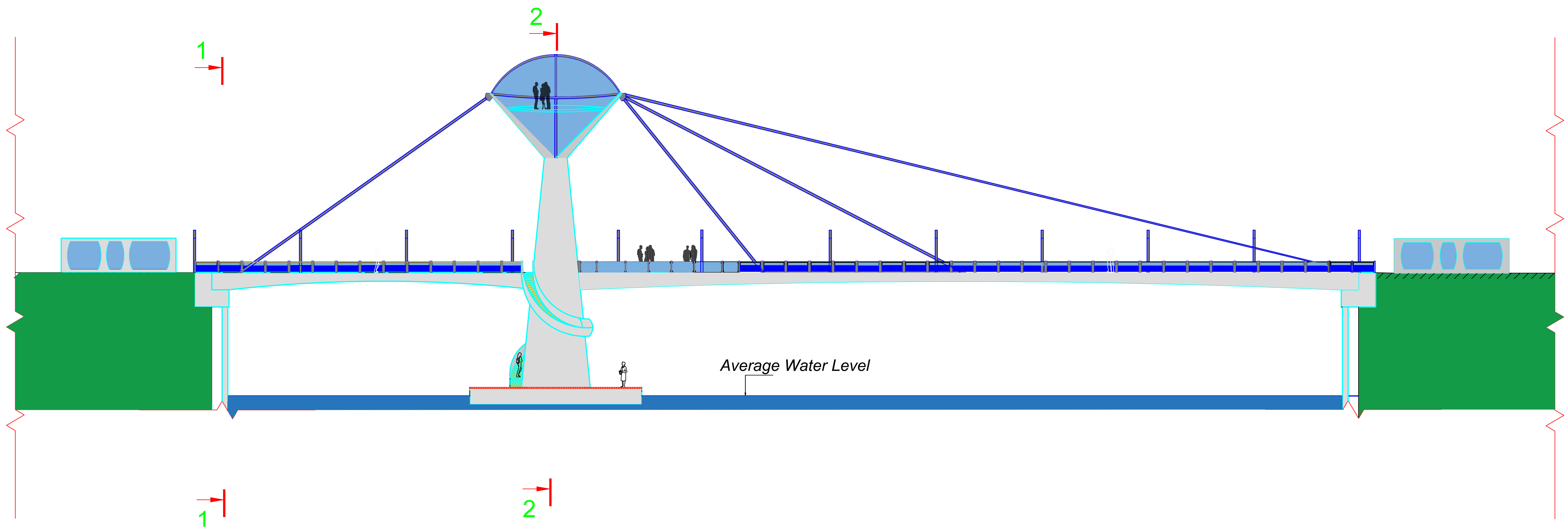

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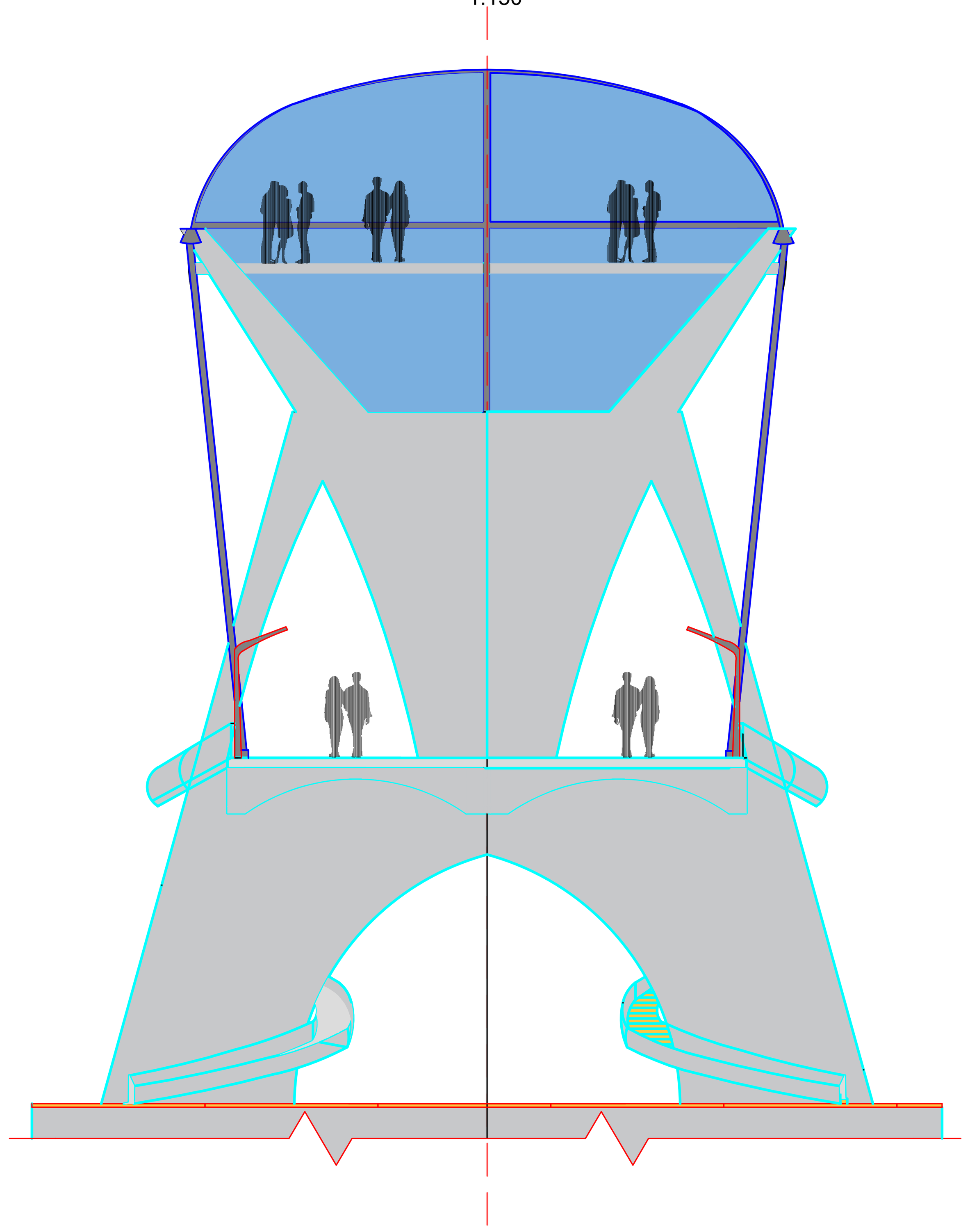

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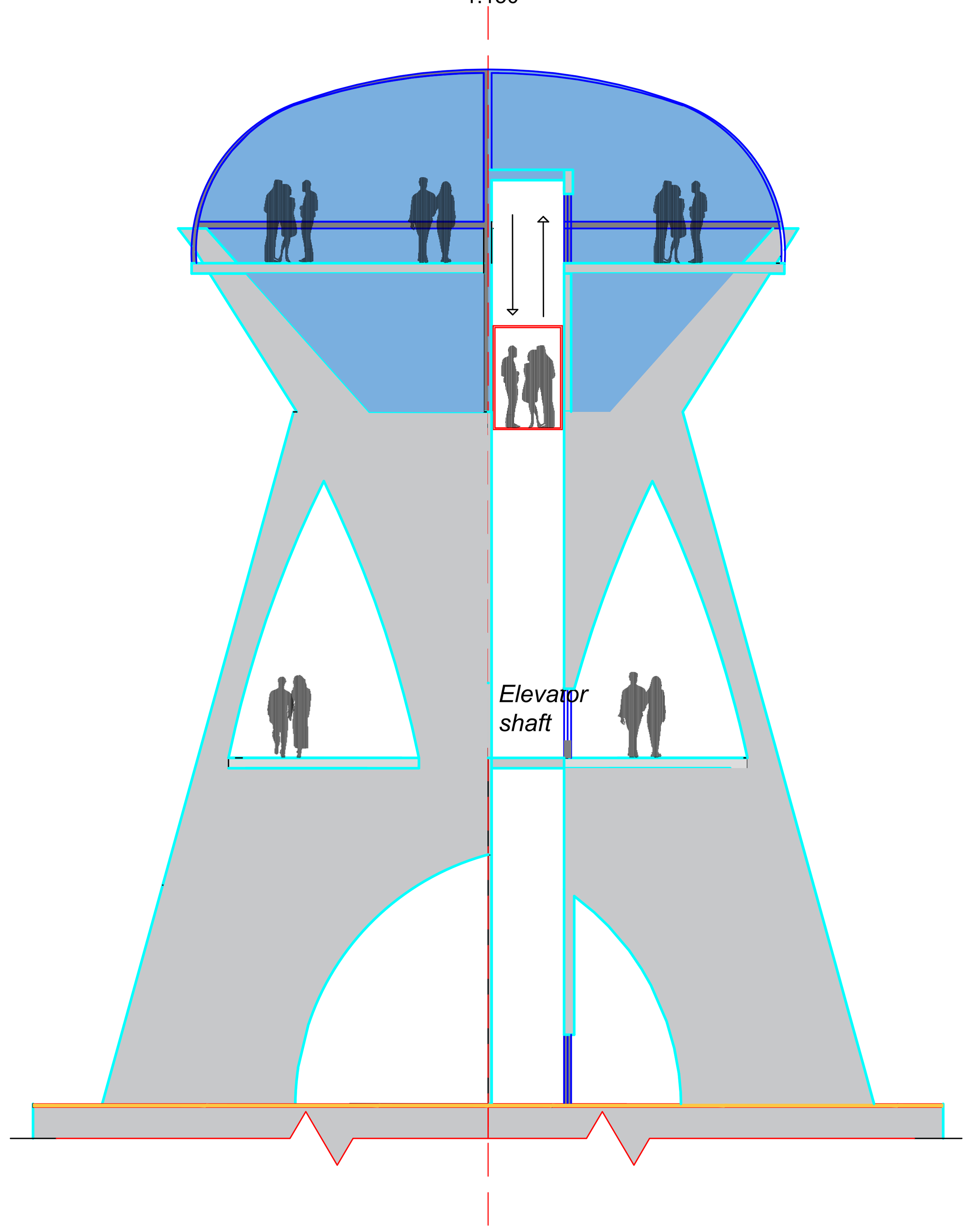

Bridge system scheme

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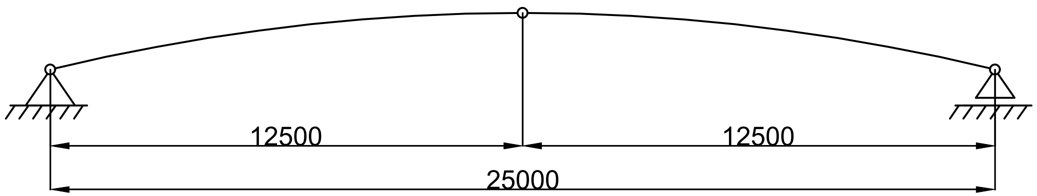

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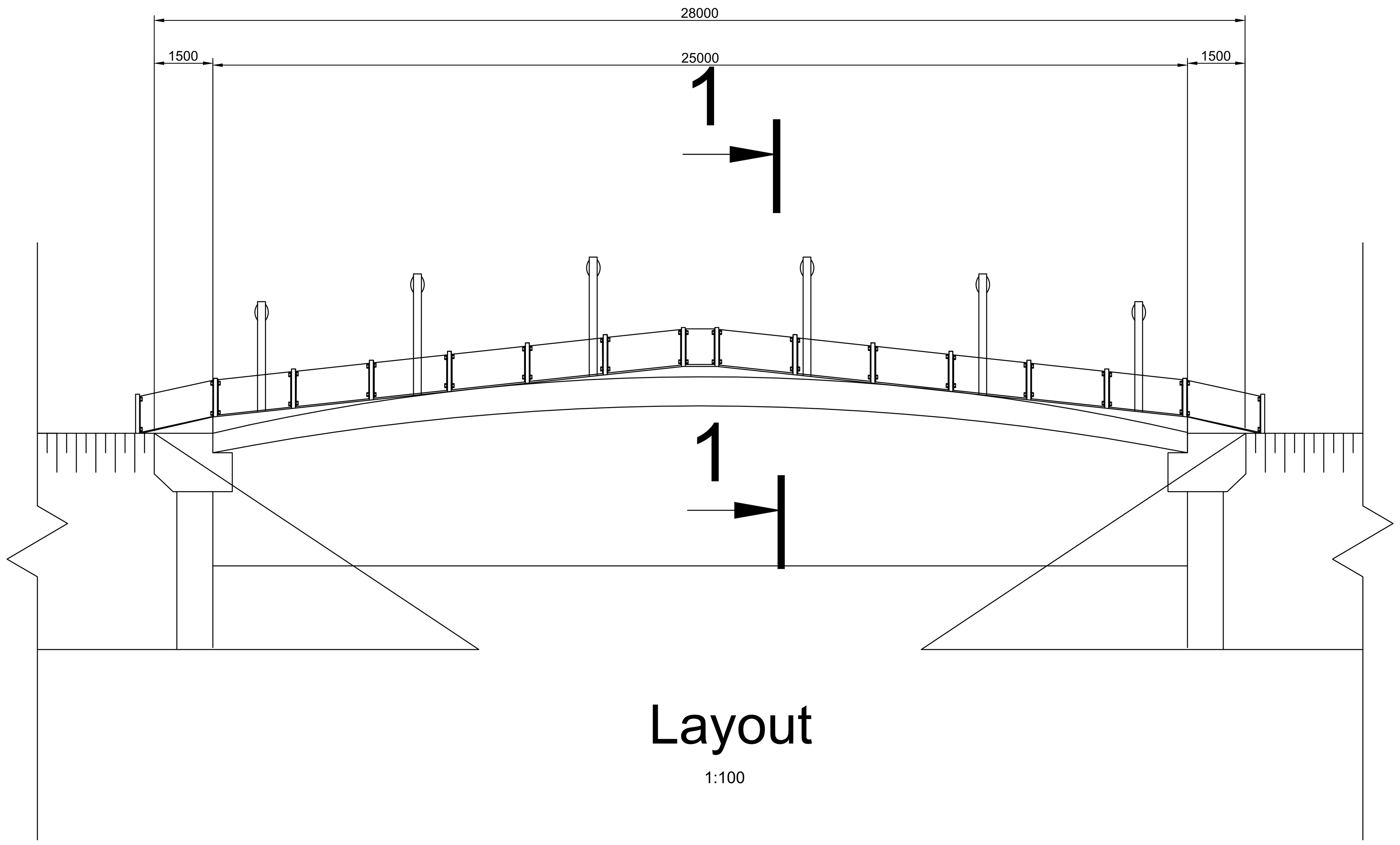

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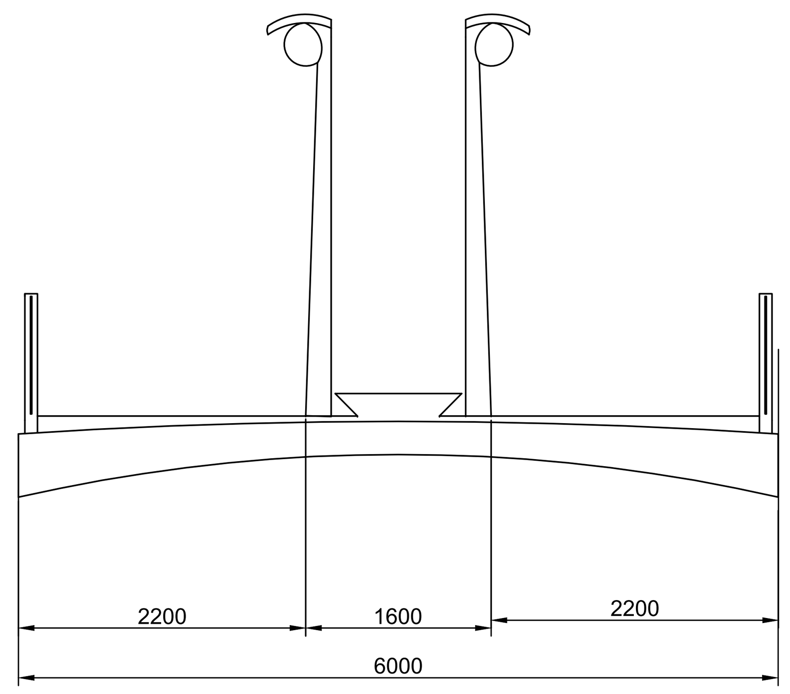

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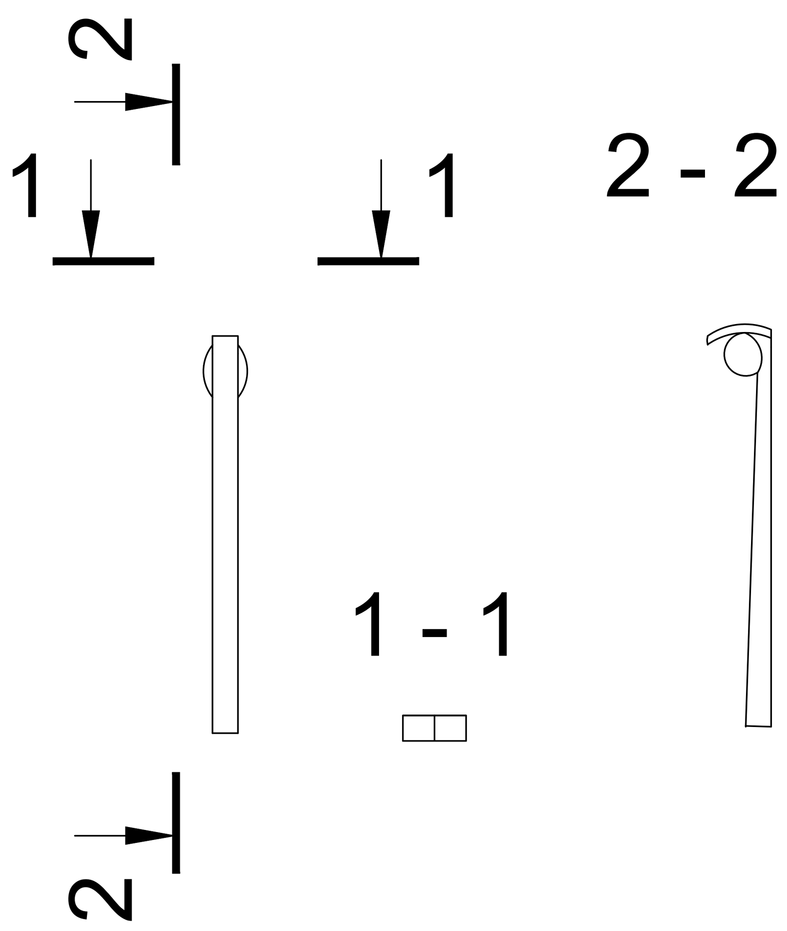

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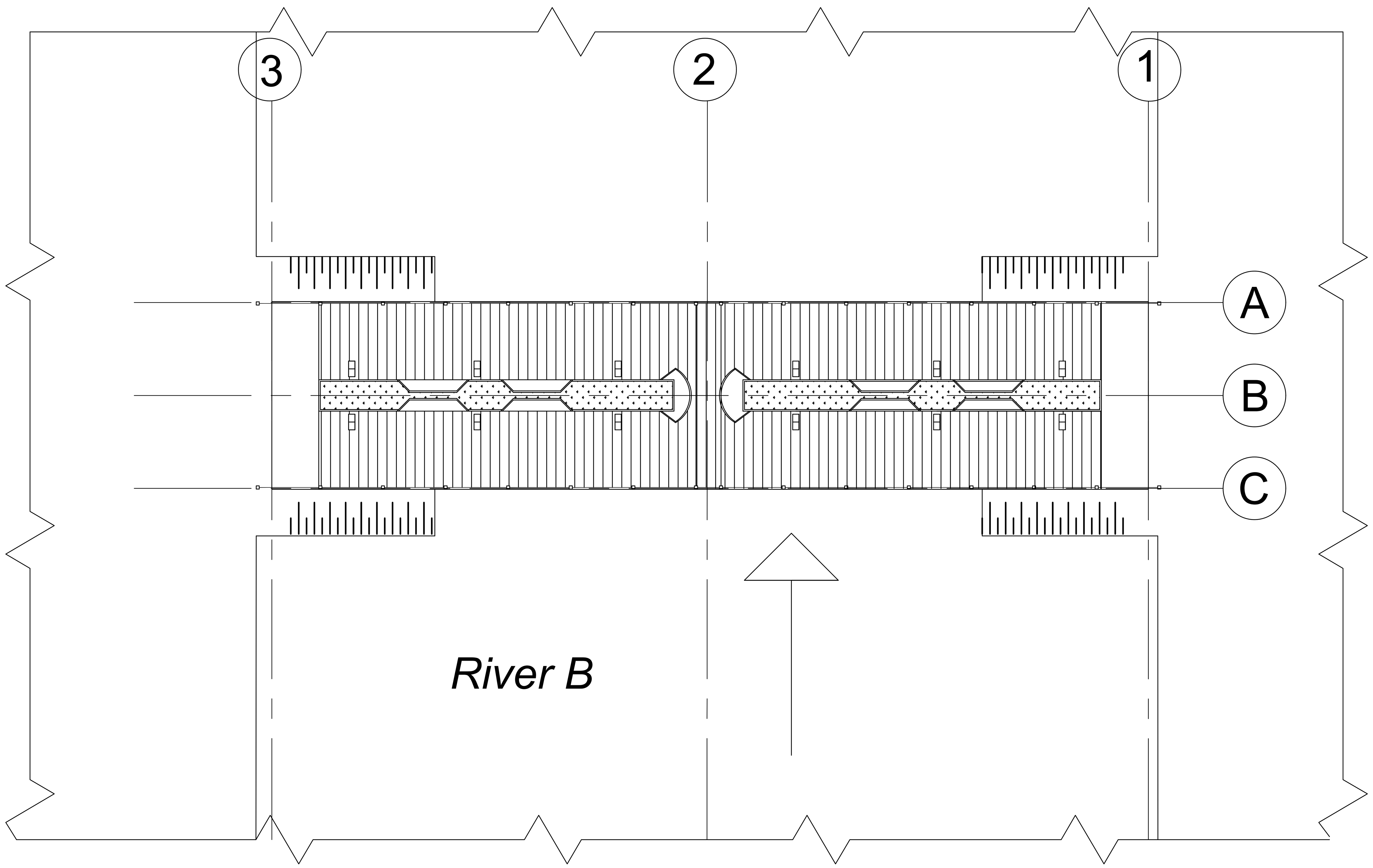

Facade (the deck is shown)

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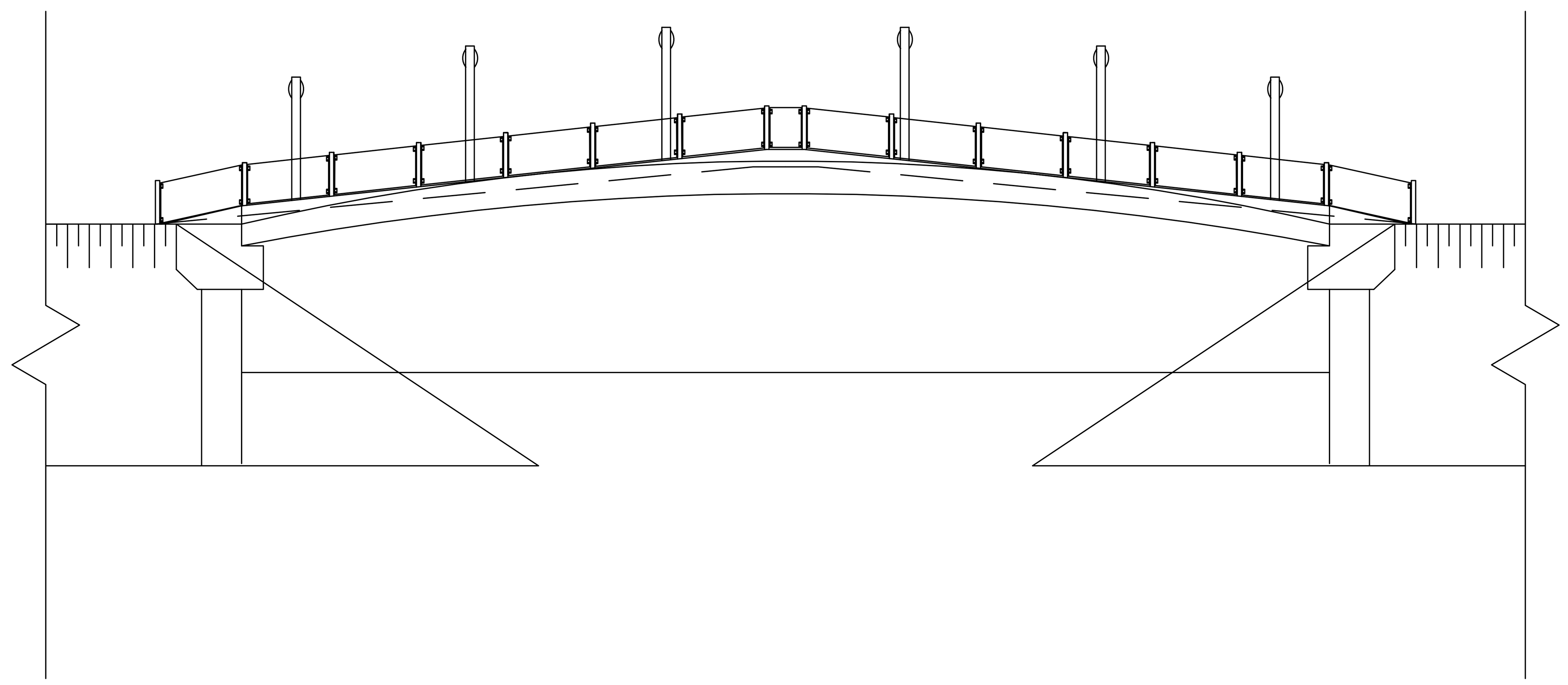

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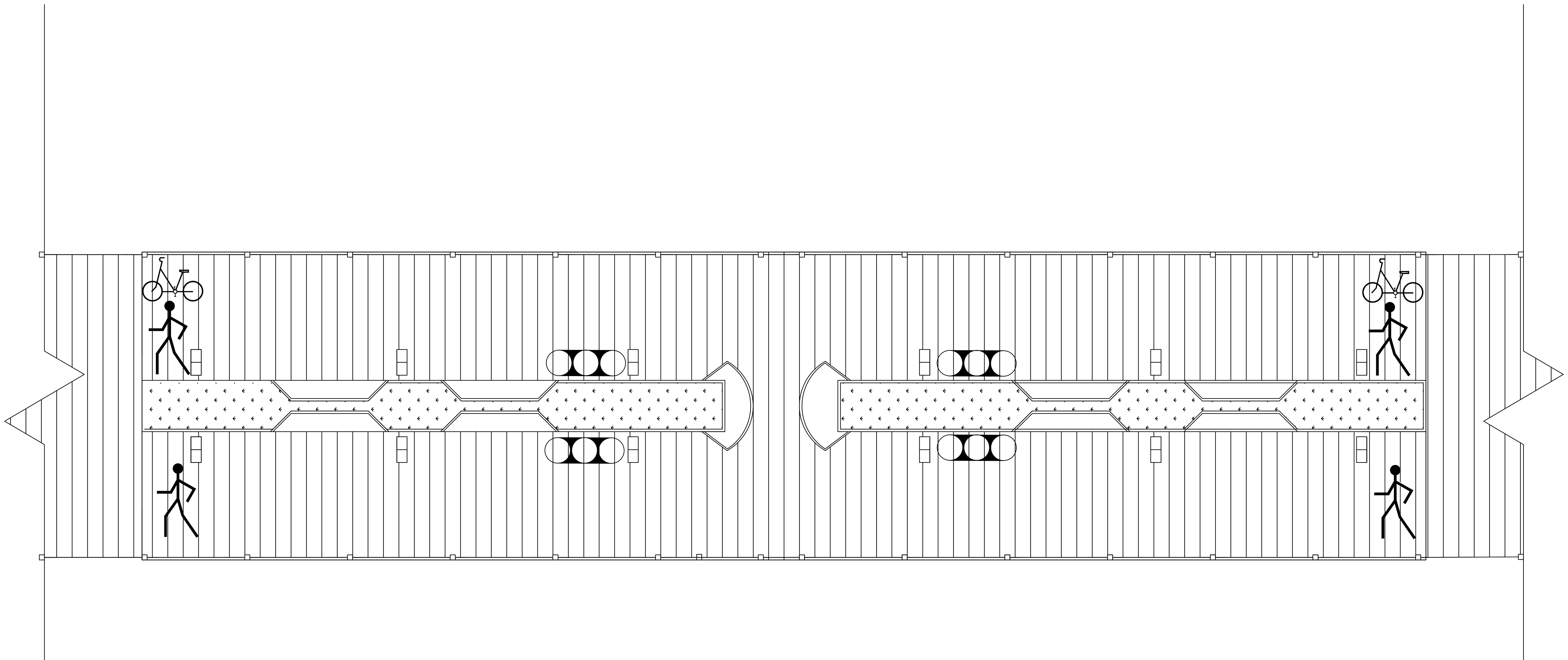

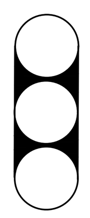

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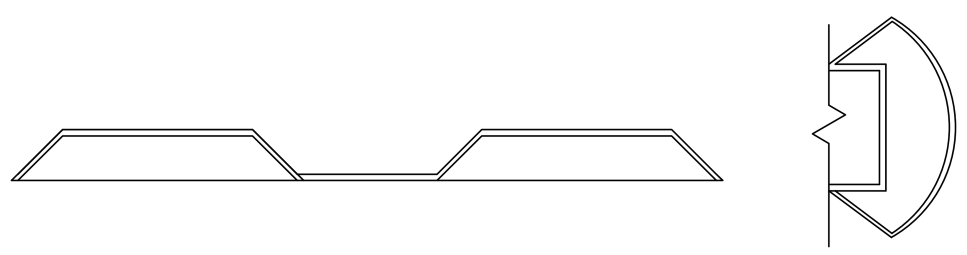

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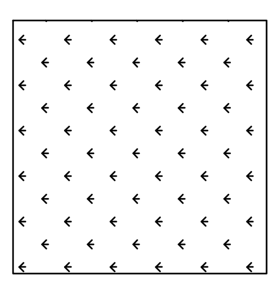

- vegetation

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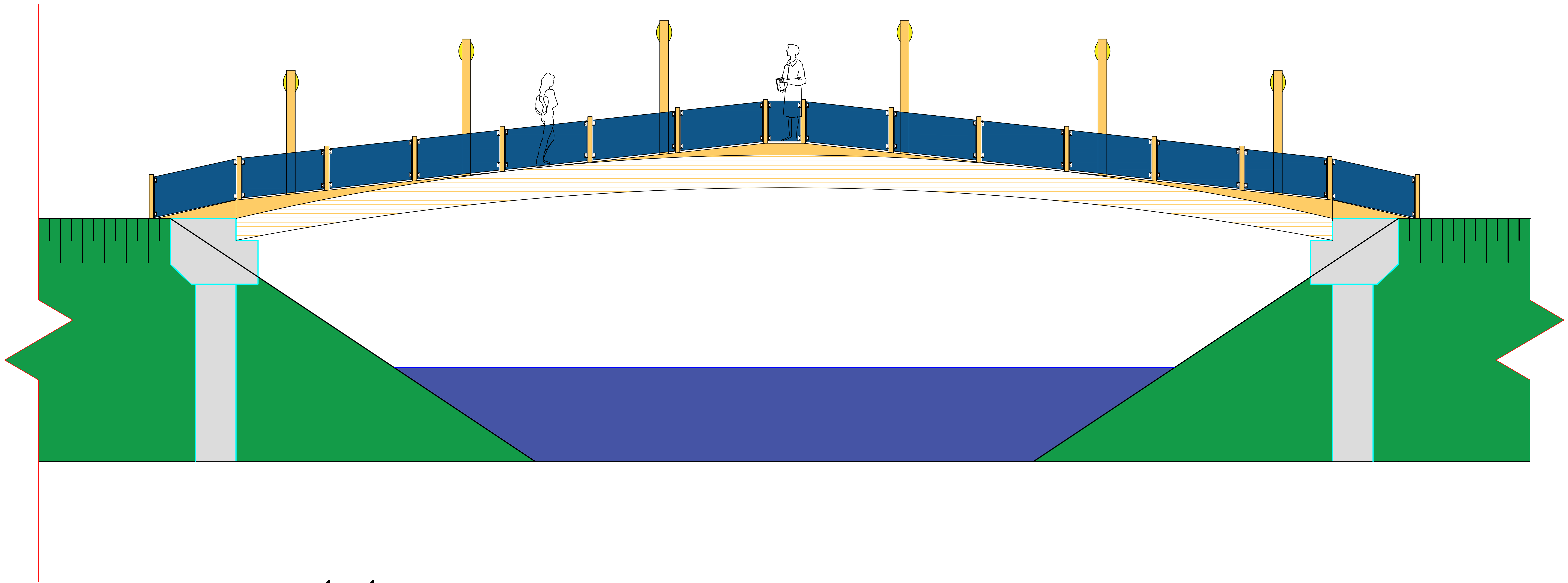

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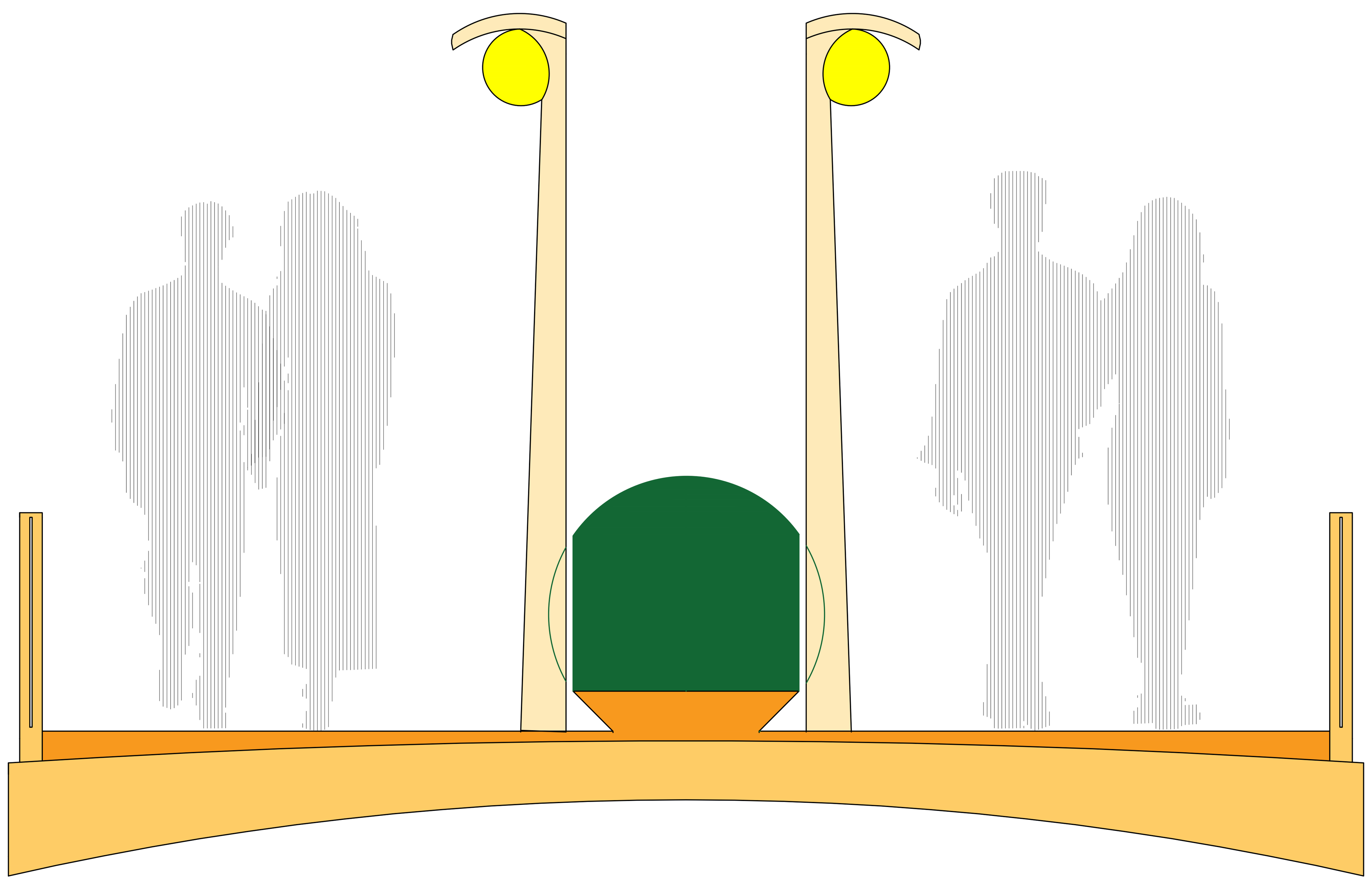

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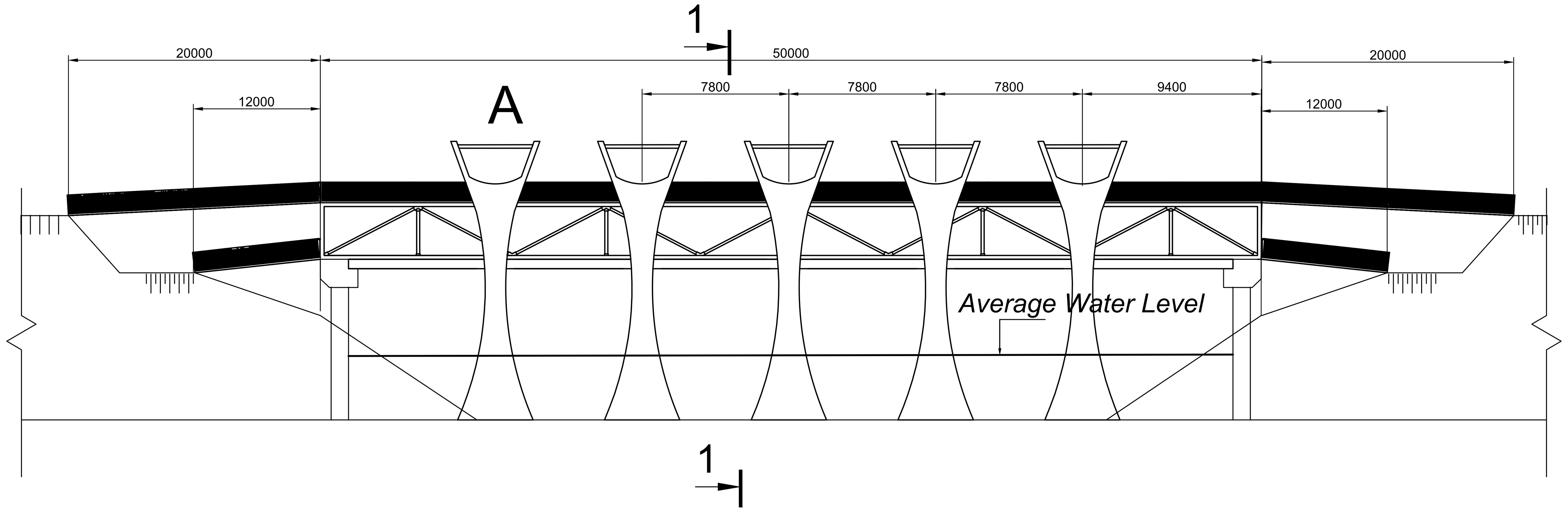

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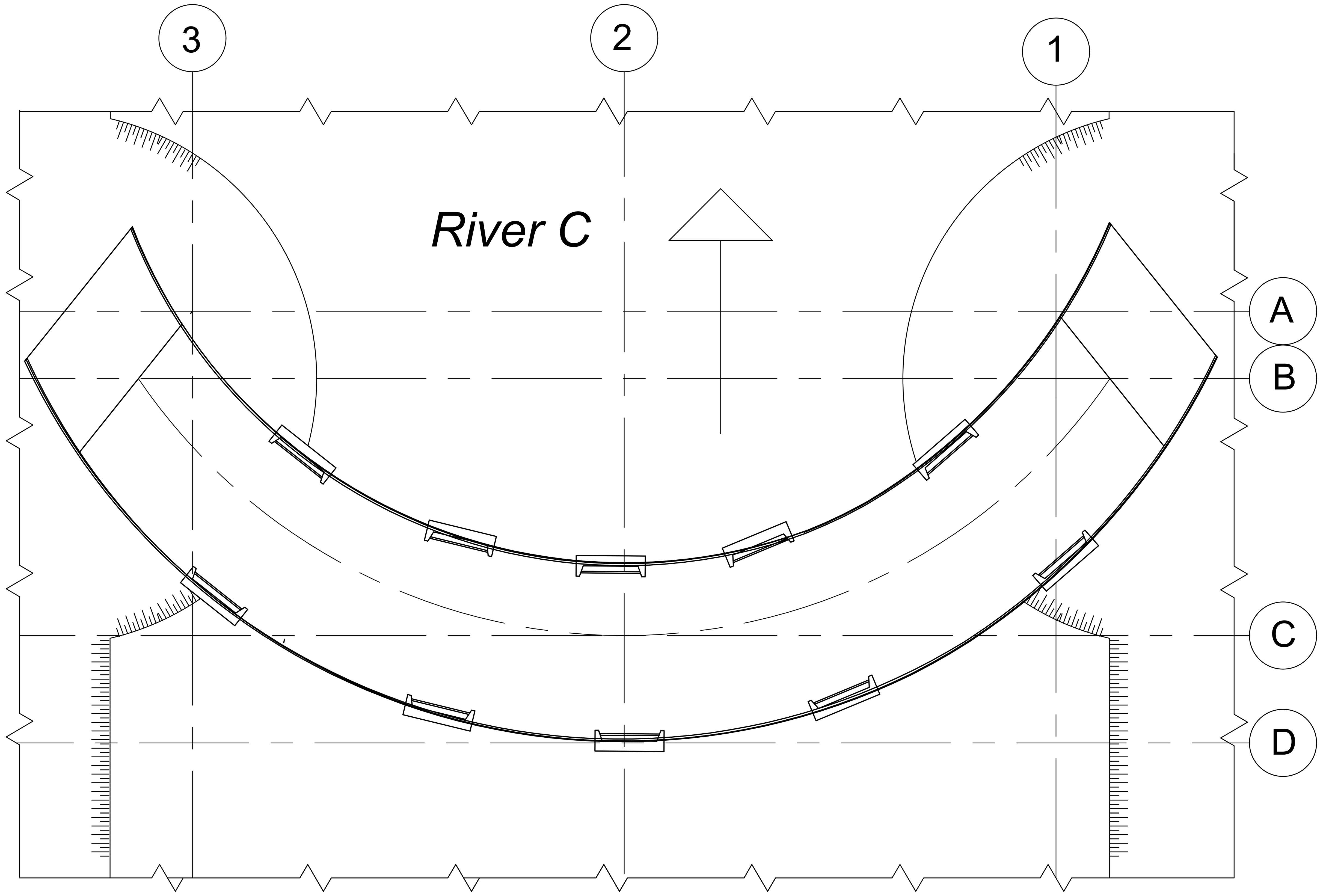

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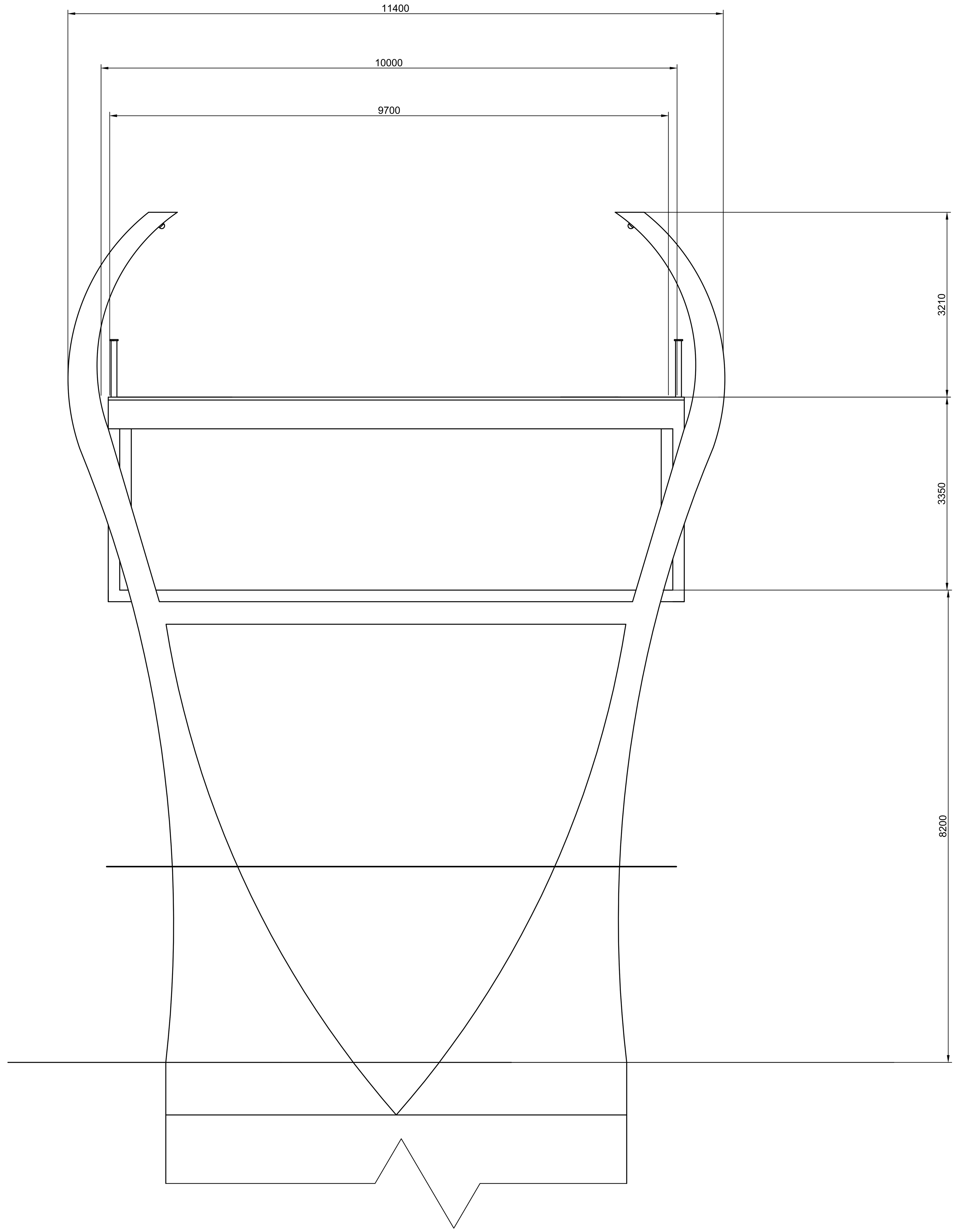

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(Bike-route)

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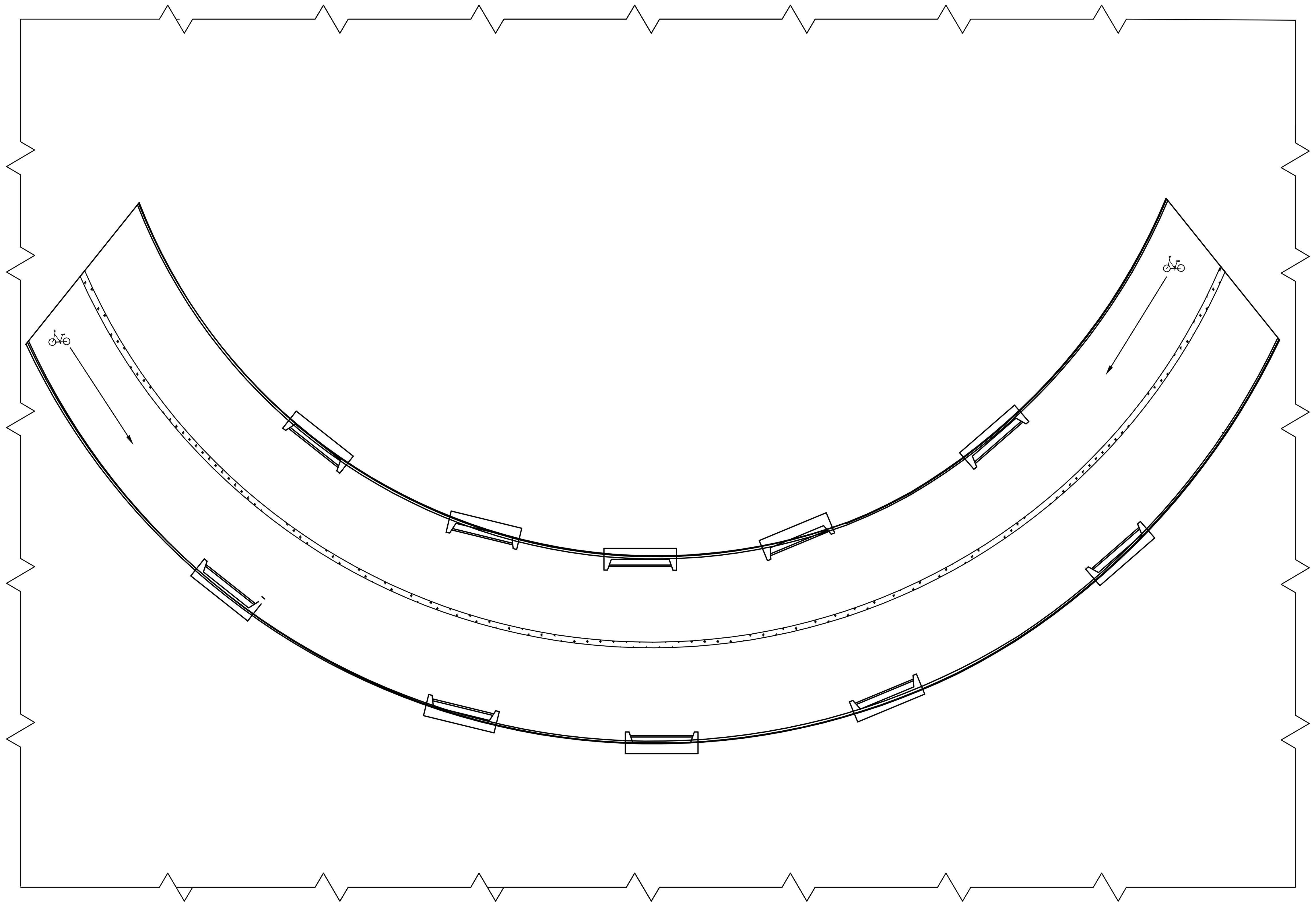

Planning Level 1
(Pedestrian route, business area and green area)

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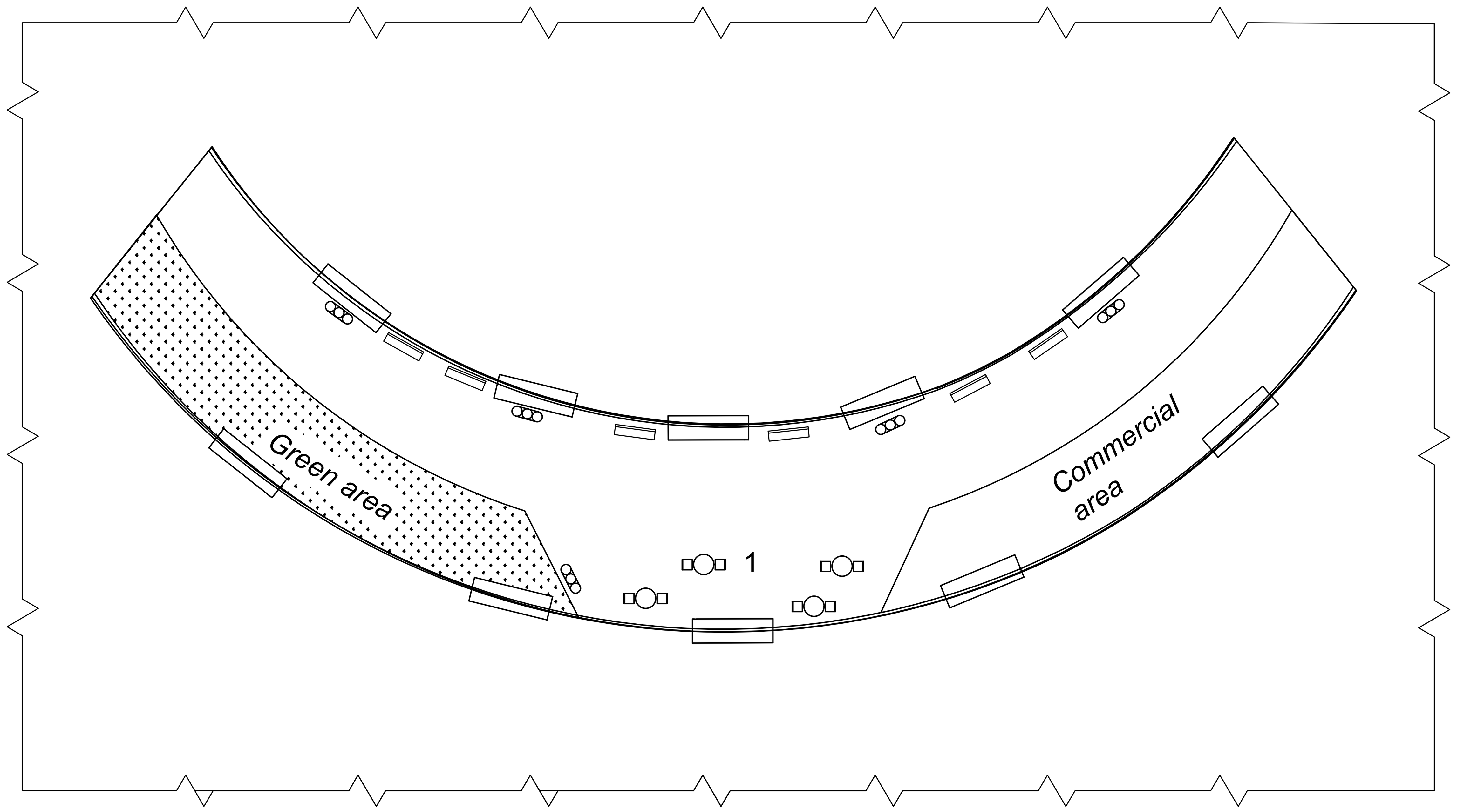

1-*Sightseeing deck and restaurant area*

- *garbage bin*

- *table and chairs*

- *bench*

Facade

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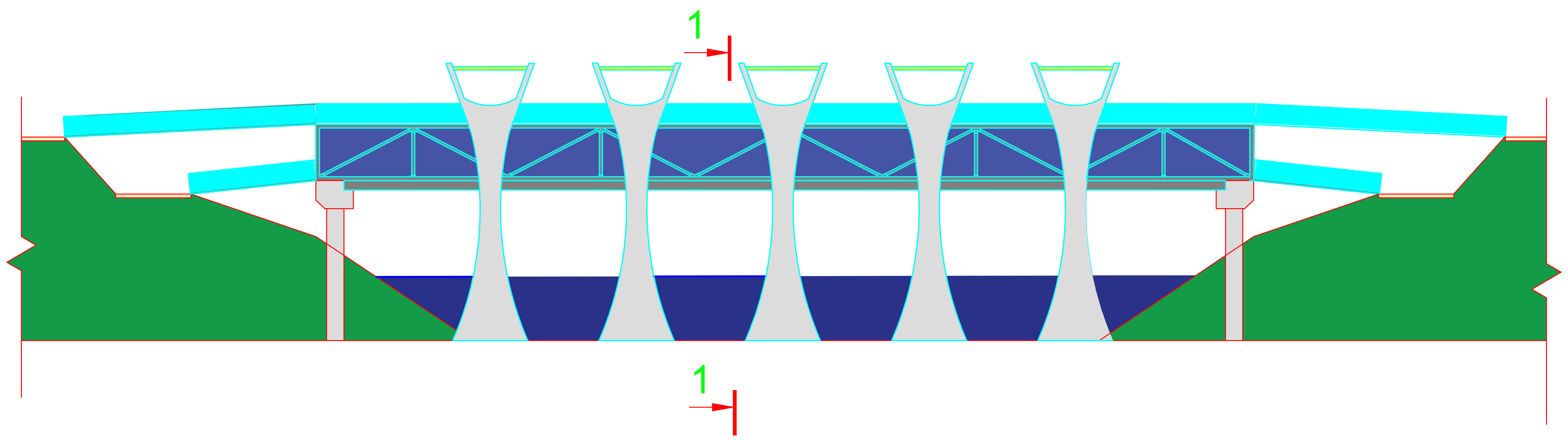

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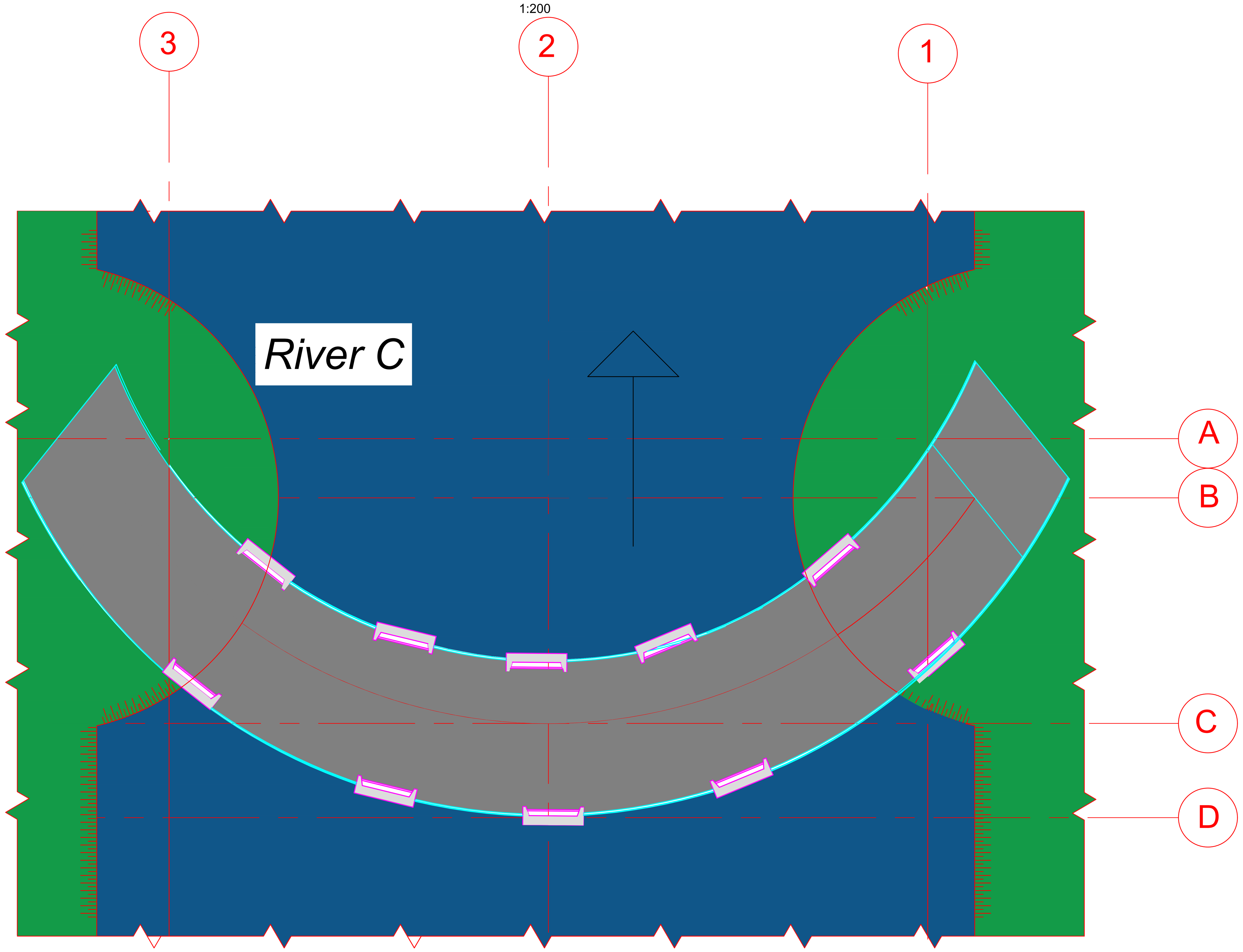

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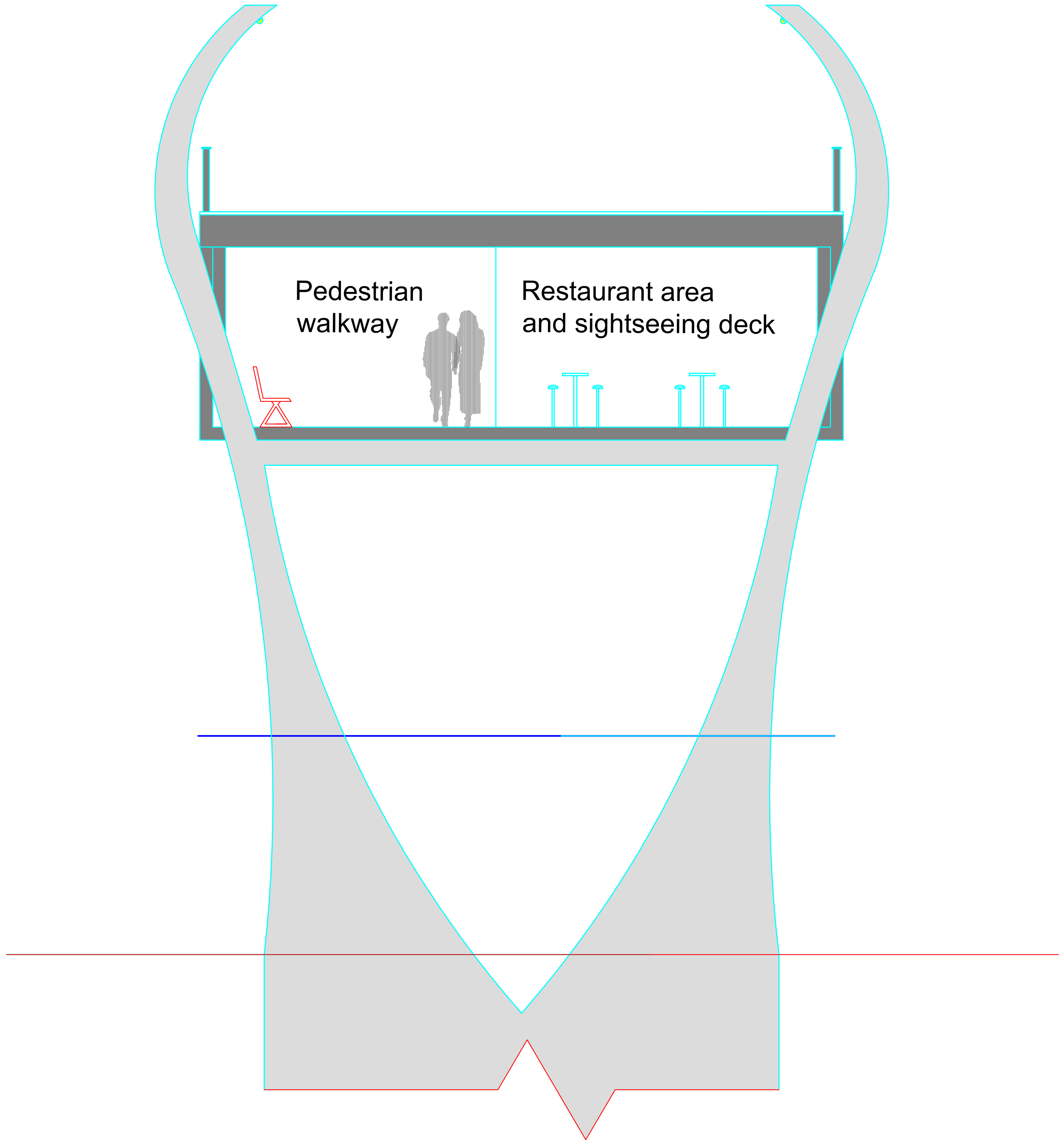

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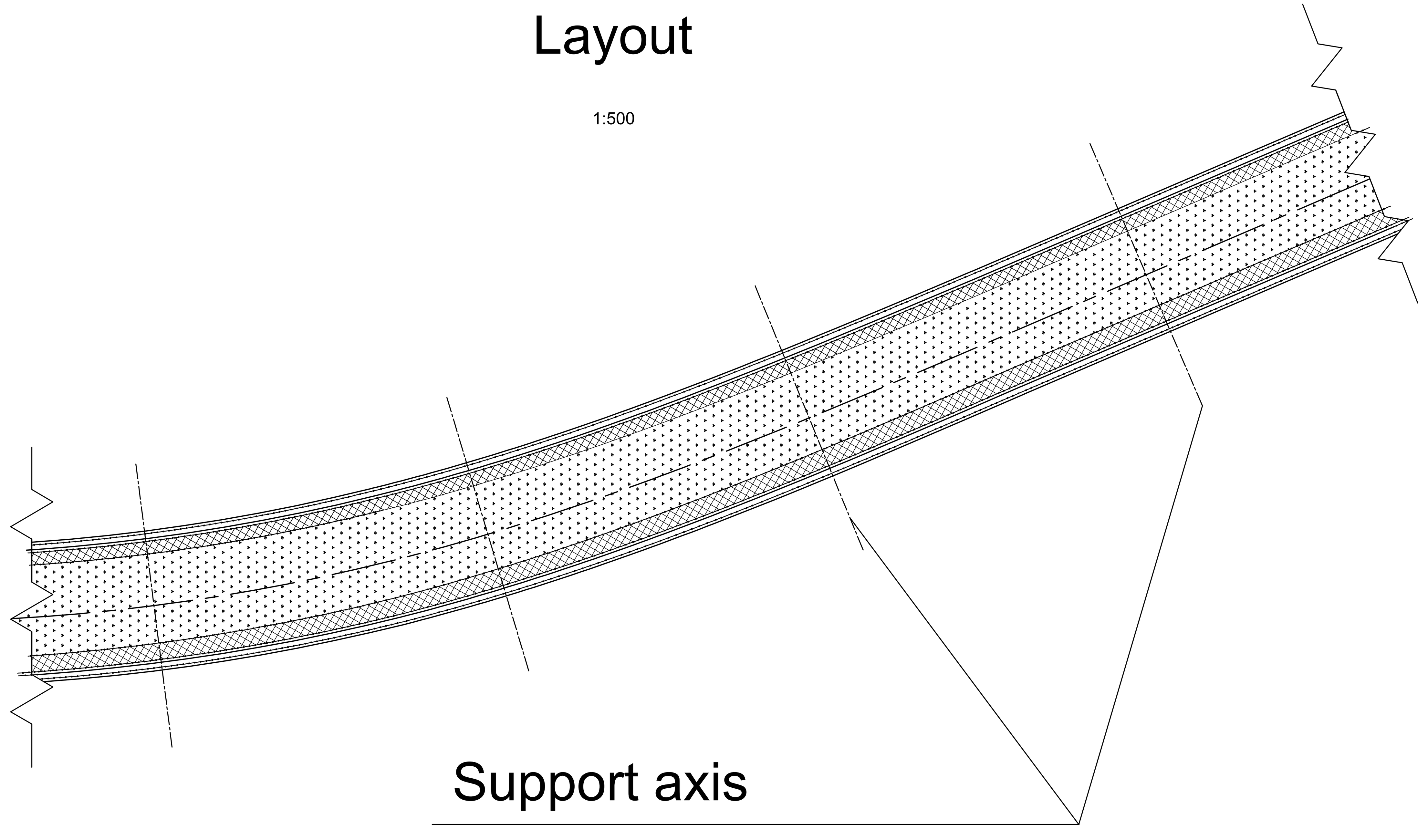

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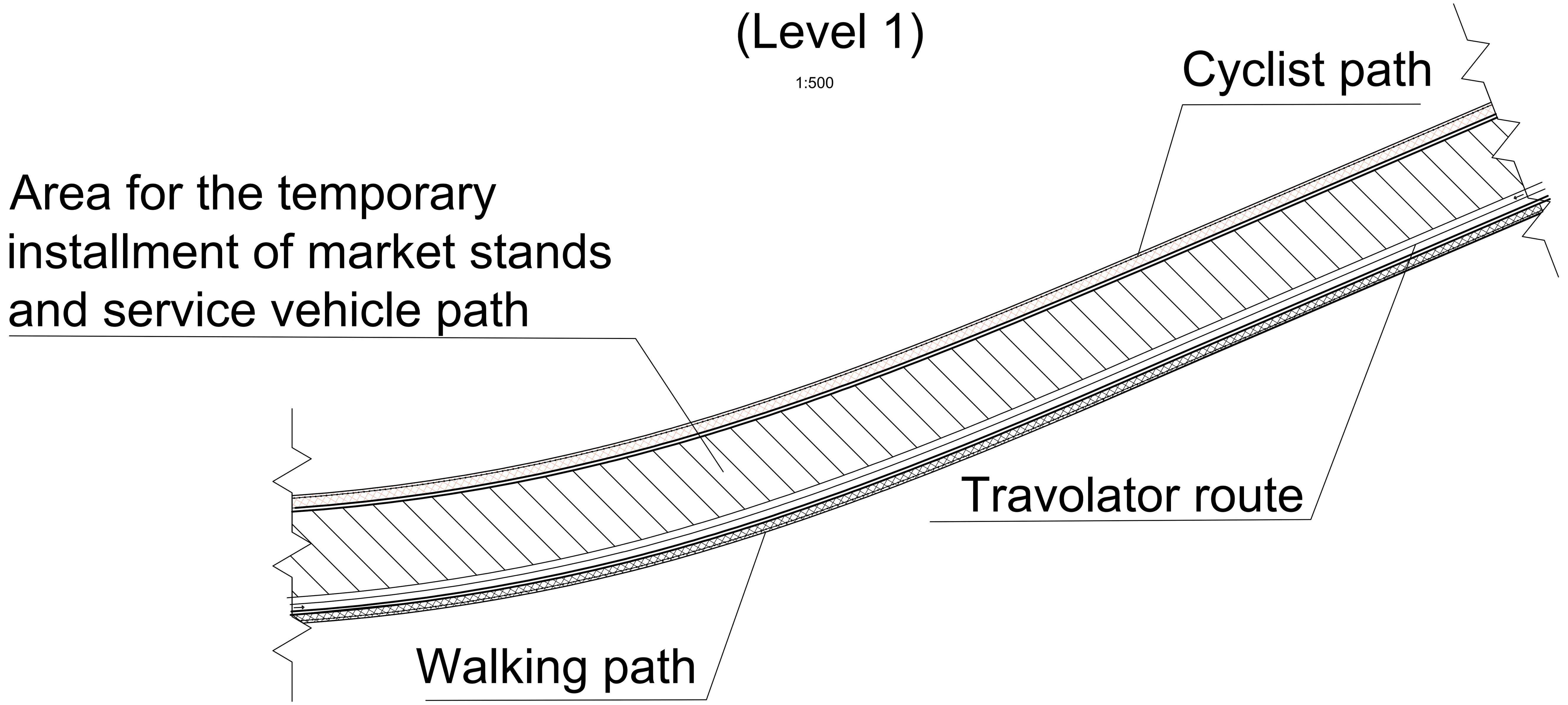

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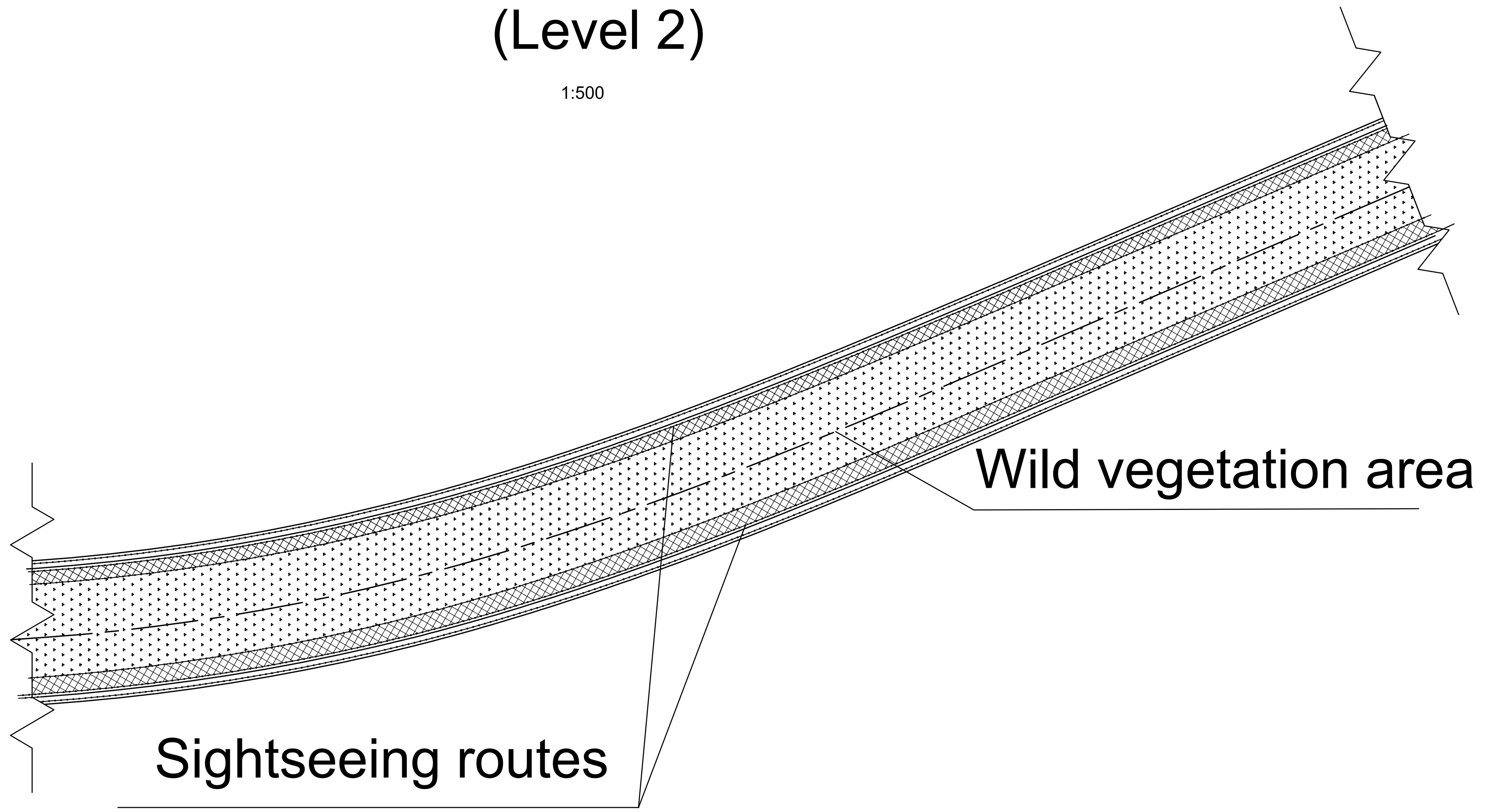

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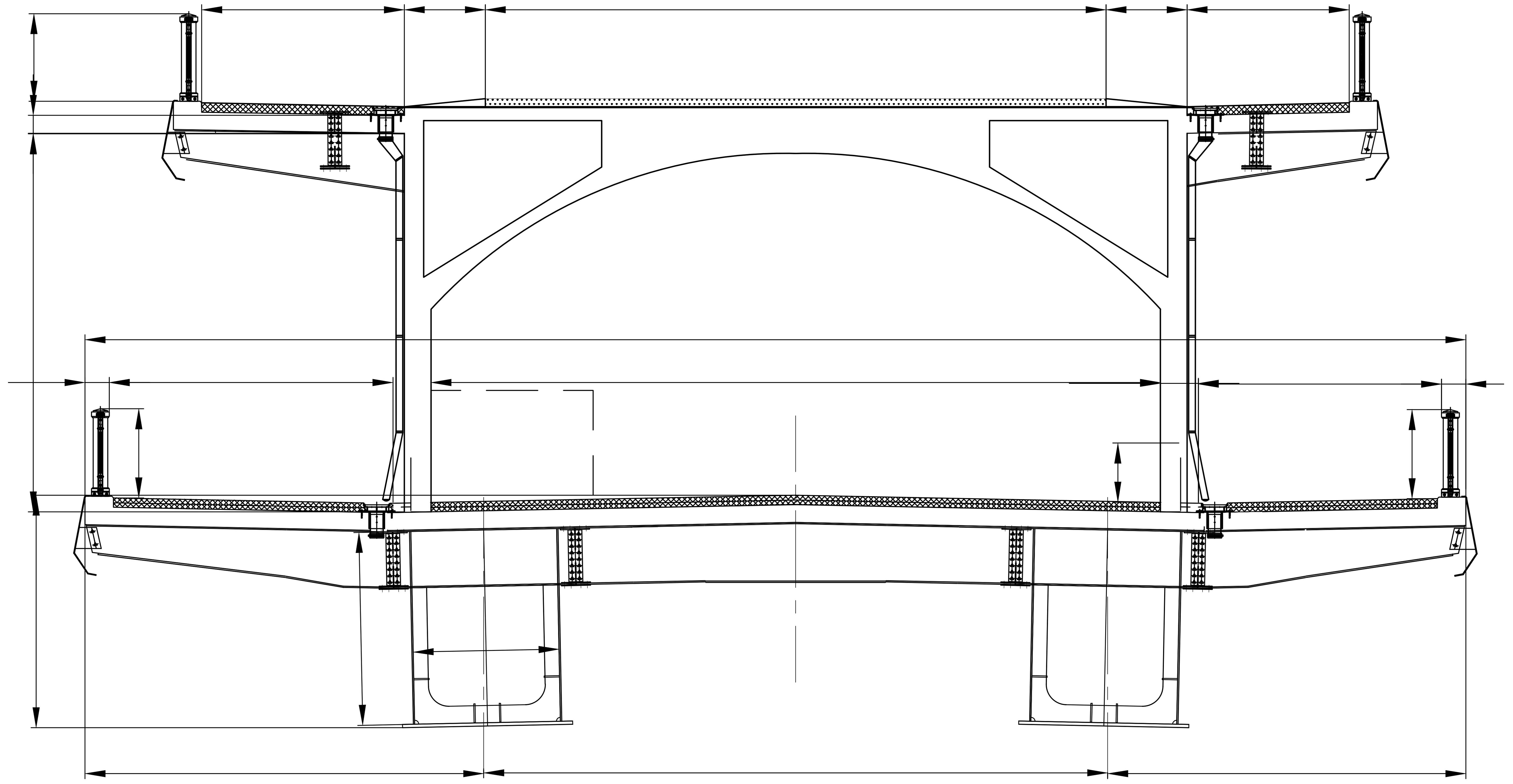

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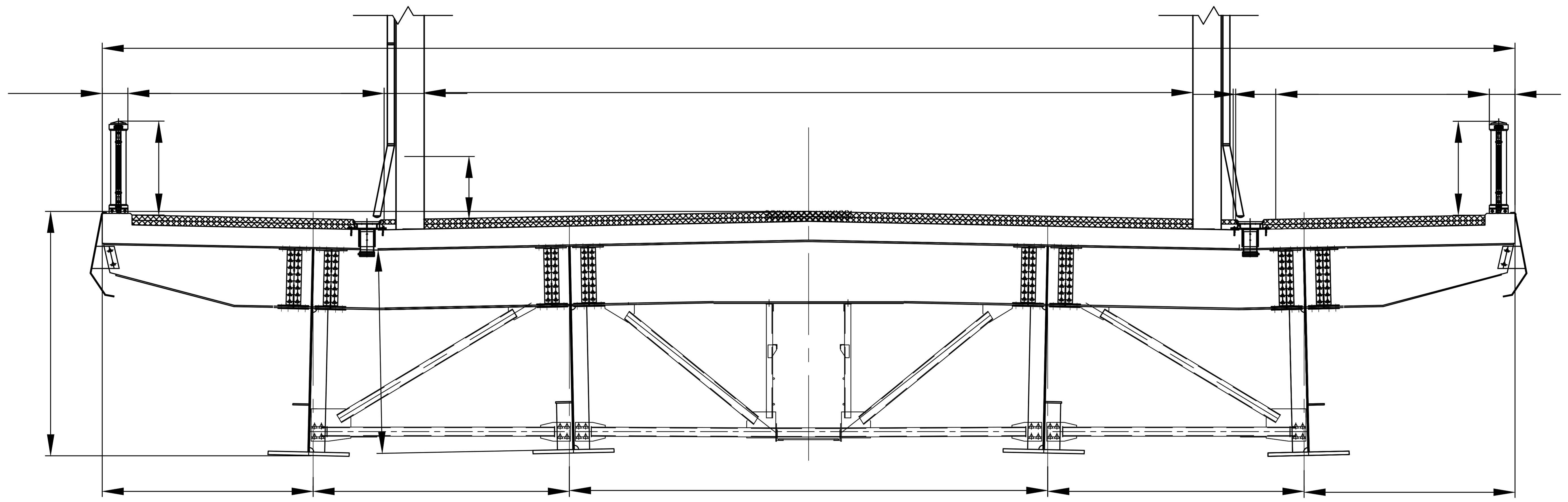

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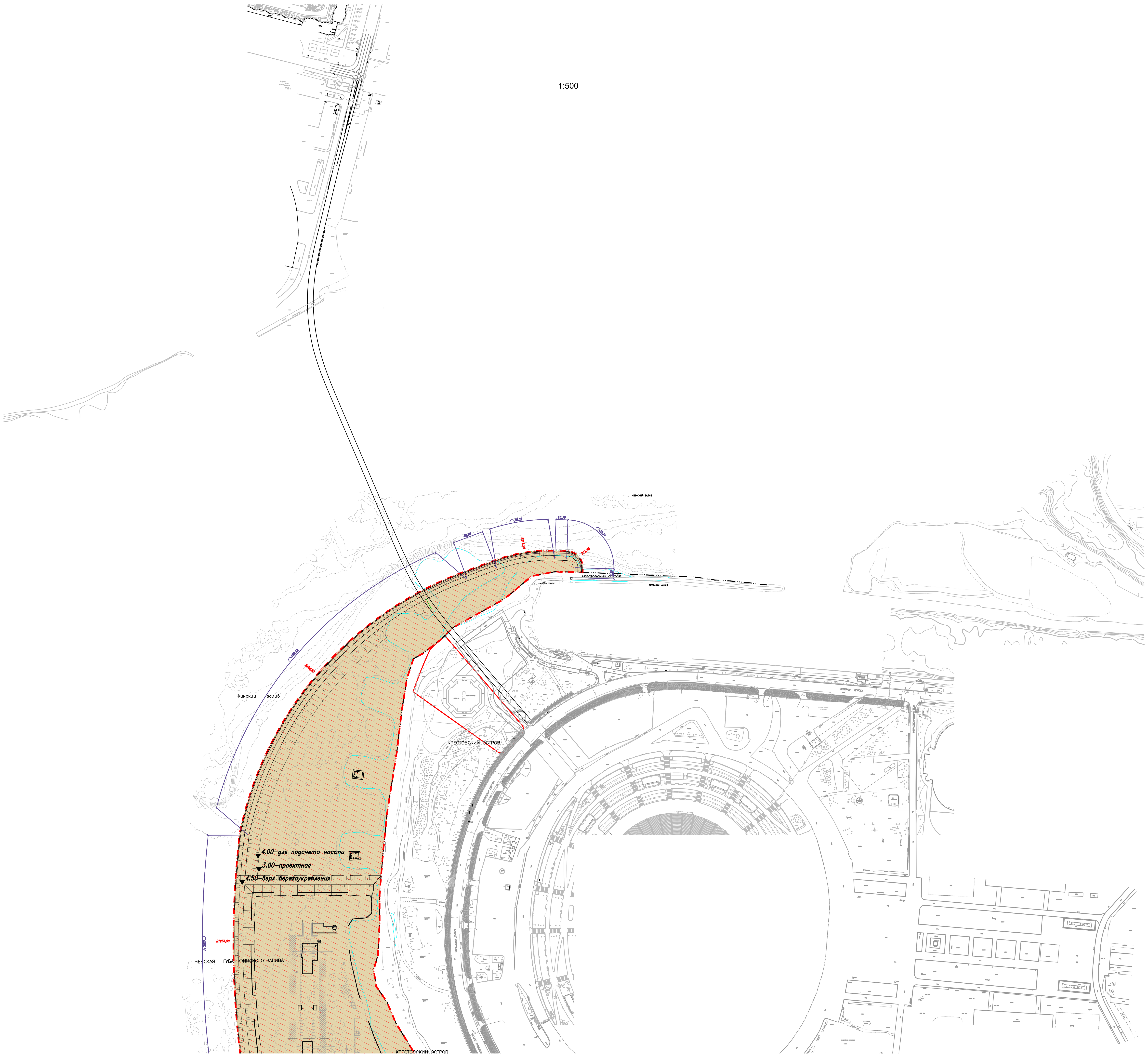
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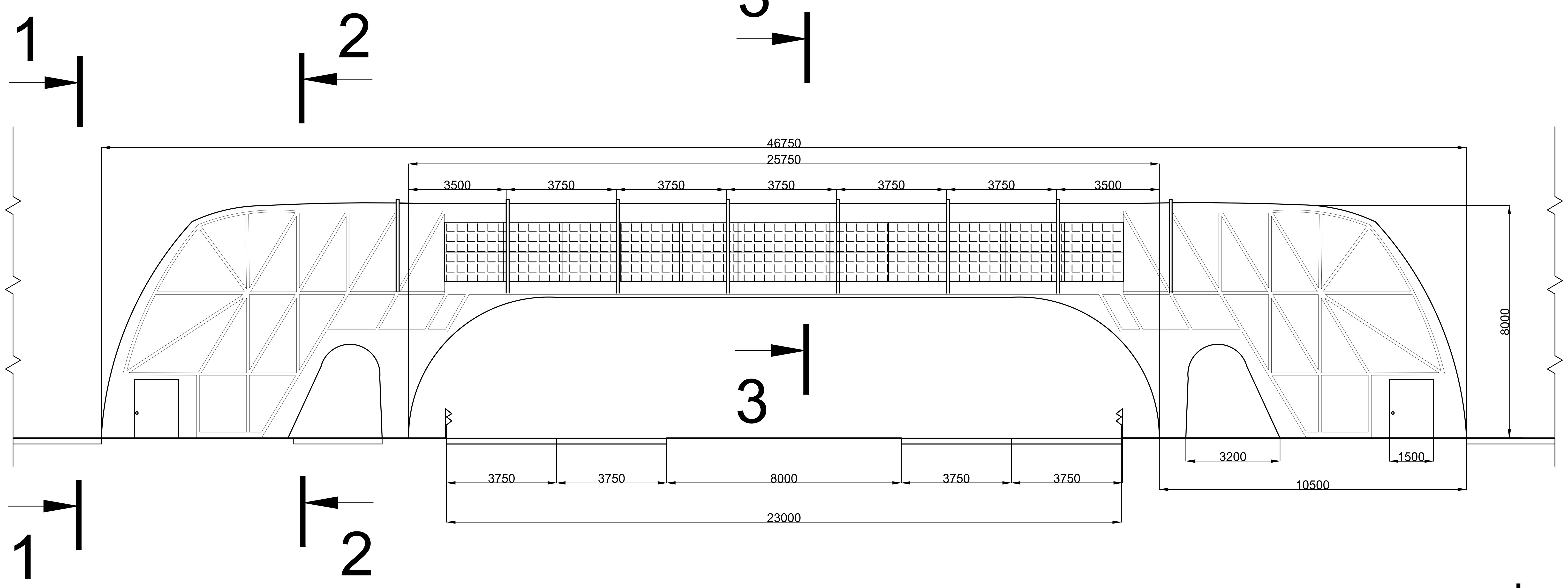
НЕВСКАЯ ГУБА ФИНСКОГО ЗАЛИВА
КРЕСТОВСКИЙ ОСТРОВ

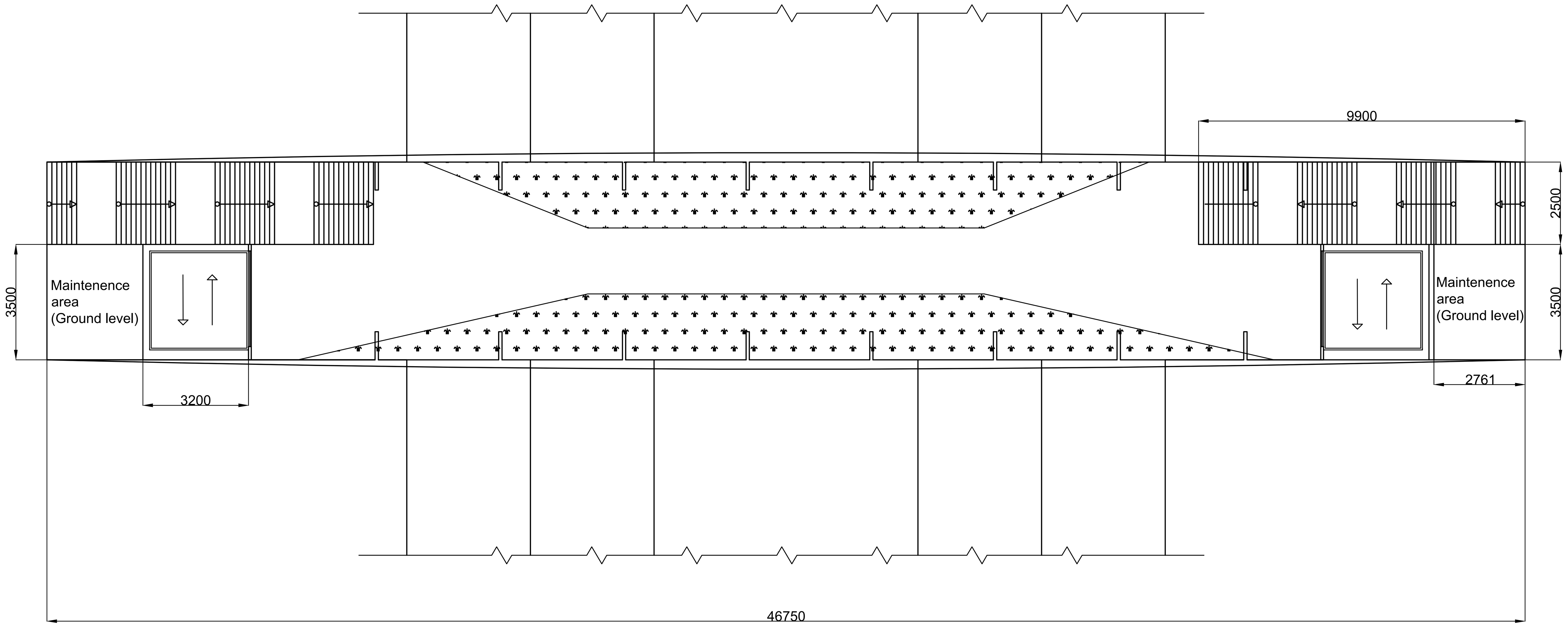
Facade

1:100



Layout

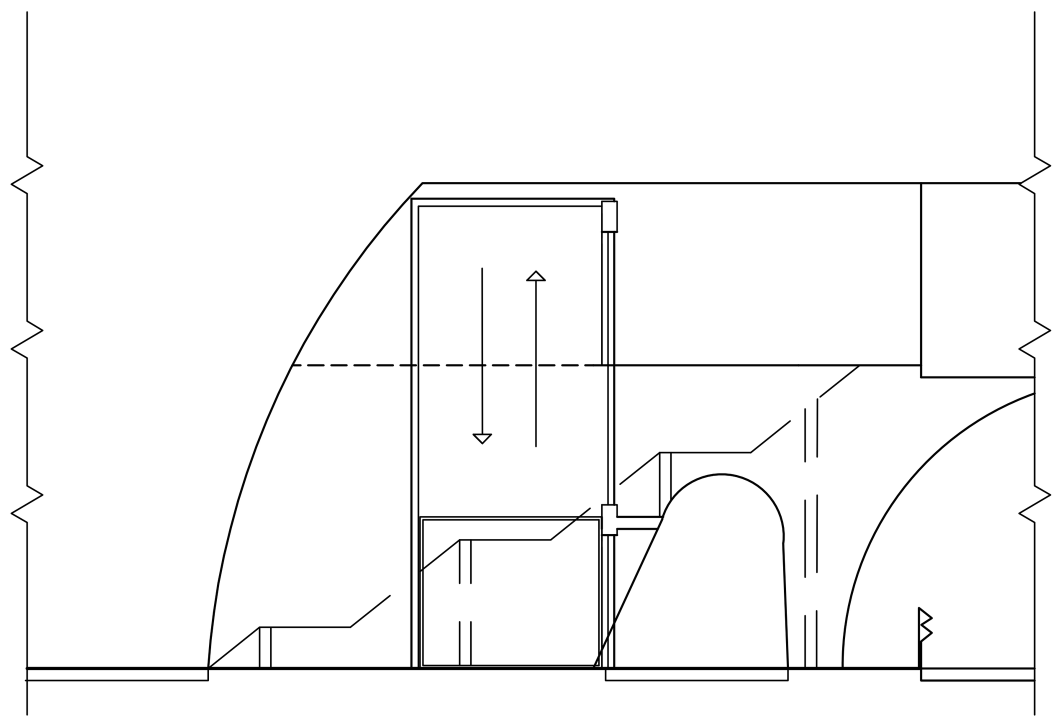
1:100



Elevator and stairs

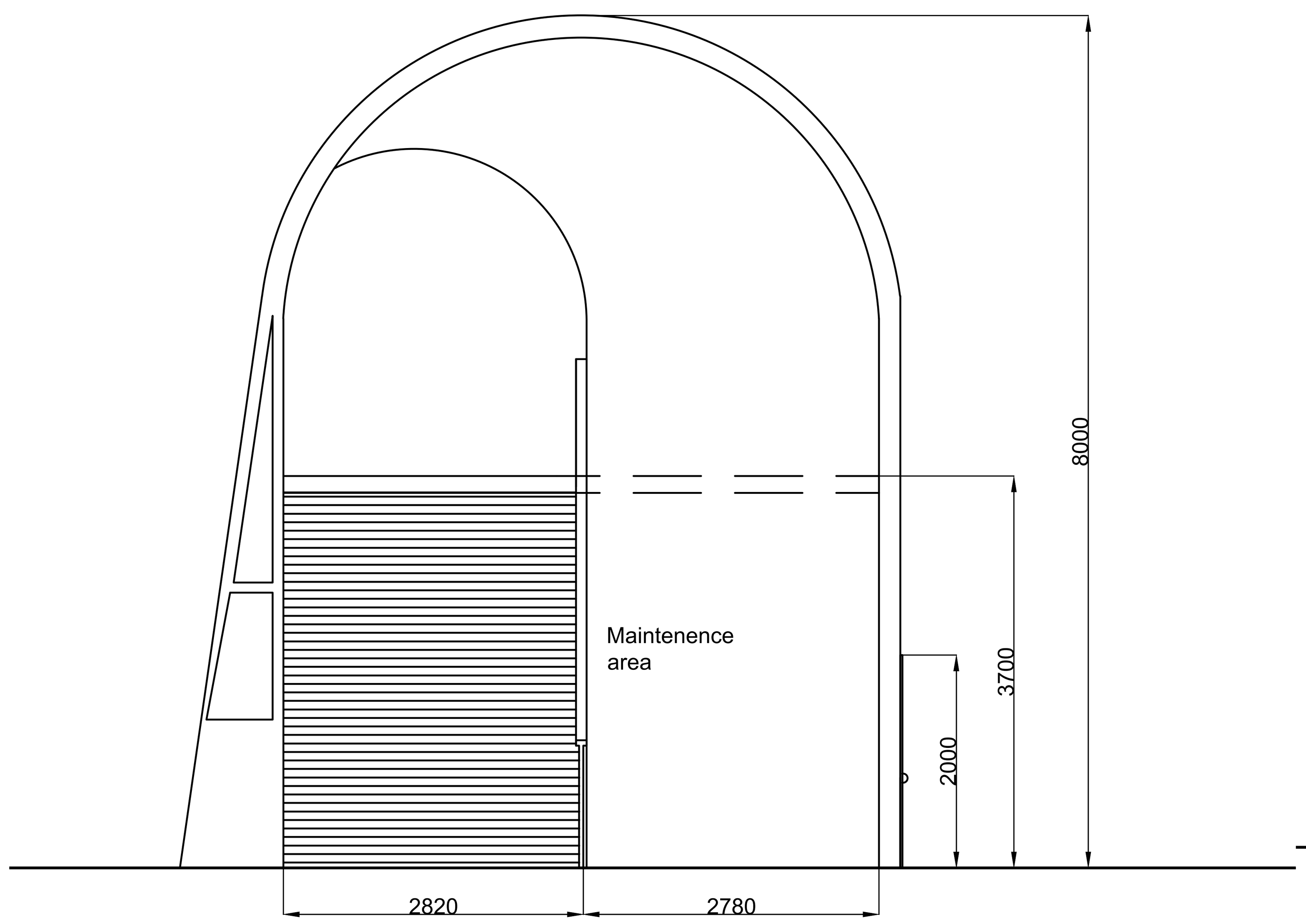
(Railings are not shown)

1:100



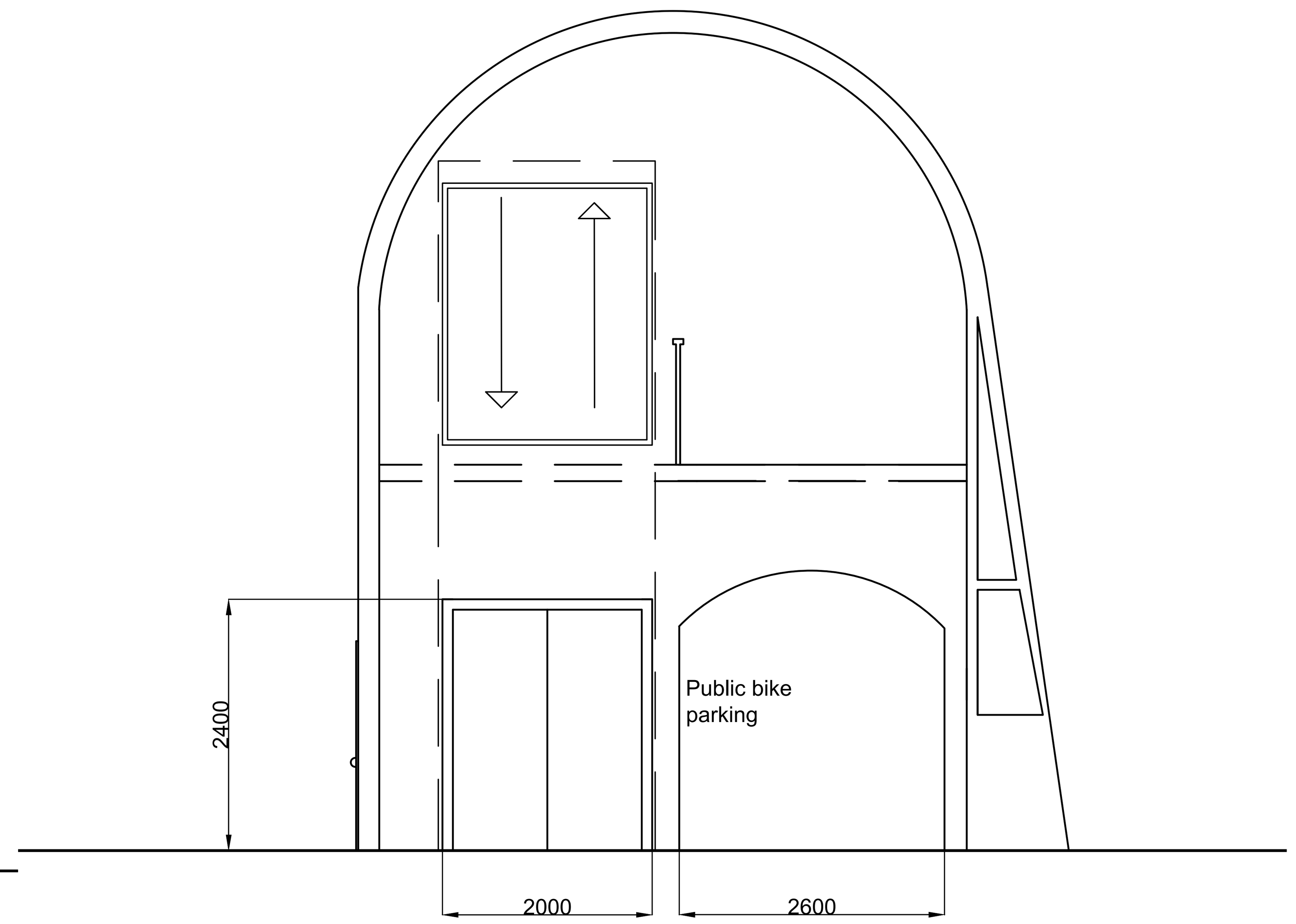
1 - 1

1:50



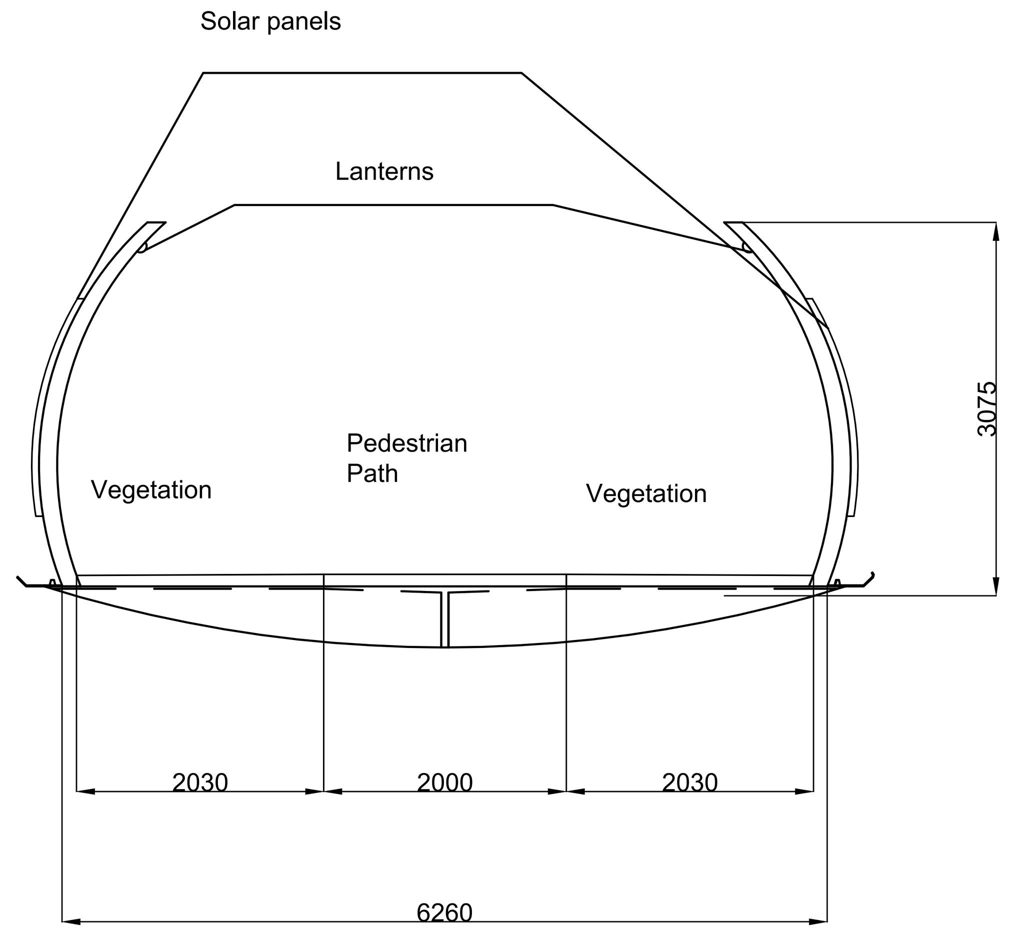
2 - 2

1:50



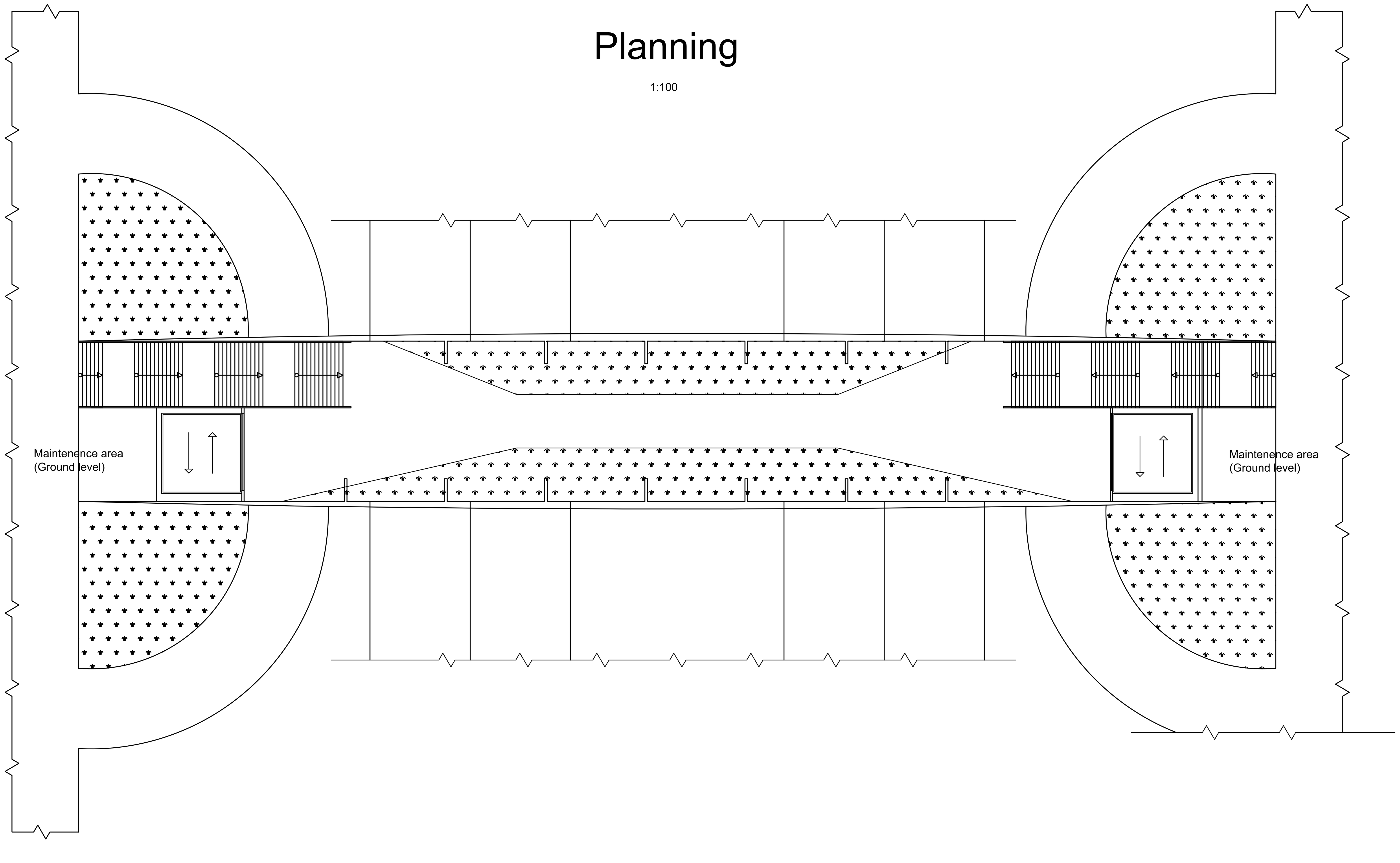
3 - 3

1:50



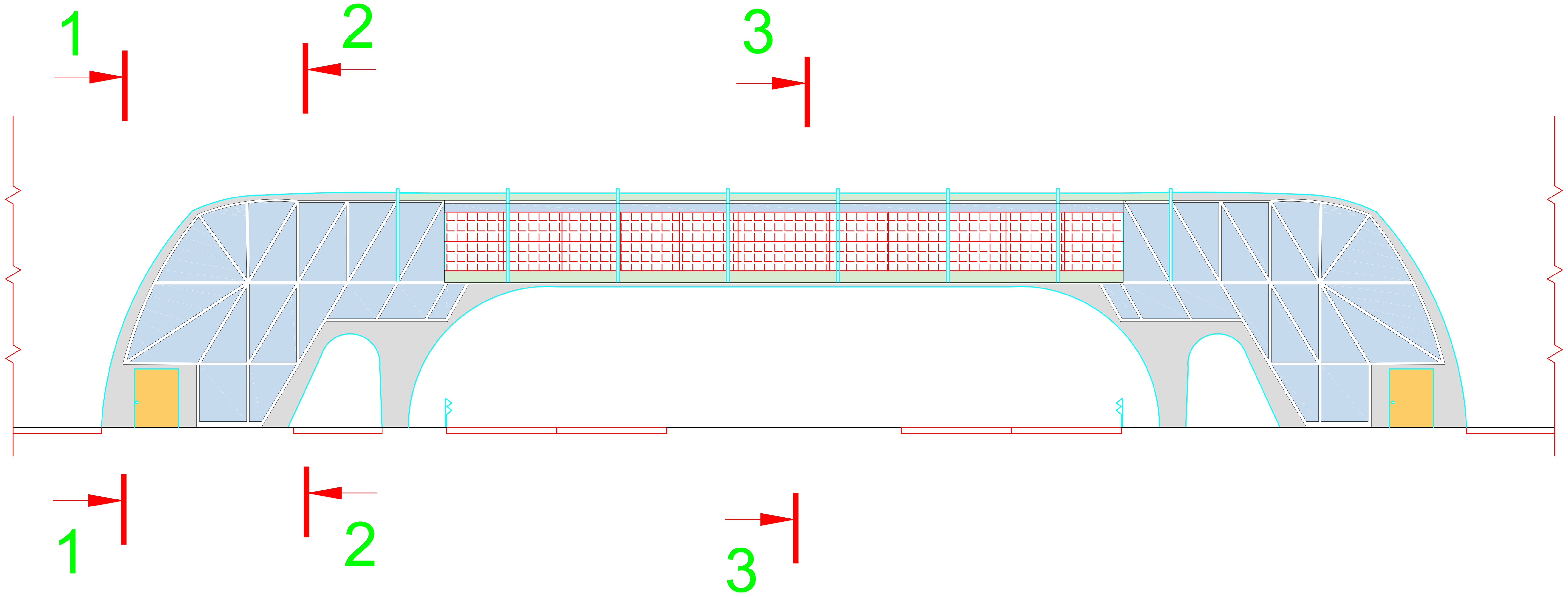
Planning

1:100



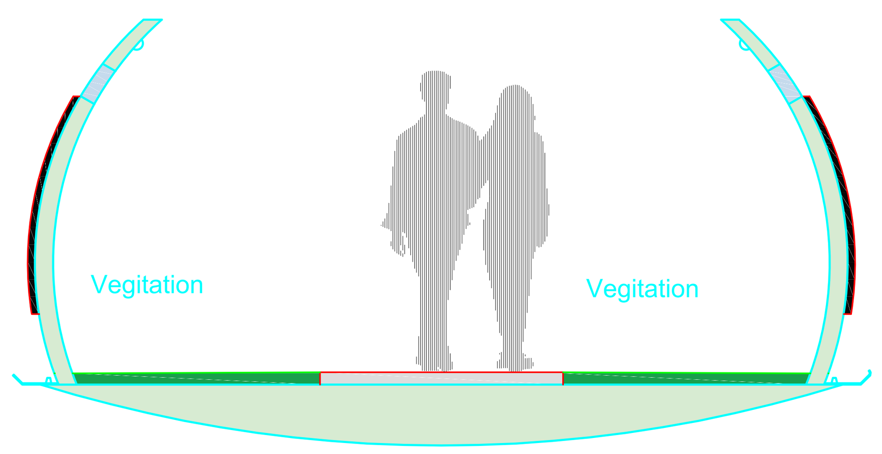
Facade

1:100



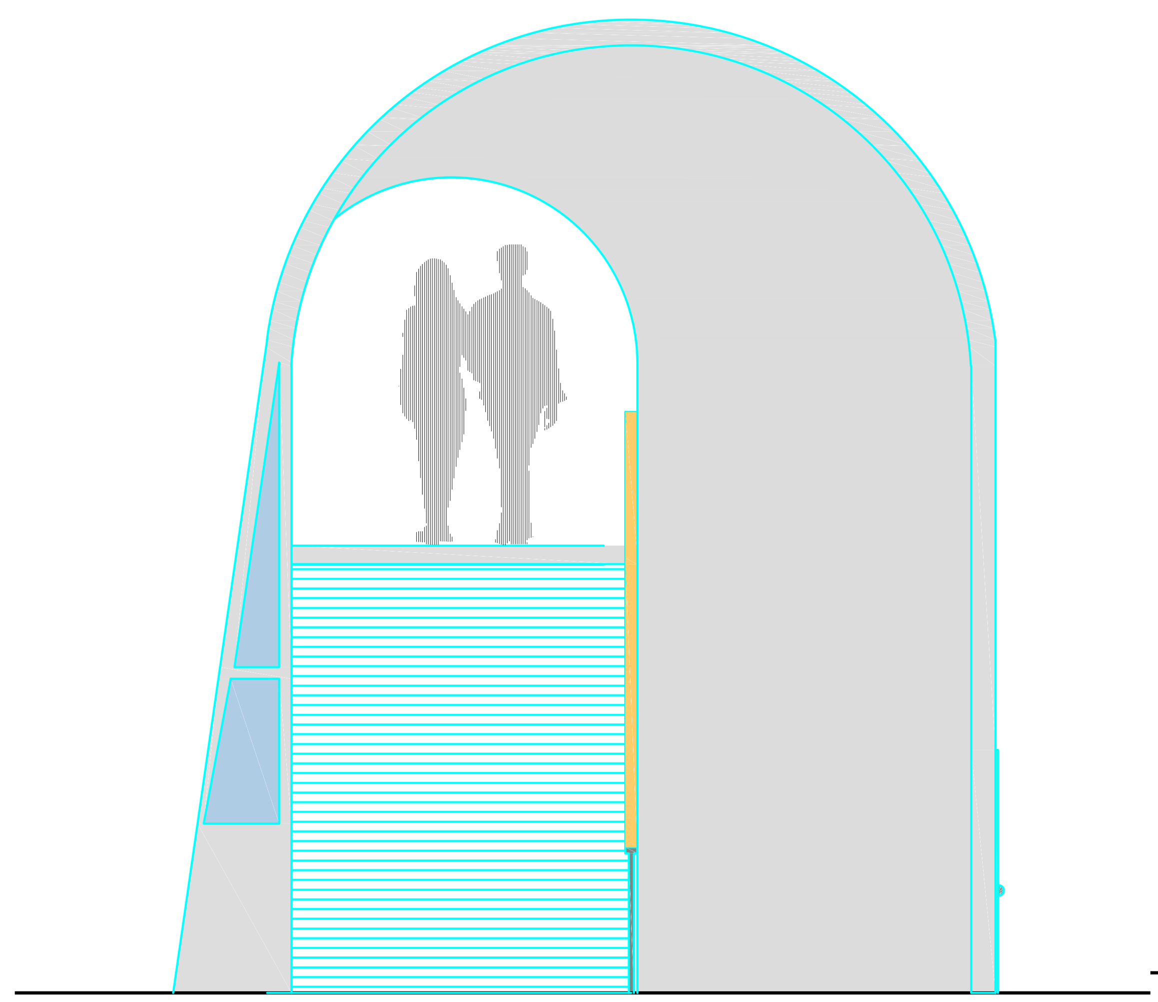
3 - 3

1:50



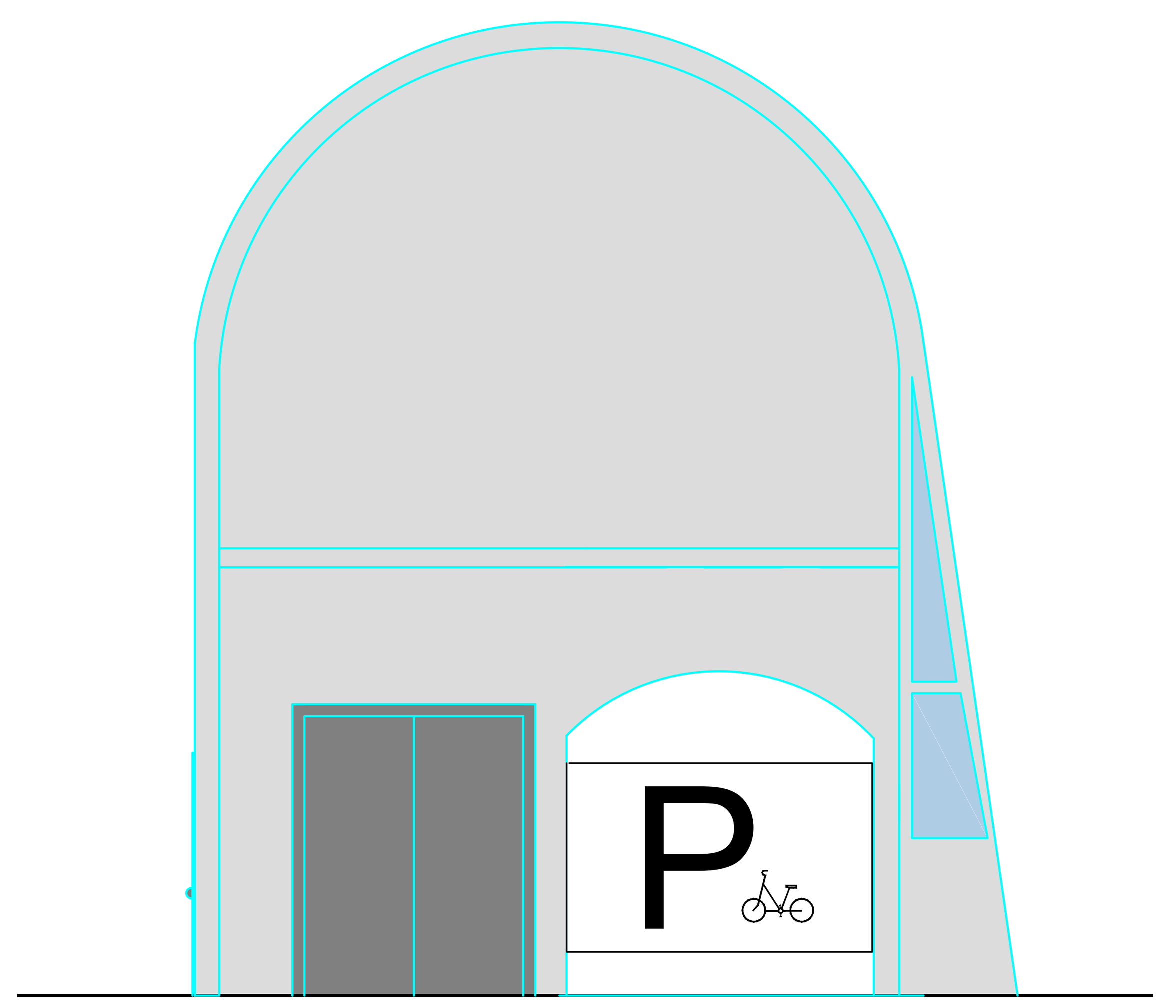
1 - 1

1:50



2 - 2

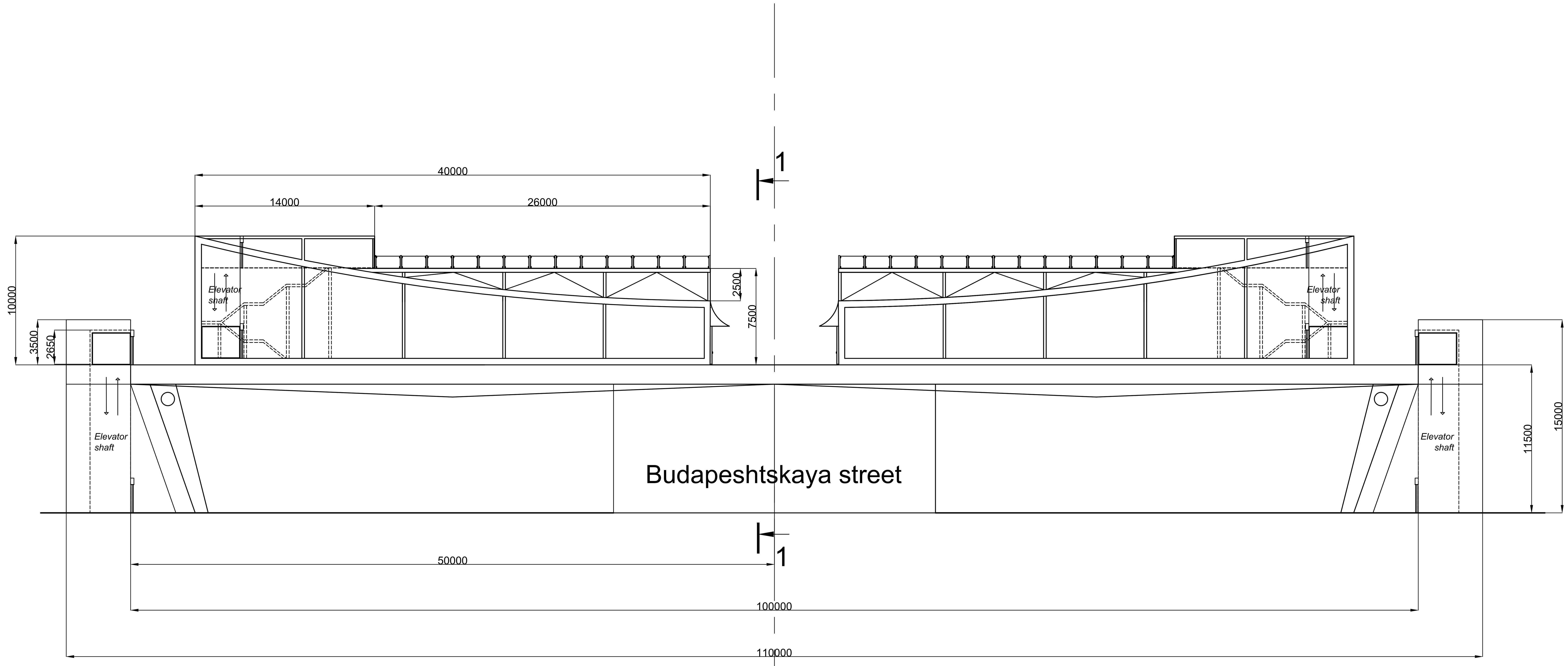
1:50



Facade

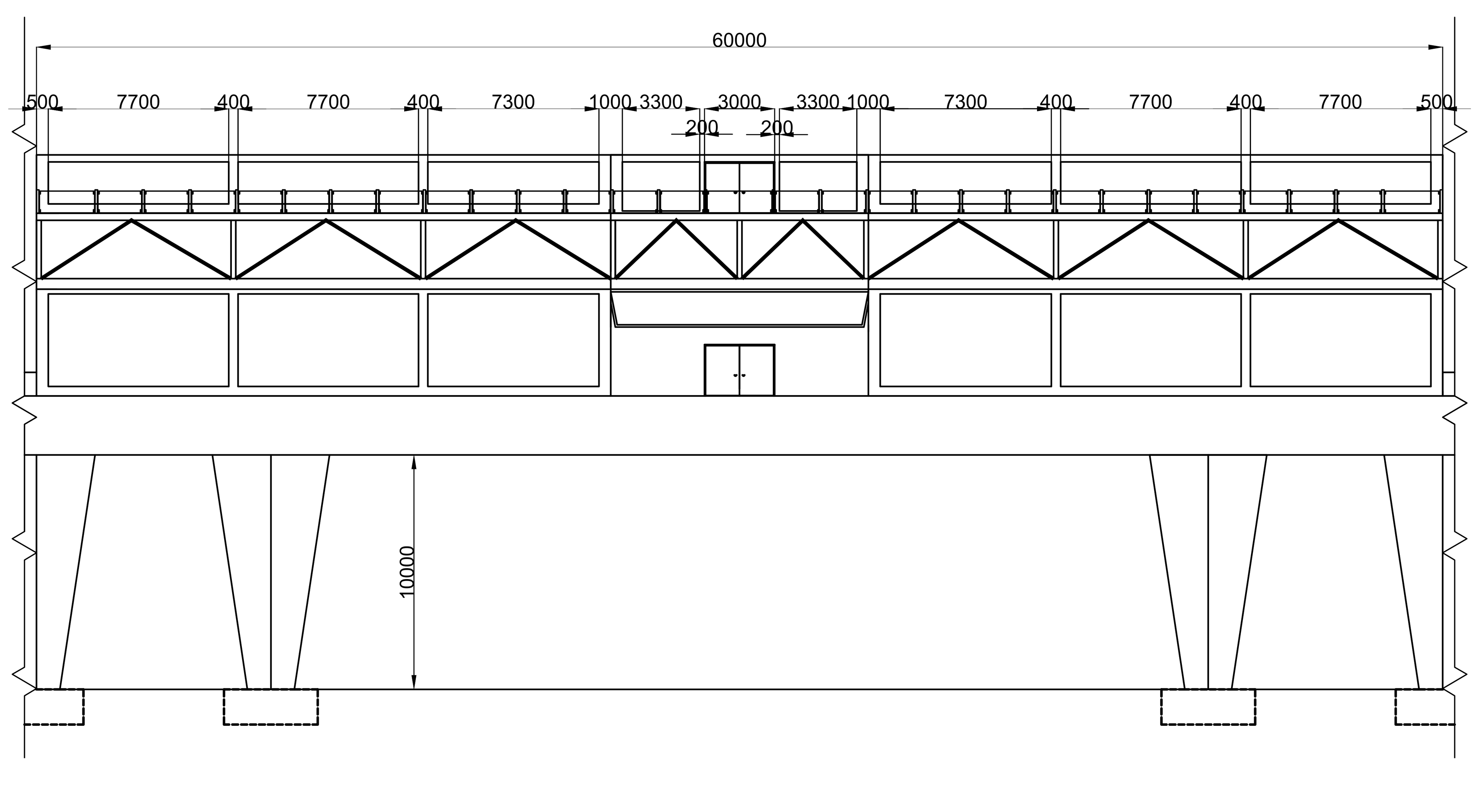
(Outer railings of the overpass, railings of the stairs, lanterns and vegetation are not shown)

1:200



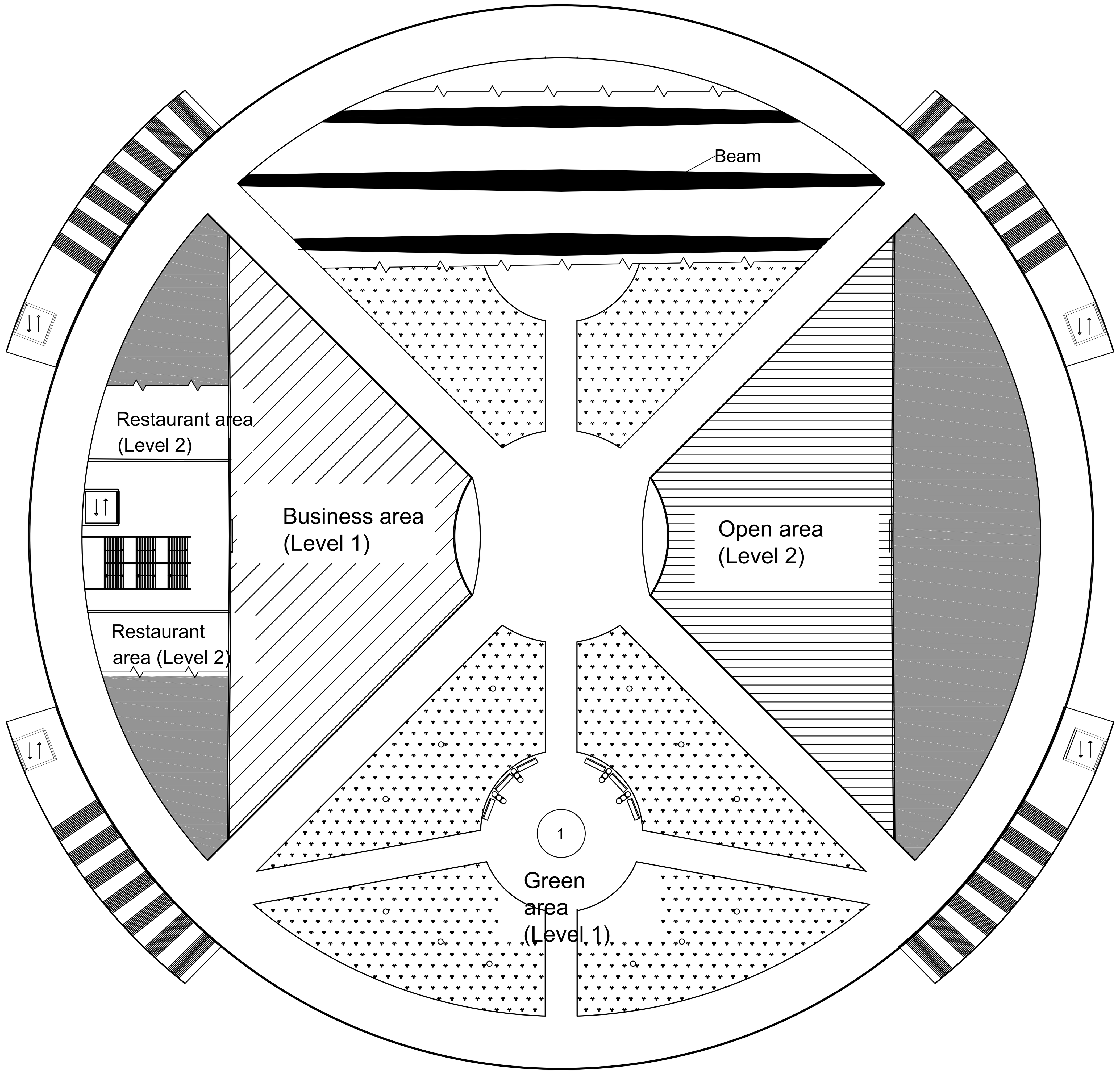
1 - 1

1:200



Planning

1:300



1 - *space reserved for temporary art installations*

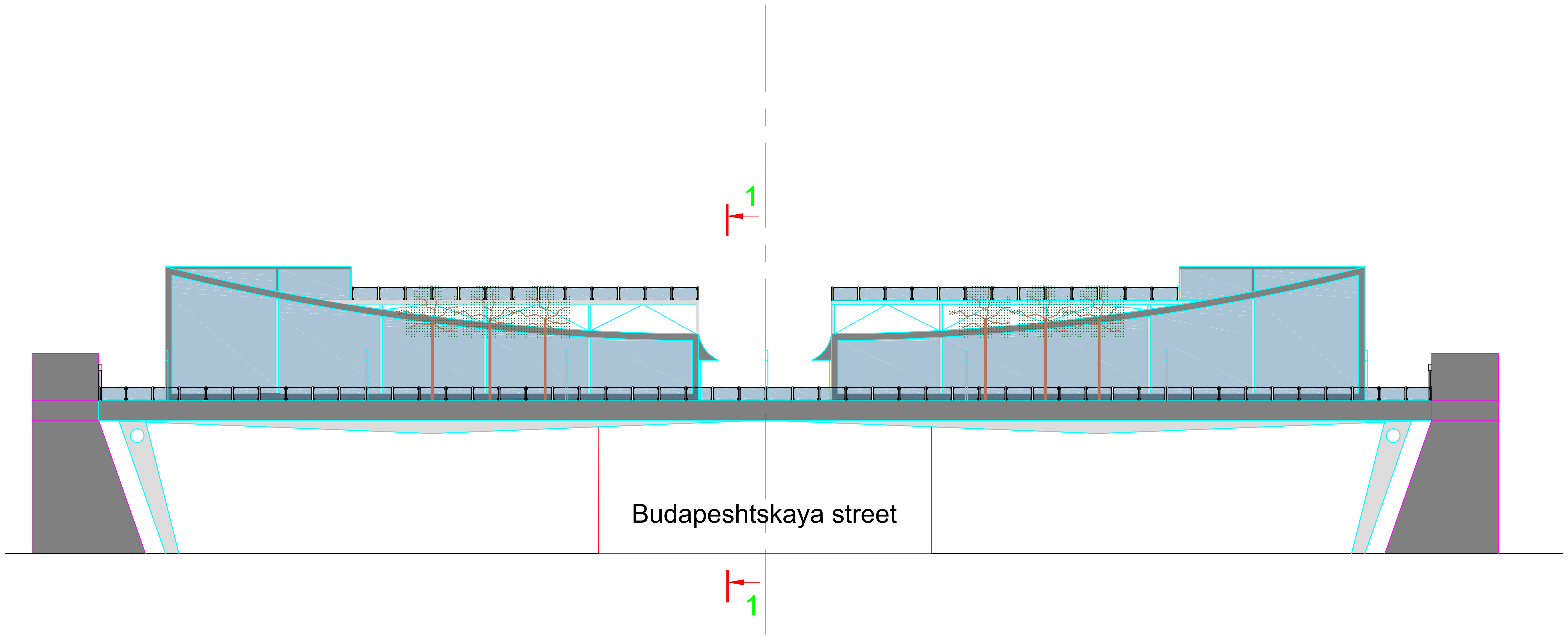
- *garbage bin*

- *bench*

- *trees and smaller vegitation*

Facade

1:200



1 - 1

1:200