Preliminary design of floating bridge for pedestrian usage.

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Abstract

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Title of the thesis

Preliminary design of floating bridge for pedestrian usage.

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Abstract

Taipalsaari municipality is one of the beautiful places near the Lappeenranta, which is more popular to visit during the summertime. As the number of residents increases, this area is developing: the Taipalsaari municipality holds dozens of activities and events, and buildings and various roads are now planned and constructed.

Travel convenience should be improved by connecting two coasts by constructing a bridge, which will externally complement the environment and be stable and affordable. In this case, the most suitable solution, according to requirements, is a floating bridge.

The floating bridge structure consists of several pontoons with anchors, concrete slabs, metal piles, timber decking, timber railing, mooring equipment, and other structural members.

This thesis report illustrates and describes the process of the preliminary design of a floating bridge and the problems and solutions that occurred during the design.

Keywords

Taipalsaari, floating bridge, pontoons, concrete

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1 Introduction

Floating bridges have been built since ancient times on all continents. Due to their unique structures and type of transferring loads, they are considered an efficient and cost-effective solution for traveling across water obstacles with soft soils or deep water. In modern bridge construction, this type of bridge is widely used worldwide, including the USA, Finland, Russia, and many other countries.

Although in some countries floating bridges are better known as temporary structures or as bridges that can be rapidly constructed in case of emergencies, such as natural disasters or military operations, in Finland, many floating bridges are constructed for permanent use and different purposes. Commonly, in Finland, pontoons are made of concrete, the decking and railing are made of timber, and the bridge is anchored according to the water flow.

The thesis's main idea is to design a preliminary design of a floating bridge for pedestrian usage in Taipalsaari municipality over the Pappilanlahti bay. Taipalsaari municipality is one of the beautiful places near the Lappeenranta, which is more popular to visit during the summertime. As the number of residents increases, this area is developing. Therefore, travel convenience should be improved by connecting two coasts by constructing a bridge, which will complement the environment and be stable and affordable. In this case, the most suitable solution, according to requirements, is a floating bridge. Visible parts of the bridge are designed to be made of timber so that the overlook of the bridge is ecologically friendly. There will be concrete and steel used in other structural parts, such as pontoons, joints, anchors, and foundation slabs.

The design was based on several customer requirements:

- the width of the bridge should be two meters;
- the size of a boat way should be not less than 3,5 meters in height and 5 meters in width;
- there should be resting platforms with a spacing of 35 - 50 meters;
- most visual parts of the bridge should be made of timber;
- there should be about 40 places for boats.

The project includes several steps:

- drawing sketches of three types of bridges in ProCreate program (two floating bridges with boat way and one beam bridge);

- comparing these bridges and choosing the best one;
- making a 3D model of a selected bridge in REVIT program;
- making a visualization of the bridge in TwinMotion program (including photos and video);
- designing materials and types of bridge's structural components;
- making a cost-estimation.

It is important to mention that the thesis contains only a preliminary design of the bridge. In the design, the place of construction of the bridge, materials, and type of structure was preliminary selected, which in the final design can be changed. This project does not take into account the actual environmental conditions that will affect the bridge, as this requires research and analysis.

There are not many requirements and regulations for pontoon bridge design unlike other types of bridges because each floating bridge is unique and its design depends on the environment. Thus, at the final stage of the bridge design, it will be necessary to measure the water flow rate, the depth of the water obstacle, and the impact of ice on the pontoon, since all these factors determine the type of pontoon, its characteristics and the type of its anchoring. It is also necessary to study the soil and, based on the results of the analysis, select suitable metal piles and concrete slabs as a foundation.

A floating bridge consists of five main parts: two approaches, two semi-floating approaches, and a floating draw. Most parts of a floating bridge are supported by pontoons, which can be made of a variety of materials and can have different shapes, structures, and joints. (Telov & Kanukov 1978, 5)

The process of designing a floating bridge is not the simplest one. It requires dozens of calculations, research, and analyses. Moreover, if a bridge is constructed for permanent use, a designer should consider ice loads and their impact on pontoons.

2 Floating bridges

2.1 General information about floating bridges

The floating bridge usually consists of the river, shore, and transition parts and has transverse and longitudinal anchoring. There are two approaches, two semi-floating approaches and a floating draw. Parts of the bridge differ not only in purpose but in the methods by which they are designed and calculated.

The river part is a floating bridge that covers the deep-water part of the water barrier. The span structure of the river part is installed on floating supports. If there is shipping traffic, the river part should have a removal section that opens the ship's passage. Usually, this section is removed manually to reduce the cost of the bridge. The river part floats and sinks depending on the presence of a temporary moving load on it or when the water level fluctuates. This feature allows designing boat docks directly on the bridge, significantly saving space and reducing spending.

In Finnish practice, floating bridges sometimes have a boat way in the structure instead of a removal part. One of the good examples is a Kailon kävelysilta in Naantali, Finland. This pedestrian floating bridge was an example of the development of this project of a floating bridge in Taipalsaari. This method of boat passage construction usually involves the design of arches or additional structures.

Figure 1 Kailon kävelysilta in Naantali, Finland.

The shore parts of the bridge are trestles on rigid supports, constructed in the area where the water depth is insufficient for the operation of floating supports and over the low bank. Since the bridge is designed for pedestrians and cyclists, i.e., for lightweight loads, in this project, the shore part is designed using a simple concrete slab. There is already a similar concrete slab at the location of the pier, which a floating bridge in the future will replace. If the concrete slab satisfies the design requirements, it can be reused in this project, reducing the costs.

The transition parts of the bridge are oscillating spans that provide a smooth transition from the shore spans to the river part that is settling under a temporary load. Both floating bridges and ferry crossings always need transitional spans if the water level changes. In this project, the boat passage will be implemented in the transition part of the bridge. This solution will reduce the slope and improve convenience for pedestrians and cyclists. (Telov & Kanukov 1978, 5)

All bridges are required to be fixed in place by an anchoring system. The anchoring system has to prevent the bridge from moving in two directions: longitudinal and perpendicular. Transverse *anchoring* of the bridge keeps the bridge from being swept away by the force of the water current or transverse wind pressure. *Longitudinal anchoring* of the ends of the river section by ropes prevents it from shifting to one of the banks during longitudinal winds.

In modern floating bridge construction, this type of bridge is usually made of a combination of materials, such as concrete, wood, steel, and polymers. The material of a bridge is usually designed according to the environment, design, and customer requirements.

One of the greatest examples of floating bridges is the Brookfield floating bridge, located in Vermont, the USA. The bridge was originally constructed in 1820 and has been restructured seven times since that year. During the bridge's history, several materials were used in its structure. For instance, in 1936, the bridge was built with old whiskey barrels used as floating supports. However, because the Brookfield floating bridge has been used for vehicular traffic, the loads on the bridge were much greater than on a pedestrian one. The design solutions of past times could not cope with the actual loads, and as a result, deformations on the bridge became unacceptable, and after a while, it was flooded with water. (Olund & Fitch 2015, 1)

Figure 2 Vermont floating bridge.

A new preliminary design of the bridge was created in 2015. At the 32nd Annual International Bridge Conference, the Brookfield floating bridge designers presented an innovative material for the construction of floating bridges. The current version of the bridge has a combination of FRP, timber, steel, and concrete. The use of FRP in floating bridge construction was innovative, as in common, pontoons are usually made of concrete.

FRP (Fiber Reinforced Polymer) is a composite material that is made by a combination of polymer and fiber reinforcement. As FRP is a composite material, it has an anisotropic structure, meaning its properties differ in a volume of a material. As stated earlier, this material was innovative in the industry of pontoon design. Therefore, it was necessary to study the properties of pontoons made of FRP and compare them with the already known properties of the concrete pontoon. (Hamakareem 2011)

According to the research in a preliminary design of the Brookfield floating bridge, FRP has many common advantages and disadvantages compared to concrete. The main advantages of FRP over concrete in the manufacture of pontoons are::

- Higher ratio of strength to density
- Corrosion resistance (with no additives)
- Thermal properties (with no additives)
- Due to the unique structure of FRP and its density, pontoons made of this material, compared to other pontons with the same volume, can withstand more

load, which means that this type of pontoon is suitable for shallow depth. (Olund & Fitch 2015, 3)

2.2 Advantages and disadvantages

Pontoon bridges have plenty of advantages over other types of bridges and crossings. Firstly, the design of a floating bridge and its flooding speed practically does not depend on water depth or the nature of the river bed soils, while these factors almost entirely determine the complexity of a rigid-supported bridge, methods, and terms of its erection. For this reason, this type of bridge is commonly used during military operations.

Secondly, it becomes easier to develop standard floating bridge designs, which may differ only in the size of bridge parts and types of anchoring. Finally, the development of a typical project requires minimum costs. Pontoon bridge assembly and alignment consists of performing a limited set of jobs, which can be performed by low-skilled labor without sophisticated bridge construction equipment.

However, there are also plenty of disadvantages, such as the need for an operating crew to monitor the condition of fixings and connections of the bridge, opening the ship's passage, draining and repairing floating supports, and periodic inspection and tightening of bolt fasteners.

There are difficulties in designing floating bridges on rivers with water flow speeds above 2-2.5 m/s. Significant deformation of the floating bridge under load reduces the speed of vehicles by a factor of two compared to bridges on rigid supports.

In addition, there are several problems with the year-round use of the bridge. Pontoon bridges are usually demolished by ice, which cannot be passed over the small spans of the bridge. However, there are ways of solving this problem in case of weak ice drift.

2.3 Floating bridge systems

The systems of the floating bridge are determined by the design of its river part. The river part has three main systems: split, hinged, and non-split. Their main difference is in how the bridge's floating supports are connected along the length of the bridge. For each of these systems, there is its special calculation methodology. (Telov & Kanukov 1978, 13)

In this project, the river part of the bridge has a split system, which consists of individual floating supports connected by freely supported or hinged transitional spans. This system significantly simplifies calculations and reduces the number of checks and investigations.

The calculation of the sectioned system is simple because it is statically determinable. Transition spans are calculated according to the girder scheme on two supports, which uses typical span structures without strength calculations. Calculation checks are required only for stability, buoyancy, and strength of supports tested as a separately floating vessel loaded with support reactions and temporary load.

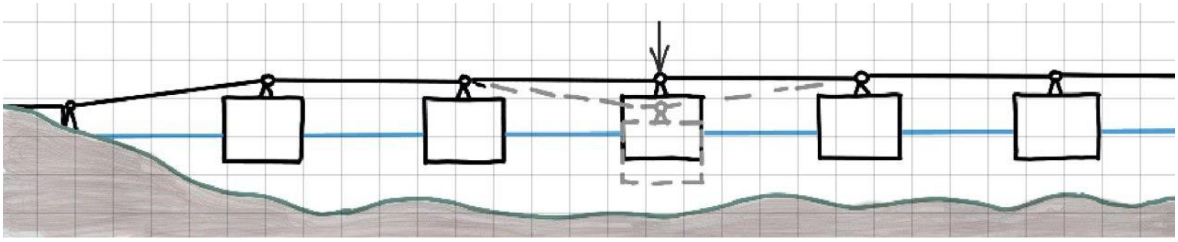


Figure 3 Structural type of the floating bridge.

2.4 Anchoring systems

Since the concept of the floating bridge is based on the natural law of water buoyancy to maintain loads, and there are no foundations in a river part, it is necessary to design and construct an anchoring system to keep the bridge stable in both transverse and longitudinal directions. The most standard anchoring system comprises a framework of mooring lines and anchors.

In the design of any anchoring system, several factors influence the type of anchors, including:

- water flow velocity
- water depth in the reservoir
- bottom conditions of the reservoir
- soil conditions. (William 1988, 107)

There are various types of anchoring systems exist. Each system is suitable for different cases, depending on the soil conditions and water depth. For instance, in the most famous project of a floating bridge in Washington State, there were four types of anchors used:

- Type A anchor was designed for the worst conditions: incredibly soft soils and deep water. They are manufactured from reinforced concrete and include tubes for the water jet. Each anchor weighs up to 86 tons. (Lwin 2000, 6)

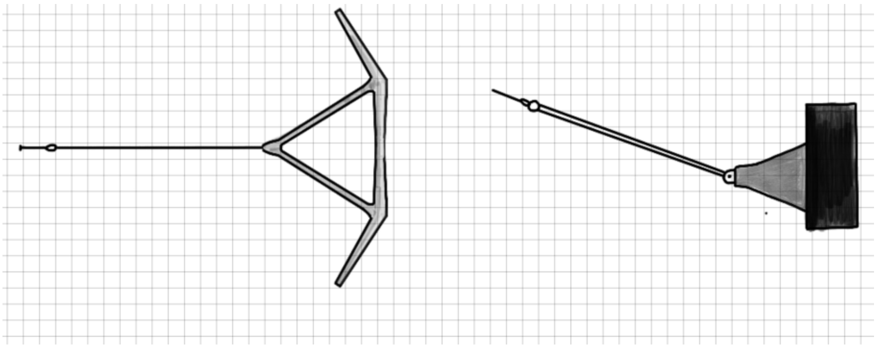


Figure 4 Type A anchors

- Type B anchor was designed for use in better conditions with rigid bottom and relatively small depth. This type consists of two steel H-piles hammered to a specific depth. (Lwin 2000, 7)

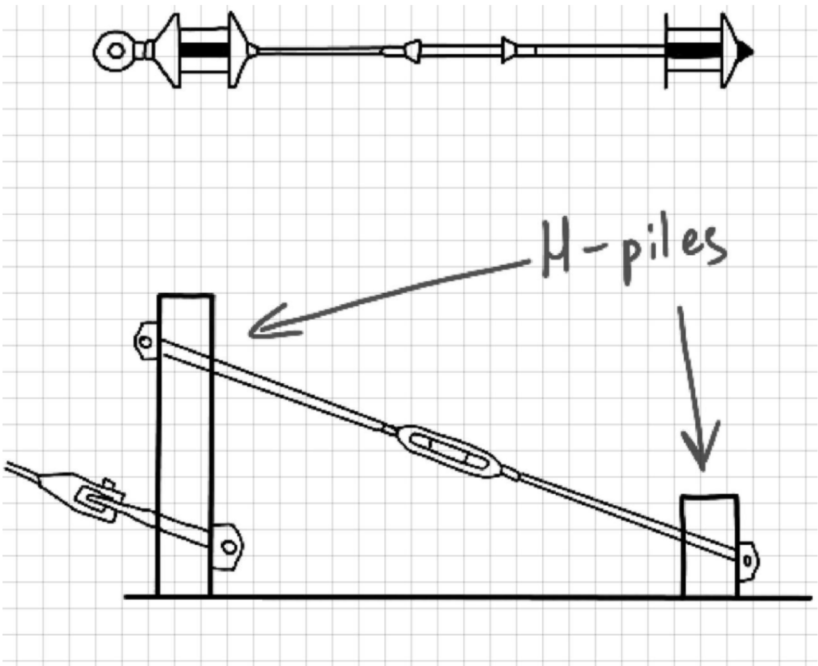


Figure 5 Type B anchors

- Type C anchor was designed for places with deep water and hard bottom. These anchors are made of reinforced concrete in the form of a box with cells and an open top. The boxes are placed and then filled with gravel to the desired weight. (Lwin 2000, 8)

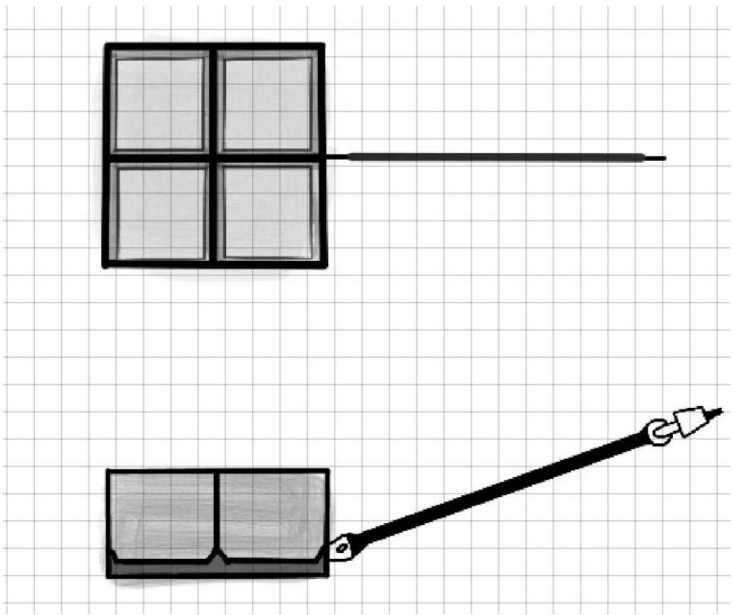


Figure 6 Type C anchors

- Type D was designed for places with deep and shallow water and relatively hard bottom. This type is preferable to the B and C anchors because of its simple construction, easy casting, and fast installation. They consist of massive reinforced concrete slabs. Each slab weighs approximately 270 tons. The first slab is lowered into position, followed by the subsequent ones. The total amount of plates is defined by the designed capacity of the anchors. (Lwin 2000, 8)

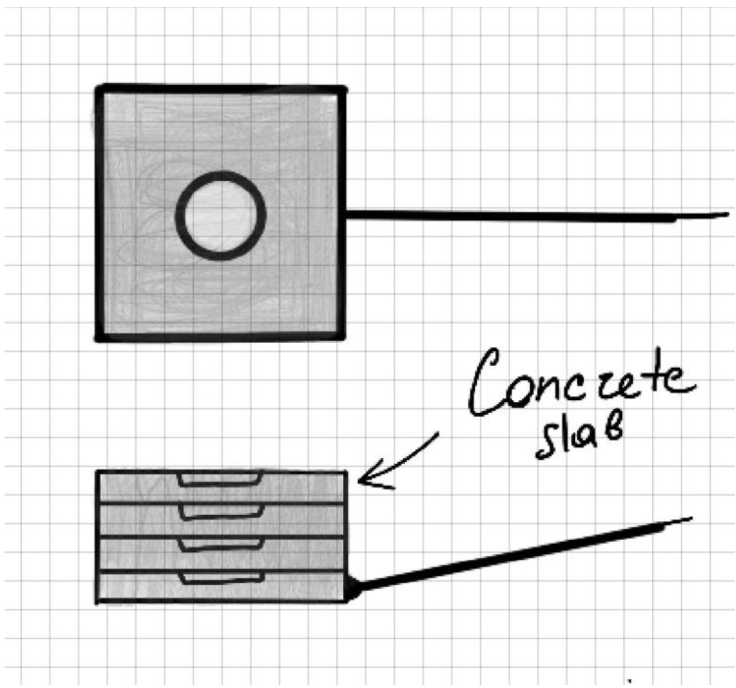


Figure 7 Type D anchors

Overall, an anchoring system is necessary for the design of a floating bridge. The system must have sufficient capacity to resist longitudinal and transverse forces arising from winds and waves. There are various anchoring systems, and the system should be designed for a particular project according to environmental conditions.

Type C and D anchors are the most suitable anchoring systems for the designed floating bridge. The depth is relatively shallow at the preliminary location of the designed bridge. The water flow and wind create a low impact on the bridge, so the required capacity of anchors is low.

2.5 Pontoons

Pontoons (also known as floats) are floating objects with hollow structures supporting heavy loads on water pontoon bridges. The primary purpose of floating supports is to bear and transfer the weight of the span and vehicles passing on the bridge to the water or transported on the ferry. In addition, the support must distribute this pressure over as large an area of the water surface as possible with minimum weight; otherwise, high drafts will hinder the use of crossings on rivers with shallow water depths near the coast.

The floating support is usually a hollow rigid structure, which acts as a beam on a continuous elastic base, loaded by the concentrated pressures from the purlins of the span (P) and its weight (q). These forces cause the overall bending of the pontoon structure.

In a free-floating pontoon, i.e., before a span structure is installed on it, there is no bending of the hull since the pontoon's weight can be balanced by the reaction of water equally distributed along the length of the floating support. Therefore, the strength check of the floating support is usually composed of separate calculations for total and local bending, followed by the summation of the stresses in the elements of the set, where necessary.

In the calculations of the total bending, only the pressure from the span and the water counterpressure (q) balancing should be considered. In order to simplify the calculations, the water counterpressure diagram is usually assumed to be rectangular.

In world practice, pontoons are made from various materials depending on the conditions and design requirements. Concrete is the most commonly used material in pontoon manufacture. The usual width of a concrete pontoon ranges between 2 and 10 meters. A manufacturer can make other geometrical characteristics such as length, angle, and configurations according to the customer preferences and requirements. The manufacture and construction of the pontoons must correspond to the most refined techniques currently used in structural and marine engineering.

Although concrete is the primary material in pontoon manufacture, several materials are also used. For example, the fiber reinforced polymer (FRP) is an innovative material with better characteristics for shallow depth places. The material and type of pontoons are usually designed according to environmental conditions.

The best solution of a pontoon for this project was a concrete pontoon with preliminary dimensions of 10x2 meters. According to the manufacturers of pontoons in Finland and the nearest countries, the concrete pontoon may be considered the most straightforward, cheapest, and well-known solution. Furthermore, concrete has been used in the production of pontoons for many years. Thus, all characteristics, behavior, and influences on concrete have already been studied and described.

3 Design process of a floating bridge

3.1 Initial data

The first step in designing a floating bridge is to make a site plan and select a location for the bridge. Then, based on the topographic map of the area provided by the technical director of the Taipalsaari municipality in the DWG format (AutoCAD), a simplified plan of the area was made and selected the place of the floating bridge.

In order to reduce the length of a bridge and minimize the influence of water flow, it is necessary to design the bridge perpendicular to the water flow. Moreover, the bridge's length affects its geometric characteristics and, consequently, the amount of work and materials. Therefore, the shorter the bridge, the cheaper it is.

After analyzing the topography, it was agreed to demolish the existing pier and build a floating bridge. Some parts of the pier could be reused in the construction of the bridge, making it much cheaper. For example, dividing beams can be used to construct the bridge, which is necessary for parking spaces for boats. A concrete slab can also be used as a foundation on one of the banks, but the floating supports will not be suitable for the bridge as their characteristics are not adequate for the design loads of the bridge.

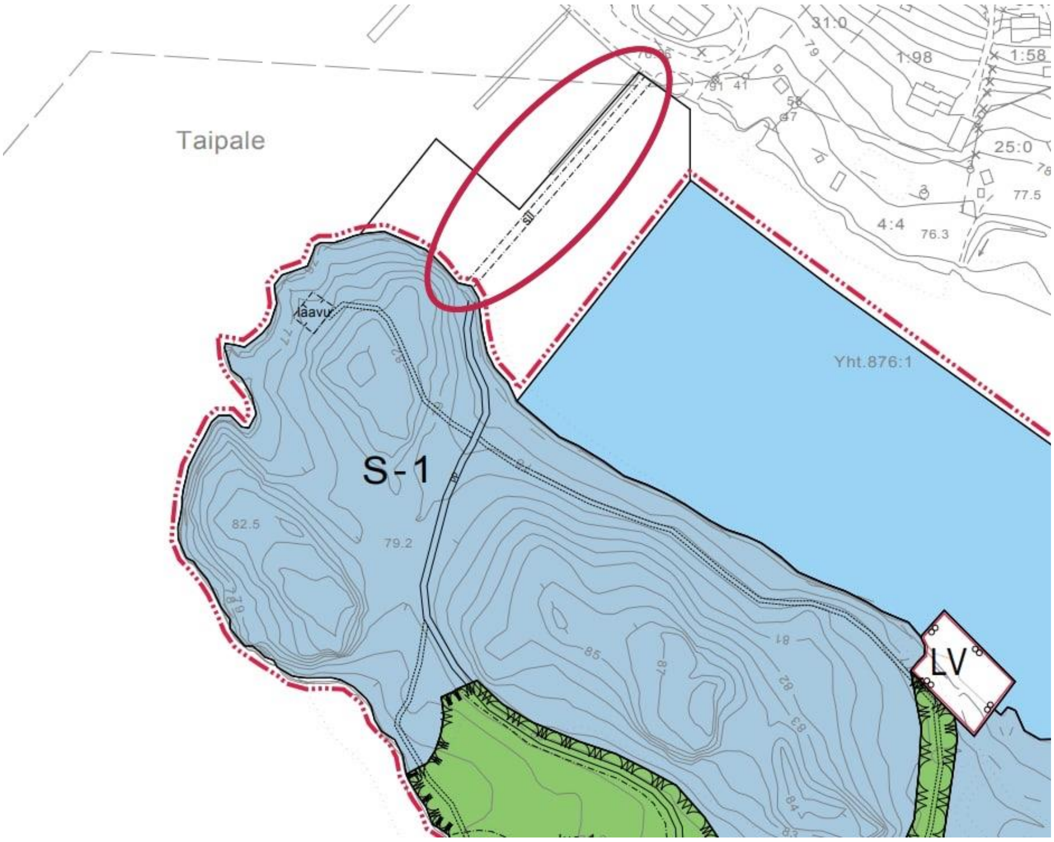


Figure 8 Place of the bridge

3.2 Sketches of three bridges in ProCreate

Once the place for the bridge construction is chosen, it is possible to proceed to the selection of the type of bridge. For a better representation of bridge types and designs for the customer, three types of bridges have been suggested and drawn. The main types were floating bridges with a different passage arrangement for boats; an alternative option was the beam bridge. All three types of bridges are affordable options that suit customer requirements.

The first option was initially considered the main; this is a floating bridge with a boat way in the middle. The river part of the bridge has a split system with concrete pontoons. On both sides, there are concrete slabs as foundations. The decking and railing are designed to be made of timber.

However, the design of this type turned out to be irrational because, to provide the required passage dimensions for boats and maintain an angle of inclination less than 12 degrees, the design of the arch will take up too much space.

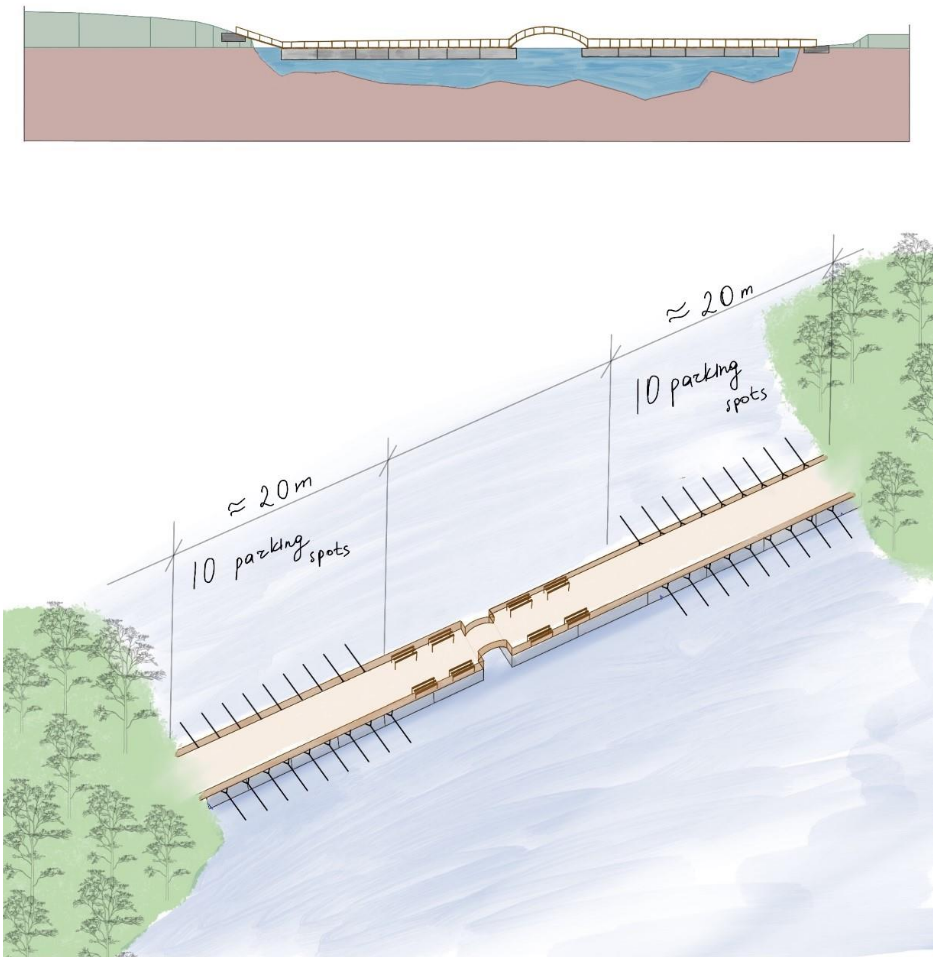
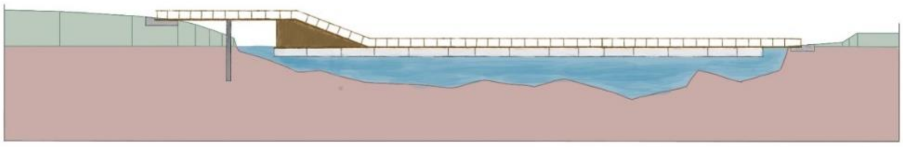


Figure 9 Sketch of a floating bridge with a boat way in the middle and its site section

The second option was a floating bridge with a boat way near the coast. In this case, all connections between members are also pinned, as in the previous bridge, and a river part also has a split system; however, there is a difference in structure, as it is necessary to consider requirements, such as dimensions of boat way and maximum angle of inclination (should be less than 12○), therefore, the structure has additional metal piles.

The design of the boat passage by the coast saved space on the bridge, simplified the design, and satisfied all requirements. In addition, since the floating bridge is designed for lightweight movement, metal piles can be used without concrete filling.



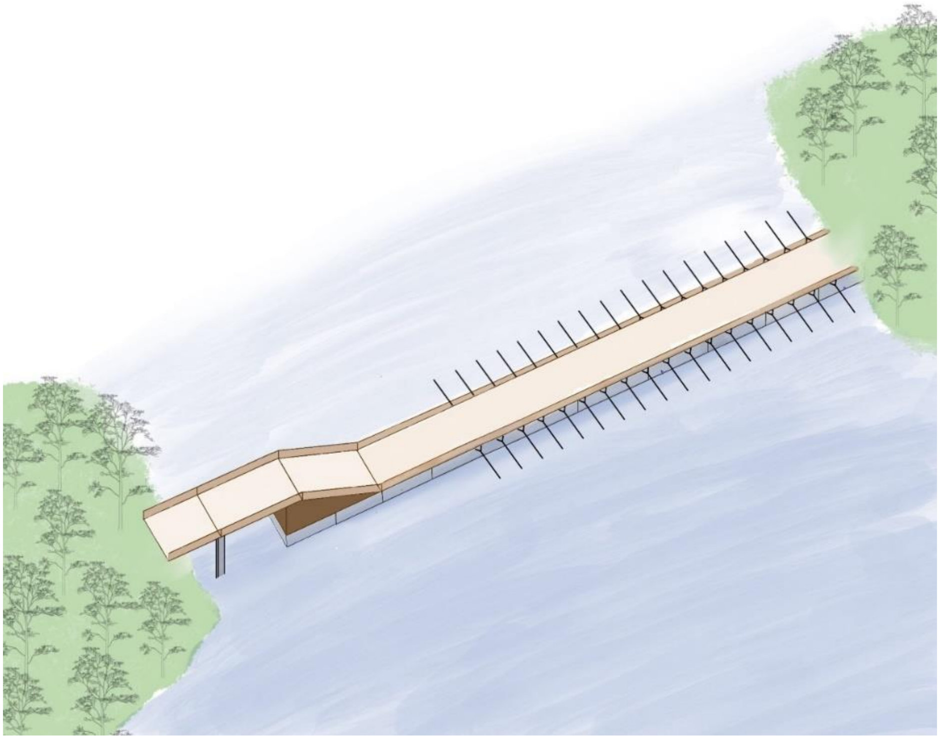


Figure 10 Sketch of a floating bridge with a boat way near the coast and its site section

An alternative version of a floating bridge was a beam bridge. This type of bridge has the simplest structure; therefore, it is the most common type among others. The beam transmits vertical forces by bending. As a result of bending, the upper part of a beam is subjected to compression and the lower part to tension. The beam is supported on both sides by vertical supports subjected to vertical compression, transferring the load to the foundation. Overall, the structure illustrates a simply supported beam model; therefore, this type is the most common in design and construction.

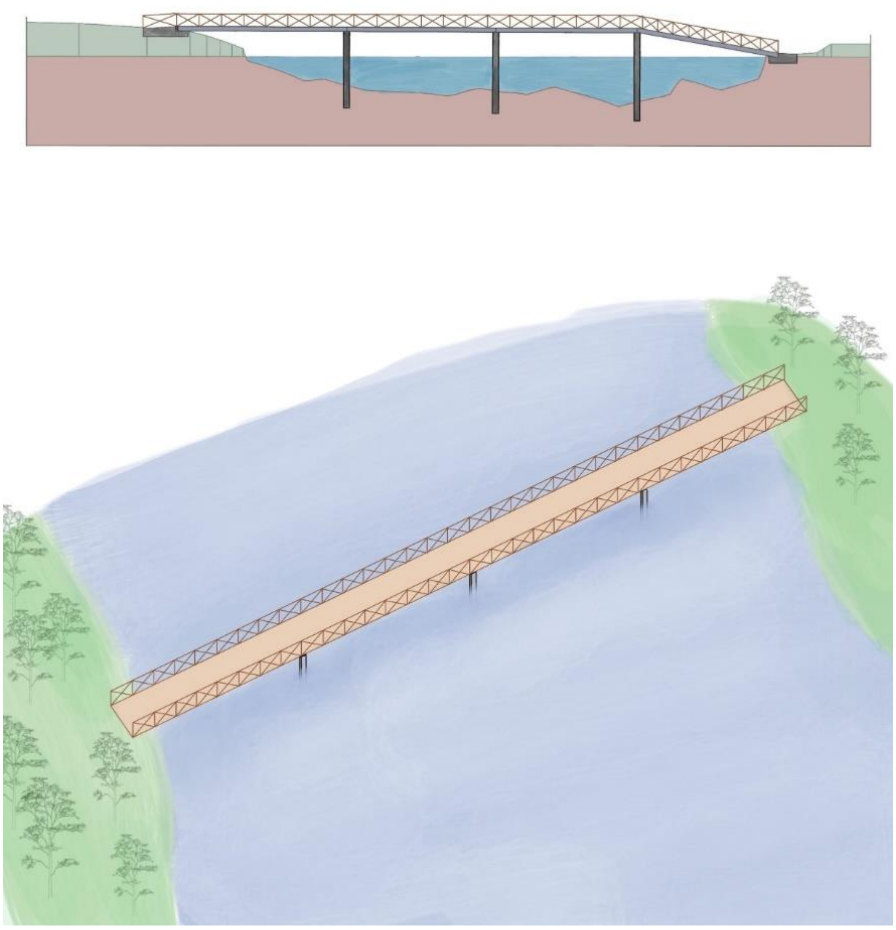


Figure 11 Sketch of a beam bridge and its site section

According to the topography map, one coast is one meter higher than another; therefore, to reduce the inclination angle and make a bridge more convenient for pedestrians and cyclists, it is better to design a boat way near the higher coast. In addition, the beam bridge is unsuitable for the current situation for several reasons. First of all, a beam bridge is a solid construction that can not follow a water level, which means that in order to create parking spaces for boats, it is necessary to design additional constructions. Secondly, although the structure of a bridge is the simplest one, and this type of bridge may be considered an affordable solution, it requires more materials than a floating bridge; thus, the total price is higher.

After a few discussions with a technical director, the floating bridge with a boat way near the higher coast was chosen as the best solution. The next step was to make a 3D model of a bridge and design materials for each structural member.

3.3 Structural design and analyses

The process of pontoon bridge design and research was constantly evolving. As time passed, bridge design progressed from empirical methods to real investigations, dynamic analysis, computer modeling, and using newer and better materials. For example, previously used reinforced concrete was replaced by prestressed concrete, which performs better under loads.

Calculations of the pontoon bridge were always based on determining the impact of various forces, such as live and dead loads. Loads such as the bridge's weight or the projected live load from pedestrians and vehicles are simple enough to calculate or specify; however, supplementary loads significantly affect the bridge design and cannot be fully calculated and foreseen. This is the impact of wind and waves on the designed bridge. The wind causes horizontal, vertical, and torsional loads on the floating bridge.

In the past, the impact of waves and wind on a floating bridge was the hardest to predict. Typically, there was limited long-term climatological data for the designed bridge site, and the interaction of waves and wind with a bridge was not understood well. With the current level of atmospheric science, computer, structural, and marine engineering knowledge, different analyses and tests provide more realistic predictions of winds and waves climatology. A long-term monitoring period of wind data is preferable to design more accurate estimated wind rates and wave conditions. Installing instrumentation at potential bridge sites to collect climatological data as early as possible is recommended for more correct results. (Lwin, M.M. 2000, 9)

Usually, floating support acts as a beam on a continuous elastic foundation, loaded by the concentrated pressures from the purlins of the span (P) and its weight (qp). Combined with the water reaction qw, these forces cause the overall bending of the pontoon structure, which is supported by the longitudinal elements of the frame. (Telov, V.I. & Kanukov, I.M. 1978, 24)

If the pontoon draft t is known, it is possible to calculate the counterpressure q_c using the following formula:

$$q_c = \gamma B(t - t_p)$$

where: $\mathbf{t_p}$ is unaccounted draft from dead load of the floating support;

B is a support width at the waterline;

γ is a water volume weight, which is about 10 kN/m^3 for fresh water.

In the case of taking the water volume weight equal to 10 kN/m^3, draft from a dead load of the floating support equal to 0,1 m. and maximum allowable draught equal to 0,5 m. and the width of floating support equal to 2 meters, it is possible to calculate the counterpressure:

$$q_c = 1 \cdot 2(0{,}5 - 0{,}1) = 0{,}8\frac{kN}{m}$$

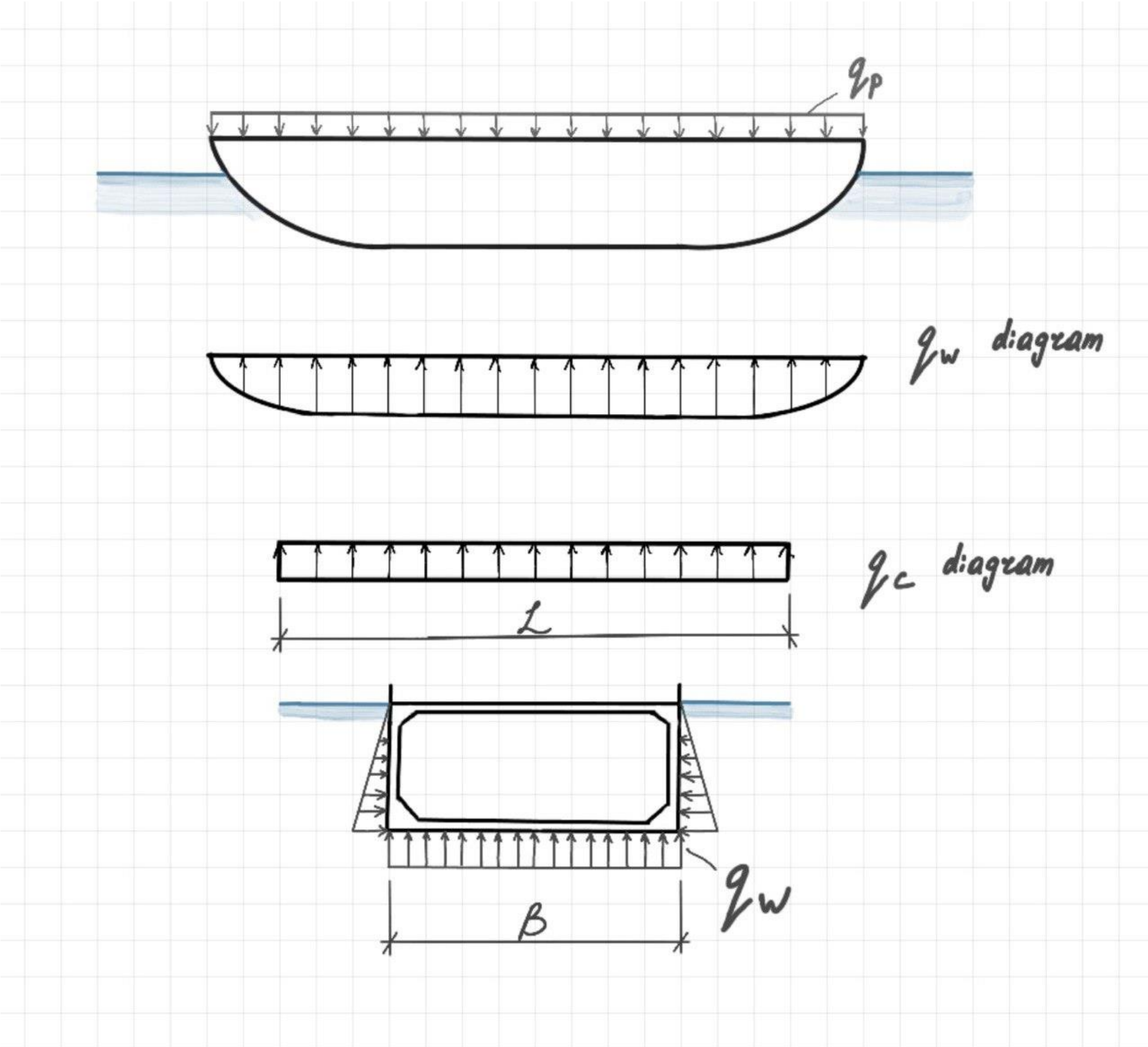


Figure 12 General view of force diagrams acting on the concrete pontoon

4 Bridge model in REVIT and its visualization

4.1 REVIT

Nowadays, various methods and tools are used to design bridges. In this project there was made a 3D model of the bridge in its natural dimensions. The bridge was fully modelled in the Revit program, with a topographic surface created based on the survey data of the area.

It is worth mentioning that the Revit program is not the best in bridge modelling. Many bridge design programs provide more advanced features and tools for various tasks. For example, one of the best programs is Midas Civil. This program is well known for its simple interface with fast processing, various analyses, auto design, load rating, etc. However, as the main task of this project is to make a preliminary design with cost estimation, and since almost all of these programs do not have a trial version for students, it was decided to use the Revit program, which is suitable for 3D modelling without making analyses.

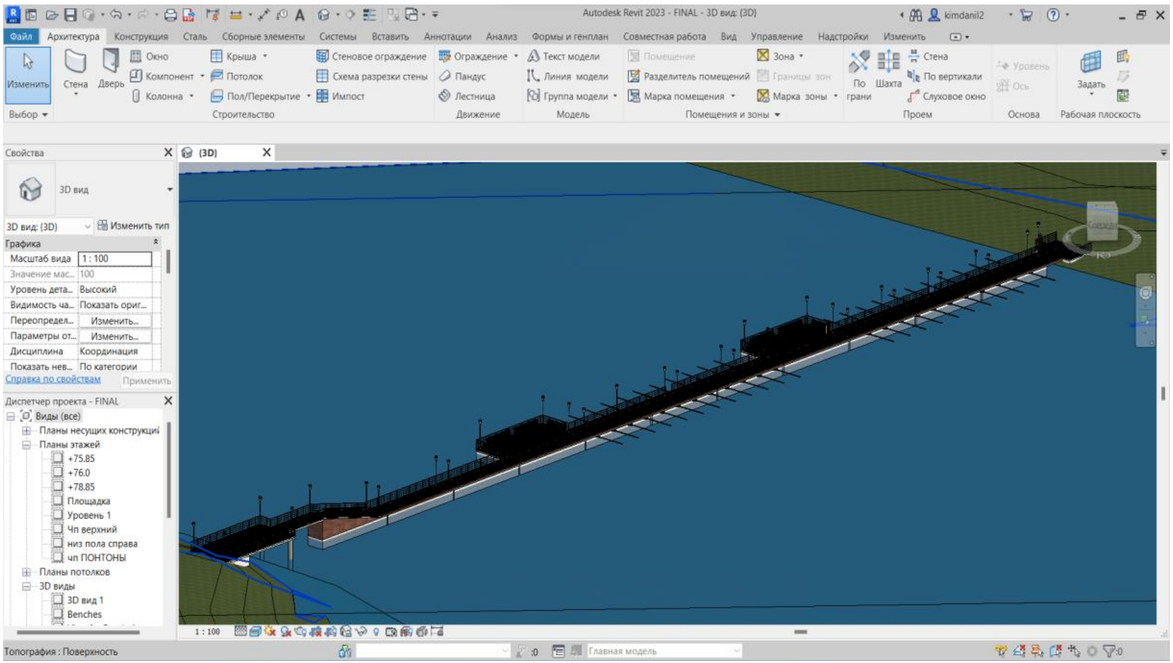


Figure 13 Revit interface and a 3D view of the bridge

4.1.1 Topographical surface

First of all, to model the bridge, it is necessary to create a topographical surface of the area, which was made based on the site survey data of the Taipalsaari municipality area. The AutoCAD drawing was simplified and imported to Revit using the topographical surface function. Each contour line was positioned at the correct Z value with the correct elevation points. With this tool, users can create the topography of a site in a fully three-dimensional image. It allows the user to study inclinations and identify areas suitable for construction. The tool enables the user to identify potentially problematic areas as well as prospective ones.

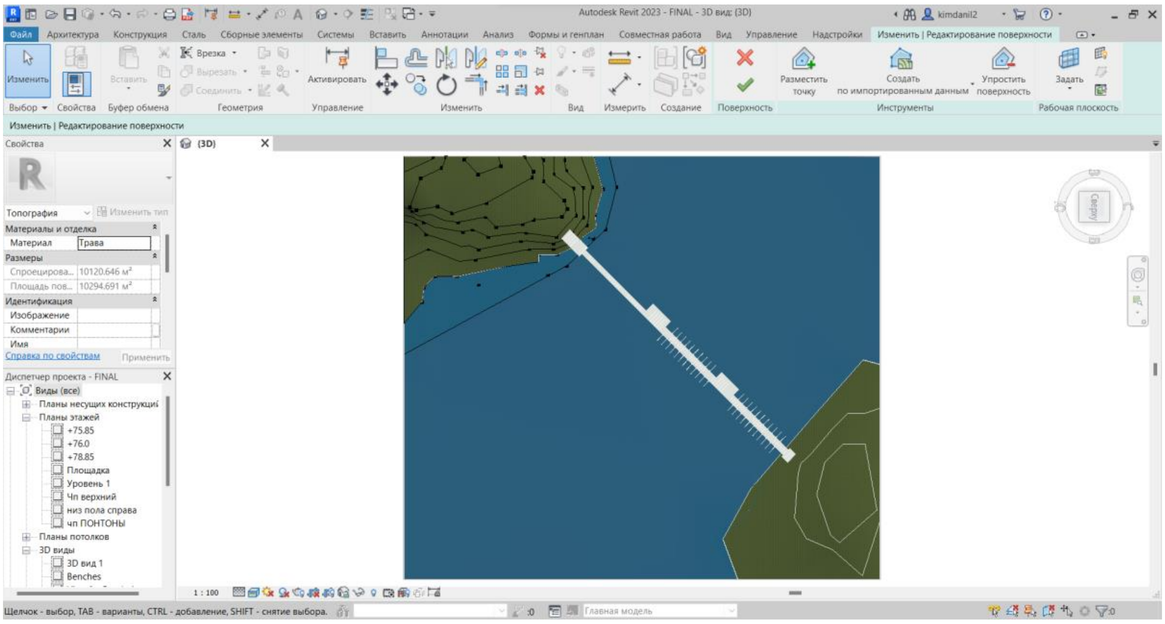


Figure 14 Topographical surface in Revit

4.1.2 Models of objects

Designing in the program Revit is based not only on existing functions and families but also on creating and using custom families and models. Some models, such as benches, lampposts, and garbage cans, were downloaded from free resources on the internet. Most of the models were made using a family creation tool in Revit. Concrete slabs, metal piles, pontoons, timber decking, and timber railing were made individually for the project.

It is worth noting that the bridge model is not analytical, and its primary purpose was to create good-looking pictures and videos. Thus, the created families have only external characteristics and textures; the strength characteristics of the models are not available since they are not needed in this project. Therefore, for further design, it is recommended to use a calculation program and a new analytical model.

4.2 Visualization in TwinMotion

After creating a 3D model of the bridge in the program Revit, the created model was exported for further visualization. The visualization part of the project was made in the TwinMotion program, which has a free version for students and provides dozens of features that can improve export pictures and videos.

In order to export files from Revit to TwinMotion, it is necessary to use FBX format. FBX file is used to transfer 3D geometry and animation data between programs. In Revit and TwinMotion, it is easy to open, edit and export this format.

Although the quality of the output material can not be classified as realistic, such as the rendering in Autodesk 3dsMAX using Corona or V-Ray rendering software, this program is very well suited to get a quick render of pictures and videos. In real-time, a user can edit various lighting effects, backgrounds, weather, and material of all models. Additionally, in the TwinMotion program, animated human and animal models have been added to the project bridge for better quality output pictures and video. The final pictures and video are attached at the end of the thesis report.

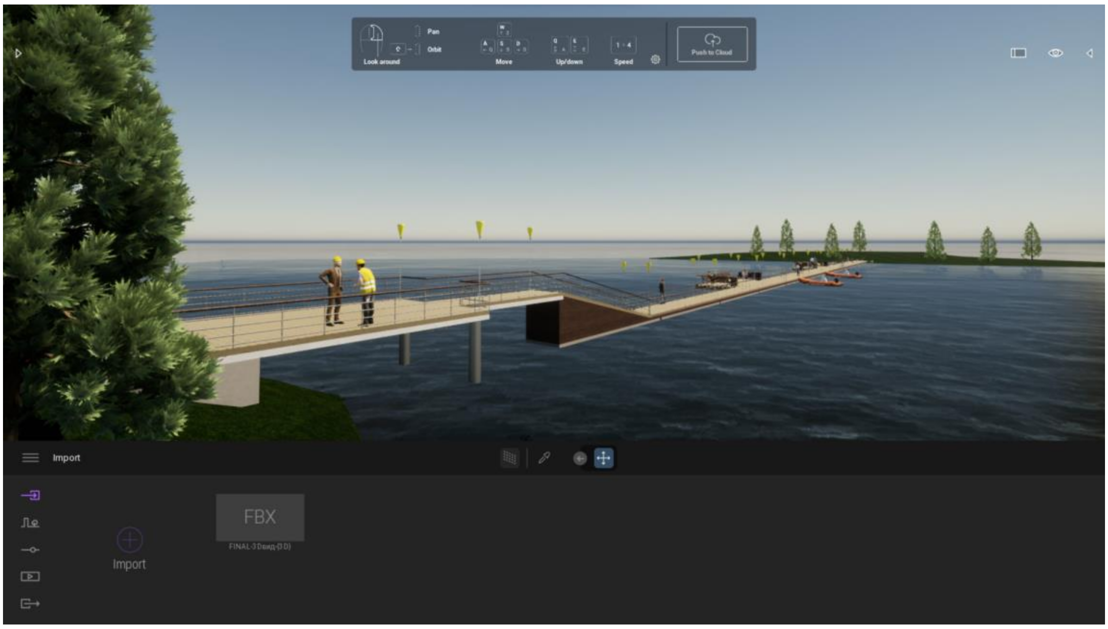


Figure 15 TwinMotion model

4.3 Site drawings for cost estimation

A site and site-section drawings contain information about the bridge, its geometrical characteristics, levels of all structural members, and their location. The site drawing illustrates a view from the top. As it can be seen, the floating bridge has two resting places and two parking spaces on both sides of the bridge. The total length of the bridge is 134,5 meters.

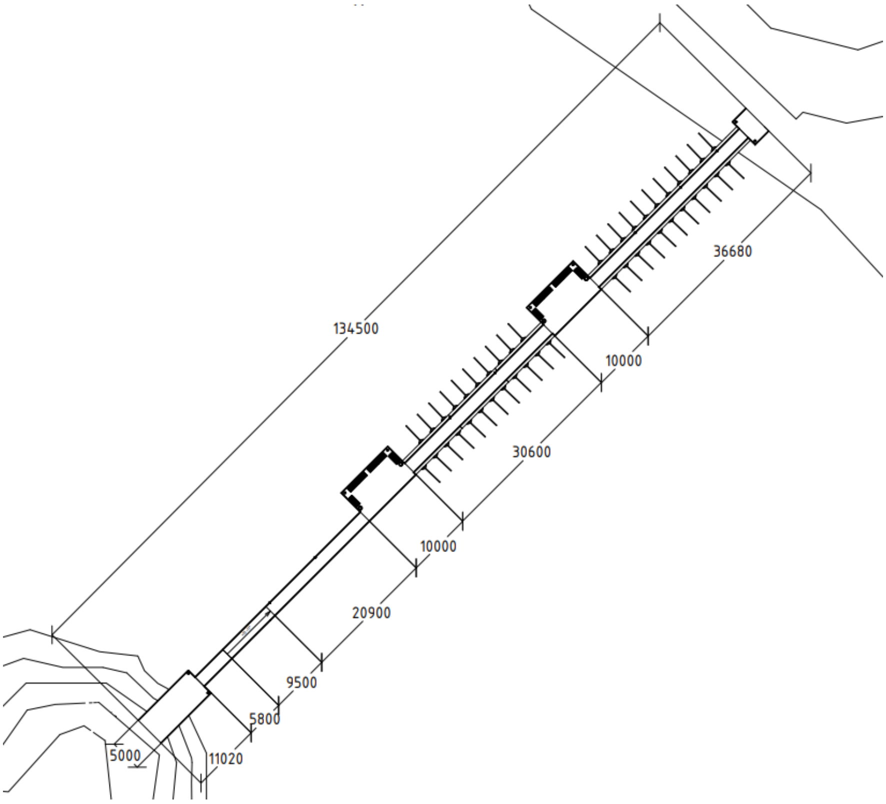


Figure 16 Site drawing

On the site section of the bridge, measurements, elevations, and the topographical surface can be seen. However, the topographical surface under the water on both drawings is not actual. During the design process, the surface under the water was created for better drawings and visualizations, but there is no information about its depth and conditions.

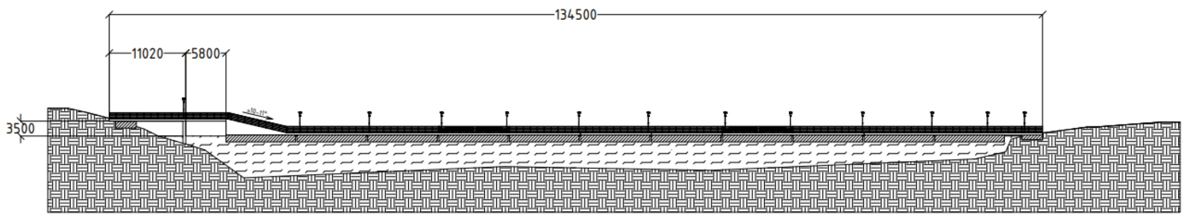


Figure 17 Site-Section drawing

5 Cost estimation

Cost estimation is one of the most important parts at the end of a preliminary design. The estimated bridge cost includes equipment, materials, and labor force. It also includes site management fees, final design costs, and excess cost reserve, which are calculated as a percent of total spending on equipment, materials, and works.

The cost of the bridge depends on the amount of work, the cost of material and its volume, and additional fees for design and construction supervision. Therefore, to make a cost estimation, it is essential to prepare all information about the bridge.

- Area ≈ 343 m^2.
- Length ≈ 134,5 m.
- Live-load ≈ 4-5 kN/m^2.

Structure composition:

- 2 concrete slabs (on each coast) as foundation 5x3x1 (m).
- 2 metal piles filled with concrete 0,2m diameter, 7m length.
- 13 concrete pontoons 10x2 (m)
- Timber decking ~343 m^2.
- Timber railing ~ 284 m.
- Equipment for the pier: 46 metal divider constructions
- Anchoring of concrete pontoons

The final estimated cost of the floating bridge is 327 126 € (VAT 0%). The price is valid for the summer of 2022. The cost of the bridge in the future may increase due to the world situation and the current crisis.

6 Summary

The main goals of the thesis were to create a visual presentation of the bridge, design a structure which will suit all requirements, suggest materials for each structural member and make a cost estimation for the project. Each goal was successfully achieved, and is described in detail in the thesis report.

The further final design of the bridge involves assessing the speed of water flow, the depth of the water obstacle, the degree of impact of ice on the pontoon, the selection of geometric characteristics and the type of pontoon, concrete slab design at the coasts, and design of metal piles depending on the geology of the terrain. The final design must also include lighting, a detailed design of the bridge nodes, considering the selected type of pontoon and shore part.

During the design, several bridge types and structure materials were suggested. The main problem was to choose a bridge design that would satisfy all requirements. Due to the size of the passage for boats, which was included in the original requirements, it was challenging to maintain the angle of inclination of the bridge surface of fewer than 12 degrees, which is necessary for the convenient movement of people with impaired mobility.

Various design features, materials, and types of bridges were considered in the design process. For example, the river section system could have been continuous, which would have changed the operation of the bridge and its calculations. Also, other materials may have been used in the design of the pontoons and other structural members, which would have affected their calculation, geometric characteristics, and structure. Eventually, after negotiations and analysis, the floating bridge with a boat way near the coast was selected as the best option.

The bridge has a split system consisting of individual floating supports connected by freely supported or hinged transitional spans. The total length of a bridge is 134,5 meters. The width of a bridge is 2 meters, and the width of resting places is 4 meters. There are two resting areas on the bridge with benches and trash cans. The distance between the resting places and the banks is less than 50 meters as it was required. Throughout the bridge, there are also lighting fixtures.

Figure 18 3D model visualization of the bridge in Revit

One of the important assignments in the design of this bridge was to use timber in as many structural elements as possible so that the bridge's appearance would blend in with its surroundings. By design, the upper part of the bridge is almost entirely made of timber, including the decking, railing, and additional structures above the top of the pontoons. As a result of this design, the appearance of the pontoon bridge not only integrates well with its surroundings but can also, in theory, become one of the landmarks of the Taipalsaari municipality area. Furthermore, the bridge will be located in Pappilanlahti bay, where residents and tourists often go fishing; therefore, the place might be quite popular.

An essential part of this project was not only the exterior design but also the calculation of the preliminary cost of the bridge. Simple materials and designs were used for reasonable design. The main elements of the floating bridge are pontoons, which in this project were designed of concrete.

As for pontoons, one of the alternative materials was FRP, which performed well in the Brookfield floating bridge project. However, the concrete pontoon is the most common, reliable, simple, and relatively inexpensive option. The variability of manufacturers, technologies, materials, and designs for concrete pontoons in Finland and neighboring countries is extensive. Moreover, the production and design of pontoons are often custom-made, allowing the customer to make a pontoon based on the environmental impact of the planned bridge's location.

Overall, the preliminary design of the floating bridge complies with all requirements. During the project, a sketch of the bridge was drawn in ProCreate, a 3D model of the bridge was made in Autodesk Revit, and a rendering of this model was made in the TwinMotion program. The final estimated cost of the floating bridge for the summer of 2022 is € 327,126 (VAT 0%).

It was enlightening to learn about the different types of bridges and the way they work, the fact that pontoon bridges can serve not only pedestrians and multiple vehicles, but also for entire land connections between cities, such as the Governor Albert D. Rosellini Bridge in Seattle, Washington.

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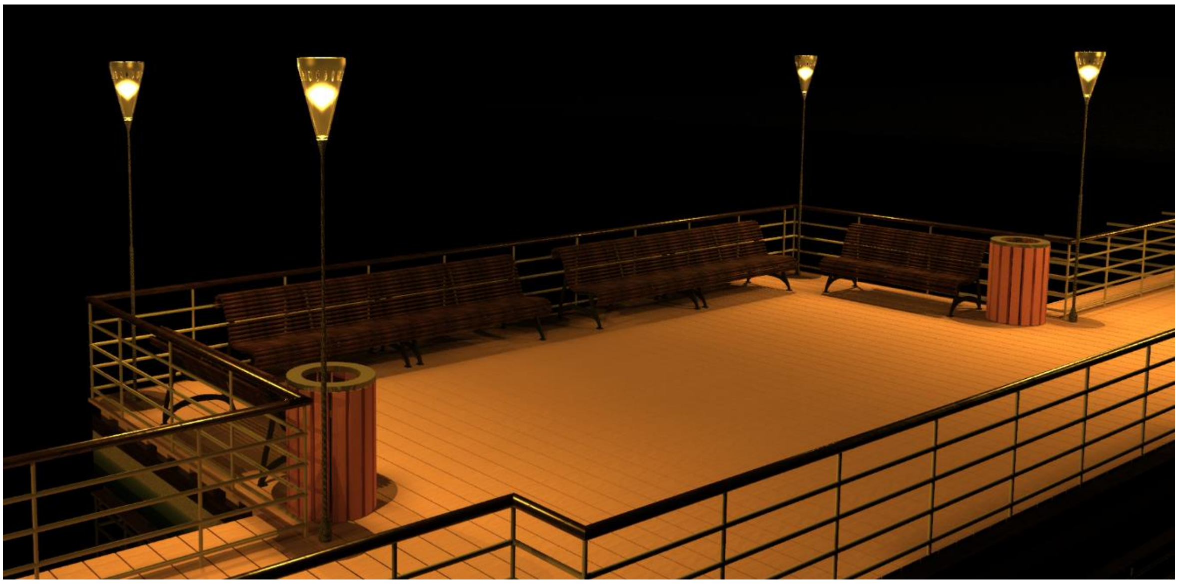
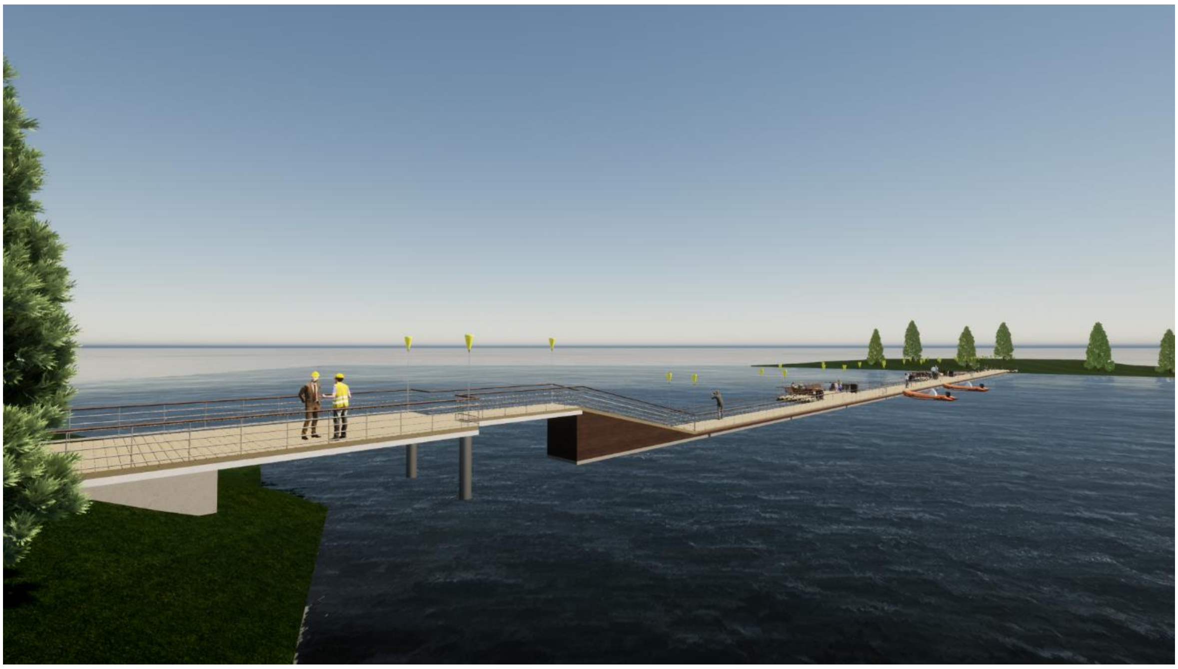
Appendix 1. 3D view of a resting space on the floating bridge in Autodesk Revit



Appendix 2. 3D view of a floating bridge in TwinMotion program



Appendix 3. Final video of a floating bridge visualized in TwinMotion program

The video is available on the YouTube at the link below:

https://youtu.be/GAiWdUFI98E