Design of a Hilti platform

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DEGREE THESIS

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Abstract

This thesis is made on behalf of Wärtsilä Energy business. The purpose of this thesis was to design and standardize a platform for an OWT unit. The main purpose of the platform is to facilitate the maintenance of the OWT unit.

A preliminary study was conducted to establish the requirements of the platform. Afterward, research about the design process and different design methods was conducted. SFS-EN standards were researched to design the platform accordingly. existing components were also researched from Hilti's product catalog to create an understanding of what the platform will be constructed of. The logistical aspect of the transportation of the platform was also planned.

A 3D design of the platform was created. The frame, guardrail, and ladder were designed only utilizing components from Hilti's Multi-Duty Channel system. The gratings and kickplate used in the design were components that are used in Wärtsilä's standard design of platforms.

The result was a finished 3D model and drawing of the platform for the OWT unit. The platform can be implemented in different projects to facilitate the maintenance of the OWT unit. The platform also fulfilled all the Wärtsilä requirements.

Language: English
Key Words: Design, Platform, Standardization

EXAMENSARBETE

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Utbildning och ort: Maskin- och produktionsteknin, Vasa

Inriktning: Drift- och energiteknik

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Titel: Design av en Hilti plattform

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Abstrakt

Detta examensarbete är gjort på uppdrag av Wärtsilä energy business. Syftet med detta examensarbete var att designa och standardisera en plattform för en Oily Water Treatment unit (OWT-unit). Platformen huvudsyfte är att underlätta underhållet på OWT-uniten.

Innan arbetet kunde påbörjas gjordes förundersökning för att fastställa vad som krävs av platformen. Efteråt undersöktes hur en designprocess går till, och olika metoder man kan använda sig av. SFS-EN standarder användes också för att platformen skulle bli standardiserad. Existerande komponenter ur Hiltis produktkatalog undersöktes för att bilda en uppfattning av vilka komponenter platformen kommer bestå av. Det planerades också hur platformen enklast kunde transporteras till site.

En 3D design gjordes av platformen. Ramen, skyddsräcket och stegen designades enbart av komponenter ur Hiltis Multi-Duty channel system. Gallerdurken och sparkplattan som användes i designen var komponenter som används av Wärtsilä i deras standardiserade platformdesigner.

Resultatet blev en färdig 3D-modell samt ritning av platformen för en OWT-uniten. Platformen kan implementeras i olika projekt för att underlätta underhållet på OWT-uniten. Platformen uppfyller också de krav som Wärtsilä krävde av platformen.

Språk: Svenska

Nyckelord: design, platform, standardisering

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Tiivistelmä

Tämä opinnäytetyö on tehty Wärtsilä Energy -liiketoiminnan puolesta. Tämän opinnäytetyön tarkoituksena oli suunnitella ja standardoida OWT-yksikön alusta. Alustan päätarkoituksena on helpottaa OWT-yksikön huoltoa.

Alustan vaatimusten määrittämiseksi tehtiin alustava tutkimus. Sen jälkeen tehtiin tutkimusta suunnitteluprosessista ja erilaisista suunnittelumenetelmistä. SFS-EN-standardeja tutkittiin, jotta alusta voitaisiin suunnitella niiden mukaisesti. Lisäksi tutkittiin olemassa olevia komponentteja Hiltin tuoteluettelosta, jotta saataisiin käsitys siitä, mistä alusta rakennetaan. Lisäksi suunniteltiin tason kuljetuksen logistinen näkökulma.

Tasosta luotiin 3D-suunnitelma. Runko, suojakaide ja tikkaat suunniteltiin hyödyntäen ainoastaan Hiltin Multi-Duty Channel -järjestelmän komponentteja. Suunnittelussa käytetyt ritilät ja potkulevy olivat komponentteja, joita käytetään Wärtsilän omissa vakiomuotoisissa lavoissa.

Tuloksena saatiin valmis 3D-malli ja piirustus OWT-yksikön alustasta. Taso voidaan toteuttaa eri projekteissa helpottamaan OWT-yksikön huoltoa. Alusta täytti myös kaikki Wärtsilän vaatimukset.

Kieli: Suomi
Avainsanat: Suunnittelu, alusta, standardointi

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LIST OF ABBREVIATIONS

OWT - Oily water treatment

EEQ - Engineered equipment

EPC - Engineering, procurement, and construction

DFA - Design for assembly

TFB - Thread-forming bolts

MT-System - Multi-Duty Channel System

TABLE OF FIGURES

1 Introduction

This thesis is made on behalf of Wärtsilä Energy Business, which is part of the Wärtsilä Corporation. The task was to design and standardize a platform for an Oily Water treatment unit (OWT unit). These units require regular maintenance, and a platform is necessary to reach certain areas of the module safely. The platform was designed to be included as an option for the customer when ordering the OWT unit. The platform's principal functions include facilitating easy access to the top of the OWT unit to enable safe maintenance operations. The idea for the design of the platform was that it would be built utilizing Hilti modules, which can be constructed without any hot work. Flexibility was also an important objective. Simple assembly and disassembly of the platform was an important factor when designing the platform.

1.1 About Wärtsilä

Wärtsilä Oyj was established in 1834 in Karelia. Wärtsilä's business began within the sawmill industries. Over the years, Wärtsilä has changed industries many times. In November 1942, Wärtsilä and Friedrich Krupp Germania Werf AG introduced the first diesel engine. In 1959 Wärtsilä decided to start designing their diesel engine in Vaasa, Finland and in June 1959, Wärtsiläs first diesel engine was started. In 1984, Wärtsilä was the first Finnish company to be quoted on the London Stock Exchange. Today Wärtsilä is the global leader in innovative technologies and lifecycle solutions for the marine and energy markets. (Wärtsilä, 2024)

Wärtsilä corporation consists of Wärtsilä Energy, Wärtsilä Marine and Wärtsilä portfolio business. Wärtsilä has over 17800 employees in 79 countries. In 2023 Wärtsilä's net sales were EUR 6,015 million. Wärtsilä strategy aims to transform and perform. Focus is put on driving decarbonization in the marine and energy business through innovation, focused investments, and selective partnerships. (Wärtsilä, 2024)

1.2 Background

Wärtsilä Energy Business sells power plant solutions to customers. The power plant solutions can be divided into two parts depending on the customers' requirements and needs, (EEQ) & (EPC). EEQ focuses on delivering the engineering equipment and the customers oversee the installation. EPC is a broader contract where Wärtsilä manages the entire project, including engineered equipment, procurement, and construction. For EPC projects Wärtsilä oversees delivering a new project from start to finish according to the contract with the customer.

When an OWT unit in a project is sold, it is important to perform the required maintenance for the unit. The maintenance needs to be done so that the unit and the plant can function properly. Maintenance also must be done to retain the warranty of the unit. For these reasons, it is important that the customer can perform the maintenance easily. If a platform is included as an option in the quotation for the OWT unit, the customer will have the possibility to select whether to order the platform.

1.2.1 Citec, a Cyient company

Citec was a consultant company with expertise in a broad array of different engineering fields, such as piping & layout, electrical, instrumentation & automation, Civil & structural, product & mechanical, documentation, and much more. Citec was founded in 1984 and has expanded vastly since then. Citec had offices in 6 countries with over 1200 employees. Citec was acquired by Cyient in 2022 and then changed its name to become a part of Cyient. Cyient designers have been involved in assisting with the design of the platform. (Citec, 2024)

1.3 Disposition

First Chapter

Chapter One introduces the subject and the purpose of this thesis.

Second chapter

Chapter two explains the preliminary study for this thesis.

Third chapter

Chapter three explains the theory behind this thesis.

Fourth chapter

Chapter four explains the methods used.

Fifth chapter

Chapter five includes the results of the thesis.

Sixth chapter

Chapter six contains a conclusion and a discussion for further improvements.

2 Preliminary study

To have a better grasp of what was required from the design of the platform, it was necessary to conduct a preliminary study. Hilti had previously introduced a platform design for an OWT unit delivered to a specific Wärtsilä project. The preliminary study was carried out to find out what requirements are needed for the final platform. Hilti's initial design was used as a base to research for improvements. One of the main challenges when designing the platform was that it needed to be according to SFS-EN standards.

2.1 Hilti's initial platform design

In an early meeting with Hilti, a platform design for a Wärtsilä project was introduced. This early design was based on a dimensional drawing of the OWT unit and dimensions provided to Hilti by the site supervisor. The initial design consisted of a platform with a guard rail around the whole platform and stairs instead of a ladder (Figure 1). This design was created as a proposition for the customer to show them what a platform that could facilitate the maintenance of the OWT unit would look like, and it was not according to SFS-EN-standards.

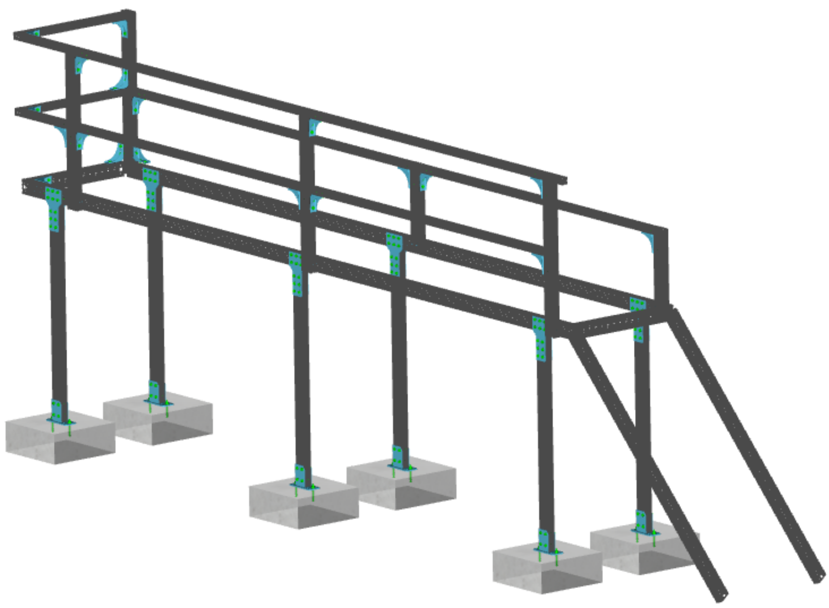


Figure 1 Hilti's initial design

2.2 Hilti product catalogue

Hilti’s product catalog was studied to understand what parts can be utilized in the platform design. The Multi-Duty Channel system (MT-System) product portfolio consists of many different products that can be used in the design. Hilti's special components were also studied. These components are not included in the MT-System and are products that Hilti can provide in special cases. By looking through the Hilti product catalog, it was determined that a platform could be designed using only Hilti components. During the meeting with Hilti, it was also explained how the different components could be utilized in the design. It was also shown where components had been used in the initial design provided by Hilti, and explanations on why the components in question were used in the design.

2.3 Wärtsilä requirements

When the thesis work was introduced, Wärtsilä had a few criteria that had to be met.

- No hot work when assembling the platform.
  hot work is a name for work conducted with tools and equipment that produces heat or sparks. Examples where hot work can occur are welding and cutting. (Mats Björs, Brandskyddsföreningens Service AB, 2024)

- Design according to SFS-EN standards.

- Design for **assembly** & disassembly.

- Delivery must be possible with the OWT unit.
  The platform must be delivered in the same container as the OWT unit and not in a separate package.

- Hilti's MT-System to be used.

2.4 Information from the site

Pictures from one of Wärtsilä's projects were studied to get a better grasp of how it looks inside the fuel treatment house. With information on how the OWT unit looks, it was easier to understand how the platform will integrate with the unit, For the same project there had also been installed a platform scaffold that had been used in the construction phase of the fuel treatment house. The installation of the platform next to the OWT unit provided a view of how the finished design could look.

Figure 2 Laborer performing maintenance from the scaffold

3 Theory

3.1 Design Process

The idea of design varies greatly between designers. An architectural designer empathizes with the visual and aesthetic aspects of the design. They focus on the human experience and try to design to appeal to the senses. Comfortable and harmonious design to give a better experience. The engineer prioritizes functionality and performance over the visual aspect. Safety and reliability are a crucial concern in engineering design. (Mital;Anoop;Anand;& Aashi, 2008)

Different kinds of designers focus on different aspects of the design. Depending on the application, what is prioritized in a design differs. It is still critical to consider all the factors to achieve the best result.

When creating a design there is a process that needs to be followed. Design problems are usually vaguely defined, and there is often more than one solution to the problem. Because of this, the design process is rarely linear, and it is frequently necessary to revert and rework things. (Khandani, 2005)

The first step in the design process is to recognize the needs for the product or the realization that there is a need to rework an already existing product. When the needs have been identified, the problem needs to be defined. Defining a clear idea of the problem is difficult and usually during the design phase more problems will be realized. With knowledge of the problems and what is needed in a product, the designer must think about the specifications of the products, such as their dimensions, means of accessibility, and weight requirements. The third step is the creative stage of the design. Here ideas of the design are proposed to get a starting point to build on and later be able to improve the design. When an idea has been chosen, an analysis needs to be made to define the components in the design to meet the demands required. Criteria like performance, cost, and logistics of the design need to be considered. When the analysis has been completed, there will be a need for optimization. If there are conflicting criteria in the design, it will in the optimization stage be decided what to adjust and what to keep. The last stage is the evaluation. Will the designed product meet the initial requirements and hold up to the standards needed? In the evaluation stage, it is common to test the design in real-world scenarios. (Childs, 2003)

3.1.1 Design for assembly (DFA)

Design for assembly (DFA) is a concept that is used to simplify the product to reduce the amount of work needed to assemble a product. When planning a design with a focus on simplifying the assembly, it is important to analyze parts and the entire product to identify problems that might occur during the assembly. Key points considered to facilitate manual assembly are:

- Eliminate the need for decision-making.
  If the worker assembling the platform easily can identify where the next piece will go or what the next step of the process is without having to decide what to do next, the assembly process will be improved.

- Minimize the number of parts needed and eliminate excess parts.
  By having fewer parts to work with the assembly process is simplified. Removing unnecessary parts and combining parts to create as few parts as possible.

- Symmetry in design
  Symmetry facilitates the assembly by simplifying the alignment and leads to a quicker assembly procedure. (Mital;Anoop;Anand;& Aashi, 2008)

3.2 Standards

Standards are a publication where specifications and requirements for a product are defined. The purpose of standards is to define the best way to create a product and to define safety requirements for the products. (SFS, 2023)

The platform can be split into three parts, the stairs, the guardrail, and the frame for the platform. All these three sections must comply with SFS-EN standards. The standard that has been thoroughly studied when designing the platforms is are Safety of machinery. Permanent means of access to machinery. Part 1-4. (ISO 14122-1/2/3/4:2016).

3.2.1 Working platforms and walkways

The general requirements for the main working platform include that the platform must be designed in a way that it can tolerate the anticipated use. The safety requirements are important when designing a platform. Important safety measures to consider are the material of the walking platform so that it is slip-resistant, there must be no gaps so the user can fall from the platform. The design must be made so that the user can quickly escape from the platform in emergency situations. The dimensions are an important factor when designing a platform. Figure 3 shows the minimal requirements with exceptions in mind. A regular walkway must have a width, *w,* at ≥800 mm (see Figure 3). If the usage of the platform is less than 30 days/year or two hours per day, the allowed width of the walkway can be reduced to 600 mm. Another exception is if the walking distance of the platform is less than 2000 mm, if that is the case the width can be a minimum of 500 mm. (Finnish Standards Association, 2016)

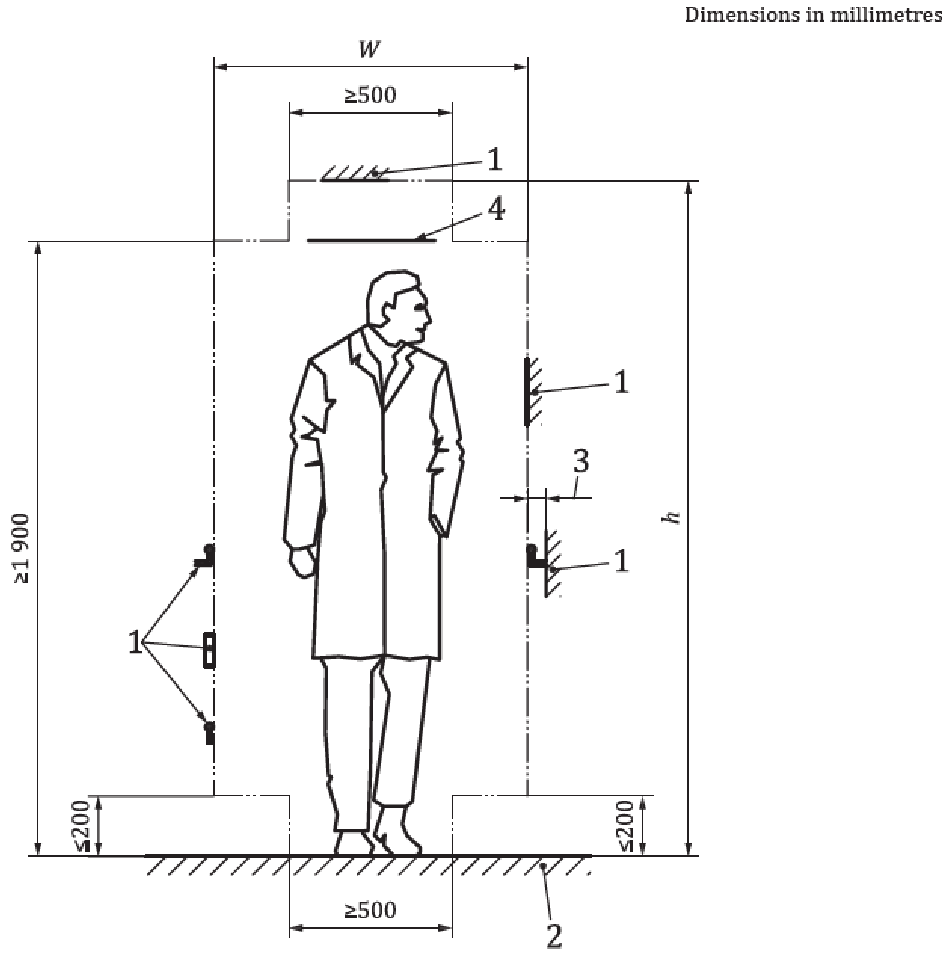


Figure 3 Access gauge on walkways (Finnish Standards Association, 2016)

1. Guardrail, wall, machine
2. Platform
3. Minimum gap between handrail and obstacle
4. Crossing obstacle

3.2.2 Permanent means of access to machinery, guard-rails

The design of the ladder and guard rail needs to follow anthropomorphic data which can be found in SFS-EN 547-3 + A1. When the construction is higher than 500 mm a guard rail must be installed. In case there is a structure next to the walkway and the gap is less than 120 mm a guard rail is not necessary. If the gap between the walkway and the structure is greater than 20 mm a kickplate must be installed. A guard-rail minimum height is 1100 mm and the handrail's maximum height is 1100 mm. A guard-rail can be designed with a knee rail, or with vertical uprights (Figure 4). Guard rail with vertical uprights can have a max of 180 mm between the uprights. Guard rails with knee rails must have at least one knee rail and the distance between the handrail and kickplate cannot be greater than 500 mm (Figure 5). The recommended length between the stanchions is less than 1500 mm. The required dimensions for the kickplate are a width of 100 mm and the maximum distance from the platform is 12 mm (Figure 5). (Finnish Standards Association, 2016)

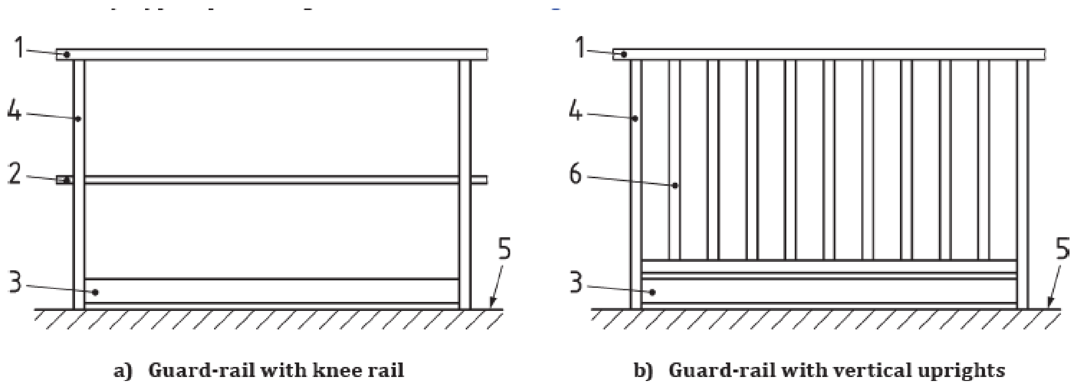


Figure 4 Different structures of guard-rails (Finnish Standards Association, 2016)

1. Handrail
2. Knee rail
3. Toe-plate
4. Stanchion
5. Walking level
6. Vertical uprights

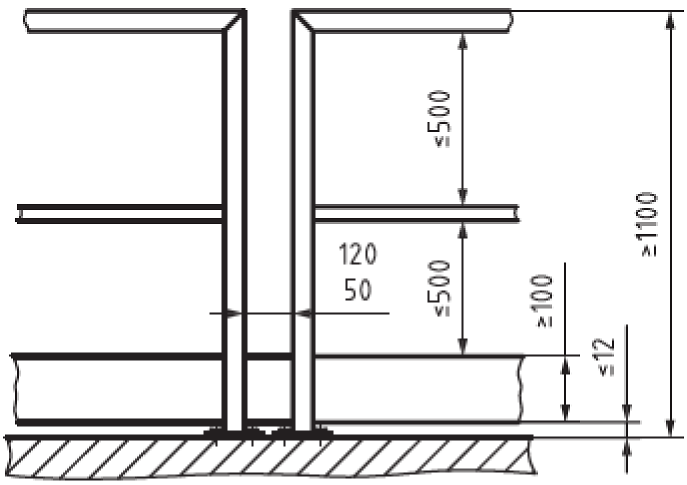


Figure 5 Guard rail with knee rail, dimension requirements (Finnish Standards Association, 2016)

3.2.3 Permanent means of access to machinery, fixed ladders

A fixed ladder should only be used if there are no possibilities of using stairs, stepladders, or a ramp. Fixed ladders demand more physical effort from the user which creates a higher risk of falling. If the falling height is greater than 3000 mm a fall protection device, such as a safety cage, must be installed. The distance between the rungs on a fixed ladder can be between 225 mm and 300 mm and must be constant between all rungs. The width between the rungs can range between 400 mm to 600 mm. The rung surface must be greater than 20 mm and flat. The surface of the rungs must be designed so that there are no sharp edges that can cause damage to the user. The surface must also be slip-resistant. The rungs positions shall be positioned so that their thread walking surfaces is perpendicular to the stile. (Finnish Standards Association, 2016)

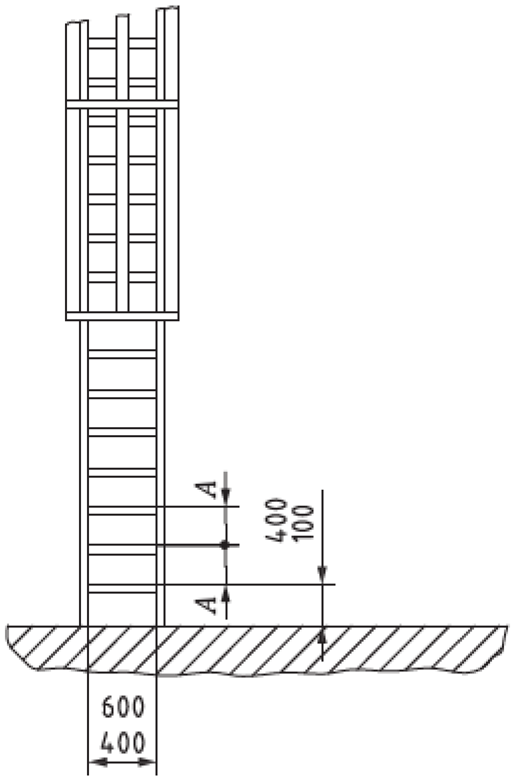


Figure 6 Dimension of rungs (Finnish Standards Association, 2016)

3.3 Hilti Multi-Duty Channel System

The Multi-duty channel system (MT) from Hilti was used in the platform's design. The Hilti MT-system was produced to enable designs to be created solely with the MT-system components. The MT system has an extensive portfolio consisting of trapeze profiles, C-channels, and closed profiles. Installation of the Hilti MT system is fast and safe. The installation is done using only fasteners. When utilizing the MT system no hot work is required resulting in fewer installation errors and a cost-efficient installation. The MT-system closed profiles can be fixed using only the Hilti MT-Thread forming bolts and connectors. The bolt is attached to the profiles so nuts and washers are not needed. Additionally, the MT system allows flexibility. It is possible to release the bolts and reposition the profiles. (Hilti, 2023)

3.3.1 MT Closed profiles

The MT closed profiles have a high load/weight ratio making it an efficient alternative for platform design. The material of the profile is S350, or better steel and the surface finish varies depending on the surrounding conditions. There are 3 different categories for the surface finish that Hilti provides: indoor-coated, outdoor-coated, and outdoor plus (Figure 7). The life expectancy of the components in different environments is shown in Appendix 3. MT closed profiles consist of 4 different profiles with different sizes, MT-70 OC up to MT-100 OC. There are two different standard lengths of the profiles, 3 meters and 6 meters. (Hilti, 2023)

HILTI CORROSION RESISTANCE			
Hilti Corrosion Resistance	INDOOR COATED	OUTDOOR COATED	OUTDOOR PLUS
Corrosion class/ min. lifetime	C1 > 50 years C2 > 20 years	C3 > 25 years C4 > 15 years	C5 > 15 years (ask expert)
Corrosion environment	low-moderate	moderate-high	high-extreme

Figure 7 Hilti corrosion resistance (Hilti, 2023)

Figure 8 MT closed profiles (Hilti, 2023)

3.3.2 MT Closed Profiles Connectors

The MT closed profile connectors are easy to install using only the MT-TFB bolts. The connectors are also adaptable and adjustable. Holes in the connectors allow adjustments up to 5 mm. The connectors used are the MT channel clamp and the base material connectors. The base material connector used is MT-C-GS A OC. Thanks to the elongated hole on the connector it enables flexibility when installing the profiles. The MT channel clamp used is MT-CC-70 OC. The connector is a cross-connector that is attached to another profile using the MT-TFB bolts. (Hilti, 2023)

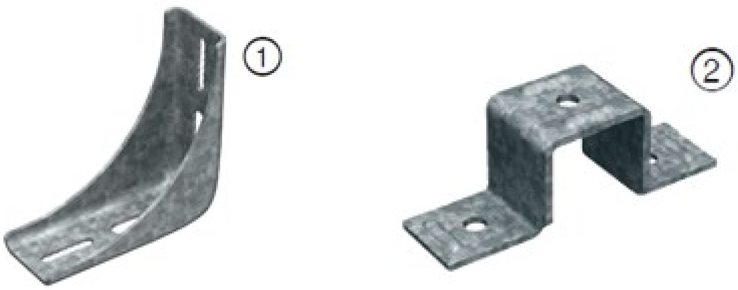


Figure 9 MT-C-GS A OC (1), MT-CC-70 OC (2) (Hilti, 2023)

3.3.3 MT Closed profile Base material connectors

The MT closed profile base material connector can be used to fasten the MT-70 and MT-80 profile to walls, floors ceilings, and structural steel. Installation of the base connector is also done using the MT-TFB bolts. The base connector used is the MT-B-GS T OC. The base connector material is made of Q235 or better steel. (Hilti, 2023)

Figure 10 MT-B-GS T OC (Hilti, 2023)

3.4 Aveva E3D Design

Aviva is a leading provider of software solutions in the engineering field. Aveva E3D is specifically designed to be used in the process plant industry. The software allows users to create 3D models of whole process plants. In E3D it is possible to design piping, equipment, and structures and generate accurate drawings and reports. E3D integrates well with other engineering tools making it simple to import design from other design programs into E3D. E3D also supports Simulations to help users detect clashes. With the simulations, it is also possible to ensure that the safety requirements are met. With E3D it is also possible to use different plug-ins enabling the design to be made with specific components provided by the plug-in. E3D is not used to design small components with detail, instead, it focuses on designing larger entities. (Aveva, 2021)

3.4.1 Hilti plug-in for E3D

Hilti has produced a plug-in for E3D for projects where Hilti's MT components are used. The plug-in is mainly used for the design of pipe support, but it is also possible to design other products. The plug-in features an attachment wizard for pipework. The attachment wizard is utilized to connect pipes with Hilti components. For steel structures, the template wizard is used to create different kinds of beams. Beams can be connected to each other by creating a starting beam and then using the template wizard to attach them. In some cases, the attachment of beams in a specific way cannot be done using the template wizard. The Connection Wizard is then used to create different connections. Both the template wizard and the connection wizard can be utilized to alter the length of the beams and change the connectors between the beams.

The Hilti plug-in also creates a part list of what parts have been used in the design and the specifications of the parts. In the part list, information about the components used in the design is given. Product number, description of the item, and the cut length and weight are found. The part list can be used to calculate how much of the product is needed to create the designed component.

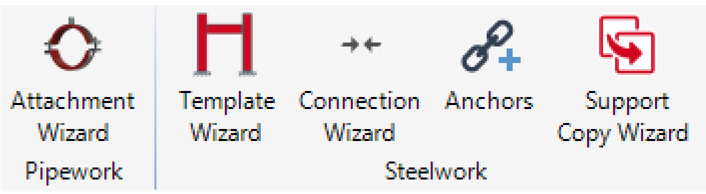


Figure 11 Hilti plug-in functions.

3.4.2 Cyient plug-in for E3D

Cyient also utilizes a plug-in for E3D named Cyient Desing Tools v1.1. This plug-in features many different tools that can be used in 3D designs for a powerplant. With the tool, standard 3D models for piping, steelwork, electrical, and civil design can be imported into E3D. The tool can also be used to check designs for conflicts.

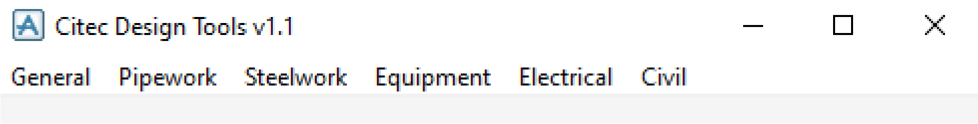


Figure 12 Cyient Design Tools functions

4 Methods

In this chapter, the methods used for the research of the design process of the platform will be discussed. Presented are also the methods used to gather information for designing the platform according to standards.

4.1 Research

Researching information on product design and understanding the scope of the design is a significant part of the design process. The main approach to understanding what is needed in the design was through meetings with Wärtsilä and Cyient employees who have experience in the design field and commissioning.

The first stage of the research was to get an understanding of why the platform is needed and what problems will it solve. Since the OWT unit is in regular need of maintenance a platform would be helpful in speeding up the maintenance process and facilitating the work. A ladder or an elevated surface could be used to perform the maintenance, but the safety concerns would be greater. It would also be more difficult to perform the maintenance from a ladder or an improvised platform. After understanding the need for a platform, research about the specifications of the platform had to be realized. The biggest constraint was the dimensions of the platform. It needs to be designed according to the dimensions of the OWT unit and its surroundings. The platform needs to fit in a quite narrow space in the treatment house building. In Figure 13 the platform is supposed to be assembled on the left side of the OWT unit. Passage to the back of the building also needed to be considered when planning the dimensions of the platform. The platform also had to be easily assembled without hot work. Because of this, the Hilti MT modules will be perfect for the design. Research on the standards was then conducted to get an understanding of what is required in a platform design. In a meeting with designers at Cyient, the standards needed for a platform design were provided.

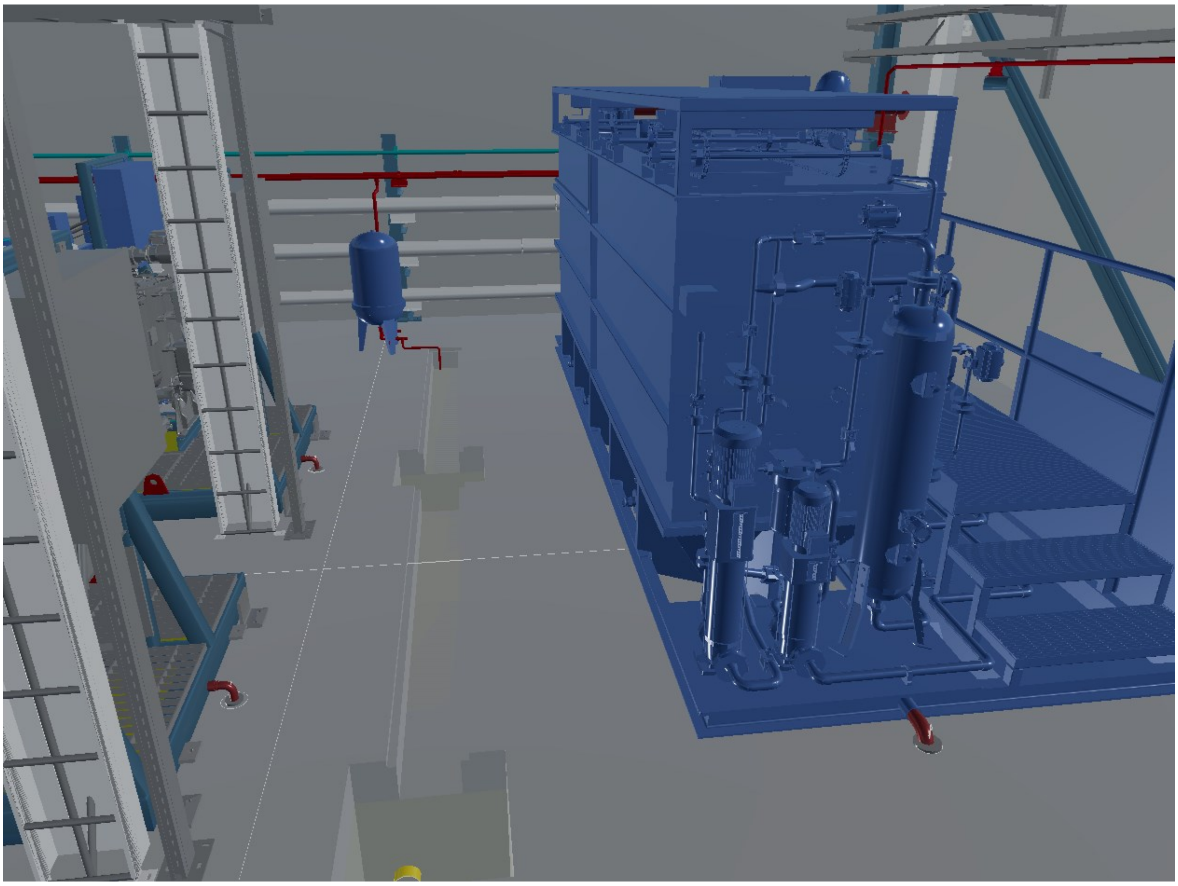


Figure 13 OWT in a fuel treatment house

4.2 Planning process

During the planning process, alternative designs were presented to get a broader view of what the final design could look like. Discussions with design engineers were conducted where the design ideas were evaluated and different opinions were taken into consideration. One of the ideas that was discussed was to use a ladder instead of stairs. Compared to stairs, a ladder would use less space making it easier for workers to move around in the treatment house. The negatives of using a ladder are that it will put more strain on the user. It is more demanding to climb a ladder than flights of stairs, and the risk of falling is also greater when using a ladder. The height of the platform was also discussed, and a few different height arrangements were proposed.

4.2.1 Planning of Logistics

How the transport of the platform would be conducted was an important question during the planning stage. The idea was that the platform should be delivered with the OWT unit straight from the unit supplier. The OWT unit is designed to fit perfectly into a container. It was discussed if the parts of the platform should be cut before transportation or after arriving at the site. Cutting the pieces of the platform at the site would result in more work for the people at the site and increase the risk of mistakes being made. It was decided that the platform must be transported in pieces ready to assemble when arriving at the site. The length of the platform was planned to be less than the total length of the unit, resulting in the parts for the platform would fit in the container lengthwise.

4.3 Meetings with Hilti

Hilti personnel have a lot of experience regarding their own components, and how they work practically. A few meetings were conducted with Hilti to get an understanding of how their components would best be utilized in the design of the platform. Discussions were carried out about how the platform will be assembled and what tools must be used. Hilti personnel provided a lot of insight into how the parts can be used practically so I could form an understanding of how to utilize them in the design. During these meetings, Hilti also presented their design software where calculations of the strength of the platform could be calculated. It was also decided with Hilti that they would use this software to produce a calculation report on the final platform design.

5 Results

In this chapter, the preliminary and final 3D design of the platform and its components are presented. The work on the final platform design will also be presented.

5.1 Preliminary 3D design

When an idea of what the final design should look like had formed, the work for the 3D designing started. As previously mentioned, the 3D design was done using E3D and the Cyient/Hilti plug-in. When commencing the design work, it was important to adhere to the standards. Every component in the 3D model had to be created with the correct measurements so that the criteria of the standards would be met. It was also important to design in accordance with what has been decided in the planning stage. The design was made so that most of the 3 m or 6 m beam would be utilized and at the same time minimize the waste. The logistics and assembly of the platform also had to be taken into consideration. With so many factors to consider when developing the design, there was a great risk for conflicts to arise.

5.1.1 First 3D design

When the first 3D design was finalized, it was presented to designers for analysis. During the analysis stage, several concerns were discussed about the design, and solutions were proposed. In Figure 14 an example of an early 3D design is presented. Concerns about this design were that the guardrail on the right side would be unnecessary. The right side is up against the OWT unit, and it was discussed if it is needed or if the unit provides enough fall protection. It was referred to SFS-EN ISO 14122-2:2016, where it is mentioned that in cases where there is a structure next to the walkway, and the gap between the structure and walkway is less than 120 mm, a guard rail is not necessary. The OWT units were imported into E3D to give a better visualization of how the platform would fit in next to the unit (Figure 15). This also simplified the process of determining the ideal platform height.

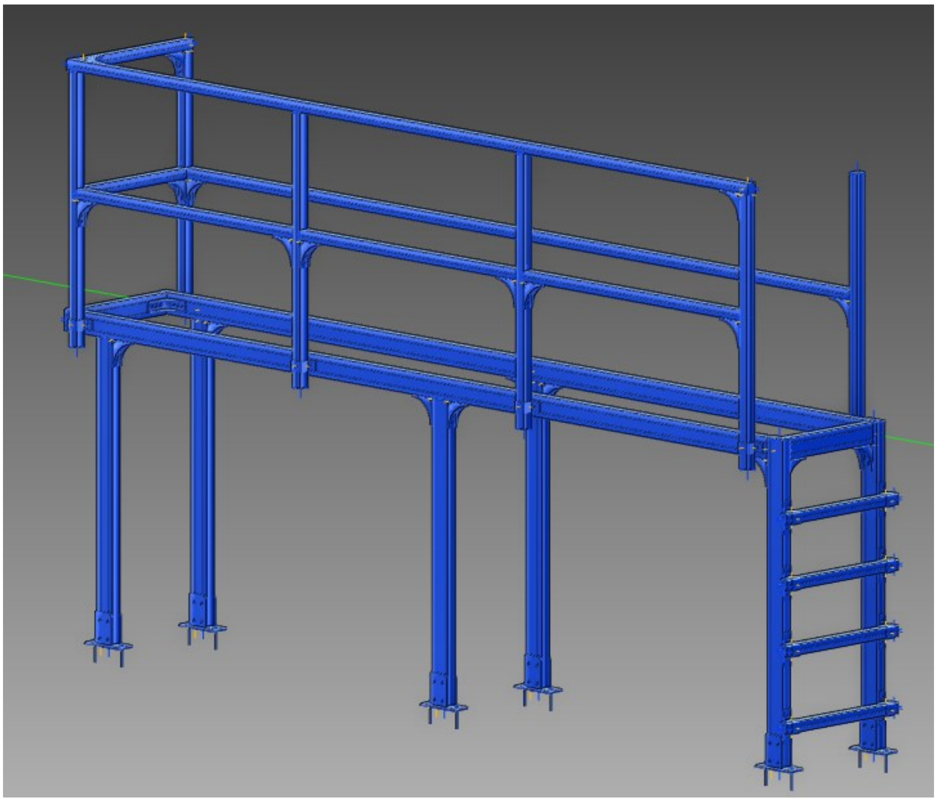


Figure 14 Early 3D design

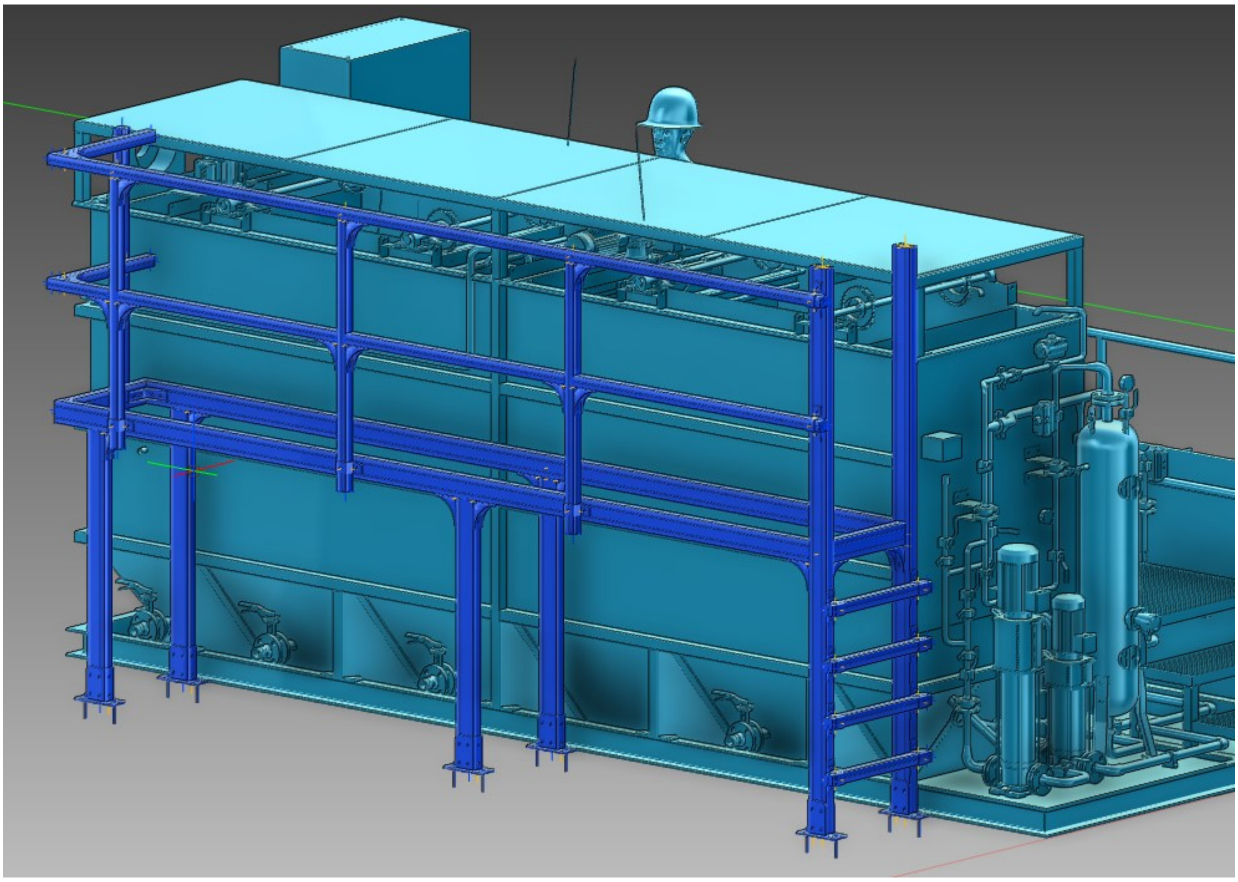


Figure 15 Platform next to OWT-unit

5.1.2 Design of gratings and kickplates

Gratings and kickplates were also added to the 3D design. These were added using the Cyient Design tool plug-in. It was agreed that the final platform product should be built with either Hilti's special components or standard components used by Cyient for the grating and kickplate. Unfortunately, it was not possible to design using Hilti's special components with their plug-in.

5.2 Construction of final design

The frame of the final product was constructed using only Hilti components. The components used can be seen in Table 1. These components will be cut before delivery according to the lengths in Table 1. The platform will then be assembled on-site. The assembly is done without any hot work. The grating and kickplates presented in this construction are standard gratings and kickplates used for platform design by Cyient and Wärtsilä. The material used for the Hilti components is S350 steel. For the grating S235JR steel was used and for the kickplate S235J2G3.

Table 1 Part List - Cut Lengths of Hilti Beams

2268365	3	HILTI CHANNEL MT-70 OC x 1200mm	1200 mm	4.69 kg	14.08 kg
2268365	3	HILTI CHANNEL MT-70 OC x 1250mm	1250 mm	4.89 kg	14.66 kg
2268365	1	HILTI CHANNEL MT-70 OC x 1400mm	1400 mm	5.47 kg	5.47 kg
2268365	1	HILTI CHANNEL MT-70 OC x 4750mm	4750 mm	18.57 kg	18.57 kg
2268365	2	HILTI CHANNEL MT-70 OC x 600mm	600 mm	2.35 kg	4.69 kg
2268365	4	HILTI CHANNEL MT-70 OC x 650mm	650 mm	2.54 kg	10.17 kg
2268365	1	HILTI CHANNEL MT-70 OC x 700mm	700 mm	2.74 kg	2.74 kg
2268367	4	HILTI CHANNEL MT-80 OC x 1185mm	1200 mm	7.18 kg	28.72 kg
2268367	2	HILTI CHANNEL MT-80 OC x 2500mm	2500 mm	15.15 kg	30.30 kg
2268367	2	HILTI CHANNEL MT-80 OC x 4650mm	4650 mm	28.18 kg	56.36 kg
2268367	2	HILTI CHANNEL MT-80 OC x 500mm	500 mm	3.03 kg	6.06 kg

The construction is also made so that if the OWT unit is turned the other way, the guard rail of the platform can be installed on the other side of the platform without any issues.

5.3 Frame

The frame consists of only two different beams from the Hilti-MT system. The different beams are CHANNEL MT-70 OC and CHANNEL MT-80 OC. The frame is constructed so that the stairs and the guardrail are attached to each other using Hilti's channel clamps. To hold up the beams in the corners, the mounting angle MT-C-GS-A OC was used. The anchor for the support beams used is the rail support MT-B-GS-T OC. For the fastening only the MT-TFB OC bolt was used, except in the anchor points where anchor bolts M12x115/20 were utilized. The final length of the frame was 4800 mm and the height was 2400 mm.

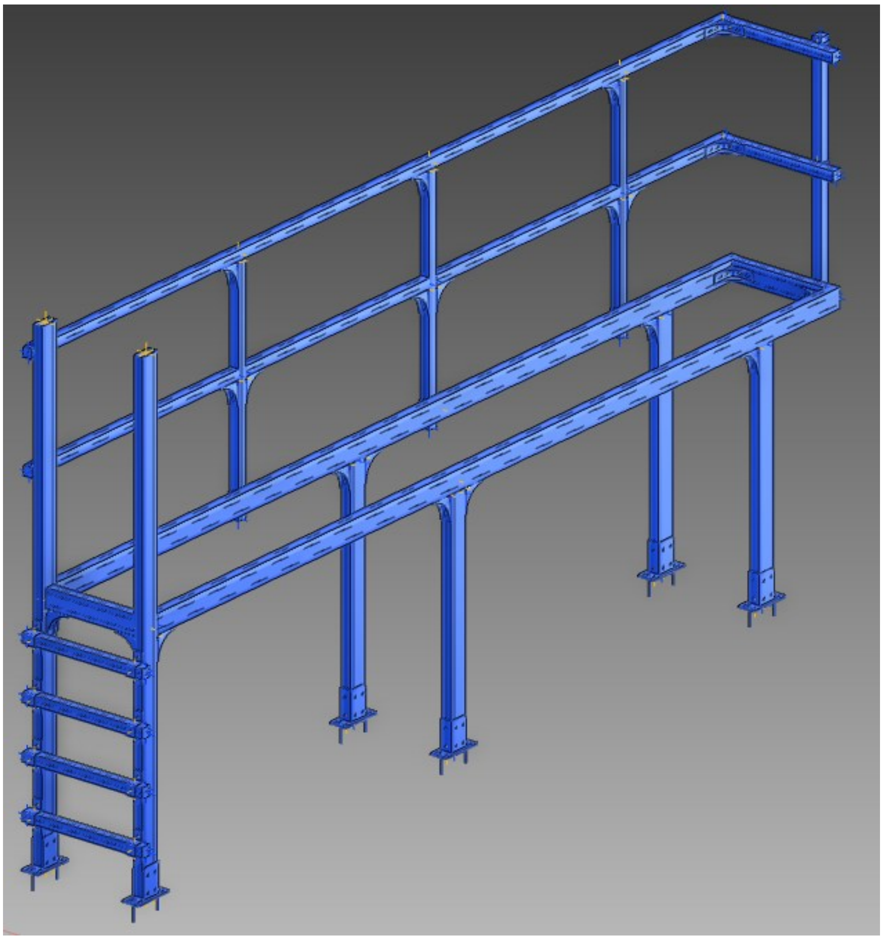


Figure 16 Final frame

5.4 Grating and Kickplate

In the end, it was decided to construct the platform with standardized gratings and kickplates. The issue with Hilti's gratings was that the apertures were too great and did not follow the standard SFS-EN ISO 14122-2. The gratings used are sized 16*75/30*2. The length of the holes in the grating is 75 mm and the width is 16 mm (Figure 17). 30*2 refers to the flat bar of the grating with a width of 30 mm and a thickness of 2 mm. The length and the width of the gratings are 1000 mm x 600 mm, except for the last one which is 725 mm x 600 mm. The first grating also must be modified to fit with the frame (Figure 18). To keep the criteria of not using hot work, and to minimize mistakes being made. The cutting of the grating must be done before shipping the platform to the site. To fasten the gratings the S-BT-GF HL threaded stud and the X-FCM-F NG narrow grating fastener disc from Hilti will be used (Figure 19). These can be attached to the beam the grating is standing on.

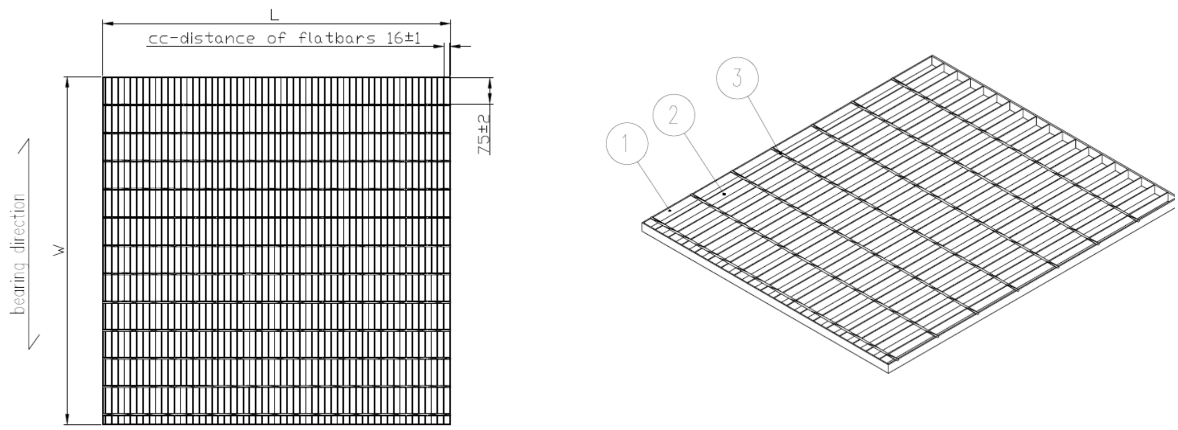


Figure 17 Dimensional drawing of grating

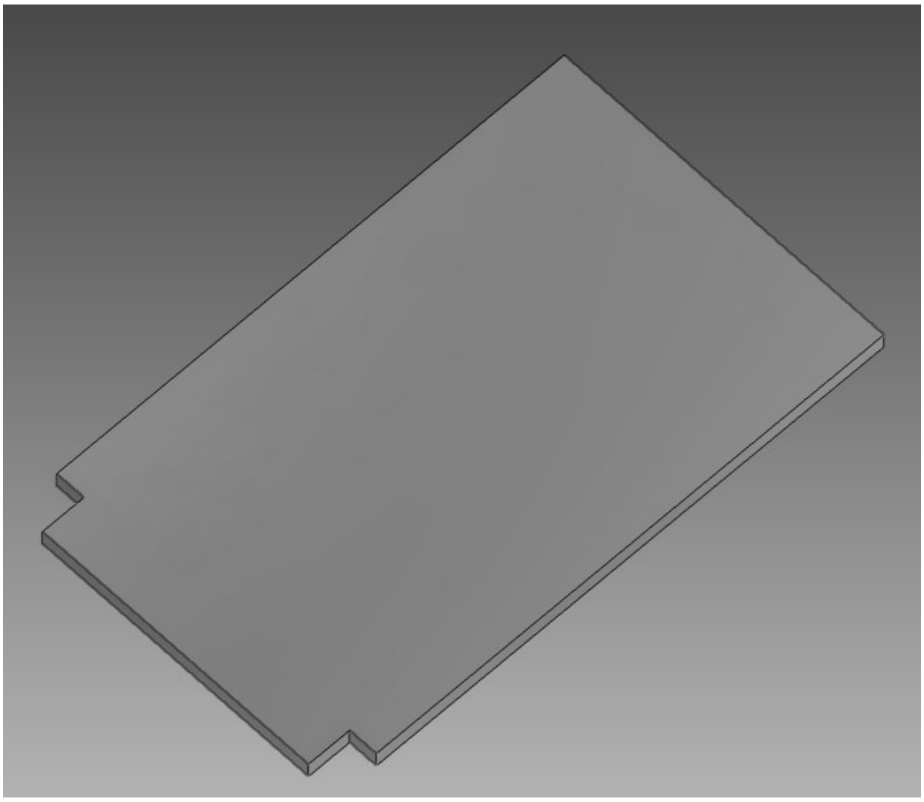


Figure 18 Grating with corners cut

Figure 19 Threaded stud (S-BT-GF GL (left) & X-FCM-F NG, right)

The kickplate used is created from a steel plate and its standard length is 2000 mm. The kick plate will also be painted according to Wärtsilä painting instructions, in the colour RAL 1003. The smaller kickplates at the end of the walkway must be cut from one 2000 mm piece to 3 pieces of 600 mm. The kickplate will be fastened to the grating at the same time the grating is fastened to the frame.

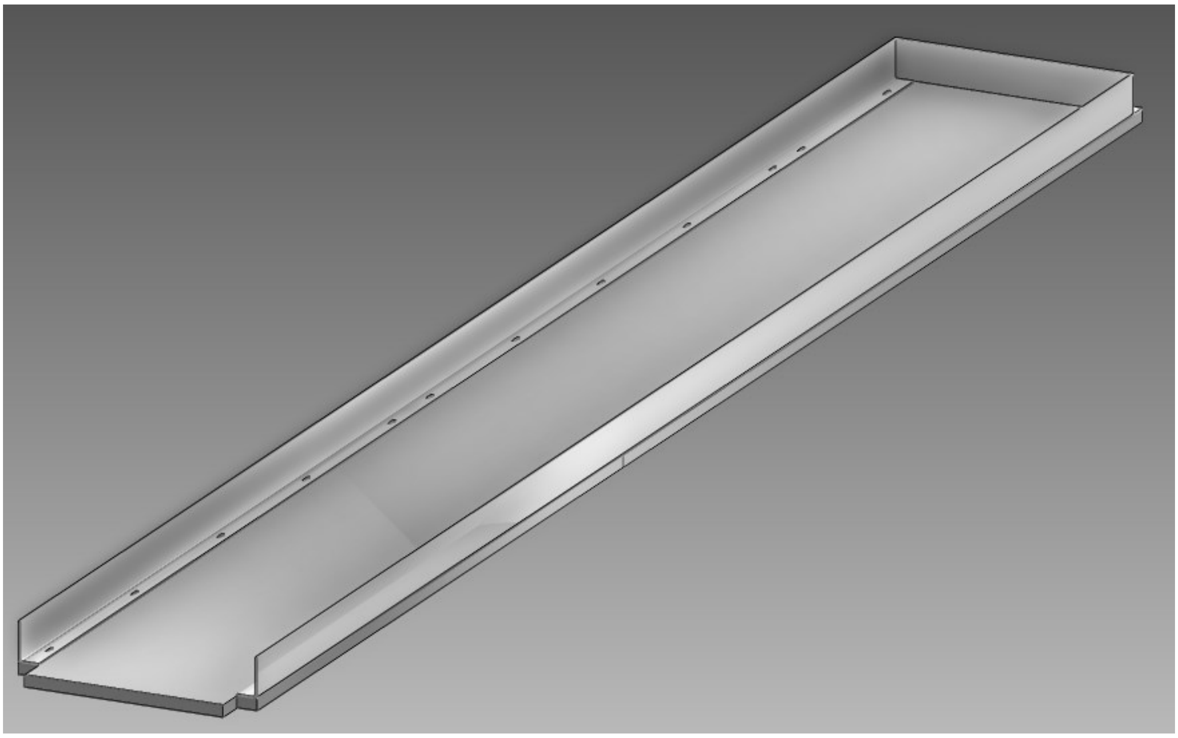


Figure 20 Completed walkway

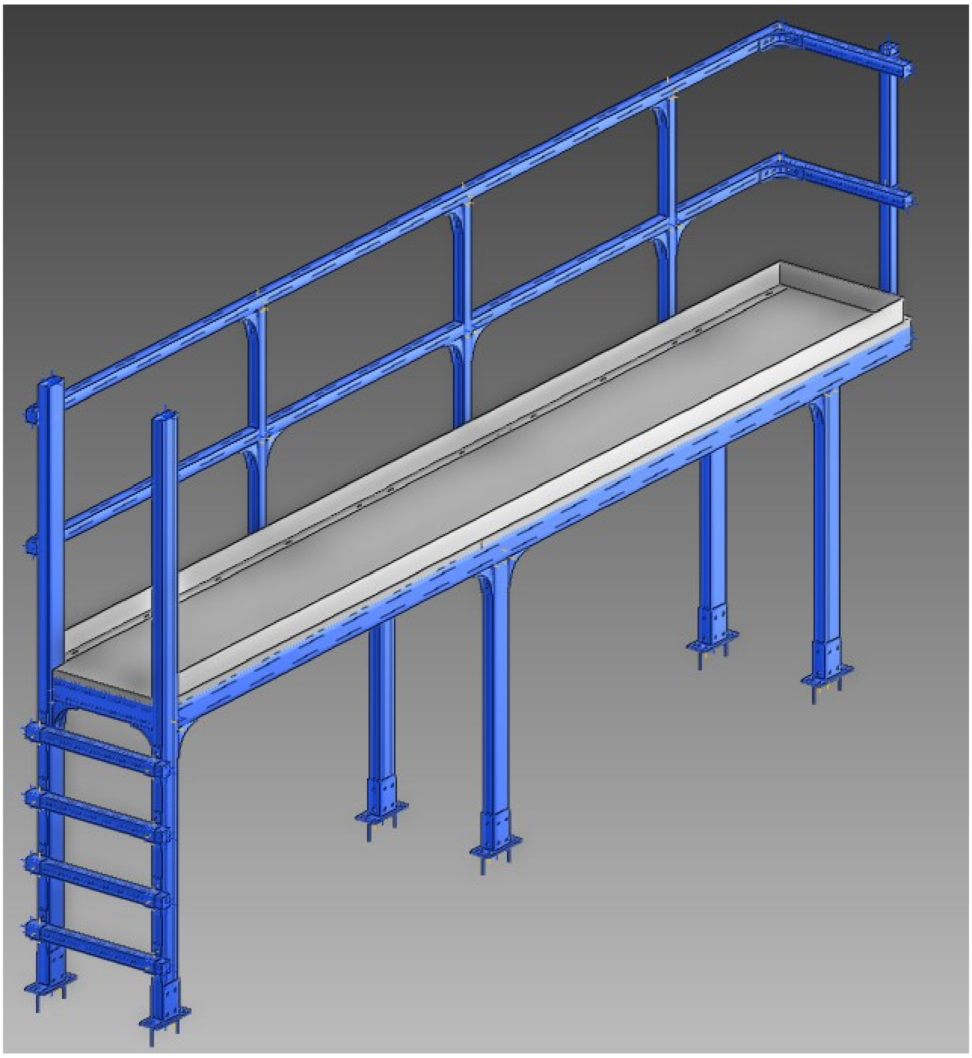


Figure 21 Final platform with gratings and kickplates

5.5 Hilti calculations

With Hilti's software, the strength of the frame and the stairs were calculated. The calculation software uses EN 1993 as the Design base and EN 1990 as the load combination design base. For the calculations a weight of 2 kN/m^2 was converted to line load acting on the frame and ladder. In Appendix 2 the result of the calculation is shown. We can see that most of the parts of the design have a low ULS percentage. A low ULS percentage means that the part is not fully utilized and could handle more weight.

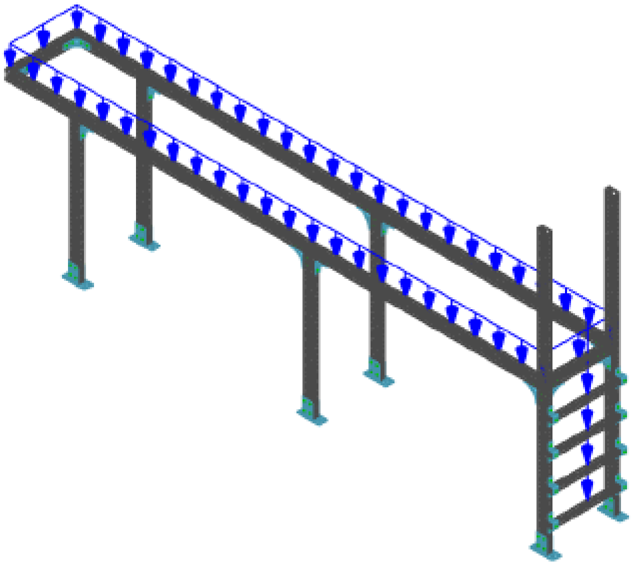


Figure 22 Load-points on the frame and ladder

6 Conclusion

The main goal of this thesis was to design a platform for the OWT unit that is standardized, requires no hot work, and can be easily assembled or disassembled. The customer can then decide if they want the platform as an option when ordering an OWT unit. With the platform installed, it will be easier to access certain parts of the OWT unit and facilitate maintenance.

Before the design stage, research about the design process and the standards needed for a platform design was conducted. A challenging part of the research was to keep track of all the various requirements in the different SFS-EN-standard documents. Notes were made of where in the documentation to find the applicable standards for this kind of construction. The construction's structural plans were also modified during the planning and design stage, meaning different standards had to be followed.

The most time-consuming aspect of this thesis work has been the design part of the platform. When it comes to the design of construction, there are many minor issues that are unknown before the design has begun. If I for example want the platform to be 4800 mm long, I created the beam 4800 mm and later realize that when the stanchion for the guard rail is added it adds another 50 mm to the total length of the platform. These issues can often easily be solved in the 3D design, the biggest challenge is that the design must be made so that it is possible to construct. An example of a small issue I faced where I had to figure out how it was done practically was when designing the rear small kickplate, it had to be placed so that the lower half faced outwards instead of inwards to not create gaps between the kickplates on the side. It could have been placed in the other direction with more modifications, but we decided against it to minimize the work on the component. When designing the kickplates I also had to consider whether we could use the same stud and fastener to fasten both the kickplate and the grating. Which was possible.

With this design, it is now possible to assemble the platform without any hot work. With the Hilti components, MT-TFB bolts, and a drill it is possible to assemble the whole frame of the platform. To attach the grating and the kickplate different studs and fasteners must be used. I would have wanted to only use Hilti's own product portfolio for every component in the design, but unfortunately, their gratings were not according to SFS-EN standards which were a requirement for the design. According to SFS-EN, floorings above a place where people are opposed to the occasional passage must have an opening so that a ball with a diameter of 20 mm cannot fall through. There are valves on the OWT unit that are placed under the platform, and people will have to access these from time to time. Because of that, this standard must be applied to the grating. For Hilti to now provide a platform they must find a new supplier for the gratings and kickplates.

6.1 Comparison of a standard constructed platform

When comparing the platform made from Hilti components to a regular platform, the ordering price of the Hilti platform is higher than that of the original one. The price of the Hilti platform is around 330% more expensive than a regular one. This was expected, it was planned that the Hilti platform would be cheaper to assemble than a standard one. There is no exact data on the manhours it exactly takes to construct the Hilti platform, but it is expected to be way less than a regular platform. To assemble a regular platform there is also more expertise needed, such as a welder, compared to what is needed when assembling the Hilti platform.

Hilti's platform also supports flexibility better than a regular platform. Parts can easily be moved and attached differently on Hilti's platform to create variation in the design, note that doing this can cause the platform to not follow safety regulations. For a regular platform, a new design must be made if small changes must be made, but with the Hilti platform, these changes can be possible to do with the existing parts.

6.2 Further development

The supply chain of the platform could be researched more to get a better understanding of how the components are manufactured. With that information, the design could be changed to save more material and reduce cost. I would like to see the platform designed with standardized parts only. Now the gratings and kickplates need to be cut before delivery. Every part of the platform that must be modified and is not standardized creates a higher total cost of the platform.

Hilti's calculation also gave a low ULS percentage on many parts. This means that the parts could be utilized more. It could be researched what parts to switch out to smaller parts to be able to utilize more of the construction. Switching the parts to smaller ones would also minimize the cost of the platform.

Different standardization bodies, such as OSHA, could be researched and the platform design could be altered to comply with such. This would result in the platform being sold in different geographical regions without having to change the design every time a customer from a region that follows different standards orders a platform.F

6.3 Comments

During the thesis work, I have gained a lot of knowledge in design, and its complexity of it. Everything from standardization to all the small things that must be considered when designing a product has made me realize the difficulty of it. The challenging part of this thesis work has been the design work. With no previous knowledge of the software used for the design, I had a rough time getting started. I have learned a lot regarding E3D and design, and this experience is something I can keep building upon and hopefully use in my career as an engineer.

7 References

Aveva. (2021). *AVEVA™ E3D Design.* Aveva.com.

Childs, P. (2003). Mechanical Design. In P. Childs, *Mechanical Design* (p. 373). Elsevier Science & Technology.

Citec. (2024). *Citec, about us*. Retrieved from Citec: https://www.citec.com/about-us/

Finnish Standards Association. (2016, July 1). SFS-EN ISO 14122-2:2016. Helsinki, Finland.

Finnish Standards Association. (2016, July 1). SFS-EN ISO 14122-3:2016. Helsinki, Finland.

Finnish Standards Association. (2016, July 1). SFS-EN ISO 14122-4:2016. Helsinki, Finland.

Hilti. (2023). *MT system product portfolio.* Hilti Corp., Schaan.

Hilti. (2023). *Technical handbook MT system.* Hilti.

Khandani, S. (2005). *ENGINEERING DESIGN PROCESS.*

Mats Björs, Brandskyddsföreningens Service AB. (2024). *Allmänt om heta arbeten*. Retrieved from Heta Arbeten: https://www.hetaarbeten.se/sv/faq/allmant-om-heta-arbeten/

Mital, A., Anoop, D., Anand, S., & Aashi, M. (2008). *Product Development: A Structured Approach to Design and Manufacture.* Elsevier Science & Technology.

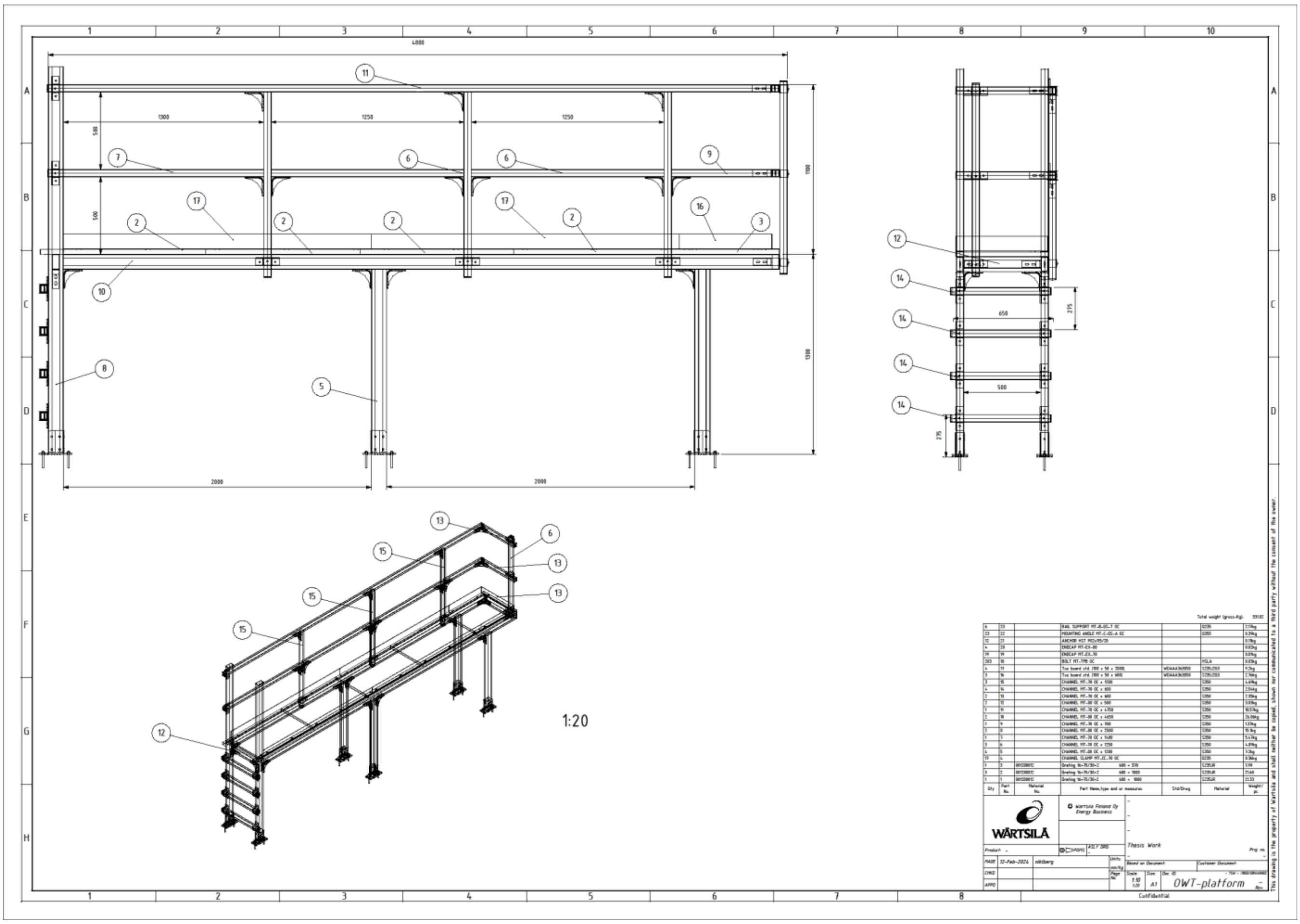
SFS. (2023). *FINNISH STANDARDS ASSOCIATION SFS*. Retrieved from FINNISH STANDARDS ASSOCIATION SFS: https://sfs.fi/en/what-is-a-standard/

Wärtsilä. (2024). *The History of Wärtsilä*. Retrieved from Wärtsilä: https://www.wartsila.com/about/history

Wärtsilä. (2024). *This is Wärtsilä*. Retrieved from Wärtsilä: https://www.wartsila.com/about

APPENDICES

Appendix 1. Assembly drawing of the platform



Appendix 2. Hilti's calculation results of the platform

5 Results

5.1 Calculation summary

5.1.3 Members

No	Member	Governing load combination number*	ULS [%]	SLS [%]	Status
1	MT-80	004b-ULS	2.85	-	OK
2	MT-80	004b-ULS	3.43	-	OK
5	MT-80	004b-ULS	2.19	-	OK
6	MT-80	004b-ULS	3.03	-	OK
7	MT-80	004b-ULS	32.43	-	OK
9	MT-80	001b-ULS	0.26	-	OK
85	MT-80	004b-ULS	32.15	-	OK
86	MT-80	004b-ULS	4.94	-	OK
87	MT-80	004b-ULS	5.76	-	OK
88	MT-80	004b-ULS	0.79	-	OK
89	MT-70	004b-ULS	15.03	-	OK
90	MT-70	004b-ULS	15.02	-	OK
91	MT-70	004b-ULS	15.03	-	OK
92	MT-70	004b-ULS	15.05	-	OK
102	MT-70	004b-ULS	1.99	-	OK
103	MT-70	001b-ULS	1.79	-	OK
104	MT-70	001b-ULS	2.31	-	OK
116	MT-70	004b-ULS	1.85	-	OK
125	MT-70	004b-ULS	4.22	-	OK
126	MT-70	004-SLS	2.53	85.48	OK

5.1.2 Base Connectors

No	Base connector	Governing load combination number*	ULS [%]	SLS [%]	Status
1	MT-B-GS T OC	004b-ULS	1.71	-	OK
3	MT-B-GS T OC	004b-ULS	3.92	-	OK
6	MT-B-GS T OC	004b-ULS	2.14	-	OK
8	MT-B-GS T OC	004b-ULS	3.70	-	OK
10	MT-B-GS T OC	004b-ULS	9.63	-	OK
13	MT-B-GS T OC	004b-ULS	9.87	-	OK

5.1.3 System Connectors

No	Connector	Governing load combination number*	ULS [%]	SLS [%]	Status
2	MT-C-GS A OC	004b-ULS	39.05	-	OK
4	MT-C-GS A OC	004b-ULS	5.76	-	OK
5	MT-C-GS OC	004b-ULS	8.52	-	OK
7	MT-C-GS A OC	004b-ULS	25.37	-	OK
9	MT-C-GS A OC	004b-ULS	4.06	-	OK
11	MT-C-GS OC	001b-ULS	3.94	-	OK
15	MT-CC-70 OC	004b-ULS	20.41	-	OK
16	MT-CC-70 OC	004b-ULS	20.30	-	OK
17	MT-CC-70 OC	004b-ULS	20.56	-	OK
18	MT-CC-70 OC	004b-ULS	21.41	-	OK
21	MT-CC-70 OC	004b-ULS	20.41	-	OK
22	MT-CC-70 OC	004b-ULS	20.30	-	OK
23	MT-CC-70 OC	004b-ULS	20.56	-	OK
24	MT-CC-70 OC	004b-ULS	21.41	-	OK
25	MT-CC-70 OC	004b-ULS	41.64	-	OK
26	MT-C-GS A OC	004b-ULS	23.26	-	OK
27	MT-CC-70 OC	004b-ULS	39.56	-	OK

Version: 1.13.1

Solution: OWT_platform_ladders_600mm-thesis

Date: 01/03/2024

No	Connector	Governing load combination number*	ULS [%]	SLS [%]	Status
28	MT-C-GS A OC	001b-ULS	19.40	-	OK
29	MT-CC-70 OC	001b-ULS	16.20	-	OK
30	MT-C-GS A OC	001b-ULS	31.28	-	OK
31	MT-CC-70 OC	001b-ULS	50.19	-	OK
32	MT-C-GS A OC	004b-ULS	20.34	-	OK
33	MT-CC-70 OC	001b-ULS	49.51	-	OK
34	MT-C-GS A OC	001b-ULS	39.42	-	OK
19	MT-C-GS A OC	004b-ULS	48.50	-	OK
20	MT-C-GS A OC	004b-ULS	60.51	-	OK
20	MT-C-GS A OC	001b-ULS	14.89	-	OK
19	MT-C-GS A OC	004b-ULS	7.02	-	OK

***004b-ULS:** SW_sup + Design Loads . Respective Combination Equation: 1.35 * LC1 + 1.00 * LC7

***001b-ULS:** SW_sup (Support Only) . Respective Combination Equation: 1.35 * LC1

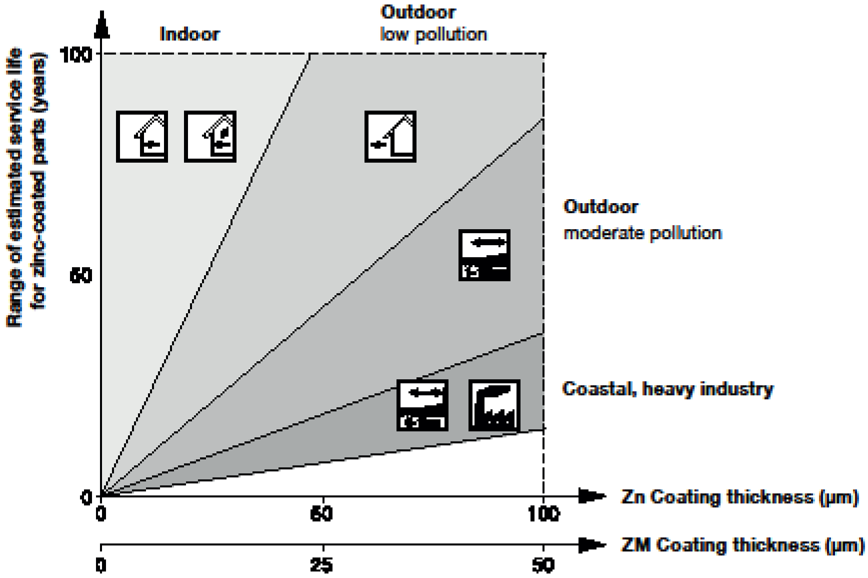
***004-SLS:** SW + Design Loads . Respective Combination Equation: 1.00 * LC1 + 0.70 * LC7

Overall Status: Calculation OK, design criteria met!

Appendix 3. General information on corrosion protection (Hilti, 2023)

Technical Notes

GENERAL INFORMATION TO CORROSION PROTECTION



HILTI CORROSION RESISTANCE			
Hilti Corrosion Resistance	INDOOR COATED	OUTDOOR COATED	OUTDOOR PLUS
Corrosion class/ min. lifetime	C1 > 50 years C2 > 20 years	C3 > 25 years C4 > 15 years	C5 > 15 years (ask expert)
Corrosion environment	low-moderate	moderate-high	high-extreme

Hilti's installation systems are supplied in various coating technologies to meet the requirements in all conditions:

Hilti System	Indoor coated	Outdoor coated		Outdoor Plus	
	Zn	HDG Zn	HDG ZM	S A2	S A4
MT-Profiles	X		X		
MT-Components	X	X			

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