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Creation of Port Maintenance Application Prototype

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The purpose of this thesis was to develop a BIM based application prototype for the maintenance of ports.

In order to achieve the goal, a research phase was carried out to understand port maintenance and its importance. The Port of Kilpilahti was chosen as a case study for this thesis, where a better understanding of the current maintenance management situation was acquired. A visit at Port of Kilpilahti and comprehensive online research gave as a result a list of software related to the subject. The software tools were analyzed, and some weaknesses were found. Moreover, it was found that there was room for general improvement in the digitalization of port maintenance.

With all the information acquired, the project proceeded consequently to the design phase. First, 3D models of the case study were created, followed by the design of the application prototype itself. The result was a sequence of photoshopped images that recreate screenshots of the application prototype throughout its layouts, options and tools. The created prototype has the potential to be developed to be a sustainable and comprehensive port management tool.

Keywords	port, maintenance, prototype, application

Contents

List of Abbreviations

BIM	Building Information Modeling.
Dwt	Deadweight tonnage. A measure of how much weight a ship can carry.
HAT	Harbour Administration Technology
TBL	Triple Bottom Line. Sustainability framework divided in three parts: social, environmental and financial.

1 Introduction

This thesis explores the creation of a BIM (Building Information Modeling) based prototype application, developed for the maintenance management of ports. This topic was chosen in collaboration with the CEO of engineering office Matti Pitkälä Oy, Mr. Tommi Pitkälä and the representative of Neste Oyj, Mr. Heikki Tegelberg, the Logistic Manager at the Port of Kilpilahti. The original idea was suggested by Mrs. Riitta Kajatkari, expert in port management and the previous technical director at the Port of Kotka.

The original idea was to create a multidisciplinary and comprehensive application for the full management of ports in all their aspects, such as logistics, environment and maintenance. During the development of the project, together with the Port of Kilpilahti, the project focused on the maintenance aspect. In fact, the topic of this thesis was chosen because of the current lack of BIM based software that would be specifically designed for maintenance management in the marine environment. Moreover, during the research phase, the marine sector was still found to be in the developing phase concerning digitalization.

The Port of Kilpilahti was chosen as a case for this thesis. In Kilpilahti, a better understanding of the current maintenance management situation was acquired, along with the basic requirements for this project. Moreover, a research of the status of the marine sector and products available on the market was carried out. With the information acquired, the project proceeded to the design phase. First, 3D models of the Port of Kilpilahti were created, and finally the application prototype itself was designed. The objective of this final year project was to provide Neste Oyj, Mrs. Riitta Kajatkari and Mr. Tommi Pitkälä with the prototype.

This thesis is divided in five chapters. Following the Introduction, chapter 2 provides an overall description of ports, their importance, the importance of proper maintenance and the need of a digital management tool, and finally the connection between maintenance and sustainability. Chapter 3 focuses on the studied case, the Port of Kilpilahti, giving general information about the port itself, the working structure, the software in use for port management and problems related to the maintenance management and their software. Moreover, chapter 3 explores the results of the research that was carried out in order to find the related applications available on the market. Chapter 4 concentrates on the creation of the prototype, the phases of the creation, the goals and requirements, and the final product delivered. Chapter 4 also explains in detail the layout and functionalities of the prototype. The chapter continues by showing the benefits of the prototype and suggests possible future developments. Finally, chapter 5 concludes this thesis by summarizing the outcome of the project.

2 Ports and Their Importance

Ports and harbours have played an important role throughout human history, enhancing the possibilities of commerce and the development of civilizations. As humans have a tendency to establish themselves near water, ports have always been of great importance in every corner of the world. In the modern world, ports are still as important as a big part of the economy of every country, in fact around 90% of the global cargo, according to Dwarakish, is transported by ships. [1.]

Besides their economic function, sustained by the transportation of cargo, raw materials and passengers, ports also have an important social function as big suppliers of jobs [1]. Another global aspect that touches ports directly is the environment. Since ports are big players in the production of greenhouse gases, it is important that environmental regulations must be applied. For example, in Finland, every port must go through Environmental Impact Assessment (EIA) procedures and receive an environmental permit. On top of it, many ports have voluntary environmental management systems. [2.]

Because of the increasing volumes of cargo, ships are also becoming bigger and ports need to answer the market demands by expanding their areas, deepening the sweeping levels and building or expanding jetties. By jetties are defined structures where a ship can be moored. Mooring means to secure a ship to the land. Jetties are also called piers when they protrude from the land to the sea, or quays when they are parallel to the shore. Sweeping level is the height of the jetty, defined by the distance between the bottom of the sea and the edge of the land. The deeper the sweeping level is, the bigger the size of the ship, that can be moored to that jetty. [3.]

The lifecycle of ports can be divided into three phases: an initial phase that includes planning and construction, a second phase of utilization of the port, and an end phase of the demolition or reutilization of the premises. It is easy to understand that the first and last phases are relatively short compared to the second phase. In fact, a common life span for a modern concrete jetty varies from 50 to 100 years for. Economically, socially and environmentally the use phase is the longest and heaviest phase. Moreover, during their lifetime, ports are constantly under the attack of natural forces and activities related to loads that can damage and deteriorate structures, with the ultimate consequence of diminishing their lifetime. It is therefore important to maintain, repair and modernize structures well in order to properly perform throughout their lifetime. [4.]

The structural materials mostly used in water structures are concrete, steel and timber. The harsh marine environment affects these materials in different ways [4]. Since most modern Finnish ports are built with reinforced concrete, this material should be paid a particular attention. Appendix 1 of this thesis explains the most common causes for the degradation of concrete in marine environment, and appendix 2 explains the most commonly used maintenance solutions.

When discussing maintenance, it is important to understand that its purpose is not just to maximize the lifetime of the port, but also to minimize costs and improve safety. When preventive maintenance schedule is implemented, it is possible to notice a reduction of unexpected failures. On the other hand, preventive maintenance means that more time is spent for inspections and repair operations, which have an impact on the busy port activities. Therefore, it is important to find a balance between the cost of preventive maintenance and the cost of having a disruption of activities due to a breakdown of some assets. [5.]

In the modern world, the number of digital solutions that can help to achieve the optimal balance between preventive maintenance and disruption of activities grows constantly. On the other hand, digitalization in the marine sector has had a slow start, due to conservative and traditional reasons. Moreover, the storing of information and digital development are still not considered a priority by many ports. Nevertheless, real-time monitoring is one of the key aspects for a port management progress. Therefore, specific tools for ports are needed. [6.]

Digitalization is also used as a tool to achieve sustainability, an often used term nowadays, since the world needs practical solutions that can fight global problems, such as climate change. But what is sustainability? The World Commission on Environment and Development defined sustainable development as the development that satisfies the needs of the present generations without compromising the possibility for future generations to satisfy their needs [7]. More specifically, the developments touch three important global aspects: Economy, Environment and Society. These three aspects are grouped together and called the Triple Bottom Line (TBL). [8.]

When looking closely at the concepts of maintenance and sustainability, it is possible to see that they are directly linked. In fact, proper planned maintenance can reduce both costs and energy consumption, which has an impact on the economy, the first part of the TBL. The assets when well-maintained, can last longer, and the amount of waste can be reduced, which is beneficial for the environment, the second part of the TBL. Safety is also increased when assets are properly maintained, improving the morale of the employees and the reputation of the company, aspects that correlate with society, the third and last part of the TBL. [9.]

During the final year project, sustainability and the TBL were taken into account among the requirements. One of the reasons for this, is the fact that the owner of the Port of Kilpilahti, the case studied in this thesis, is Neste Oyj. Their sustainability report of 2018 states that the company aims to be more and more sustainable in the future [10]. In fact, throughout its existence, Neste has developed from a solely oil refinery company to the largest producer of renewable diesel in the world [11].

Looking at the financial statement of Neste, it is possible to see that in the year 2018 alone, 159 million euros were invested in renewable products. On the other hand, bigger numbers are found in maintenance investments, with 253 million euros spent in the same year. This comparison shows how important maintenance is for a company like Neste that has sustainability as one of his main goals. [12.]

Because of the close correlation between the concepts of maintenance and sustainability, it is possible to also link the application prototype created in this thesis with sustainability. In fact, the application prototype aims to improve planned maintenance.

Therefore, it can help to save money, reduce waste, human errors, and also to improve safety; all aspects that are related to the TBL.

3 Port of Kilpilahti

The Port of Kilpilahti, owned by Neste Oyj, is located in the southern part of Finland, near the city of Porvoo, just a 40 minutes' drive from the capital, Helsinki. The port serves as a gateway to the industrial area of Kilpilahti, where Neste Oyj has its own refinery.

Figure 1. Aerial view of Kilpilahti industrial area and part of its harbour [13].

The Kilpilahti website states that, the area is the home to many other companies besides Neste Oyj, which mainly produce normal and renewable fuels, such as: AGA, a company that produces gas products, Bewi Styrochem Oy, which produces insulation materials, Borealis Polymers Oy, connected with the production of chemicals and plastic fabrication, Veolia Oy, water, waste management and energy services, and VR Transpoint, company connected with transportation. The all area is over 13.5 km^2, making it the biggest chemical area in northern Europe. As can be seen from figure 1, the area is quite extensive. In total there are 11 companies and around 3,500 workers in the entire area. In addition, there are hundreds of contractors, with a few thousands more people involved in working activities. [14.]

The following information in this chapter were acquired during an interview with Mr. Heikki Tegelberg, manager of Kilpilahti Harbour Logistics, that took place at Kilpilahti harbour office on the 11th of July 2019.

In figure 1it is also possible to see part of the harbour and some of its jetties. The port has a total of nine jetties and two passage channels. The main channel is 15,3 m deep. The depth permits a safe passage to all ships that can sail into the Baltic sea from all over the world, since the channel between Sweden and Denmark has the same depth. The second channel has a depth of 9 m. The average depth of the vessels coming to Kilpilahti is around 8 m. [15.]

The Port of Kilpilahti has an average of 1,300 port calls annually. This number makes it the second busiest port of Finland after the full complex of the Port of Helsinki, which includes many sub-ports. The port activities result with an average of 25 million tons of cargo exchanged per year. With this number, the Port of Kilpilahti is the first in Finland. As far as Mr. Tegelberg knows, all the other south eastern Finnish ports, such as Helsinki, Hamina-Kotka and Loviisa, have about the same weight of cargo exchange per year combined. He also added that the planning of arrivals of ships is done with a maximum of two weeks' advance notice, which is quite a short notice considering the high traffic at the harbour. [15.]

The vessels coming to Kilpilahti usually belong to class 150 dwt (deadweight) which means the weight of the empty ship expressed in tons, and sometimes as big as 200 dwt. Most vessels come in with a full load of crude oil for the Neste Oyj refinery, 90% of crude oil coming from Russia. The port also exports the final products from the refineries to other Finnish ports. The Kilpilahti industrial area is the biggest Finnish producer and exporter of sulfur products. In the interview, Mr. Tegelberg also added that the Neste Oyj spend an average of ten million euros per year on harbour maintenance, excluding investments. [15.]

3.1 Kilpilahti Harbour Working Structure

The total amount of workers at Kilpilahti industrial area is 3,500. Of them,1,800 work for Neste Oyj, 400 of them work in activities related to maintenance, and 100 of the 1,800 operators work directly at the harbour. Normally, 14 operators, 13 plus one supervisor, are present at the harbour all through the period of a 12-hour working shift. During a shift, the operators take care of the mooring of the incoming ships and the safety of the mooring operations. The operators are also involved in the exchange of items needed from the harbour to the vessels. [15.]

The 100 harbour operators are not connected with any sort of maintenance of the harbour structure and assets. The workers that work with maintenance operations are under the Department of Assets Management that is part of the organization of Neste Oyj refinery. The maintenance workers that are assigned to the harbour take care of the immediate problems at the harbour facilities. They also take care and prepare the areas before certain operations can be carried out, for example, they might ensure that a pipeline is empty before an inspection can be done by a contractor. For the purpose of this thesis, it is important to underline that the maintenance workers do not do of any preplanned maintenance activities. [15.]

3.2 Software in Use at Kilpilahti

It is relevant to know that, at the time of the interview, it was in program a change of software that would have gradually happen in the whole Kilpilahti area. The process started in 2017 and is to last for five years. The new system has an estimated cost of 300 million euros. The aim of the change is to gather all applications under one centralized system called SAP so that all Neste Oyj facilities around Finland would use the same software. The port of Naantali has already implemented the new system. According to Mr. Tegelberg, SAP would be a text-based application without any sort of 3D visualization. Nevertheless, the situation by the time of the interview at Kilpilahti was that the main applications were still separated. [15.]

Five computer programs are used at the harbour:

- HAT
- JAWA
- METSO
- Tamburi
- M+

They are all specifically tailored for the harbour of Kilpilahti [15].

HAT (Harbour Administration Technology) is an application that is used for controlling and bookkeeping all vessel operations. It registers everything that is exchanged between the harbour and the vessels and vice versa. It is instantly updated and records the details of every activity. It also records the time of the operations, and the data can be used to improve the planning of future operations. The software stores the information in text format. [15.]

JAWA is a software that is used for the communication between the harbour and the refinery. Therefore, it is not only used by the harbour operators, but also by the refinery operators [15].

METSO is an application that is used to control the automations of the pipelines that run from the harbour to the refinery. It also shows the pipelines or valves malfunction. METSO is the only software with a graphical visualization of the harbour and pipelines. [15.]

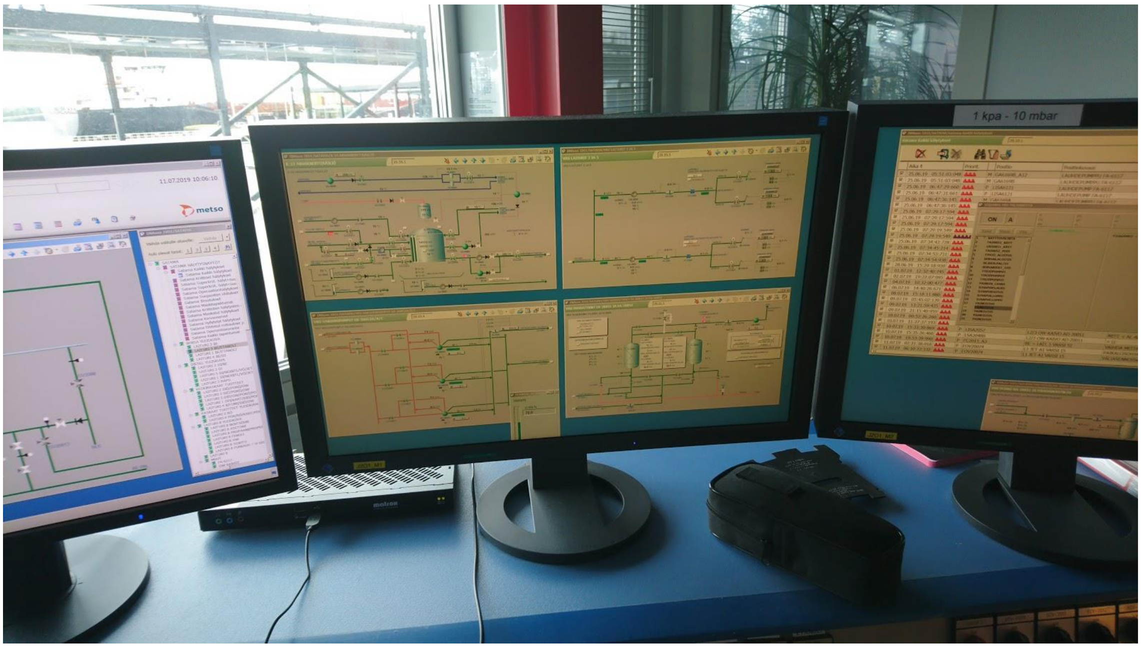

Figure 2. Graphical visualization of the pipelines used by the METSO software [15].

As shown in figure 2, METSO uses 2D visualization of the pipelines, tanks, valves and the connected components.

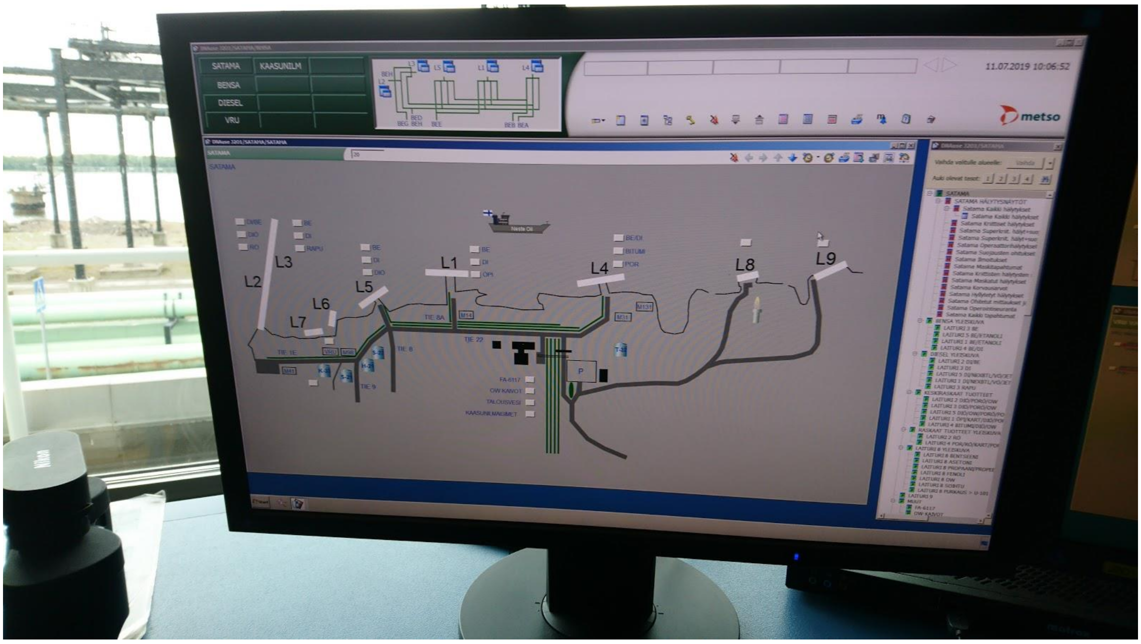

Figure 3. Graphical visualization of the jetties by the METSO software [15].

Figure 3 shows the visualization of the harbours and its jetties. The letters L with the numbers stand for the word laituri, Finnish for jetty, pier or quay. The number shows the number of the jetty. As for JAWA, the software is also used in the refinery. [15.]

Tamburi is a text-based application that is used for the exchange of information, for activities between different departments of the refinery and harbour, such as snow work, sand removal, moving furniture or assets from one department to another one, and so on [15].

M+ is an application used for maintenance management. Therefore, it is the most relevant for this thesis. The main function of the software is the bookkeeping of work permits, work permits applications, maintenance jobs that need to be done, spare parts lists and contractors information. The application is divided into four parts: work permits, ongoing work orders, orders of materials to the warehouse and reports of broken assets. [15.]

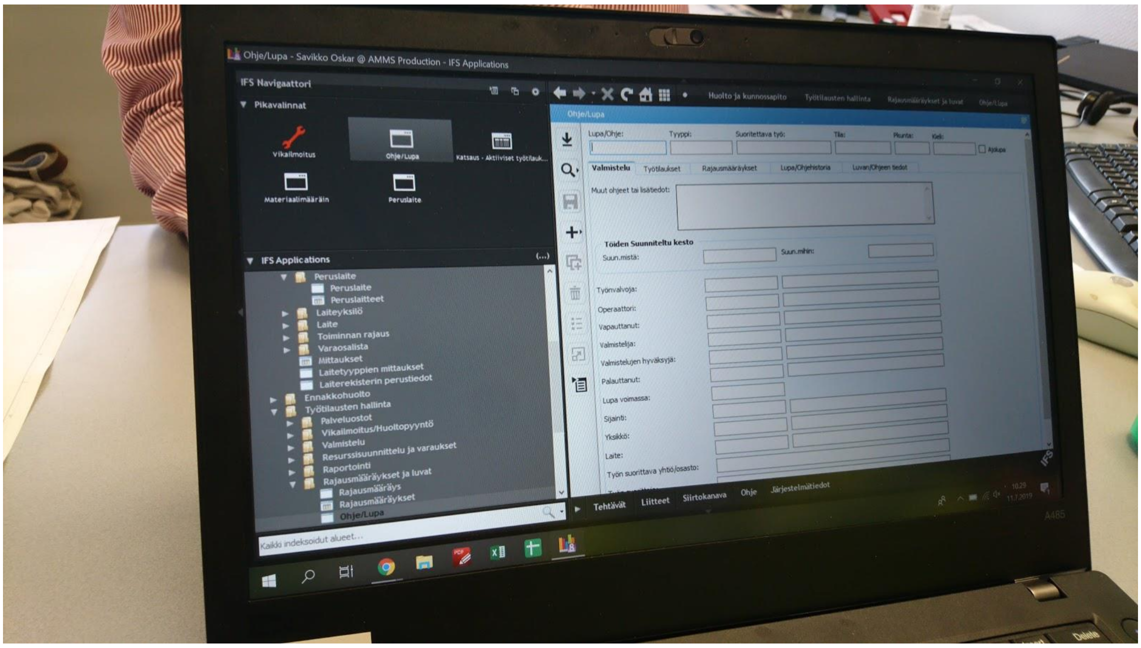

Figure 4. A screenshot of the maintenance software M+ [15].

As shown in figure 4, M+ is a text-based application and does not offer any sort of 2D or 3D visualization. The following chapter will describe the weaknesses of M+ according to Mr. Tegelberg in more detail.

3.3 Weaknesses of M+

As previously mentioned, M+ is a text-based software without any kind of 2D or 3D visualization. Because of this, there is no location information of the different assets or maintenance jobs to be done. According to Mr. Tegelberg, most of the time the only location information is a generic specification of which jetty is involved in the job. The operators must often use large, A1-sized printed technical drawings together with M+ in order, for instance, to see where the job has to be done. The use of the large printed drawings is considered to be a slow and difficult operation because the drawings are usually full of extra details, complicated to read and, furthermore, not updated. According to Mr. Tegelberg, this can easily lead to delays and mistakes. [15.]

Another problem with M+ is that it can be very generic when it comes to the assets break down list, for example, a whole building, that include thousands of different assets like lamps, furniture and so on, can be listed as one asset, similarly it would be for a very specific spare part of a pump located on a very specific place. The M+ software it mostly used for the maintenance of the pipelines that run from the harbour to the refinery. Specific marine assets, like fenders or bollards, are not listed in M+, and as previously explained, a jetty can be seen in M+ simply as a whole asset, without any break down. [15.]

According to Mr. Tegelberg, it would be very helpful for the users of M+ to have the possibility to visualize the harbour structures and assets in 3D. This would decrease human error and boost the efficiency of the maintenance [15].

3.4 Maintenance Related Problems at Kilpilahti Harbour

For the purposes of this thesis, it is important to know that most of the jetties at Kilpilahti were built between 1965 and 1977. Therefore, they are now reaching the end of their lifetime. In order to keep the jetties functional, major maintenance has to be carried out. At the moment one of the biggest issues is that there is no system or schedule for preplanned maintenance of the structures. [15.]

As previously stated, another issue is the lack of an application that would be based on a 3D model. According to Mr. Tegelberg, Neste Oyj owns some 3D models based on point clouds of certain areas of the refinery and pipelines, but they are not used for any maintenance purposes. A 3D model of the pipelines and structures would be useful, not only for maintenance planning in an office but also on the field, used on tablets. This would clearly improve the users' knowledge of current maintenance situations. [15.]

Mr. Tegelberg also stated that a big recurring problem is the lack of communication between the personnel. In fact, there is no comprehensive system for the exchange of information between the teams from shift to shift. This clearly leads to human errors that could be avoided. The system in use is simply notes in written text form and most of the time, only big issues on assets are written on these notes without any detailed information. A simple way to improve this would be the possibility to exchange visual information, like pictures, from one team to another. [15.]

3.5 Systems and Software Available on the Market

Acknowledging that the Kilpilahti harbour was just one of the ports that is facing the previously mentioned challenges, a comprehensive web search was conducted in order to find what solutions are available on the market. The three best results of this search are described below.

The first solution encountered was a series of software called Port Forward that the Port of Rotterdam in the Netherlands advertises on its website. According to the website, Port Forward is a complete tool that manages port operations more efficiently, reducing costs and increasing safety. [16.]

Of the different tools offered, Port Asset Tooling seems the one that meets the objectives of this thesis best. The Port of Rotterdam webpage states that their tool includes deterioration models for the jetties and assets, database with complete information of the assets and maintenance schedules. These aspects are, in fact, key factors for this project. Unfortunately, after many attempts to communicate with them, it was not possible to acquire more information than what is stated on their website. [17.]

The second solution found was a database for harbour maintenance from the Swedish company MTE, part of MarCon group. On their website, MTE state that with their solution, the maintenance departments can be assisted with a maintenance program, plant description, drawings, instructions and analysis of risks. Even though most of the aims of this thesis are fulfilled, this is not a 3D model-based application. [18.]

A third solution found was from the Finnish company VRT. VRT provides solutions for 3D surveys with sonar and laser scan, and 3D data utilization via an online tool called Gisgro [19]. Gisgro is an online 3D visualization tool that allows the user to visualize structures both above and underwater that are previously scanned with sonar or laser technologies. In addition, Gisgro is used for survey, inspection reports and asset management [20]. Fortunately, it was possible to get in touch with the Gisgro team, and for the purpose of this thesis, a trial period of 14 days was consented. Figure 5 below shows a screenshot of the software.

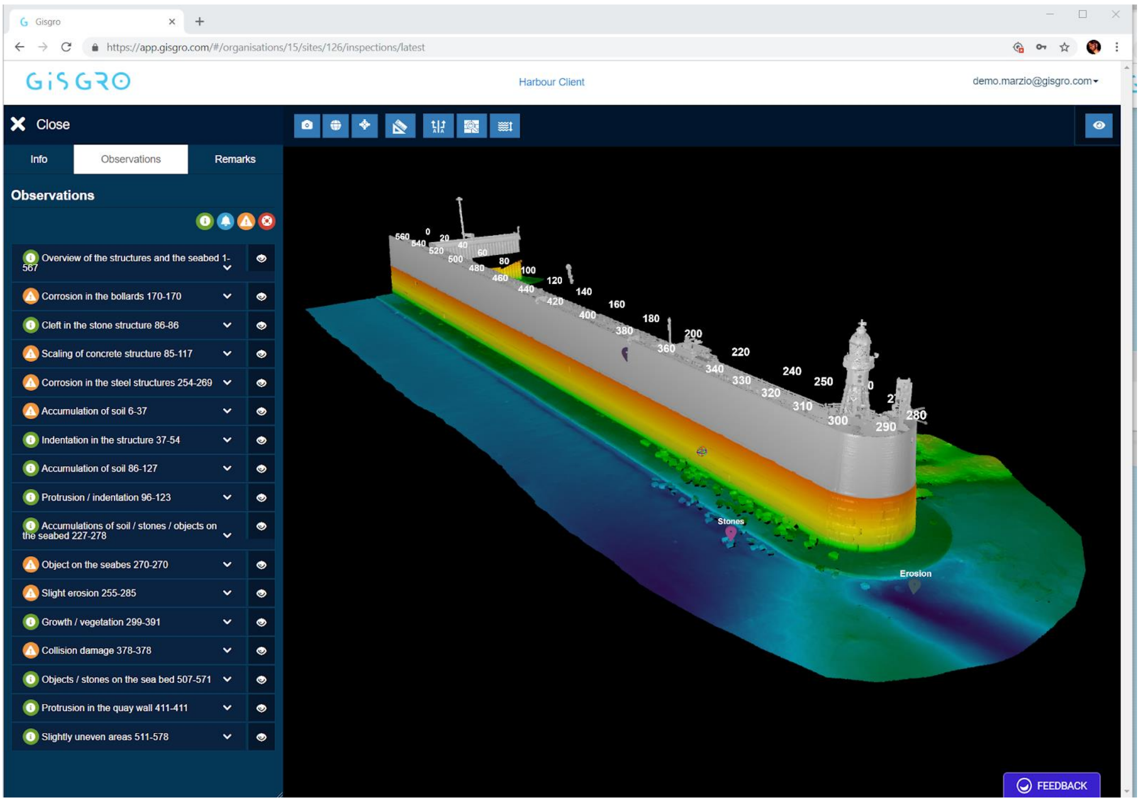

Figure 5. Screenshot of Gisgro taken during the trial period [21].

As can be seen from figure 5, the demo shows a 3D visualization of a pier structure, including the seabed and the assets on top of the pier. On the left side of the screen different observations and alarms are listed. It is possible to visualize the remarks also on the 3D model. Gisgro also offers some basic visualization tools such as cross section, measurements and water level visualization.

Gisgro seems a very good base for the purpose of this thesis. On the other hand, this software uses cloud points that are the product of laser or sonar scans, making it practically impossible to give any sort of extra information to the 3D models of all the different assets and structures present on a jetty. A solid based application would solve this issue.

4 Creation of Application Prototype Based on the Case

Different phases were required during this project in order to achieve the result of the creation of an application prototype. At first, the idea that was given was the creation of an application prototype that would be multi-disciplinary and consider all aspects of a port management, such as logistics, environment and maintenance.

After a preliminary phase where all the aspects were broken down into more detailed parts, it was very quickly possible to understand how big this project would have been. After discussion with this project supervisor Mr. Tommi Pitkälä, it was decided to focus on one aspect of the port management only. When the Port of Kilpilahti was contacted, Neste Oyj showed a particular interest in the maintenance aspect of the original project idea.

A first meeting with the representative of Neste was organized at Matti Pitkälä Oy engineering office, and the main point of discussion was to understand their needs. After that, a second meeting was organized at the harbour facilities of Neste in Kilpilahti with Mr. Heikki Tegelberg, Manager of the Harbour Logistics. During this meeting, general information regarding Neste and Kilpilahti was gathered. Also, specific information regarding their software in use, maintenance related issues and state of their jetties were gathered.

After understanding that no application with 3D visualization was in use at Kilpilahti, the following step was to research what products are available on the market. The research gave some results, which are present in subchapter 3.5, and inspiration for the following steps.

Solid based, detailed 3D models of three jetties present at Kilpilahti were made: jetty 1, 2/3 and 7. In addition, a comprehensive and less detailed 3D model of the whole Kilpilahti harbour was designed. This was done in order to have enough material to work with for the following steps. The creation of the 3D models was carried out with Autodesk AutoCAD and Autodesk Civil 3D. The first was used for the creation of the 3D models, the second for the possibility of exporting those files in the industry foundation classes (ifc) format, a format that is accepted and read by every BIM application. Detailed 3D models were created from the reading of old drawing documents, mainly from the 1970's. An estimated over 200 hours were spent in order to recreate those 3D models. A full list of the files created is shown in Appendix five.

With the help of the research material, supervisor and personal knowledge, a map of how the application should have looked like was drawn. The mind map included all different aspects and options that the new application should have. From the mind map it was then possible to sketch a first layout of the application.

Following, the buttons were designed: some of the images were downloaded from free web databases of images, some were recreated using the images of some already existing software as a reference. In addition, the pop-up option windows were designed, taking as a reference already existing option windows from Autodesk Autocad and modifying them with the help of Microsoft Paint according to the need of the application prototype.

The second step was then to combine all the images and screenshots of the 3D models into the final layout of the application prototype. In fact, the final product of this project was intended to be a sequence of photoshopped layouts of the application prototype that could aid in developing a real application in the future. The software tools used for this step were Microsoft Paint and Corel Paintshop Pro X6.

While proceeding with this step, errors and mistakes were corrected along the way. For example, a button was developed on a second stage, and then added in all the 50 plus screenshots already processed. An estimation of around 80 hours were spent to recreate the photoshopped application layout.

The final step was to create a guideline booklet that would briefly explain the main functionality of the application. The booklet uses some of the images created during the project for better understanding.

The final product was then presented to Mr. Tegelberg, Manager at Neste Oyj of Kilpilahti Harbour Logistics, Mrs. Riitta Kajatkari and Mr. Tommi Pitkälä, CEO at Pitkälä engineering office and positive response was provided for the outcomes of the project.

4.1 Goals and Requirements for Application Prototype

As described in chapter number three, the Port of Kilpilahti is one of the busiest ports in Finland. During the interview, Mr. Tegelberg added that Neste Oyj spend an average of ten million euros per year for the harbour maintenance, excluding the investments. In addition, there are around 400 people involved in daily maintenance jobs in the Kilpilahti area. Understanding the scale of the needs of Neste Oyj was one of the starting points for the development of this project. During the meeting with Mr. Tegelberg, it was also possible to acknowledge that, at current times, there was no pre-planned maintenance schedule. As concluded during the studies presented in Appendix 1 and 2, a proper maintenance schedule can avoid the quick degradation of water structures and, therefore, enhance their life span, making them, in comparison with badly maintained structures, more sustainable. Moreover, the current maintenance software used at Kilpilahti harbour is M+. M+ lacks any kind of visualization, incrementing the possibility for human errors. [15.]

The idea that was developed was not intended to fully replace M+, but to be its visualization implementation. Since the beginning of the project, certain goals and requirements were decided to be of absolute importance for the application prototype. Below, some of the main ones are listed:

- Friendly user interface
- Zoom in/Zoom out interface
- Quick access to the detailed and heavy 3D model files, such as: .dwg or .ifc
- Possibility of giving different properties to different assets
- Fast and clear visualization of broken assets
- Possibility to visualize maintenance schedule, history and timeframe of the structures
- Possibility to quickly contact the responsible person or company for specifics jobs
- Possibility to attach images, drawings and pictures to the different assets or situations
- Possibility to add notes and comments to the different assets

According to the requirements preestablished together with the representative of Neste Oyj, Mr. Tegelberg, a prototype was created. The prototype was subsequently named Port 4D.

4.2 Port 4D, Application Prototype for Port Maintenance Management

This chapter explains in detail all the different functionalities and layouts of the application prototype. The prototype created is visualized as a sequence of photoshopped images that recreate screenshots of Port 4D, exploring its options and tools.

Following the requirements for this project, Port 4D aims to be an inspection and maintenance management application for ports that works on solid based 3D models. The main goal of Port 4D is to have an immediate visual understanding of the current situation of port structures and assets. In addition to the assets, also correlated personnel and contractors can be quickly accessed through the application.

Besides the visualization of the port, with the jetties and assets in a 3D environment, Port 4D uses time as the fourth dimension. In fact, a chronology can be accessed through the application and the port can be visualized in its status throughout its timeline, past, present and future.

The intended user for this application is all personnel that is connected with maintenance activities. For example, a supervisor can visualize the overall status of the port and book necessary inspection or maintenance and maintenance workers can visualize and add different kinds of alerts or modify the status of the alerts once the maintenance job is completed. In addition, an inspector has the possibility to add reports and information related to the inspection directly on the 3D model. The different user rights are defined by the user IDs and passwords. As it is possible to understand, a key factor of Port 4D is the possibility for immediate communication between inspectors, supervisors and maintenance workers.

This subchapter is divided into nine sections, each of them explaining different aspects, tools and options of the application.

4.2.1 Layout

The application layout was made with the Autodesk Autocad as a reference. Figure 6 shows the general layout of Port 4D.

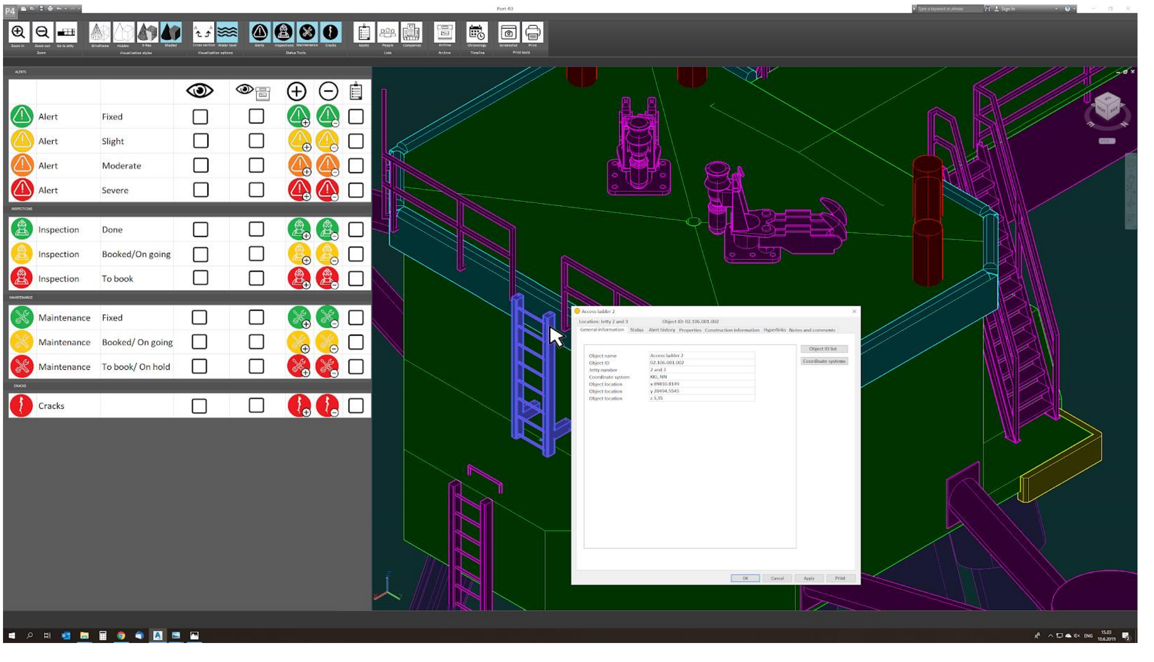

Figure 6. Layout of Port 4D

In figure 6 it is possible to visualize the basic layout of the application. On the top part it is possible to notice the horizontal stripe of the main commands and tools. When tools are selected, their options appear on the left side of the screen. On the central/right part of the screen there is the actual 3D visualization. If an asset is selected, in figure 6 an access ladder, a pop-up options window appears next to the cursor.

On the 3D visualization sector, the central/right side of the screen, there are always two viewing tools visible: a view cube and the coordinate system symbol. The view cube is in the upper left-hand corner of the screen. By clicking on its surfaces, the visualization of the 3D model of the jetty will change accordingly. This is a very useful tool for navigating and checking the 3D model. In addition, the cube also shows the position of the cardinal points. The coordinate system symbol is just a visualization of the three axes and their disposition in the space. The coordinate system is used to locate the different assets in the 3D environment.

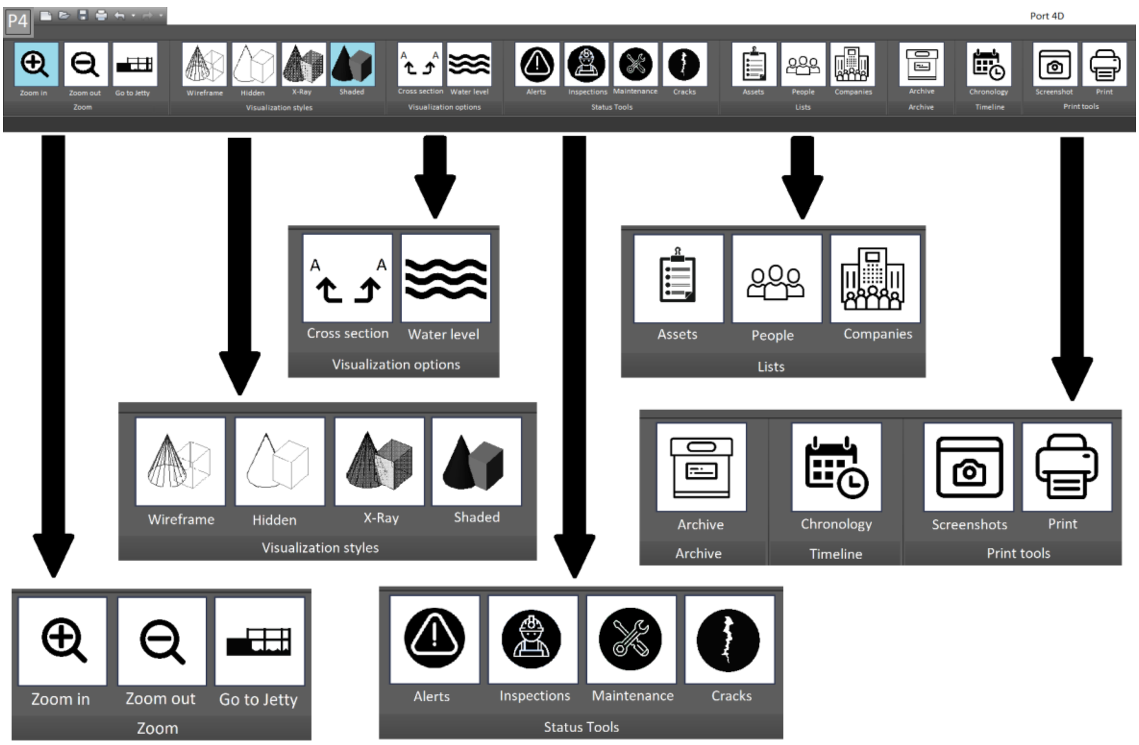

Figure 7. Commands stripe placed in the upper area of the screen and zoomed in groups of commands.

The upper horizontal stripe is the area where all the main commands and buttons are. Figure 7 shows this stripe from a closer point of view. Moreover, as it is possible to notice from figure 7, the buttons are divided in groups. The idea is to have commands with similar functionality in the same group, for a more efficient user-friendly interface. The groups are the followings:

- Zoom
- Visualization style
- Visualization options
- Status tools
- Lists
- Archive
- Timeline
- Print tools

The functionalities of the commands inside the groups are described in subchapters 4.2.4 till 4.2.9.

4.2.2 Solids System

As previously explained, it was very important to use a 3D model with the possibility to give different properties to different items and assets. The solution used in Port 4D is to use solids. Solids can be easily created with software like Autodesk AutoCAD and in other such environments, they can be given different properties. In fact, in Port 4D every solid has its own properties and it can be categorized according to the group it belongs to.

The creation of the solids and therefore the 3D model of the whole port is something that only needs to be done once only for every Port 4D client. When Port 4D is operative, the 3D models can be changed if the reality of the port changes. This has to be done by a professional 3D designer and not by the everyday user of Port 4D.

4.2.3 Object ID

The 3D designer is also the person who has to categorize all the solids present in the port. This operation can be a relatively long one for big ports with a large number of assets, but it is necessary in order to have an organized system of assets in Port 4D. Having a standard organization of assets allows the use of the system for any port. Therefore, Port 4D can be used globally with any port or harbour. The organization system was divided in five categories. The categories are:

- 00 Jetty number
- 00 Material
- 000 First category, structural
- 000 Subcategory
- 000 Asset number

In the list is possible to notice that every category is preceded by a sequence of zeros. The sequences have the purpose of creating an object identification number, or an Object ID. The Object ID is used to identify every solid present in the 3D model. Therefore, every asset must have its specific Object ID. For example, a specific steel access ladder, present in jetty number 2 will have the Object ID 02.02.106.001.003.

The first 02 indicates that the ladder is present on jetty number 2. The second number, 02, shows that the ladder is made out of steel. The number 106 indicates is the category that includes all access ladders. 001 is the group of ladders that are of a certain design. In fact, in the same jetty there can be different kinds of ladders, for example, with different inclinations or sections. The last 003 indicates the specific numeration of the asset, as usually there are a different number of access ladders for every jetty. In this particular example, the ladder is the third on from the most southern point of jetty number 2.

This division allows the allocation of separate properties to the different items. Therefore, items belonging to similar categories can be selected all at once in Port 4D. Once a group selection is made, it would be possible to input or output information to or from all the assets in the same category.

Object IDs are also discussed in subchapter 4.2.7. The full list of categories is shown in Appendix three of this thesis. It is to be noted that the organization system and its numeration, shown in the appendix, is a guideline and can be changed depending on the needs of the application user. Categories and subcategories can be added, deleted or modified in Port 4D.

4.2.4 Zooming System

For the purpose of this thesis, four files were created with Autodesk AutoCAD. Three of the files contain detailed 3D models of jetties number 1, 2/3 and 7, present at Port of Kilpilahti. The files have a .dwg extension and their size vary from 8 MB till 29 MB. With the help of Autodesk Civil 3D, they have been transformed to .ifc extension, which is the universal extension for any BIM software. The size of the .ifc files increments of about three to four times the .dwg original size. In fact, because of the number of solids and their detailed level, the files tend to be relatively big and heavy to visualize on basic computers.

Because of this, Port 4D needs a system that runs the heavy 3D models in the lightest possible way. The solution was to visualize the 3D model without heavy details when it is shown from a distance and the closer the visualization is, the more details appear on the screen. Thus, when opening the application or when zooming into a jetty, the loading time for the 3D model should diminish drastically. At the same time, the visualization passage, without changing of zooming from one area to another one should happen smoothly without having to wait for loading. The following figures shows a sequence of zooming in the Kilpilahti harbour area.

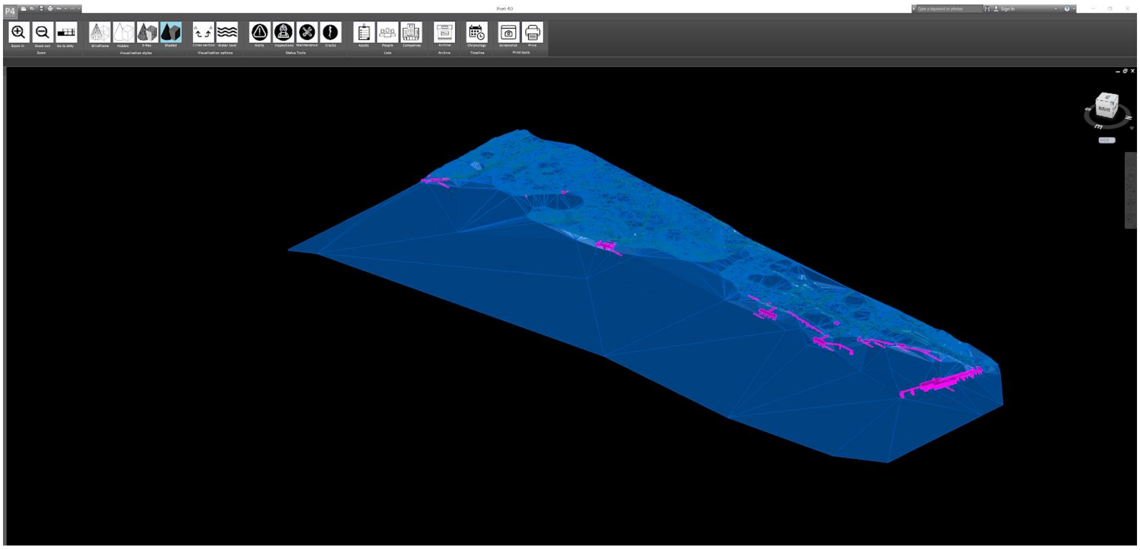

Figure 8. 3D of the whole Kilpilahti harbour area

Figure 8 is the 3D image of the whole Kilpilahti area. Only the jetties are visualized in purple on the blue coloured land and sea surface.

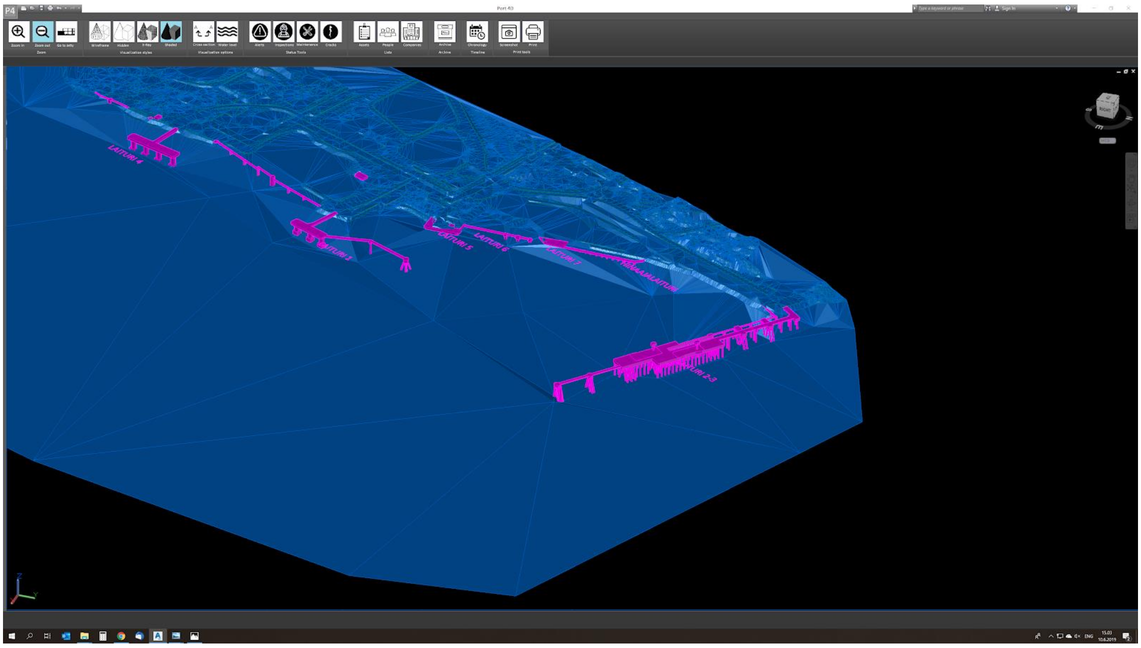

Figure 9. 3D of the zoomed eastern side of the area

Figure 9 shows the eastern side of the Kilpilahti area. Similar visualization as in figure 8 is used.

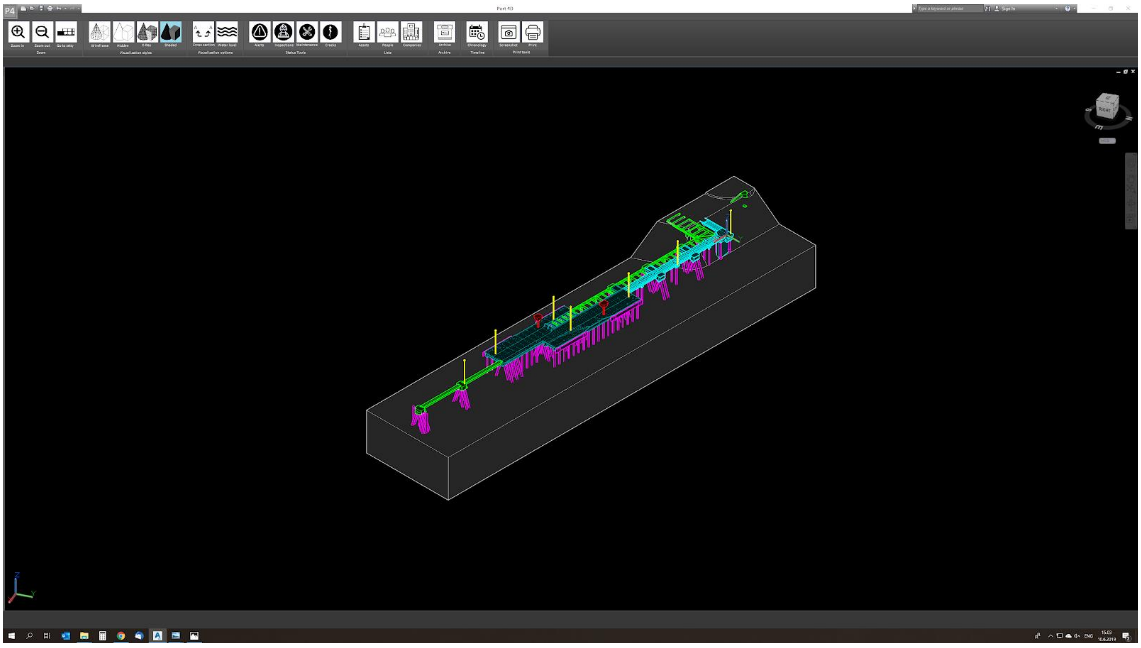

Figure 10. 3D of the full jetty number 2/3

Figure 10 shows the entire jetty number 2/3. The land and sea surfaces around the jetty disappear, giving focus on the structures of the jetty.

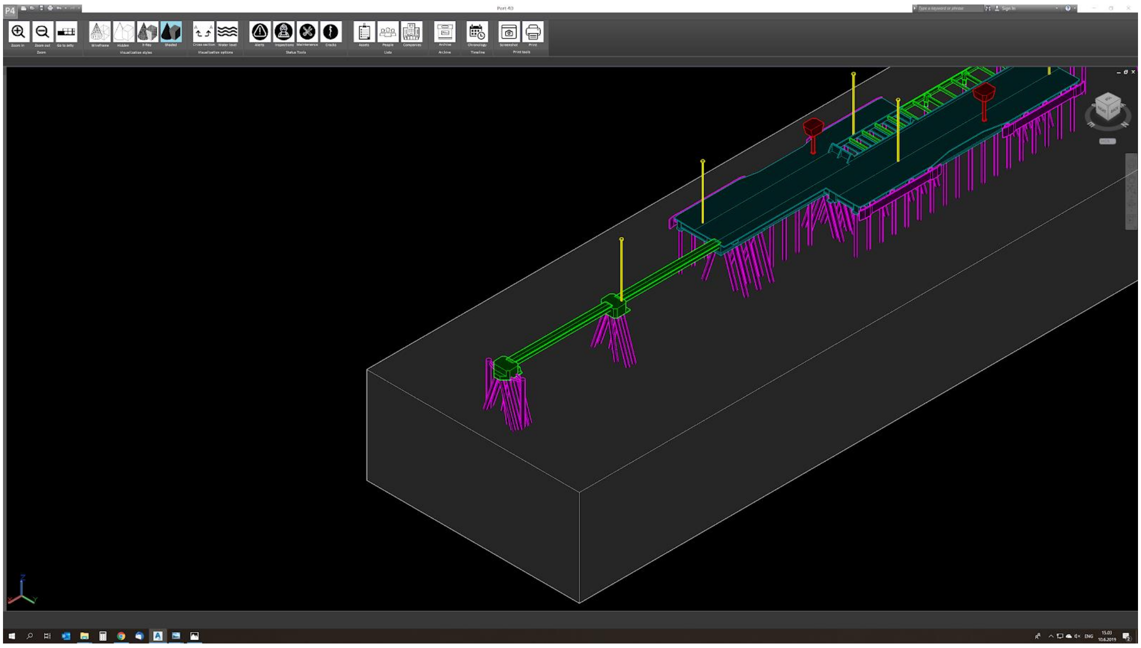

Figure 11. 3D of the zoomed end of jetty number 2/3

Figure 11 shows the zoomed end of jetty number 2/3. Similar visualization as in figure 10 is used.

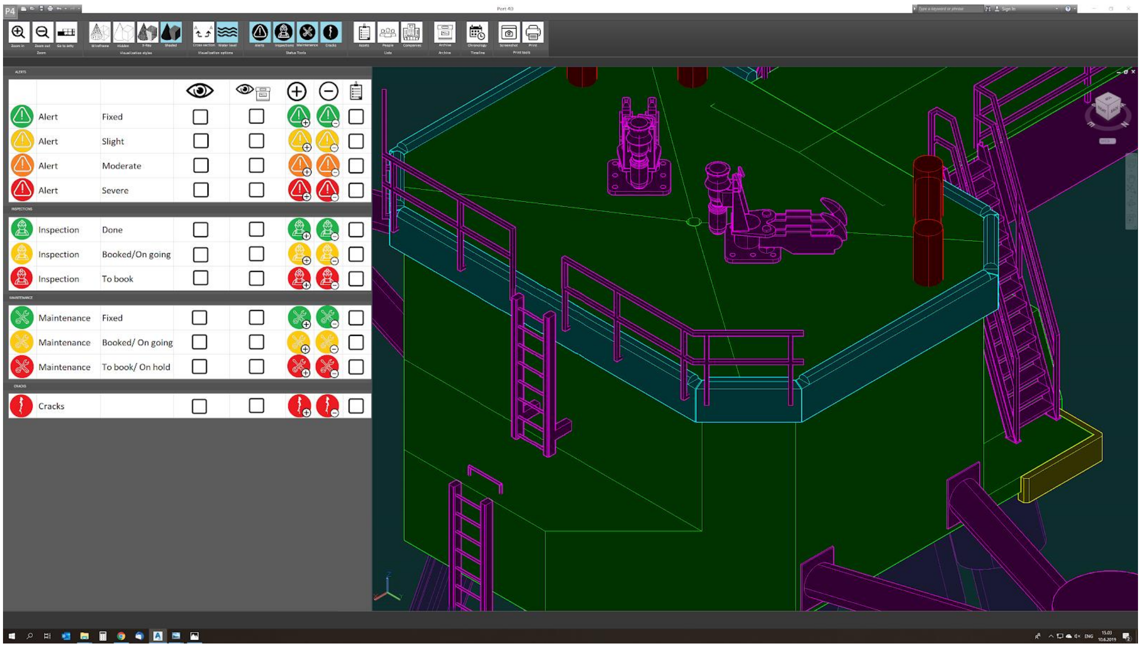

Figure 12. 3D of the detailed zoom of the last dolphin of jetty number 2/3

As it is possible to see from figures 8, 9, 10, 11 and 12, the level of detail increases the more is zoomed into a specific area. In figure 8 and 9 only the whole jetties as singular structures are shown. From figure 10 it is possible to notice the main structures of jetty 2/3, while figure 12 shows all sorts of details of the assets present on the last dolphin of jetty 2/3.

It is important for the functionality of the application that the whole port is under control simultaneously. Moreover, depending on the zone of interest, there should be a possibility to quickly visualize any jetty. Therefore, besides the classic zoom in and zoom out buttons present in many 3D applications, a specific button was added, called Go to Jetty, as shown in figure 13.

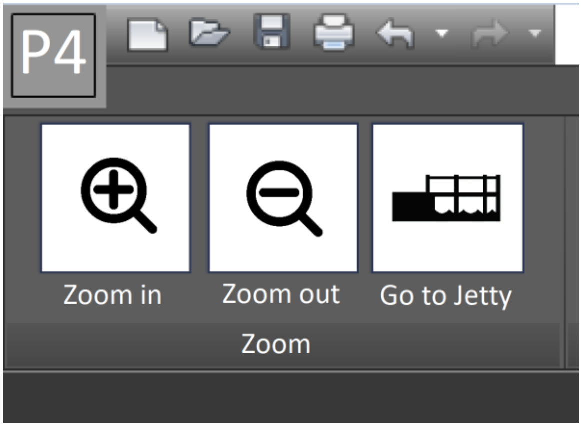

Figure 13. Zooming tools present in the upper left corner of the screen

Figure 13 shows the Zoom group of commands, present in the upper left corner of the screen. Besides the two zooming buttons, it is also possible to see the Go to Jetty button. When selected, this tool opens a list on the left side of the screen that allows the user to quickly move from one jetty to another one, as shown in figure 14.

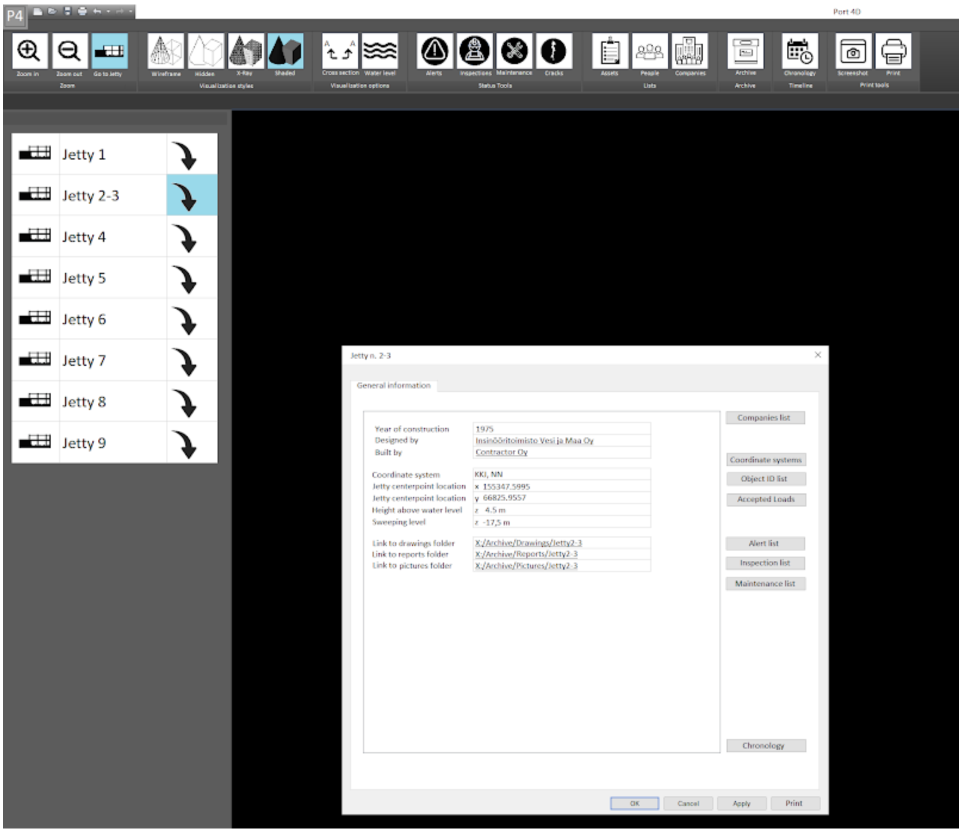

Figure 14. List of jetties shown when the tool Go to Jetty is selected

Besides the opened list of the jetties, figure 14 shows also the window that opens when one of the jetties is selected. Like in the example shown, the general information window of jetty number 2/3 is visualized. This window shows basic information of the jetty such as:

- Year of construction
- Designer company
- Contractor company
- Coordinate system used
- X location
- Y location
- Height of the structure above water level
- Sweeping level
- Links to correlated drawing folder
- Links to correlated report folder
- Links to correlated picture folder

On the right side of the window there are eight buttons, each of them opens a new window or list of interest. The buttons are:

- Companies list
- Coordinate systems
- Object ID list
- Accepted loads
- Alert list
- Inspection list
- Maintenance list

More information concerning the lists is explained in subchapter number 4.2.7.

4.2.5 Visualization Tools

On the horizontal command line present at the top of the screen, to the right from the zooming tools, there are the visualization tools and options, like shown in figure 15.

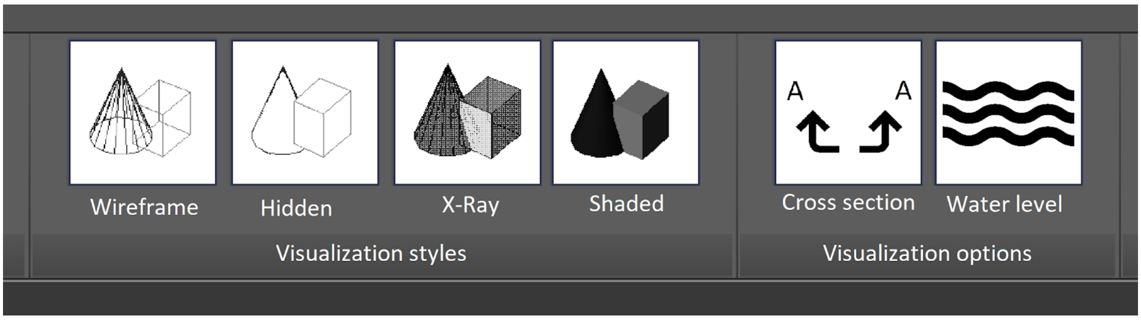

Figure 15. Visualization styles and options

As figure 15 shows, there are four different visualization styles used in Port 4D: wireframe, hidden, X-ray and shaded. Autodesk AutoCAD was used as a reference for the styles. The visualization styles can be chosen depending on the user preferences. The wireframe style shows all the main lines of the 3D objects, not only the one towards the user, but also the ones that behind. It is the lightest of the visualizations, but it can be very hard to understand the model if the model itself is very complex with many assets present. The hidden style uses the same lines as the wireframe, but it does not show the lines that are behind the object. This is still a relatively light visualization but might show a complex model in a better and more understandable way. The X-ray and shaded tools are both visualizing the surfaces of the solids. In X-ray visualization, the surfaces are semitransparent, while in shaded they are matt and the user cannot see through them. The last two are heavier visualizations, but easier to understand.

On the top right in figure 15, two visualization options are shown: cross section and water level. Cross section allows the user to create an imaginary plane that cuts through the solids, showing what is behind or under certain structures.

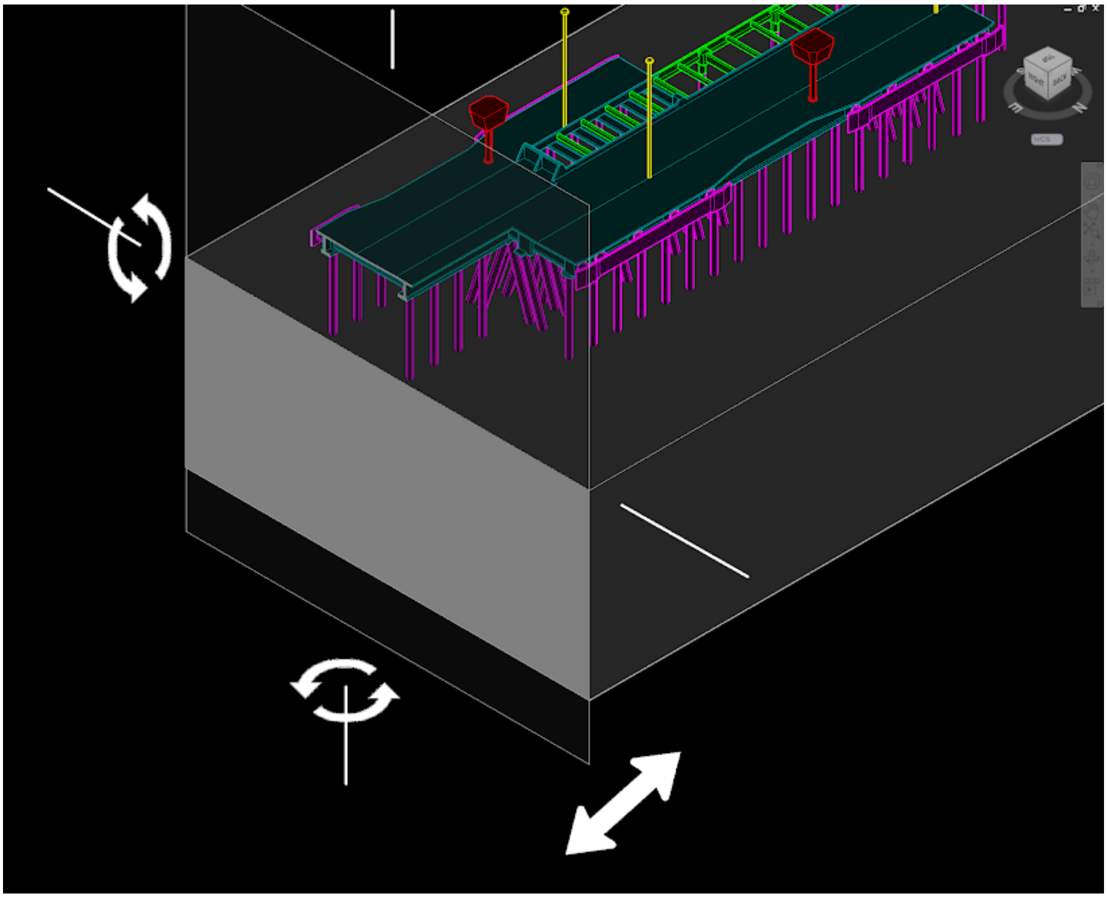

Figure 16. Options available within the cross-section tool

In figure 16 it is possible to see how the cross-section tool works when selected. A cutting plane appears, hiding everything that lays in front of it. It is possible to rotate the cutting plane along two rotation axes, shown in white colour, and move it along its perpendicular axes, as the double headed arrow in figure 16 shows.

The other visualization option tool is called Water level. This allows to visualize the water or not, depending on the user preference. The water is visualized in a semitransparent blue surface, that does not fully hide the solids that are below the water level.

4.2.6 Status Tools

The status tools are basically the core of the application. In the Status Tools category at the top of the screen, there are four buttons, like figure 17 shows: Alerts, Inspections, Maintenance and Cracks.

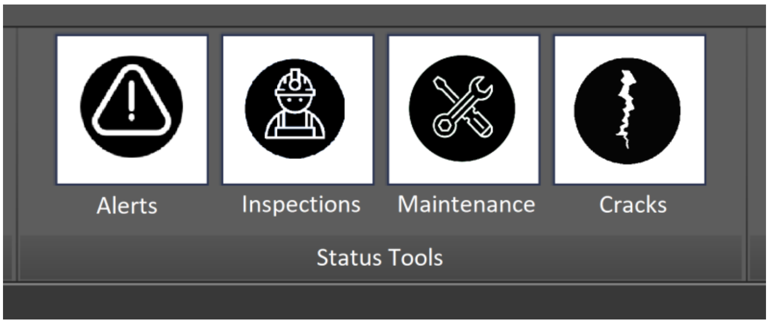

Figure 17. The four status tools and their symbols

When selected, all the buttons in figure 17 open more options on the left side of the screen as shown in figure 18, where all of them are fully open.

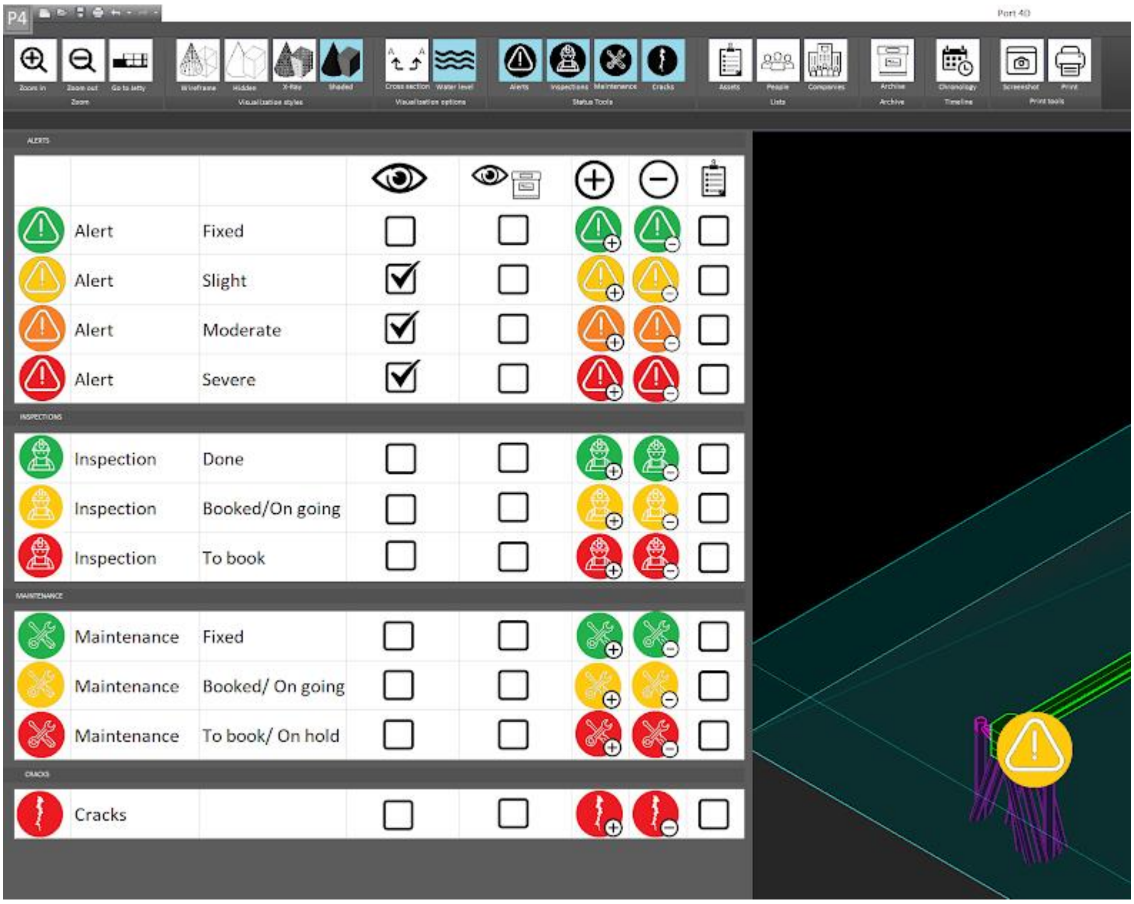

Figure 18. All the four status tools with their options open and a yellow slight alert sphere visualized to the right on the screen.

Figure 18 also introduces the concept of spheres and their colours. As it is shown every colour has a meaning for different status tool. The alerts can be: Severe, marked in red, moderate, marked in orange, slight, marked in yellow, and fixed marked in green. Inspections can be: to be booked, marked in red, booked or on going, marked in yellow, and done, marked in green. Maintenance can be: to be booked or on hold, marked in red, booked or on going, marked in yellow, and done, marked in green. Cracks are just visualized in red colour.

When the box under the eye symbol is ticked, it is possible to see the spheres at their locations on the right. In figure 18, slight, moderate and severe alert are ticked, therefore it is possible to see a yellow slight alert sphere on top of the dolphin of jetty 2/3.

To the right of the eye symbol is another smaller eye together with a box. This symbol, when selected allows the visualization of the selected spheres that have been already archived on the 3D model. This option, when unselected, gives the possibility to visualize only the current issues and hide the archived ones. The archive and its functions are discussed more in subchapter 4.2.9.

Next to the right, there are icons with plus and minus symbols. When selecting the icon with the plus symbol, it is possible to drop a new sphere on a specific place or asset on the 3D model. The minus option allows the removal of such status sphere, for example if a mistaken sphere is placed in the wrong place. Spheres present on the model can also be modified by clicking on them with the right button, or by entering the properties of such sphere, accessible with a double click. For example, a red inspection sphere, meaning a not yet booked inspection, can be modified to yellow, when the inspection is booked, without having to place a new sphere.

The last columns, present an asset list option, visualized with the icon of a checklist folder. When the boxes of this column are ticked, Port 4D opens a complete list of the selection made, as shown in figure 19, at the bottom of the screen, on the left.

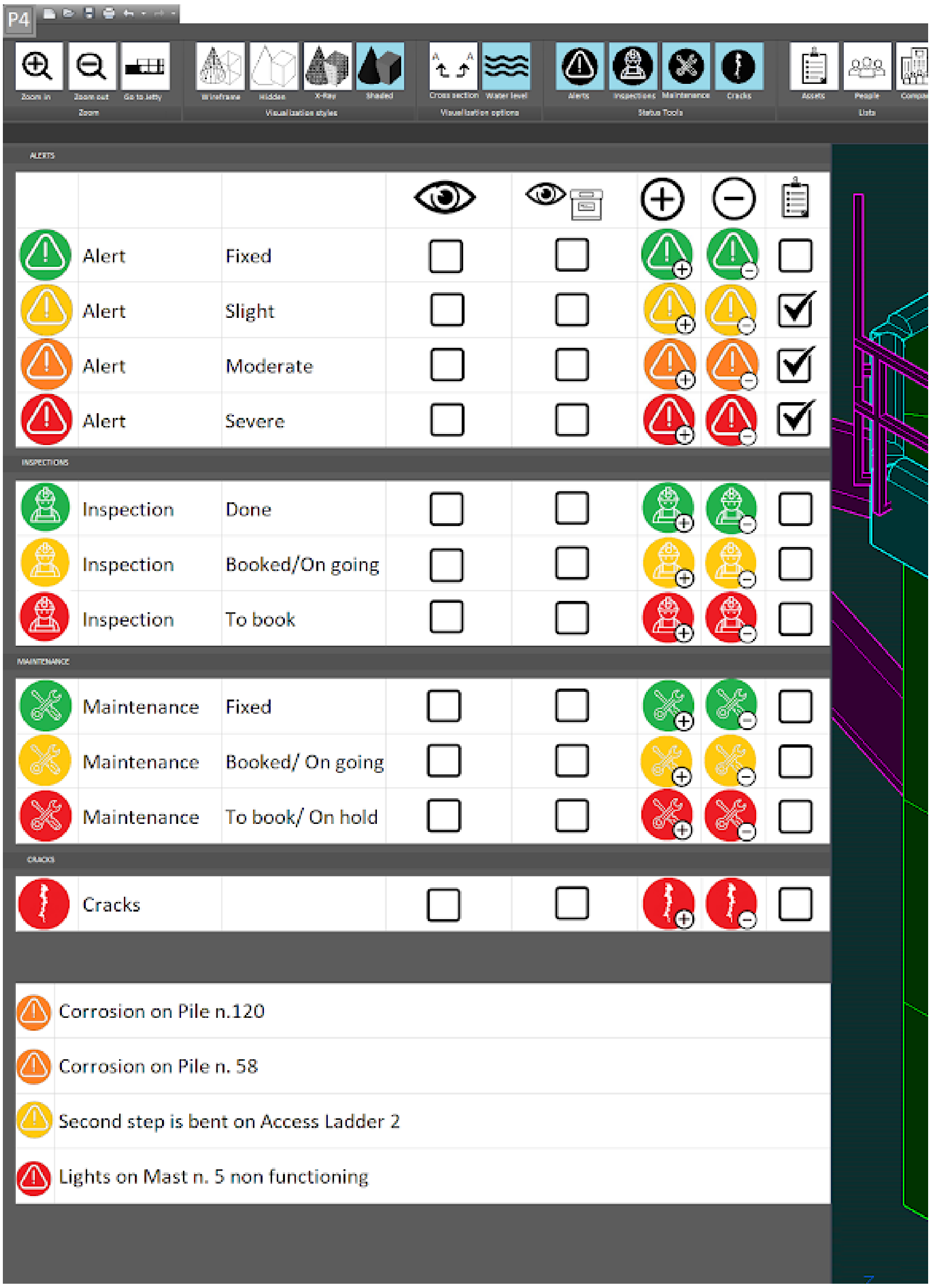

Figure 19. List of slight, moderate and severe alerts are selected and therefore shown on the bottom left part of the screen

Figure 19 shows an example where slight, moderate and severe alerts are selected under the checklist folder symbol. Consequently, a list appears at the bottom of the screen, with all the alerts of the port. In the example, only four alerts are present on the jetty.

For these three tools, alerts, inspection and maintenance, spheres are used as a location system. The spheres can be correlated to assets, or simply placed in a generic area of the jetties. If a sphere is connected with an asset, when clicking with the left button of the mouse one time, the application will show brief information commanded to the situation. Figure 20 shows an example of what happens when a yellow alert is selected.

Figure 20. A slight alert is selected with a single left click and therefore shows more information

In figure 20, the yellow alert is connected to the access ladder number two. When selecting the sphere, a smaller inspection and maintenance sphere appear along with a small window that states the name of the asset related to the alert sphere, the date of the alert and a brief description of the alert itself.

When double clicking with the left button of the mouse, on either the assets or the spheres, Port 4D opens a window with much more information related to the alert and the asset itself, as shown in figure 21.

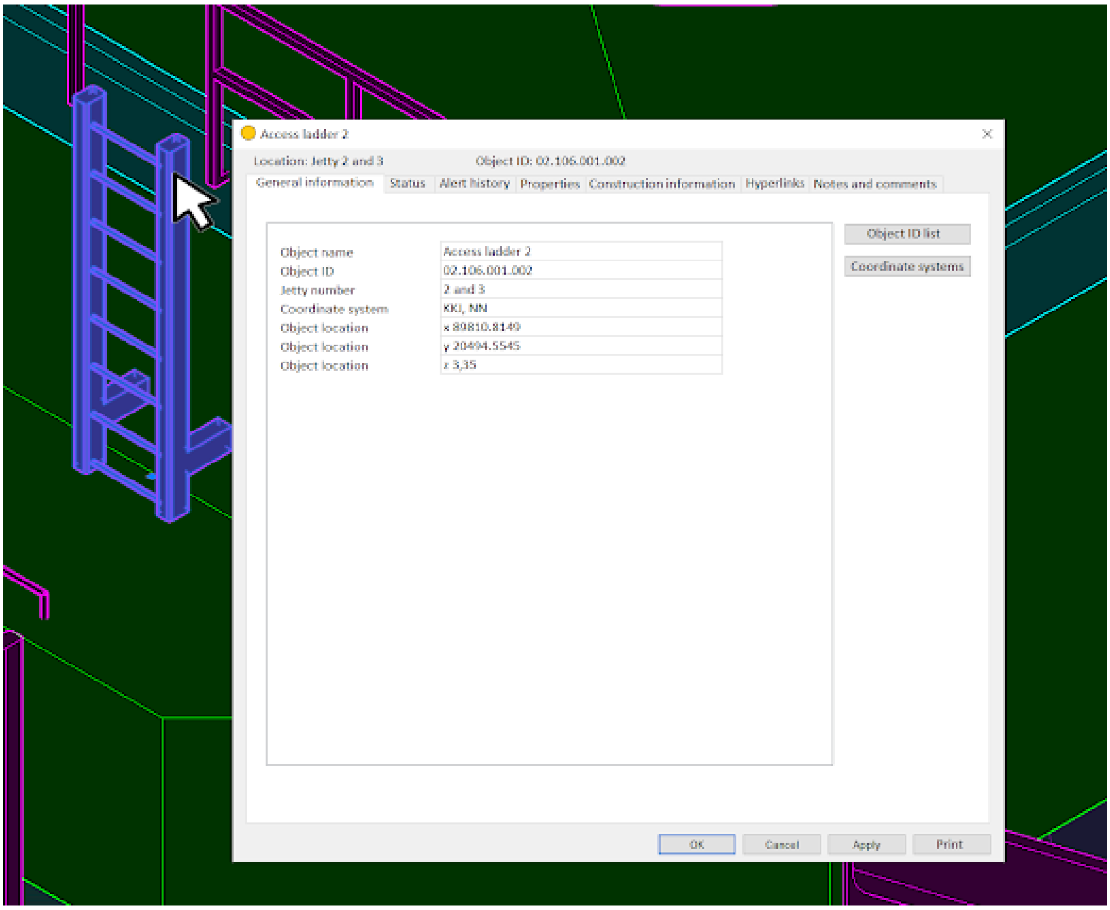

Figure 21. An access ladder is double clicked, and the option window appears next to the ladder

Figure 21 shows that an asset is double clicked and therefore an option window opens. The same option window opens if the alert symbol, shown in figure 20, is double clicked. The option window and its functionalities are fully explained in subchapter 4.2.8.

The Cracks tool works in a very similar way as the other tools, except that it uses lines visualization instead of spheres, as shown in figure 22.

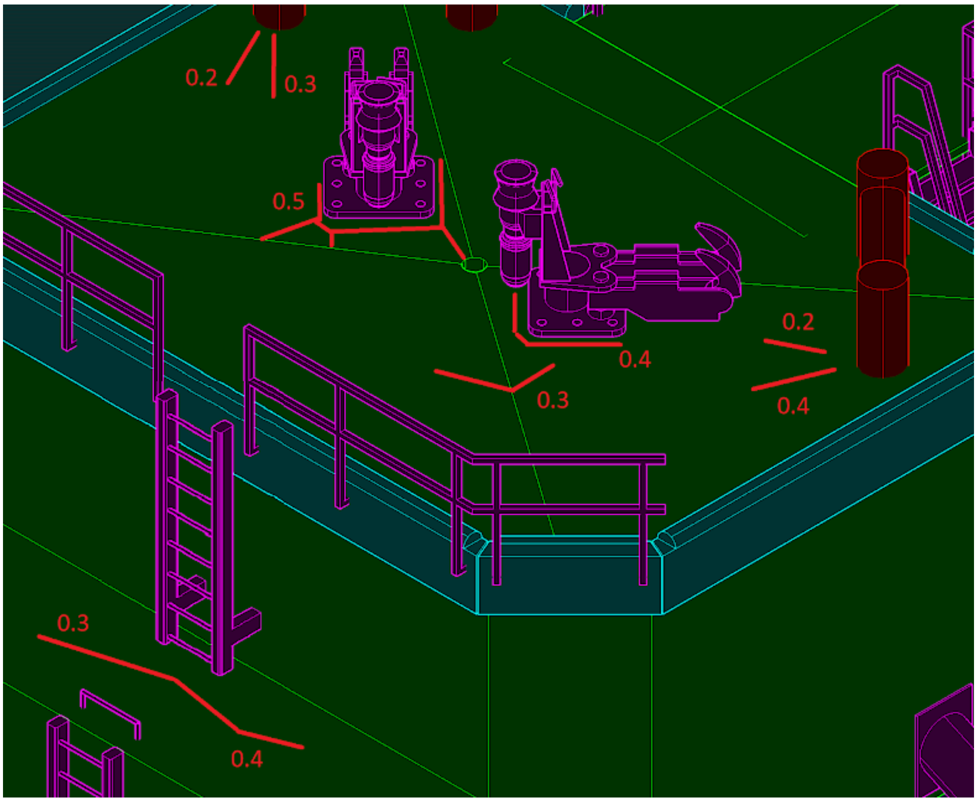

Figure 22. Cracks are visualized on the 3D model of the concrete dolphin

Figure 22 shows also that when cracks are visualized, along the red lines it is possible to see how wide the cracks are, in millimeters. For example, the crack that on the lower part of the dolphin runs from 0.3 mm to 0.4 mm wide.

The following paragraphs explain in detail the functionalities of the four status tools: alerts, inspection, maintenance and cracks tools.

Alerts are intended to be marks on the 3D model that notify some sort of error, mistake or anything that needs to be checked or repaired. The marks are symbolized by a sphere with a triangle and an exclamation mark. As previously explained, there are four different kinds of alerts and each one has a different colour:

- Severe alert - Red colour
- Moderate alert - Orange colour
- Slight alert - Yellow colour
- Fixed alert - Green colour

Severe alerts are intended for situations where the functionality of the asset is fully compromised, and it requires immediate attention. Moderate alerts are placed in situations where an asset is functionality is currently at risk and measures must be taken in the immediate future. Slight alerts are intended for assets that are still functional, but a slight error or degradation has been noticed and measures should be taken at some point. Fixed alerts symbolize alerts that were previously severe, moderate or slight but have now been taken care of. Fixed alerts are normally never placed on the model but only modified after they have been taken care of. Once an alert has been fixed it can also be placed in the archive, in order to have a clearer visualization of the 3D model.

Alert spheres can be placed generically on the 3D model or they can be connected with one or more assets. For example, if a complete jetty is momentarily not in use, it is possible to place a generic alert on the whole area, without connecting it with any specific assets. In most cases the alerts should be connected with one or more assets. For example, in case all the aging fenders of a jetty must be replaced, an alert can be placed on the selected fenders and once the alert is confirmed, it will appear on top of every fender of the jetty. A similar situation can be achieved for a singular asset, by selecting just the necessary asset.

Alerts can be placed on the model by any user of the application: maintenance workers, harbour workers, supervisors and inspectors alike. Workers on the field should have the possibility to notify about erroneous or dangerous situations instantaneously, with tablets or EX tablets, right on the field. Supervisors can add, delete and modify alerts. Inspectors have the possibility of adding alerts after an inspection, together with a report of the current situation.

The second status tool is the Inspection tool. Inspections are intended to be marks located on the 3D model that notify about the need of a professional inspection. The marks are symbolized by a sphere with a helmet. As previously expressed, there are three different kinds of inspection spheres that define the status of the inspection itself. Each one of them has a different colour:

- Inspection to be booked - Red colour
- Booked inspection - Yellow colour
- Carried out inspection - Green colour

Inspection spheres are usually connected with alerts and therefore to assets, but they can also be placed generally on the 3D model, for example when an inspection has to be carried out for an entire jetty.

The alert and inspection spheres are placed on Port 4D by a supervisor or by an inspector. Supervisors have the possibility to mark what needs to be inspected and they can check if the assessment has already been booked or not. The inspector has the possibility to change the marks from yellow to green, once the inspection has been carried out.

The third status tool is the maintenance tool. Maintenance are intended to be marks located on the 3D model that notify about need to fix something. The marks are symbolized by a sphere with a crossed screwdriver and spanner. As previously mentioned, there are three different kinds of maintenance spheres. Each one of them has a different colour:

- Maintenance to be booked - Red colour
- Booked maintenance - Yellow colour
- Carried out maintenance - Green colour

Maintenance spheres are mostly connected with alerts, and inspections and, therefore, to assets. For example, a sphere can be placed directly on an alert that does not require a professional inspection, but simply maintenance, or it can be connected to an alert that has been placed after an inspection.

Like the case of inspection spheres, the maintenance spheres are placed on Port 4D by a supervisor or by an inspector. Both supervisors and inspectors have the possibility to mark what needs to be fixed after an alert has been placed. The difference of colours of the spheres should help the user of Port 4D to visualize what needs to be done and what has been done.

Once maintenance has been carried out and the sphere is changed from yellow to green, the alert can be changed also from red, orange and yellow to green, signing the end of the issue.

The fourth status tool is the crack tool. As described in the appendix of this thesis, cracks can occur on concrete structures for different reasons, especially in marine environment, and they can even lead to structural failure. Therefore, it is important to assess them and keep them under control. The crack tool in Port 4D was created for this purpose. It is a specific tool that can be used on the 3D model of concrete structures. Differing from the previous tools, crack tool does not use spheres but lines. Red lines can be added to the 3D model where cracks are present and when they have been assessed by a professional inspector. As shown in figure 22, the cracks visualizations are lines that are applied to the concrete surface. It is also shown that when cracks are visualized, it is possible to see how wide the cracks are, in millimeters, beside the lines. For example, the crack that is present on the lower part of the dolphin runs from 0.3 mm till 0.4 mm wide.

Maintenance actions can be taken and added to the lines, or to the concrete element where the lines are placed. The crack tool is intended to be used only by a professional inspector, though any user of Port 4D can report possibly dangerous cracks by adding an alert. After an inspection has been carried out, the crack tool can be used.

4.2.7 Lists

Continuing on the horizontal command line visualized on the top of the screen, the list tools are present, as shown in figure 23.

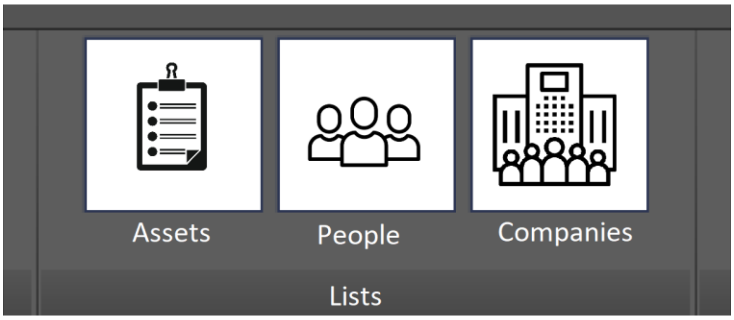

Figure 23. Lists tools and their icons

Figure 23 shows the three options for the lists section: Assets, People and Companies. All three buttons, when selected open lists on the left side of the screen. People and Companies are less complex tools than Assets. Therefore, they are introduced first.

When the tool People is selected, the left side of the screen shows a full list of all the personnel and external workers that are registered in the system. The list is shown in alphabetical order. Next to the name, surname and title of the worker, there are his or her contact number and email. All sorts of information related to the personnel can be added.

When double clicking on a name a window opens with the full lists of actions that this person has carried out in the application. Thus, it is possible to follow who has done what, when and where, and recognize responsibilities.

The selection of the tool Companies works in a very similar way, though in this case a list of all the external companies is shown. By external companies is intended suppliers, customers and all the firms that are connected with the harbour. Next to the name of the company, contact information and address are shown. Like in People, more information can be added if necessary.

Assets work in a similar way, but the list visualization, rather than in alphabetical order, is more complex. In fact, the idea behind the organization of the Assets is based on the Object ID system, that was described in sub chapter 4.2.3. Figure 24 shows an example of how the list of assets appears, by default, on Port 4D.

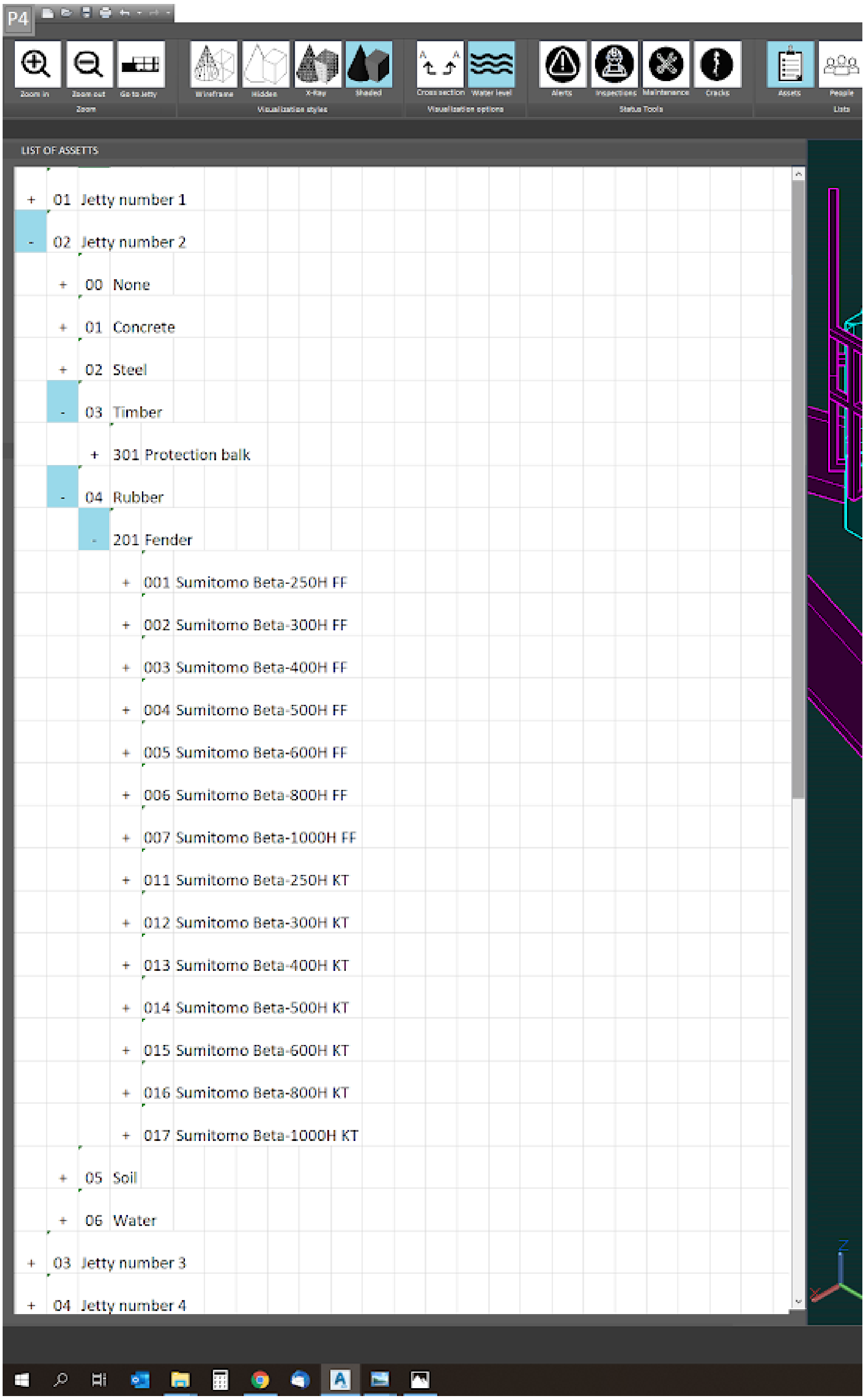

Figure 24. List of Assets is selected and opened on the left side of the screen

Figure 24 shows how the list of Assets is visualized. It is possible to see that next to the numbers that are part of the Object ID, there are plus and minus symbols. When the plus is selected, a sub list opens, while the selection of a minus symbol closes such a sub list.

Firstly, furthest to the left, the jetties are shown, then materials can be opened, followed by the asset category, subcategory and finally the asset number. The example of figure 24 shows that jetty number 2 is opened to show the list of materials, then timber and rubber are opened to show the different groups of assets available under those lists, then the Fenders are opened to show the list of all specific types of fenders available. In a similar way, also the type of asset can be opened to show the number of assets present, as shown in figure 25.

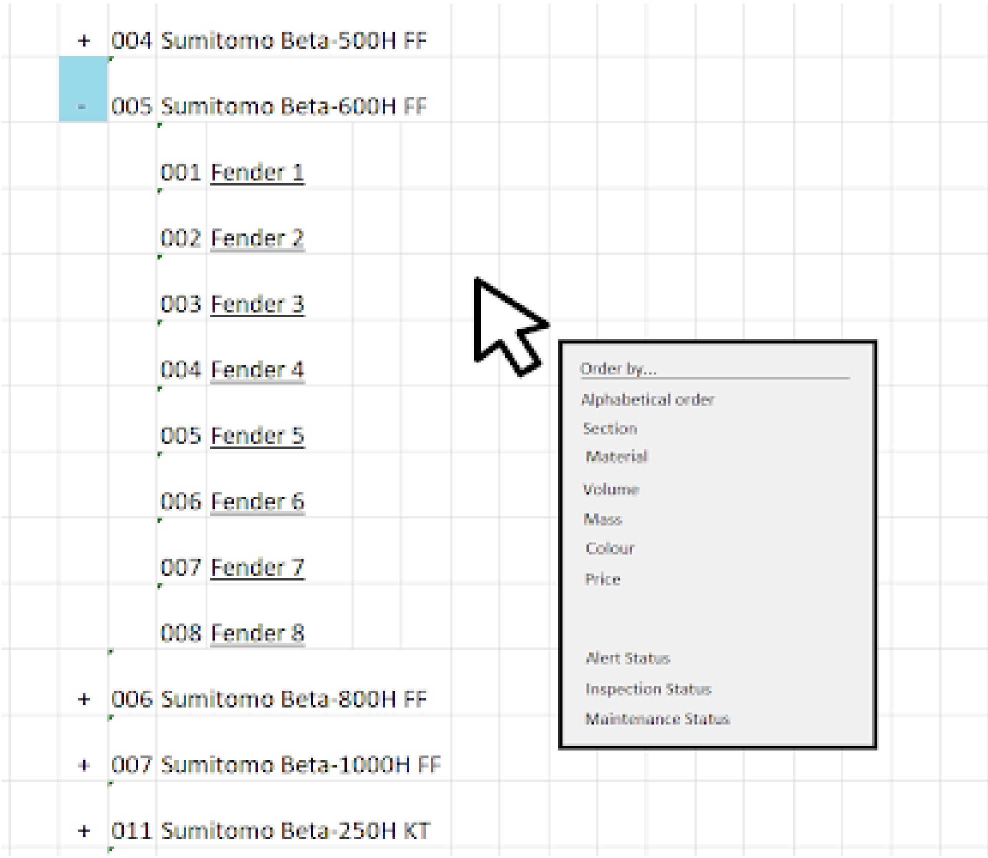

Figure 25. The list of all the eight “Sumitomo Beta-600H FF” fenders present in jetty number 2 and the options window that appears with a right click of the mouse

Figure 25 continues the example of figure 24 by opening the complete list of “Sumitomo Beta-600H FF” fenders. In figure 25 it is possible to see that in jetty number 2 there are eight fenders that are of the same type. Figures 24 and 25 also show the full object ID of the fenders. For example, fender number four has the object ID 02.04.201.005.004.

Figure 25 also shows what happens when the list is clicked with the right button of the mouse. A window opens with a possibility to select the order of visualization of the assets list. The purpose of having the possibility of changing the visualization order is to be able to select similar interesting items all at once.

There are two groups of orders that can be selected: the first group is based on certain properties, the second is based on the current status. Besides the alphabetical order, the properties that can determine the new visualized order are:

- Section type
- Material
- Volume
- Mass
- Colour
- Price

The current status orders include the three main aspects of Port 4D: Alert, Inspection and Maintenance. Choosing one of the last three options visualizes the list of assets that are connected with alerts, inspection or maintenance spheres. It is to be noted that if a sphere is not connected with any asset, it does not appear on this list. If, for instance, the alert order is selected, the list shows on the top the assets connected with severe alerts, then moderate, slight and at the end of the list, the alerts that have already been fixed.

Port 4D carries out two actions when double clicking on one of the assets in the list: firstly, it moves the visualization of the 3D model towards the area where the selected asset is, and secondly, it opens the asset option window. The functionalities of such a window are explained in the following subchapter.

4.2.8 Asset Options

As previously explained, the asset options window can be opened by double clicking on the 3D visualization of the asset or its name on the asset list.

Some basic information is shown on top of the window: the colour of the alert, name of the asset, location and object ID. The information is seen on the top of figure 26, which shows such a window for the same access ladder previously used as an example.

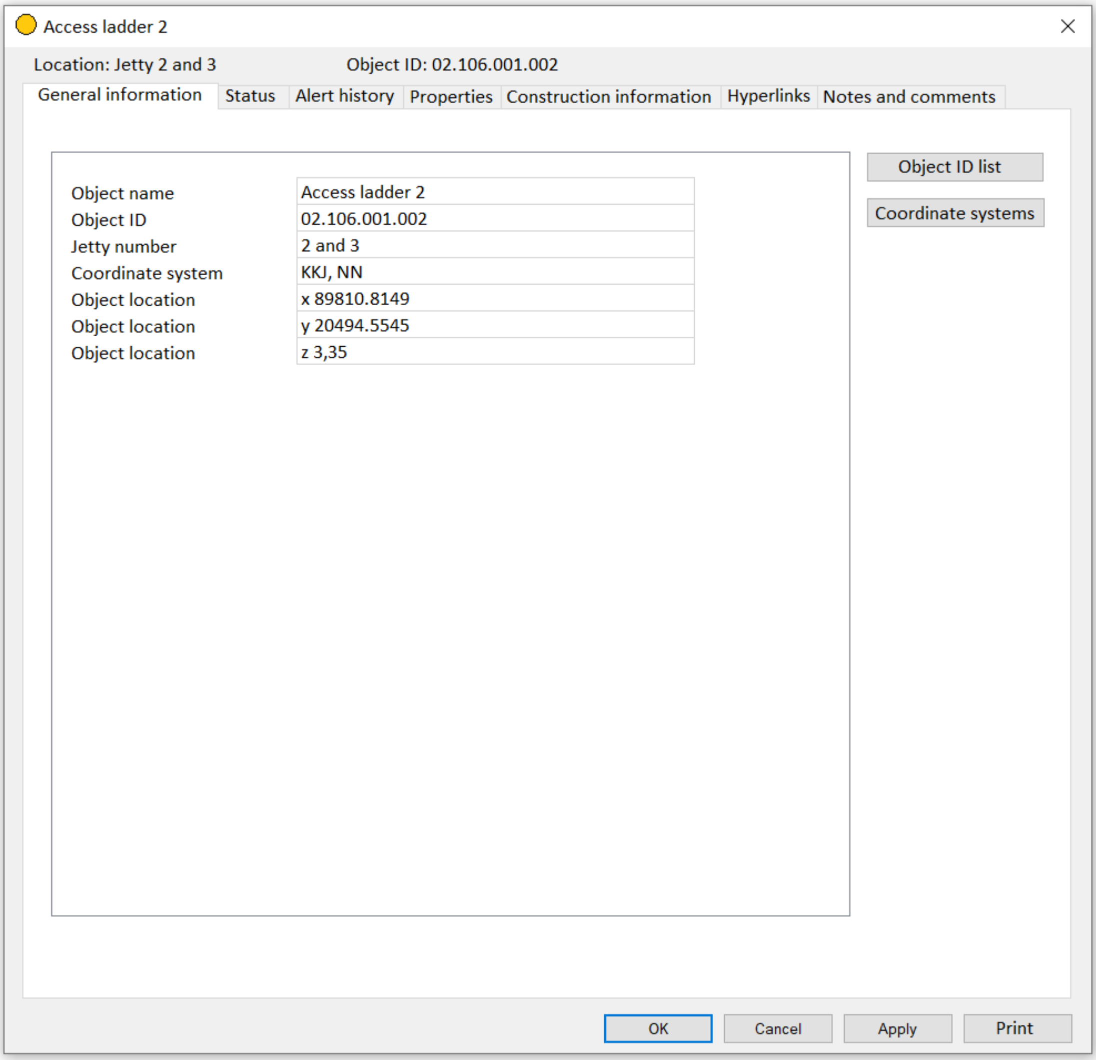

Figure 26. The asset option window is opened on the first section, general information

As shown in figure 26, the option window is divided into parts that can be opened by selecting the tabs present on the top strip. These are General information, Status, Alert history, Properties, Construction information, Hyperlinks, Notes and comments.

General information shows some basic information of the asset, like its name, object ID, and location. To the right of the window, the object ID list can be opened along the coordinate system options.

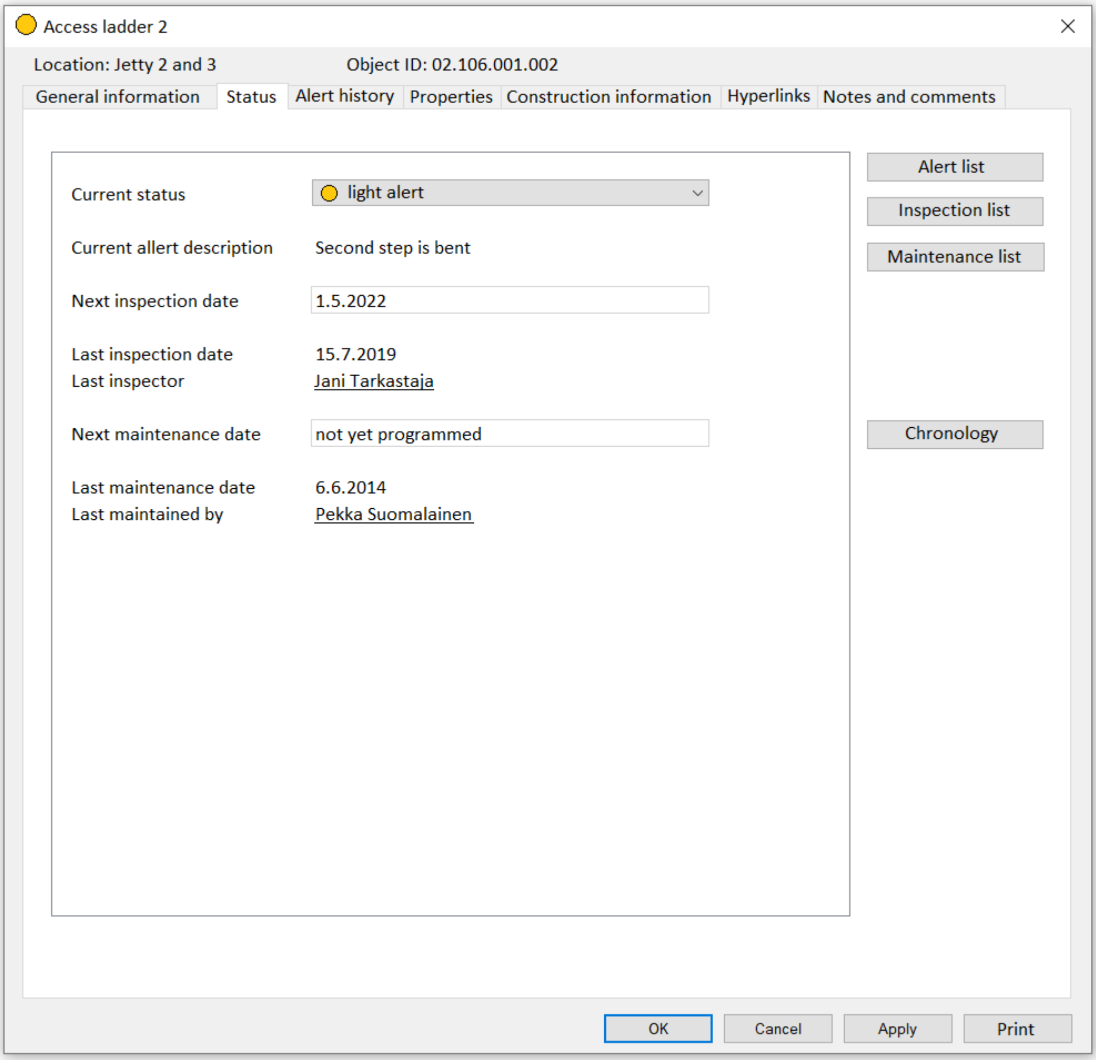

Figure 27. The Status section of the asset option window

Figure 27 shows the Status section of the option window. On the top part it is possible to change the current status of the alert of the asset, then there is information concerning the inspection and maintenance of the asset. To the right of the window, alert, inspection and maintenance lists can be opened. Chronology is here introduced and by clicking on it, Port 4D opens the timeline of the asset. More about Chronology is explained in chapter 4.2.9.

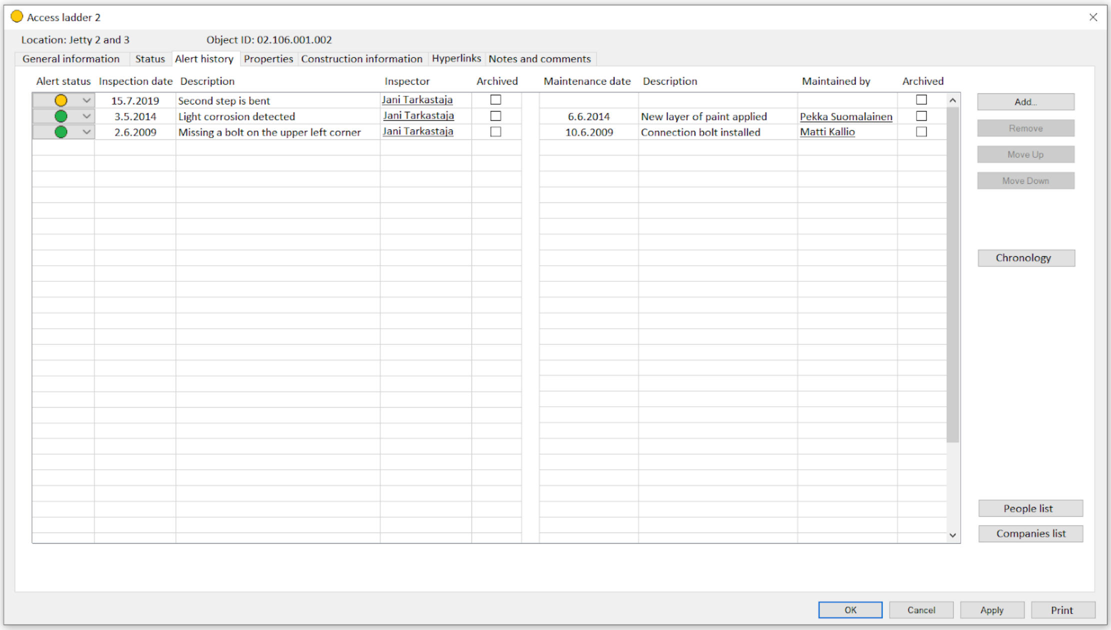

Figure 28. The Alert history section of the asset option window

As figure 28 shows, in the alert history section it is possible to access the history of alerts, inspections and maintenance of the asset.

On the left it is possible to choose the different status of the alert. Here it is possible to change an alert from one grade to another. For example, a moderate alert that has been taken care of and properly maintained, can be changed to fixed alert by selecting a green circle. Immediately to the right it is possible to insert information about such alert: the date of the reported issue, description of the alert, the person who insert the alert in Port 4D and the possibility to flag the alert as archived.

Further to the right, there is the information related to the maintenance of the alerts. The information are date of the maintenance, description of the work done, the person in charge for the job and the possibility to flag the maintenance issue as archived.

In the example shown in figure 28, it is possible to see that the access ladder number two has three alerts, one slight and two are fixed, though none is yet archived. On the same lines of the alerts there are the carried out inspection description and the respective maintenance actions taken. It can be seen in figure 28 that the last alert is not yet maintained as the line is empty.

On the right side of the window, it is possible to add a new alert on the asset, remove it and move the order of alerts. The chronology button is also present, in case the user wants to check the schedule of the related issues. At the bottom on the right the People and Companies buttons will open their respective lists on the left on of the screen.

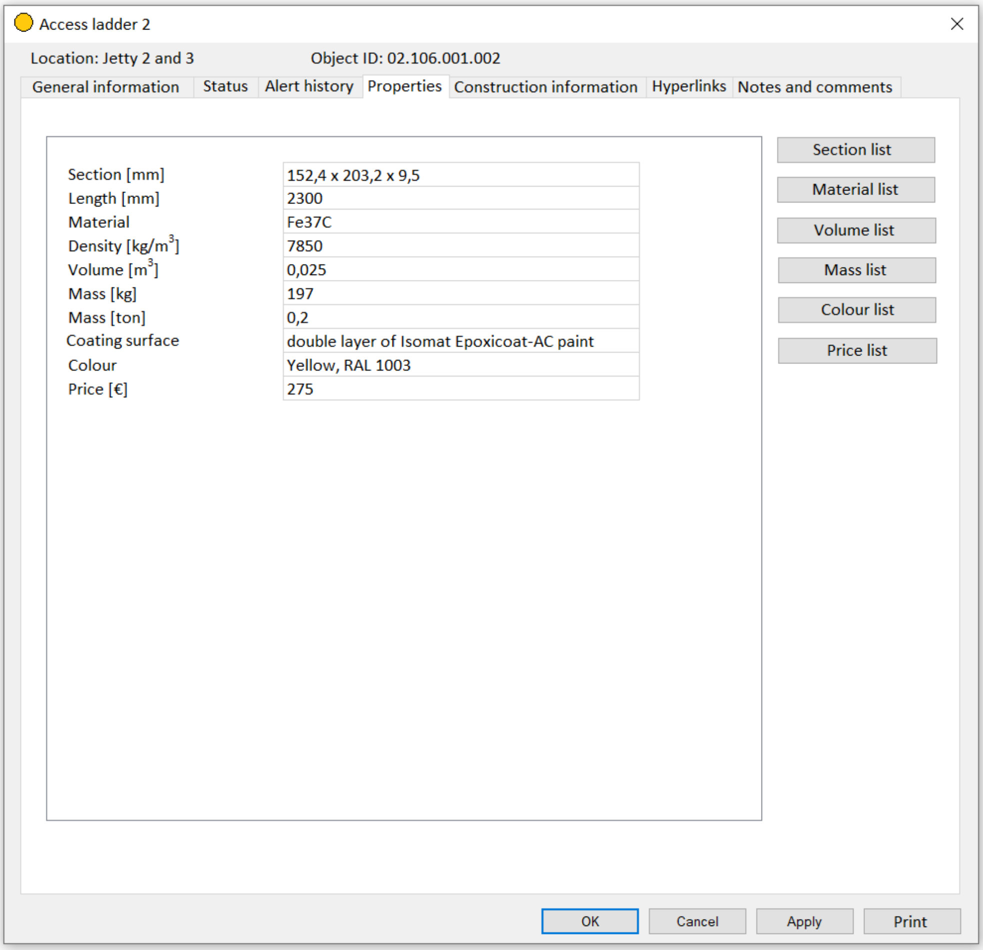

Figure 29. The Properties section of the asset option window

Figure 29 shows the properties section of the asset option window, where the technical characteristics of the selected asset are listed. The properties are:

- Section
- Length
- Material
- Density
- Volume
- Mass in kg
- Mass in tons
- Coating surface
- Colour
- Price

The properties can be modified if necessary and updated. On the right side of the window there are six buttons that, if selected, will open the full asset list. Each of them will then present the same list but displayed in different orders. The orders are:

- By section
- By material
- By volume
- By mass
- By colour
- By price

For example, when opening the Price list, the list of assets will appear with all the assets organized from the cheapest to the most expensive asset.

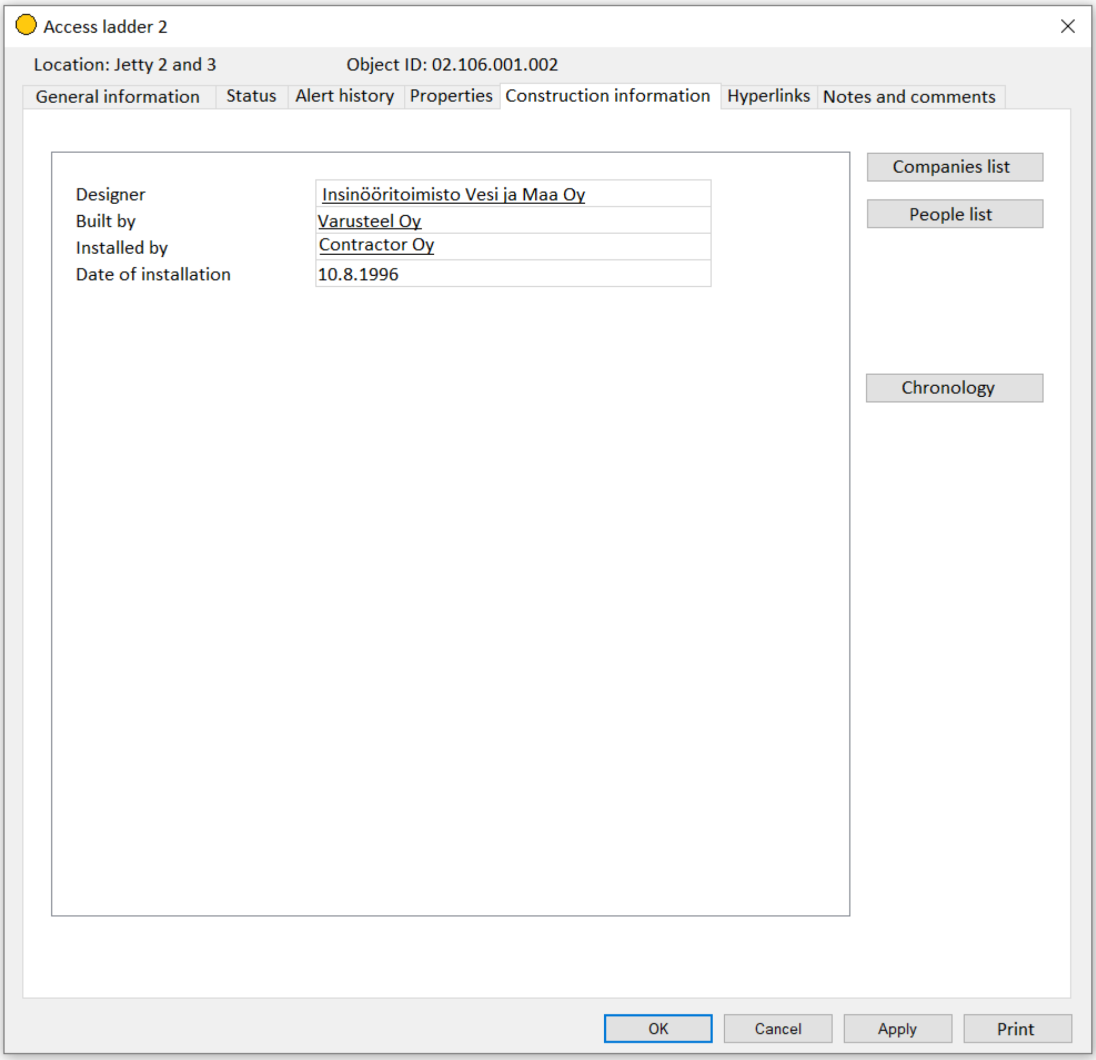

Figure 30. The Construction information section of the asset option window

Figure 30 shows the construction information section of the asset option window. The information listed is:

- Designer of the asset/project
- Company that built the asset/project
- Company that installed the asset, in case it differs from the company that built it
- Date of installation of the asset

As in other sections of the asset options window, the right side gives the possibility to open Companies and People list among the Chronology.

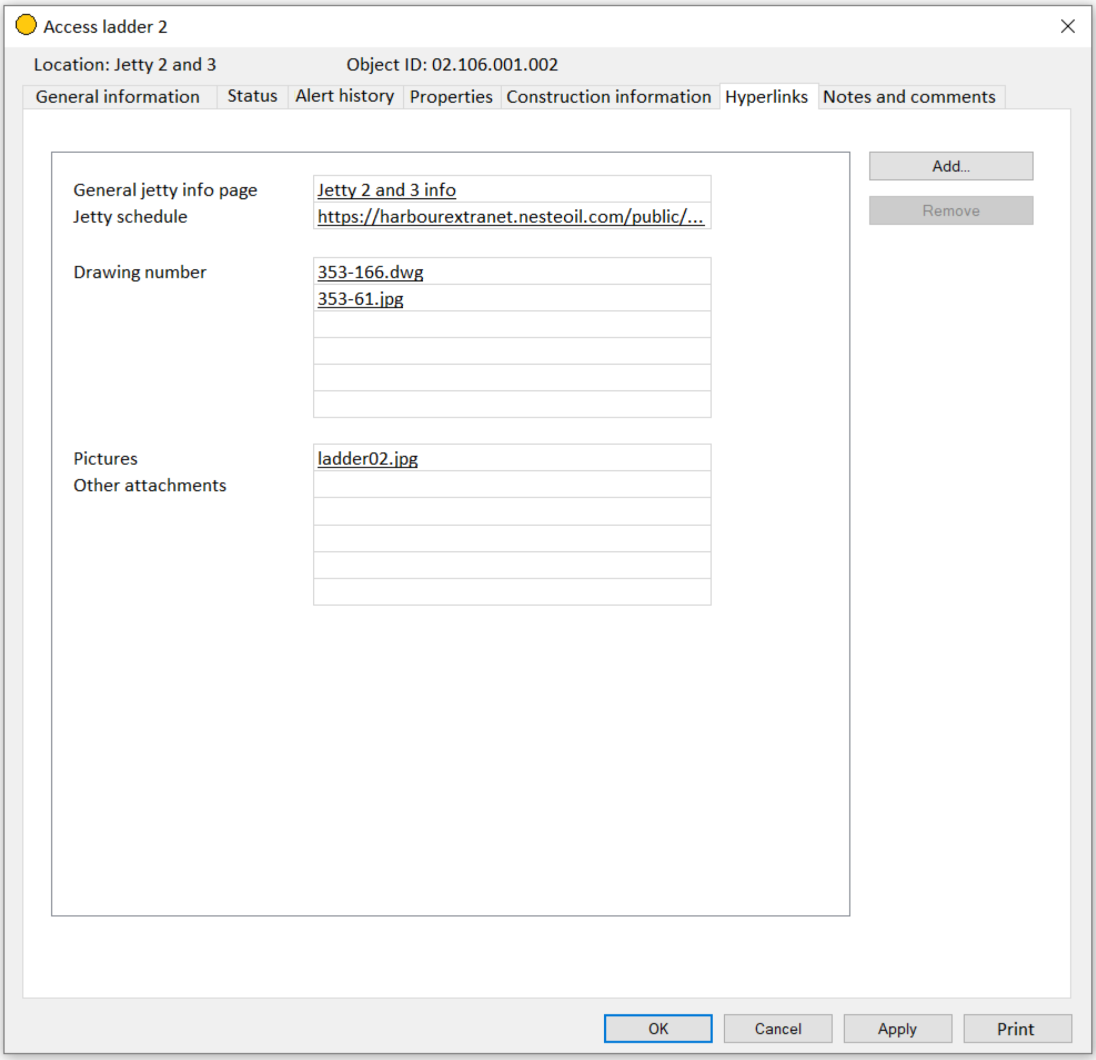

Figure 31. The Hyperlinks section of the asset option window

Figure 31 shows the hyperlink section of the option window. Hyperlinks are intended to be links that open different kinds of documents related to the asset.

The first is a link to the window of the General jetty info page, which was previously explained in subchapter 4.2.4. This is followed by the schedule of the jetty, which, for example, at Kilpilahti, harbour is an open source website. Right under there are the technical drawings of the assets and pictures. As previously explained, it was a requirement of the project to have the possibility to attach drawings and pictures. In addition, there is the possibility to add any external links to any asset, in the section Other attachments. For example, a link to the cathodic protection control webpage.

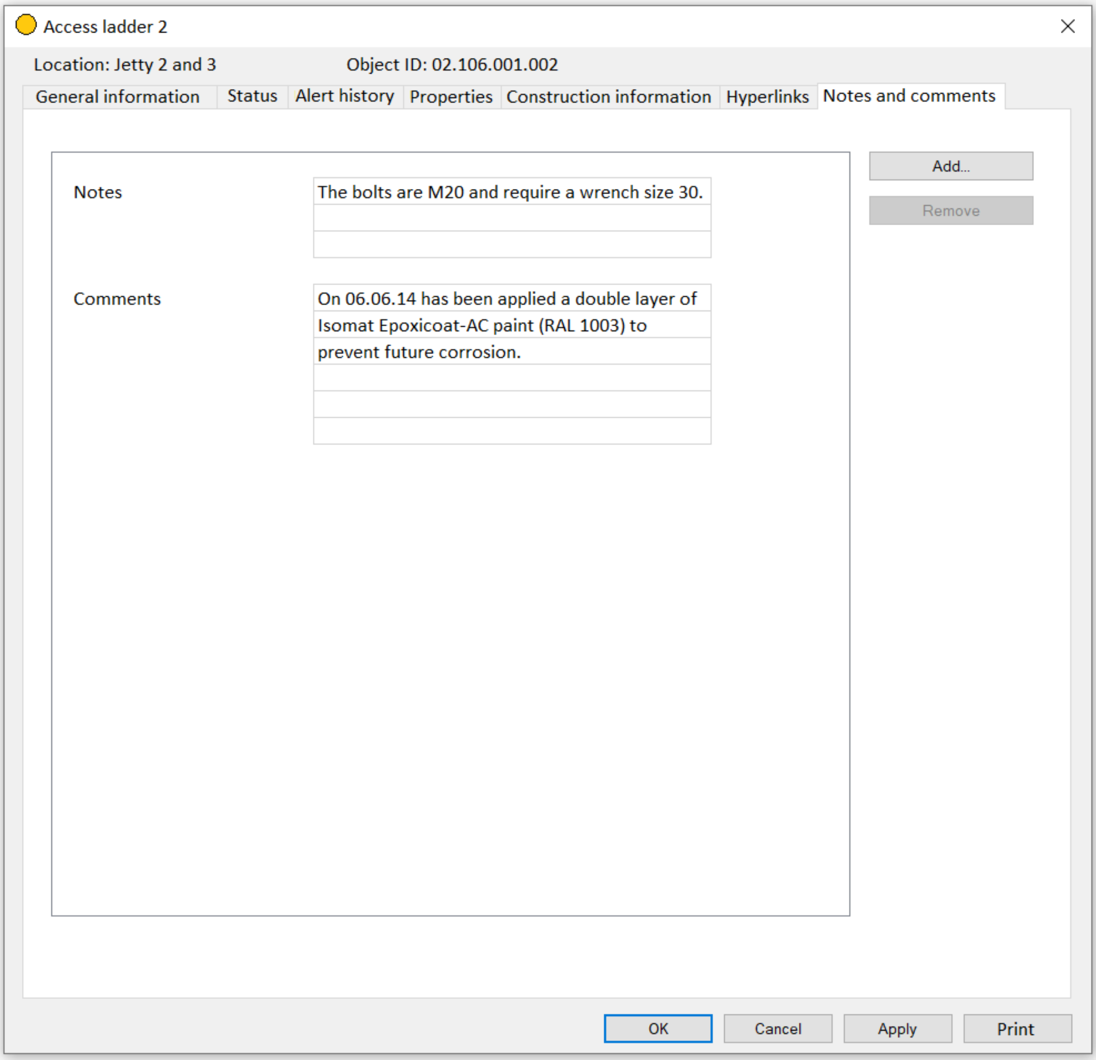

Figure 32. The Note and comments section of the asset option window

Figure 32 shows the last section of the asset option window: Notes and comments. Here the users of Port 4D can add any sort of notes or information that are not stored in other sections of the option window, but that should be remembered about the asset or issue. This information and notes can be useful for other users of the application or to the writer of the comment himself/herself in the future.

4.2.9 Archive, Chronology and Printing Tools

Continuing on the horizontal command line at the top of the screen, the last four tools of the application are shown in figure 33.

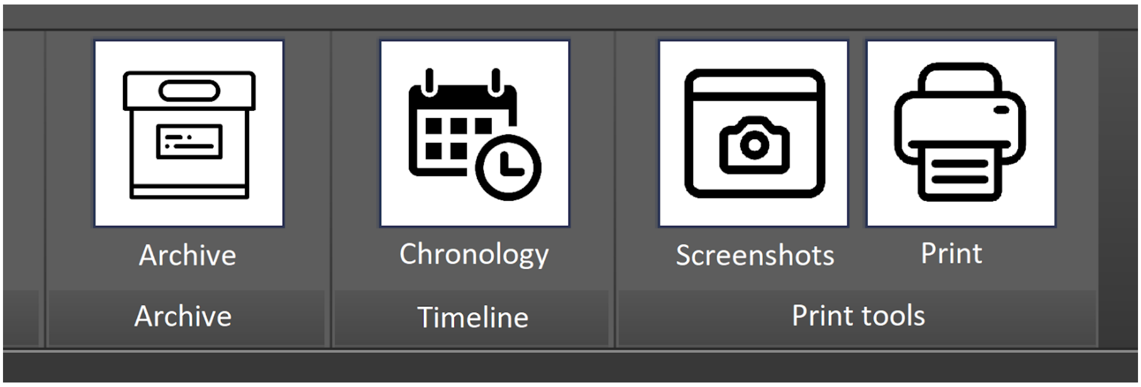

Figure 33. The last four tools of the application: Archive, Timeline, Screenshots and Print

As shown in figure 33, the last four tools of the application are divided in three groups: Archive, Timeline and Print tools. The last group includes Screenshots and Print.

The main purpose of the archive tool is to clean the 3D model visualization from any issues, alerts or situations that have already been fixed and that are in the past. It is possible to imagine that throughout the years, many issues can appear on the jetties, and many times they can even overlap, year after year.

The Archive tool works similarly to the List of Assets tool. When selected, it opens a list on the left of the screen, as shown in figure 34.

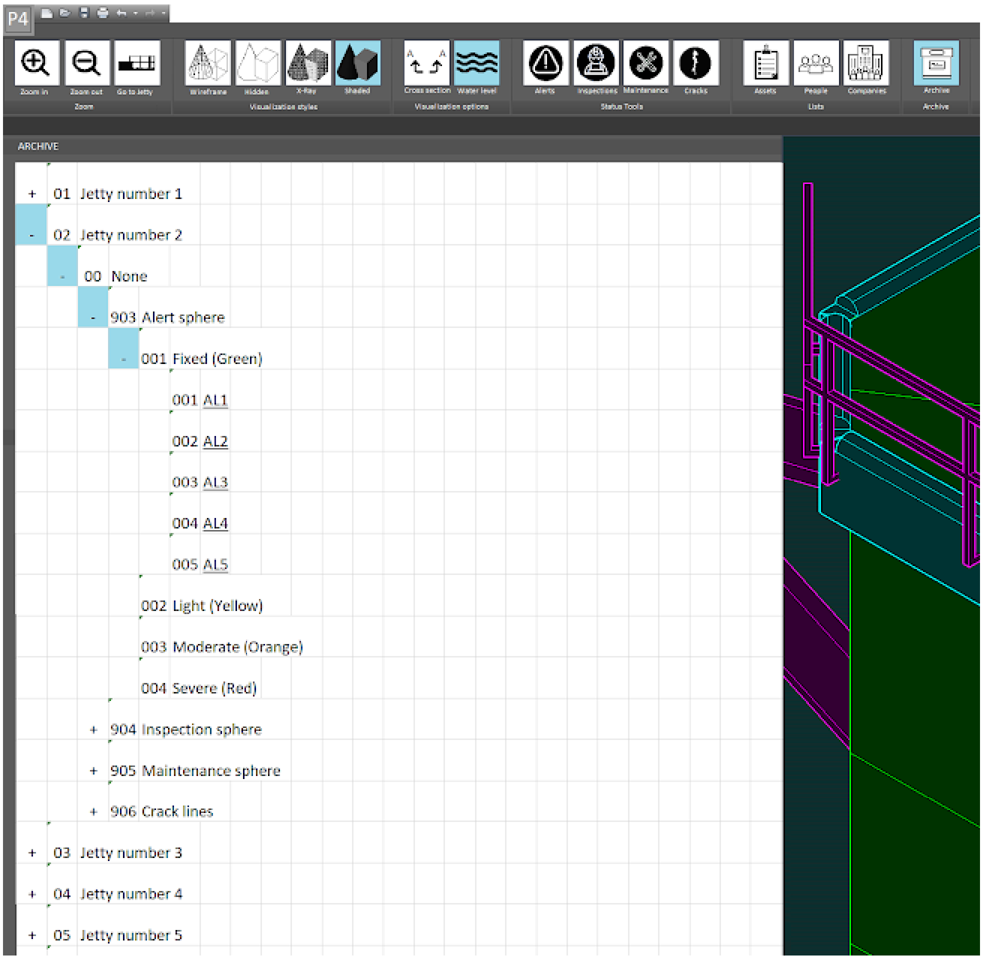

Figure 34. The Archive tool is selected, and its related list opens on the lefts side of the screen

As it is possible to notice from figure 34, the Archive works in exactly the same way as the list of assets, though only alerts, inspection, maintenance and cracks can be archived. Assets are items that stay as a part of the 3D model, without having the possibility of being not visualized.

The idea is to archive only those alerts and cracks that have already been inspected and maintained. In special cases, also other grades of alerts can be archived.

Following the Archive, there is the Chronology tool. When selected, Port 4D shows a full screen calendar, as shown in figure 35.

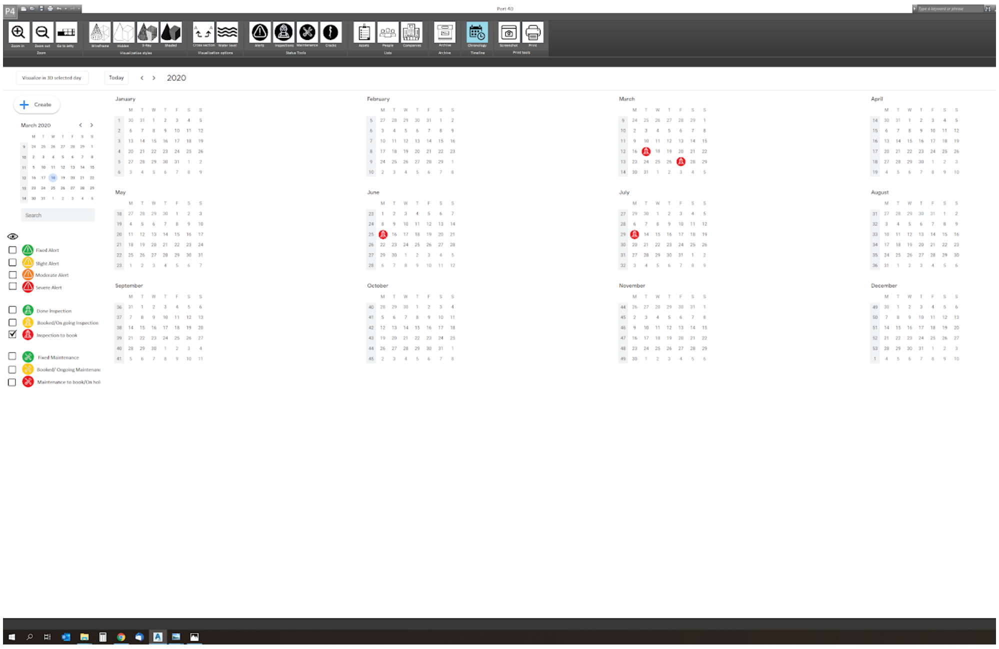

Figure 35. The layout of Port 4D when Chronology tool is selected

Figure 35 shows the layout of Port 4D when the Chronology tool is selected. As it can be seen, Chronology works as a calendar. It is, in fact, meant to be a tool for checking the timeline of the harbour, where all sorts of events can be registered or booked, from the design of the jetties to their estimated end of life.

This is a very important tool that can be used to control what has happened in the past and what actions should be taken in the future. Concerning the future, it is possible to add future events, such as inspections of planned maintenance. Furthermore, it is possible to get a notification from Port 4D when it is time to take the future actions.

On the left on the screen in figure 35, it is possible to see that alerts, inspections and maintenance can be visualized similarly to the 3D visualization. The events appear with the same symbols as in the 3D visualization.

In Chronology there are different ways to visualize the timeline. Figure 35 shows the year in a single layout, but it is possible to see one month at the time, one week, or even day by day if necessary. Figure 36 shows what the top left of the screen looks like when the weekly view is selected.

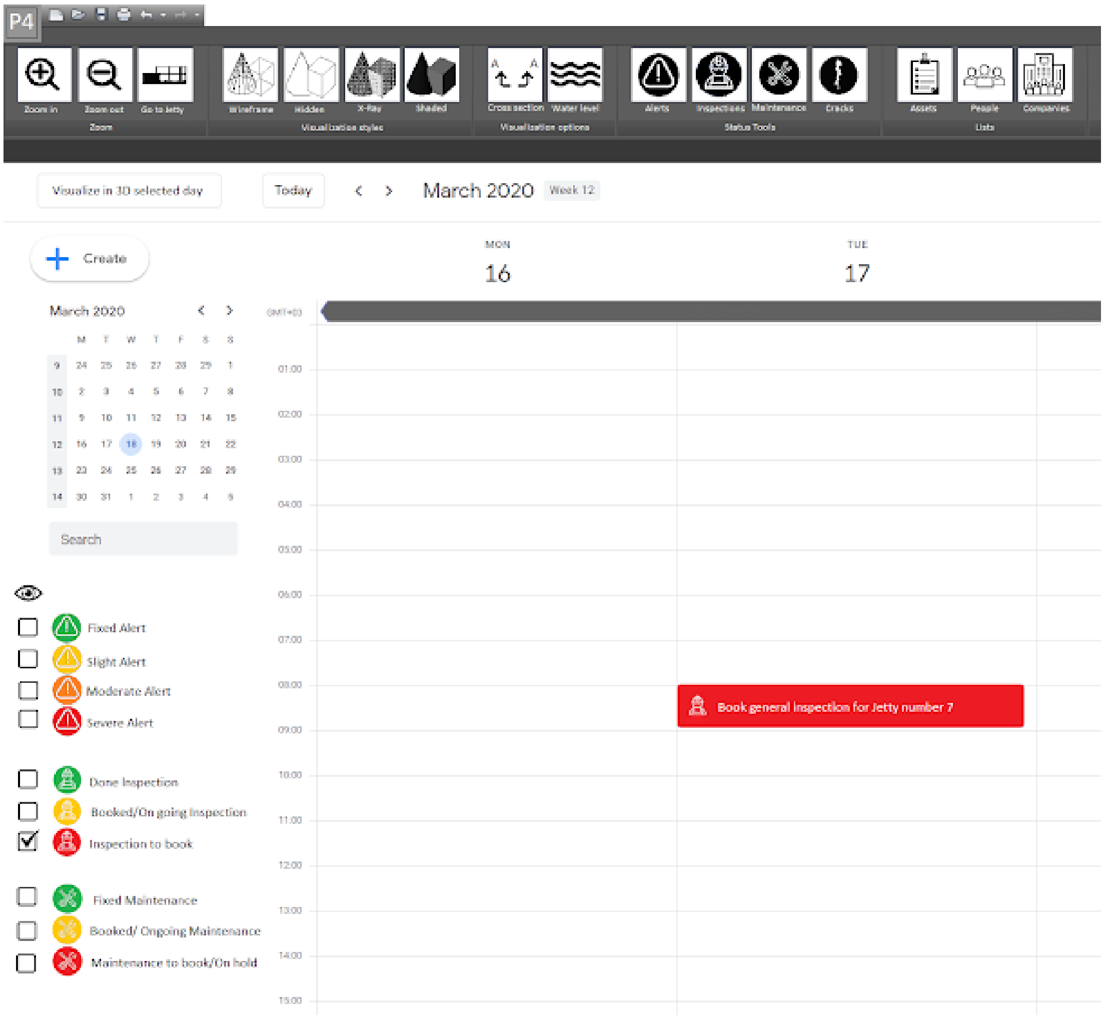

Figure 36. Zoomed in view of the upper left corner of the screen when Chronology and its weekly view are selected

Figure 36 shows an example of how a booked inspection for 17th March 2020 looks like. On the same figure it is possible to better notice the viewing options on the left on the screen, shown the same way as in the 3D visualization.

The last two tools on the horizontal command line at the top of the screen are Screenshots and Print. These two self-explanatory tools allow the user to extrapolate information from Port 4D and print them on paper or as a pdf file.

4.3 Benefits of Using Port 4D

As discussed in the previous chapters of this thesis, Port 4D was developed to be a complete managing system for the maintenance of ports. The application aims to be beneficial mainly for port maintenance departments, but it can also be used by other departments that have any relation with the port. The following is a list of benefits that can be achieved with the use of Port 4D:

- Comprehensive workspace
- Enhanced collaboration
- Complete database
- Easy storing of information
- Detailed scheduled maintenance
- Minimal disruption of port activities
- Clear risk overview
- Easier decision making
- Personalized visualization
- Efficient information sharing
- Versatility of usage
- Human error reduction

The first benefit listed is the fact that Port 4D was designed to be a comprehensive application, with all maintenance related information stored in a single application. The second benefit of Port 4D is the enhanced collaboration between all parts involved. The application allows every user to upload information that is immediately visible to other users. Furthermore, the contact information of internal departments and external companies and the history of jobs done are stored in the tools People and Companies. The third benefit is the possibility of having a complete database of the assets under the tool Assets. In addition to that, complete information about the assets are stored in relevant categories.

The fourth benefit is the possibility to store information easily. The Archive tool allows the user to easily store alerts, inspections, maintenance and cracks, leaving a clear visualization of the current situation of the port, with the older information still accessible whenever needed. The fifth benefit is the possibility of having a detailed scheduled maintenance, which is achieved with the tool Chronology. This tool allows the user to plan future inspections and maintenance, but also shows all related past events. When maintenance is properly planned and all involved parties are aware of the current situation, it is also possible to have a minimal disruption of port activities, another benefit of Port 4D.

The seventh benefit listed is the fact that Port 4D gives a clear risk overview and it is therefore possible to predict when repairs are to come, for example this can be achieved with the help of the Cracks tool, that allows an immediate visualization of the condition of concrete structures. Similarly, the following benefit is easier decision making, which can be achieved by the user-friendly colours used for the Alert, Maintenance and Inspection tools. The ninth benefit of Port 4D is personalized visualization, which is achieved with multiple tools, such as the four visualization styles, plus the possibility to visualize water level or not, and the cross-section tool.

Since Port 4D is thought to be an application that can be used both on computers and on portable tablets, the users can share information from different locations around the port, enhancing efficient information sharing. The eleventh benefit listed is the versatility of Port 4D, as it is possible to use the application for both new and old port structures. Once a 3D model of a jetty is designed, it can be imported into the application. When as-built-models are used, Port 4D visualizes a 3D model that resembles the reality. This can, for instance, diminish the risk for human errors, for example during the purchase of spare parts.

Even though not included in the list of benefits, it is possible to conclude that Port 4D would be able to save money and time with a proper maintenance plan throughout the lifetime of the port structures. When construction materials can be better managed and therefore saved, the environment benefits. Saving money and time are directly connected to the economy, people and society. Therefore, it is possible to say that Port 4D is a sustainable tool, since all three aspects of the triple bottom line are affected.

Another important aspect that can be considered a benefit is the fact that Port 4D is currently a prototype. Therefore, it can be developed and tailored according to the needs of the port. The following subchapter examines the future possibilities.

4.4 Future Development

Since Port 4D is currently a prototype, many different aspects could be changed, modified and implemented. This chapter presents some of the changes, modifications or additions. The changes can be classified from small details to major additions. In the last case, some changes can have a possible end result of modifying the main functionality of the application, expanding its purpose and use.

Classified as a small improvement, a possible change is the implementation of a more realistic visualization style. This new style could be called Real colours or Render. This style might help the user of Port 4D to better visualize the jetties and their assets by using the same colours as the reality.

Another option connected with the 3D visualization that could be added is that, not only 3D solid models but also point clouds can be visualized in the application. For instance, if a scan has been made of a specific area of the port, like pipelines in the case of Kilpilahti, the point cloud of the pipelines could be implemented in Port 4D. This would enhance the possibilities of visualizing a complete and current state of the assets.

Besides point clouds, the assets can also be added as solids. This would not just improve the visualization but also add the possibility of managing the maintenance of the complex assets. For example, other than pipelines, also cranes, loading equipment, roads, railroads, bridges and buildings can be implemented. This would extend the use of the application not just to the maintenance of water structures, but to all equipment and infrastructure that belongs to a port.

In addition, the systems used to control assets like pipelines or cathodic protection control could be implemented in Port 4D. The mentioned systems usually use simple 2D visualization. As seen in chapter 3, the Port of Kilpilahti uses METSO for the control of valves and pipelines which only offers a schematic 2D view of the harbour. Port 4D could in the future implement these features, in order to achieve a more comprehensive control of the port.

At the current stage, Port 4D is intended to work side by side with M+, the maintenance software used at the Kilpilahti harbour. In the future, M+ could be integrated into Port 4D for a full management of maintenance and repairs.

Port 4D is already intended to work not just with computers, but also with tablets and EX. The layout for the portable devices would be more user friendly but would give the same possibilities of usage as the computer software. However, more features can be added when tablets and EX have GPS signals. For example, Port 4D could include a visualization of the personnel of the harbor on the 3D model. This would give the possibility to have the personnel in risk areas under control, enhancing general safety. For example, if an alert on a certain area is signaled by a user of Port 4D, all personnel present in that area would get a notification of imminent danger.

Instead of tablets, also virtual reality or augmented reality could be used in the future. They would be easily implemented in a detailed 3D environment like Port 4D. Although virtual and augmented reality are still in a developing phase, it is already clear that they will be part of most working environments in the near future.

Lastly, there is the biggest and more complex addition that Port 4D could get in the future as environmental and logistic aspects could be added to the application. More specifically, environmental aspects of interest are air, water and soil quality data, energy consumption and waste management. Furthermore, logistics could include all the marine and land traffic management aspects. The last additions would change Port 4D to a full multidisciplinary application that could be able to keep track of any port in all its aspects. The new application should be able to produce all kinds of documentation such as energy consumption, environmental reports, official documents, logistic documents, relevant data to be exchanged between the port and vessels, traffic schedules and carbon footprint. This future development would turn Port 4D to a comprehensive sustainable tool for any port around the globe.

5 Conclusion

The purpose of this thesis was to develop an information based application prototype with visualization possibilities to support the maintenance of ports. In order to achieve such a goal, a study was carried out to get a better understanding of port maintenance and its importance. A correlation between properly planned maintenance and sustainability was confirmed by previous studies. The research continued, focusing on the available solutions on the market, finding that there was room for improvement in the field of port maintenance applications. Moreover, the study of the Port of Kilpilahti confirmed that there was a need for an application that would visualize the port and its assets in 3D. For a better understanding of port maintenance, a study of the most common degradation causes of concrete in marine environment was carried out, and different maintenance solutions were found. This research was added to the Appendix of the thesis and it helped to develop some of the tools of the prototype, for example the Crack tool.

Together with the Port of Kilpilahti, goals and requirements for the prototype were discussed. The main requirements found were: friendly user interface, clear visualization of broken assets, storing of asset information, history and people connected to the different maintenance activities, and a possibility to visualize a maintenance schedule. According to these requirements, preestablished together with the representative of Neste Oyj, Mr. Tegelberg, a prototype, named Port 4D was created.

The prototype was a sequence of photoshopped images that recreate screenshots of Port 4D throughout its layout, options and tools. In order to achieve such a result, detailed models of three jetties present at Kilpilahti, together with one full model of the entire port area, were created. The information and measurements for the solid based 3D models were taken from the old construction drawings available. The models were used to recreate screenshots of the prototype. Moreover, buttons, layout and option windows were designed with the use of photoshop software. The result was a sequence of over 50 screenshots that explore all the features of the prototype. As a final step, a booklet explaining the main functionalities of the prototype was created. The booklet was designed with the purpose to summarize this thesis.

The benefits of using Port 4D were listed and explained. The main benefits found were comprehensive workspace, enhanced collaboration, complete database, easy storing of information, detailed scheduled maintenance and easier decision making. Moreover, the prototype met the requirements preestablished with Mr. Tegelberg. Positive feedback from the collaborators was received.

Nevertheless, the prototype created was found to have a lot of room for improvement and future development, such as more realistic visualization of the 3D model, the possibility to add complex assets, such as pipelines, and the possibility to develop the software to be a complete sustainable management tool for ports, in all their logistic and environmental aspects in the future.

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Concrete Degradation Causes in Marine Environment

According to Eng. Edoardo Mocco, manager and technical expert at Azichem, the marine environment is particularly aggressive towards concrete structures and in order to understand the causes, it is important to categorize the marine structures, depending on their location as they are affected by different actions [22]. It is possible to divide structures in the following groups:

- Completely submerged
- In the near proximity of the shoreline
- Partially or cyclically submerged

The first category is the one that has the least risk when compared to the other two. In fact, underwater there is a reduced availability of free oxygen that would fasten the processes of degradation. On second place are coming the structures that are close to the shore, as they are affected mainly by the salts and agents present in the water that are transported by the wind. The last group, with the highest risk of degradation, is the one with partially of cyclically submerged structures. In fact, the actions of salts and agents are enhanced by the mechanical action of the waves, tidal changes and the freezing-thawing cycles. [22.]

It is important to understand that the previously mentioned aggressive processes are in most cases combined with the corrosion of the steel rebars, present inside the concrete. The degradation of the rebars can drastically influence the safety of the whole structure till its ultimate failure and collapse. [22.]

It is then possible to distinguish that the actions causing concrete degradation are of different nature even if often combined. As Eng. Mocco states, the nature of the attacks can be divided into three categories: chemical, physical/mechanical and even biological. [22.]

Mr. Akhtar Surahyo, in his book Concrete Construction, categorize the main forms of chemical attack as follows [23]:

- Chloride attack
- Sulphate attack
- Carbonation
- Acid attack

He explains that chlorides, which are originated from the dissociation of salt in water and therefore naturally present in seawater, can enter the concrete through its surface or through already present cracks. When they reach the steel rebars, they can destroy the oxide film that protects the rebars and start the process of steel corrosion. Once the corrosion has started, the chlorides increase the electrical conductivity of the concrete, that result in even faster corrosion of the rebars. Since during corrosion layers of rust are building on top of each other, the rebars expand and this causes even more cracks and delamination of the outer layers of concrete. [23.] [24.]

Concerning sulphates, Mr Akhtar Surahyo lists sodium, calcium and magnesium sulphates as the most active ones and commonly present in seawater. The mentioned solutions react with calcium present in hydrated concrete and form calcium sulphate. When this new compound crystallizes, it expands, which causes disintegration and delamination of the outer layer of concrete. This attack is particularly effective in areas that are cyclically wet and dry, because where water evaporates, sulphates remain and can start the crystallization process. [23.]

Carbonation is one of the most common problems with reinforced concrete. In fact, carbonation reduces the alkalinity of concrete to a pH of around eight, when normally is around 14. High alkalinity is commonly a wanted factor in concrete as it protects the rebar from corrosion. When the alkalinity lowers to pH eight, this protection is lost and the rebars tend to rust, with consequential expansion that transfer into internal stresses in the concrete. Mr Akhtar Surahyo explain that carbonation is the process that creates calcium carbonate $CaCO_3$ from the reaction of Carbon dioxide (CO_2) present in the air with calcium hydroxide $Ca(OH)_2$ present in hydrated concrete. The effect of carbonation increases in places with high relative humidity. [23.]

As explained, concrete is of alkaline nature, this means that the components of cement break down when in contact with acids. Some of the most harmful acids are sulphuric, hydrochloric, nitric and hydrofluoric acids. When the mentioned acids are in contact with calcium hydroxide $Ca(OH)_2$, present in hydrated Portland cement, a reaction occurs and calcium compounds are created. The calcium compounds are water soluble, therefore are carried away when in contact with water, causing surface erosion. [23.]

Eng. Edoardo Mocco explain, that the physical and mechanical processes that attack concrete are cracking, erosion and freeze-thaw cycles. The attacks are often resulting with volume loss that come from leaching of soluble compounds and from the mechanical erosion caused by the movement of the water, such as waves and tidal changes. [22.]

Cracks can also be mechanically caused by repeated loading, vibrations, overloading, thermal expansion and unexpected hazard, such as impacts, earthquake, fire or hurricanes. Concrete structures can also be affected by the cycles of humidification and exsiccation of water or by the long term freezing-thawing cycles. As previously explained, when water evaporates, it leaves behind on the concrete surface salts and agents. When those crystalize, they increase in volume causing cracking and degradation. [22.] [25.]

Ending the list made by Eng. Mocco, are biological attack, which are known as “fouling”. Fouling is in fact a term to describe the growth of animal and vegetal organisms on man-made structures. In the marine environment, fouling is usually found in those areas that are directly in contact with sea water. These alive coating layers are connected with the production of organic acids that come from the metabolism of the micro or macro organisms, lowering the alkalinity of concrete and enhancing the corrosion of rebar. [22.]

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Requirements and Solutions against Concrete Degradation

As understood, degradation of concrete can form from different causes. In most of the cases, degradation gives the first signals in forms of cracks, usually visible in rebar corresponding areas. This irreversible process, if not stopped in time can cause the failure of the structure itself. [26.]

It is important then to approach the problems with specific solutions. The solutions can be divided into two: design phases requirements and maintenance solutions. Moreover, particular attention has to be given to the inspection phase, prior the maintenance choice.

In order to achieve the wanted lifetime of concrete, it is of absolute importance to prevent right from the beginning the possibility of degradation of the concrete. In fact, the design phase is crucial, as important choices are made, such as concrete composition, the rebar protective layer thickness and the kind of spacers used for the rebars in the formwork. [27.]

In the harsh marine environment, the choice of the concrete is extremely important. The Eurocodes gives, among others, the requirements for minimum strength class, water-cement ratio and also to the minimum protective layer thickness in front of the rebars. The requirements vary depending on the environmental classes that should be taken into account. The main exposure classes defined in EN206-1 are [28]:

- XO - no risk of corrosion attack
- XC - risk of corrosion by carbonation
- XD - risk of corrosion from non-marine chlorides
- XS - risk of corrosion from marine chlorides
- XF - risk of freeze-thaw attack
- XA - Chemical attack

For each of the listed classes, grades are given and consequently minimum requirements. For example, for class XS3, where grade three refer to areas that are partially submerged, the cover layer minimum thickness is 45 mm, recommended water-cement ratio is 0.5 and minimum strength class is C35/45. [29.]

In addition to the concrete composition choice and the rebar material choice, it is also important to choose the right spacers used to keep the rebars in place during the casting phase. Rebars spacers can be made of concrete, metal or plastic. In marine environment it is recommended to use concrete ones, specifically with the same kind of concrete, in order to avoid local attacks from the environment in the spacers surrounding area. Moreover, it is important to have spacers of the right size that are able to withstand the weight of all the rebars, plus the weight of the pouring concrete during casting. In fact, if the spacers are too weak or not often enough, the rebars will tend to bend under the casting pressure, consequently, when the concrete dries, the rebars will find themselves too close to the air and they will have higher chances of rusting. [27.]

An odd solution is also to build marine structures without the use of rebars. In Middle East, it is quite a common solution, since the salinity of the ocean in that area is higher than everywhere else in the world. Those structures are usually massive blocks of concrete placed one on top of each other. The idea of this solution is that the main stress involved is compression and all other forces are so small in comparison that they can be neglected. [27.]

In order to determine which practical solution is the most suitable for already existing and degrading structures, a preceding inspection is of extreme importance. Moreover, if inspections are done regularly the beneficial consequences can be many.

As Mr. Li, Mr. Leung and Mr. Xi write in their book Structural Renovation of Concrete, regular inspections can: avoid failure and even casualties caused by unexpected damages, can prevent the sudden disruption of use of the structures and facilities and therefore, protect capital investment. As they suggest, frequent and well-planned inspections are the best practice of reducing maintenance and their related costs throughout the lifetime of the structures. [30.]

According to them, the suggested inspection intervals can vary depending on two variables: the importance of the structure and the environmental and loading conditions. The importance of the structure can be divided into three classes [30]:

- Class 1 - Very important use of the structure where failure would be catastrophic.
- Class 2 - Considerable important use of the structure where failure could end in casualties
- Class 3 - Structures where a disruption of use can be tolerated, and it is unlikely that failure could lead to casualties.

The environmental and loading conditions can also be divided into three categories [30]:

- 1 - Very Severe - Aggressive environment and extreme loading circumstances
- 2 - Severe - Aggressive environment with static loading or normal environment with extreme loading circumstances
- 3 - Normal environment and static loading

Based on the listed factors and divisions, Mr. Li, Mr. Leung and Mr. Xi use a table to show their recommended interval between one inspection and another. The intervals are expressed in years. [30.]

Table 1. Intervals in years between inspections depending on classes and conditions.

Intervals in years	Class 1	Class 2	Class 3
Very Severe	2	6	10
Severe	6	10	10
Normal	10	10	15

In table one, it is possible to notice that inspections are required more often for structures that have higher importance and more aggressive environment and loading circumstances, compared to structures that have lower importance and normal life conditions.

Once inspections, investigations and laboratory tests are carried out, results become available and the best maintenance practice is chosen, depending on the degree of degradation. The following list shows the most common repairs strategies:

- General repair
- Crack repair
- Jacket system for marine piles
- Chloride removal and Re-alkalization
- Coating or Impregnation
- Cathodic protection

General repair is a common practice that consists of the following four steps:

- Removal of the damaged concrete
- Preparation of the concrete surface
- Preparation of the existing rebar
- Replacement of concrete

The correct preparation of the concrete surface is essential for the positive result of the maintenance. For both under and above water level structures, the first step is to remove the old and degraded concrete, at least, till a depth where the before mentioned attacks are under the required limits. Nevertheless, it is recommended to remove concrete so that the first layer of rebar is fully exposed. The removal methods can vary: pneumatic drilling, electrical sawing, electric or pneumatic hammering, sand blasting and hydro demolition. [31.]

The second step is the preparation of the new surface. In fact, in order to have a good adhesion of the new layer, the existing concrete must have coarse surface, a moisture content smaller than 5% and the required strength of adhesion should be greater than 1.5 MPa. This last requirement can be tested by a pull-out test, where a metal plate is glued to the concrete and then pulled by the testing machine that measures the adhesion strength. [30.]

The third step is the preparation of the freshly exposed rebars. In fact, every sign of rust and oxidation can now be removed via sanding or mechanical brushing. Eng. Mocco recommends that the maximum oxidized part of the rebars should not be more than 20%. In that case, new rebar should be placed, in connection to the existing one. [31.]

The last phase is the placement of the new concrete. It is important to choose the new material accordingly to the environmental and structural characteristics of each repair. The main factors that determine the choice of the products are: impermeability, chlorides and sulfides resistance, high cohesion and adherence and the correct elastic modulus. Also, the new thickness cover is an important factor that has to be planned thoroughly, as it might affect the durability of the repair. The new concrete is then casted and properly cured. For submerged structures it is important that casting the new concrete is done in a period of maximum of eight hours from the removal of the existing concrete, in order to anticipate the fouling process. [31.]

In case concrete is partially damaged, but rebars are assessed to be in good condition, it is possible to skip, or postpone, a relatively expensive general repair and simply repair the visible cracks. If cracks are in fact wider than allowed by building codes, it is recommended to repair them before they get bigger and lead to bigger problems. The most common crack repair techniques are: gluing the crack back together by the use of grouting or epoxy injection, stitching the crack with dowels or the combined technique of first enlarge the crack and then seal them with a flexible sealant. [30.]

For structures that are partially submerged, and therefore exposed to the mechanical attacks of the water movements, a solution called “jacket” can be used. Specifically, the solutions are designed to protect concrete piles that sustain piers, bridges and general water structures. Common materials used are steel sheets of fiberglass that are wrapped around the existing column. The new jacket works as a mould when the new concrete is poured to repair the damaged pile. [32.]

Jackets on piles can also be beneficial against the ice friction and pressure caused by the incoming ships during mooring maneuvers. In fact, big ice slabs that compresses between the ship and the harbour, can deteriorate the external surface of concrete pile if not properly protected. [27.]

In the case of carbonated concrete, therefore with lower alkalinity, re-alkalization is a long-term solution. This process restores the alkalinity of concrete to a higher pH via the passage of electricity through the rebar, that allow the electrolyte, an alkaline solution of potassium or sodium carbonate, to diffuse into the structure towards the rebar. This process results with a higher protection towards further corrosion of the rebars. At the same time chloride is being extracted from the damaged concrete as chloride ions are attracted and moving in the opposite direction. Therefore, two beneficial effects can be achieved at once. Because of the presence of a liquid solution, this process, that last from a few days to a few weeks, is available only for structures that are not underwater. [30.]

In some cases, the external concrete surface might seem satisfactory, but the rebar might have already started the corrosion process. An alternative to the previously discussed solution is impregnation with water-proof products or corrosion inhibitors. These substances can be applied either by spraying or brushing. Once applied they create a protective coating that can slow the corrosion process as attacking agents are stopped from reaching the rebars. [29.]

Another solution that is used to protect the rebars is cathodic protection. Cathodic protection is a common solution for the protection of metals against corrosion. It is used not only for rebars in concrete, but also for pipelines, tanks, ships offshore platforms and more. Cathodic protection connects the steel that its needed to be protected from corrosion to a sacrificial piece, made of a metal that corrodes faster than steel. This sacrificial piece is usually a highly active metal that provides free electrons and act as an anode. The free electrons are causing the sacrificial metal to loose ions and keep the steel from corroding. [33.]

The two main types of cathodic protections are: galvanic and impressed current cathodic protection. Galvanic protection uses a layer of protective zinc around the steel [33]. This solution is only temporary, in fact, once the layer of zinc is no longer capable of providing free electrons, the steel will start the corrosion process. Impressed current protection system on the other hand is a more long and stable solution. The system utilizes a power source that provides with electricity to anodes. The anodes releases ions and it causes a counter reaction of oxidation of the dissolved chloride ions, that ultimately help to protect the steel. [34.]

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Classification System

Jetty number:

- 01 Jetty number 1
- 02 Jetty number 2
- 03 Jetty number 3
- 04 Jetty number 4
- 05 Jetty number 5
- 06 Jetty number 6
- 07 Jetty number 7
- 08 Jetty number 8
- 09 Jetty number 9

Material division:

- 00 None
- 01 Concrete
- 02 Steel
- 03 Timber
- 04 Rubber
- 05 Soil
- 06 Water
- 07 etc.

Element category:

- 000 None
- 001 Column
- 002 Beam
- 003 Pile
- 004 Wall
- 005 Footing
- 006 K-element

- 007 S-element
- 008 Super structure
- 009 Slab
- 010 Anchoring slab
- 011 Dolphin
- 012 Erosion beam
- 013 Erosion slab
- 014 General Element
- 015 Infilled concrete
-
- 101 Pipe
- 102 Anchor bar
- 103 Bollard
- 104 Baluster
- 105 Edge bar
- 106 Access ladder
- 107 Stairway
- 108 Rope guide
- 109 Control tower
- 110 Bridge structure
- 111 Walking grid
- 112 Emptying tanks
- 113 Hatch
- 114 Light pole
- 115 Safety equipment
- 116 Foam gun tower
- 117 Bolts
- 118 Mounting plate
- 119 Sheet pile
-
- 201 Fender
-
- 301 Protection balk

- 401 Ground surface
- 402 Water surface
- 901 Coordinate sphere
- 903 Alert sphere
- 904 Inspection sphere
- 905 Maintenance sphere

Example of Subcategories

Subcategory for structural elements:

- 000 None
- 001 A (ex. A type of beam)
- 002 B
- 003 C
- 004 D
- 005 E
- 006 F
- 007 etc. etc.
- 101 H section
- 102 L section
- 103 square section
- 104 square hollow section
- 105 round section
- 106 round hollow section
- 107 etc.

103 - Bollard Subcategory:

- 000 None
- 001 PTT600
- 002 PTT600 with hydrant
- 003 PTT750
- 004 PTT750 with hydrant
- 005 PTT1000
- 006 PTT1000 with hydrant
- 007 PTT1500
- 008 Quick releasing gear
- 009 Old bollard style 1
- 010 Old bollard style 2
- 011 Old bollard style 3
- 012 Old bollard style 4

117 - Bolts divided by dimension:

- 001 M10
- 002 M12
- 003 M14
- 004 M16
- 005 M20
- 006 M24
- 007 M30
- 008 etc.

201 - Fender Subcategory:

- 001 Sumitomo Beta-250H FF
- 002 Sumitomo Beta-300H FF
- 003 Sumitomo Beta-400H FF
- 004 Sumitomo Beta-500H FF
- 005 Sumitomo Beta-600H FF
- 006 Sumitomo Beta-800H FF
- 007 Sumitomo Beta-1000H FF
- 011 Sumitomo Beta-250H KT
- 012 Sumitomo Beta-300H KT
- 013 Sumitomo Beta-400H KT
- 014 Sumitomo Beta-500H KT
- 015 Sumitomo Beta-600H KT
- 016 Sumitomo Beta-800H KT
- 017 Sumitomo Beta-1000H KT
- 021 Sumitomo LMD-250H FF
- 022 Sumitomo LMD-300H FF
- 023 Sumitomo LMD-400H FF
- 024 Sumitomo LMD-500H FF
- 025 Sumitomo LMD-600H FF
- 026 Sumitomo LMD-800H FF
- 027 Sumitomo LMD-1000H FF
- 031 Sumitomo LMD-250H KT
- 032 Sumitomo LMD-300H KT
- 033 Sumitomo LMD-400H KT
- 034 Sumitomo LMD-500H KT
- 035 Sumitomo LMD-600H KT
- 036 Sumitomo LMD-800H KT
- 037 Sumitomo LMD-1000H KT

401 - Ground surface divided by kind of soil:

- 001 Morein
- 002 Sand
- 003 Clay
- 004 Silt
- 005 Fine gravel
- 006 Gravel
- 007 Infill
- 008 etc.

903 - Alert sphere:

- 001 Fixed
- 002 Slight
- 003 Moderate
- 004 Severe

904 - Inspection sphere:

- 001 Done
- 002 Booked/On going
- 003 To book

905 - Maintenance sphere:

- 001 Fixed
- 002 Booked/On going
- 003 To book/On hold

List of Created Files

3D General	DWG	10546 KB
3D General	IFC	40074 KB
3D Laituri 1	DWG	8149 KB
3D Laituri 1	IFC	30235 KB
3D Laituri 2 ja 3 – Simple version	DWG	8815 KB
3D Laituri 2 ja 3	DWG	29048 KB
3D Laituri 7	DWG	11537 KB