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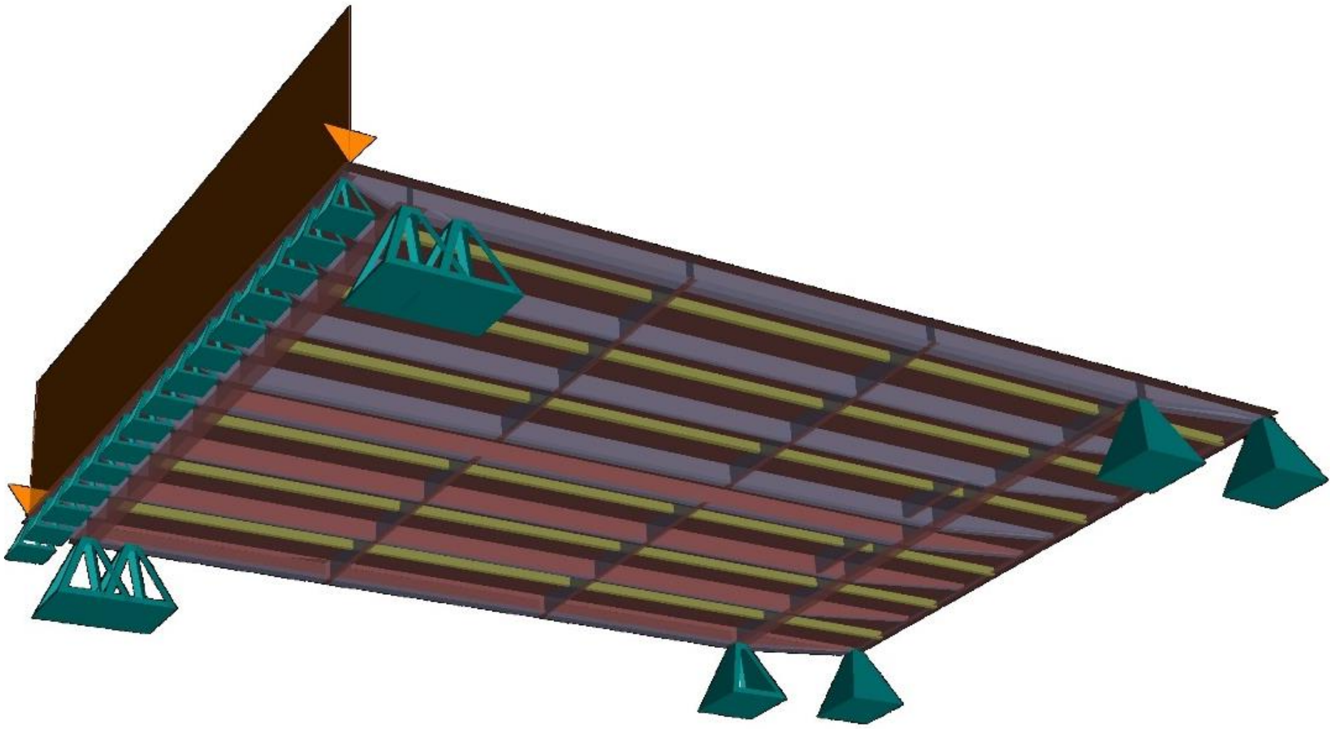

Design modularisation and weight optimization on cargo equipment

Master's thesis in the International Master's Programme Naval Architecture and Ocean Engineering

VICTOR ERIKSSON & OTTO MÅRDÉN

Department of Shipping and Marine Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

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Cover:
Ramp item generated in GeniE

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ABSTRACT

This master thesis is carried out at TTS Marine AB in Gothenburg; a company specialized in design, engineering and construction of large complex and moveable steel structures for large ships, such as PCTC, RORO and ROPAX. Typical products is equipment and solutions of rolling goods, i.e. large off and on loading ramps, car decks, hoist able decks, quarter stern ramps, etc. The procedure for developing and designing a new product or steel structure is first to create a JavaScript that combined with the software program GeniE generates a computer model. Due to the fact that no products are identical, these scripts need to be redeveloped and rewritten for each new product is designed, a time consuming and costly process. Utilization of man hours and the duration of the engineering phase is of great importance in the time aspect of weight optimization of the steel structure, this is particularly important in designing and construction of floating vessels. Reduced weight reduces fuel consumption, increases cargo capacity and allows for increased speed, factors that have an impact on company revenue. Calculations related to weight optimization of TTS products is currently performed mainly manually, the result and accuracy is of high quality due to extensive experience, references and large knowledge. By using a developed and sophisticated tailor made software system may man hours and duration be decreased and at the same time gain traceability and transferable documentation

This thesis has two purposes. The first is the modularization of a number of structures. This is achieved by developing a JavaScript that with the right input values can generate a number of different products, (i.e. ramps) thus reducing man hours and duration for weight optimization calculations. The second purpose is to define an optimizing method that can be implemented with GeniE. The optimization method is foreseen to be a part of the basis for the planned development of a new software program that automatically will optimize the steel structure in a ramp.

A large number of existing ramps has been studied in order to identify components and features that are common in the different ramps. These features are compiled and described and an explanation of how the script is built is included in the report. The final script has been evaluated and tested by engineers with extensive experience to calculate structures by using the software program GeniE. In preparation for the optimization calculations, a number of different variable parameters in the structure have been reviewed, variables not applicable for optimization has been precluded. A study of optimizing methods has been undertaken and a suitable method is identified. An optimizing algorithm for the structure has been developed.

Key words: Finite element method, GeniE JavaScript, Optimization, Sesam

Design modularisering och viktoptimering på lastutrustning

Examensarbete inom Naval Architecture and Ocean Engineering
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SAMMANFATTNING

Den här uppsatsen är utförd hos TTS Marine AB i Göteborg, ett företag specialiserad på utveckling, konstruktion och tillverkning av stora komplexa och rörliga stålkonstruktioner för skepp, såsom PCTC. RORO och ROPAX. Typiska produkter är utrustning och lösningar för rullande gods så som stora av och påkörnings ramper, bildäck, lyftbara däck, kvartsramper osv. Proceduren för att utveckla och konstruera en produkt eller en stålkonstruktion är först att skapa ett JavaScript som kombinerat med programvaran GeniE skapar en datormodell. Eftersom inga produkter är identiska måste man för varje ny produkt skapa ett nytt script, vilket är tidskrävande och följaktligen kostsamt. Utnyttjande av mantimmar och varaktigheten av konstruktionsfasen är av stor betydelse i tidsaspekten vikt optimering av stålkonstruktionen, detta är särskilt viktigt i design och konstruktion av fartyg. Minskad vikt minskar bränsleförbrukningen och ökar lastkapacitet samt möjliggör ökad hastighet, faktorer som har en inverkan på företagets ekonomi. Beräkningar relaterade till viktoptimering av TTS produkter utförs huvudsakligen manuellt, resultatet och noggrannhet är av hög kvalitet på grund av lång erfarenhet, referenser och stor kunskap. Genom att använda en utvecklad och sofistikerad skräddarsydda programvara kan antalet mantimmar och kalendertiden minskas, detta skulle också kunna öka spårbarhet och öka överförbarheten mellan olika dokument.

Denna uppsats har två syften. Den första är att utveckla en JavaScript som med rätt ingångsvärden kan generera ett antal olika produkter, (d.v.s. ramper) vilket minskar mantimmar och som sagt kalendertiden för arbetet med viktoptimeringen. Det andra syftet är att definiera en optimeringsmetod som kan genomföras med GeniE. Optimeringsmetoden som har utvecklat kan ingå som ingångsdata till eventuellt framtida större utvecklingsarbete med målet att ta fram ett nytt dimensionering program som automatiskt kommer att optimera stålkonstruktionen i en ramp

Ett stort antal befintliga ramper har studerats i syfte att identifiera komponenter och funktioner vilka är vanligt förekommande i de olika ramperna. Funktionerna har sammanställts och beskrivits, förklaring till hur skriptet har byggts upp ingår i rapporten. Det slutliga scriptet har utvärderats och testades av ingenjörer med lång erfarenhet av att beräkna strukturer med hjälp av programvaran GeniE. Som förberedelse för optimeringsberäkningar, har ett antal olika variabla parametrar i strukturen granskats, variabler som inte lämpliga för en optimering har utesluts. En studie av optimeringsmetoder har genomförts och en lämplig metod identifieras. En optimering algoritm för strukturen har utvecklats.

Nyckelord: Finita elementmetoden, GeniE, JavaScript, Optimering, Sesam

Contents

Preface

This thesis is a part of the requirements for the master's degree in Naval Architecture and Ocean Engineering at Chalmers University of Technology, Gothenburg. The work has been carried out at the Division of Marine Design within the Department of Shipping and Marine Technology, Chalmers University of Technology between January and June of 2016 with Senior Lecturer Per Hogström as examiner and principal supervisor.

The project has been performed at the structure department at TTS Marine AB with Rebwar Venya and Jeremy Peter as supervisors.

We would like to acknowledge and thank our examiner and supervisors, Senior Lecturer Per Hogström, M.Sc. Rebwar Venya and M.Sc. Jeremy Peter. We would also like to thank M.Sc. Hamed Shakib at TTS Marine and M.Sc David Engerberg, at DNV GL for their excellent guidance and support throughout the work with this thesis. In addition we want to express our gratitude to all employees at TTS Marine AB that has assisted and supported us in the development and finalization of this report.

Göteborg, May 2016

Otto Mårdén and Victor Eriksson

Notations

Roman case letters

U_i	Generalized displacement
∂U_i	Change of generalized weight
w_j	Weight of the j member or beam
∂W_j	Change of weight of the j member or beam
ΔU_i	Approximation of displacement

Cleat	Locking mechanism
DNV	DEN NORSKE VERITAS
Flap	Structure attached to ramp that eases a vehicles transition
Item	Refers to the specified product
JavaScript	Programing languish
Longitudinal girders	Major Beam in longitudinal direction
Spacing	Distance between longitudinal
Span	Distance between transverses
Stiffener	Smaller beam
Top plate	Plate located on the top of the item
Transverse girders	Major Beam in transverse direction

1 Introduction

This thesis will be concentrating on the design and engineering phase in the structure department. Focus is to reduce man hours and duration and developing a software for computer aided optimize of the steel structure with regard to weight while maintaining strength and rigidity.

1.1 Background

TTS Marine AB is specialized in design, engineering and constructing large ship equipment such as ramps, decks, doors and visors. In order to be competitive on the market the products needs to have a low price, high quality, high strength as well a low weight. Decreased weight results in increased cargo capacity, decreased fuel consumption and increased revenue for the ship owner.

This way of thinking can be recognized in some of the seven wastes of lean production. Carreira and Trudell (2006)

- Overproduction. Exes of material used in the structure
- Excess of inventory. Less material in inventory
- Transport. Unnecessarily weight to transport
- Process. Unnecessarily optimization procedures
- Rework. Redesigning of models
- Waiting. Waiting on analyses
- Unnecessary motions

The cost of a product is generally greatly affected by the number of man hours and the time span it requires to finalise it. One of the stages towards a finished product is the engineering part. By reducing man hours used in the engineering work, which in these kind of products especially comes from the structural as well as the design department. Using more efficient tools will shorten lead times, reduce overall project time and lower project cost.

Reducing the weight of each individual item in a complex product like movable large ramps requires an optimization process where all parts in the large structure is included and targeted, a work that traditionally mainly is performed by manually calculations. Done correctly, the final product will be able to meet requirements set on structural strength and product quality with a reduced steel weight. In the early phase of the design and engineering process a comprehensive specialized software system will be capable to increase the number of iterations required to optimize the steel structure in the same or reduced time span compared to manual calculations. An automatic computer aided design process where experience and good workmanship is included will probably reduce risks and value to the final product.

In the above mentioned processes, the structural department plays a vital role and they have a support role towards the design department. Their tasks consists of optimizing the structure, checking for structural integrity and are responsible for class approval. The requirements to meet can be maximum allowable stress set by classification societies, deflections of steels structures set by operational limits and ship owner's requirements.

The designers find solutions, design the products and are in charge of various items in the company.

1.1.1 Modularisation

To be able to perform the FE analysis of the steel structure a computer model needs to be created. Software based models of a large number of individual items has been developed; these are often reused to create drawings for these individual items. The itemized models are in most cases not suitable for use in the FE analyses. New software models has to be created in a separate program that is only used as a basis for the FE analyses. One of these programs that is often used in the maritime industry is created by DNV GL is GeniE.

GeniE is a Finite Element method software program that uses shell and beam elements to create models and analyses them. DNV GL (2010)

There are two means of construct an item in GeniE, it is graphically or by using a JavaScript. After discussions with TTS, the pros and cons with the two methods became clear. Creating the model graphically in GeniE is viable, the benefits using JavaScript to generate the model is considerable. JavaScript ensures that no gaps, overlaps or other errors occurs in the model, even if errors occurs they are easy to find and correct. If changes of the geographical structure are required, these are relatively easy to make. It is however time consuming to use JavaScript since a new script needs to be created for each new product are designed.

This part of the engineering process has possibilities for improvement. The possibilities to use individual abbreviations and structure when using JavaScript may create misunderstandings, problems and rework in cases when more than one engineer is involved in the same design or product. A stricter disciplined companywide valid drawing system and abbreviation protocol has to be developed and implemented. A system where all engineers are forced to use same abbreviations and same structure in the JavaScript. A strict protocol is especially important in the situation where change of or additional engineers is required to continue or finalize the design work or additional.

1.1.2 Weight optimization

The engineers at TTS have a considerable knowledge and they have large number of years of experience, they know how the different structures are optimized. As for now, the structure department is performing the weight optimization calculations of structures manually by using computers as calculators. This ties the engineer to the computer and limits the use of the computers and the software to normal working hours, normally eight hours a day, five days a week, instead of utilizing every hour, everyday which would be 168 hours a week. Another limiting factor is that there are only a few licenses available at TTS. While it is a functional system with good accuracy regarding all the different restrictions in the structure there are room for improvements.

Figure 1 illustrates the drawing and 3D models iteration and process flow in Structure Department in their work to make a model for the FE analyses.

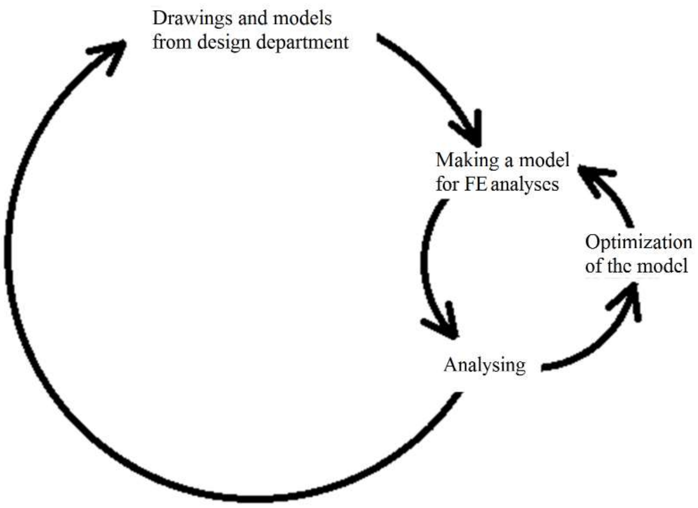

Figure 1 Present work flow to optimize a steel structure

A new loop starts to check if it fulfils the criteria's to optimize the structure, if not it lops again When the requirement is met and the actual steel structure is optimized will the results be sent back to the Detail Design Department to update the drawings.

1.2 Purpose

Reducing the time spent for a calculation in Structure Department will also reduce its bottleneck effect and it will reduce the overall work load. This is also beneficial for the interaction with the design department. Late changes in the structure affects more design details. The earlier the designers can get feedback from structural department, the better.

The first step in this process is to initiate the development and to implement a useful automatic software tool for weight optimization at TTS. The tool will make the design process in GeniE more effective and consequently more time will be given for detecting and adjusting errors, countermeasures taken as well as optimizing the structure.

Minimizing the weight of the steel structures will have a direct impact on the amount of steel and cost. No oversizing of stiffeners and no extra girders. Additionally less steel need to be stored, less onshore transportation required and lighter weight of the transportation ship. Fewer parts need to be welded to the structure. The design department may minimize waiting time and slack, unnecessary interruptions in the detail design department due to waiting on the calculations will be reduced.

1.2.1 Modularisation

GeniE allows two different systems of making a FE model, either graphically and with a script. The structure department uses scripts to generate models in GeniE. A large number of separate parts in the structure are very similar, still these needs to be redesigned and recalculated in every new product case. This is quite time consuming, to make the whole design process more efficient a tool for reducing the coding time has to be developed, implemented and used.

1.2.2 Weight optimization

The scope for the study included to develop the basic structure for a optimization software program and to develop a theory that may form the basis for future development and if possible to formulate an algorithm that can automatically optimize structures. The scope also included to define the parts that is possible to improve and were more studies and work has to be done to solve problems that may arise.

1.3 Task description

This master thesis consists of two main tasks, the optimization of the design procedure in GeniE and the identification of potential means of weight optimization.

The modularization consists of

- Create a script with more features
- Create a chart of abbreviations
- Create a document that explains the different parameters

The script is going to contain features related to large ramps used on ships, it will make the design phase more efficient as more features is going to be pre done. A chart of the abbreviations will be created to make it easier to move over parts of scripts from different project and to make it easier to understand the scripts, the abbreviation chart will also reduce misunderstandings and rework. A second chart will be created to explain how the different parameter change the design of the ramp,

The weight optimization

- Making an Algorithm for an automation of the weight optimization

Optimization of a structures weight is important both for the usage of the item and profits. All parts of the steel structure interact with each other; the main and important issue is the question of prioritizing what parts of the structure should be optimized first and in what order the changes should be done. A literature study and calculations regarding the products produced by TTS Marine is to be done.

1.4 Limitations

TTS Marine has a large number of and different kind of products. In this project, for the modularization part the products listed below will be focused on.

- Side ramp
- Self-hoisted ramp
- Lifted ramp
- Ramp + Cover
- Two ramp, cleated

Parts outside the top plate and below the main structure is not included. The height of the structure will be limit to the height of the transverse girders. The design choices are done in collaboration with TTS. The area limited by the black lines seen in *Figure 2* is subject for this study.

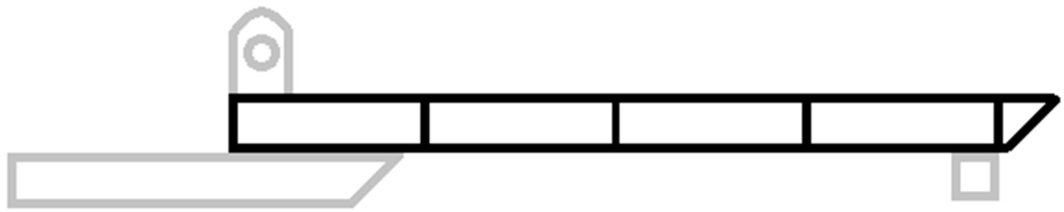

Figure 2 Structure seen from the side. The grey area is not part of this study

Structures outside the main part of the ramp are often unique for each ship and each purpose. Specific minor parts of standard character are used in the design of different ramps.

The weight optimization review will only focus on car deck panels. These contains of a limited number of structural parts compared to more complex large aft ramps that includes components that may interfere with the results. All car decks have different designs and dimensions. The car deck subject to this study is of a generic design.

The load case used in the weight optimizations is uniformly distributed load acting on the top plate. The limiting criteria's are stress and deflection. No regard has been taken to their size but only the difference in magnitude in the various parameters.

The study is limited to optimization methods applicable to FE-analyses and no elementary cases or mathematical methods are concerned.

1.5 Method

1.5.1 Modularization

A study of existing TTS Marine line of products has been done in order to compare them and identify features used in all or in a substantial number of the products. The scripts of the existing products were also reviewed to gather information and get an initial idea how to best commence the development of a new script. A online help-functions for JavaScript; W3Schools (2016), as well as the help function in GeniE was often used to solve software problems when they occurred and if this didn't work, council was given by direct contact with software expertise at DNV GL. A chart of abbreviations has been developed and concluded by the authors based on discussions with the engineers at TTS.

A test of the script has been undertaken by two employees at TTS-Marine. Both of them each designed a model in GeniE of varying complexity level with the help of the script. The time this required was compared to an estimation of how long two previous methods took; one where the script was generated from scratch and one where other scripts were used to get started.

1.5.2 Weight optimization

By studying product descriptions and conducting interviews with engineers and drafts men within the company, changeable parameters on the structures are identified and the one most suitable for weight optimization is concluded. A literary study on optimization methods was undertaken to identify the most suitable method for the case in hand. Defining how the structure could be optimized were done in cooperation with experienced engineers at the company, all with great knowledge and extensive experience on how the optimization is done today and how it have been done historically. They also had great insight in how many man hours and how long time it usually requires to develop and finalize the calculations for a ramp.

2 Analyses of the different items

Five different ramp types from TTS Marine item portfolio are studied:

- Side ramp
- Hoistable ramp
- Lifted ramp
- Ramp + Cover
- Two ramp, cleated

Following chapters describes these five ramp types. They have been selected based on information and advices given by engineers and expertise at TTS. The selected ramps are viable and currently important products for the company.

It should be highlighted that there, for the moment, are no defined guidelines or specific engineering instruction within TTS describing how these particular ramps shall be designed in detail. All ramps are built up by large number of separate parts with a specific function. Therefore, a lot of minor steel items and details may vary due to various factors, such as product type, owner requirements, strength requirements and operational requirements. The descriptions in this chapter are based on products used by TTS Marine and the objective is to identify details and functions that need to be included in the new script.

With all different details, all ramps have some parts that are always recurring. These can be viewed in *Figure 3*.

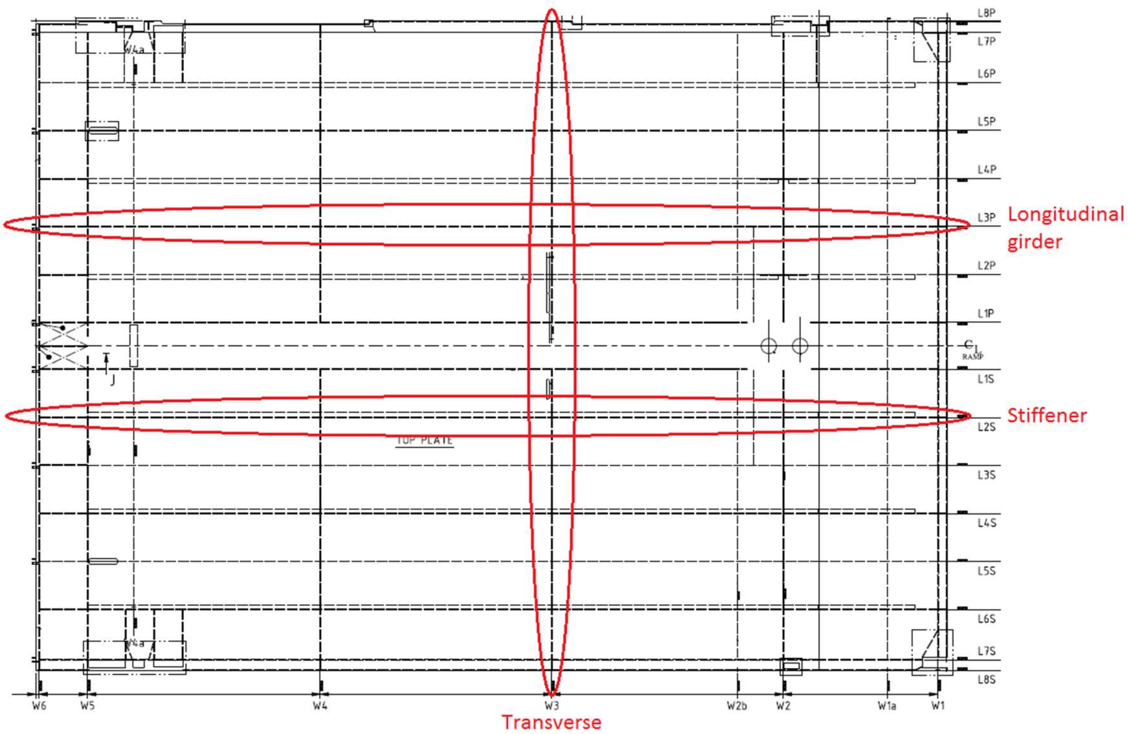

Figure 3 Top view of a general ramp with a Transverse, Longitudinal girder and Stiffener marked out

All ramps are built up by a top plate, longitudinal girders, longitudinal stiffeners and transverses. In the drawing *Figure 3* the girders and transverses can be seen as dotted lines. The stiffeners are illustrated with two dotted parallel lines as seen in *Figure 3*. All parts of the ramp are designed differently but with an amount of similarity. The drawings may contain separate details that are not included in the model generated in GeniE. These separate details is designed based on local strength calculations, GeniE is a system for global strength.

2.1 Side ramp

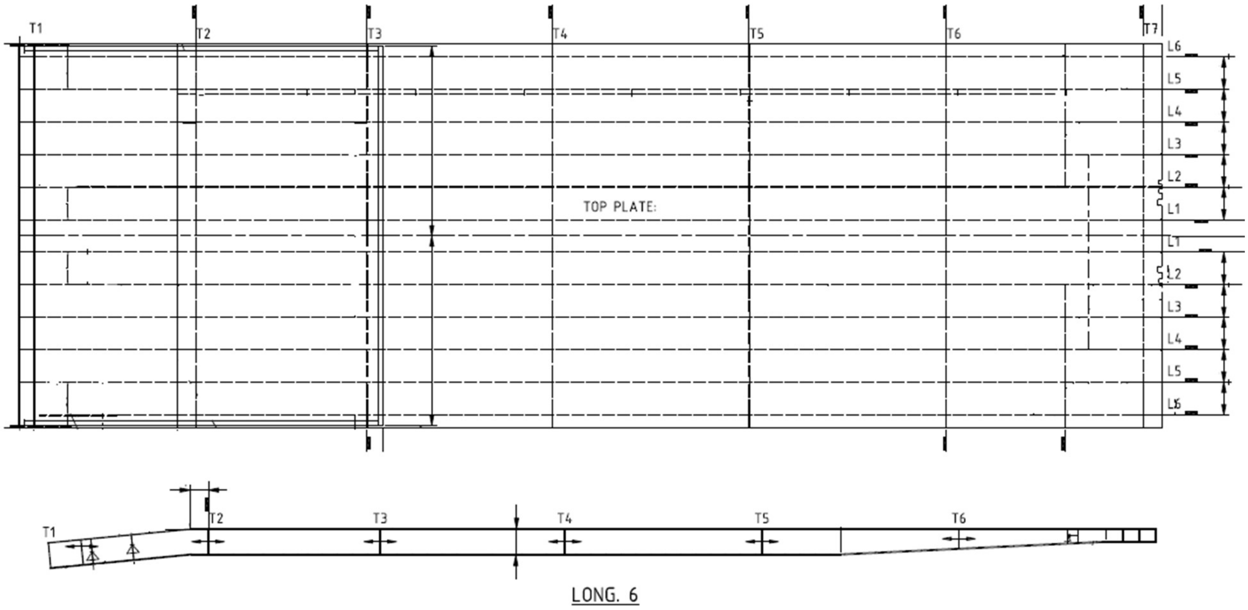

Figure 4 Top view of side ramp and side view of a longitudinal girder

The Side ramp (*Figure 4*) is located at the side of the ship and is used to load vehicles from the land onto the ship or vice versa. In the ramp seen in *Figure 4* there are four longitudinal girders. The middle girders have a T-profile and the outermost has an L-profile. Eight longitudinal stiffeners are located between the girders. On the forward end there are brackets located on every position there would have been stiffeners or longitudinal girders. The brackets reinforces the structure and add extra rigidity to handle the flap. Seven transversal girders are placed along the ramp. The ramp is slightly bent in the section near T2 as seen on the side profile marked as LONG 6 in ***Figure 4***. At the aft part of the ramp there are four hinges mounted. Forward of the hinges and in the forward part ramp there are cleats for locking the ramp in deck position. In the forward part there are also sheaves for hoisting the ramp.

2.2 Hoistable ramp

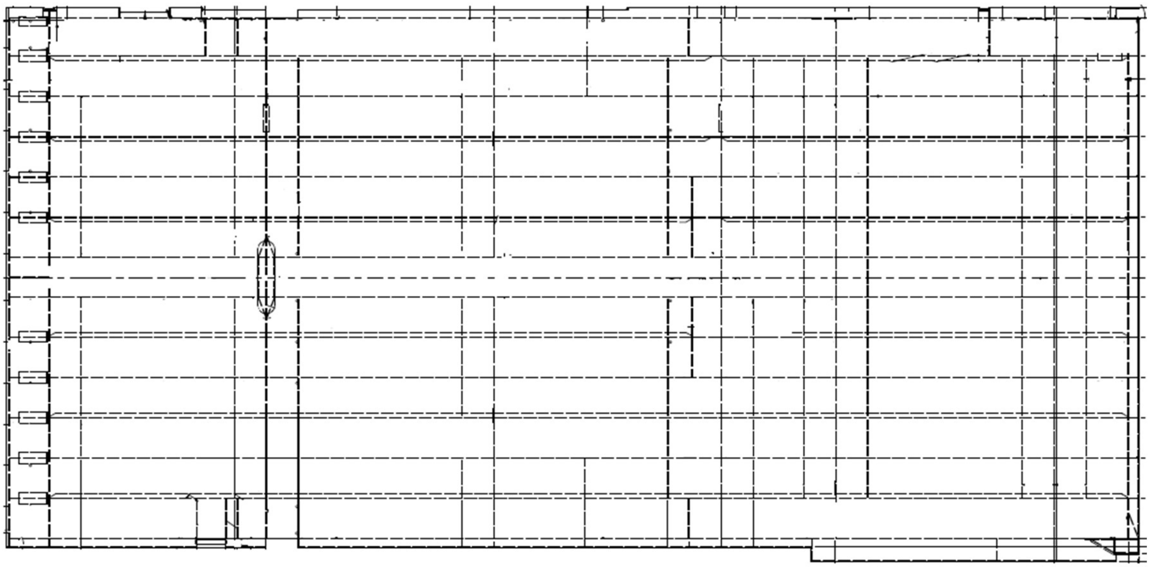

Figure 5 Top view of hoistable ramp

The Hoistable ramp (*Figure 5*) is mainly used when the ramp needs to be able to be stored under the deck above. Therefore the hinges are not attached to a surrounding deck like other ramps. In this case the hinges are attached to foldable "arms" called suspension stay. These arms are hanging from the deck above with the purpose of stabilizing the ramp in deck position. The special configuration of the hinges are irrelevant when the ramp is calculated and designed in GeniE since the hinges affect the ramp the same way regardless of how the they are attached to the ship. Notice that the suspension stay themselves are outside the scope of this thesis. In order to lift the ramp up into its stored position the ramp has a cylinder attached to the ramp located in the centre which lifts the ramp via cables and sheaves. The usage of sheaves is also beneficial when the ramp is very long and large and needs multiple points where it's hoisted. In these cases sheaves are positioned all over the ramp and not only in the corners. To fit the cylinder the transverses don't run all the way across the ramp, a gap is left in the middle of the ramp.

2.3 Lifted ramp

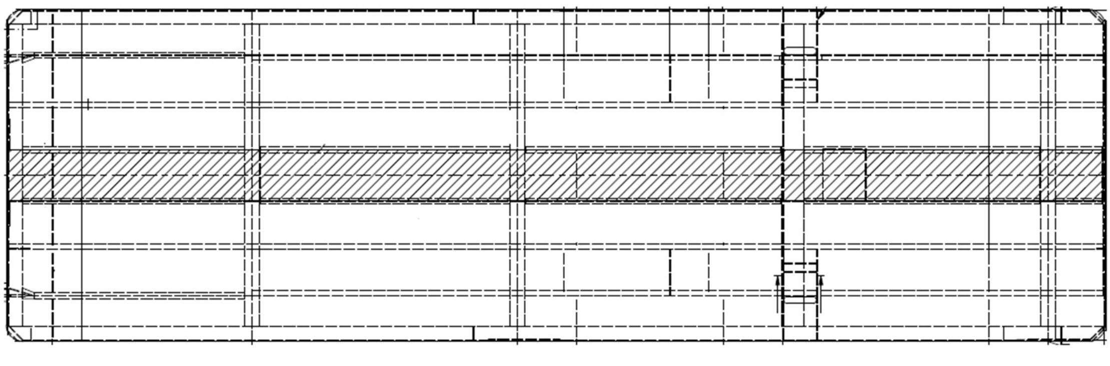

Figure 6 Top view of a lifted ramp

A Lifted ramp (*Figure 6*) is called lifted when it is pushed up with hydraulics connected between the ramp and the deck below. The hydraulics can either be fixed to the deck below or have the ability to disconnect which gives it the ability to be stored underneath the ramp. The choice of system depends on where in the ship the ramp is located. When the ramp is located in the lower part of the ship there is not much need for space below the ramp. The hydraulic can then be fixed since it won't be in the way of any vehicles. Higher up in the ship there is contrary need for space, thus the hydraulic is stored away, allowing vehicles to fit below the ramp. Depending on how the ramp is used and how the cargo is stored on the ramp, there can be either one hydraulic cylinder or two. If there are two hydraulics lifting the ramp there is a box see *Figure 6* located in the middle along the whole length designed to deal with the torsion load that occurs in case one hydraulic malfunction and the ramp is lifted in only one point or if the hydraulics works with different speed.

2.4 Ramp + Cover

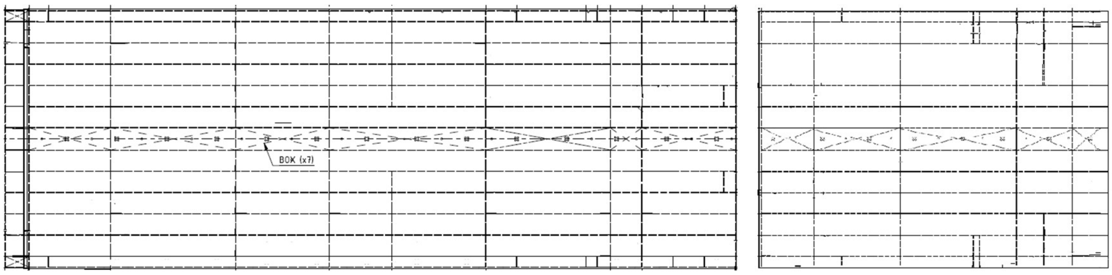

Figure 7 Top view of a ramp and its cover

A Ramp + Cover (*Figure 7*) is basically a lifted ramp combined with a cover. The cover is lifted so that vehicles can drive up the ramp without hitting the deck above. Similar to the lifted ramp, covers are lifted with one or two hydraulics and a covering box may be required.

2.5 Two ramp, cleated

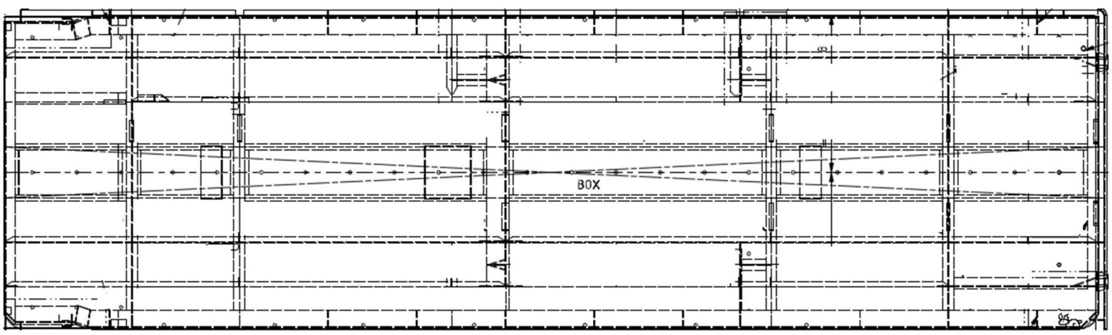

Figure 8 Top view one of the ramps in a configuration of two cleated ramps

The Two ramp, cleated (*Figure 8*) consists of two lifted ramps next to each other. Similar to previous examples it has a box. Both ramps are operating independent to allow the loading operation to be as flexible as possible. If positioned properly this arrangement may give vehicles access to three decks simultaneously. When they are stored in deck position they are cleated at the sides as well as in the middle into each other. It is also not uncommon to combine these two ramps with a cover.

2.6 Details in the designs

Based on different design features items are identified and given names for convenience. These will be explained in the next chapter. Except for above mentioned specific features the following have been identified.

Depending on how the ramp is connected to its surroundings, different extra girders could be added between the transverses at the aft or in forward part of the ramp. The extra girders may be of ordinary type with no extra features, flap girders or two versions of hinge girders.

Three types of mid sections have been identified in the different items, T-profile, L-profile and a Box. The last and first transverse girders also had three different designs, flat bar, L-profile and T-profile. The outer longitudinal girders had two different designs L-profile and T-profile.

Depending on if the ramp is hoisted by hydraulics or lifted by wires there may be a requirement for room to contain and protect the hydraulic cylinders. Due to special requirements or decision taken during design some ramps has an extra longitudinal girder in the middle section. Extra outer brackets has been included in a number of ramps.

Stiffeners of different profiles, both with angle and flat profiles may be used particularly near to the edge of the top plate.

Depending on how the ramp was operated, various supports were located at different locations.

The various designs and functions makes all ramps to be a unique unit. Knowledge about all the combinations is important to have and to understand the details and final products function. Therefore it is important to be able to create the different alternations in the script. In chapter 4 these variations will be explained as well as how the script is built.

3 Parts to be modelled

The aim is to make the script as general as possible, it should include as many different parts as possible. This has been the goal but in limited cases separate and individual parts has to be modelled graphically. This section describes the different parts of the script and how the various features and details are created in the script.

The entire script can be found in Appendix 1.

3.1 Script layout

The beginning of the script includes *Design choices, Thicknesses, Materials* and *Mesh*.

In *Design choices* the user can alter different aspects of the design of the ramp. A variable that represent a design of the ramp is given a value that represent the alternation in the design. For example:

edge_stiff = 0;

This variable dictates if the product will have edge stiffeners or not and the value 0 equals no edge stiffener while 1 equals edge stiffener. An if-statement is then connected to this variable and depending on the choice of value it can become active or not, creating edge stiffeners or choose not to.

Thicknesses include a list of standard thicknesses, *Materials* specifies the structure's self-weight and material attributes and in *Mesh* the size of the mesh is defined. In order for GeniE to recognize some values as properties some special GeniE - JavaScript based commands needs to be used, for example in these cases, "*Thickness()*", "*MaterialLinear()*" and "*MeshDensity*".

The rest of the code are divided into the sections:

- INPUTS: Here all values needed to create the geometry is assigned such as the number of, distance to and dimensions of different parts.

- CREATING GEOMETRY: Contains various functions, commands and for-loops that are used to create the entire geometry.

- GRAPHIC CHANGES: This section is at first empty. The section is meant for code that is generated by the users graphically changes that can't be done otherwise. The placement in the layout is so that these changes won't cause errors when the geometry is created.

- PREPARING ANALYSE: This includes the final preparations needed before an analyse can be performed, such as position of the supports and to create and define the different load cases for the actual ramp.

Drawings with input data are always drawn in the same direction of the ship. The structure can however operate in any direction depending on how and where on the ship it's located. For example can the lowered side of a ramp face both the stern of the ship or the bow. Therefore the script is made so that the structure can be designed in both directions and all details can be placed either at the aft part or the forward part.

As mentioned GeniE works with flat surfaces and many details in the drawings are simplified when designed in the software. One example is the angled top plate and longitudinal girder seen in *Figure 4*.

3.2 Top plate

When designing and creating a ramp, the design work always commence with the top plate. This is, like the majority of the parts of a ramp, created as a mid-surface plate with assigned properties. All mid surfaces plates is created with the command for creating a plate which requires the corner point of the surface.

top_plate = plate(point(0,0,0),point(tpl,0,0),point(tpl,tpw,0), point(0,tpw,0));

DNV GL (2015)

After this the properties are assigned. The material attributes are already set as default in Inputs and doesn't need to be specified except for a few parts with different attributes. The thickness of the plate may alter depending on specific requirements on the different parts of the ramp and needs to be set.

top_plate.thickness = tpt;

DNV GL (2015)

3.3 Transverses

The transverses are positioned across the top plate along the length. They are created as T-shaped girders. As seen in *Figure 9*, thickness of the individual flanges and webs may alter if required. Due to logistic limitation on construction sites, at shipyards and in warehouses, this is seldom used. The height and flange width in individual webs often differ along the ramp

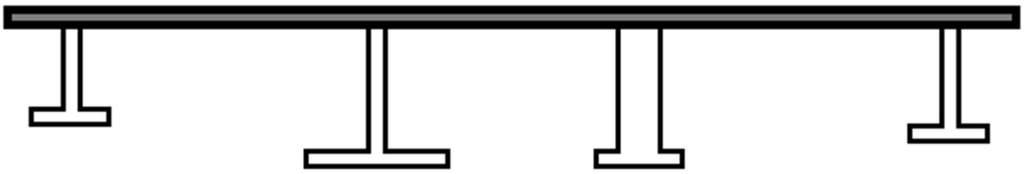

Figure 9: Different versions of a transverse cross-section

The design engineer is able to choose number of transverse based on requirements, dependencies and amount that is specified in Input Specification Based on these defined figures and values; dimensions for every transverse as well as the distance to each of them, a for-loop is used to generate the transverses. The y-distance will here be the width of the top plate and does not need to be specified in the loop since it will, unlike the other distances, be the same between every transverses. The last step in the loop is to rename the newly created geometries so it won't be replaced in the next cycle of the loop.

Figure 10 shows a transverse and the coordinates needed to create the transverse. The coordinates depend on dimensions of the top plate, dimensions of other structure elements as well as the distance to other elements.

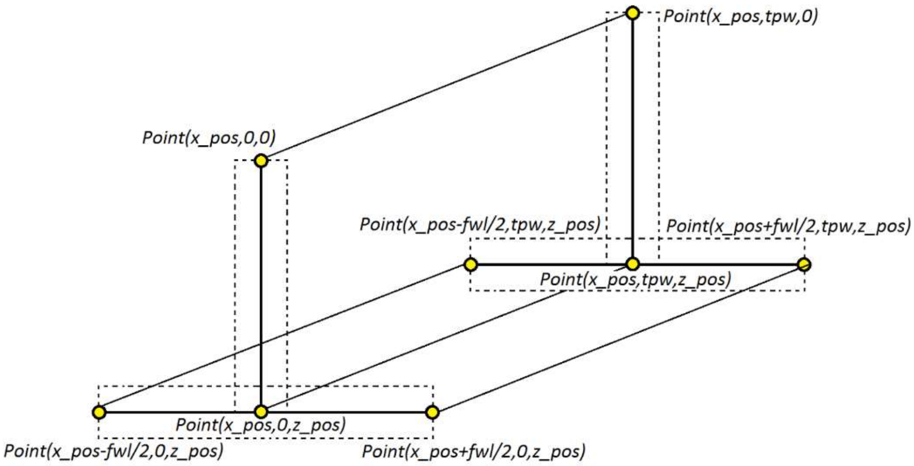

Figure 10: A transverse and its connection points

3.4 Longitudinal girders

The longitudinal girders are created in sections between the transverses with a T-profile like the transverses. Longitudinal girders are created in a similar way as the transversals using a for-loop function; the difference is that the plate command needs 6 corner points to be able to create the web as seen in the *Figure 11*. Since they are created in sections between the transverses, a double for-loop is required, in other words a loop inside another loop. The first loop generates each longitudinal girder and the second loop generates each girders section

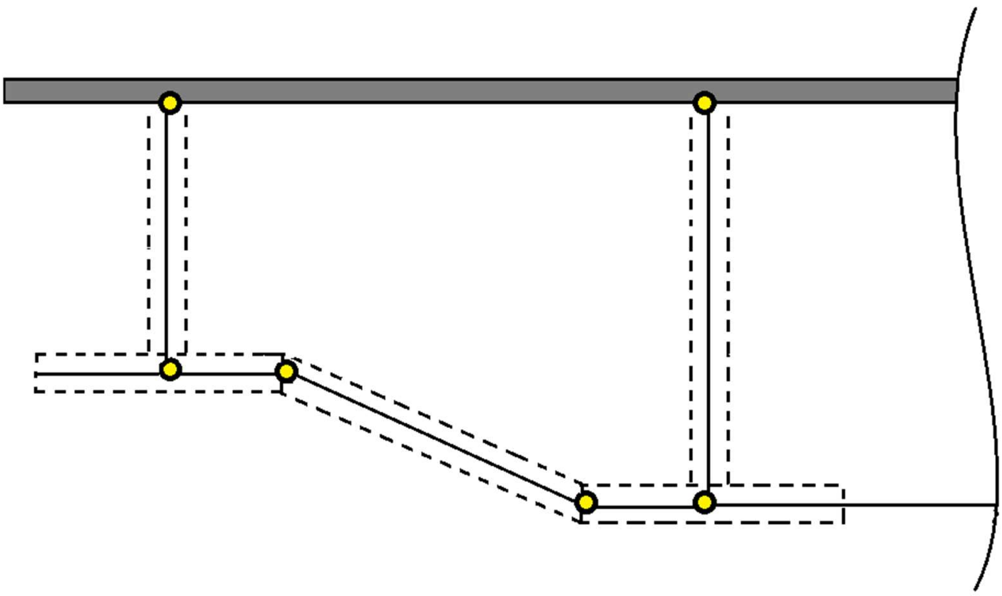

Figure 11: Side view of the first section of a longitudinal girder

Creating the flange requires 4 points, depending on the flanges of surrounding transverses, as seen in *Figure 11*.

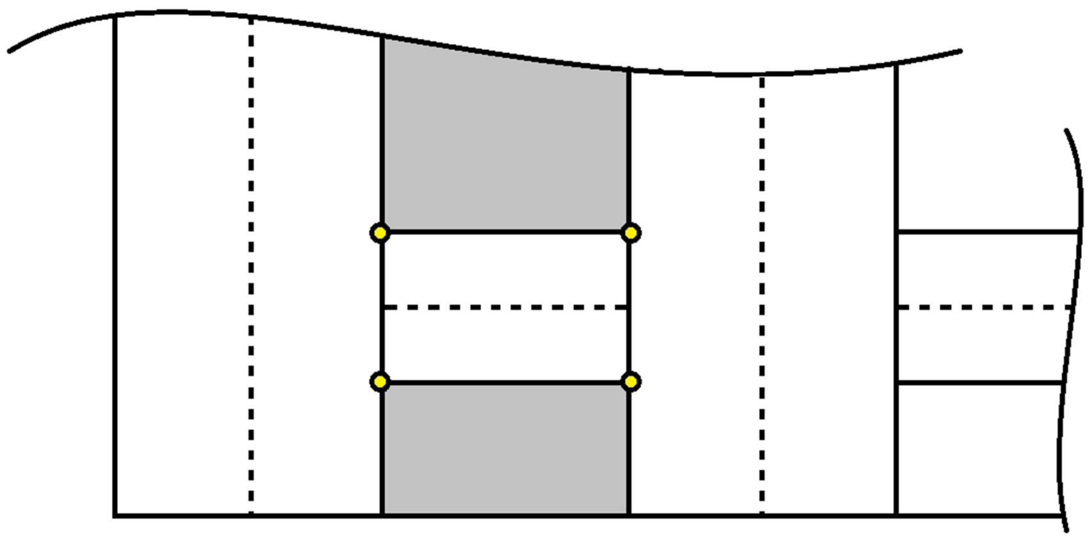

Figure 12 Top view longitudinal girder

3.5 Middle longitudinal girder

Some ramps are designed and constructed with only one longitudinal girder in the middle instead of an even number of longitudinal girders. The two longitudinal girders, one on each side of the centre girder may have different profiles. This will be explained later in this document. Due to that the coding for the design of the two surrounding girders is based on there being an even number of girders, the coding for the middle longitudinal girder needs to be done separated from the rest of the longitudinal girders.

3.6 Stiffeners

Stiffeners are added in the longitudinal direction (*Figure 13*) between the longitudinal girders. Their function is to locally strengthen the structure and support the top plate carrying load from the each wheel, the load depends on how the cargo is stored on the truck. The stiffeners may have two different cross-sections and are modelled in GeniE as beam elements with the straight beam command.

S=StraightBeam(point(d_t1,y_pos,0),point(GetNamedObject("d_t"+NT),y_pos,0))

DNV GL (2015)

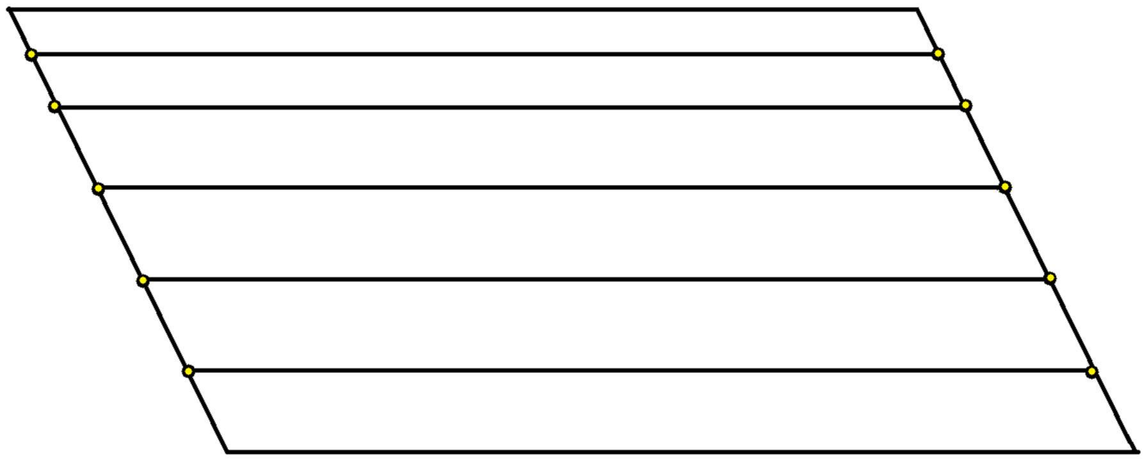

Figure 13 Stiffeners position along the top plate

In inputs the beam elements is set as default to an L-profile. In the real world they are either L-shaped or shaped as a bulb but in GeniE the bulb is simplified with an L-profile with the dimensions as close to the bulb as possible. The z-position of the beam will automatically be placed where the centre of the mass is. Therefore it is required to use an offset command to move the stiffener so it starts at the top plate.

S.CurveOffset = AlignedCurveOffset(frFlushTop, 0 m)

DNV GL (2015)

The stiffeners is visible in *Figure 14* spanning across the length of the ramp between longitudinal girders. They are not created in sections like the longitudinal girder but created as a single beam element across the whole length.

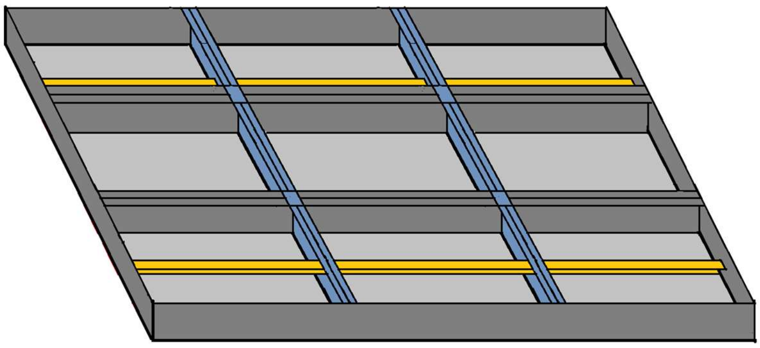

Figure 14 Stiffeners marked as yellow. Notice the structure is upside down so the structure members are visible

3.7 Edge Stiffeners

Ramps may also require stiffeners along the edges of the top plate (*Figure 15*). Due to the location at the edges, no for-loop is required to generate the edge stiffeners.

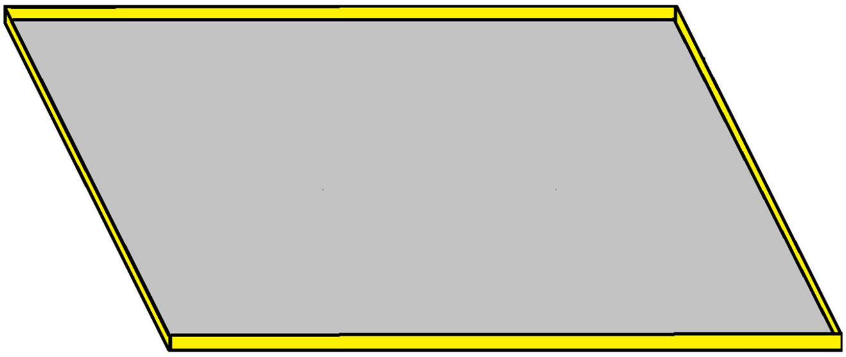

Figure 15 Edge stiffeners marked with yellow

Unlike the normal stiffeners these are created as flat bars. The profiles are set for all four edges separately so the default setting won't apply.

Es_s.section = FB_section;

DNV GL (2015)

The offset command needs to be used to achieve required design seen in *Figure 16*.

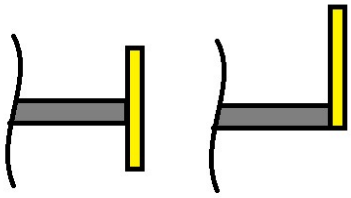

Figure 16 The change on the edge stiffener after offset function is used

3.8 Design for transverse at aft or forward

All transverses are at start of the design work considered as T-shaped profiles, this is not changed for most of them. The transverses furthest out in the aft part or forward part can however be changed to either an L-profile or a Flat bar profile as seen in *Figure 17*. When changing into the L-profile the flange is translated in the x-direction.

autoMSet = Set();

autoMSet.clear();

autoMSet.add(Tf1);

autoMSet.moveTranslate(Vector3d(GetNamedObject("fw_t"+1)/2,0m,0m),ge UNCONNECTED);

DNV GL (2015)

If on the other hand a flat bar profile is to be designed, the flange is deleted.

delete(Tf1);

In above case the longitudinal girder sections closest to the altered transverse need to be redesigned/changed. The corner point for both the web and the flange of the longitudinal girder needs to be changed with the translation or deletion of the transverse flange if not an unwanted gap would occur. This is done by simply deleting the web and flange of the longitudinal girder section and recreating them.

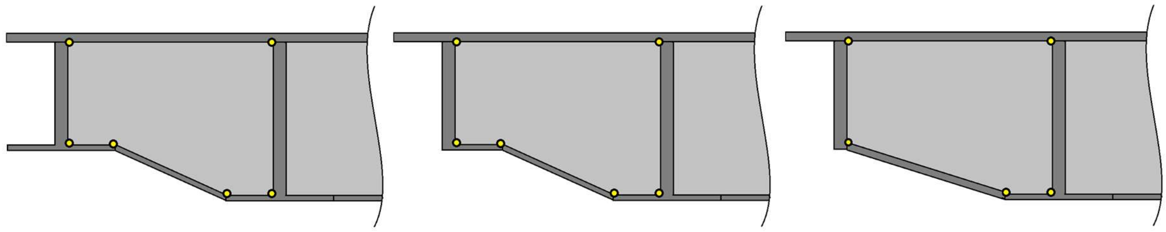

Figure 17 T-, L- or flat profile of the transverse furthest to the aft/forward

3.9 Flap girders

Flap girders, seen in *Figure 18*, are additional stiffening girders placed between the outmost and second outmost transverse in order to handle the load generated by the flap. They are T-shaped and created with mid-surface and replace every longitudinal girder as well as every stiffener in that section. Since every stiffener is created as a whole part this needs to be divided before the undesired section can be deleted.

```
GetNamedObject("S"+i).divide(XPlane3d(GetNamedObject("d_t"+(NT-1))))
```

DNV GL (2015)

In order to place the flap girders at the distances to every longitudinal girder as well as every stiffener they are created with two separate for-loops. The first for-loop uses the distances to the longitudinal girders and the second uses the distances to the stiffeners. An exception is the two longitudinal girders furthest out at the sides which will not be replaced with flap girders.

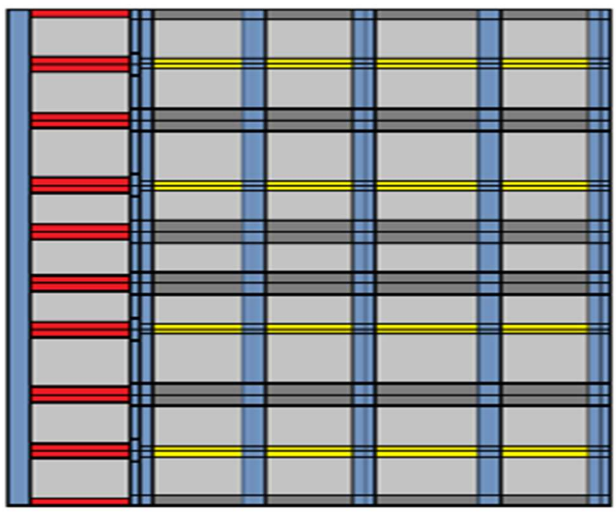

Figure 18 Flap girders (red) replaces longitudinal girders and stiffeners

3.10 Hinges girders

Hinge girders are similar to flap girders but it replaces only the two stiffeners located furthest out to the sides. This is to deal with stress that occurs when the hinges are placed at these locations. The hinge girders can replace either one or two sections. Their placement is shown in *Figure 19*.

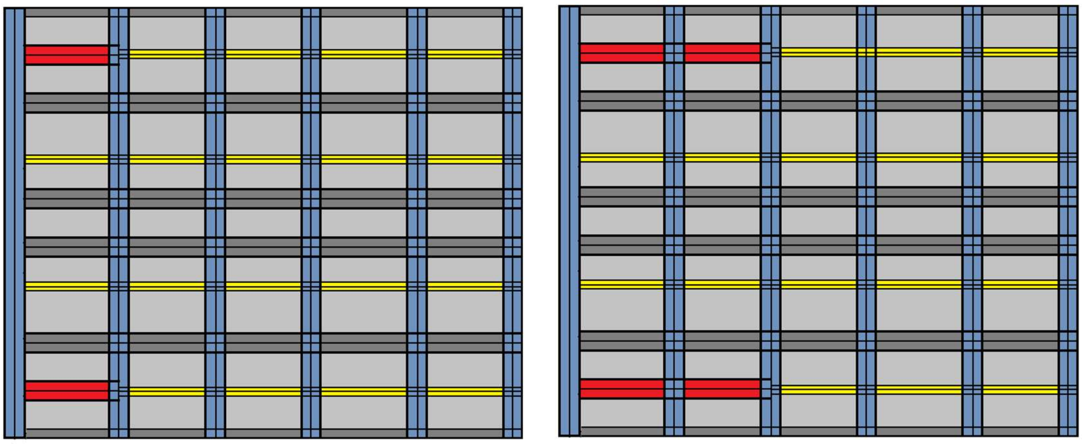

Figure 19 Hinge girders, top view, positioned at one section and two sections

3.11 Outer brackets

The outer brackets are stiffening plates located between the outermost transverse and the edge of the top plate. Depending on the transverse having a T-profile or L-profile or flat bar profile the bracket is connected either with four or three corner points as seen in *Figure 20*.

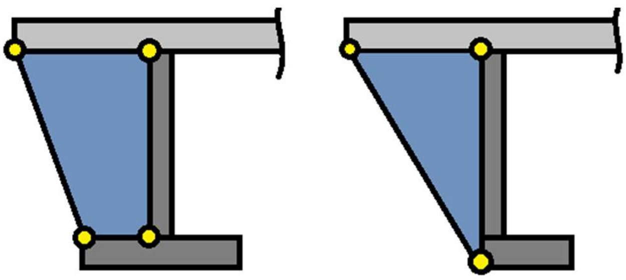

Figure 20 Outer brackets, connected to a T and L-profile transverse side view

3.12 Mid-section

The two centremost longitudinal girders, except the middle longitudinal girder, can for different purposes have different designs. They are from the beginning created with a T-profile and may be altered into L-profile or a Box structure. This can be viewed in *Figure 21*. The Box means in reality that the two girder webs are connected by one single large flange that creates a watertight box.

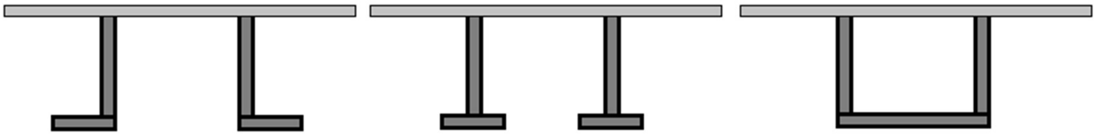

Figure 21 Three mid-section designs, L-, T- or box profile

The L-profile allows more space for hydraulics and other equipment to be installed close to the surface plate and the Box structure is used when high of torque is be expected to occur. When both a box and a middle longitudinal girder is used, the flange of the latter needs to be removed to give space for the box flange. The correlation between the mid-section design, design for aft/forward transverse and flap girders also needs to be considered. The change in geometry with regards to these designs is already done for the normal T-profile for the mid sections design. For the flange in both the L-profile and Box recalculations needs to be performed.

3.13 Design of outer longitudinal girders

The two longitudinal girders furthest out to the sides may have the flanges mowed inwards, by this transformation the T-profile changes into an L-profile.

3.14 Making cuts

Hydraulic systems are often placed in between the steel structure in the middle of the ramp. Due to this requirement an option is made in the coding system to cut all transverses, except the first and last, so that a separate section is obtained between the two centremost longitudinal girders. The new created sections needs to be deleted graphically and inserted into the codes section Graphic changes. This procedure, including the deleting the section, is shown in *Figure 22*.

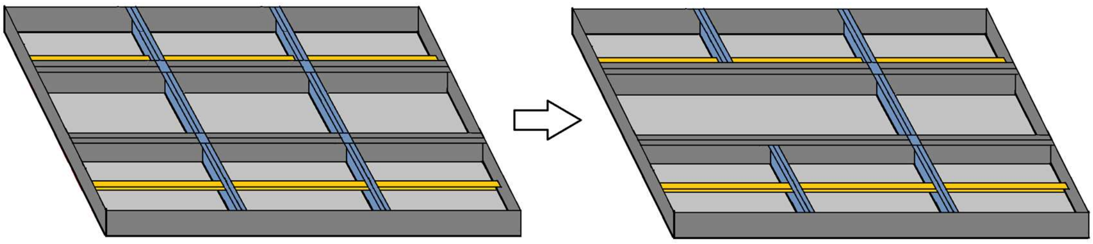

Figure 22 Making cuts for hydraulic equipment

When the hydraulics is installed in the ramp but not in the middle section, the number alternatives will be too large for coding in these cases is it done graphically and later inserted into the code.

3.15 Supports

The supports are the first part of *Preparing Analyse.* Since they all are symmetrical across the structure, coordinates for their positions are only given for the starboard side. The port side is then generated by mirroring the starboard side.

The supports are divided into:

- **Hinges:** Hinges are used when the structure is movable around a fix axis..
- **Vertical support (Cleats & Stoppers):** There are a difference between Cleats and Stoppers. Both are used to lock the ramp in a position but the difference is in what direction. Cleats prevent the structure from translating downwards and Stoppers prevents it from translating upwards. In GeniE however, this doesn't matter and both versions are summarised as Vertical supports.
- **Sheaves:** Sheaves is used when the structure is going to be lifted in cables or if the system is self-hoisted.
- **Support line:** Support line is the location where a ramp is leaned against the supporting below in an inclined position. In practice no extra parts are installed except for minor enforced beams.
- **Emergency lifting:** Supports meant for lifting the structure if other lifting devices in emergency situations or when the ordinary lifting system is malfunctioning.
- **Cylinder points:** The cylinder points are the connection points between the steel structure in the ramp and the hydraulic cylinders that lifts the ramp. Whether the cylinder/cylinders can be disconnected or not, as described in chapter 2.3, has no effect on the way these supports are designed in GeniE.

3.16 Sets

Sets in GeniE is the entire geometry combined with boundary conditions where the boundary conditions are the various supports. One set could be said to describe one specific position and depending on what analyse the set is going to be used for, different supports are included in the set.

Since all parts of the geometry and some of the supports are included, the script creates a complete set including every part of the geometry and all supports required. It excludes supports that are not used. It is easier to manually remove a few parts then adding a lot of parts.

The various positions of the ramps and thus the different sets are:

- Stowed position
- Deck position
- Ramp position
- Hoisting position
- Emergency lifting

3.17 Analyses

After the sets, their correlated analyses are created. As such there will be five different analyses with the sets assigned to each of them.

3.18 Load cases

The load cases are created and defined when it is specified how and where these loads are positioned on the structure. The magnitude of the different loads affecting the ramp is given in the Input. Data such as on what surface the load is positioned, in what direction it is working or if it is a uniformly distributed load, point load or a line load are included Input

The load cases are divided into two categories,

- **Load cases that are always included**
  Those which are always present are the self-weight and the load generated by the flap.

- **Load cases specific to boundary conditions**.
  Thus with uniformly distributed loads for deck position, ramp position and hoisting position as well as the point load or point loads generated by the hydraulic cylinders pushing the ramp upwards.

3.19 Load combinations

A load combination is a combination of load cases unique to a certain position and analyse. For example is the ramp in its stowed position only weighted down by the self-weight and the flap. In the script the load combination is first assigned to a specific analyse and different load cases are added to the load combination afterwards

4 Weight optimisation

Reducing weight of structures and installations attached to a ship has an direct positive impact on increased cargo capacity, higher speed and better fuel efficiency for the ship Additionally, a weight optimized design requires less steel and reduces to cost for the ramp.

A more time efficient design process, more sophisticated computers and more intelligent and self-supporting software will allow engineers more opportunities to exploring possibility's to optimise the structure.

4.1 Car decks panels

Weight optimisation is focusing on hoistable Car deck panels only. The panels are large structures that used for carrying cars. A car deck is a structure that built up of several panels. *Figure 23* illustrates three deck panels creating a car deck.

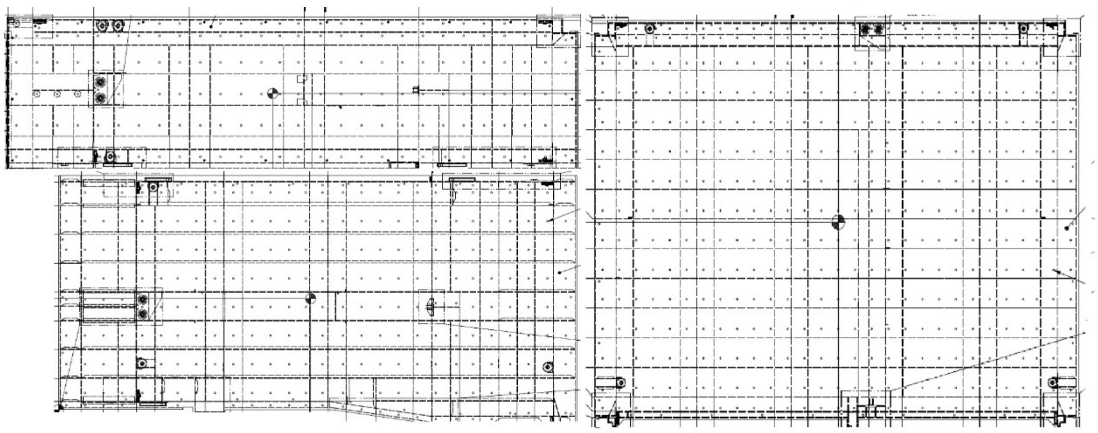

Figure 23 Car deck panels

Car deck is a large flat steel structure that consists of a primary and secondary structure. The secondary structure consists of several stiffeners in the longitudinal direction and the top plate. This is to handle the loads from the wheel footprints and it is called local loads. There are as well more addition parts in the structure that's ads strength to the structure.

The primary structure consists of the major structure that takes care of the global loads. Seen in *Figure 24* are two large girders in the longitudinal direction and several girders in the transverse direction. In some cases there are two extra longitudinal girders that together forms a square in the middle of deck. This structure is made for deck lifting equipment. The span between the transverses girders differs as they need to be integrated to rest of the structure.

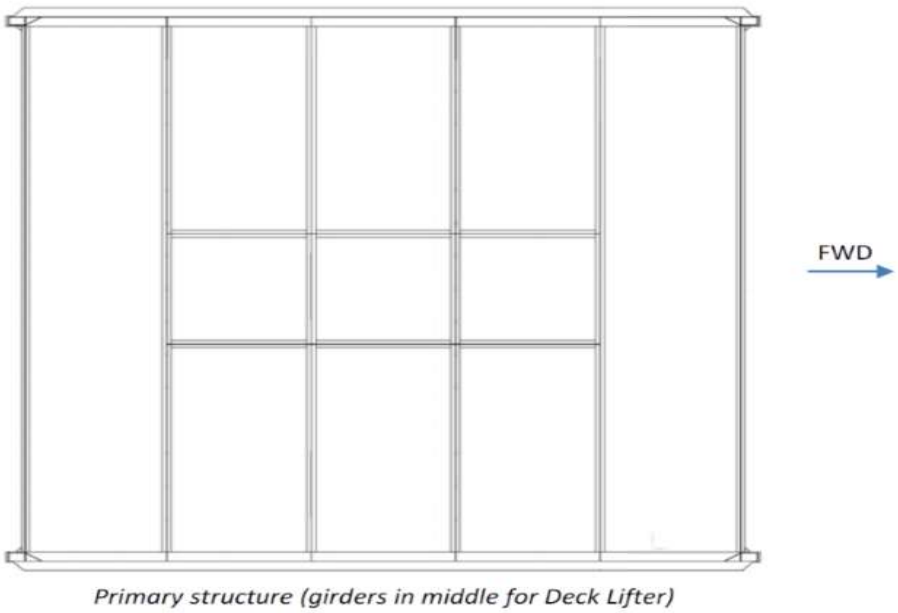

Figure 24 Example of the primary structure of a car deck panel

4.1 Parameters

Following parameters has been evaluated in cooperation with TTS, as possible to change in order to optimize the structure.

4.1.1.1 Web height

The web height of both longitudinal girders and transverses has considerable impact on the stiffness and strength of the structure. Thus this should be a given choice to start the optimization. It does however give complications since it affects the building height. From the ship-owners there are requests on the free height needed for operations on decks. This limits the space for the panels. Installations inside the ramp require space that increases the construction height of the ramp. The sheaves are such an example. The sheaves are circular wheels for the cables that lifts decks. The sheaves are of different sizes and are mounted inside the panels in as high extent as possible.

4.1.1.2 Plate thickness

Plate thicknesses may be altered for all parts on a structure and will greatly affect a structures attributes. The scope of work of designing includes not only strength, it includes also constructability, material availability, and cost and to minimize risks. An optimized weight structure may have require a number of different steel qualities and number of different plate thicknesses that increases cost for material, storage and certificates and increase de requirement on welders on the shipyards. Specific plates may also be considered as long lead items. The parts are cut out from large steel plates. It is expensive to have a large number of different thicknesses in storage. Carreira and Trudell (2006) In many cases the shipyards can also only offer a limited selection of thicknesses. The structures are therefore often built with parts with only two different thicknesses, normally one for the top plate and webs and one for the flanges.

4.1.1.3 Stiffeners

The profile of the stiffeners depends on how the cargo is stowed on the deck, the cargos weight as well as the span. The profile are normally of Holland profile which is a bulb shaped profile. The profiles may be shaped as angle bars and have the same dimension as above.

4.1.1.4 Topology structure

The topology structure refers to how girders and stiffeners are organized and placed to create the overall strength of the structure. Directions of girders and stiffeners for deck panels in ships used for transportation of cars are quite simplistic. They are placed in the longitudinal and transverse directions. Number of profiles and distances between them may be altered from ship to ship. In car decks there are always two longitudinal girders located at each side of the deck, thus the spacing is always the same as the width of the ramp. The number of transverses can on the other hand be changed.

4.1.1.5 Material

Low cost steel grade is often used in the structures such as ramps, decks etc. For other use and for applications with higher requirement on grade, most shipyards are able to supply various steel grades and dimensions but regarding applications like ramps the choice of grade is a question of cost.

4.1.1.6 Flange width

All parts, such as the flanges, profiles, stiffeners, etc. are cut from plates and are therefore easy to alter. A way to improve the strength of the steel structure without increasing the height of the structure is to increase width or thickness of the flanges, or both. A benefit from changing the width of the flanges, except for improving the structures strength, is that it does not causes problems for other parts of the structure such as the web height did with the building height.

4.1.1 Parameter to optimize

Due to the limitations and complications, the web height and topology structure are deemed to not be suitable for optimization. Thicknesses of web and stiffeners are predefined and complicated to change while the choice of material is a matter of cost and availability on the market.

The parameter chosen for optimization is flange width regarding longitudinal and transverses. The flange width is the least complicated to change and is estimated to have positive impact on weight optimizing of the structure.

4.2 General optimization

There are several different means to optimise the structure. The main purpose is to lower the weight within the allowed stresses and deflection.

Following functions is always used in a structure optimization.

The object function $f(x, y)$ and it represent the weight of the structure where y is the state variable and it is the stress and deflection. The design variable x is the design change such as the thickness.

$$(\mathbb{SO})\begin{cases} \text{Minimize } f(x,y) \text{ with respect to } x \text{ any } y \\ \text{Subject to } \begin{cases} \text{Behavior constraints on } y \\ \text{Design constranints on } x \\ \text{Equilibrium on constraints} \end{cases} \end{cases}$$

Christensen and Klarbring (2009)

The optimisation is done to get as low weight as possible.

A analogue way to optimise the structure is to use the software program Sesam Extract for the calculation. Identify spots or locations with minimum stresses. Reduce dimensions on that particular part and run the calculation again, Identify new spots and locations with minimum or low stress levels and change the dimensions.

4.2.1 Continuous Optimization versus Discrete Optimization

Some of the design parameters are of continuous number. Continuous means that it is finite dimensional such as the height of the structure. But in reality the dimensions will be of discrete character. Discrete is that the data only could have certain values Changes of the flange width is done in 1cm intervals. Christensen and Klarbring (2009)

4.2.2 Classification

Problems in designing and calculating steel structures may be divided in three different sub layers.

- **Unconstrained**

Unconstrained problems are problems that have no constraints. These problems are of non-linear type as they have global and min and maximums as limits. They cannot be of linear type as the answer will go to infinity.

- **Liner programming**

Liner constrained problems have linear constraints functions and optimizations problems in which one or more constraints functions are non-linear.

- **Non-linear programming**

Non-linear problems have constraints and as well min and max points. These constraints are stress and deflection. Structures like ramps and decks that is subject for this report and study is of nonlinear type. Bonnans et al (1997), Bhatti and Asghar (2000)

4.2.3 Dependent or Independent

If the structure is of nonlinear type beams depends on each other. If the dimensions of one specific beam are decreased the result will be that stress and deflection will increase in the surrounding beams. Bhatti and Asghar (2000)

A test was done in GeniE and SESAM Xtract to check the dependency. The results can be observed in *Figure 25* and shows that the problem is non-linear and that the beams depended on each other.

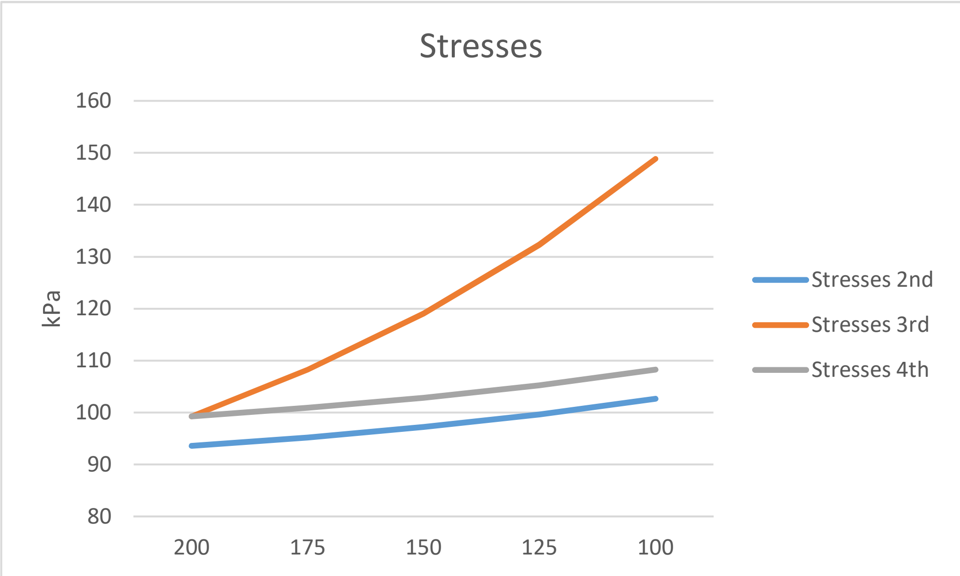

Figure 25 Comparison between the Von Mises stresses in the beams

The test object is a car deck panel with two longitudinal and six transverse beams. The third transverse is changed from 200 to 100 millimetres and the rest of the transverse is kept at 200 millimetres. The span was 3.6 meters and the same between all beams.

4.2.4 Local and global mini points

As the optimization problem contains multiple variables there are number of different local and global minimums and maximums. The optimal position is the global minimum. For a car deck panel with the parameters flange width is this zero width of flange. Several different designs and sizes on the beams may result in the same weight for the complete steel structure. *Figure 26* illustrates mini and maxi-points with two variables, X1 and X2. Constraints are marked with blue and red lines. Observe that *Figure 26* is an example to show these points and does not reflect the situation at hand.

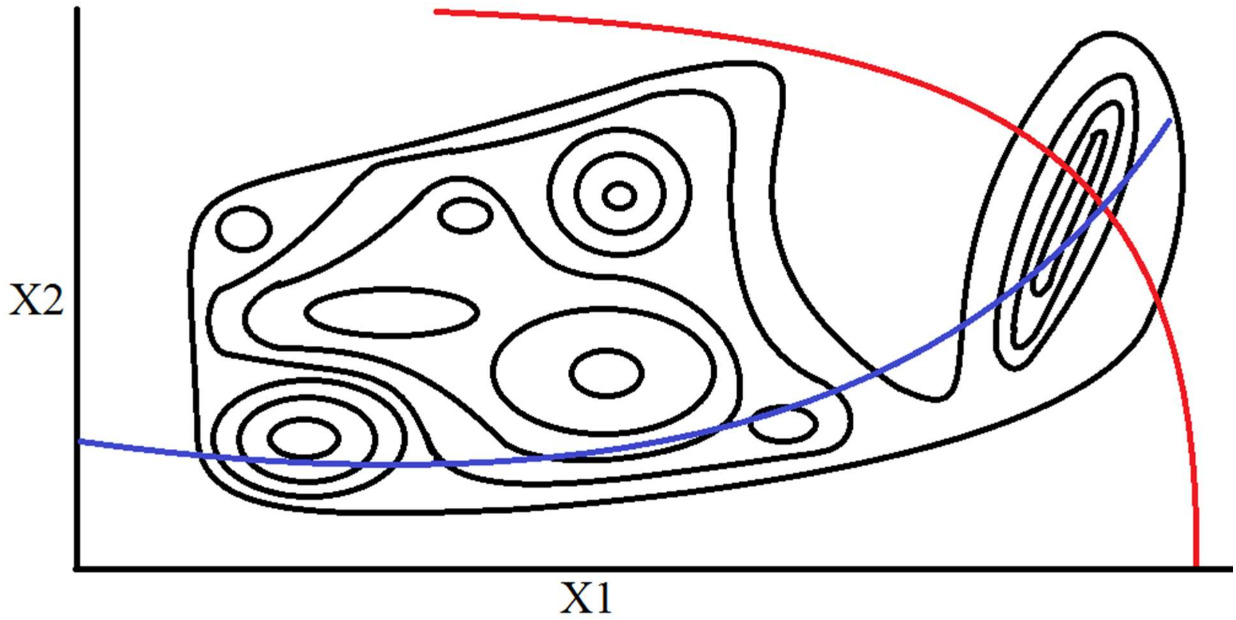

Figure 26 Mini- and maxi-points with two variables

It is very difficult to estimate where the overall global minimum is located, there are however methods to achieve this. Christensen and Klarbring (2009)

4.2.5 Step size

There are a number of means to choose the different steps and step sizes. As mention in 4.2.1.1 the steps will be of discrete type. In each iteration a number of steps will be taken for a number of iterations until the result will past the limit value given.

The steps could be taken as centimetres or as standard sizes of flange width. Increase of steps per iteration could results in a decreased number of iterations. But there could be cases were the number of steps is too many and the result end up far away from the limit. By taking smaller steps the correct dimensioning could then be found.

For this example seen in *Figure 27*; the step size various from 1 to 2 or 3 steps per iteration. The limit in this case was located at 3.5 steps away. The blue line indicates that 1 step is taken for each iteration and the result will be reached after 4 iterations. Brown takes 2 steps and it takes 3 iterations. Grey takes 4 iterations to reach a result, but it took only one iteration to reach 3. At this point it couldn't be certain that 3 was the limit and more values needed to be checked.

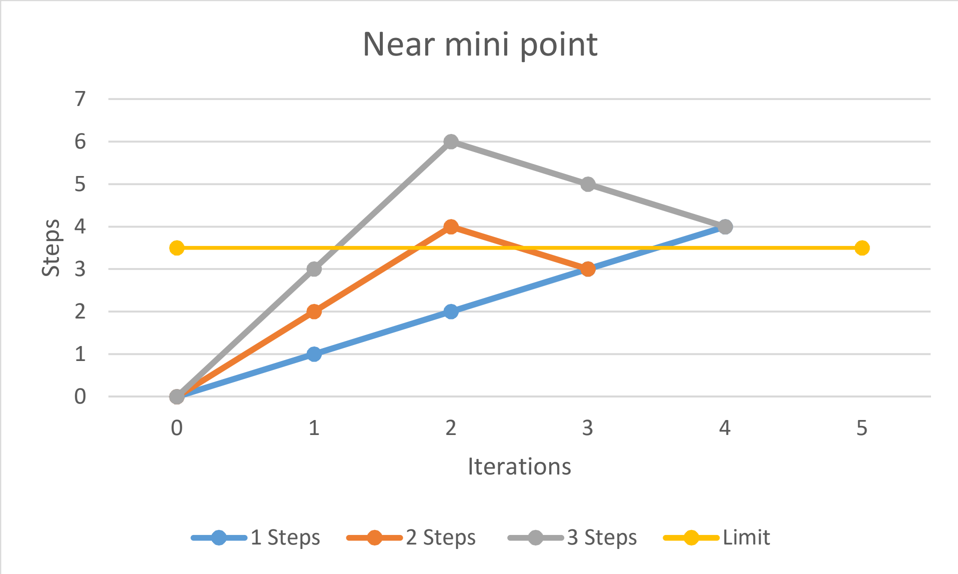

Figure 27 Initial design near the limit

When the base design is finalized the engineer does not know how many steps is needed to reach the optimal design. Everything depends on the initial design, if this is close to the optimal result, fewer steps and iterations will be required.

If the initial design is further away from the optimal design the software need to iterate in more steps. In *Figure 28* it could be seen that 3 steps forward is the fastest one with only 9 iterations. If the step is too long the global maximum could be over shot and missed.

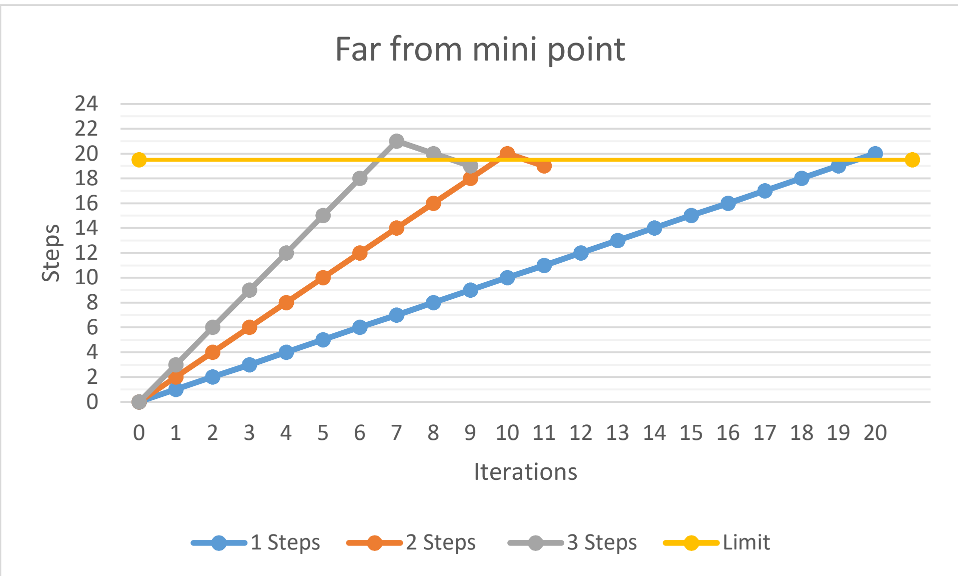

Figure 28 Initial design far from the limit

4.2.6 Stress concentrations and displacement

When the object is meshed and a FE calculation has been done then could stresses and deflection be calculated. The appearance of stress concentrations are dependent on the shape of the structure and on the mesh. These values are not representable for the structure and the displacement will not have such problems. Möller (2016)

4.3 Optimizing methods

The FE-program that is used is SESAM Xtract. The program shows graphical results with stress and deflection. There is a possibility to extract a script from the software. The script could not be read during the time this master thesis was performed and finalized.

4.3.1 Monte Carlo method stochastic optimization

The Monte Carlo method is used when a large number of parameters needs to be changed. The Monte Carlo method uses random numbers within a span. In this case would the span be between max and min of the flange width. N numbers of strength calculations could be done. This will give variation of results. This is illustrated in *Figure 29*.

Some of the results will be neglected because of the limits. The lightest design that fulfils the stress and defection is selected. A second loop is done with narrower boundaries around the selected design from the first loop to get the most optimum design.

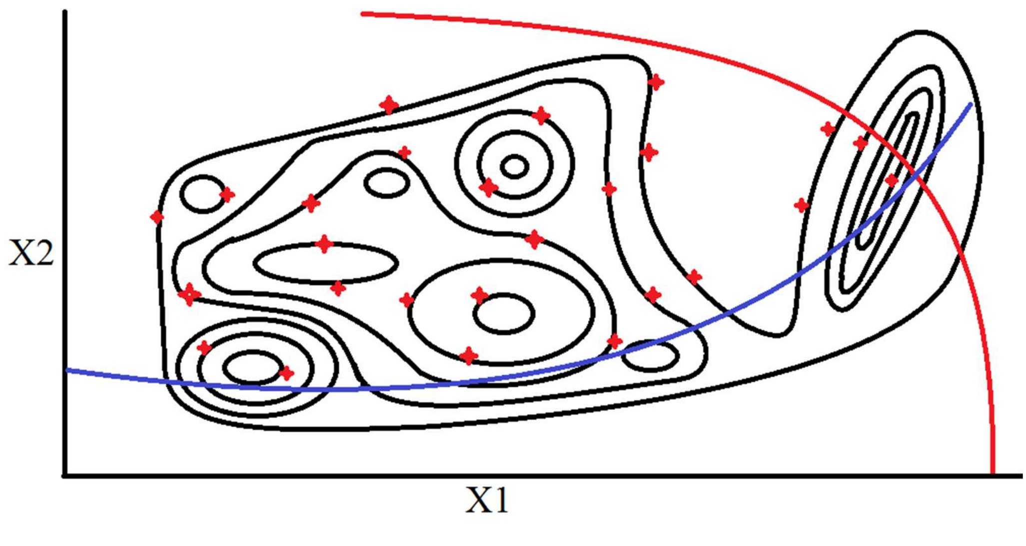

Figure 29 Monte Carlo simulations, X1 and X2 is design variables

The script is estimated to be more difficult to code. This type of optimisation does not consider what parameters that is easiest to change or the most economical. It does not give an exact result but it checks all the different possibilities. Johannes and Kirkpatrick (2006)

4.3.2 Displacement gradients

The method is a systematic search procedure that works directly with the merit function and the constraints and converges to either the global or local minimum weight design. The convergence is illustrated in *Figure 30*.

To obtain a rational result, the software program needs to have some knowledge of how sensitive the displacements are to changes in beam sizes. This is accomplished by computing the displacement gradients.

The displacement gradients is $\frac{\partial U_i}{\partial W_j}$ (1)

Where U_i is the *i:th* generalized displacement and w_j represents the weight of the j member or beam.

The computer would then know which beams are most effective in reducing the displacements that violate the constraints and by using the approximation

$$\Delta U_i = \sum_J (\partial U_i / \partial W_j) * \Delta W_j \quad (2)$$

The computer program could also estimate the magnitude of the required redesign.

(Kiusalaas.J (1972))

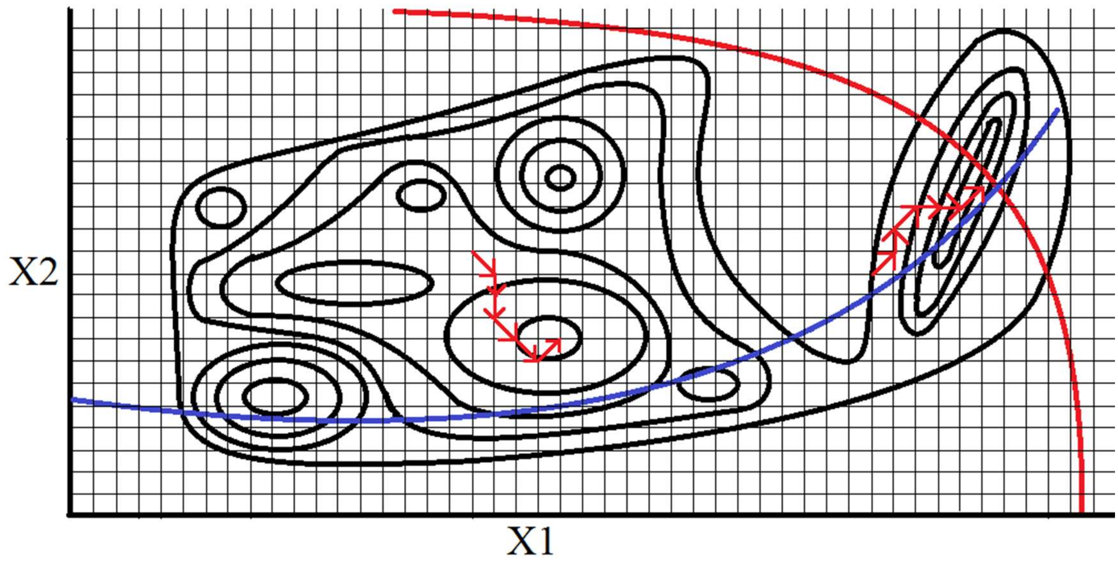

Figure 30 Gradient movement

5 Abbreviations used in script

To get better understanding and to make it easier to alternate the script a document that lists with all the different abbreviations is required., a Abbreviation List This document explains and defines all abbreviations allowed to be used in the script. If all users at TTS used the same abbreviations it will be easier to connect the different scripts, misunderstandings will be decreased, mistakes will be avoided and man hours used on each design will decrease Additional to this, the learning curve for new engineers will be shorter and more effective.

All the abbreviations used in older scripts were reviewed. How the abbreviations have been named before needs to be taken under considerations. It is easier for the user to use a script that is similar to the old one.

If the abbreviation starts with a d it means that it is a distance. # is instead of a number.

d_t#	Distance to **transverse** # from aft part of top plate

If the design changes is located in the aft or the forward there will be a aft or fwd in the abbreviations. The same applies for starboard and portside.

T_aft_design	Choose what design to have on the **aft** transverse

In some of the abbreviations could there be seen ##. The fist is spacing and the second is span.

Lw##	**Longitudinal web,** the first # is span and second is # spacing

To create geometry in loops need temporary abbreviations. These abbreviations have names that refers only to that it is for example a transverse web. Not the exactly position.

fwl#	temporary **flange width longitudinal girder** # used in for-loops, # is discarded if there is only one flange width
Tw	temporary **transverse web** used in for-loops and If statements

For More information se Appendix 2.

6 Results

6.1 Script

The final script produced can be found in Appendix 1. It has the ability to create most versions of fairly simple ramp items and with the addition of the users own graphical changes; the diversity of items that can be produced will increase.

The script has been tested continually during the process of creating it. It was however believed that it needed to be tested by someone else than its programmers to see if it was user friendly and understandable for someone using it for the first time. The script was tested by Jeremy Peter and Rebwar Venya at the structural department at TTS. The time it took to produce two different items with varying complexity were compared to the time it would have taken with two older methods. One method was modelling without any base script which means that it was coded for from scratch. The other method was to use an existing similar item with a script and use it as a base for the new item. The time for these two methods was estimated from experience. The result can be viewed in Appendix 4 but in short it gave the outcome shown in Table 1.

Table 1 Comparison between time spent on older methods to the test results

Method	**Time**
Without base code (from scratch)	8 – 11 hours
From existing similar item	4 – 6 hours
Test 1	1 hour 52 minutes
Test 2	1 hour 21 minutes

With these results we also received comments from the testers:

(1) The part to create different types of geometry is very easy to use and understandable

(2) The less easy-to-use and understandable part is "tweaking" the support points.

a. Relatively easy to create the support points

b. Very confusing to change sets and to pick which points goes in which sets.

(3) Analysis and loads are well done and seems to be working for most common cases.

From the tests it was shown that the script seems to be working well and successfully reducing the required time for modelling. There were however some things that was somewhat confusing or in need of improvement.

The numbering of longitudinal girders is different in the drawing compared to the script and model. In the drawings they are numbered outwards with number 1 in the middle.

For the sake of the script working properly, they are instead numbered from one side to the other. This can be seen in *Figure 31*.

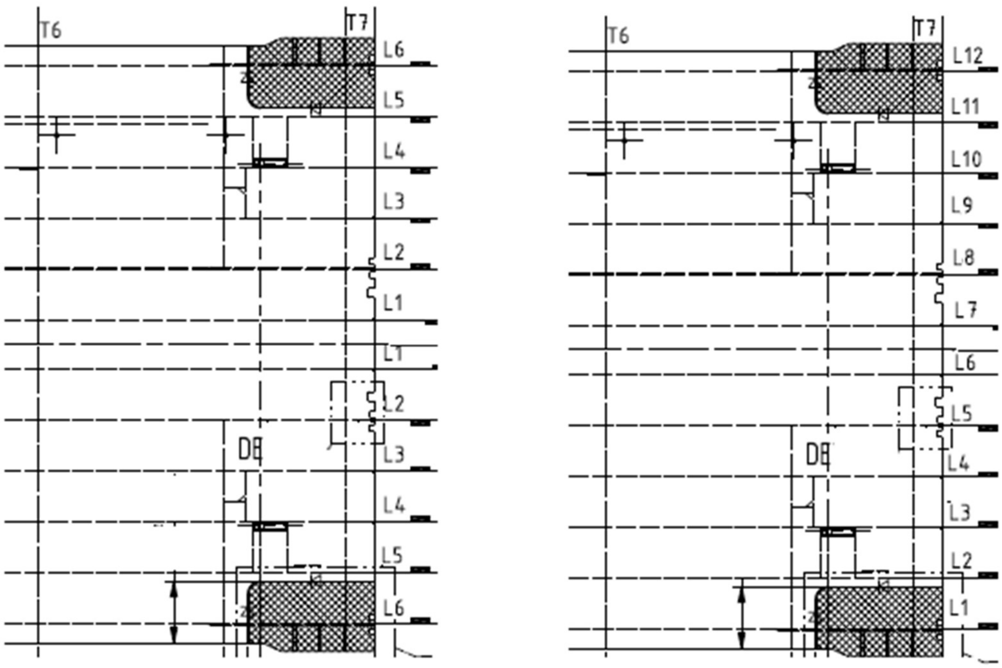

Figure 31 Numbering of longitudinal girders in the drawings (left) and in the script (right)

Another problem was as mentioned the support points and the sets. The creation of them was, if not perfect, at least satisfactory. When it came to assigning them to the proper set and choosing set on the other hand, the script failed to deliver. These changes had to be done graphically.

With the script, there was also produced a simple guide on how to use the former (Appendix 3) as well as a list of the abbreviations used in the script (Appendix 2). The list of abbreviations was partly meant as a help if something in the script was unclear. It was also meant as a template for everyone using GeniE so as to simplify the collaboration within the company, a result given by the same usage of abbreviations.

In addition to all above, an excel sheet was also made that was meant to be connected to the code, giving a user the ability to alter the script and create an item in GeniE without having to enter the script. This if the person was not comfortable using JavaScript. The connection between the sheet and the script was however not finalized. The sheet can be found in Appendix 5.

6.2 Optimization

The optimization procedure is not as straight forward procedure. The simplified ramp has only using fewer variables compared with the real ramp. From the studies of how the ramp moves and behaves could it be seen that all beam are depending on each other. If one flanges is made thinner the stress increase in the other beams.

Because of the ramp has many different components that could be changed there is several different variables that could be changed. If the ramp had even more variables it would have been harder to find the optimal positions.

The optimization with Monte Carlo will perhaps not be useful as there is a lot of knowledge within TTS that is not taken in to consideration. The initial design will probably be close to the optimal design with only few iterations needed. The positive is that the method will find the optimal design but it will perhaps take longer time.

Taking longer steps in the iteration process will result in an inaccurate algorithm. There is by all means a possibility that changes of another beam will be have greater effect than the selected beam.

6.2.1 Optimization algorithm

The algorithm we have developed is able to handle nonlinear problem that are depending on each other. Every iteration will change the flange width one step and starting with the lowest gradient. If the size of the flanges is available in steps in cm the optimization should be done in cm. The base design refers to the initial design and it should be within the criteria. The optimization is continuing in loops until the criteria fails on all parameters as showed in *Figure 32*.

Step 1. Base design:
The structure engineer creates a Base design that fulfils the criteria's regarding stresses and deflection. The Base design geometry and technical attribute is based on a large number of previous projects and the engineer's long experience and knowledge together with the project team.

Step 2. Calculating stress and deflection as reference:
The Base design in form of numeric data is used for the input to the software program Sesam. Sesam analyses stresses and deflections and present a result.

Step 3. Reading the results:
From Sesam an external document is created. This document illustrates and describe stress and deflections in the nodes and elements.

Step 4. Calculating the gradient:
From the results from the document in step 3 could the gradient be calculated. The first loop acts as a reference for calculating the different gradients.

Step 5. Changing the parameters:
The first parameter is changed. In every loop a new design parameter is changed. The order of the changed parameter does not matter. The changes are done in one step.

Step 6. Calculating the stress and deflection of the new design:
The new designs in form of numeric data is used as input into Sesam. Sesam analyses stresses and deflections and present a result. Same procedure as Step 2 above.

Step 7. Reading the results:
The same procedure as Step 3. Above Step 3 to Step 7 will be repeated in loops until satisfied results are achieved.

Step 8. Optimized design:
The optimized design should be established and output sent to detail design department for development and finalizing construction and workshop drawings.

The optimization algorithm that should be used to achieve this optimized design can be seen in *Figure 32*.

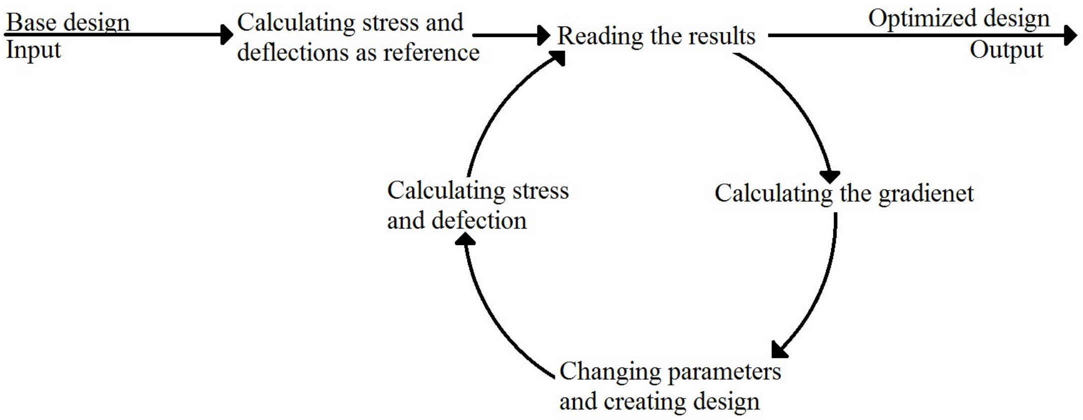

Figure 32 Optimization algorithm

Seen in *Figure 33* is an example of an optimization algorithm for a four transverses. It is using the same mythology seen in *Figure 32*.

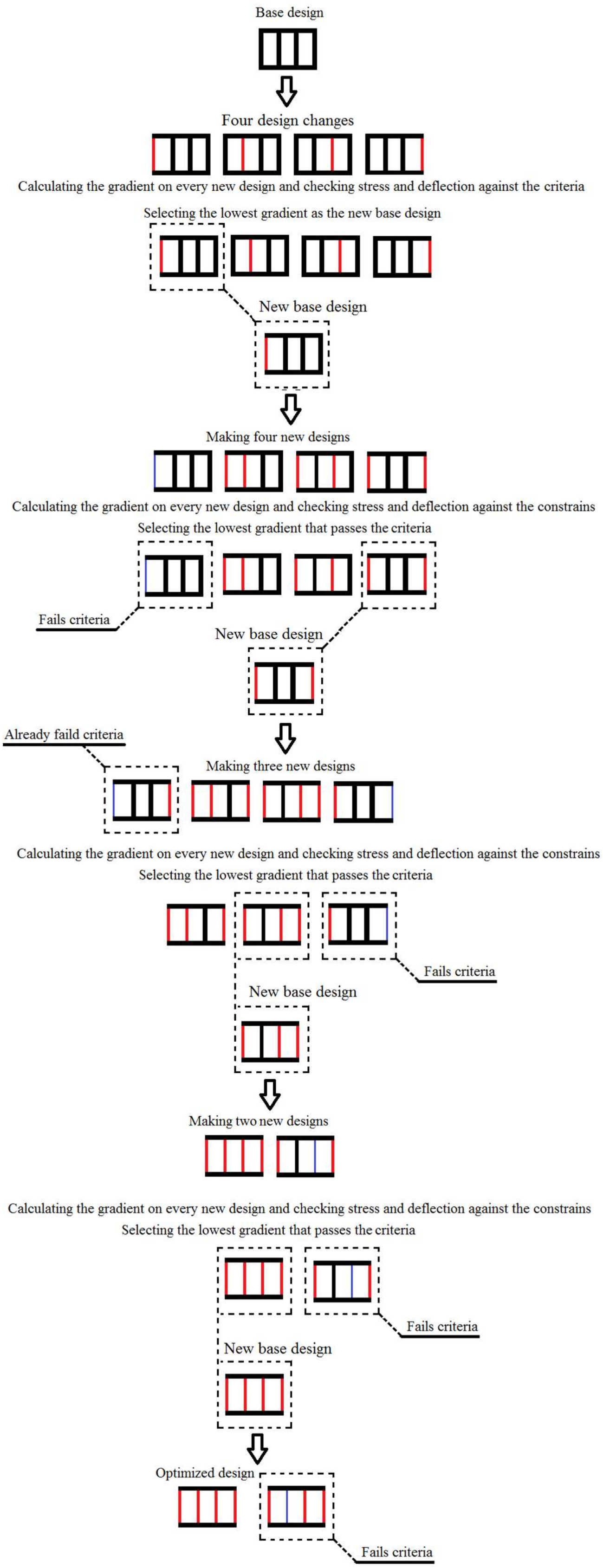

Figure 33 Algorithm. Black beam 200mm, Red beam 150mm, Blue beam 100mm

The Algorithm used in *Figure 33* uses 15 iterations to change all beams one step. It would have taken approximate 7.5 minutes to calculate.

7 Discussion

7.1 Script

The target was to develop a script able to generate as many necessary features as possible. There is a limit to what the script can perform without new input from the user's graphical changes.

The size of the script may increase exponentially by adding more functions, therefore is it not advisable to add numbers of features to the script without having corresponding computer capacity. Due to that most of the parts of the structures and the script connects to and depends on each other, the consequence of adding functions will be that an increased complexity and changes are required in most parts of the script, this will require increased skills and more strict discipline among the engineers operating the script.

The script shall only contain features that are frequently used in the products. A feature that only occurs once or twice in the product portfolio is not of any interest and will create complications. These un-usual features shall be created by the graphic changes.

Except for the increase of script size, more features can also be negative for the script being user-friendly. Too many small feature options included will have negative impact on the simplicity and will make it less convenient for the users and more difficult to understand and correct. Therefore, in this study it was selected to not include un-usual features and changes.

Choices have also been made on how to code for parts that could have been done in alternative means. When designing the longitudinal girders it was decided that, for the sake of the mid design, there is going to be an even number and the odd one, if any, will be created in the middle separately. This could probably have been done by creating all girders at once and made the two girders surrounding the middle one be changed for the mid design. The "two girder surrounding" alternative is not included in this study due to the increased complexity it will create to the script. The benefit to use the alternative would been that the girders are created with just one function instead of two and for the user it would have been an easier alternative. In principle it requires the number of girders and type of mid design and a well-developed script. . It is advisable to further study this method in order to improve the script.

Originally it was discussed to develop a box flange by translating the flanges inwards and connect them. This alternative is not included in the study due to that this configuration would increase the complexity further by changing the width to fit the spacing.

All flat bars are created by deleting the flange and whatever connects to it and recreating it with connection to the flat bar. Thoughts was given to instead just shorten the flange so much that it becomes irrelevant for the global strength which would make it basically a flat bar. This was avoided because of the problems it would cause. The very small flange would give irregularities in the meshing of the model even though it wouldn't affect the global strength. It is also most likely that problem could occur when the user are doing graphic changes. If there is a small flange the model would have two points very near each other and the user would probably not notice or have control of to which point the marker would be snapping.

The result from the test defined as reduced "time" by using our script is regarded as a successful result. One of the benefits to shortening the time is that the risk for unplanned interruptions also is reduced. Preferably shall the script for a ramp require less than two hours, the modelling could be done in one sitting to be efficient.

The correctness of the estimations in the two methods described in Appendix 4 may be subject for additional review. Nevertheless given the experience the engineers performing the test has with these methods, the estimation is most likely valid.

The numbering system of longitudinal girders in the model was not consistent with the numbering in the drawings, this misalignment created confusions. It is advisable to develop and implement a numbering procedures manual together with a numbering guideline to align and control the whole numbering system in the company. The numbering in the model was required for functionality. It could be possible to make it work with the "proper numbering" but this was not aspired due to lack of time and increased complexity.

Misinterpretations and misunderstandings related to supports, sets and their connection resulted in the script malfunction. Creating the geometry was time consuming resulting in reduced time available for preparing analyses that has impact on product quality. Changes made in the test was done graphically and took 25 respectively 20 minutes. This should ideally be made by the script and improvements related the supports and sets in the script will reduce this time.

The test was performed by engineers with a lot of experience in using JavaScript to generate items in GeniE. It is estimated that the required time from the test would have increased if an inexperienced person had done the test. The test was however a comparison between methods and had the test person been inexperienced, the time for the previous methods would have increased as well.

As a reference to our script, we have also reviewed alternative methods to develop and designing a script. An alternative is a shorter script that meets the requirement from the engineer. An opportunity is to create a number of shorter sub-scripts with only one feature each. Depending on desired features, specific "sub-scripts" can be selected and inserted and incorporated in the main script. The dependency between features is however a problem here as well. Some parts are created with the condition that other parts are already present. If that requirement isn't fulfilled and an error occurs, the script wouldn't work. It would also be important to remember to design all "sub -scripts" with the same coordinate system or the parts would not fit together.

An alternative is a similar script to the script that we have developed. The difference would be that instead of having everything in one script the script would, depending on choices from the user, activate JavaScript-functions that "calls" on smaller scripts stored in the same folder. These smaller scripts would then only be a part of the end product if the user chooses to. A benefit from this is that the script wouldn't be so "messy" with a lot of code lines. The downside would be that the shorter scripts would probably need to be present in the same folder. Therefore an entire folder needs to be stored and moved around instead of just a single script. This way of coding could be achieved, assuming there is such a “call command” and that it works the way it’s assumed.

The connection between the script and the excel file were never made. The basis was that engineers with no experience or knowledge in JavaScript would be able to make changes in the excel file. . Using the script to create new designs is however not that complicated. Good skills in JavaScript is needed if changes is to be done on the script itself, not when changing inputs. Inexperienced employees will require limited practice and time to learn enough to be able to use the script. Moreover, engineers working with GeniE really are better off knowing more about the particular programming language that are used.

Simplicity is the key word. An excel file attached to the programme it’s a common element of the whole procedure that can cause large errors and mistakes.

7.1.1 Abbreviations used in scripts

Abbreviations are frequently used in scripts. It is very important that all users working together understand each other’s scrip. To develop and use a company common standard of abbreviations minimizes misunderstandings rework and avoids mistakes. It should be a part of the company Quality system. The present situation is that working hours are used for trying to understand colleagues abbreviations and script, to understand what has been done and how.. The names of the abbreviations should have some kind of standard. This report only scratches on the surface on all different abbreviations used for designing ramps.

The meaning of specific abbreviations may be changed due to that engineers and designers uses the same abbreviations for different purpose. A continues updated abbreviation list will make all involved more updated. The Excel template that exists should be available for all users on TTS to be useful. Some abbreviations is difficult to understand and explain, additionally some small brackets and some parts does not even have names or abbreviations. Picture and figures of good and informative examples will increase the understanding.

Abbreviations go hand in hand with the script. If there is a loop function that names a certain part from -5 to +5 it could equally be named 1 to 10. The purpose is the make it the easiest to for the user to design it from a drawing.

Some of the details seen in the drawings are not named in a specific way. Undefined objects make it difficult to transform them into a script and other standard need to be used to resolve the issue.

7.2 Optimization

There are a number of means to optimization these types of structures. As no physical test of the developed algorithm has been possible to perform, the algorithm has been reviewed and checked if the ramp meets the set criteria and converges in to optimal design.

A Monte Carlo optimization will probably find the local mini position faster compared with a gradient method if the start position was not optimized. The selected start position will have great influents on how many calculations and iterations that is required to find the optimal design. If the start position is the optimal design, then it will only the amount of parameters plus one be the amount of iterations.

As an example: A structure with four changeable parameters needs at least five iterations. The first iterations as reference and the fourth for calculating the gradient and checking the criteria. If the problem was solved with a Monte Carlo optimization will a pre-determined number of iterations be done?

“It should be pointed out, however, that it seldom is feasible to obtain an efficient design without any human participation whatsoever” Kiusalaas (1972)

A combination of these two optimization techniques could be a good way to optimize to structure if there was no time limit. Starting with the Monte Carlo method and finding the area, later on changing to the gradient method. This combination will have probably be using allot of iterations.

There is a problem that occurs by using the gradient method, this is the so called chess board problem, seen in *Figure 34*. This problem is common in topology optimization. The effect of the problem is that the structure is almost turning in to a chessboard. Half of the beams will be big and the other half very small and week. These problems are common in FE optimization. Bendsön,and Sigmund (2004)

If the problem is seen as linear and if the step size is increased these problems could also appear.

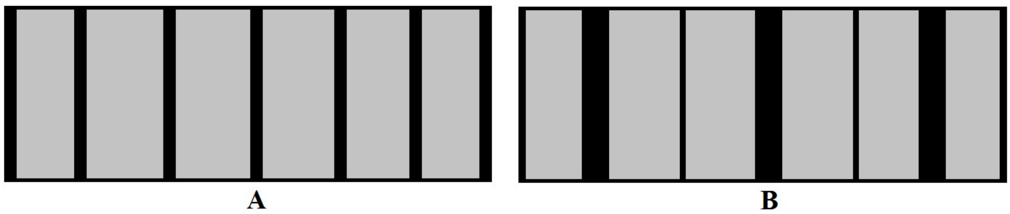

Figure 34 Chessboard problem. Ramp A and B has the same weight and fulfil the criteria in stress and deflection.

Car panel A and B has the same weight and both of them fulfil the criteria. Depending on how the base design looks will the gradient start moving to different local minimums seen in *Figure 35*.

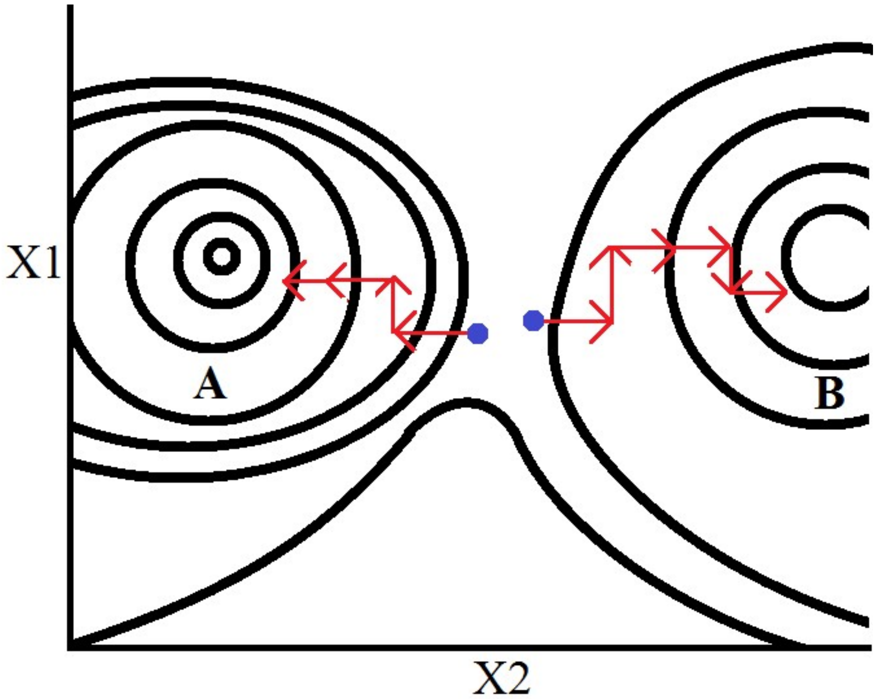

Figure 35 Start points for design A and B

The optimal design may be reach faster by using longer steps in each iteration. The problem with taking long steps is that another beam perhaps had a better gradient within the steps. If a beams width is changed in an interval of five centimetres instead of the original 1 cm, will maybe result in that another beam will be critical.

Alternative methods for optimizing the structure have been discussed within the Company. One of these is a sequential process, starting with optimizing the first beam, continues with the second, third up to the last beam. The beams will be seen as completely independent and have no influence on each. If this method was used there will be no need of calculating what beam has the most impact on the structure. This means that this method may result in fewer iterations to reach an optimal design as well a simpler program could be made. This technique needs to be further developed.

To classify the structure as a linear problem then may even fewer iterations be required to find an optimal design. Below algorithm may be used if the problem is seen as an independent and linear function. The flange width is the only parameter that is allowed to be changed. This means that the moment of intertie will be linear.

Moment of inertia

$$\frac{B*h^3}{12} = I \qquad (3)$$

The beams in the structure is seen as simple beams with uniformly distributed load

$$M_{Max} = \frac{Ql^2}{8} \qquad (4)$$

Bending stresses

$$\frac{M_{Max}}{I} * z = \sigma \qquad (5)$$

Ringsberg (2011)

With only two calculations and a linear equation, the optimal design could be found on every beam. Most likely is this type of assumptions to inaccurate to be used for optimization of complex structures like ramps on large cargo ships.

There were discussions if all flanges should have a fixed width to start with. Additional iterations will be required and in extreme cases some of the beams will be too weak and fail the criteria at the start position. Two changes may be done to make corrections if the base design is too weak and all the beams has to high stress. Reverse the last change, starting with the beam with the highest gradient as defined as the largest change of stress level compared with the weight. Another mean is to change all beams that are over the limit at the same time. Changing more parameter simultaneously may result in reduced number of iterations to reach to the optimum design.
By making the optimizations time faster, the optimization could be implementer earlier in the design stage. Changing the design earlier in the devolvement phase won't interfere with other parts of the project that is depended on the structure. Dimensioning the correct design as early as possible will shorten the lead times.

8 Conclusion

Time, in the sense of both man-hours and calendar days or a function of these, is a major concern in the design phase. If the spent time may be reduced, focus could be put on tasks that add value to the product. Standardize the design processes will reduce spent time in the design phase.

A modularized script have been produced that, based on tests, indicate being able to efficiently reduce the time designing models for FE analyses. (Appendix 1) The script is so far perceived to be easy to use and no major errors have been encountered. The part that deals with supports and sets are however not working the way it should be but this can most likely be fixed with smaller changes. The rest of the script is working fine but can still be improved with further coding.

Along with the script there has also been produced a guide on how to use the script (Appendix 3), a list of abbreviations meant for everyone to abide by in order to facilitate cooperation between co-workers (Appendix 2) as well as an excel sheet designed to be help users inexperienced in JavaScript create models without having to enter the script (Appendix 5). The excel sheet has not yet been connected to the script.

The time saved in the design phase will allow more time to be used for optimization of the large and complex steel structures that is the core business for TTS.

An algorithm has been derived that describes a way to optimize simpler car deck panels. It was however concluded that not enough knowledge was gathered to conclude if this method is the most efficient and further studies are needed.

In the future this algorithm, or another preferable if further studies prove so, is meant to be developed into a software program. The optimization is with this done automatically by a computer which will hopefully take the optimization to its full extent.

When done automatically it will also give the engineer opportunity to put time into working with other important work, thus contributing to reducing the seven waste.

9 Future work

9.1 Modularization

Future development work can be done into making the modularized script more accurate and efficient. This work is preferably managed and performed by a engineer with documented good skills in both JavaScript and GeniE, beginning with the function for the supports and sets.

Additional assessments and reviews may be performed to validate if it is worth spending time and money improving various functions in the script. If so, based on this thesis authors, following improvements can be worth looking into:

- **Creation of longitudinal girders & mid design**
  Creating all longitudinal girders, even if they are an odd number, with one function and adjust the mid design function so it works with whatever configuration that are present in the middle part of the ramp.

- **Numbering of longitudinal girders**
  If not too complicated, an effort could be made into making the number of longitudinal girders in the model match the numbering in the drawings. An easier solution is to explain the difference thoroughly in the guide.

If deemed worthy of the effort, attempts can be made on achieving the same result with the two alternative methods of creating the script mentioned in the discussion. Regard should then be taken to that if this is attempted, due to the complexity of the existing script, the easiest way would probably be to start over from the beginning, not being able to utilize the time already spent on making the script.

In the future, efforts should also be put into connecting the mentioned excel sheet to the script.

9.2 Optimization

It is proposed that a separate larger study shall be focused on development of an optimization procedure. Additional studies and tests need to be done to test of the proposed algorithm.

To make the optimization process more automatically a comprehensive software program need to be developed. The requirements that this software needs to meet are:

- Read the results.
  - Reading the results from the separate document crated from GeniE
- Calculate the gradient
  - Based on the result in GeniE calculating the gradient and instructing the script which beam to change and how.
- Checks if the criteria's is fulfilled
- Changing the different parameters in the scripts.
- Run the script again
- Present the result when optimum design is achieved

These steps are shown in *Figure 36*.

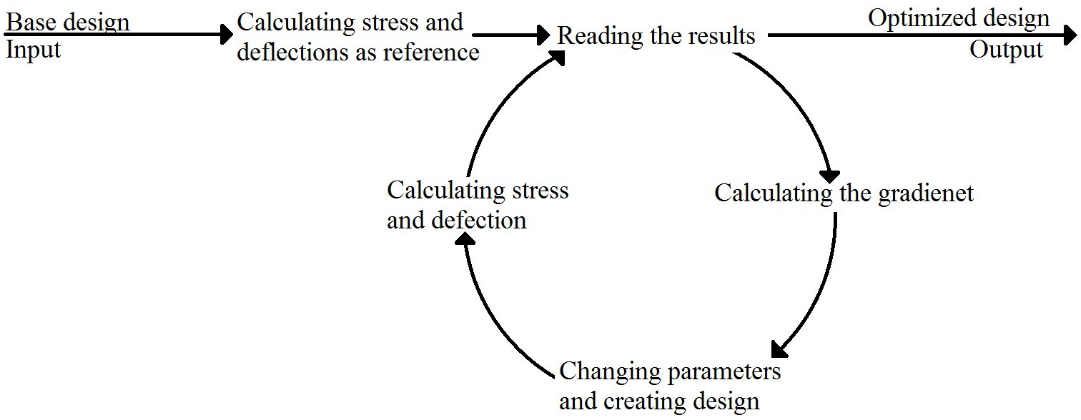

Figure 36 The arrows shows what need to be done automatic

After a testing period using the proposed algorithm future studies needs to be done to find errors and to make improvements.

Additionally, future studies and investigation are proposed to be done based on the assumption that a structure may be seen as linear and independent. If the structure is independent and linear probably fewer iterations is needed to optimize the structure.

The whole concept of optimizing of a steel structure is not limited to optimizing weight only; it includes constructability, availability of profiles and plates, workmanship the yard, engineering knowledge etc.

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