Comparing current barge designs with double deck plate barge designs

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Bachelor Thesis

Final internship Heerema Marine Contractors

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Date April 2015
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Project -Afstuderen
Subject **Double deck barge**

Bedrijfsomschrijving
De Heerema Group ontwerpt, fabriceert, transporteert, installeert en verwijdert verschillende faciliteiten benodigd voor de exploitatie van olie- en gasvelden. Het bedrijf voert werkzaamheden uit in de Golf van Mexico, West-Afrika, het Verre Oosten, Brazilië en in de Noordzee. Klanten waarvoor deze werkzaamheden worden uitgevoerd zijn veelal de grote energiebedrijven of nationale oliemaatschappijen.
Heerema Group is onderverdeeld in twee aparte onderdelen, de Heerema Fabrication Group (HFG) en Heerema Marine Contractors (HMC). Bij die laatste zal de afstudeerstage plaats vinden.
Heerema Marine Contractors transporteert, installeert en verwijdert allerlei typen offshore installaties. Hierbij moet worden gedacht aan vaste constructies, complete infrastructuren en drijvende installaties, in ondiep, diep en ultra diep water.

Probleemstelling
Bedoeling van de opdracht: een bestaande wat grotere bak te kiezen (H-541) want hier zijn alle gegevens van bekend. Vervolgens is de vraag om een alternatief ontwerp te maken voor een bak van dezelfde afmetingen met dezelfde frame afstand maar ook met een specifiek verschil. Standaard worden bakken gemaakt door op een plaat langs verstijvers (stiffeners) te lassen en vervolgens de dwarsframe T liggers er overheen te zetten, uiteindelijk worden uit deze verstijfde platen de bak gemaakt.
Het verschil tussen de standaard bak en de alternatieve constructie is dat de dekbak uit het dwarsframe nu niet zal bestaan uit een dekplaat met een T ligger eronder maar deze zal bestaan uit een dek plaat, een lijfplaat en een plaat die door loopt over alle frames. Het frame dat onderzocht gaat worden is een "typical web frame 13".
Het toepassen van de alternatieve constructie heeft als gevolg dat er relatief veel materiaal in de barge toegevoegd moet worden waardoor het totale gewicht toe zal nemen. Daarom zullen er per web frame 2 columns verwijderd worden om gewichtstoename te voorkomen. Echter moet de capaciteit van het web frame wel toenemen (of gelijk blijven, maar dan wel met een gewichtsafname) om het nut van het alternatieve ontwerp te behouden.
Het vooronderzoek behelst begrip krijgen van de ontwerpcriteria voor een transportbak en hoe deze criteria zijn toegepast op een bestaande bak.
Het verdere onderzoek bestaat dan uit het ontwerpen/detailleren van een alternatieve constructie, afgesloten met een vergelijking tussen de twee bakken.

De opdracht
De vraagstelling is: maak een vergelijking tussen een bestaande transportbak en een concept transportbak die gebruik maakt van een dubbele dekplaat. Deze vergelijking moet onder andere in gaan op:
- Globale sterkte
- Lokale sterkte (Handberekeningen en SACS model)
- Gewicht

René Smit
Stagair

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Bedrijfsbegeleider

Opdracht afstuderen R Smit HMC v6.docx

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Acknowledgement

This thesis is commissioned by the Hague University Delft in association with Heerema Marine Contractors. The thesis is developed after extensive research on the subject: comparing conventional barge designs with double deck barge designs.

I would like to thank Anne Merlevede for the daily guidance, providing information about all kinds of subjects like reading ship drawings, working with Bentley SACS, explaining theoretical subjects of the assignment, the feedback on the SACS model, and all other parts like the thesis itself and calculations was very helpful. Whenever I had to work with HMC in-house spreadsheets, Anne explained how the spreadsheets work and what the theory behind these sheets meant. The preparedness from Anne to help, whenever there were any questions created a very pleasant work environment.

I would also like to thank Peter Schoenmaekers for compiling the subject of this research. Peter was always prepared to give feedback on the thesis, and give pointers on what aspects should be taken into account regarding the assignment. The meetings with Anne and Peter were very useful in order to continue the work whenever there were difficulties or questions about the research.

At least I would like to thank Haris Nikocevic for his assistance on finding information about the barge H-541. Haris gave pointers on where to find certain data (like drawings), but also gave explanation about the engineering guideline which was very helpful during modelling the SACS model.

Index

Definitions and Symbols

Barge	Flat top vessel which is capable to move production Platforms and other offshore structures overseas.
Bulkhead	Plate field that divides a barge into several compartments.

Not necessarily watertight (regulating ballast)

- Longitudinal
- Transverse

Buoyancy	The upwards force that a body in a liquid or gas encounters
Capacity	Maximum allowable amount of load an object can endure (safety factors taken into account)
C.o.G.	Centre of gravity
Float-over method	Method of installation of a topside, where the topside will be “floated-over” the structure it will be attached to, then the barge the topside is welded onto will lower itself by filling its ballast tanks in order to get the topside in position
Grillage	Steel construction that spreads static and dynamic vertical loads
Heave	Translation in z-direction
Jacket	Steel substructure to support topsides that bridges from mud line to above sea-level
Load-out	Loading a structure on a barge previous to transportation of the structure
MTO sheet	Material take off sheet, used to obtain a value for the amount of material that has to be added or removed
Roll	Rotational motion on the sailing direction of the barge
Pitch	Rotational motion around the y-axis of the barge
Stiffeners	Stiffeners are welded on different plates to improve the buckling capacity of these plates.
Surge	Linear motion in the sailing direction of the barge
Sway	Linear motion right-angled on the sailing direction of the barge
Yaw	Rotational motion around the vertical axis of the barge

Symbol	Unit	Meaning
b_{eff}	mm	Effective width
b	mm	Distance
L	mm	Length
F	N	Force
V	N	Shear force
A	mm^2	Cross sectional area
I	mm^4	Area moment of inertia
τ	$\frac{N}{mm^2}$	Shear stress
σ	$\frac{N}{mm^2}$	Bending stress
f	mm	Deflection
M	Nm	Moment
Q	mm^3	Statical moment
W	mm^3	Section modulus

Table 1 List of symbols used in this thesis

Summary

Barges are used in order to transport all types of offshore structures and equipment. Structures which are transported are becoming larger and heavier. Therefore, there is need for barges that can handle these structures. This research will explore the possibilities to increase barge capacity by adding a secondary deck.

This research includes a comparison between a typical web frame 13 of the H-541 and an alternative design of a web frame. The goal of this research is to improve web frame capacity and global capacity of a typical web frame 13 by adding a secondary deck to the deck beams, and increase the web height of the deck beams. The reason to check this typical web frame over other the typical web frames is that the web height of the typical web frame 13 is continuous over the entire length of the deck beam.

Adding a secondary deck will result in a significant increase in weight. Not only will the secondary deck contribute to the addition of weight but also the stiffeners which are required in order to prevent buckling of the secondary deck. In order to compensate for the increase in weight, material from another section of the web frame will be removed. The section which will be removed are 2 particular columns of the web frame. By removing 2 columns, the dimensions of the deck beams will change, creating relatively large bending moments. In order to avoid these relatively large bending moments, 2 columns will be re-positioned.

During this research hand calculations are made for the conventional web frame 13 and the alternative web frame 13. These calculations are made in order to check web frame capacity. After calculations by hand, a SACS model is created for the alternative web frame 13. With this SACS model, the web frame capacities of the alternative web frame are determined and compared with capacities of the conventional web frame.
Global capacity of the conventional and alternative web frames are made using a excel spreadsheet in order to determine the allowable bending moment and the allowable shear force.

Hand calculations show that mid-beam capacities of the alternative web frame have decreased. The capacity near the support point of the beam have increased due to the increase of web height (therefore reducing shear stress).

The SACS model shows that capacities of the alternative web frame have decreased as well. Primarily half way the beam sections, capacities have decrease because the span of the deck beams has increased. The increase of span creates larger bending moments and therefore increases bending stress. However, capacities of the deck beams near the brackets and columns have increased due to adding the secondary deck and the increase of web height.

According to the calculations on the global strength of an alternative typical web frame 13, the global capacity will decrease. The allowable shear force will decrease as a result of removing 2 columns (and therefore also 2 longitudinal bulkheads). As a result of the shift of the distance from the neutral axis to the outer fiber of the bottom plating, the allowable bending moment will decrease as well.
Further research on adding a secondary deck should be done in order to increase web frame and global capacity of a typical web frame 13.

1. Introduction

The Heerema Group designs, fabricates, transports, installs and removes a variety of facilities, required for exploitation of oil- and gas wells. The company has projects in the Gulf of Mexico, West Africa, the far East, Brazil and the North-Sea. The clients whose the projects are executed are mainly oil companies and large energy companies.
Heerema Group is divided in two separate companies, the Heerema Fabrication Group (HFG) and Heerema Marine Contractors (HMC). Heerema Fabrication Group is specialized in fabricating large complex structures (jackets, topsides and decks) for the oil and gas industry. Heerema Marine Contractors transports, installs and removes a variety of types of offshore installations. The following structures are examples of objects Heerema Marine Contractors deals with: fixed structures, complete infrastructures and floating installations in shallow, deep and ultra-deep water. These activities are executed by one or more of the many vessels Heerema Marine Contractors owns. Some of the vessels are used for heavy lifting (Aegir, Balder, Hermod, Thialf), some are used for pipe laying, and other vessels are used to transport and/ or launch offshore structures (i.e. H-541).

This final internship will be executed at Heerema Marine Contractor (department: Technology - Structural).

1.1 Problem statement

"Barges" are used to transport installations (like jackets, see figure 1.1) from the fabrication site to the installation site. These barges are moved to their location using towing boats. Because the structures Heerema designs are becoming larger and heavier, there is demand for barges which can handle larger loads compared to current barges. Therefore it's necessary to explore alternative solutions in order to be able to transport larger and heavier installations.

Figure 1.1 The H-851 carrying a jacket [7].

1.2 Objective

The main assignment of this thesis is: make a comparison between an existing barge and a concept barge, which is made using a secondary deck plate. This comparison includes:

- Global strength
- Local strength
- Weight

Intention of the assignment is: to pick an existing relatively large barge (The H-541, because all specifications are available). Then make an alternative design for a barge with similar dimensions, the same frame-distance as the conventional design but also with a specific difference.

During the first four weeks the assignment has been specified in order to focus on a particular subject and to determine which issues need to be discussed.

The possibility to remove 2 particular columns in the transverse web frames will be explored in this thesis. Removing these columns will cause a reduction in weight. However this weight can also be added to the deck beam to increase the strength that is lost by increasing span width of the deck beams. Material can be added to the flanges and web in order to improve shear and bending properties. By increasing the web height of the deck beam the shear properties of the beam will improve. By adding material in the top and/or bottom flange the bending properties will improve.

The main difference between a conventional barge and the alternative barge is that the deck beam from the web frame will not exist out of a T beam underneath the deck but will exist out of a deck plate and a “second deck plate” which is continuous over all the frames (Figure 1.2). To apply this structure, the barge has to have certain (large) dimensions because there has to be enough space to able to work within these plates.

Previously to design/draft related work, research regarding barge strength will find place. Research includes getting familiar with current design criteria for conventional barges and knowing how these are applied to a conventional barge. With this knowledge a list of requirements must be compiled for an alternative barge (structure), which is designed with a double deck plate structure.

Further research consists of drafting and detailing an alternative structure in SACS, subsequently realizing a comparison between these two web frames.

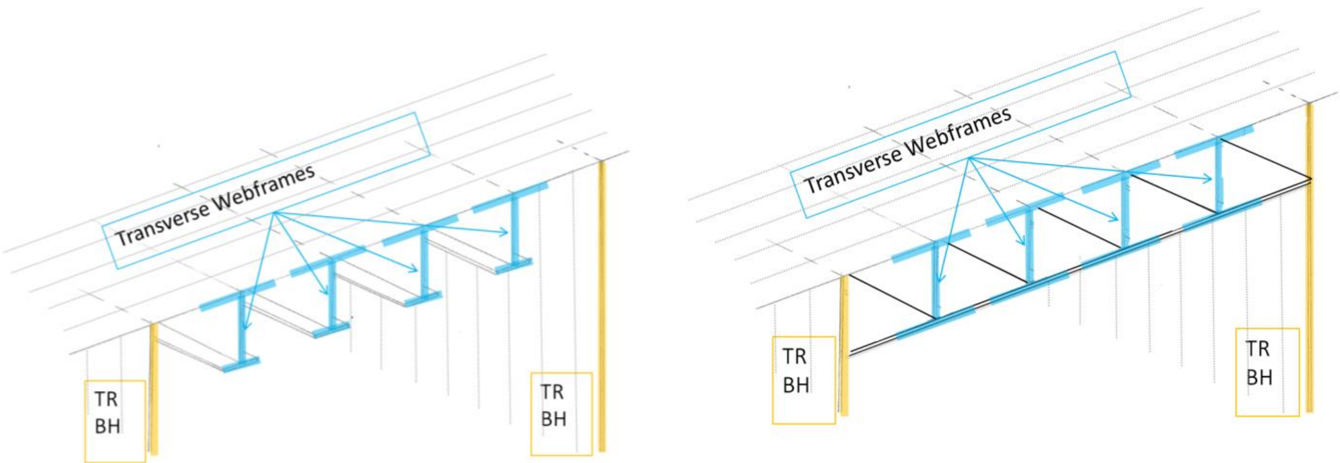


Figure 1.2 Left the conventional deck beams, right the secondary deck, deck beams (Not the H-541)

2. General barge structure

A barge is a flat-bottomed vessel used for transportation of structures like: top sides, flare booms, offshore equipment, piles and jackets. Barges are towed by tugs because they are not self-propelled. There is a variety of type of barges i.e.: cargo barge, launch barge and heavy transport barges and every barge has its own use.

2.1 bulkheads

Modules and equipment meant for offshore construction will be transported to designated offshore locations by cargo barge. A barge is made out of multiple plate fields which separates the barge in multiple compartments (figure 2.1). The transverse plate fields are named transverse bulkheads and the longitudinal plate fields are named longitudinal bulkheads. To obtain a structural integer barge, web frames are placed in between these transverse bulkheads. In the H-541, 3 web frames are placed in between 2 transverse bulkheads.

Bulkheads are used to divide the barge into several tanks. As mentioned before, there are two types of bulkheads: longitudinal bulkheads and transverse bulkheads. These bulkheads can be both watertight as not watertight (swash). The swash bulkheads are used to join multiple tanks together. Usually the middle tanks are joined together (because outer tanks have more effect for stabilizing than inner tanks). The reason to join tanks together is to save costs on ballast equipment.

As mentioned before a barge consists of multiple tanks, divided by bulkheads. These divisions are constructed out of several (transverse) web frames and placed in between transverse bulkheads. Transverse web frames are used for load introduction to the bulkheads. These transverse web frames are positioned at the same, repetitive distance over the whole length of the barge.

For the transport of larger structures a construction has to be designed between the structure and the deck. This structure is called “grillage and seafastening”(Chapter 2.5, Figure 2.8). The grillage and seafastening spreads the loads into the barges strong points and are generally placed on top of a transverse bulkhead because it is one of the strong parts of the barge. More aspects of grillage and seafastening are discussed in chapter 2.5.

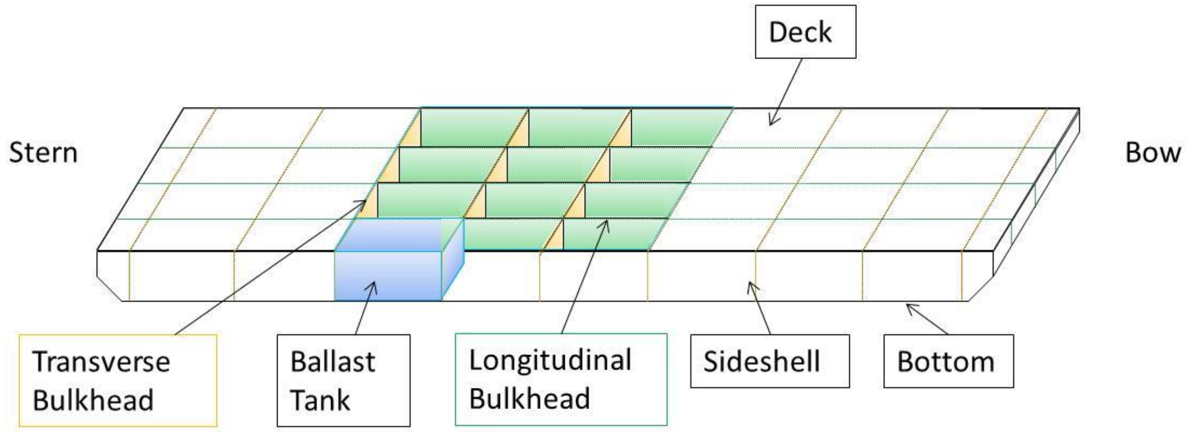


Figure 2.1 Structure of a barge, this figure shows how the transverse and longitudinal bulkheads create multiple tanks in the barge [22]. (Figure III.D and figure III.E in appendix A.III also give an impression of the general barge structure)

2.2 Transverse section of a barge

Figure 2.2 shows a section between web frames of a barge (not the H541). In this figure several parts of the barge are displayed in order to understand how a barge is constructed. This figure shows that any transverse section includes the following parts:

- Deck plating
- Bottom plating
- Side shell plating
- Longitudinal bulkhead plating
- Longitudinal stiffeners

The side shell plating (seen in Figure 2.2) can take up the vertical loads of the sea fastening and grillage, the deck can take up the horizontal load of the sea fastening (Chapter 2.5 Grillage & Seafastening). Therefore the side shell plating has to be one of the strong parts of the barge. The longitudinal bulkheads (seen in Figure 2.2) can be used to introduce vertical loads into the barge and are also strong points of the barge.

The barge (H-541) is equipped with longitudinal stiffeners (Appendix III.A, Figure III.F) on every plate field except transverse bulkheads, the transverse bulkheads are equipped with vertical stiffeners. The stiffeners on the longitudinal bulkheads, side shell and bottom/top -deck are used to increase buckling strength and also contribute to the global strength of the barge. The longitudinal stiffeners continue over the entire length of the barge, from stern to bow.

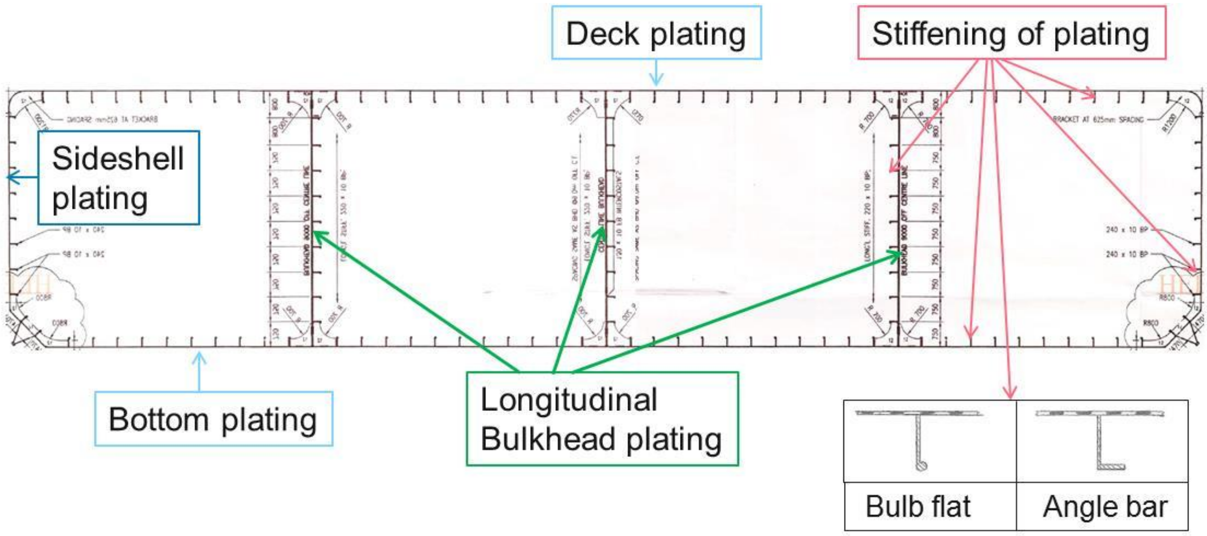


Figure 2.2 This random transverse cross section of a barge (not the H-541) shows the types of plating and stiffeners which can be found in a barge [22].

2.3 Structure web frame

A transverse web frame (figure 2.3) is one of the strong parts of a barge. Web frames are positioned over the entire barge and combined they function as the "skeleton" of the barge. A web frame is built up out of the following parts/beams: deck beams, side shell columns, brackets, bulkhead columns and bottom beams.

These beams are constructed by a web with a bottom flange welded on a plate field. The deck plate and the web with bottom flange together will form the deck beam. The bottom beams are similar to the deck beams, but the plating is orientated on the bottom of the beam. The side shell columns, bottom beams and the bulkhead columns are constructed in the same way as the deck beams.

The beams of a web frame are equipped with brackets and flat bars. The brackets are useful for load introduction into the web frame to avoid load concentrations. Often these brackets are equipped with flanges and/or flat bars. The flat bars (welded on the web of the beams, figure 2.3) are mainly used to avoid buckling in the web of beams. Flat bars are not exclusively placed at the deck beams but are also applied in the column and bottom beams.

As described in chapter 2.2 the barge is equipped with stiffeners. To be able to fit the webs over the stiffeners, cut-outs (figure 2.4) in the web have to be made. This cut-out is taken into account in strength calculations of the beams because the capacity has to be calculated with the highest stresses that occur.

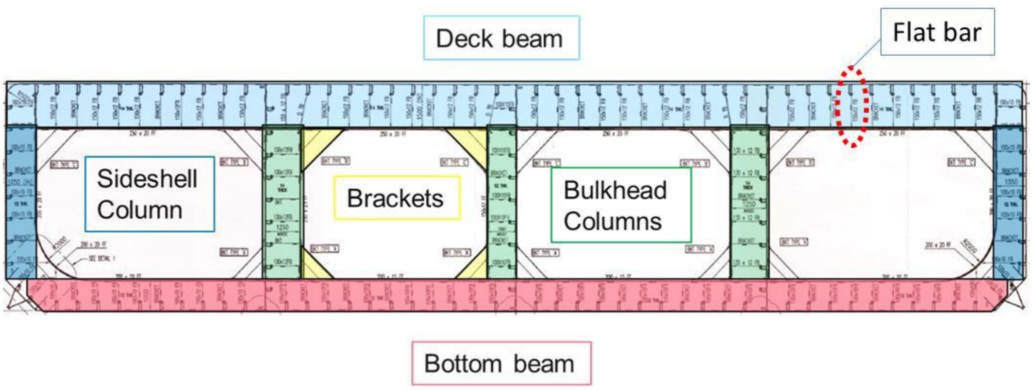


Figure 2.3 Transverse section of a web frame (not the H-541) shows where the column beams, deck and bottom beams and brackets. [22]

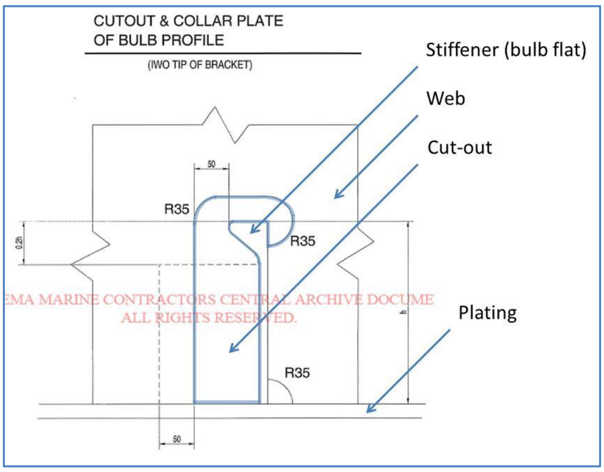


Figure 2.4 Cut-out web of beams in order to place beams over the stiffeners (applied on the H-541) [8]

2.4 Typical web frames H-541

The H-541 contains 66 frames as shown in figure 2.5 (and appendix III.A, figure III.A). Web frames in this barge have different properties due to the load positioning of the cargo on the barge. Because accelerations at the middle of the barge are lowest, cargo on this barge will generally be positioned in the middle of the barge. Web frames positioned in the middle of the H-541 (Figure 2.5, typical web frame 13 and 21) are relatively high strength web frames compared to other web frames in the barge.

Generally web frames in a barge will have similar dimensions and properties except in the stern and bow because the shape (i.e. height) of the vessel changes in this section. In the H-541 not all web frames are similar but there are certain groups of web frames with similar dimensions and properties. For example web frame 13 (figure 2.6) is a typical web frame which is positioned near the stern and bow. The following web frames have similar dimensions and properties as web frame 13: web frame 14- 19, 45-55.

Web frame 21 also is a typical mid-ship section web frame. The following web frames have the same/similar properties as web frame 21: web frame 22-31. This research will not concern a typical web frame 21 because the web height of the deck beam varies which makes it more complex to apply a secondary deck.

As show in figure 2.5 there is a repetitive distance between the web frames. The distance between web frame 16 to web frame 24 is 20.000 [mm]. This results in a frame distance of: $\frac{20000\ [mm]}{8} = 2500\ [mm]$. This property will be used later in this thesis to calculate the effective width of deck beams of a typical web frame 13. Web frame 13 will be used for calculations of strength, bending stress, shear and capacity. This research will "zoom in" on the properties of web frame 13.

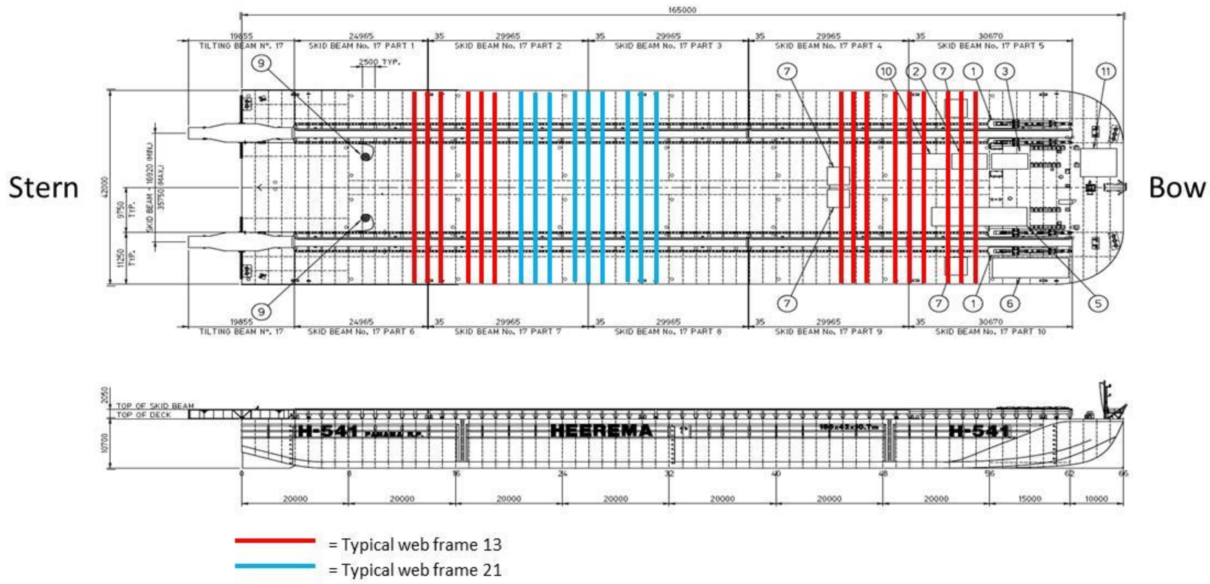


Figure 2.5 Typical web frame 13 and 21, the red lines indicate where the typical web frame 13 is positioned, the blue lines indicate where the typical web frame 21 is positioned [8].

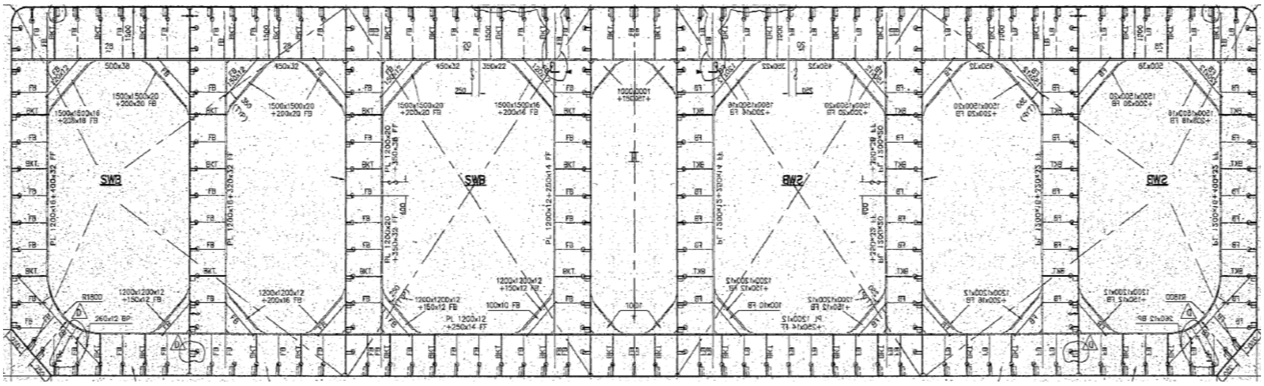


Figure 2.6 Typical web frame 13 of the H-541. In general drawings of web frames only show one half of the web frame because most web frames are symmetrical from the centerline. The left side of this figure has been mirrored to give an impression of the complete web frame.

2.4.1 Ballasting

Ballasting of a barge is regulated as result of the weight, dimensions and the position of the cargo on the barge. When the barge has no cargo on deck the barge is more or less leveled (not exactly but in comparison to when cargo is placed concentrically on the barge it is), but when for example cargo is placed near the stern of the barge, the barge will tilt to the back (figure 2.7). Because cargo is placed in the middle of the barge, relatively strong web frames are positioned at this location.

When a relevant amount of items on a barge are not positioned with considerable precision, the vessel will float under unfavorable angles of heel[1], and trim[2] (Appendix III.A).

The tow behavior of this situation is not favorable [19]. To obtain the desired draft and the desired trim (and thus favorable tow conditions), the ballast tanks near the bow of the barge will have to be filled in order to level the barge. The favorable tow behavior is according to [19]:

- Draft; ~40%-60% of depth for ocean tow, less for sheltered areas
- Trim; ~0,5-0,8% of barge length (in order to avoid excessive tow resistance)
- Heel; has to be <1% of the barge width in any case (as close as possible to 0%)

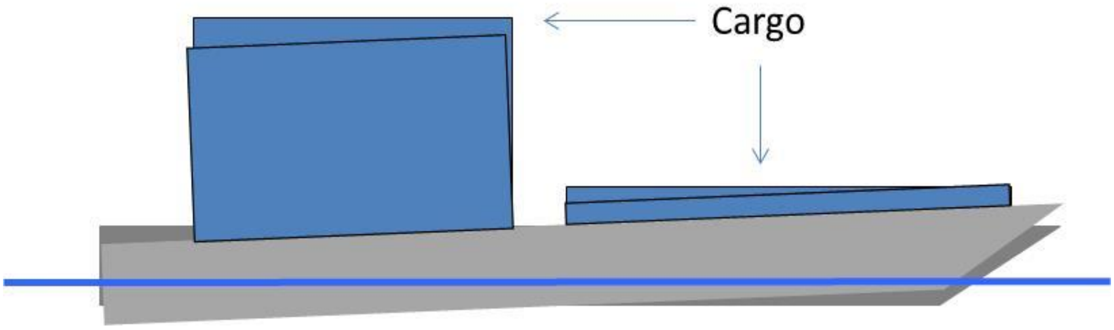


Figure 2.7 Cargo placed near the stern of the barge will make the barge tilt backwards [19]

[1] Endwise inclination
[2] Sideways inclination

2.5 Grillage and Seafastening

In preparation to transport, structures are welded on to grillage and seafastening. In general the grillage and sea fastening is positioned at the mid-section of the barge (figure 2.8). The reason to place grillage and seafastening and therefore the loads in the middle of the barge is that accelerations are here at a minimum. Therefore loads will be introduced at the mid ship section of the barge. This makes it interesting for this research to investigate if any improvements in capacity of mid-ship web frames can be accomplished.

The structures which are welded onto the grillage and seafastening have their own support points. However it is not likely for these support points to exactly align with the strong points of the barge, therefore some type of load spreading has to be achieved. Load spreading is also required if more strong points of the barge need to be mobilized to take up the load of one support point of the structure.

Load spreading is used in order to create a load distribution over the web frames and bulkheads. To achieve this load distribution grillage beams are used, which can have a various type of shapes depending on type, weight and load-out of the structures. [16]

Grillage and seafastening spreads the vertical loads into strong points of the barge. The grillage will take up all the vertical loads i.e. static and dynamic transport forces. The seafastening will take up all horizontal transport forces which originate from, i.e. roll and pitch (figure 2.9). The material used for grillage and seafastening is generally made from high strength steel [16]. This high strength steel S355 has a yield stress of 355 [N/mm^2], while the barge is made out of steel with a yield stress of 235 [N/mm^2]. High strength steel is generally used when controlling weight is a critical factor and the requirements are given for high resistance to stress.

Figure 2.8 Photo of grillage and seafastening on a barge. The grillage beams will spread loads into the strong points of the barge.

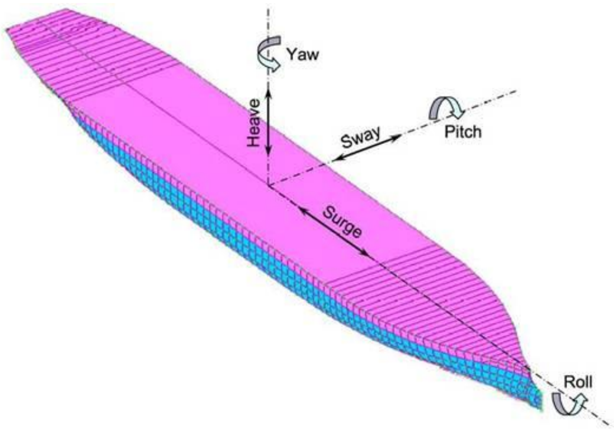


Figure 2.9 Types of rotation and translation which occur during transport. Pitch and roll will cause dynamic loads during transport which will be taken up by the grillage and seafastening.

2.6 Load type

A barge can/will be subjected to several types of loads. Therefore the capacity of several points in a barge will be calculated. Important points on the barge where for example bending or shear stress is at a maximum have to be checked in order to determine if these point meet the required capacities. In general, to determine barge capacity the following capacities can be calculated:

- Local capacity
- Web frame capacity
- Bulkhead shear capacity (1. In figure 2.10)
- Side shell capacity
- Global barge capacity

For bulkhead and side shell column capacity Heerema Marine Contractors uses several methods of calculation. The bulkhead and side shell column capacity can be calculated with the in-house spreadsheet IPEX (bulkhead column and side shell column capacity) but also with a computer model. The capacities of the top/bottom beams and columns can also be checked with calculation by hand. Calculation on the top beam (with the alternative secondary deck) made by hand can be found in appendix I and II. In these calculations the deck beams are considered as simply supported beams with a concentrated load at any point (point load). In this way it is possible to compare conventional deck beams with the alternative secondary deck beams. Calculating with this method the capacities of the deck beams will not be as high as when the deck beams are continuously supported with more than two supports. Assuming the beams are continuously supported will give more realistic values and will give a better view of what the capacities really are. However the values which are obtained using SACS are used to compare capacities too. The capacities in appendix II.D are useful to obtain a simple comparison in order to check which changes will occur in capacity by applying a secondary deck.

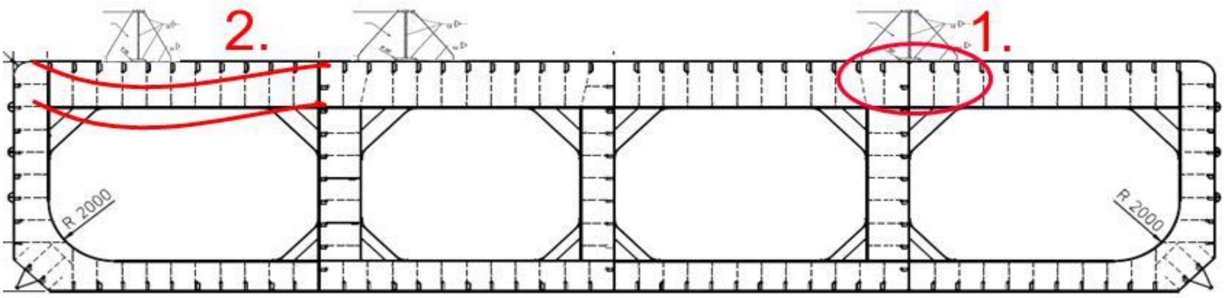


Figure 2.10 Transverse section of web frame. 1. Shows where the load is placed to check bulkhead column capacity, 2. local capacity. (Not the H-541) [22]

3. Beam strength

Beams are structural elements used for the support of vertical loads introduced perpendicular on the longitudinal direction. Internal bending moments and shear forces originate as a result of these loads. These moments and forces vary throughout the longitudinal direction of the beam. Some beams are also stressed with internal axial forces, however the effect of these forces are often not taken in to account when dimensioning a beam because the tension caused by axial stress is usually relatively small compared to shear and bending stress. A beam that has to endure both shear forces and bending stress will be designed on strength. This chapter will discuss beam properties in general, and beam properties of the deck beam that is used in barges Heerema designs, uses and owns.

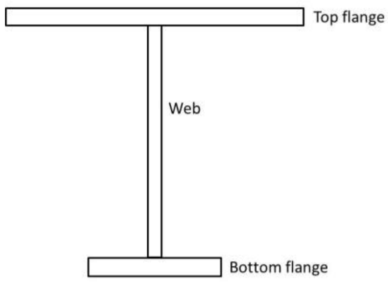


Figure 3.1 Components of a beam, categorized in: top flange, web and bottom flange.

3.1 Effective width

Transverse web frames consist of beams, columns and brackets. The beams and columns are actually stiffened panels/plate fields which endure lateral forces like water pressure. The top flange of the deck beams is part of a continuous plate field consisting the deck plate. To calculate the properties of these beams, there has to be taken an effective width into account. The effective width [20] will be calculated according to equation 3.1:

$$b_{eff} = 0,3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0,3 \cdot \sqrt[3]{L^2 \cdot b} \leq b \qquad (3.1)$$

With:

b_{eff} : Effective width [m]
b : Distance of c.t.c. (center to center) of the transverse web frames [m]
L : Distance between columns or beams [m] (brackets excluded)

L is the distance between 2 column beams or between the top and bottom beams. When L increases the effective width will increase. The effective width will decrease when L becomes smaller. The effective width will be taken into account with the calculations of the cross section area of web frame beams. The cross section area will increase at a larger effective width and will decrease at a lower effective width. The effective width is interrelated with the distance between the webs. As equation 3.1 shows, the effective width will increase if b increases, and the effective width will decrease when b decreases.

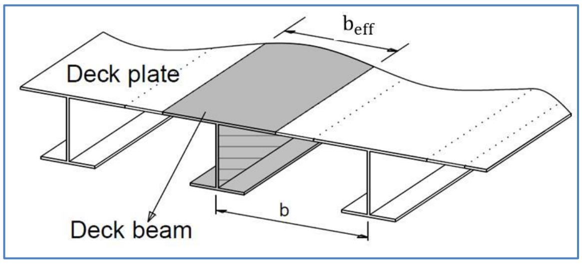


Figure 3.2 Effective width of deck plating [20]

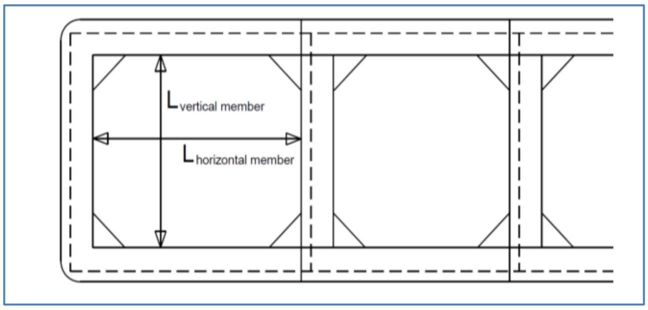


Figure 3.3 Length between columns or beams [20]

3.2 Area moment of inertia

Area moment of inertia is a geometric property of the cross section of shapes. This geometric property projects how locations on the shape are distributed to a common axis. The area moment of inertia is exclusively dependent on its shape and dimensions, and not by the material it is made of.

The manner of calculation of the area moment of inertia is dependent on shape as mentioned earlier. Complex shapes have a different manner of calculating the area moment of inertia. The cross section of complex shapes often exists out of several basic shapes like rectangulars, triangles and half circles. Assuming the area moment of inertia of each of these shapes is known pertaining to a common axis, the compiled area moment of inertia can be determined by summing up the individual moments of inertia (equation 3.2 [17] for rectangular shapes). To correctly determine the area moment of inertia of such a shape the area has to be divided into separate areas with a certain distance to the neutral axis.

$$I_y = \sum \left(e_{z,i}^2 \cdot b \cdot h + \frac{b \cdot h^3}{12} \right) \qquad (3.2)$$

(Source: [17])

With:
$e_{z,i} = (Z - e_z) - e_z'$

Where [17]:

I_y	: Area moment of inertia		[mm^4]
b:	: Width of cross section		[mm]
$e_{z,i}$	: Distance between C.o.G.[3] of the plate girder and the C.o.G. of the subject section [17]		[mm]
h:	: Heigth cross section		[mm]
Z:	: Total height		[mm]
e_z'	: Distance top outer fiber to the C.o.G.of the subject section		[mm]

Equation 3.2 from the IPEX manual can also be written in the commonly known version (Steiner equation 3.3 [15]):

$$\sum I = \sum \frac{1}{12} \cdot b \cdot h^3 + \sum A \cdot z^2 \qquad (3.3)$$

With:
$I = \frac{1}{12} bh^3$: Area moment of inertia for a prismatic shape [mm^4].

And:
$\sum A \cdot z^2$: Area moment of inertia of a compiled profile with distance (z) to a common axis.

The Steiner equation, multiplies the areas of a compiled cross section with the corresponding distances to the neutral axis, and sums up these values. Summing up these values will result in the total amount of area moment of inertia.

[3] *Center of gravity*

3.3 Statical moment ⟶ Shear

Statical moment (Q [mm^3]) or first moment of area is a measure of how the area of a shape is spread in relation to a common axis.

For a rectangular shaped cross section (figure 3.4), equation 3.4 is used [15]:

$$Q = \bar{y}'A' = \left[y + \frac{1}{2}\left(\frac{h}{2} - y\right)\right]\left(\frac{h}{2} - y\right)b = \frac{1}{2}\left(\frac{h^2}{4} - y^2\right)b \qquad (3.4)$$

With:

Q	:	Statical moment	[mm^3]
$\bar{y}'$	:	Distance from the center of gravity of A' to the neutral axis	[mm]
y	:	Distance neutral axis to relevant location	[mm]
A'	:	Upper (or lower) part of the cross section	[mm^2]
h	:	Height	[mm]
b	:	Width	[mm]
NA	:	Neutral axis	

Plate girders are usually I-beams built up from separate rectangular shaped cross sections, with a vertical web and horizontal flanges. The top and bottom deck beams are plate girders (beam built up out of multiple rectangular shaped cross-sections). The statical moment of these plate girders are calculated by summing up the statical moments of the separate sections (equation 3.5):

$$Q = \sum Q_{sections} \qquad (3.5)$$

The statical moment of a cross sectional area is a property which is needed to calculate the amount of shear stress in relevant locations (Chapter 3.4).

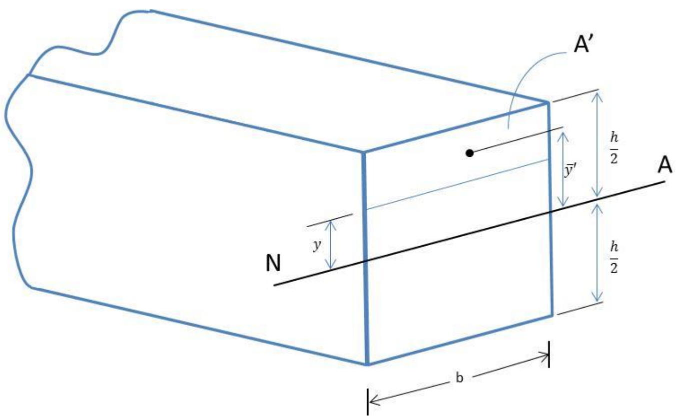


Figure 3.4 Data which is needed to obtain the statical moment of a rectangular shaped cross-section [15]

3.4 Shear stress

When shear stress in beams is calculated, multiple locations of the beam are taken into account due to different amount in shear stress in the different locations. Normally the graph of shear stress as a function of position in a I-beam shows a parabolic shaped graph with next to zero shear stress in the top and bottom (the flanges) of the beams and a maximum of shear in the middle of the web of a beam (figure 3.5). The maximum shear stress is mainly dependent on the height of the web. In appendix II.E, calculations have been made to demonstrate what the effects are on shear stress when the web height increases.

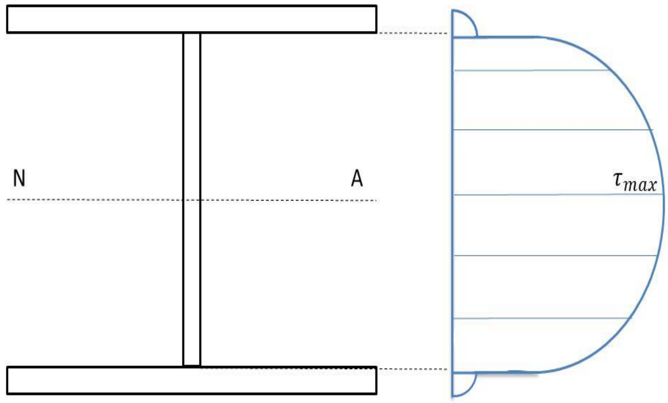


Figure 3.5 Maximum shear is found at the neutral axis [15]

$$\tau = \frac{V \cdot Q}{t \cdot I_y} \leq 0{,}4 \cdot \sigma_y \qquad (3.6)$$

With:

τ:	Shear stress	[N/mm^2]
V:	Shear force	[kN]
Q:	Statical moment	[mm^3]
t:	Thickness web	[mm]
I_y:	Area moment of inertia	[mm^4]

The statical moment will vary over the height of the beam. Calculating the statical moment, the distance from the neutral axis to the area of the needed statical moment is required. The smaller the distance to the neutral axis, the larger the statical moment and therefore, the larger the shear stress will become.

3.5 Section Modulus ⟶ Bending

When dimensions of a beam are compiled, the bending stress and shear stress should not be of a higher value than the allowable bending stress[4] and shear stress[5] for the specific material (chapter 3.6). The section modulus (also known as resistance moment against bending) is the ratio between the area moment of inertia and the distance from the beams outer fiber to the neutral axis (figure 3.6). As there is one section below the neutral axis (equation 3.7) and one section above the neutral axis (equation 3.8), the section modulus will be calculated separately:

$$W_{y,bottom} = \frac{I_y}{e_z} \qquad (3.7)$$

$$W_{y,top} = \frac{I_y}{Z - e_z} \qquad (3.8)$$

With:

W_y:	Section modulus	[mm^3]
I_y:	Area moment of inertia on Y-axis	[mm^4]
Z:	Height	[mm]
e_z:	Distance (outer fiber) bottom flange to neutral axis	[mm]
$Z-e_z$:	Distance (outer fiber) top flange to neutral axis	[mm]

When the cross sectional area increases, the section modulus will increase as well. This causes the bending stress to decrease (equation 3.9). According to [16] allowable bending (Chapter 3.6) stress is 0,66 times the yield stress of the used material.

$$\sigma_b = \frac{M \cdot y}{I_y} = \frac{M}{W} \leq 0{,}66 \cdot \sigma_y \qquad (3.9)$$

With:

σ_b:	Bending stress	[N/mm^2]
M:	Moment	[Nmm]
W:	Section modulus	[mm^3]
I_y:	Area moment of inertia on Y-axis	[mm^4]
y:	Distance outer fiber to neutral axis	[mm]

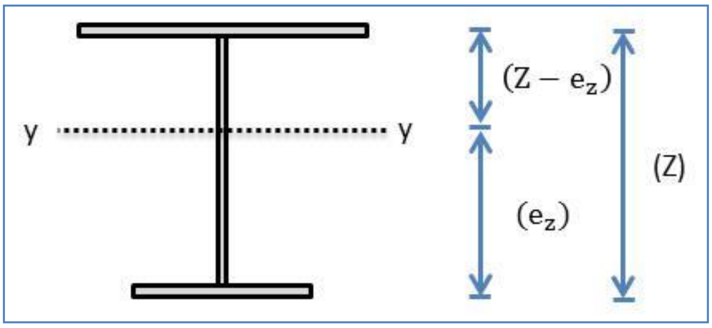


Figure 3.6 Distances to neutral axis

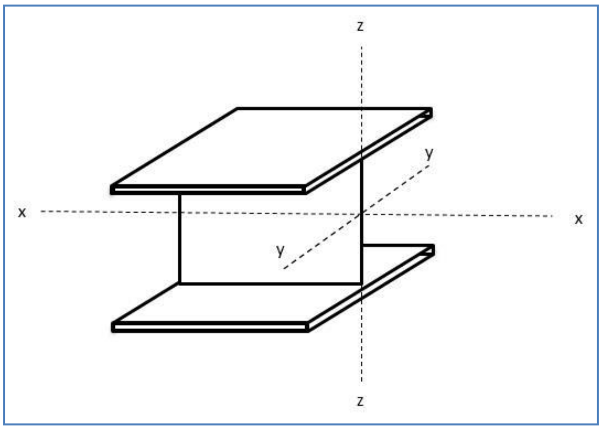


Figure 3.7 Positioning of beam relative to the coordinate system

[4] $\sigma_V = 0{,}40 \cdot \sigma_{yield}$
[5] $\sigma_B = 0{,}66 \cdot \sigma_{yield}$

3.6 Allowable stresses HMC

At Heerema Marine Contractors safety factors are implemented when parts or complete structures are engineered. Not only Heerema Marine Contractors applies these safety factor, but almost every offshore structure has to be engineered using formula's based on the AISC/API.

Within Heerema Marine Contractors the following allowable stresses (based on AISC/API) are used [16]:

Stress type :	Allowable Stress
Shear	$\sigma_v = 0{,}40 \cdot \sigma_y$
Bending	$\sigma_b = 0{,}66 \cdot \sigma_y$
Combined	$\sigma_c = 0{,}66 \cdot \sigma_y$
Tension	$\sigma_t = 0{,}60 \cdot \sigma_y$
Compression	$\sigma_a = 0{,}60 \cdot \sigma_y$
Bearing	$\sigma_p = 0{,}90 \cdot \sigma_y$

Table 3.1 Allowable stresses HMC

Combined stress is the resultant stress of bending stress and shear stress combined (equation 3.10). The hand calculations which are displayed later in this thesis will calculate the combined stress. Only shear stress and bending stress are taken into account in these situations because these are the critical stresses which occur during the applied load cases. Combined stress will be calculated according to the Huber Hencky equation [16]:

$$\sigma_c = \sqrt{\sigma_b^2 + 3\tau^2} \leq 0{,}66 \cdot \sigma_y \qquad (3.10)$$

With:

σ_b: Bending stress $\left[\frac{N}{mm^2}\right]$

τ: Shear stress $\left[\frac{N}{mm^2}\right]$

σ_c: Combined stress $\left[\frac{N}{mm^2}\right]$

In order to check if a structure meets the strength requirements, unity checks are applied. Unity checks are an expression of structural integrity of all structural parts which are designed and calculated. Unity checks should always have the value of 1 or lower in order to meet with the allowable stresses and to maintain structural integrity. The maximum stress will be divided by the allowable stress, from which a unity check results. Table 3.1 shows the allowable stress (used within Heerema) for several types of stresses. In order to check if the combined stress (equation 3.10) meets with the unity check of 1,0 or lower, equation 3.11 is used.

$$U.C. = \frac{\sigma_c}{0{,}66 \cdot \sigma_y} \leq 1{,}0 \qquad (3.11)$$

To determine the capacity of e.g. a beam, the applied load will be divided by the value of the unity check (equation 3.12).

$$Capacity = \frac{Applied\ load}{U.C.} \qquad (3.12)$$

4. Alternative web frame

(1.) Removing columns

The possibility of removing 2 columns in a web frame and adding this material to the deck beams will be explored in this chapter. The goal of removing 2 columns in the alternative web frame is to maintain the same weight as the conventional web frame and improve capacities.

Removing these columns results in changes of the global and web frame capacities . First of all, bending moments will increase because the span of the deck beams has increased. The span increase results in larger beam deflections in the deck beam, because of higher occurring bending moments.

To avoid the length of a deck beam will become too long (creating 1 relatively long beam and 1 relatively short beam), the column that is placed at 9750 [mm] off the centerline will be moved to 11250 [mm] off the centerline (figure 4.1).

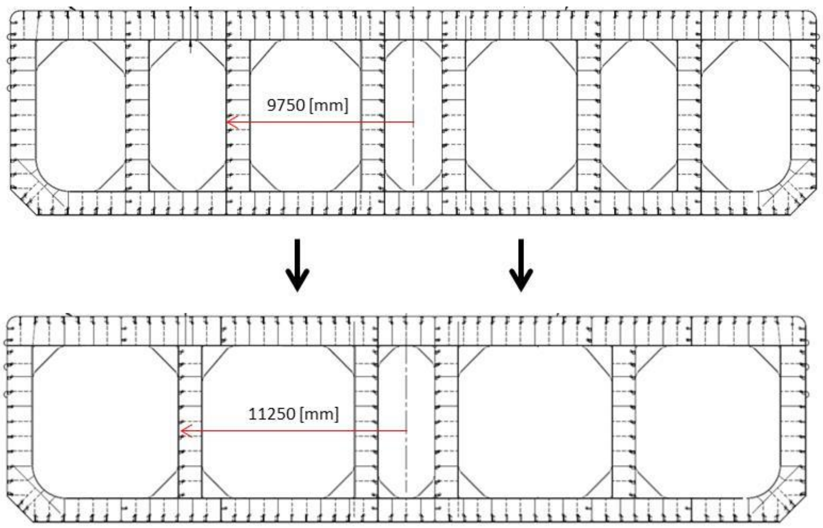


Figure 4.1 The conventional web frame (on top) and the alternative web frame (bottom) with 1 column removed, and 1 column moved from 9750 [mm] off center line to 11250 [mm] off center line.

(2.) Adding deck

The original objective of this internship is to examine the possibility to maintain the weight of a typical web frame 13, while improving the global and web frame capacity of the alternative web frame. The main difference is made in the flange section of the deck beam. Generally a deck beam is build out of the following parts: The deck plate (with an effective width taken into account), a web and a flange. The "alternative" structure will have a secondary deck plate instead of a flange (Figure 4.2).

In this thesis, hand calculations of the conventional deck beams (seen as I-profiles) with an un-equal flange width are applied. In the alternative web frame, the secondary deck plate has replaced the flanges; the beams can be seen as I-profiles with equal flanges. Adding the secondary deck causes a significant increase in weight. However properties such as stiffness will increase . Stiffness of the deck beam will increase because the secondary deck also results in a larger moment of inertia (assuming height of the secondary deck is equal to the flanges). A larger area moment of inertia will result in less shear and bending stress (assuming other properties of the beam stay the same). (equation 3.6 and 3.9))

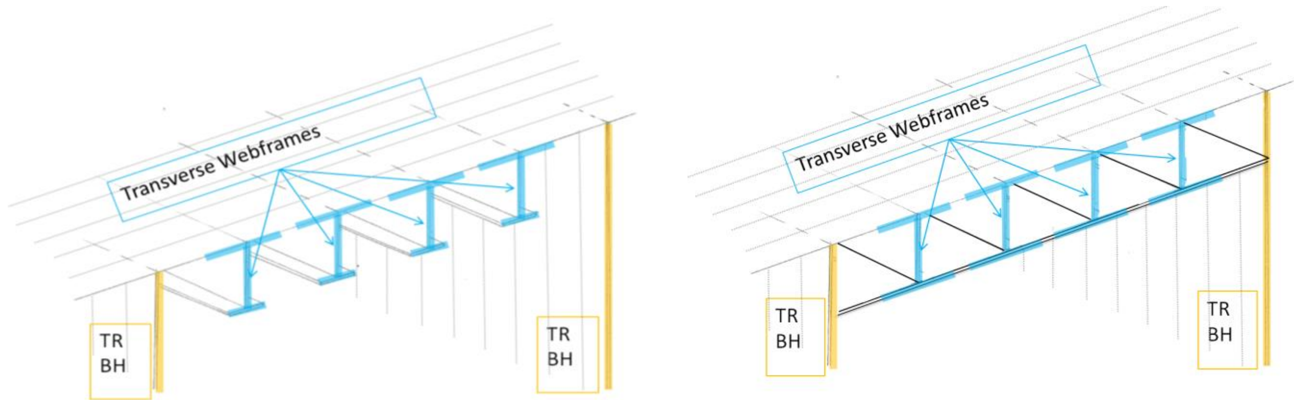


Figure 4.2 Left side of the figure shows the conventional web frame, the right side of the figure shows the web frames with the secondary deck.

(3.) Height beam

The alternative web frame 13 will have an increased web height (Figure 4.3). The reason to increase the web height of the deck beams is to gain extra shear capacity. Any increase in web height will cause a decrease in shear stress because shear forces will now be spread over a larger area, however any increase in these dimensions will also contribute to an increase in weight of the deck beams.

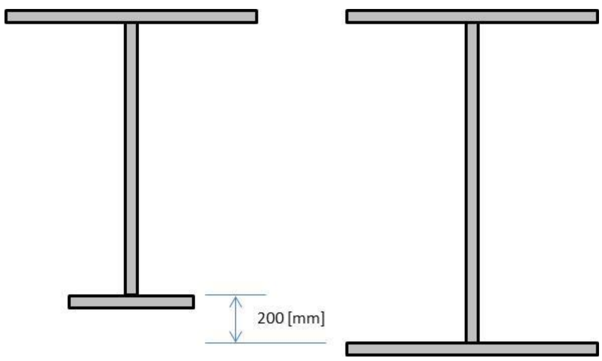


Figure 4.3 The web height will be increased in order to reduce occurring shear stress.

(4.) Material Take-off sheet

At Heerema Marine Contractors there are multiple in-house spreadsheets available for a variety of uses. One of these spreadsheets is the MTO sheet (appendix IV). The MTO sheet can be used to determine how much weight has to be removed or has to be added to a vessel. This spreadsheet calculates the weight of items of the conventional web frame and the total weight of the items combined. In this case the spreadsheet will be used to check how much weight can be reduced when a column and a part of the longitudinal bulkhead is removed.

MTO web frame 13

This MTO is applied on a typical web frame 13 and is used to examine how much weight is lost by removing 1 column. Flanges, stiffeners and all other parts which are attached to the columns or bulkhead plates that will be removed are taken into account.

This way it is possible to see how much weight can be put back into the deck beam. If the reduced weight per web frame that can be put back in the deck beam is determined, calculations can be made to examine how thick the secondary deck can be.

Most drawings of the cross section of a web frame only show the left side of the web frame. The reason to only show the left side on the drawings, is that the barge is symmetrical from the center line. In every MTO only the left side of the barge is taken into account. In the MTO all parts from web frame 12 to 16 (appendix IV.F) are integrated in the MTO.

Removed *material*

All MTO-sheets will form 1 summary sheet (appendix IV.F) where is shown how much the material take off sheet takes off in total. This summary sheet adds up the weight of all the following separate sheets (appendix IV): the longitudinal bulkhead and stiffeners, the stringers, the column, the vertical brackets and the flanges of the deck beams. The total netto weight that has been removed in the material take off sheet amounts: 33,975 [mT] (appendix IV.F). This netto weight can be maintained in the MTO sheet which will be used to determine how much material can be put back.

Added material

The material take off sheet can also be used to calculate the amount of material that can be added (appendix IV.G). The known amount of weight that has been taken off the web frames in the previous MTO (Appendix IV.F) can now be compared with the amount of weight that will be added to the web frames (appendix IV.G). The netto weight which has been removed in appendix IV.F amounts 33,975 [mT], so to maintain the same weight per web frame in the alternative web frame the material take off sheet will have to amount to the same netto weight.

For the secondary deck plate longitudinal stiffeners will be required. This has to be taken into account when the thickness of the secondary deck is determined. Longitudinal stiffeners are available in multiple dimensions and their associated weights. The dimension of the plate field determines what types of stiffeners are required.

In the alternative web frame 25 flat bulbs (size: FB200x12) will be added which adds up to 5.809 [mT]. The double deck is 21 [m] in length, 10 [m] wide and 16 [mm] thick. This will result in an addition in weight of 26.376 [mT]. The increase of web height (with 200 [mm]) of the 28 [mm] thick web, will result in an addition of 1.484 [mT]. The addition of the total amount of weight which has been added is 33.669 [mT]. This results in a negligible reduction in weight of the alternative web frame compared to the conventional web frame. In other words, the weight of the alternative web frame will be the same as the conventional web frame.

5. Capacity web frame hand calculations

In this chapter, the results of the capacity calculations are shown. The deck beams have been subject to individual point loads at multiple locations on the beam. Obtaining capacities using this simplified situation does not give realistic values of the actual capacities of the deck beams. A reason lower capacities will be achieved using this method of calculation is that the brackets are not taken into account, which means that higher bending moments occur at the point where a load is placed. However comparing these capacities does give an indication whether the capacities of the deck beams will increase by applying a secondary deck.

5.1 Flange vs. Secondary deck

The "alternative" concept of the barge (web frames), have one main difference with the conventional design. This difference is found in the bottom flange in every web frame. The conventional barge has web frames with relatively small bottom flanges on the deck beams. In the alternative concept, the bottom flanges will be removed and replaced by a plate field (with an effective width taken into account). This plate field is continuous over the length of the barge.

Capacities are calculated by applying a unity check (equation 5.1) on the maximum combined stresses the beam has to endure. Only combined stress is checked because stresses that occur consider bending stress and shear stress. All load cases in these simple supported beam calculations are vertical loads of 1000 [kN].

$$U.C. = \frac{\sigma_{comb}(highest\ value)}{0{,}66 \cdot 235} \qquad (5.1)$$

(Heerema Marine Contractors, Offshore Technology, Introduction Course for the Structural Engineer chapter 1.3 E "remarks and explanation on AISC/API based allowable stresses" [23]).

5.2 Effective width

The effective width of the I-beam will be used in strength calculations because this is the part of the deck plating (appendix III, figure III.J) that actually is subjected to the loads that will be introduced in the barge.

(For a conventional typical web frame 13 of the H-541)
L_1 = 4752 [mm]
L_2 = 4004 [mm]
L_3 = 5770 [mm]
L_4 = 3000 [mm]
b = 2500 [mm]

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \sqrt[3]{L^2 \cdot b} \leq b \qquad (5.2)\ [20]$$

$b_{eff\ 1}$ = 1151 [mm]
$b_{eff\ 2}$ = 1027 [mm]
$b_{eff\ 3}$ = 1310 [mm]
$b_{eff\ 4}$ = 847 [mm]

The effective width of the conventional deck beams have been calculated for 4 beams of the web frame. The same calculations are made for the alternative web frame, however for 3 beams as a result of removing a column beam and longitudinal bulkhead.

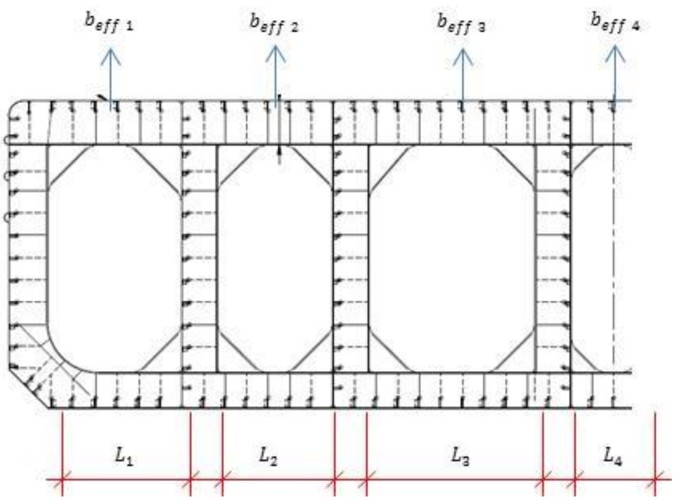


Figure 5.2 Effective width conventional web frame

Because L in the alternative web frames is larger (except the beam that intersects the center line) than in the conventional web frame, the effective width of the alternative web frame beams will increase. Therefore the effective width for the alternative web frame has to be calculated.

Effective width alternative web frame
L_1= 8502 [mm]
L_2= 7272 [mm]
L_3= 3000 [mm]
b = 2500 [mm]

$b_{eff\ 1}$= 1696 [mm]
$b_{eff\ 2}$= 1528 [mm]
$b_{eff\ 3}$= 847 [mm]

The effective widths of the beams of the alternative web frame appear to be larger than the effective widths of the conventional web frame beams. The effective ($b_{eff\ 4}$ of the conventional web frame and $b_{eff\ 3}$ of the alternative web frame are the same because L and b do not change).

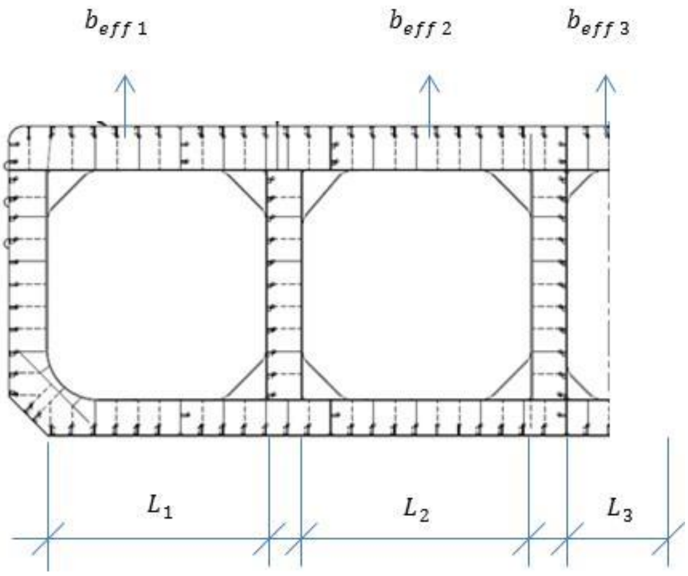


Figure 5.3 Effective width alternative web frame

5.3 Capacity simple beam

The properties of the conventional deck beam and the secondary deck beam show several differences through which conclusions can be made. For example: the area moment of inertia of the alternative deck beams is relatively large compared to the conventional deck beams. A higher area moment of inertia implies less bending stress and less shear, therefore a lower combined stress (if the span of the beams would maintain the same length).

1.) Properties

According to IPEX sheets: (Appendix II.D) the minimum and maximum section modulus increases when a secondary deck is used. A higher section modulus means that the stiffness of the beams has been increased because stresses, according to equation 5.3 and 5.4 will become lower when the area moment of inertia increases. To calculate the amount of which bending stress occurs in the beam (equation 5.4), the bending moment (at certain position in the beam, depending on where a load case is placed) will be divided by the section modulus to obtain the bending stress. So if this section modulus increases the occurring stress will decrease.

	Conventional deck			Alternative deck	
Beam	**α1.0**	**α 2.0**	**α 3.0**	**β 1.0**	**β 2.0**
$I_y \cdot 10 \cdot 10^{10}$ [mm^4]	3,66	3,13	3,19	5,60	5,09
$W_{y\,min} \cdot 10^7$ [mm^3]	4,18	3,53	3,22	5,43	4,97

Table 5.1 Properties of the deck beams of the conventional and the alternative web frame. Beams are shown in figure 5.4 and 5.5.

2.) Capacity

When properties of the beams are acquired, capacities of beams can be calculated. In appendix II.A the input values of the conventional deck beam are shown. This input is used to make several handmade calculations to determine capacity in several points of the deck beams. When the method of calculation appeared to be correct, the calculation is imported in MS Excel, which saves time on making the same calculations for all beams. Figure 5.4 and 5.5 show the capacities of the conventional and the alternative deck beams. This figure shows that capacities from the alternative deck beams at x= L/4 and x=L/8 have been increased compared to the capacities of the conventional deck beam. However the capacity at x=L/2 where the bending moments are the largest appear to have decreased. The reason for this decrease in capacity is the relatively larger length of the beams. The length of the beams have increased more because 1 column at 15000 [mm] off center line has been removed, and the column at 9750 [mm] off center line has been moved to 11250 [mm] of the center line.

The results of the calculations show that the capacities of the alternative beams have decreased when the beams are loaded mid beam. The reason mid beam capacities have been decreased is the increase in bending moments. In order to compensate this effect, the flanges of the beams have to be re-dimensioned (because bending stress is transferred into the flanges). Re-dimensioning the flanges to compensate this effect will not be part of this research.

The capacities have increased at the locations near the supports (figure 5.4 and 5.5). Shear stress is the critical factor at this location, and because properties of the alternative beam considering shear stress have improved, the capacities at these locations have increased.

The figures in appendix II.D show the positions where on the beams loads are placed on according to the strength calculations which are made. As figure 5.4 and 5.5 shows, the capacities of beam β1.0 are not the same as β2.0. The reason capacities are lower in beam β2.0, is that the span of beam β1.0 is larger than beam β2.0 and the effective width of beam β2.0 is smaller than the effective width of beam β1.0. Capacities have been increased for several locations, however on other locations capacities have been decreased.

3.) Effects:

$$\sigma_{bending} = \frac{M}{W} = \frac{M \cdot y}{I} \qquad \begin{matrix} y \downarrow \\ I \uparrow \end{matrix} \quad W \uparrow \qquad \text{(y decreases, I increases)} \qquad (5.3)$$

$$\tau = \frac{Q \cdot V}{t \cdot I} \qquad \begin{matrix} V \uparrow \\ I \uparrow \end{matrix} \qquad \text{(V increases, I increases)} \qquad (5.4)$$

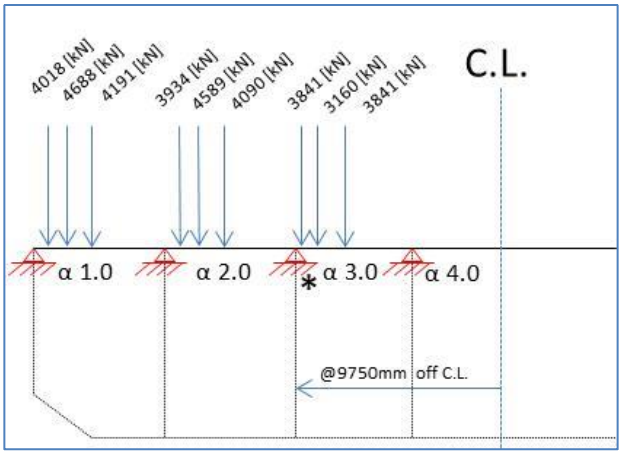


Figure 5.4 capacities conventional web frame

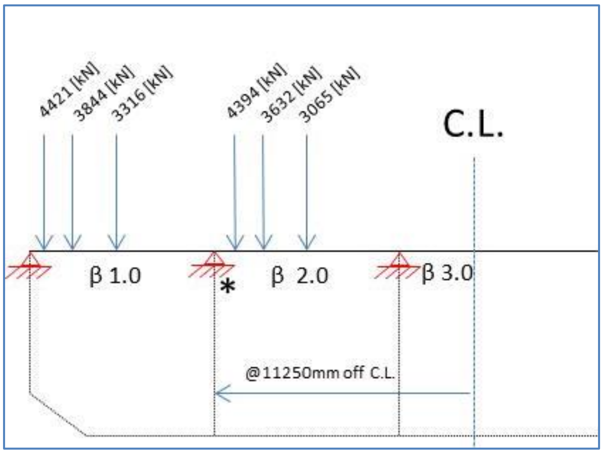


Figure 5.5 capacities alternative web frame

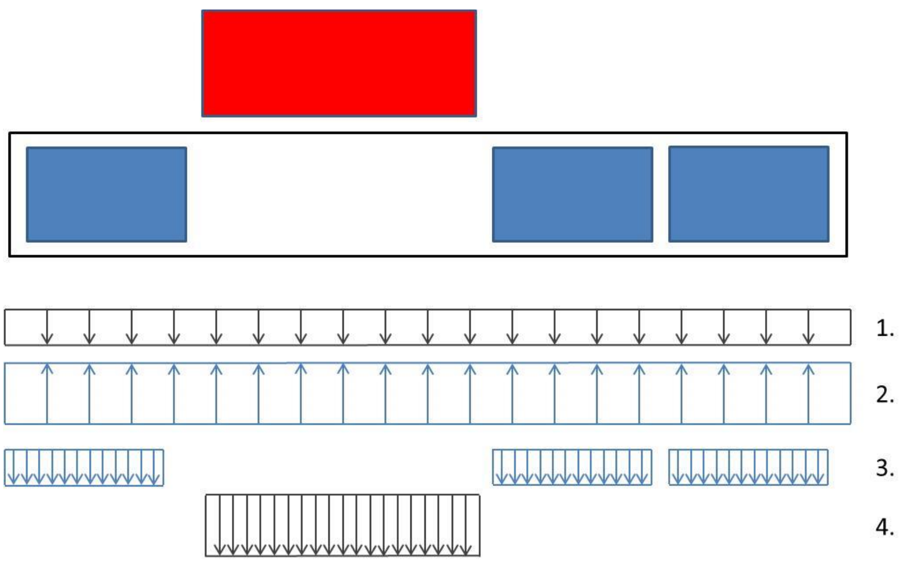
5.4 Global barge strength

A barge can be seen as a beam where several loads are objected to (figure 5.6). The section of the beam is a box girder (a tubular shape with multiple walls, in this case the longitudinal bulkheads, the bottom and deck plating). The parts of the box girder that contribute in global strength are [22]:

- Deck/ and bottom plating
- Side shell plating
- Longitudinal bulkhead plating
- All stiffeners

This beam has to endure the weight of the cargo it has to transport, the load of the ballast water in the tanks, self-weight and buoyancy. In order for the barge to float the buoyancy force has to be equal to the forces that work in the negative z-direction. As shown in figure 5.6 there is no ballast water in the tanks under the cargo. The reason not to fill the ballast tanks under the cargo is to avoid load concentrations.

The alternative barge concept has a secondary deck, which is equipped with longitudinal stiffeners. Longitudinal stiffeners on the deck and the secondary deck contribute to the global strength of the barge. On the other hand, removing columns will reduce the shear area of the box girder.



1. Barge self weight
2. Buoyancy
3. Ballast water
4. Cargo weight

Figure 5.6 Horizontal loads which interact on the barge [22].

Determining global barge strength of the alternative barge will be done by using a spread sheet (appendix VI). This spreadsheet calculates the allowable bending moment and the allowable shear force. In order to calculate these values the total moment of inertia, the section modulus of the deck and bottom section, and the shear area are required. The area moments of inertia of the deck and bottom plating and the side shell and bulkhead plating are calculated with the standard equation for rectangular shapes:

$$I = \frac{1}{12} b h^3 \qquad [15]$$

The area moments of inertia for the stiffeners are given values from a Heerema Marine Contractors handbook [23] in which the dimensions and properties of cross sections of the stiffeners are given.

General properties

$\sigma_{y\ barge}$:	235	[N/mm^2]
$\sigma_{bending\ allowable}$:	$0,66 \cdot \sigma_{y\ barge}$	[N/mm^2]
$\tau_{allowable}$:	$0,4 \cdot \sigma_{y\ barge}$	[N/mm^2]
h_{barge}:	10700	[mm]

		Conventional web frame	***Alternative web frame***	***Relative to conventional web frame %***
I_x total	[10^4 mm^4]	$9,43 \cdot 10^9$	$9,77 \cdot 10^9$	+3.6
$W_{x\ deck}$	[10^3 mm^3]	$4,81 \cdot 10^{14}$	$4,47 \cdot 10^{14}$	-7.1
$W_{x\ bottom}$	[10^3 mm^3]	$1,68 \cdot 10^3$	$1,59 \cdot 10^3$	-5.4
A_{shear}	[mm^2]	$1,49 \cdot 10^6$	$1,09 \cdot 10^6$	-26.8
$M_{bx\ allowable}$	[kNm]	$2,61 \cdot 10^6$	$2,47 \cdot 10^6$	-5.4
$F_{shear\ allowable}$	[kN]	$1,40 \cdot 10^5$	$1,02 \cdot 10^5$	-27.1

Table 5.3 Properties of the beam section of the alternative web frame 13. From table VI.A and VI.B in appendix VI

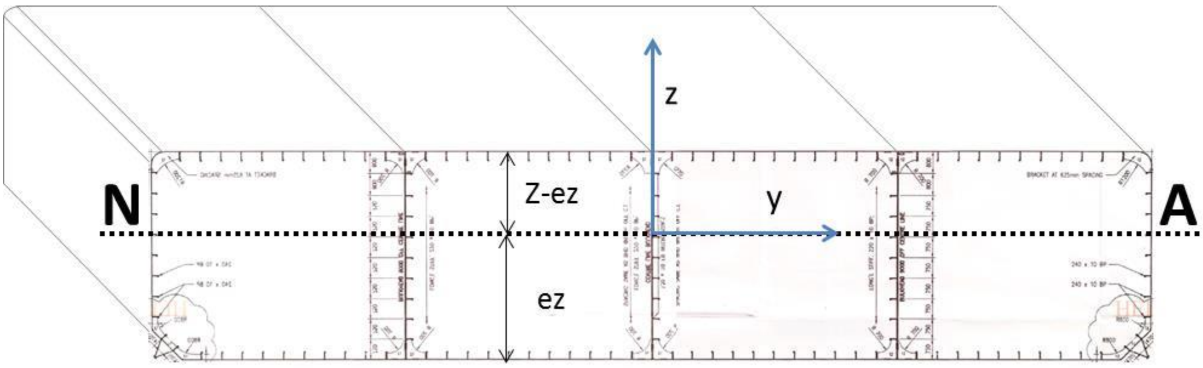


Figure 5.7 During global strength calculation the barge will be seen as a single beam (box girder section), with its own neutral axis, distances to the neutral axis and properties. (Not the H-541) [22].

Results of the calculations show that the allowable bending moment of the alternative web frame is lower than the allowable bending moment of the conventional web frame. The reason the allowable bending moment decreases is that the neutral axis has shifted more than the area moment of inertia. The allowable bending moment has become lower in order to meet with allowable bending stress.

The allowable shear force of the alternative web frame is also lower compared to the allowable shear force of the conventional web frame. The reason the allowable shear force decreases is the decrease in shear area. By removing 2 columns in the web frame the amount of shear stress will be spread over less area as in the conventional web frame. Figure 5.8 visualizes the decrease in shear area in the alternative web frame compared to the conventional web frame.

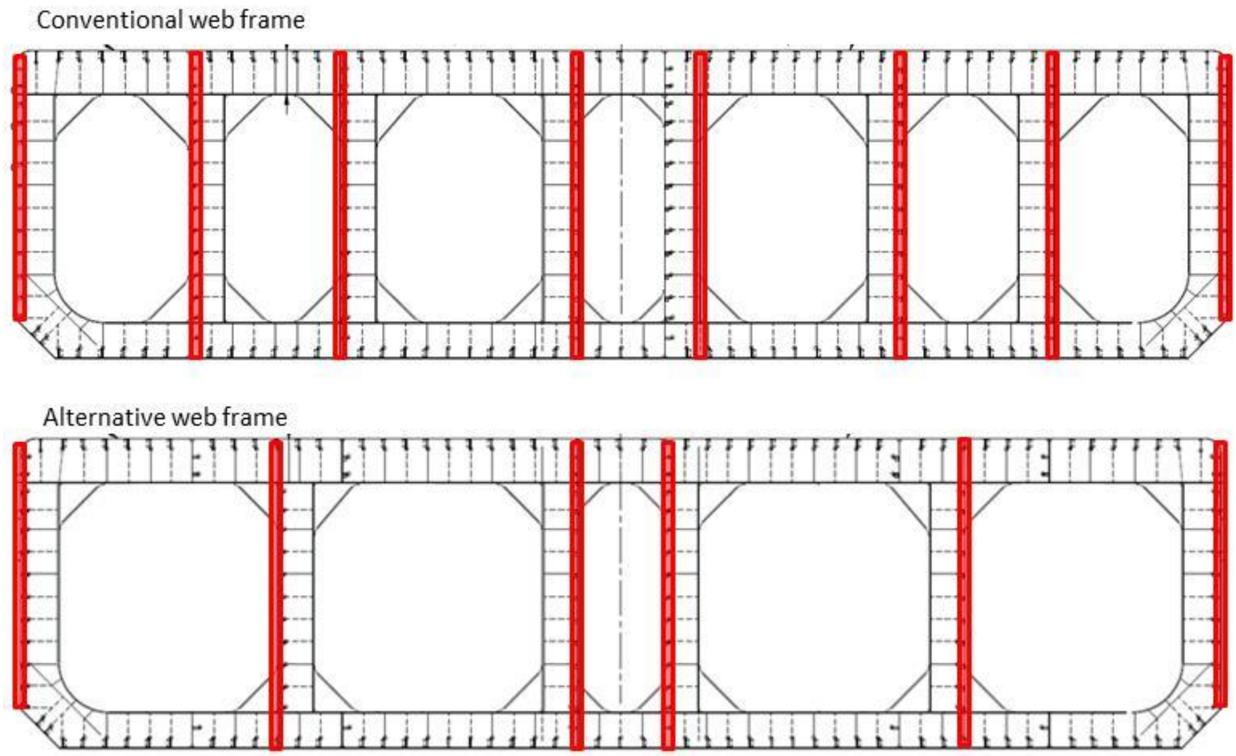


Figure 5.8 The conventional web frame [8] has a larger shear area than the alternative web frame. Therefore the allowable shear force of the alternative web frame is lower than the conventional web frame.(Shear area is marked red)

5.5 Side shell and bulkhead column capacity

In tables 5.4 and 5.5 values of side shell and column capacities are shown. These values are calculated by a HMC in-house spreadsheet. The following sheets have been used to obtain these values: side shell column capacity sheet, and the bulkhead column capacity. All the other columns stay at their same positions and will maintain the same dimensions. This causes the span of the beam from side shell to bulkhead column to increase significantly, and therefore lose capacity in this deck beam.

In table 5.4 the web frame which will be compared with the conventional web frame is shown. In this web frame the column, positioned at 15000 [mm] of the center line has been removed, and the column positioned at 9750 [mm]of the center line has been moved to 11250 [mm] of the center line.

Table 5.5 shows that applying the secondary deck will give different capacities than a conventional deck. For example the side shell column capacity has increased with 40 [kN]. The column which has been moved to 11250 [mm] of the center line has increased capacity from 9003 [kN] to 9221 [kN] which means the capacity has been increased with 218 [kN]. At last, the column at 1500 [mm] of the center line has increased in capacity with 138 [kN]. However these changes in column capacity are relatively small. The reason the column capacity has improved a relatively small amount is that the properties of the columns have not been changed. The properties of the deck beams however have experienced an increase in stiffness and therefore take up more moment. Therefore the column capacity have increased (a relatively small amount).

Conventional deck:

Load case	IPEX load
Side shell	8484 [kN]
BHD column 1 @15000 [mm] of C.L.	8170 [kN]
BHD column 2 @9750 [mm] of C.L.	9003 [kN]
BHD column 3 @1500 [mm] of C.L.	6169 [kN]

Table 5.4 Column capacity conventional web frame

Alternative deck:

Load case	IPEX load
Side shell	8524[kN]
BHD column 1 @11250 [mm] of C.L.	9221 [kN]
BHD column 2 @1500 [mm] of C.L.	6307 [kN]

Table 5.5 Column capacity alternative web frame

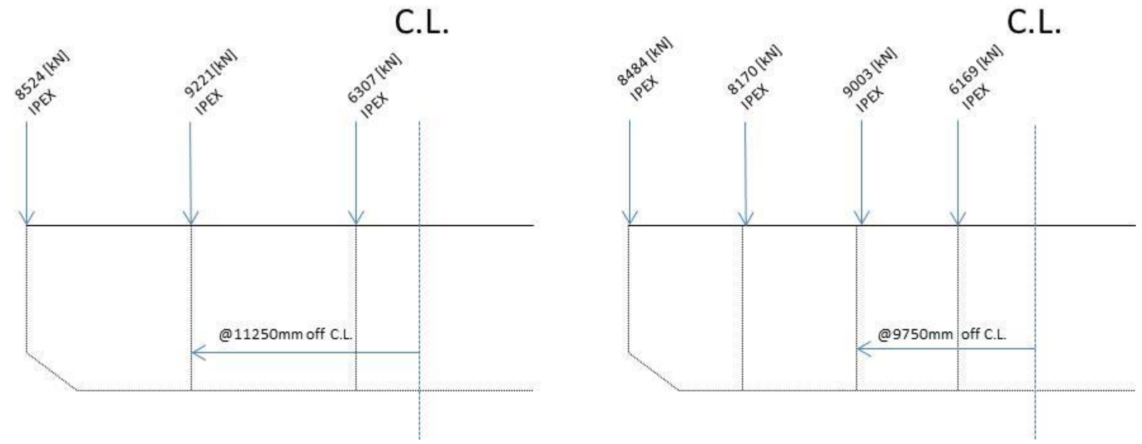


Figure 5.9 Column and side shell capacity according to IPEX column and side shell capacity (Alternative web on the right side of the figure, conventional web frame on the left side of the figure)

6. Modeling web frames in SACS

During this research there has been made use of the program Bentley SACS. This software is used within Heerema Marine Contractors to check or verify the structural integrity of a variety of offshore structures. During this research SACS is used to determine the web frame capacity of a typical web frame 13. The capacities of the conventional web frame 13 have been defined by Heerema Marine Contractors. The alternative web frame 13 is a concept model which has not been designed in SACS yet. The alternative web frame 13 is designed for this research and will be analyzed in this chapter. Previous to comparing conventional web frame 13 with alternative web frame 13 capacities, the SACS model and several aspects of SACS will be discussed.

6.1 Properties

The beams of the conventional barge and the alternative barge can be seen as unsymmetrical plate girders. In SACS there is a possibility to give beams this geometrical property. However the actual plate girders are equipped with cut-outs to fit over the longitudinal stiffeners (chapter 2.3, figure 2.4). SACS cannot take cut-outs into account, nevertheless there is the possibility to select a suitable section-type for these types of beams. The section-type that is used in SACS is the prismatic section type, making use of optional properties. The optional properties will apply to the actual properties of the plate girders [20].

First the member properties of the beams were determined by using the IPEX "plate girder properties" excel sheet (Appendix VI.B). These properties are used in the properties section of the member section and in the optional properties section (in SACS). According to the HMC engineering guideline [20], the properties of the bracket sections, the rigid sections and the beam sections will have to be multiplied by a specific value in order to obtain valid results in SACS.

6.2 Joint numbers

Joint are used to connect member in a SACS model. The SACS model includes several joints spread over the model. Every joint has its own properties, which are: position in the coordinate system (x-position, y-position, z-position), their corresponding fixity (translation and rotation over the x, y, z axis) and which members the joint is connected with. The deck beams have joints halfway the beam to apply a load case on the middle of the beam sections.

Fixed joints can be found under longitudinal bulkheads or side shells (Figure 6.1; Joint: 600, 240, 230, 220, 210, 190, 180, 170, 160) [25]. Fixities have been placed here because the longitudinal bulkheads and the side shell spread the loads into the barge. The fixities of these joint are: 011000, which means only translation in the y- and z direction can find place. Translation in the x-direction is not possible, neither are rotations in x/y/z axis.

Figure 6.1 shows that one fixity is also placed at the deck beam (joint 600). This fixity (110000) is placed in order to prevent translation of the frame in the z direction.

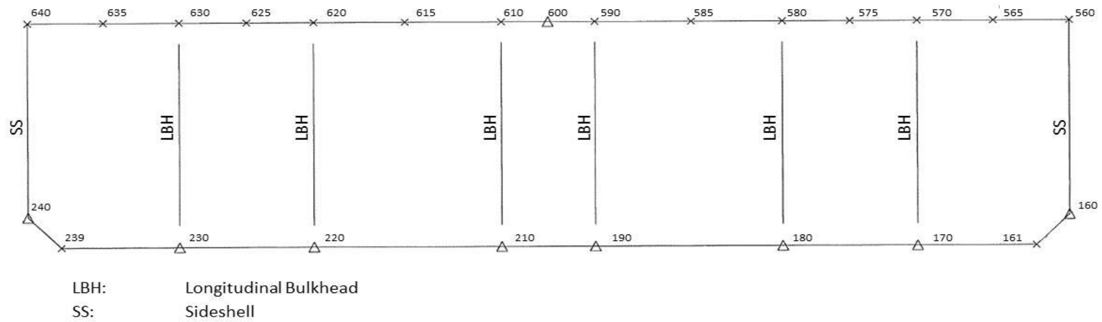


Figure 6.1 SACS model of the conventional web frame with the joint numbers displayed [25].

6.3 Member groups

The member sections of the beams are compiled into groups. Almost all groups exist out of 3 member sections: a bracket section, rigid section and a beam section. Because member groups exists out of more member sections, the properties aren't the same over the length of the members. The bracket section is the part of the beam that continues over the length of the bracket. The rigid section is the part of the beam from the neutral axis of a column to the bracket section.

Generally the segment length of the rigid and bracket section will be entered in the group section in SACS. The length of the beam section will be determined be the program itself. The segment length of the beam is determined by the distance between the nodes.

Member groups will be given names by the type of beams it exists out of. As shown in figure 6.2 the top beams start with a T follow by a number, the bottom beams start with B, the side shell beams start with an S and the column beams start with C. The various beams are also given a number in order to organize the various beams.

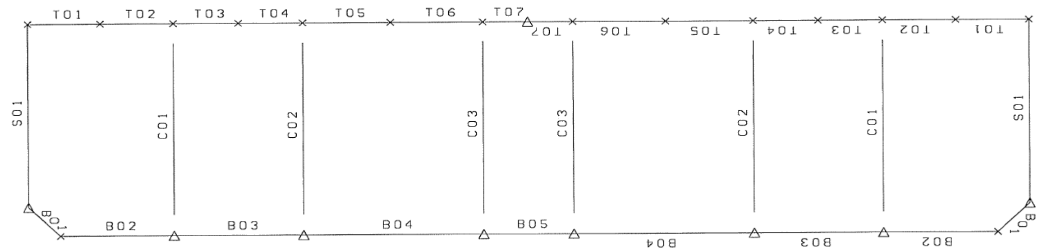


Figure 6.2 SACS model of conventional web frame with member groups displayed [25].

6.4 Member sections

Usually 3 different types of members are present in a SACS web frame model: the beam section, the bracket section and the rigid section. Every section has its own properties over a part of the beam, and a new section will be defined when the properties of the beam change (for example when the thickness of the web increases due to extra strength needed in this section) [22].

The abbreviations for the different sections are [22]:
T = Top (deck beam)
B = Bottom (bottom beam)
S = Side shell (side shell beam)
C = Bulkhead column (bulkhead column beam)

RG = Rigid section	(Section from neutral axis of column to bracket section)
BR = Bracket section	(Section over the length of the bracket)
BM = Beam section	(Section between bracket sections (Figure 6.3))

The various members which are used in the alternative web frame 13 model in SACS are shown in appendix V (sectional properties member sections SACS), with their associated drawing (cross section of the beams), and IPEX sheets.

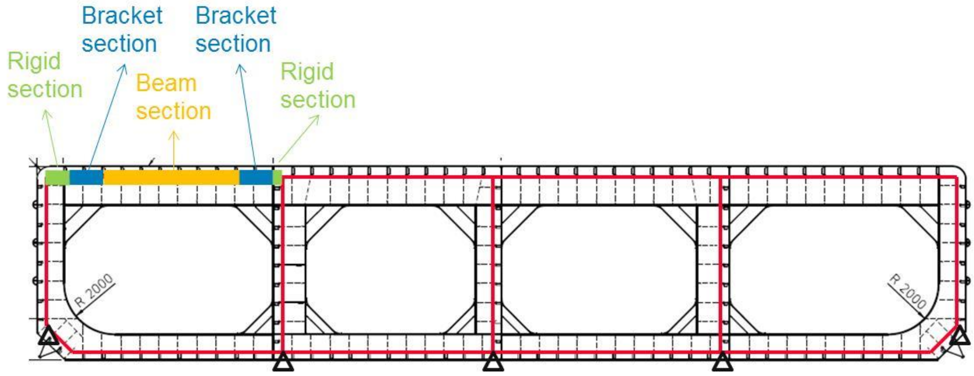


Figure 6.3 Beam sections of a web frame (not the H-541), divided in: rigid section, bracket section and beam section [22].

6.5 Average neutral axis

The members (beams) in SACS do not have similar properties. The neutral axis is not equal for top beam 1 as it is for top beam 2. In order to obtain a geometrical correct model the average neutral axis has to be determined. The average neutral axis for the alternative web frame only has to be determined for the top and bottom beams. The average neutral axis for the side shell beams and the column beams will stay the same as in the conventional web frame model and thus the properties do not change.

The average neutral axis is calculated by the following manner [25]:

Distance deck plate/Neutral axis EHT

Height of the top beam: Z top beam = 1698 mm

$$EHT = \frac{\sum(Z - e_z)_{BTBM} \cdot L_{BTBM})}{\sum L_{BTBM}}$$

Qty. (n)	Section	Z-ez [mm]	L [mm]
2	BTBM1	667	9750
1	BTBM3	674.3	5750
1	BTBM4	652	4000
1	BTBM5	817.7	1500
	Z average [mm]	**674**	

Table 6.1 Determining the neutral of the deck beams.

Distance Bottom plate/Neutral axis EHB

Height bottom beam: Z bottom beam = 1242 mm

$$EHB = \frac{\sum(Z - e_z)_{BBBM} \cdot L_{BBBM})}{\sum L_{BBBM}}$$

Qty. (n)	Section	Z-ez	L
1	BBBM1	214.5	9750
1	BBBM2	273.0	9750
1	BBBM3	342.9	1500
	Z average [mm]	**251**	

Table 6.2 Determining the neutral axis of the bottom beam.

6.6 Model conventional deck

The conventional web frame 13 has been designed by Heerema Marine Contractors in order to check the structural integrity of the web frame. The SACS model for the conventional typical web frame 13 is shown in figure 6.4. This model will be used in order to compare capacities of the conventional web frame with the alternative web frame. The model of the web frame 13 can be subjected to several load cases according to [20]. The same load cases are applied to the alternative SACS model.

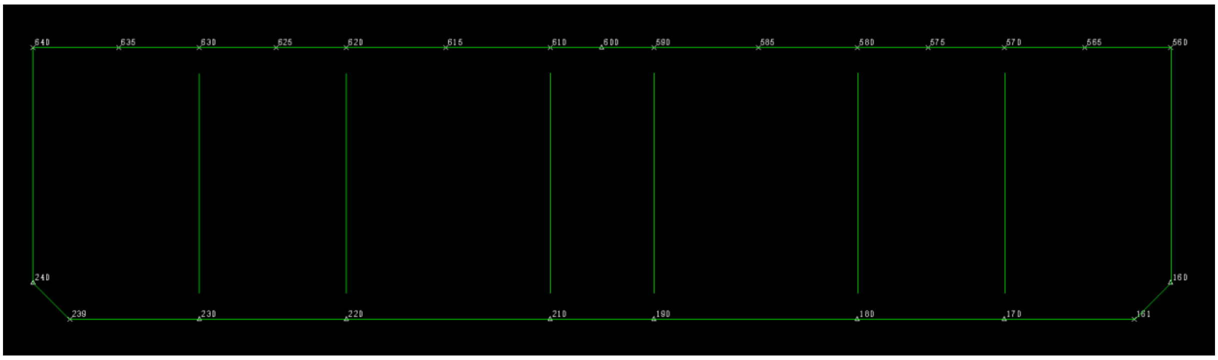


Figure 6.4 SACS model of conventional web frame [25]

6.7 Model secondary deck

The alternative SACS model (figure 6.5) appears to be similar to the conventional SACS model. Comparing the alternative model with figure 6.4; the only difference between the two models seems to be that 2 columns have been removed. However every member has their specific properties. As a result of removing the 2 columns at 15000 [mm] of the center line and moving the columns at 9750 [mm] of the center line the effective width has changed as discussed in chapter 2.5. Another difference between the alternative model and the conventional model are the properties of the deck beams. The properties of the deck beam have been adjusted because a secondary deck was adjusted. Not only the secondary deck has changed the properties of the deck beams but also the increase in web height contributed to changes of the properties.

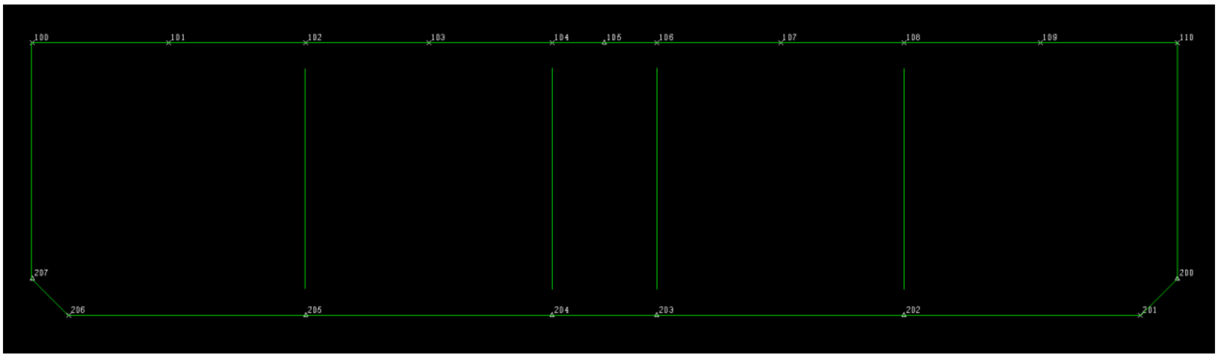


Figure 6.5 SACS model of alternative web frame, as mentioned in chapter 5 the columns at 8250 [mm] of center line has been moved to 11250 [mm] of center line, however the properties of the columns will experience no changes.

6.8 Comparing web frame capacity

The conventional web frame made by Heerema Marine Contractors have been subjected to several load cases. These load cases are submitted according to the engineering guideline for barge strength and modeling [20]. As described earlier in this chapter, the load cases for point loads are placed at the following points in the SACS model: at the outer fibers of the column beams, half way the beam sections, 1 [mm] in front of the bracket section (in order to obtain correct shear capacity) and at the neutral axis of columns. In order to make a valid comparison between the conventional web frame model and the alternative web frame model, the point loads in the alternative model (figure 6.6) have been placed at the same positions as the conventional model.

Using the same positions for load cases (as in load cases, in appendix I) can result in large capacity differences. Where for example a loads case is applied halfway a beam section of the conventional web frame, the load case will not be positioned half way of the beam section of the alternative web frame.

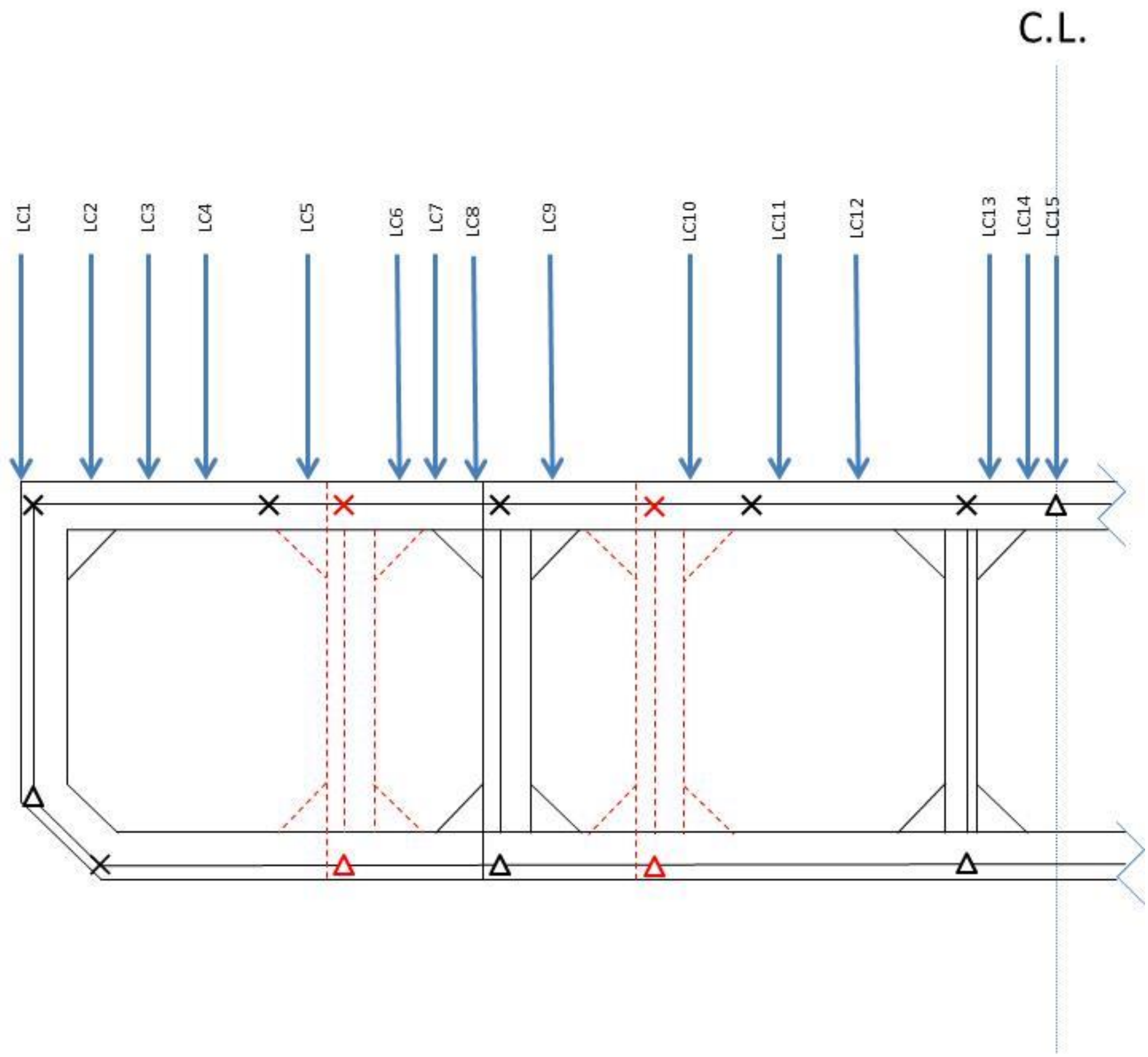


Figure 6.6 Positions of load cases in SACS model. Point loads are placed according to [20] for the conventional web frame in order to make a valid comparison. The red columns show where the columns of the conventional web frame are positioned.(not to scale)

As shown in table 6.3 capacities of the alternative web frame have decreased at certain load cases. Decrease in capacity will mostly find place half way the beam section. The reason capacity near this section decreases is that the span of the deck beams has increased due to the removal of 1 column and replacing a column to another position. Therefore larger bending moments will occur which has a negative effect on bending.

However in certain load cases, the capacities of the alternative web frame have increased. For example: load case 8 and 11 (figure 6.6). In the alternative web frame this load case is applied near a column, however this load case is positioned mid-beam on the conventional web frame. This results in a higher capacity on this location on the alternative beam.

LC	Capacity Conventional [kN]	Capacity Alternative. [kN]	Percentage %
1	8333	7042	-15.5
2	4762	5051	+6.1
3	5263	4367	-17.0
4	5556	4444	-20.0
5	7143	4545	-36.4
6	5263	4878	-7.3
7	5263	4695	-10.8
8	5000	6369	+27.4
9	7143	6135	-14.1
10	5000	4444	-11.1
11	3030	3802	+25.5
12	3030	2874	-5.1
13	5882	6897	+17.3
14	4762	4545	-4.6
15	4348	4000	-8.0

Table 6.3 Capacities of the conventional and the alternative deck beams (visualized in figure 6.6)

Figure 6.7 shows load cases of the alternative web frame according to [20]. The capacities of the beams according to the subjected load cases are shown in table 6.4. Load case 20 is an example that shows that mid-beam capacities have decreased as a result of the increased span of the deck beam.

The bottom beams have also been subjected to a load case. In order to check if the bottom beams of the alternative web frame also meet with the unity check of 1, or lower. For this load case a distributed load has been applied which represent the water pressure under the barge. Calculations of the water pressure and the values of the unity check are found in appendix VII.D. The model shows a unity check larger than 1 which means the bottom beams do not meet the strength requirements.

LC	***Capacity Alternative. [kN]***
19	*6623*
20	*3778*
21	*4425*
22	*5076*
23	*6410*
24	*6452*
25	*5236*
26	*4505*
27	*4016*
28	*5000*

Table 6.4 Capacities of the conventional and the alternative deck beams (visualized in figure 6.7)

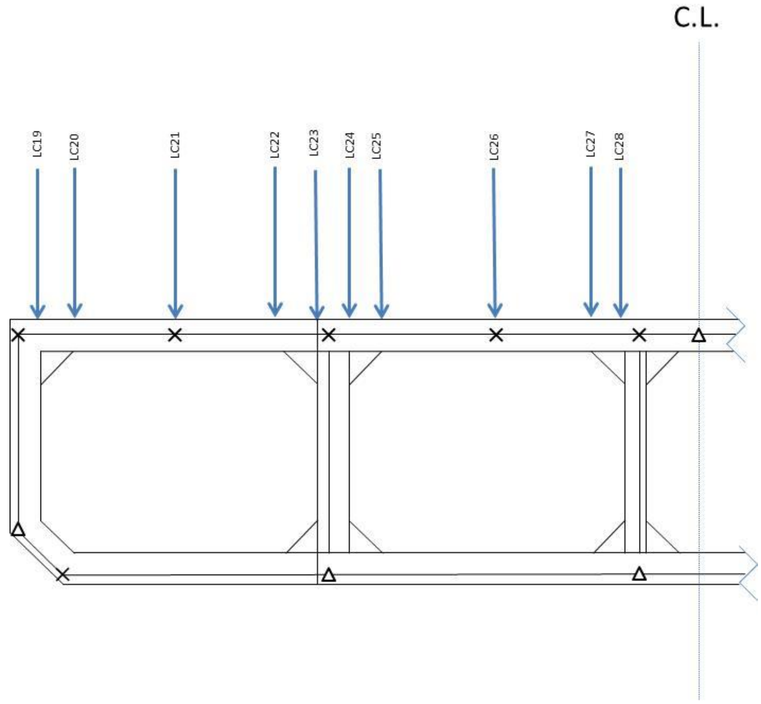


Figure 6.7 Positions of load cases of the alternative model. The loads have been placed according to [20].(not to scale)

7. Conclusions

[1] This research includes a comparison between a typical web frame 13 of the H-541 and an alternative design of a web frame. The alternative web frame has the same weight as the conventional web frame.

Adding a secondary deck will increase the area moment of inertia of the deck beams, which leads to a decrease in occurring bending stress. However the span of the alternative deck beams have become relatively large compared to the increase in area moment of inertia. Therefore bending moments increase relatively more than the area moment of inertia, this results in lower capacities because of higher occurring stresses. As result the web frame capacities in the alternative web frame 13 have not improved.

[2] The alternative deck beams are equipped with a secondary deck. Adding a secondary deck will improve the global strength. Both the deck plate as the secondary deck plate are equipped with longitudinal stiffeners (which contribute to global strength), therefore increasing global strength. However the global strength of web frame 13 in this research does not improve. The reason global capacity does not improve is that the neutral axis has shifted relatively more than the area moment of inertia has increased. This results in higher bending stress, causing the allowable bending moment to decrease.

[3] The goal of the research was to increase web frame and global capacity without an increase in weight. In order to maintain the same weight in the alternative web frame compared to the conventional web frame, 2 columns and therefore 2 longitudinal bulkheads removed. This results in a decrease in shear area. Therefore the allowable shear force of the alternative web frame is lower than the allowable shear force of the conventional web frame.

[4] The beams of the alternative beams have a larger span compared to the conventional web frame beams. Balance between span and beam geometrics are crucial, a relatively large span will cause larger bending moments. The double deck has to be of certain dimensions in order to compensate the larger bending moments. When the beam length increases because of the removal of 2 columns/bulkheads and moving 2 columns, the section dimensions of the beam need to be adjusted in order to meet with the strength requirements. Because bending stress will be higher in the alternative web frame compared to the conventional web frame, the dimensions of the flanges need to be adjusted (because bending stress will be transferred into the flanges), in order to improve capacity.

[5] When a distributed load of the water pressure (when the barge is fully submerged) is subject to the bottom beams the unity checks end up above 1. The reason the bottom beams do not meet with the unity checks is the increase in span of the bottom beams. Increasing the span of the bottom beams will result in a larger effective width. A larger effective width results in a higher area moment of inertia and therefore supposedly decreasing bending and combined stresses. However the bending moments have increased relatively more than the area moment of inertia, creating a weaker beam.

[6] The side shell and bulkhead column capacity of the alternative web frame have increased, compared to the column beams of the conventional web frame. The reason side shell and column capacity has increased is the increase in stiffness of the deck beams. The deck beams of the alternative web frame will take up more moment because of increase in stiffness.

[7] Increasing the web height of the deck beams will cause a decrease in shear stress. However shear properties of the deck beams are only the critical factor if a deck beam is loaded close to the brackets or columns. The deck beams of the alternative web frame have a larger span than the conventional web frame. In this case bending is governing. The beam properties would improve more when the top and bottom flange plate thickness would increase because bending stress will be transferred into the flanges and shear stress will be transferred into the webs.

8. Recommendations

[1] When a secondary deck is added to the deck beams of a barge, it is favorable to add a secondary deck to the bottom beams as well, in order to improve global barge strength. Applying a secondary deck to the top beams and not to the bottom beams will cause the neutral axis to shift towards the outer fiber of the deck causing a decrease in allowable bending moments. When a secondary deck on both top beams and bottom beams is applied, the neutral axis will shift to the center of the barge with can result in an increase of the allowable bending moment. Therefore it is recommended to extend the research by investigation the effects of adding a secondary deck to the bottom beams.

[2] During this research the top beams have been equipped with a double deck in order to improve web frame and global capacities. The bottom beams have been left out of scope but should also be taken into account if all parts of the web frame have to meet up to the given strength requirements. Removing 2 columns in the web frame causes larger bending moments in the bottom beams. So either a secondary deck should be added to the bottom beams of the web frames, or the bottom beams need to be re-dimensioned in order to resist the occurring stresses.

[3] In order to increase the allowable shear force, the plate thickness of the longitudinal bulkheads should increase this will improve shear properties of the alternative web frame. However increasing plate thickness of the longitudinal bulkheads will cause a significant increase of weight of the barge because the longitudinal bulkhead plates continue from the bow to the stern of the barge. It is recommended to research a way to keep a certain amount of shear area by increasing plate thickness of the longitudinal bulkheads without increasing the weight of the web frame.

[4] During this research the ballast arrangement is left out of scope. However by removing 2 columns and relocating 2 columns, the dimensions of the ballast tanks will change. The ballast arrangement will have to be adjusted (if possible), in order to obtain a barge without ballasting issues. Further research/investigations need to be done to assess the consequents of these issues.

[5] It can be possible to increase web frame and global capacities without increasing the weight of the barge. The columns should stay at their same positions and the web height of the top beam should be equal to the conventional web frames. A secondary deck at the top beam section will be added to increase these capacities. However in order not create an increase in weight; dimensions like plate thickness of deck, bottom, columns and longitudinal bulkheads should be reduced. The “saved” material by reducing these plate thicknesses can be used for the double deck section.

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Appendix I

A Deck beam calculations

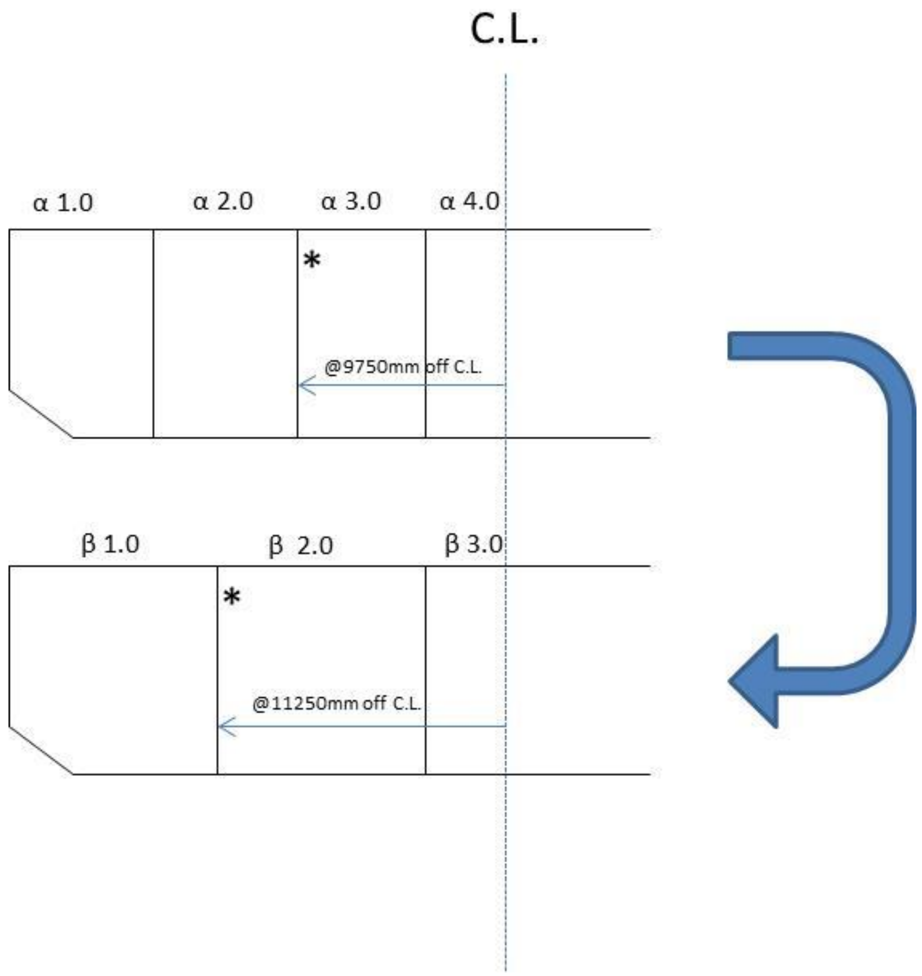
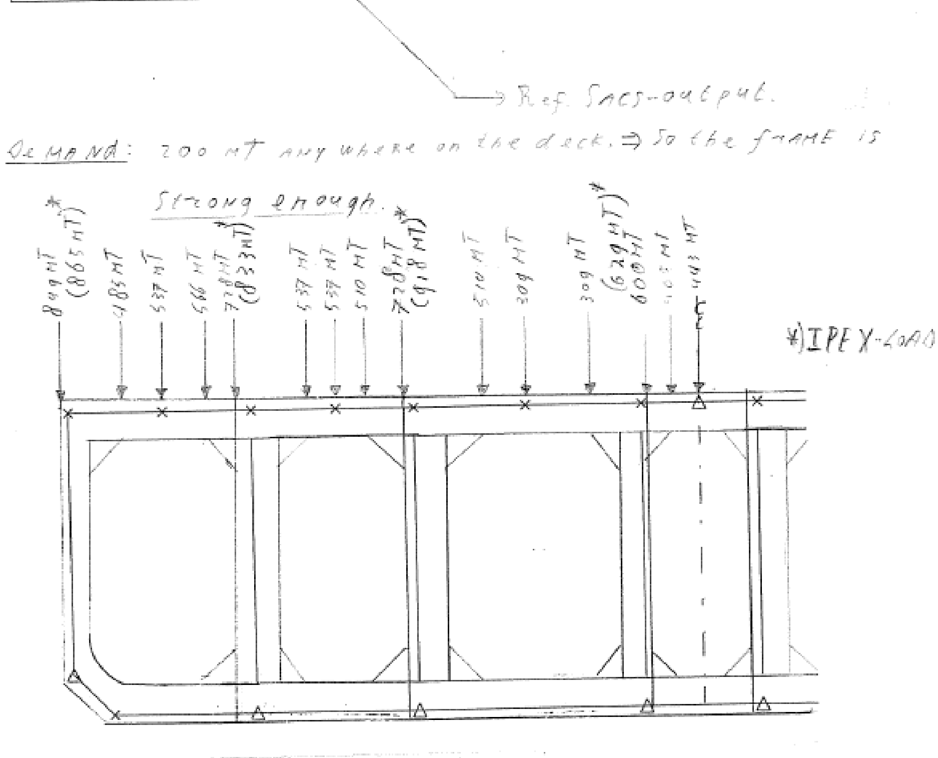


Figure I.A.I Simplified drawing of the conventional web frame (top drawing) with naming of the beams, and bottom figure shows a simplified drawing of the alternative web frame also with naming of its beams.

Load case	Load	Maximal Unity Check	Maximum Capable Load		Ipex Load	
1	1000 kN. and 509 kNm.	0.12	8333 kN.	849 mTon.	8484 kN	865 mT
2	1000 kN.	0.21	4762 kN.	485 mTon.	-	-
3	1000 kN.	0.19	5263 kN.	537 mTon.	-	-
4	1000 kN.	0.18	5556 . kN.	566 mTon.	-	-
5	1000 kN.	0.14	7143 kN.	728 mTon.	8170 kN	833 mT
6	1000 kN.	0.19	5263 kN.	537 mTon.	-	-
7	1000 kN.	0.19	5263 kN.	537 mTon.	-	-
8	1000 kN.	0.20	5000 kN.	510 mTon.	-	-
9	1000 kN.	0.14	7143 kN.	728 mTon.	9003 kN	918 mT
10	1000 kN.	0.20	5000 kN.	510 mTon.	-	-
11	1000 kN.	0.33	3030 kN.	309 mTon.	-	-
12	1000 kN.	0.33	3030 kN.	309 mTon.	-	-
13	1000 kN.	0.17	5882 kN.	600 mTon.	6169 kN	629 mT
14	1000 kN.	0.21	4762 kN.	485 mTon.	-	-
15	1000 kN.	0.23	4348 kN.	443 mTon.	-	-



Load cases Conventional web frame [10]

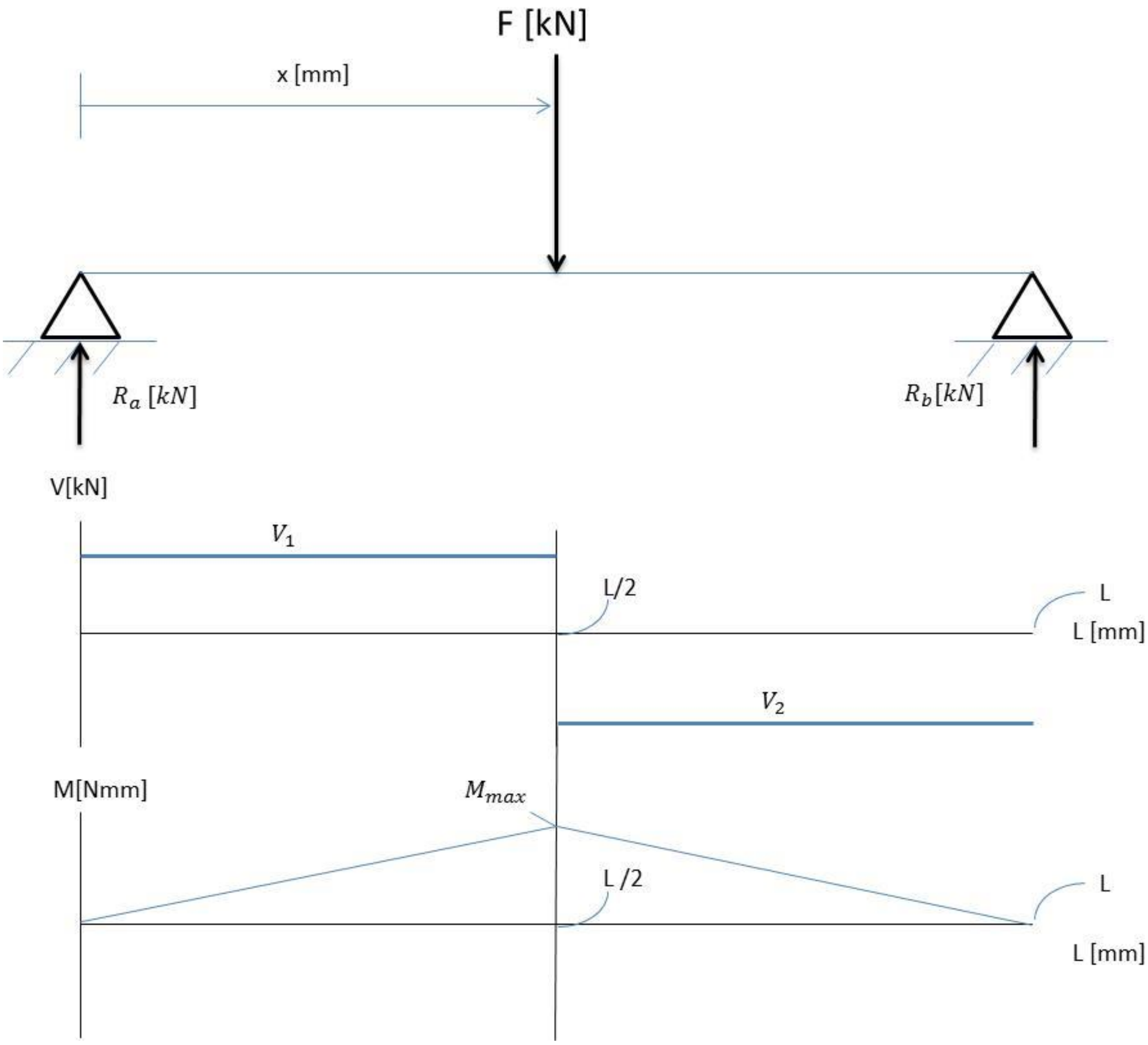


Figure I.A.II Simple supported beam. Calculations have been applied on this type of support beam. The properties of the conventional beams and the alternative beam have been applied. From these calculations the shear stress and bending stress from both conventional and alternative beams are calculated and compared with each other.

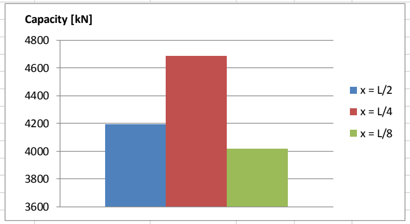
Figure I.A.II shows the M-V diagram of the simply supported beam calculations. A force has been applied at a distance (x). This force results in shear force and moment in the beam. These values are required in order to calculate the shear stress and the bending stress in the beam. These values are found in the "input" tables in appendix II.A

	α 1.0	α 2.0	α 3.0	α 4.0
B1	1151	1027	1310	847
B2	28	28	28	20
B3	500	450	350	350
H1	32	32	32	20
H2	38	32	32	28

	τ shear [n/mm2]	σben.[n/mm2]	comb.[n/mm2]
α 1.0 (load at x=L/2)	0.0	28.4	28.4
	0.3	27.1	27.1
	12.2	11.8	24.2
	12.7	0.0	22.1
	8.0	34.3	37.0
	0.0	35.9	35.9
α 1.0 (load at x=L/4)	0.0	21.3	21.3
	0.4	20.3	20.4
	18.3	8.8	32.9
	19.1	0.0	33.1
	11.9	25.8	33.0
	0.0	26.9	26.9
α 1.0 (load at x=L/8)	0.0	12.4	12.4
	0.5	11.9	11.9
	21.3	5.1	37.3
	22.3	0.0	38.6
	13.9	15.0	28.4
	0.0	15.7	15.7
α 2.0 (load at x=L/2)	0.0	28.4	28.4
	0.3	27.0	27.1
	12.4	11.3	24.2
	13.0	0.0	22.5
	7.1	35.9	37.9
	0.0	37.2	37.2
α 2.0 (load at x=L/4)	0.0	21.3	21.3
	0.5	20.3	20.3
	18.6	8.5	33.3
	19.5	0.0	33.8
	10.7	26.9	32.7
	0.0	27.9	27.9
α 2.0 (load at x=L/8)	0.0	12.4	12.4
	0.6	11.8	11.9
	21.7	5.0	37.9
	22.8	0.0	39.4
	12.5	15.7	26.7
	0.0	16.3	16.3
α 3.0 (load at x=L/2)	0.0	37.1	37.1
	0.3	35.0	35.0
	13.1	11.1	25.3
	13.3	0.0	23.1
	6.1	61.9	62.8
	0.0	64.0	64.0
α 3.0 (load at x=L/4)	0.0	27.8	27.8
	0.4	26.3	26.3
	19.6	8.3	35.0
	20.0	0.0	34.6
	9.2	46.5	49.1
	0.0	48.0	48.0
α 3.0 (load at x=L/8)	0.0	16.2	16.2
	0.5	15.3	15.4
	22.9	4.9	40.0
	23.3	0.0	40.4
	10.7	27.1	32.8
	0.0	28.0	28.0

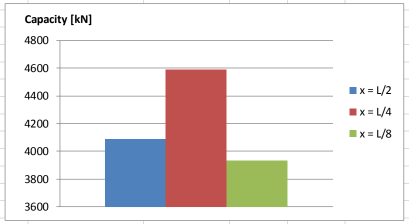
α 1.0

V [N]	L[mm]	t [mm]	Q [mm3]	y [mm]	Iy [mm4]	F [N]		M [Nmm]		Capacity [kN]
500000	6000	1151	0	694	3.66E+10	1000000	**load at x=L/2**	1500000000	2	4191
750000		1151	2.50E+07	662			**load at x=L/4**	1125000000	4	4688
875000		28	2.50E+07	287			**load at x=L/8**	656250000	8	4018
		28	2.61E+07	0						
		28	1.63E+07	838						
		500	0	876						



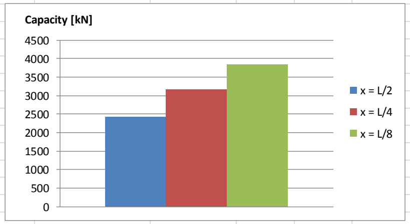
α 2.0

V [N]	L[mm]	t [mm]	Q [mm3]	y [mm]	Iy [mm4]	F [N]		M [Nmm]		Capacity [kN]
500000	5250	1027	0	677	3.13E+10	1000000	**load at x=L/2**	1312500000	2	4090
750000		1027	2.17E+07	645			**load at x=L/4**	984375000	4	4589
875000		28	2.17E+07	270			**load at x=L/8**	574218750	8	3934
		28	2.28E+07	0						
		28	1.25E+07	855						
		450	0	887						



α 3.0

V [N]	L[mm]	t [mm]	Q [mm3]	y [mm]	Iy [mm4]	F [N]		M [Nmm]		Capacity [kN]
500000	8250	1310	0	574	3.19E+10	1000000	**load at x=L/2**	2062500000	2	2423
750000		1310	2.34E+07	542			**load at x=L/4**	1546875000	4	3160
875000		28	2.34E+07	172			**load at x=L/8**	902343750	8	3841
		28	2.38E+07	0						
		28	1.09E+07	958						
		350	0	990						



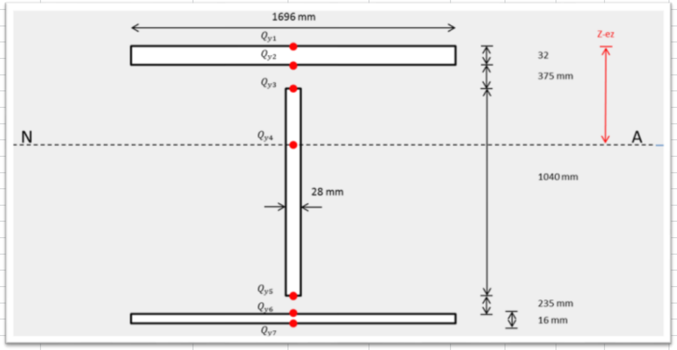
Excel sheet I

	τ shear [n/mm2]	σben.[n/mm2]	comb.[n/mm2]
β 1.0(load at x=L/2)	0.0	29.0	29.0
	0.2	27.6	27.6
	11.3	11.3	22.5
	11.6	0.0	20.0
	8.9	34.0	37.3
	8.9	44.2	46.8
	0.0	44.9	44.9
β 1.0 (load at x=L/4)	0.0	21.8	21.8
	0.3	20.7	20.7
	16.9	8.5	30.5
	17.4	0.0	30.1
	13.3	25.5	34.3
	13.3	33.1	40.4
	0.0	33.7	33.7
β 1.0 (load at x=L/8)	0.0	12.7	12.7
	0.3	12.1	12.1
	19.7	5.0	34.5
	20.3	0.0	35.1
	15.5	14.9	30.7
	15.5	19.3	33.1
	0.0	19.6	19.6

		β 1.0				
V [N]	L[mm]	t [mm]	Q [mm3]	y [mm]	Iy [mm4]	F [N]
500000	9750	1696	0	667	5.60E+10	1000000
750000		1696	3.53E+07	635		
875000		28	3.53E+07	260		
		28	3.63E+07	0		
		28	2.78E+07	780		
		28	2.78E+07	1015		
		1696	0.00E+00	1031		
		β 2.0				
V [N]	L[mm]	t [mm]	Q [mm3]	y [mm]	Iy [mm4]	F [N]
500000	9750	1528	0	674	5.09E+10	1000000
750000		1528	3.22E+07	642		
875000		28	3.22E+07	267		
		28	3.32E+07	0		
		28	2.48E+07	773		
		28	2.48E+07	1008		
		1528	0.00E+00	1024		

	M [Nmm]		Capacity [kN]
load at x=L/2	2437500000	2	3316
load at x=L/4	1828125000	4	3844
load at x=L/8	1066406250	8	4421

	τ shear [n/mm2]	σben.[n/mm2]	comb.[n/mm2]
β 2.0(load at x=L/2)	0.0	32.3	32.3
	0.2	30.7	30.7
	11.3	12.8	23.4
	11.6	0.0	20.2
	8.7	37.0	40.0
	8.7	48.3	50.6
	0.0	49.0	49.0
β 2.0 (load at x=L/4)	0.0	24.2	24.2
	0.3	23.1	23.1
	16.9	9.6	30.9
	17.5	0.0	30.3
	13.1	27.8	35.8
	13.1	36.2	42.7
	0.0	36.8	36.8
β 2.0 (load at x=L/8)	0.0	14.1	14.1
	0.4	13.5	13.5
	19.8	5.6	34.7
	20.4	0.0	35.3
	15.2	16.2	30.9
	15.2	21.1	33.8
	0.0	21.5	21.5



Excel sheet II

Appendix II

A. Calculations conventional web frame

Input:

	α 1.0	α 2.0	α 3.0	α 4.0
B1	1151	1027	1310	847
B2	28	28	28	20
B3	500	450	350	350
H1	32	32	32	20
H2	38	32	32	28

Table II.A.I corresponding drawing II.B.II

α 1.0										
x[mm]	F [kN]	M [kNmm]	V [kN]		t[mm]	Q [mm^3]	z[mm]		Iy [mm^4]	L[mm]
L/2	1000	1500000	500		1151	0	694		$3.66\cdot10^{10}$	6000
L/4		1125000	750		1151	$2.50\cdot10^{7}$	662			
L/8		656250	875		28	$2.50\cdot10^{7}$	287			
					28	$2.61\cdot10^{7}$	0			
					28	$1.63\cdot10^{7}$	838			
					500	0	876			

Table II.A.II Input from excel sheet I

α 2.0										
x [mm]	F [kN]	M [Nmm]	V [kN]		t[mm]	Q [mm^3]	z[mm]		Iy [mm^4]	L[mm]
L/2	1000	1312500	500		1027	0	677		$3.13\cdot10^{10}$	5250
L/4		984375	750		1027	$2.17\cdot10^{7}$	645			
L/8		574219	875		28	$2.17\cdot10^{7}$	270			
					28	$2.28\cdot10^{7}$	0			
					28	$1.25\cdot10^{7}$	855			
					450	0	887			

Table II.A.III Input from excel sheet I

α 3.0										
x [mm]	F [kN]	M [kNmm]	V [kN]		t[mm]	Q [mm^3]	z[mm]		Iy [mm^4]	L[mm]
L/2	1000	2062500	500		1310	0	574		$3.19\cdot10^{10}$	8250
L/4		1546875	750		1310	$2.34\cdot10^{7}$	542			
L/8		902344	875		28	$2.34\cdot10^{7}$	172			
					28	$2.38\cdot10^{7}$	0			
					28	$1.09\cdot10^{7}$	958			
					350	0	990			

Table II.A.IV Input from excel sheet I

Output:

α 1.0			
x [mm]	**τ shear [N/mm²]**	**$\sigma_{bend.}$[N/mm²]**	**$\sigma_{comb.}$[N/mm²]**
L/2	0.0	28.4	28.4
	0.3	27.1	27.1
	12.2	11.8	24.2
	12.7	0.0	22.1
	8.0	34.3	37.0
	0.0	35.9	35.9
L/4	0.0	21.3	21.3
	0.4	20.3	20.4
	18.3	8.8	32.9
	19.1	0.0	33.1
	11.9	25.8	33.0
	0.0	26.9	26.9
L/8	0.0	12.4	12.4
	0.5	11.9	11.9
	21.3	5.1	37.3
	22.3	0.0	38.6
	13.9	15.0	28.4
	0.0	15.7	15.7

Table II.A.V Output from excel sheet I

α 2.0			
x [mm]	**τ shear [N/mm²]**	**$\sigma_{bend.}$[N/mm²]**	**$\sigma_{comb.}$[N/mm²]**
L/2	0.0	28.4	28.4
	0.3	27.0	27.1
	12.4	11.3	24.2
	13.0	0.0	22.5
	7.1	35.9	37.9
	0.0	37.2	37.2
L/4	0.0	21.3	21.3
	0.5	20.3	20.3
	18.6	8.5	33.3
	19.5	0.0	33.8
	10.7	26.9	32.7
	0.0	27.9	27.9
L/8	0.0	12.4	12.4
	0.6	11.8	11.9
	21.7	5.0	37.9
	22.8	0.0	39.4
	12.5	15.7	26.7
	0.0	16.3	16.3

Table II.A.VI Output from excel sheet I

α 3.0			
x [mm]	***τ shear [N/mm²]***	***$\sigma_{bend.}$.[N/mm²]***	***$\sigma_{comb.}$[N/mm²]***
L/2	*0.0*	*37.1*	*37.1*
	0.3	*35.0*	*35.0*
	13.1	*11.1*	*25.3*
	13.3	*0.0*	*23.1*
	6.1	*61.9*	*62.8*
	0.0	*64.0*	*64.0*
L/4	*0.0*	*27.8*	*27.8*
	0.4	*26.3*	*26.3*
	19.6	*8.3*	*35.0*
	20.0	*0.0*	*34.6*
	9.2	*46.5*	*49.1*
	0.0	*48.0*	*48.0*
L/8	*0.0*	*16.2*	*16.2*
	0.5	*15.3*	*15.4*
	22.9	*4.9*	*40.0*
	23.3	*0.0*	*40.4*
	10.7	*27.1*	*32.8*
	0.0	*28.0*	*28.0*

Table II.A.VII Output from excel sheet I

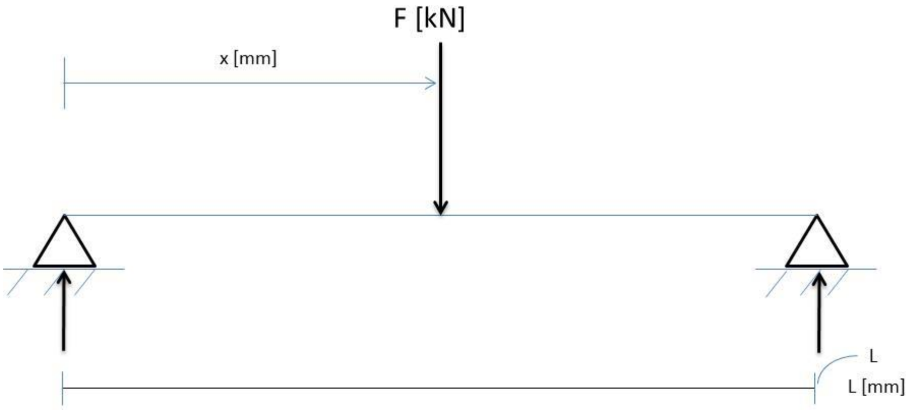


Figure II.A.I

B. Calculations alternative web frame

Input:

					β 1.0					
x[mm]	*F [kN]*	*M [kNmm]*	*V [kN]*		*t[mm]*	*Q [mm³]*	*z[mm]*		*Iy [mm⁴]*	*L[mm]*
L/2	*1000*	*2437500*	*500*		*1696*	*0*	*667*		$5.60 \cdot 10^{10}$	*9750*
L/4		*1828125*	*750*		*1696*	$3.53 \cdot 10^{7}$	*635*			
L/8		*1066406*	*875*		*28*	$3.53 \cdot 10^{7}$	*260*			
					28	$3.63 \cdot 10^{7}$	*0*			
					28	$2.78 \cdot 10^{7}$	*780*			
					28	$2.78 \cdot 10^{7}$	*1015*			
					1696	*0*	*1031*			

Table II.B.I Input from excel sheet II

					β 2.0					
x[mm]	*F [kN]*	*M [kNmm]*	*V [kN]*		*t[mm]*	*Q [mm³]*	*y[mm]*		*Iy [mm⁴]*	*L[mm]*
L/2	*1000*	*2437500*	*500*		*1528*	*0*	*674*		$5.09 \cdot 10^{10}$	*9750*
L/4		*1828125*	*750*		*1528*	$3.22 \cdot 10^{7}$	*642*			
L/8		*1066406*	*875*		*28*	$3.22 \cdot 10^{7}$	*267*			
					28	$3.32 \cdot 10^{7}$	*0*			
					28	$2.48 \cdot 10^{7}$	*773*			
					28	$2.48 \cdot 10^{7}$	*1008*			
					1528	*0*	*1024*			

Table II.B.II Input from excel sheet II

Output:

	ϐ 1.0		
x [mm]	***τ shear [N/mm²]***	***$\sigma_{bend.}$[N/mm²]***	***$\sigma_{comb.}$[N/mm²]***
L/2	*0.0*	*29.0*	*29.0*
	0.2	*27.6*	*27.6*
	11.3	*11.3*	*22.5*
	11.6	*0.0*	*20.0*
	8.9	*34.0*	*37.3*
	8.9	*44.2*	*46.8*
	0.0	*44.9*	*44.9*
L/4	*0.0*	*21.8*	*21.8*
	0.3	*20.7*	*20.7*
	16.9	*8.5*	*30.5*
	17.4	*0.0*	*30.1*
	13.3	*25.5*	*34.3*
	13.3	*33.1*	*40.4*
	0.0	*33.7*	*33.7*
L/8	*0.0*	*12.7*	*12.7*
	0.3	*12.1*	*12.1*
	19.7	*5.0*	*34.5*
	20.3	*0.0*	*35.1*
	15.5	*14.9*	*30.7*
	15.5	*19.3*	*33.1*
	0.0	*19.6*	*19.6*

Table II.B.III Output from excel sheet II

	ϐ 2.0		
x [mm]	***τ shear [N/mm²]***	***$\sigma_{bend.}$[N/mm²]***	***$\sigma_{comb.}$[N/mm²]***
L/2	*0.0*	*32.3*	*32.3*
	0.2	*30.7*	*30.7*
	11.3	*12.8*	*23.4*
	11.6	*0.0*	*20.2*
	8.7	*37.0*	*40.0*
	8.7	*48.3*	*50.6*
	0.0	*49.0*	*49.0*
L/4	*0.0*	*24.2*	*24.2*
	0.3	*23.1*	*23.1*
	16.9	*9.6*	*30.9*
	17.5	*0.0*	*30.3*
	13.1	*27.8*	*35.8*
	13.1	*36.2*	*42.7*
	0.0	*36.8*	*36.8*
L/8	*0.0*	*14.1*	*14.1*
	0.4	*13.5*	*13.5*
	19.8	*5.6*	*34.7*
	20.4	*0.0*	*35.3*
	15.2	*16.2*	*30.9*
	15.2	*21.1*	*33.8*
	0.0	*21.5*	*21.5*

Table II.B.IV Output from excel sheet II

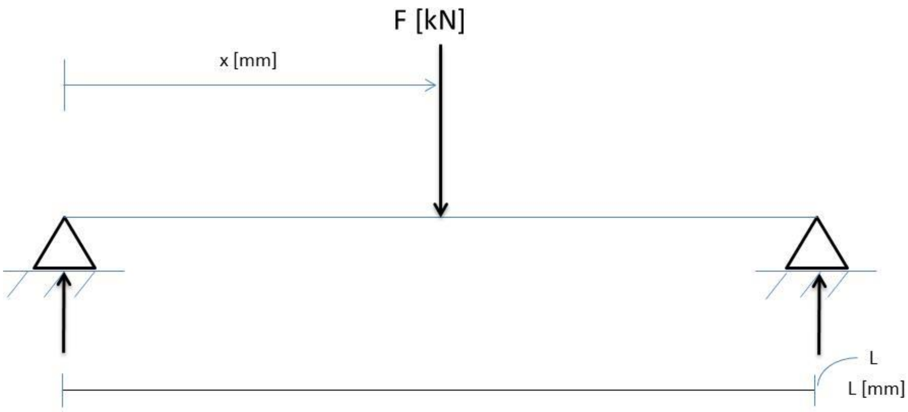


Figure II.B.I

Example of stress calculations in beams

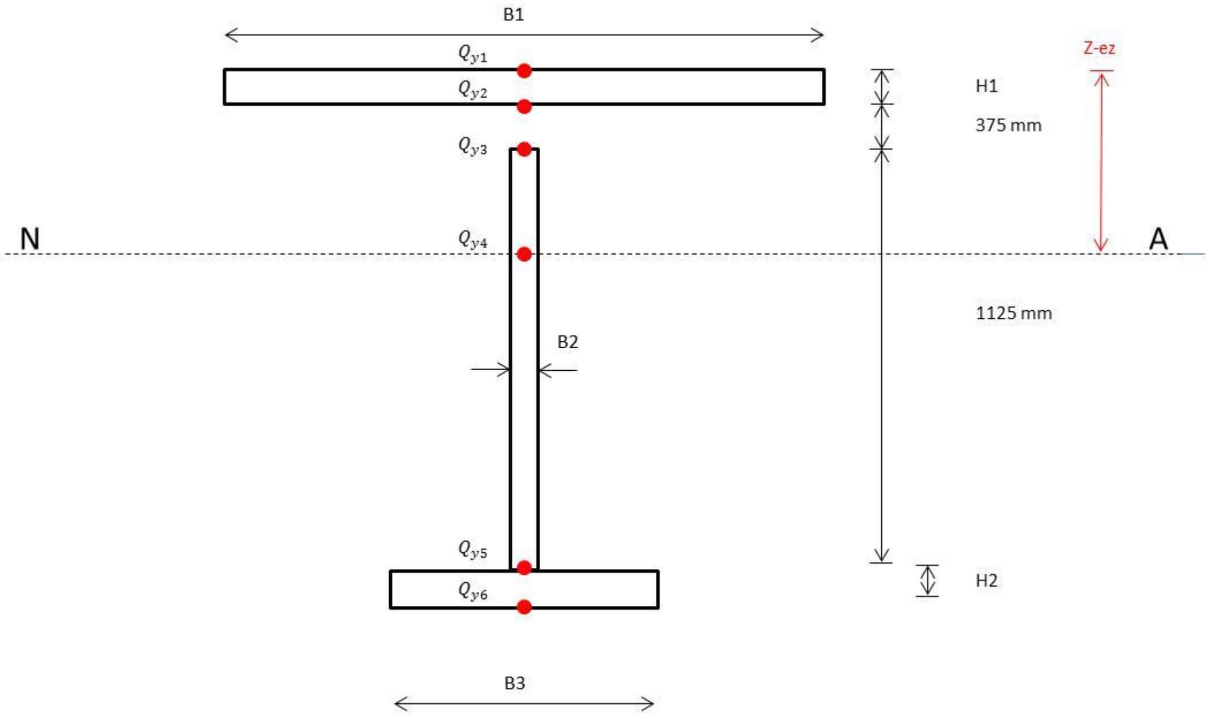


Figure II.B.II

	α 1.0	α 2.0	α 3.0	α 4.0
B1 5[mm]	1151	1027	1310	847
B2 [mm]	28	28	28	20
B3 [mm]	500	450	350	350
H1 [mm]	32	32	32	20
H2 [mm]	38	32	32	28

Table II.B.V

Example (maximal shear at point Q_{y4} figure II.B.II)

$$\tau_4 = \frac{500 \cdot 10^3 \cdot 2{,}61 \cdot 10^7}{28 \ \cdot 3{,}66 \cdot 10^{10}} = 12{,}7 \left[\frac{N}{mm^2}\right]$$

Example (maximal bending in bottom flange at point Q_{y6} figure II.B.II)

$$\sigma_6 = \frac{15 \cdot 10^8 \cdot 876}{3{,}66 \cdot 10^{10}} = 35{,}9 \left[\frac{N}{mm^2}\right]$$

Example (Combined stress Huber hencky [16] at point Q_{y1} figure II.B.II)

$$\sigma_{comb\ 1} = \sqrt{(28{,}4)^2 + 3(0)^2} = 28{,}4 \left[\frac{N}{mm^2}\right]$$

C. IPEX Sheets Conventional beams

α 1.0

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \left(\frac{4752}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 1151\ [mm]$$

Project	Barge H-541 Typical web frame 13
Subject	Beam 1
Job / Bid no.	Conventional deck beam
Date	31-Mar-15
Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1151.0	32.0	0.0	36832	672	2.50E+07
2	0.0	375.0	0.0	0	0	2.50E+07
3	28.0	287.0	0.0	8036	8036	2.61E+07
4	28.0	838.0	0.0	23464	23464	1.63E+07
5	500.0	38.0	0.0	19000	798	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1151	1570		87332	32970	

Section Properties

Areas:		AX	87332	[mm²]
		AY	55832	[mm²]
		AZ	32970	[mm²]
Dimensions:		Y	1151.0	[mm]
		Z	1570.0	[mm]
		Weight	6.7	[kN/m]
Distances to neutral axis:	ez	(From bottom)	876.1	[mm]
	Z-ez		693.9	[mm]
	ey	(From left)	575.5	[mm]
	Y-ey		575.5	[mm]
Section moduli:		Wy,min	4.18E+07	[mm³]
		Wy,max	5.28E+07	[mm³]
		Wz,min	7.76E+06	[mm³]
		Wz,max	7.76E+06	[mm³]
Moments of inertia:		Iy	3.66E+10	[mm^4]
		Iz	4.46E+09	[mm^4]
Torsional constant (torsional resistance):		It	2.99E+07	[mm^4]
Radii of gyration:		ry	647.4	[mm]
		rz	226.1	[mm]

α 2.0

$$b_{eff} = 0,3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0,3 \cdot \left(\frac{4004}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 1027\ [mm]$$

Project	Barge H-541 Typical web frame 13						
Subject	Beam 2						
Job / Bid no.	Conventional deck beam						
Date	31-Mar-15		Sheet	1			

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1027.0	32.0	0.0	32864	672	2.17E+07
2	0.0	375.0	0.0	0	0	2.17E+07
3	28.0	270.0	0.0	7560	7560	2.28E+07
4	28.0	855.0	0.0	23940	23940	1.25E+07
5	450.0	32.0	0.0	14400	672	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1027	1564		78764	32844	

Section Properties

Areas:		AX	78764	[mm²]
		AY	47264	[mm²]
		AZ	32844	[mm²]
Dimensions:		Y	1027.0	[mm]
		Z	1564.0	[mm]
		Weight	6.1	[kN/m]
Distances to neutral axis:	ez (From bottom)		886.6	[mm]
	Z-ez		677.4	[mm]
	ey (From left)		513.5	[mm]
	Y-ey		513.5	[mm]
Section moduli:		Wy,min	3.53E+07	[mm³]
		Wy,max	4.62E+07	[mm³]
		Wz,min	6.10E+06	[mm³]
		Wz,max	6.10E+06	[mm³]
Moments of inertia:		Iy	3.13E+10	[mm^4]
		Iz	3.13E+09	[mm^4]
Torsional constant (torsional resistance):		It	2.44E+07	[mm^4]
Radii of gyration:		ry	630.4	[mm]
		rz	199.5	[mm]

α 3.0

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \left(\frac{5770}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 1310\ [mm]$$

Project	Barge H-541 Typical web frame 13			
Subject	Beam 3			
Job / Bid no.	Conventional deck beam			
Date	01-Apr-15		Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1310.0	32.0	0.0	41920	672	2.34E+07
2	0.0	375.0	0.0	0	0	2.34E+07
3	28.0	167.0	0.0	4676	4676	2.38E+07
4	28.0	958.0	0.0	26824	26824	1.09E+07
5	350.0	32.0	0.0	11200	672	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1310	1564		84620	32844	

Section Properties

Areas:		AX	84620	[mm²]
		AY	53120	[mm²]
		AZ	32844	[mm²]
Dimensions:		Y	1310.0	[mm]
		Z	1564.0	[mm]
		Weight	6.5	[kN/m]
Distances to neutral axis:	ez	(From bottom)	990.3	[mm]
	Z-ez		573.7	[mm]
	ey	(From left)	655.0	[mm]
	Y-ey		655.0	[mm]
Section moduli:		Wy,min	3.22E+07	[mm³]
		Wy,max	5.57E+07	[mm³]
		Wz,min	9.33E+06	[mm³]
		Wz,max	9.33E+06	[mm³]
Moments of inertia:		Iy	3.19E+10	[mm^4]
		Iz	6.11E+09	[mm^4]
Torsional constant (torsional resistance):		It	2.64E+07	[mm^4]
Radii of gyration:		ry	614.3	[mm]
		rz	268.7	[mm]

α 4.0

$$b_{eff} = 0,3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0,3 \cdot \left(\frac{3000}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 847\ [mm]$$

Project	Barge H-541 Typical web frame 13			
Subject	Beam 4			
Job / Bid no.	Conventional deck beam			
Date	01-Apr-15		Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

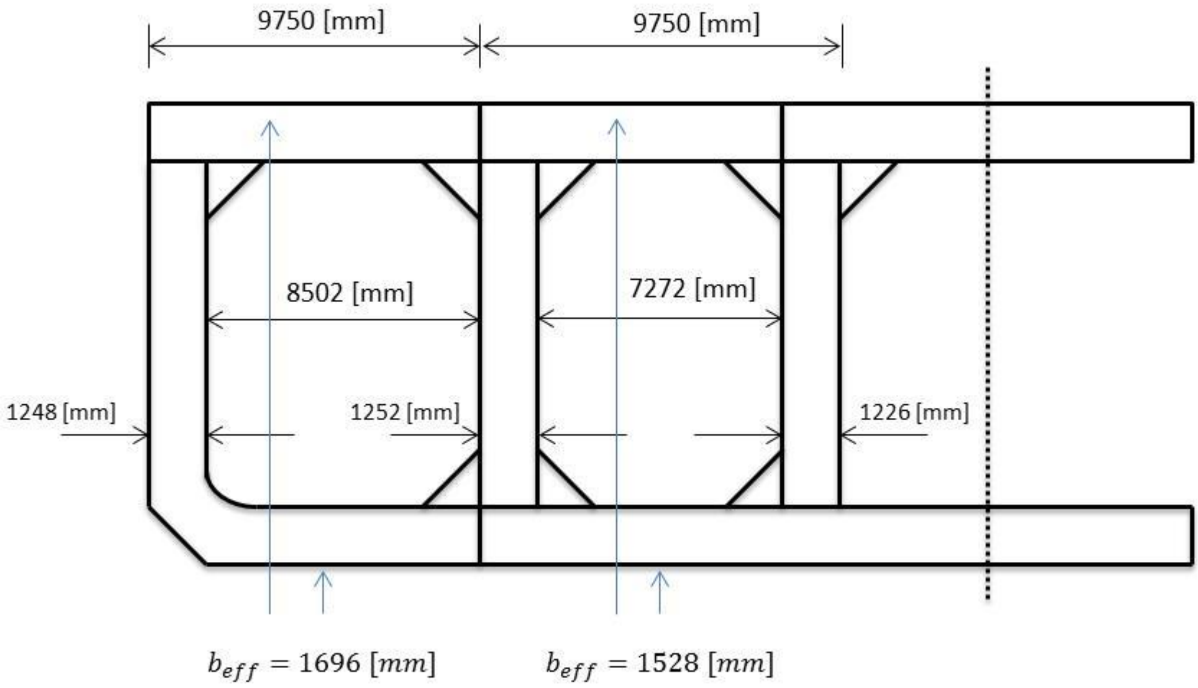
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	847.0	20.0	0.0	16940	300	1.25E+07
2	0.0	375.0	0.0	0	0	1.25E+07
3	20.0	351.0	0.0	7020	7020	1.37E+07
4	20.0	774.0	0.0	15480	15480	7.72E+06
5	350.0	28.0	0.0	9800	420	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	847	1548		49240	23220	

Section Properties

Areas:	AX	49240	[mm²]
	AY	26740	[mm²]
	AZ	23220	[mm²]
Dimensions:	Y	847.0	[mm]
	Z	1548.0	[mm]
	Weight	3.8	[kN/m]
Distances to neutral axis:	ez (From bottom)	801.7	[mm]
	Z-ez	746.3	[mm]
	ey (From left)	423.5	[mm]
	Y-ey	423.5	[mm]
Section moduli:	Wy,min	2.33E+07	[mm³]
	Wy,max	2.50E+07	[mm³]
	Wz,min	2.63E+06	[mm³]
	Wz,max	2.63E+06	[mm³]
Moments of inertia:	Iy	1.86E+10	[mm^4]
	Iz	1.11E+09	[mm^4]
Torsional constant (torsional resistance):	It	7.82E+06	[mm^4]
Radii of gyration:	ry	615.3	[mm]
	rz	150.4	[mm]

D. IPEX Sheets Alternative beams

β1.0 & β2.0



Effective width beams alternative web frame:

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \left(\frac{8502}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 1696\ [mm]$$

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \left(\frac{7272}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 1528\ [mm]$$

β1.0

Project	Barge H-541 Typical webframe		
Subject	Beam one = Beam two		
Job / Bid no.	Double deck barge		
Date	02-Apr-15	Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1696.0*	*32.0*	*0.0*	54272	565	3.53E+07
2	*0.0*	*375.0*	*0.0*	0	0	3.53E+07
3	*28.0*	*260.0*	*0.0*	7280	7280	3.63E+07
4	*28.0*	*780.0*	*0.0*	21840	21840	2.78E+07
5	*0.0*	*235.0*	*0.0*	0	0	2.78E+07
6	*1696.0*	*16.0*	*0.0*	27136	282	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1696	1698		110528	29967	

Section Properties

Areas:		AX	110528	[mm²]
		AY	81408	[mm²]
		AZ	29967	[mm²]
Dimensions:		Y	1696.0	[mm]
		Z	1698.0	[mm]
		Weight	8.5	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1031.0	[mm]
	Z-ez		667.0	[mm]
	ey	(From left)	848.0	[mm]
	Y-ey		848.0	[mm]
Section moduli:		Wy,min	5.43E+07	[mm³]
		Wy,max	8.40E+07	[mm³]
		Wz,min	2.30E+07	[mm³]
		Wz,max	2.30E+07	[mm³]
Moments of inertia:		Iy	5.60E+10	[mm^4]
		Iz	1.95E+10	[mm^4]
Torsional constant (torsional resistance):		It	2.85E+07	[mm^4]
Radii of gyration:		ry	711.8	[mm]
		rz	420.2	[mm]

β2.0

Project	Barge H-541 Typical Webframe				
Subject	Beam beta				
Job / Bid no.	Job / Bid no.				
Date	13-May-15		Sheet	1	

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1528.0*	*32.0*	*0.0*	48896	565	3.22E+07
2	*0.0*	*375.0*	*0.0*	0	0	3.22E+07
3	*28.0*	*1040.0*	*0.0*	29120	29120	2.48E+07
4	*0.0*	*235.0*	*0.0*	0	0	2.48E+07
5	*1528.0*	*16.0*	*0.0*	24448	282	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1528	1698		102464	29967	

Section Properties

Areas:		AX	102464	[mm²]
		AY	73344	[mm²]
		AZ	29967	[mm²]
Dimensions:		Y	1528.0	[mm]
		Z	1698.0	[mm]
		Weight	7.9	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1023.7	[mm]
	Z-ez		674.3	[mm]
	ey	(From left)	764.0	[mm]
	Y-ey		764.0	[mm]
Section moduli:		Wy,min	4.97E+07	[mm³]
		Wy,max	7.55E+07	[mm³]
		Wz,min	1.87E+07	[mm³]
		Wz,max	1.87E+07	[mm³]
Moments of inertia:		Iy	5.09E+10	[mm^4]
		Iz	1.43E+10	[mm^4]
Torsional constant (torsional resistance):		It	2.64E+07	[mm^4]
Radii of gyration:		ry	704.8	[mm]
		rz	373.2	[mm]

β 3.0

$$b_{eff} = 0{,}3 \cdot \left(\frac{L}{b}\right)^{\frac{2}{3}} \cdot b = 0{,}3 \cdot \left(\frac{3000}{2500}\right)^{\frac{2}{3}} \cdot 2500 = 847\ [mm]$$

Project	Barge H-541 Typical webframe		
Subject	Beam one = Beam two		
Job / Bid no.	Double deck barge		
Date	03-Apr-15	Sheet	1

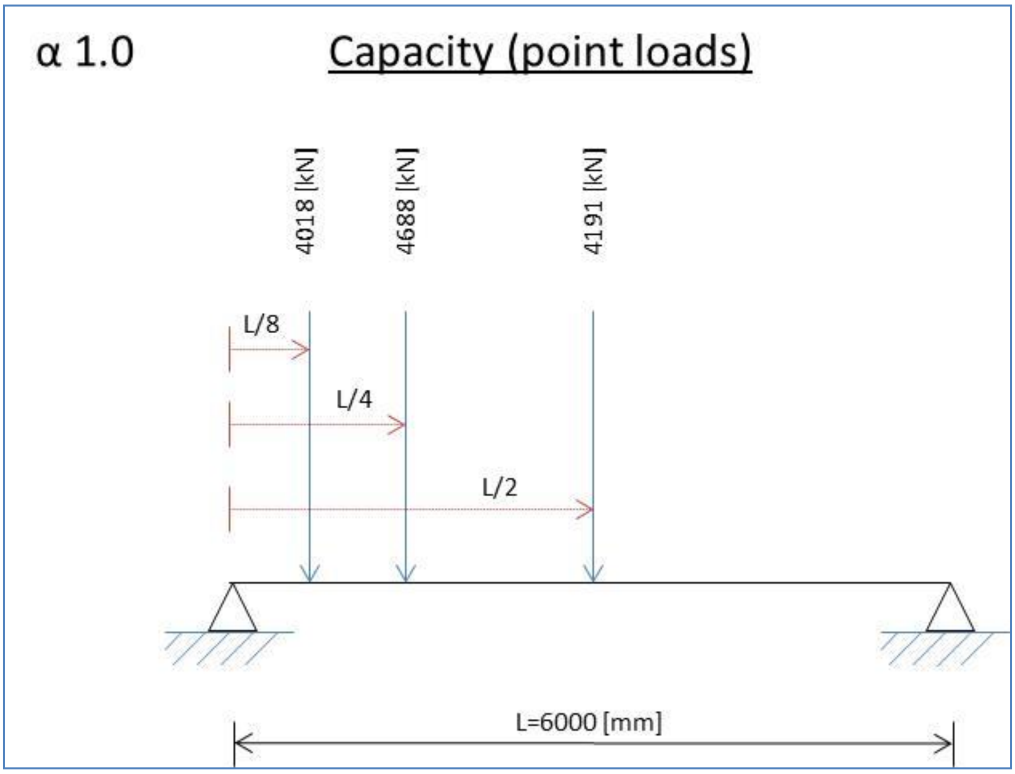
PLATE GIRDER PROPERTIES

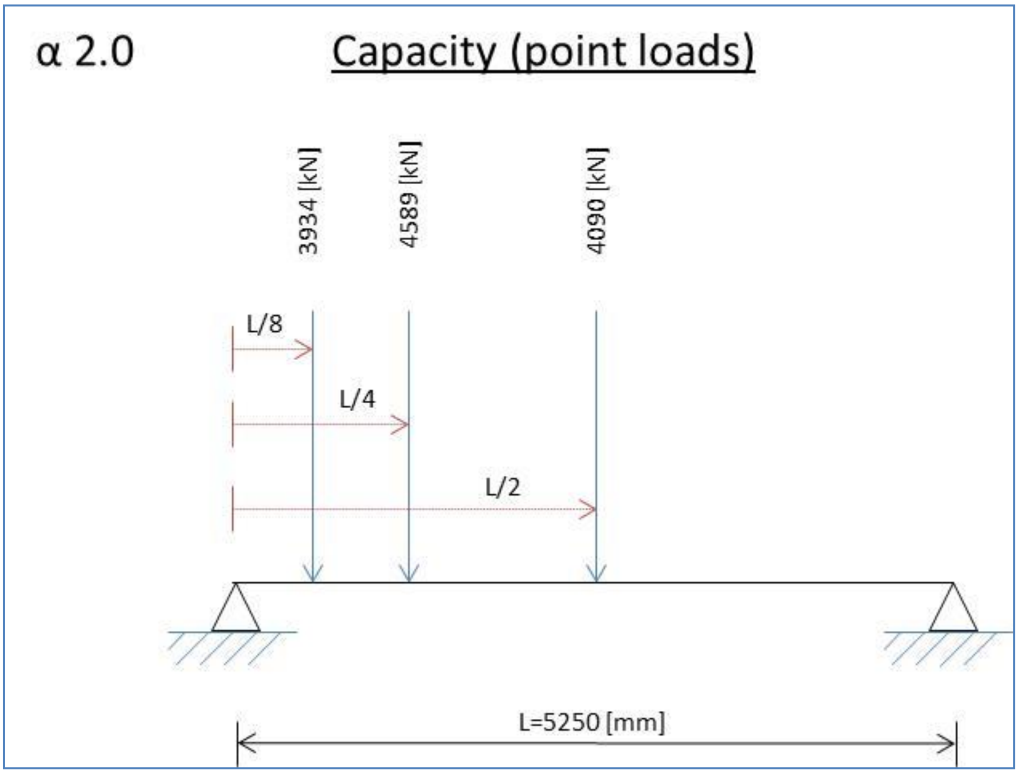
Plategirder Description

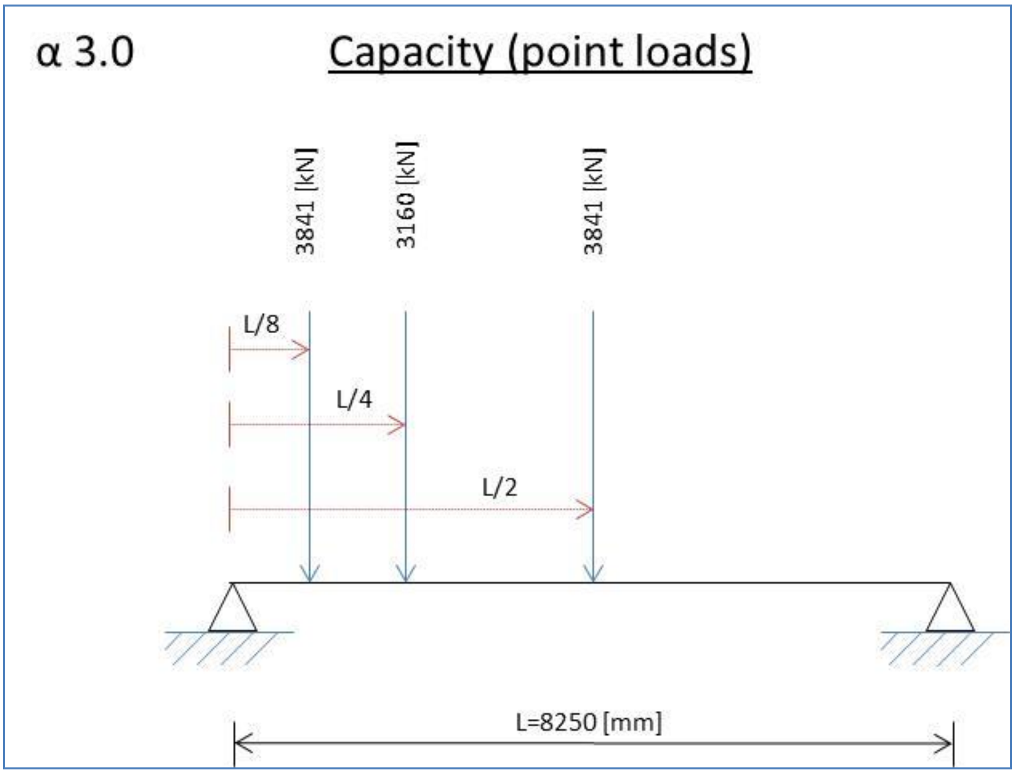
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	847.0	20.0	0.0	16940	252	1.37E+07
2	0.0	375.0	0.0	0	0	1.37E+07
3	20.0	423.0	0.0	8460	8460	1.55E+07
4	20.0	617.0	0.0	12340	12340	1.17E+07
5	0.0	235.0	0.0	0	0	1.17E+07
6	847.0	16.0	0.0	13552	202	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	847	1686		51292	21254	

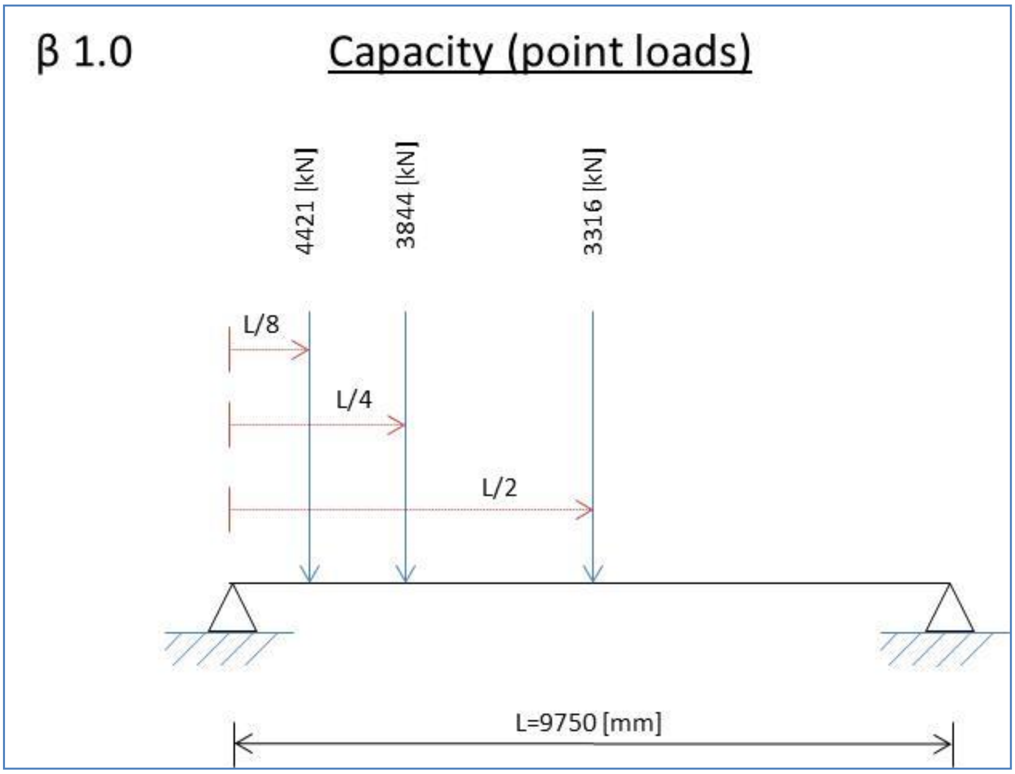
Section Properties

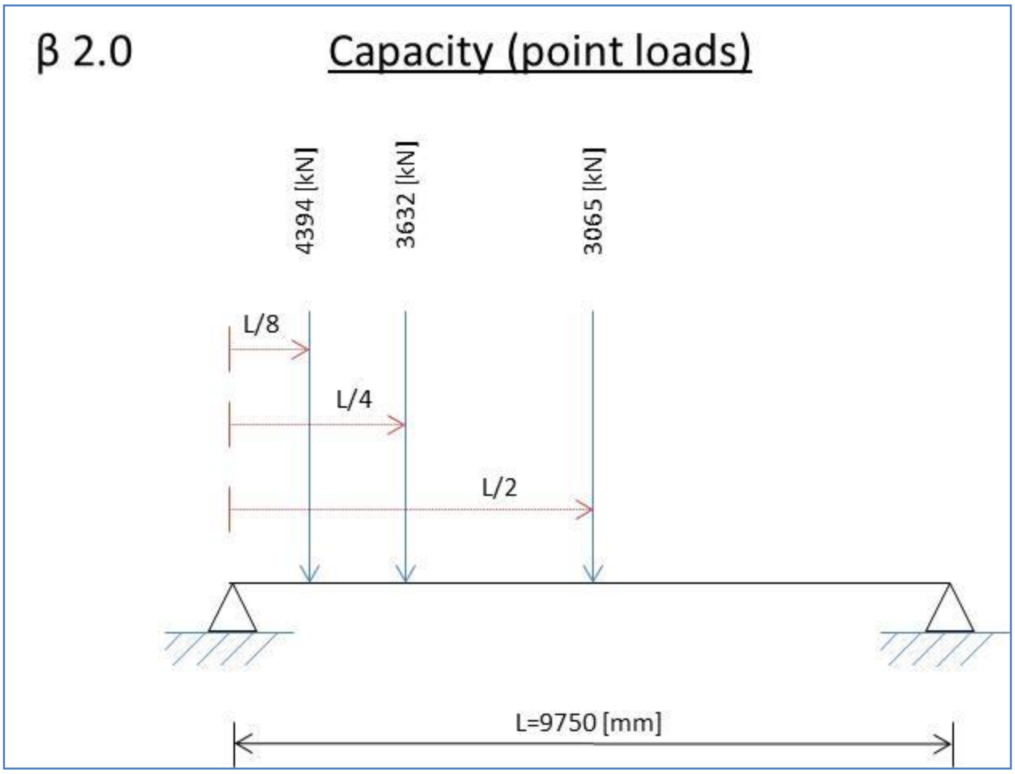
Areas:	AX	51292	[mm²]
	AY	30492	[mm²]
	AZ	21254	[mm²]
Dimensions:	Y	847.0	[mm]
	Z	1686.0	[mm]
	Weight	3.9	[kN/m]
Distances to neutral axis:	ez (From bottom)	868.3	[mm]
	Z-ez	817.7	[mm]
	ey (From left)	423.5	[mm]
	Y-ey	423.5	[mm]
Section moduli:	Wy,min	2.67E+07	[mm³]
	Wy,max	2.83E+07	[mm³]
	Wz,min	4.31E+06	[mm³]
	Wz,max	4.31E+06	[mm³]
Moments of inertia:	Iy	2.32E+10	[mm^4]
	Iz	1.82E+09	[mm^4]
Torsional constant (torsional resistance):	It	6.19E+06	[mm^4]
Radii of gyration:	ry	671.9	[mm]
	rz	188.6	[mm]

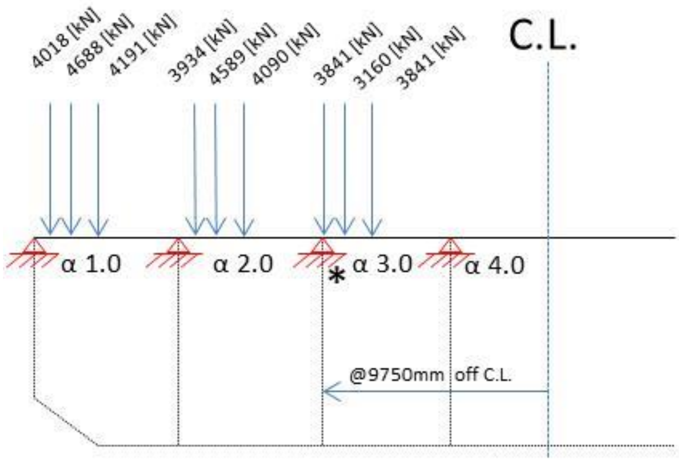

α 1.0
Capacity (point loads)
4018 [kN]
4688 [kN]
4191 [kN]
L/8
L/4
L/2
L=6000 [mm]


α 2.0
Capacity (point loads)
3934 [kN]
4589 [kN]
4090 [kN]
L/8
L/4
L/2
L=5250 [mm]

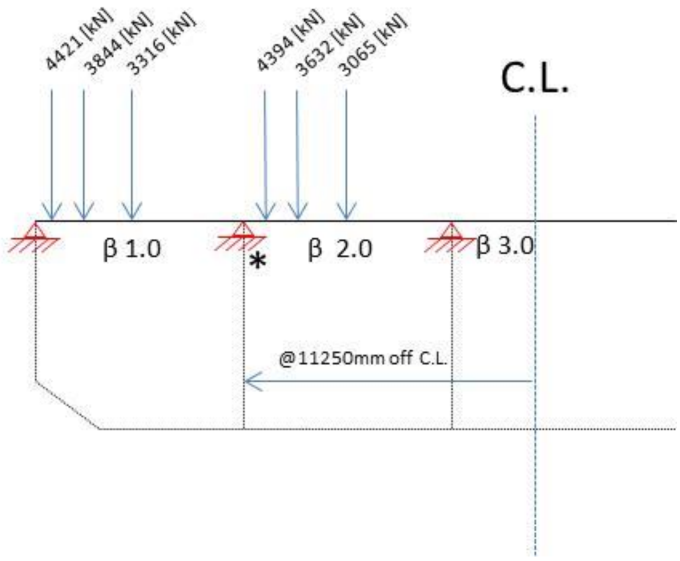

α 3.0
Capacity (point loads)
3841 [kN]
3160 [kN]
3841 [kN]
L/8
L/4
L/2
L=8250 [mm]


β 1.0
Capacity (point loads)
4421 [kN]
3844 [kN]
3316 [kN]
L/8
L/4
L/2
L=9750 [mm]


β 2.0
Capacity (point loads)
4394 [kN]
3632 [kN]
3065 [kN]
L/8
L/4
L/2
L=9750 [mm]



4018 [kN]
4688 [kN]
4191 [kN]
3934 [kN]
4589 [kN]
4090 [kN]
3841 [kN]
3160 [kN]
3841 [kN]
C.L.
α 1.0
α 2.0
α 3.0
α 4.0
*
@9750mm off C.L.



4421 [kN]
3844 [kN]
3316 [kN]
4394 [kN]
3632 [kN]
3065 [kN]
C.L.
β 1.0
β 2.0
β 3.0
*
@11250mm off C.L.

E. Increase web height (shear reduction)

Project	Example shear increase			
Subject	I beam			
Job / Bid no.				
Date	07-Apr-15		Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1000.0	20.0	0.0	20000	400	1.02E+07
2	20.0	500.0	0.0	10000	10000	1.27E+07
3	20.0	500.0	0.0	10000	10000	1.02E+07
4	1000.0	20.0	0.0	20000	400	0.00E+00
5	0.0	0.0	0.0	0	0	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1000	1040		60000	20800	

Section Properties

Areas:		AX	60000	[mm²]
		AY	40000	[mm²]
		AZ	20800	[mm²]
Dimensions:		Y	1000.0	[mm]
		Z	1040.0	[mm]
		Weight	4.6	[kN/m]
Distances to neutral axis:	ez	(From bottom)	520.0	[mm]
	Z-ez		520.0	[mm]
	ey	(From left)	500.0	[mm]
	Y-ey		500.0	[mm]
Section moduli:		Wy,min	2.32E+07	[mm³]
		Wy,max	2.32E+07	[mm³]
		Wz,min	6.67E+06	[mm³]
		Wz,max	6.67E+06	[mm³]
Moments of inertia:		Iy	1.21E+10	[mm^4]
		Iz	3.33E+09	[mm^4]
Torsional constant (torsional resistance):		It	8.00E+06	[mm^4]
Radii of gyration:		ry	448.6	[mm]
		rz	235.7	[mm]

Project	Example shear increase			
Subject	I beam			
Job / Bid no.				
Date	07-Apr-15		Sheet	1

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1000.0	20.0	0.0	20000	400	1.52E+07
2	20.0	750.0	0.0	15000	15000	2.08E+07
3	20.0	750.0	0.0	15000	15000	1.52E+07
4	1000.0	20.0	0.0	20000	400	0.00E+00
5	0.0	0.0	0.0	0	0	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1000	1540		70000	30800	

Section Properties

Areas:		AX	70000	[mm²]
		AY	40000	[mm²]
		AZ	30800	[mm²]
Dimensions:		Y	1000.0	[mm]
		Z	1540.0	[mm]
		Weight	5.4	[kN/m]
Distances to neutral axis:	ez (From bottom)		770.0	[mm]
	Z-ez		770.0	[mm]
	ey (From left)		500.0	[mm]
	Y-ey		500.0	[mm]
Section moduli:		Wy,min	3.73E+07	[mm³]
		Wy,max	3.73E+07	[mm³]
		Wz,min	6.67E+06	[mm³]
		Wz,max	6.67E+06	[mm³]
Moments of inertia:		Iy	2.87E+10	[mm^4]
		Iz	3.33E+09	[mm^4]
Torsional constant (torsional resistance):		It	9.33E+06	[mm^4]
Radii of gyration:		ry	640.7	[mm]
		rz	218.3	[mm]

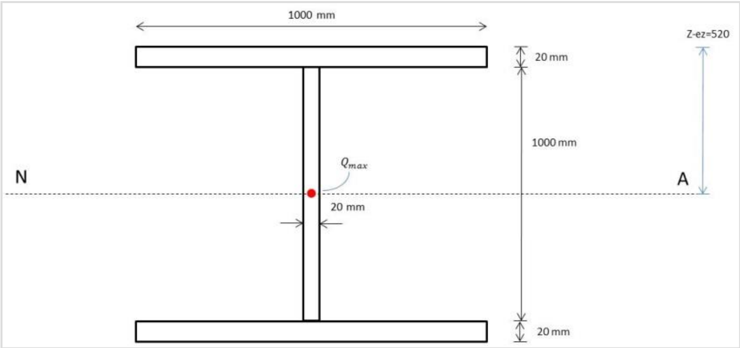


Figure II.E.I

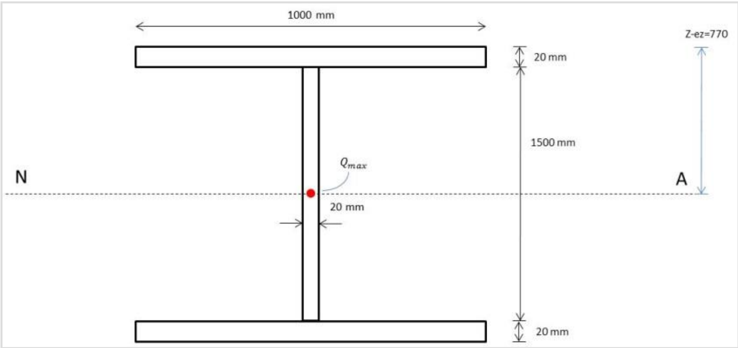


Figure II.E.II

Assume V = 500 [kN]

$$\tau = \frac{V \cdot Q}{t \cdot I_y}$$

Figure II.E.I:

Maximum statical moment occurs on the neutral axis

Q_{max} = (510·1000·20)+(250·20·500) = 1,27·10^7 [mm^3]

I_y=1,21·10^{10} [mm^4]

Z-ez = 520 [mm]

$$\tau = \frac{(500 \cdot 10^3) \cdot (1{,}27 \cdot 10^7)}{20 \cdot (1{,}21 \cdot 10^{10})} = 26{,}24 \left[\frac{N}{mm^2}\right]$$

Figure II.E.II:

Maximum statical moment occurs on the neutral axis

Q_{max}=(760·1000·20) + (375·20·750)=2,08·10^7 [mm^3]

I_y=2,87·10^{10} [mm^4]

Z-ez = 770 [mm]

$$\tau = \frac{(500 \cdot 10^3) \cdot (2{,}08 \cdot 10^7)}{20 \cdot (2{,}87 \cdot 10^{10})} = 18{,}12 \left[\frac{N}{mm^2}\right]$$

The amount of shear is dependent on the web height of the beams. When the web height increases, the statical moment will increase, and the area moment of inertia will relatively increase more. This will cause the amount of shear stress to decrease because the shear force times the statical moment will now be divided by a relatively larger number because the area moment of inertia has been increased relatively more. The statical moment of the beam of the enlarged web height has increased as well. However the area moment of inertia has increased relatively more and therefore lower shear stress will occur.

Appendix III

A. Figures

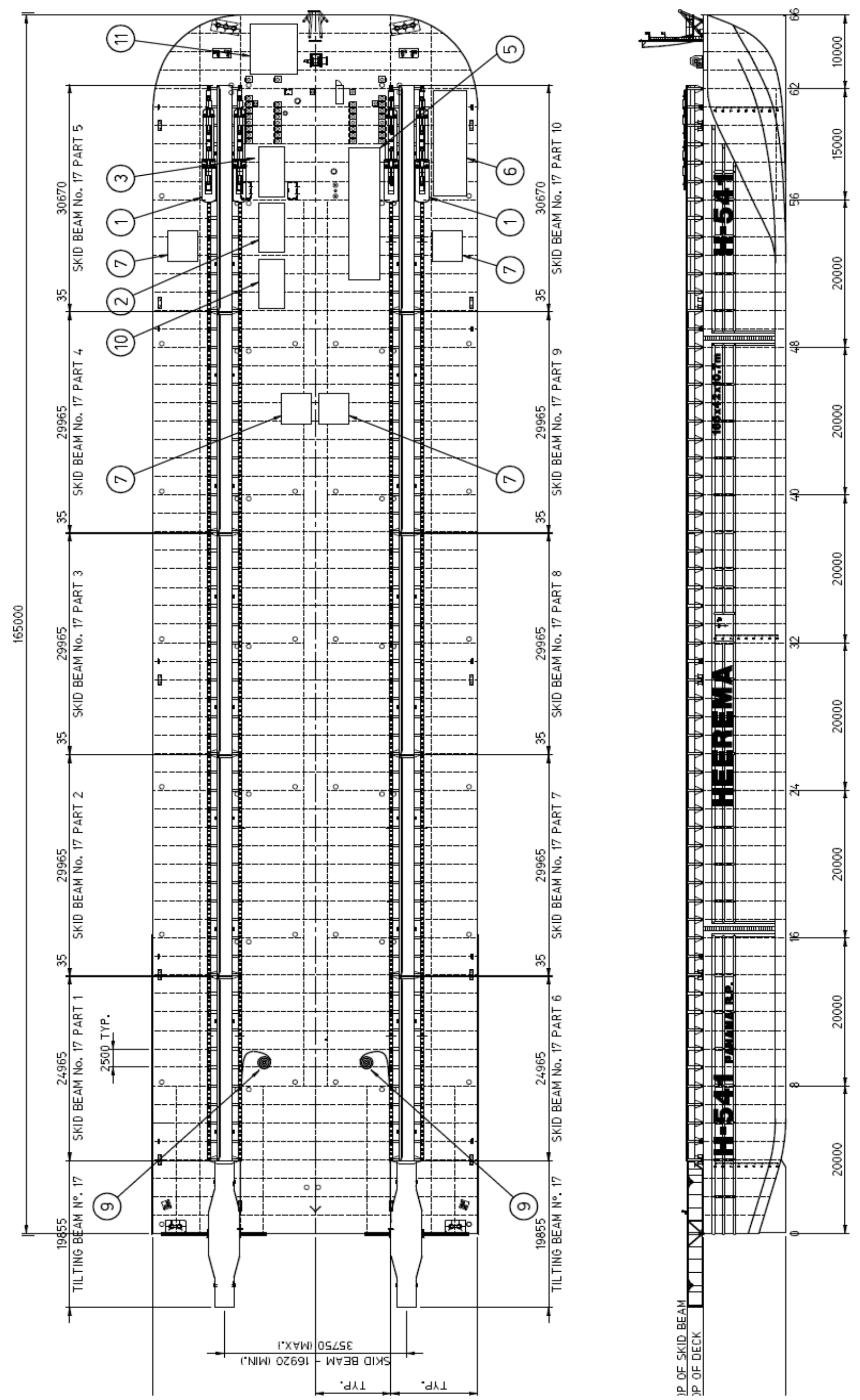


Figure III.A

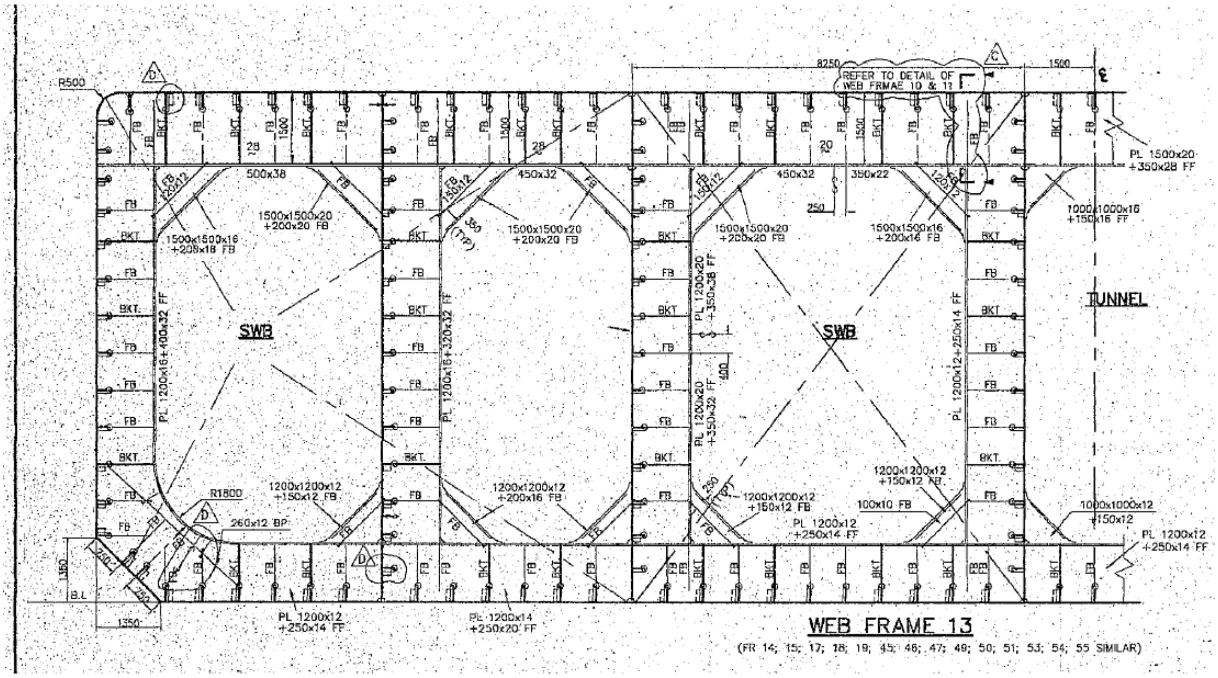


Figure III.B Drawing of a typical web frame 13. This drawing shows half a web frame because the frame is symmetrical from the center line.

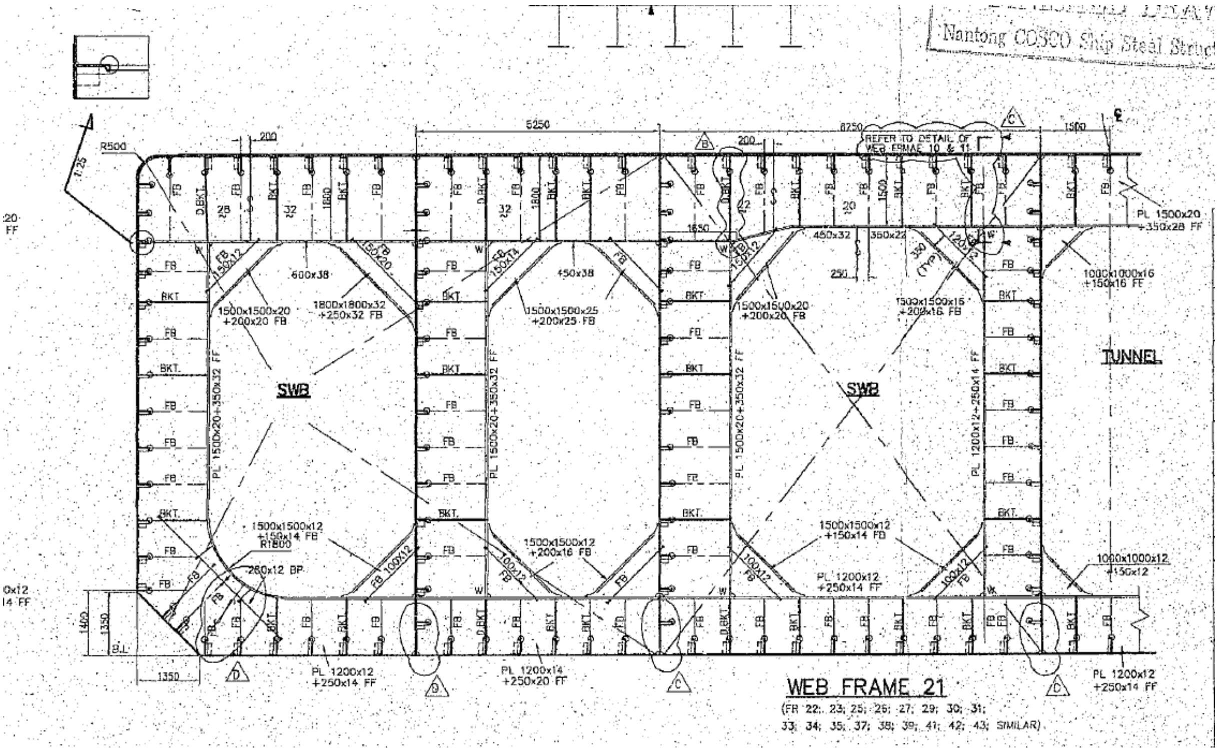


Figure III.C Drawing of a typical web frame 21. This drawing shows half a web frame because the frame is symmetrical from the center line.

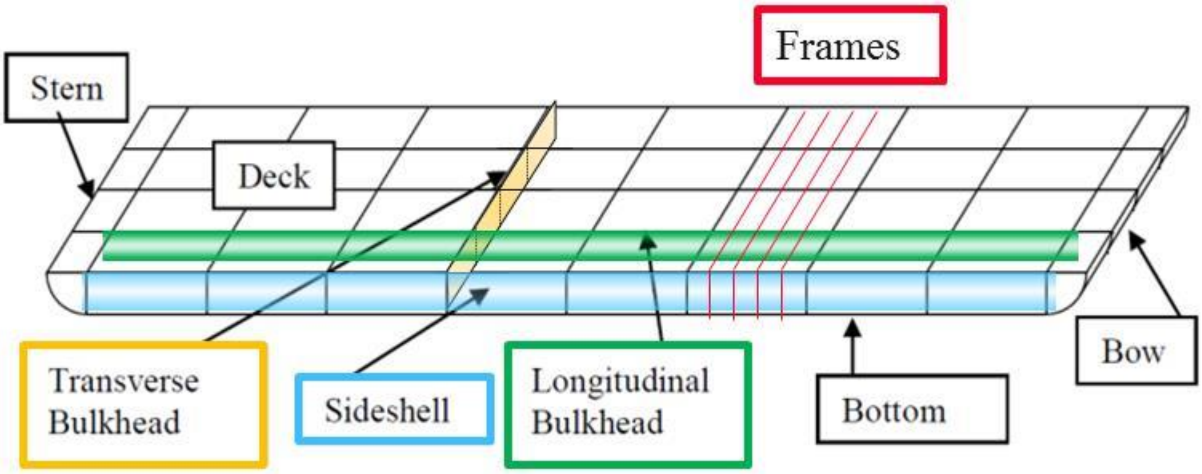


Figure III.D Simplified figure of a barge. Overview of parts and plate fields a barge consists of. Bulkheads, bottom/ -deck plating and side shell are highlighted in order to create a clear view of important parts of a barge.

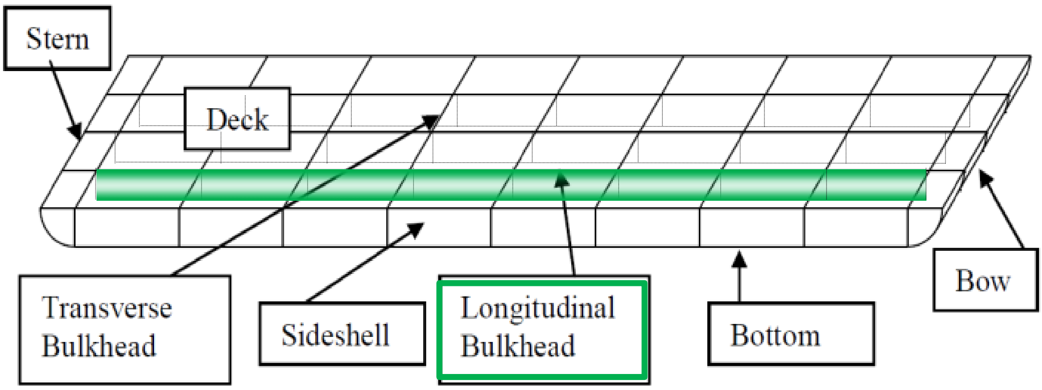


Figure III.E Simplified figure of a barge. Longitudinal bulkhead in this figure is highlighted in this figure.

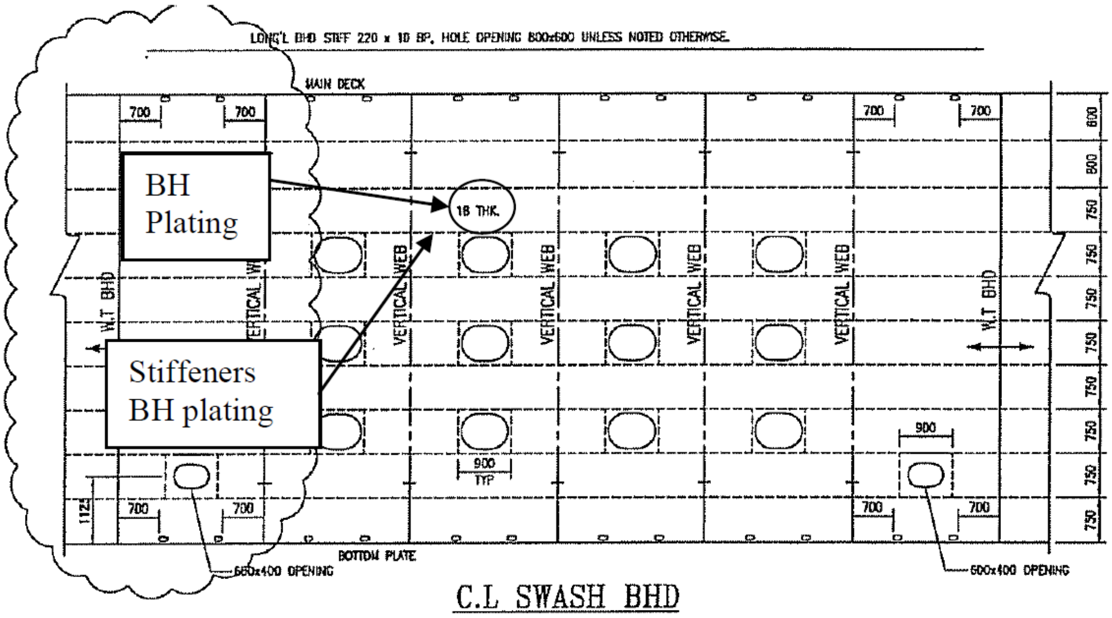


Figure III.F Part of a (Swash) longitudinal bulkhead, Bulkhead plate thickness and thickness are mentioned in the drawings. (Not the H-541)

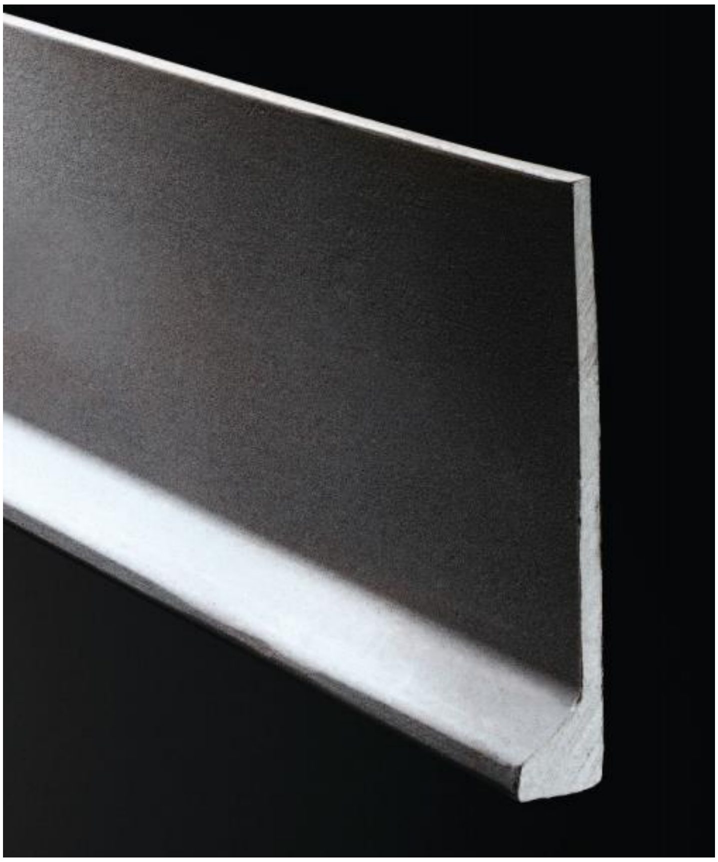


Figure III.G Metric Bulb Flat stiffener [24] (TATA Steel)

Figure III.H Picture of a Grillage and Seafastening. Grillage and seafastening take up static and dynamic transportation forces.

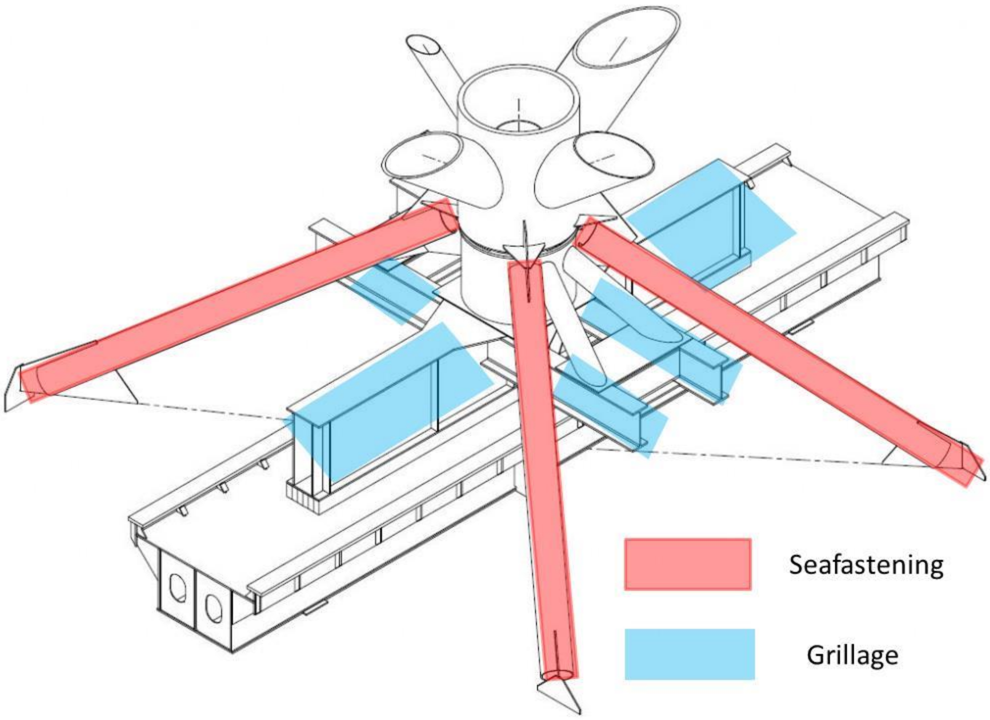


Figure III.I Drawing of a Grillage and Seafastening

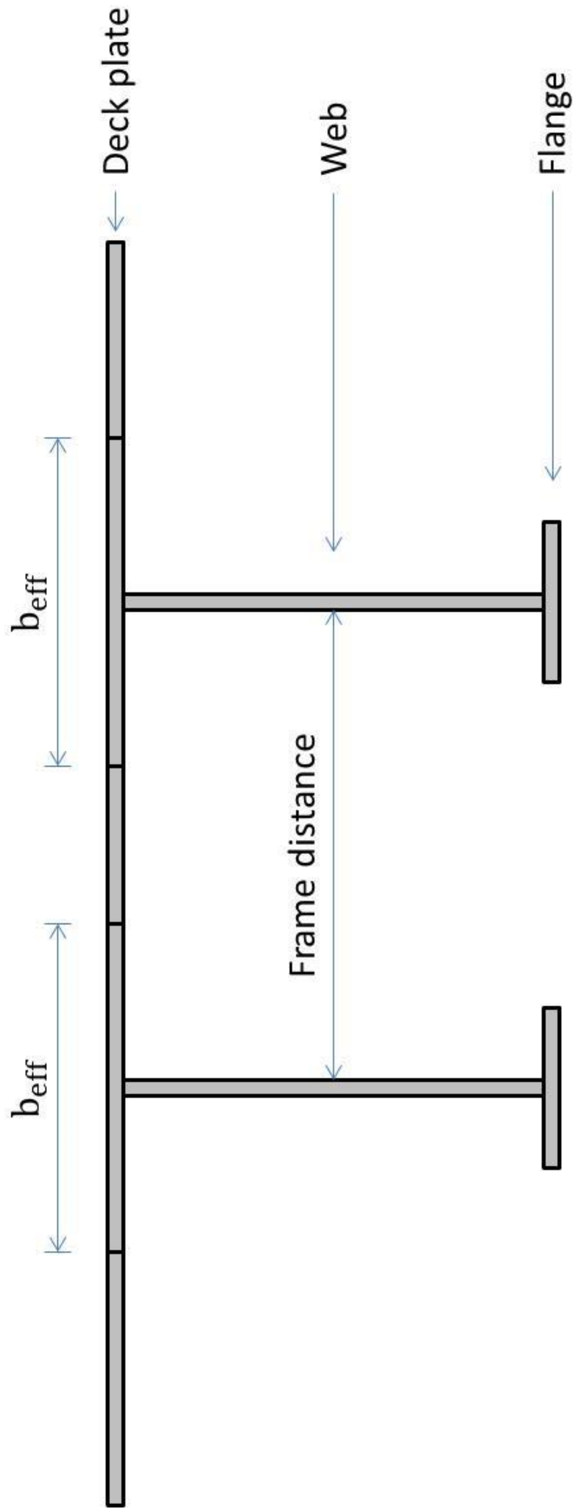


Figure III.J Effective width of beams

Appendix IV

A. Bulkhead plate

If the specific column is removed, the longitudinal bulkhead which the column is attached to has to be removed as well. Because the subject considers the "typical" web frame 13, the bulkhead between part 12 and part 16 (at 15000 [mm] off C.L.) will be taken in account. The reason to take this particular part in account is that the web frames between these parts are all typical 13 web frames. Between this section 3 web frames are positioned, so if the weight reduction of the material between part 12 and 16 is determined, the total weight reduction can be dived over 3 web frames.

MARINE CONTRACTORS — **Material Take Off** — **Sheet 1 of 5**

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PROFILE	FB200x12	10,000							10.000	10.000	12	23.2	2,788	2,788	nr. 4
2	PLATE	PLATE					24	3,950	950	3.753	3.753	3	188.4	2,121	2,121	nr. 1
3	PLATE	PLATE					16	10,000	10,700	107.000	95.743	1	125.6	13,439	12,025	nr. 2
4	PROFILE	FB200x12	5,000							5.000	5.000	2	23.2	232	232	nr. 3

Figure IV.A MTO for bulkhead plate, numbers in "remarks" match with figure IV.F.1

B. Stringer

The stringer can be seen as a horizontal bracket. Because an entire column and a longitudinal bulkhead will be removed, the stringers which are attached to the longitudinal bulkhead will be removed to. The brackets and all other connections that are positioned at the same height as the stringers are taken into account in this MTO sheet. The dimensions of the stringer and the other parts are shown in figure () in appendix ().

MARINE CONTRACTORS — **Material Take Off** — **Sheet 2 of 5**

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						12	2,500	750	1.875	1.875	2	94.2	353	353	nr. 1.1
2	PLATE						12	2,500	200	0.500	0.500	2	94.2	94	94	nr. 1.2
3	PLATE						12	1,600	1,200	1.920	1.920	2	94.2	362	362	nr. 2.1
4	PLATE						16	1,600	250	0.400	0.400	2	125.6	100	100	nr. 2.2
5	PLATE						12	1,000	400	0.400	0.272	2	94.2	75	51	nr. 3.1
6	PLATE						12	1,224	100	0.122	0.122	2	94.2	23	23	nr. 3.2
7	PLATE						12	900	900	0.810	0.405	2	94.2	153	76	nr. 4.1
8	PLATE						12	1,273	150	0.191	0.191	2	94.2	36	36	nr. 4.2
9	PLATE						12	750	750	0.563	0.280	2	94.2	106	53	nr. 5.0
10	PLATE						12	1,000	800	0.800	0.480	4	94.2	301	181	nr. 6.1
11	PLATE						12	1,325	120	0.159	0.159	4	94.2	60	60	nr. 6.2
12	PLATE						12	438	500	0.219	0.145	2	94.2	41	27	nr. 7.1
13	PLATE						12	609	100	0.061	0.056	2	94.2	11	11	nr. 7.2

Figure IV.B MTO for stringer, numbers in "remarks" match with figure IV.F.2

C. Column

This is the MTO sheet for the column which is positioned at 15000 [mm] of the center line. The column has a web that is 16 [mm] thick and 8000 [mm] high. The web is equipped with a flange of 32 [mm] thick and 8000 [mm] high. To increase strength and avoid buckling the column is equipped with brackets and flat bar. All these parts are taken into account.

Material Take Off — **Sheet 3 of 5**

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						32	8,000	320	2.560	2.560	3	251.2	1,929	1,929	nr. 1.1
2	PLATE						16	8,000	1,200	9.600	9.600	3	125.6	3,617	3,617	nr. 1.2
3	PLATE						12	965	150	0.145	0.145	18	94.2	245	245	nr. 2.0
4	PLATE						12	965	400	0.386	0.386	9	94.2	327	327	nr. 3.1
5	PLATE						12	1,264	100	0.126	0.126	9	94.2	107	107	nr. 3.2

Figure IV.C MTO for column, numbers in "remarks" match with figure IV.F.3 in appendix IV.H

D. Brackets

The web frames are equipped with brackets. The brackets are used to spread loads more equally into the columns. If the web frame would not have brackets, high point loads would occur in the section where the deck beam is attached to the column. To increase strength of the brackets, the brackets are equipped with flat bars and flanges.

Material Take Off — **Sheet 4 of 5**

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						20	1,500	1,500	2.250	1.125	6	157.0	2,120	1,060	nr. 1.1
2	PLATE						12	1,421	150	0.213	0.213	6	94.2	120	120	nr. 1.2
3	PLATE						20	2,121	200	0.424	0.418	6	157.0	400	394	nr. 1.3
4	PLATE						12	1,200	1,200	1.440	0.720	6	94.2	814	407	nr. 2.1
5	PLATE						10	1,196	100	0.120	0.120	6	78.5	56	56	nr. 2.2
6	PLATE						12	1,697	150	0.255	0.255	3	94.2	72	72	nr. 2.3
7	PLATE						16	1,667	200	0.333	0.333	3	125.6	126	126	nr. 3.0

Figure IV.D MTO for brackets, numbers in "remarks" match with figure IV.F.4 in appendix IV.H

E. Flange beams

Because the flanges will be replaced by a secondary deck, the flanges are included in this MTO sheet. The flanges have their own specific dimensions for every beam because some beams have to be stronger because of load positioning on the barge.

Material Take Off — **Sheet 5 of 5**

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						38	6,000	500	3.000	3.000	3	298.3	2,685	2,685	Beam 1
2	PLATE						32	5,250	450	2.363	2.363	3	251.2	1,780	1,780	Beam 2
3																
4	PLATE						32	3,875	450	1.744	1.744	3	251.2	1,314	1,314	Beam 3
5	PLATE						22	4,375	350	1.531	1.531	3	172.7	793	793	Beam 4
6																
7	PLATE						28	1,500	350	0.525	0.525	3	219.8	346	346	Beam 5

Figure IV.E MTO for flange beams, numbers in "remarks" match with figure IV.F.5 *in appendix IV.H*

F. Summary removed material

Material Take Off — **Summary**

MARINE CONTRACTORS

Rev. 04.9
01-2013

Project:	**Double deck barge**	MTO No.	F:\AFSTUDEREN HEEREMA\Excel bestanden\MTO\[MTO v8 column r
Job no:		Revision	
Subject:	**Weight reduction removal column**	Remarks	
Prepared By:		Checked eng.	

Sheet	MTO No.	Rev.	Subject		Gross Weight [m.T.]	Net Weight [m.T.]
1	**FB**	**0**	**LONG.BH. & STIFF**	**0**	18.581	17.167
2	**Stringer**	**0**	**Stringer**	**0**	1.717	1.428
3	**COLUMN**	**0**	**COLUMN**	**0**	6.226	6.226
4	**VERTICAL BRACKET**	**0**	**VERTICAL BRACKETS**	**0**	3.707	2.235
5	**FLANGE BEAMS**	**0**	**FLANGE BEAMS**	**0**	6.919	6.919
					-	-
Gross weight only to be used as a check for Net weight.		Net weight is true weight of items on drawing.		**Total**	37.150	33.975

Figure IV.F

G. Added material

Material Take Off — **Sheet 1 of 3**

MARINE CONTRACTORS

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PROFILE	FB200x12	10,000							10.000	10.000	25	23.2	5,809	5,809	
2																
3																

Figure IV.G.I Flat bulbs

Material Take Off — **Sheet 2 of 3**

MARINE CONTRACTORS

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						16	21,000	10,000	210.000	210.000	1	125.6	26,376	26,376	thickness = 16mm
2																

Figure IV.G.II Double deck plate

Material Take Off — **Sheet 3 of 3**

MARINE CONTRACTORS

Pos No.	Description	Profile / Item Type	Profile / Item Length (mm)	Pipe / Bar O.D. (mm)	Pipe / Bar W.T. (mm)	Pipe / Bar Net Length (mm)	Plate/Sq.Bar/Grating/Wood THK. (mm)	Plate/Sq.Bar/Grating/Wood Length (mm)	Plate/Sq.Bar/Grating/Wood Width (mm)	Gross Length (m) Area (m²)	Calc Length (m) Area (m²)	Req'd	Unit Weight (kg) / (kg/m3) (kg/m) / (kg/m²)	Gross Weight * (kg)	Net Weight ** (kg)	Remarks
1	PLATE						28	6,000	200	1.200	1.200	3	219.8	791	791	
2	PLATE						28	5,250	200	1.050	1.050	3	219.8	692	692	

Figure IV.G.III Increase web height

Material Take Off — **Summary**

MARINE CONTRACTORS

Rev. 05.0
03-2014

Project:		MTO No.	\\ALECTO\users$\renesm\AFSTUDEREN R SMIT\PEX NEW\[MTO 16n
Job no:		Revision	
Subject:	**To be added weight**	Remarks	
Prepared By:	**R.Smit**	Checked eng.	

Sheet	MTO No.	Rev.	Subject		Gross Weight [m.T.]	Net Weight [m.T.]
1	**FLAT BULBS**	**0**	**FLAT BULBS**	**0**	5.809	5.809
2	**DOUBLE DECK PLA**	**0**	**DOUBLE DECK PLATE**	**0**	26.376	26.376
3	**INCREASE WEB HEI**	**0**	**INCREASE WEB HEIGHT DECK BEAM**	**0**	1.484	1.484
					-	-
Gross weight only to be used as a check for Net weight.		Net weight is true weight of items on drawing.		**Total**	33.669	33.669

Figure IV.G.IV

H. Drawings MTO

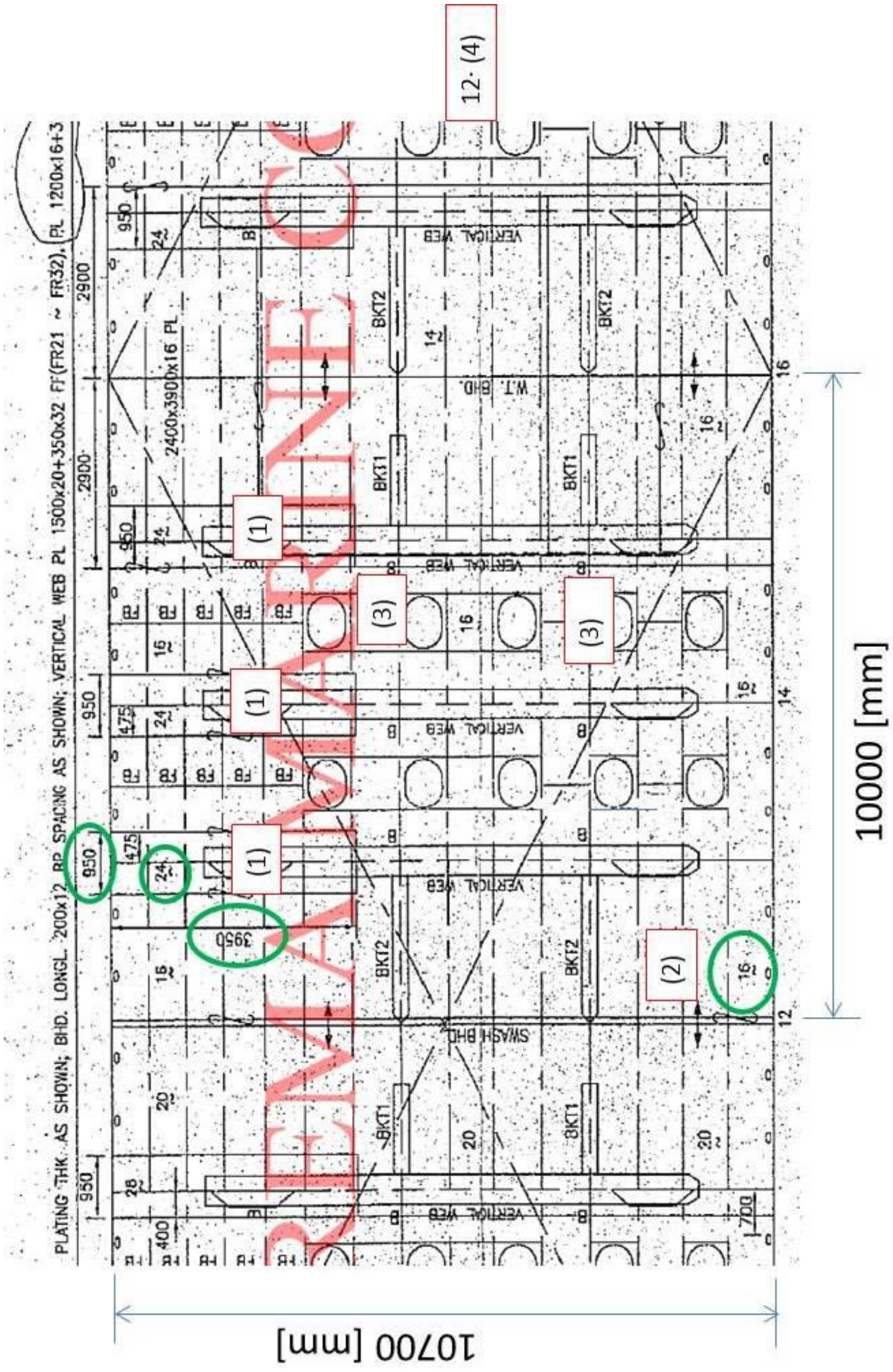


Figure IV.F.1 Longitudinal Bulkhead plating of the bulkhead at 1500 [mm] off center line of the H-541

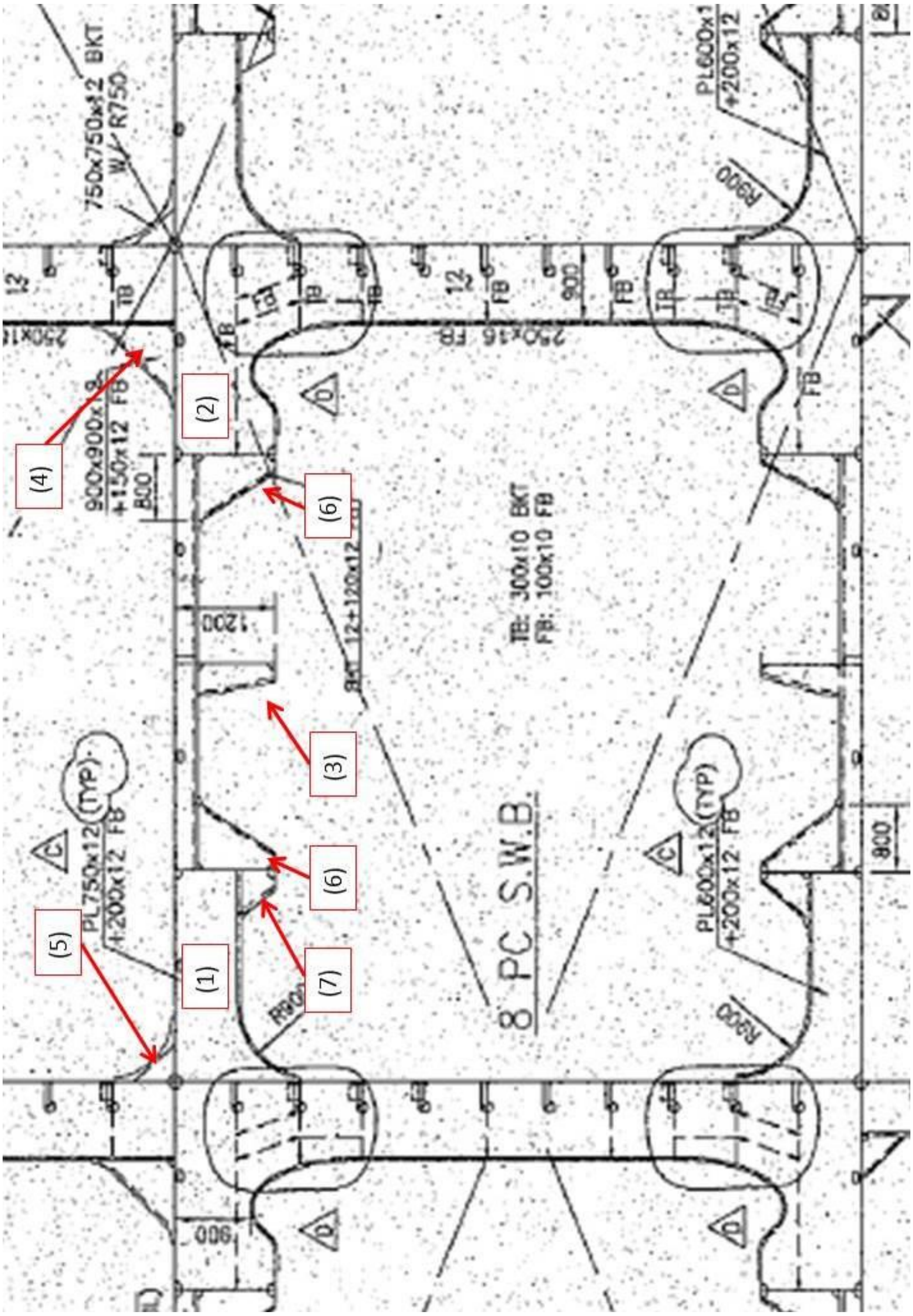


Figure IV.F.2 Stringer

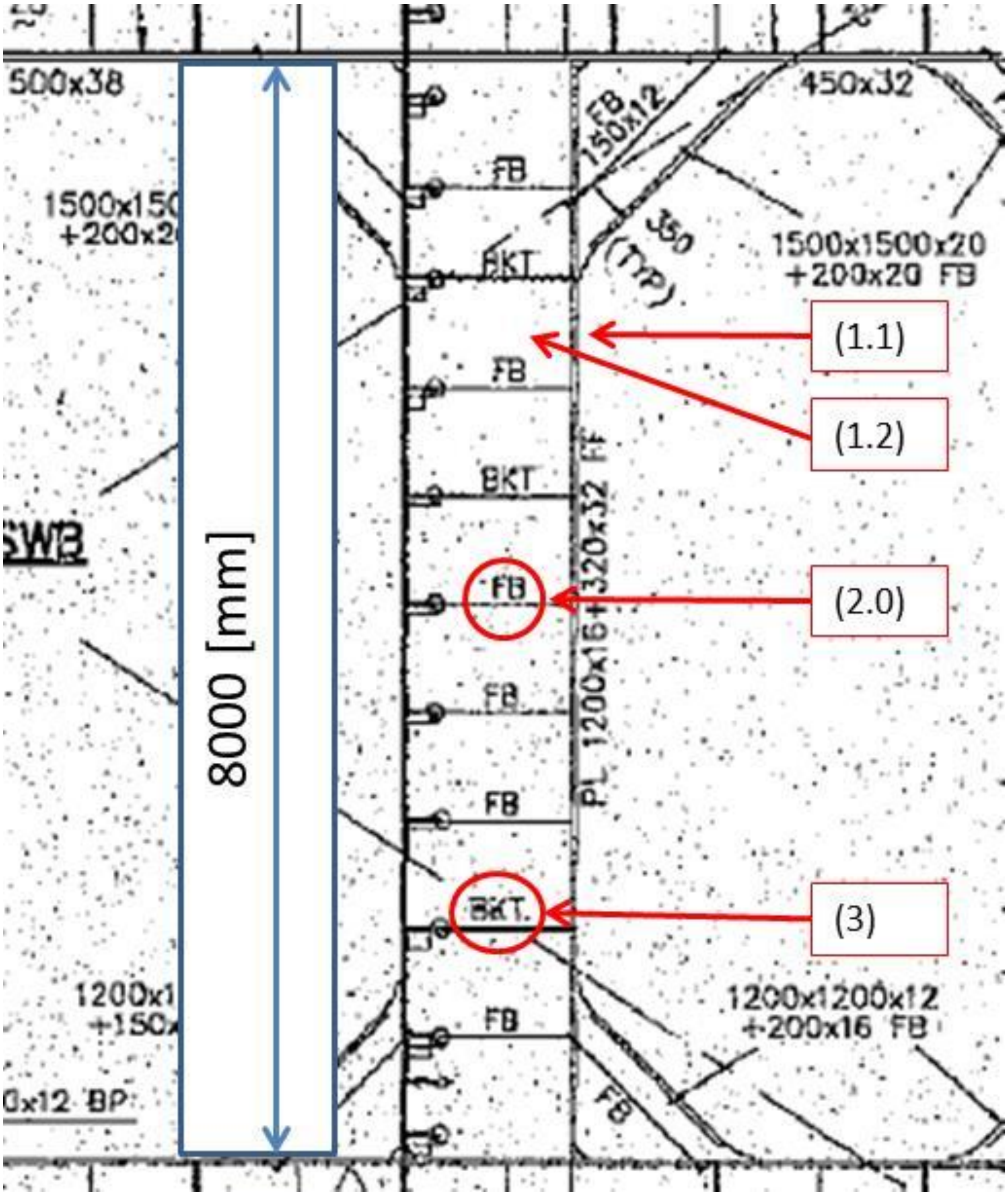


Figure IV.F.3 Column beam (Column at 15000 [mm] of center line of the H-541)

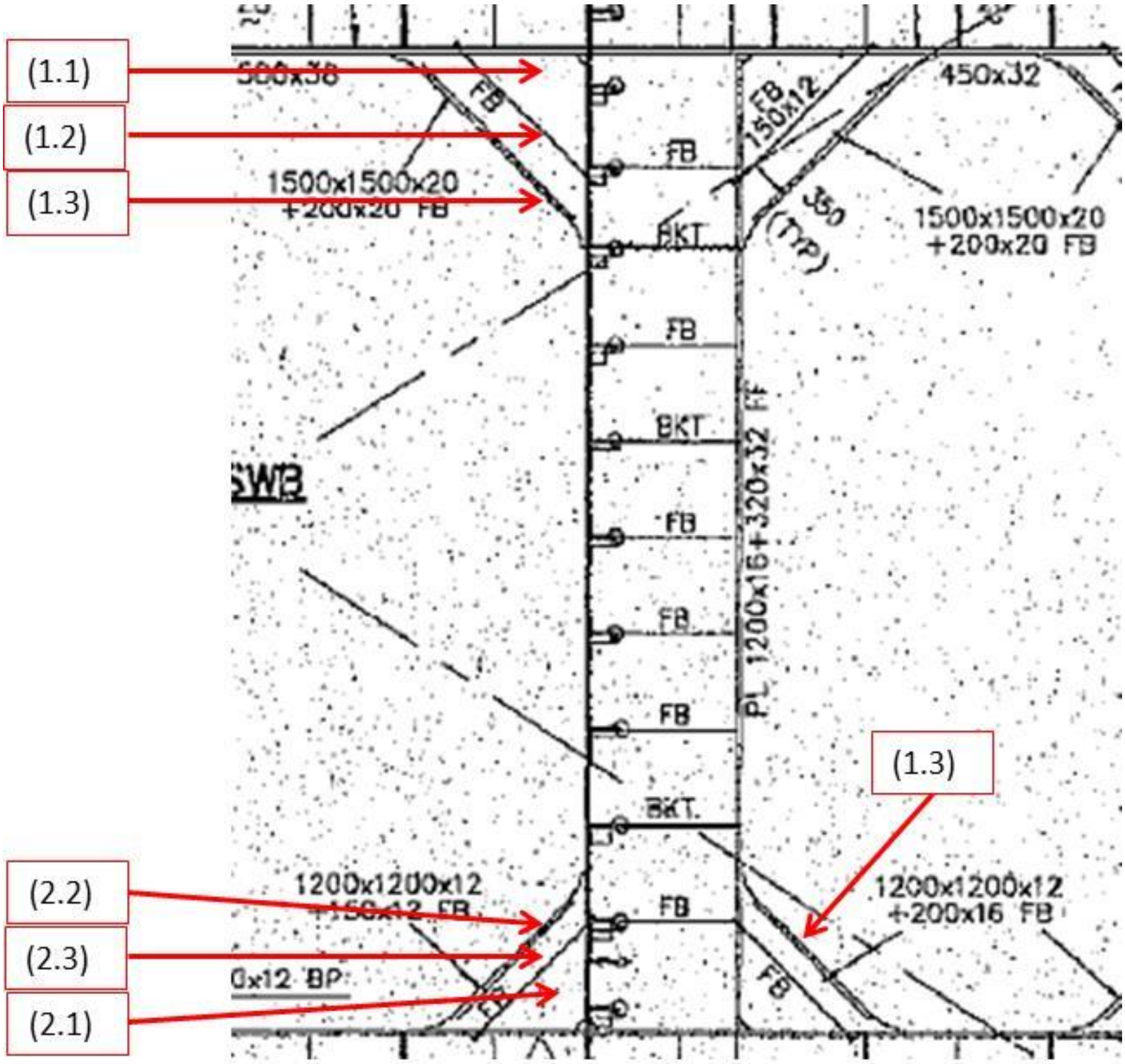


Figure IV.F.4 Brackets column beam (Column at 15000 [mm] of center line of the H-541)

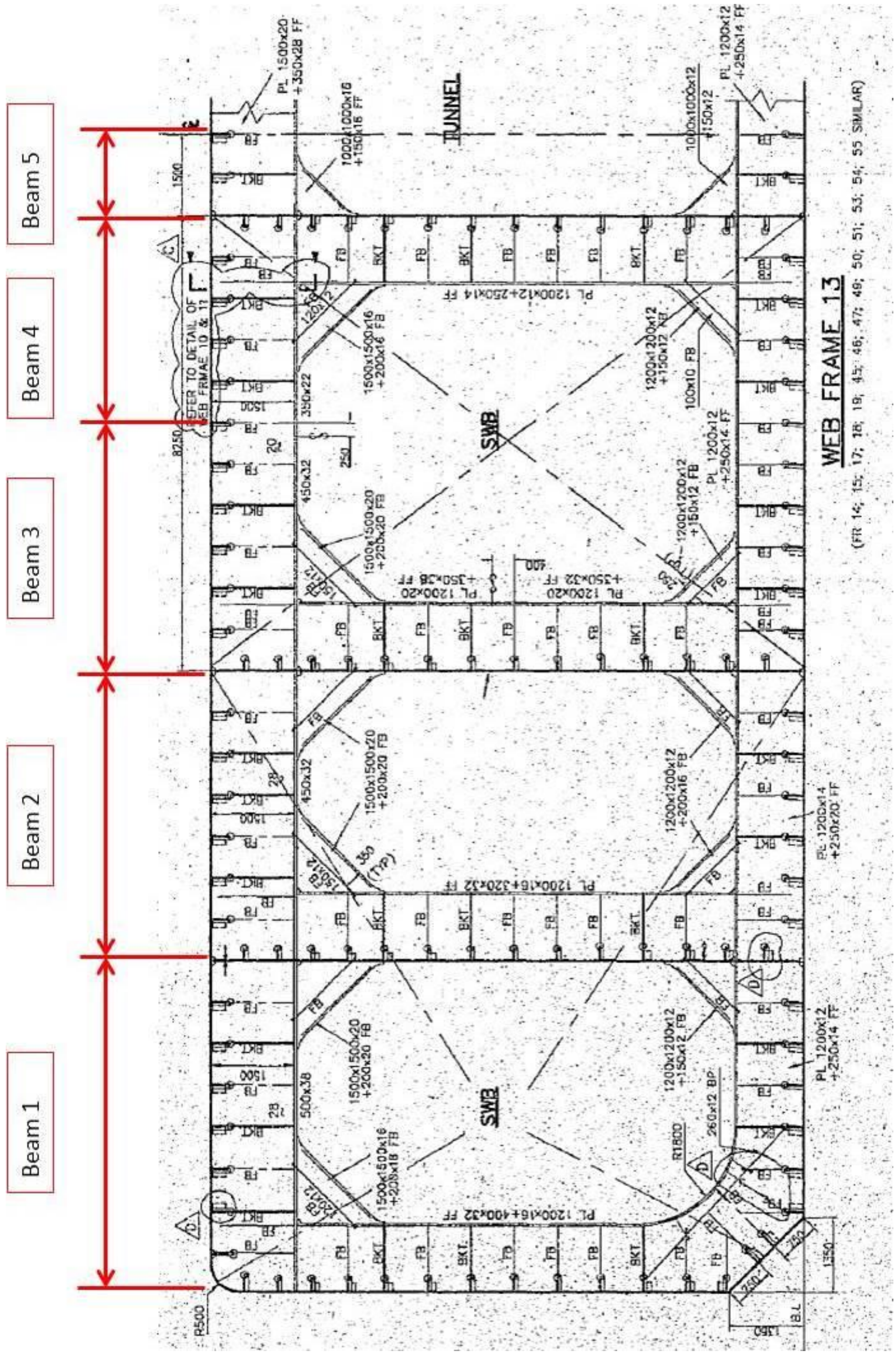


Figure IV.F.5 Top beams of conventional web frame 13 of the H-541

Appendix V

A. Sectional properties member sections SACS

Member	Section
T01	BTRG1
	BTBR1
	BTBM1
T02	BTBM1
	BTBR2
	BTRG2
T03	BTRG3
	BTBR3
	BTBM3
T04	BTBM4
	BTBR4
	BTRG4
T05	BTRG5
	BTBR5
	BTBM5
B02	BBBM1
	BBBR1
	BBRG1
B03	BBRG2
	BBBR2
	BBBM2
	BBBR3
	BBRG3
B04	BBRG4
	BBBR4
	BBBM3
	BBBR5
	BBRG5

Table V.A Naming of the members of the alternative web frame in SACS

Member	L [mm]	b [mm]	b_eff [mm]
T01	8502	2500	1696
T02	8502	2500	1696
T03	7272	2500	1528
T04	7272	2500	1528
T05	3000	2500	847
B02	8502	2500	1696
B03	7278	2500	1529
B04	3000	2500	847

Table V.B Effective width of the members of the alternative web frame SACS model

Distance deck plate/Neutral axis EHT

$$EHT = \frac{\sum(Z - e_z(BTBM) \cdot L_{BTBM})}{\sum L_{BTBM}}$$

Qty. (n)	Section	Z-ez [mm]	*L [mm]*
2	BTBM1	667	*9750*
1	BTBM3	674.3	*5750*
1	BTBM4	652	*4000*
1	BTBM5	817.7	*1500*
	Z average [mm]	**674**	

Table V.C The average neutral axis of the top beam

Distance Bottom plate/Neutral axis EHB

$$EHB = \frac{\sum(Z - e_z(BBBM) \cdot L_{BBBM})}{\sum L_{BBBM}}$$

Qty. (n)	Section	Z-ez	*L*
1	BBBM1	214.5	9750
1	BBBM2	273.0	9750
1	BBBM3	342.9	1500
	Z average [mm]	**251**	

Table V.D The average neutral axis of the bottom beam

Z top beam = 1698 mm
Z bottom beam = 1242 mm

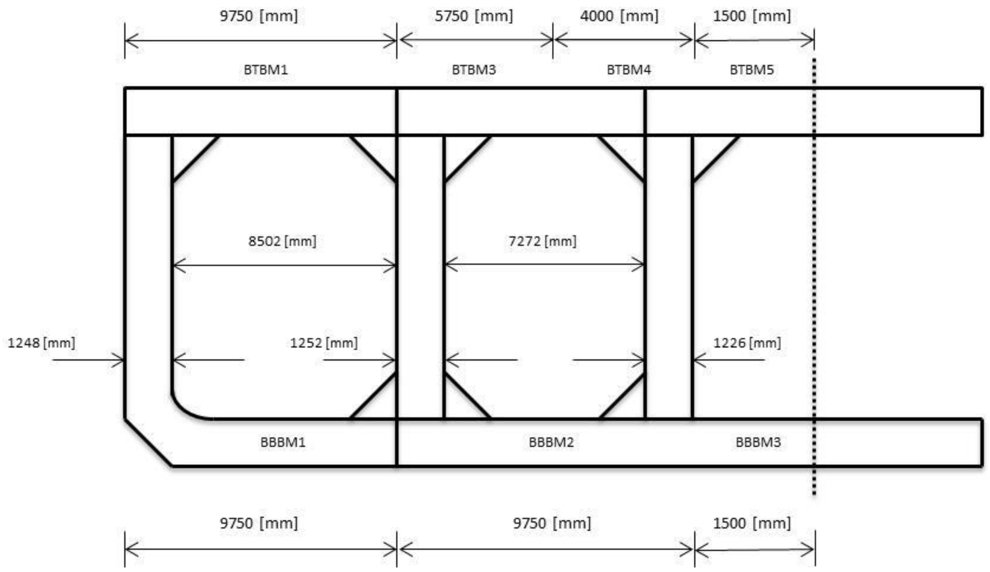
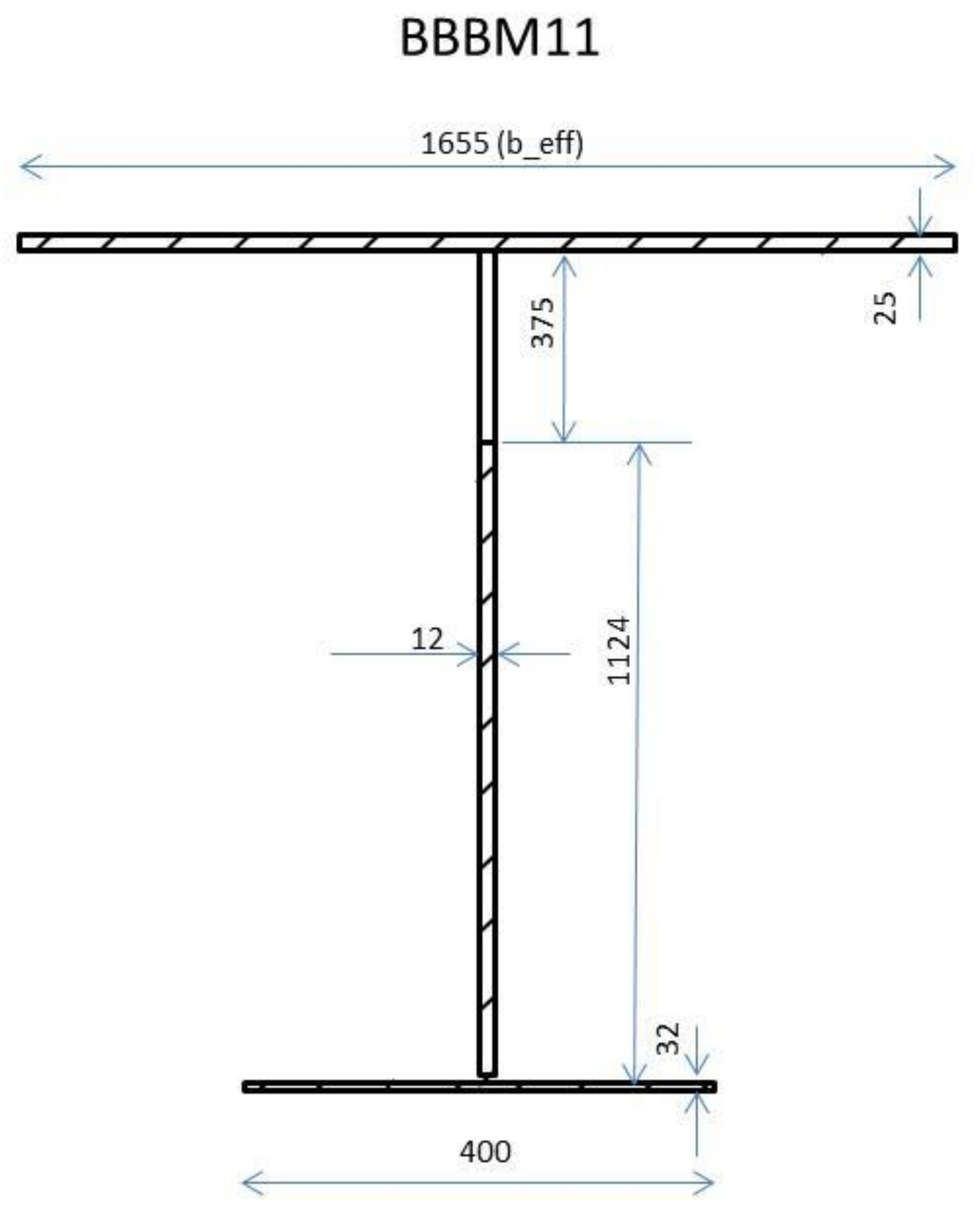


Figure V.A Dimensions of the alternative web frame. These dimensions are required to calculate effective widths and the average neutral axis.

BBBM1 b_{eff} *=1696 [mm]*
BSBM1 b_{eff} *= 1613 [mm]*
BBBM11 $b_{eff} = \frac{1696+1613}{2} = 1655\ [mm]$



BBBM11

Project	Barge H-541		
Subject	BBBM11		
Job / Bid no.	Job / Bid no.		
Date	20-May-15	Sheet	1

PLATE GIRDER PROPERTIES

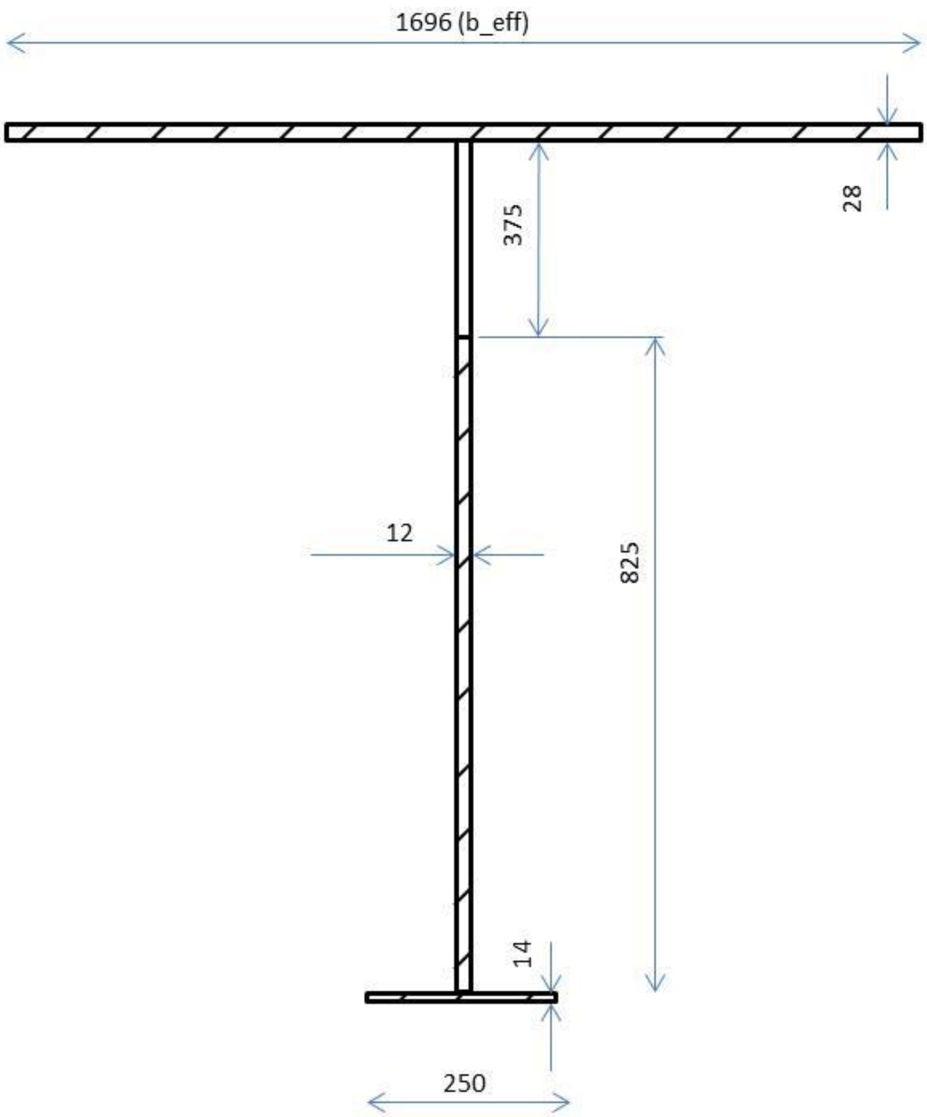
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1655.0	25.0	0.0	41375	225	1.98E+07
2	0.0	375.0	0.0	0	0	1.98E+07
3	12.0	1124.0	0.0	13488	13488	1.34E+07
4	400.0	32.0	0.0	12800	288	0.00E+00
5	0.0	0.0	0.0	0	0	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1655	1556		67663	14001	

Section Properties

Areas:	AX	67663	[mm²]
	AY	54175	[mm²]
	AZ	14001	[mm²]
Dimensions:	Y	1655.0	[mm]
	Z	1556.0	[mm]
	Weight	5.2	[kN/m]
Distances to neutral axis:	ez (From bottom)	1065.3	[mm]
	Z-ez	490.7	[mm]
	ey (From left)	827.5	[mm]
	Y-ey	827.5	[mm]
Section moduli:	Wy,min	2.63E+07	[mm³]
	Wy,max	5.70E+07	[mm³]
	Wz,min	1.16E+07	[mm³]
	Wz,max	1.16E+07	[mm³]
Moments of inertia:	Iy	2.80E+10	[mm^4]
	Iz	9.61E+09	[mm^4]
Torsional constant (torsional resistance):	It	1.36E+07	[mm^4]
Radii of gyration:	ry	643.0	[mm]
	rz	377.0	[mm]

BBBM1



BBBM1

Project	Barge H-541			
Subject	BBBM1			
Job / Bid no.	Double deck barge			
Date	30-Apr-15		Sheet	1

PLATE GIRDER PROPERTIES

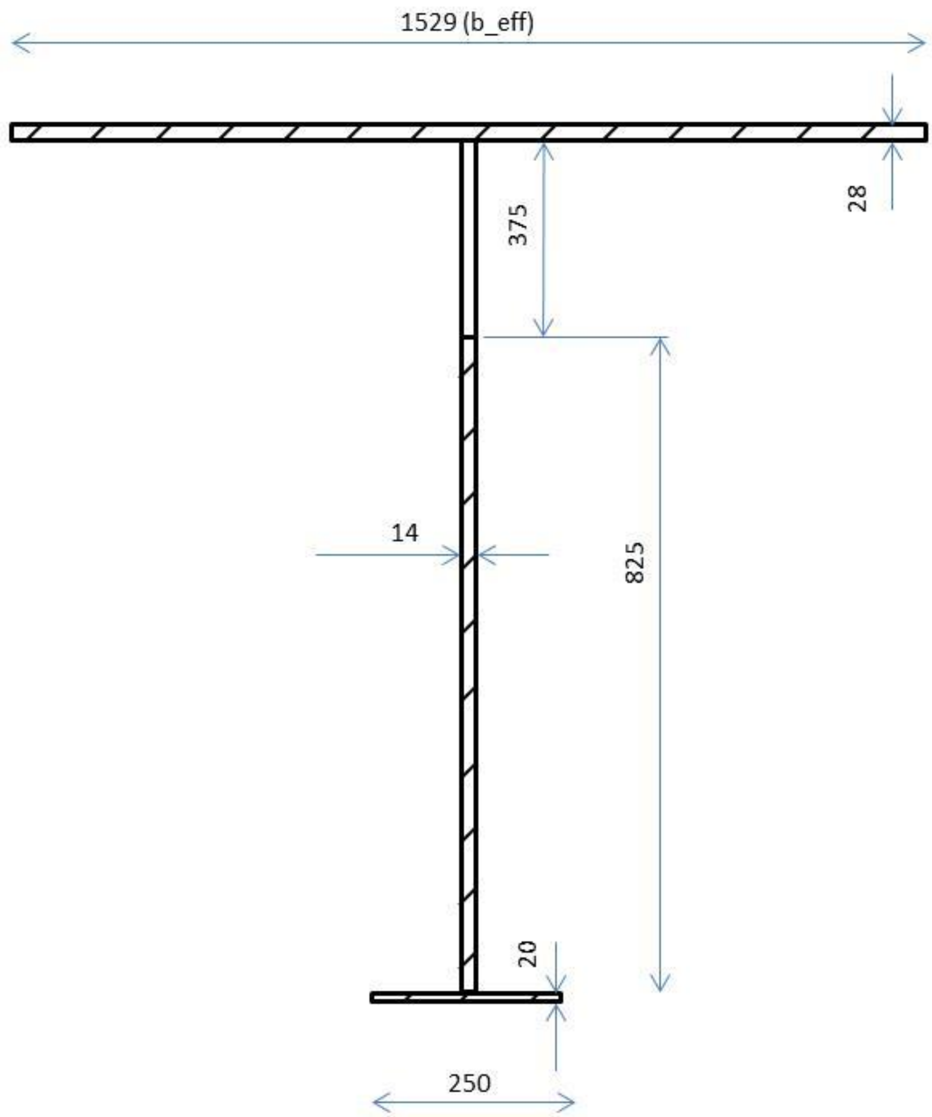
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1696.0*	*28.0*	*0.0*	47488	231	9.52E+06
2	*0.0*	*375.0*	*0.0*	0	0	9.52E+06
3	*12.0*	*825.0*	*0.0*	9900	9900	3.57E+06
4	*250.0*	*14.0*	*0.0*	3500	116	0.00E+00
5	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1696	1242		60888	10247	

Section Properties

Areas:		AX	60888	[mm²]
		AY	50988	[mm²]
		AZ	10247	[mm²]
Dimensions:		Y	1696.0	[mm]
		Z	1242.0	[mm]
		Weight	4.7	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1027.5	[mm]
	Z-ez		214.5	[mm]
	ey	(From left)	848.0	[mm]
	Y-ey		848.0	[mm]
Section moduli:		Wy,min	9.44E+06	[mm³]
		Wy,max	4.52E+07	[mm³]
		Wz,min	1.34E+07	[mm³]
		Wz,max	1.34E+07	[mm³]
Moments of inertia:		Iy	9.69E+09	[mm^4]
		Iz	1.14E+10	[mm^4]
Torsional constant (torsional resistance):		It	1.31E+07	[mm^4]
Radii of gyration:		ry	399.0	[mm]
		rz	432.7	[mm]

BBBM2



BBBM2

Project	Barge H-541		
Subject	BBBM2		
Job / Bid no.	Double deck barge		
Date	13-May-15	Sheet	1

PLATE GIRDER PROPERTIES

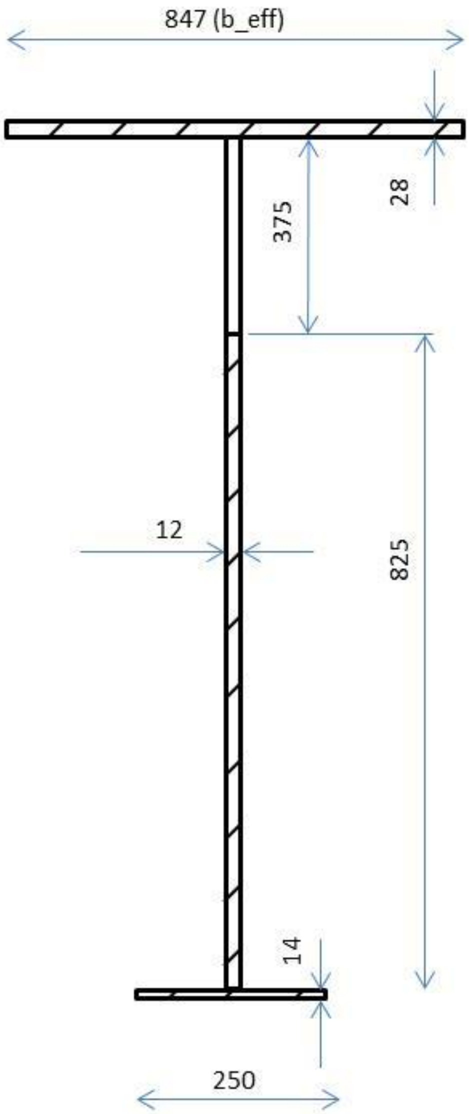
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1529.0*	*28.0*	*0.0*	42812	270	1.11E+07
2	*0.0*	*375.0*	*0.0*	0	0	1.11E+07
3	*14.0*	*825.0*	*0.0*	11550	11550	4.82E+06
4	*250.0*	*20.0*	*0.0*	5000	193	0.00E+00
5	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1529	1248		59362	12012	

Section Properties

Areas:	AX	59362	[mm²]
	AY	47812	[mm²]
	AZ	12012	[mm²]
Dimensions:	Y	1529.0	[mm]
	Z	1248.0	[mm]
	Weight	4.6	[kN/m]
Distances to neutral axis:	ez (From bottom)	975.0	[mm]
	Z-ez	273.0	[mm]
	ey (From left)	764.5	[mm]
	Y-ey	764.5	[mm]
Section moduli:	Wy,min	1.19E+07	[mm³]
	Wy,max	4.24E+07	[mm³]
	Wz,min	1.09E+07	[mm³]
	Wz,max	1.09E+07	[mm³]
Moments of inertia:	Iy	1.16E+10	[mm^4]
	Iz	8.37E+09	[mm^4]
Torsional constant (torsional resistance):	It	1.26E+07	[mm^4]
Radii of gyration:	ry	441.8	[mm]
	rz	375.4	[mm]

BBBM3



BBBM3

Project	Barge H-541				
Subject	BBBM3				
Job / Bid no.	Double deck barge				
Date	30-Apr-15		Sheet	1	

○ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

○ millimeters ○ centimeters ○ meters ○ inches

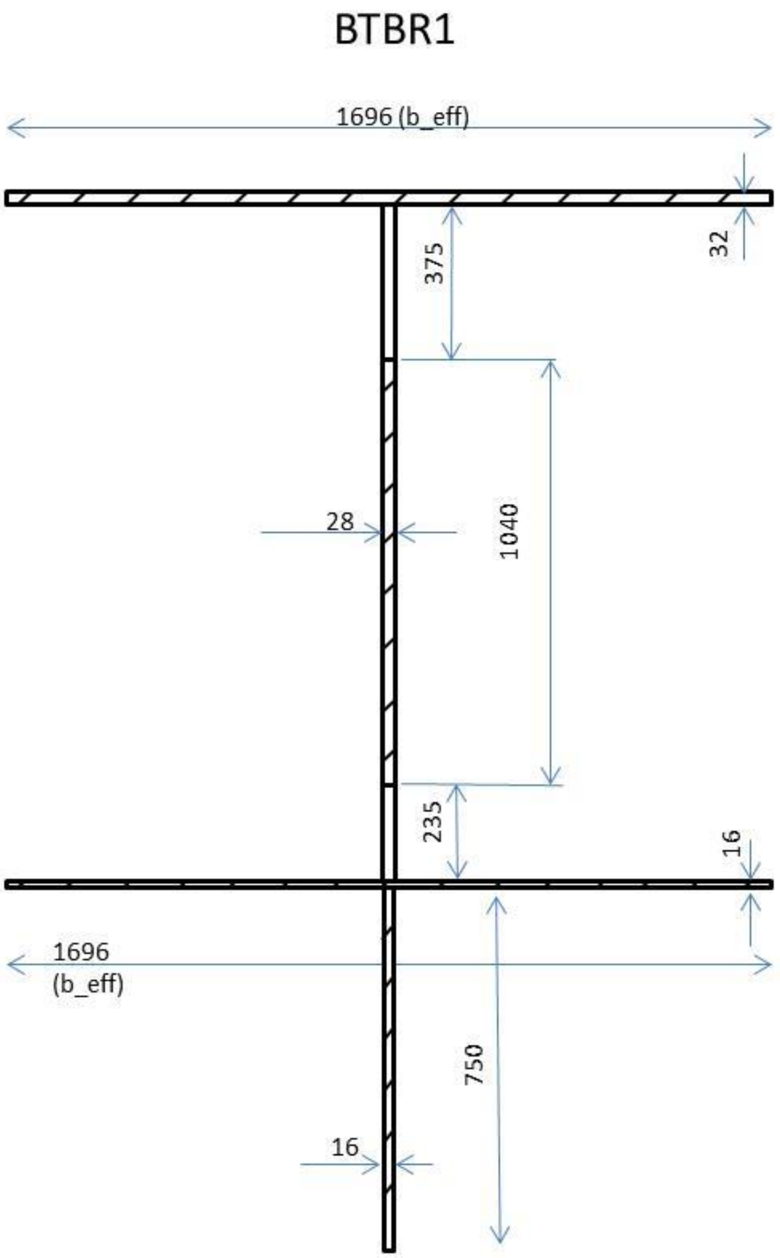
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	847.0	28.0	0.0	23716	231	7.80E+06
2	0.0	375.0	0.0	0	0	7.80E+06
3	12.0	825.0	0.0	9900	9900	3.12E+06
4	250.0	14.0	0.0	3500	116	0.00E+00
5	0.0	0.0	0.0	0	0	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	847	1242		37116	10247	

○ KN/m ○ Kg/m ○ mT/m ○ lb/ft ○ lb/inch ○ lb/yard

Section Properties

Areas:	AX	37116	[mm²]
	AY	27216	[mm²]
	AZ	10247	[mm²]
Dimensions:	Y	847.0	[mm]
	Z	1242.0	[mm]
	Weight	2.9	[kN/m]
Distances to neutral axis:	ez (From bottom)	899.1	[mm]
	Z-ez	342.9	[mm]
	ey (From left)	423.5	[mm]
	Y-ey	423.5	[mm]
Section moduli:	Wy,min	9.04E+06	[mm³]
	Wy,max	2.37E+07	[mm³]
	Wz,min	3.39E+06	[mm³]
	Wz,max	3.39E+06	[mm³]
Moments of inertia:	Iy	8.13E+09	[mm^4]
	Iz	1.44E+09	[mm^4]
Torsional constant (torsional resistance):	It	6.90E+06	[mm^4]
Radii of gyration:	ry	467.9	[mm]
	rz	196.7	[mm]


BTBR1
1696 (b_eff)
32
375
1040
28
235
16
1696
(b_eff)
750
16

BTBR1

Project	Barge H-541 Typical webframe			
Subject	BTBR1			
Job / Bid no.	Double deck barge			
Date	30-Apr-15		Sheet	1

- ◉ millimeters
- ○ centimeters
- ○ meters
- ○ inches

PLATE GIRDER PROPERTIES

- ◉ millimeters
- ○ centimeters
- ○ meters
- ○ inches

Plategirder Description

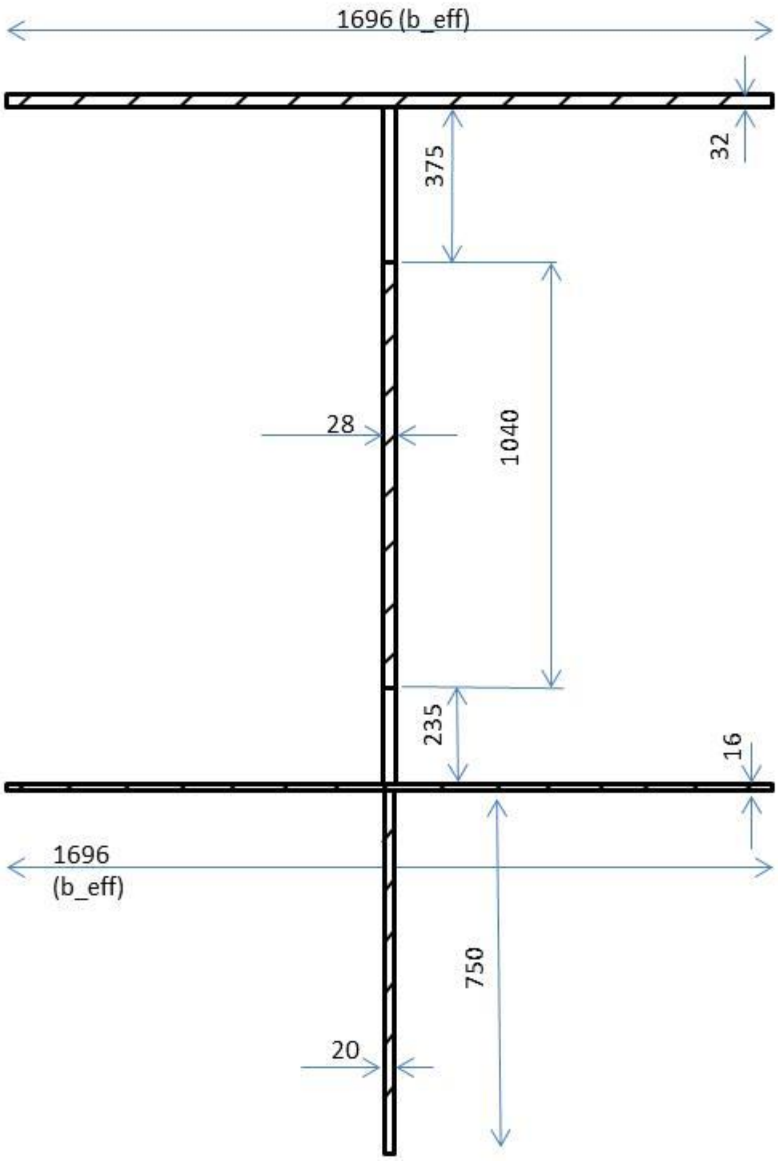
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1696.0*	*32.0*	*0.0*	54272	548	4.28E+07
2	*0.0*	*375.0*	*0.0*	0	0	4.23E+07
3	*28.0*	*1040.0*	*0.0*	29120	29120	3.92E+07
4	*0.0*	*235.0*	*0.0*	0	0	3.92E+07
5	*1696.0*	*16.0*	*0.0*	27136	274	1.52E+07
6	*16.0*	*750.0*	*0.0*	12000	12000	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1696	2448		122528	41942	

- ◉ KN/m
- ○ Kg/m
- ○ t/m
- ○ lb/ft
- ○ lb/inch
- ○ lb/yard

Section Properties

Areas:		AX	122528	[mm²]
		AY	81408	[mm²]
		AZ	41942	[mm²]
Dimensions:		Y	1696.0	[mm]
		Z	2448.0	[mm]
		Weight	9.4	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1643.3	[mm]
	Z-ez		804.7	[mm]
	ey	(From left)	848.0	[mm]
	Y-ey		848.0	[mm]
Section moduli:		Wy,min	4.74E+07	[mm³]
		Wy,max	9.69E+07	[mm³]
		Wz,min	2.30E+07	[mm³]
		Wz,max	2.30E+07	[mm³]
Moments of inertia:		Iy	7.80E+10	[mm^4]
		Iz	1.95E+10	[mm^4]
Torsional constant (torsional resistance):		It	2.95E+07	[mm^4]
Radii of gyration:		ry	797.7	[mm]
		rz	399.1	[mm]

BTBR2



BTBR2

Project	Barge H-541 Typical webframe			
Subject	BTBR2			
Job / Bid no.	Double deck barge			
Date	30-Apr-15		Sheet	1

○ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

○ millimeters ○ centimeters ○ meters ○ inches

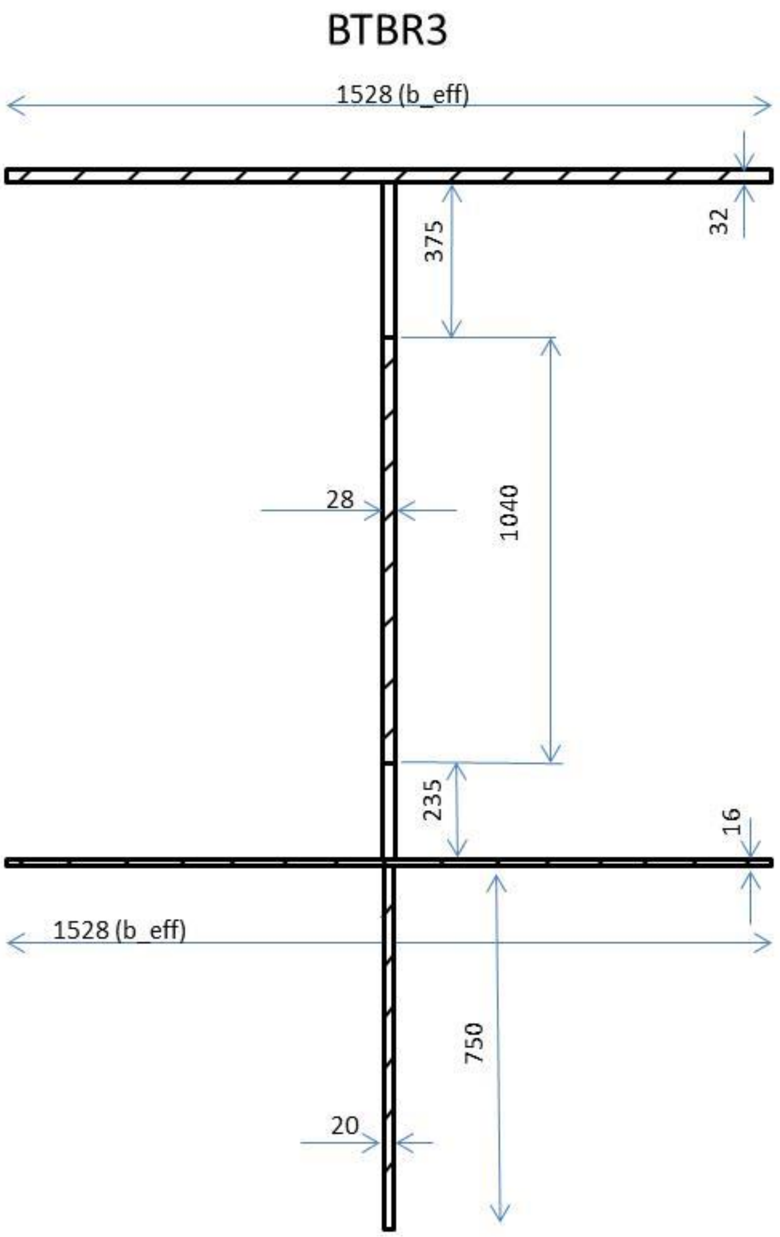
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1696.0	32.0	0.0	54272	588	4.44E+07
2	0.0	375.0	0.0	0	0	4.41E+07
3	28.0	1040.0	0.0	29120	29120	4.13E+07
4	0.0	235.0	0.0	0	0	4.18E+07
5	1696.0	16.0	0.0	27136	294	1.86E+07
6	20.0	750.0	0.0	15000	15000	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1696	2448		125528	45002	

○ kN/m ○ kg/m ○ lb/ft ○ lb/inch ○ lb/yard

Section Properties

Areas:		AX	125528	[mm²]
		AY	81408	[mm²]
		AZ	45002	[mm²]
Dimensions:		Y	1696.0	[mm]
		Z	2448.0	[mm]
		Weight	9.7	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1613.0	[mm]
	Z-ez		835.0	[mm]
	ey	(From left)	848.0	[mm]
	Y-ey		848.0	[mm]
Section moduli:		Wy,min	5.13E+07	[mm³]
		Wy,max	9.92E+07	[mm³]
		Wz,min	2.30E+07	[mm³]
		Wz,max	2.30E+07	[mm³]
Moments of inertia:		Iy	8.28E+10	[mm^4]
		Iz	1.95E+10	[mm^4]
Torsional constant (torsional resistance):		It	3.05E+07	[mm^4]
Radii of gyration:		ry	812.2	[mm]
		rz	394.3	[mm]


BTBR3
1528 (b_eff)
32
375
28
1040
235
16
1528 (b_eff)
750
20

BTBR3

Project	Barge H-541 Typical webframe				
Subject	BTBR3				
Job / Bid no.	Double deck barge				
Date	13-May-15		Sheet	1	

◉ millimeters
○ centimeters
○ meters
○ inches

PLATE GIRDER PROPERTIES

◉ millimeters
○ centimeters
○ meters
○ inches

Plategirder Description

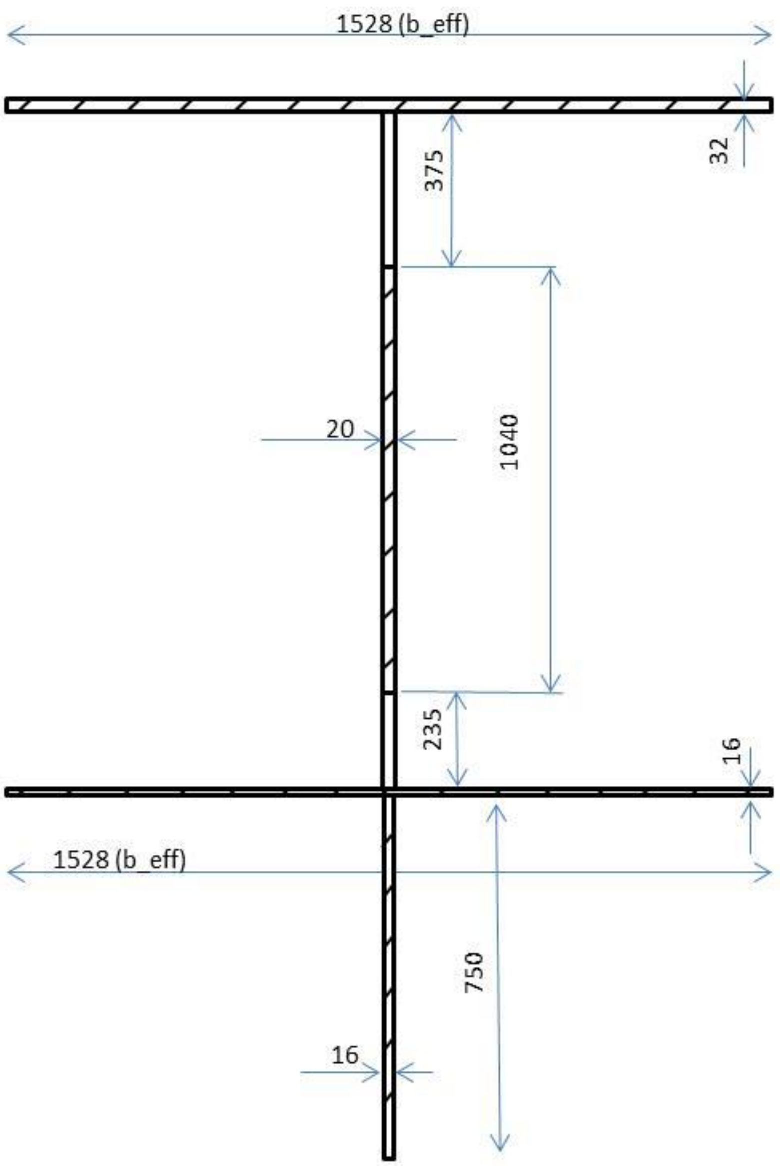
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1528.0	32.0	0.0	48896	588	4.09E+07
2	0.0	375.0	0.0	0	0	4.09E+07
3	28.0	1040.0	0.0	29120	29120	3.88E+07
4	0.0	235.0	0.0	0	0	3.88E+07
5	1528.0	16.0	0.0	24448	294	1.83E+07
6	20.0	750.0	0.0	15000	15000	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1528	2448		117464	45002	

◉ KN/m
○ Kg/m
○ mT/m
○ lb/ft
○ lb/inch
○ lb/yard

Section Properties

Areas:	AX	117464	[mm²]
	AY	73344	[mm²]
	AZ	45002	[mm²]
Dimensions:	Y	1528.0	[mm]
	Z	2448.0	[mm]
	Weight	9.0	[kN/m]
Distances to neutral axis:	ez (From bottom)	1595.1	[mm]
	Z-ez	852.9	[mm]
	ey (From left)	764.0	[mm]
	Y-ey	764.0	[mm]
Section moduli:	Wy,min	4.84E+07	[mm³]
	Wy,max	9.05E+07	[mm³]
	Wz,min	1.87E+07	[mm³]
	Wz,max	1.87E+07	[mm³]
Moments of inertia:	Iy	7.72E+10	[mm^4]
	Iz	1.43E+10	[mm^4]
Torsional constant (torsional resistance):	It	2.84E+07	[mm^4]
Radii of gyration:	ry	810.7	[mm]
	rz	348.6	[mm]

BTBR4



BTBR4

Project	Barge H-541 Typical webframe			
Subject	BTBR4			
Job / Bid no.	Double deck barge			
Date	13-May-15		Sheet	1

◉ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

◉ millimeters ○ centimeters ○ meters ○ inches

◉ KN/m ○ Kg/m ○ mT/m ○ lb/ft ○ lb/inch ○ lb/yard

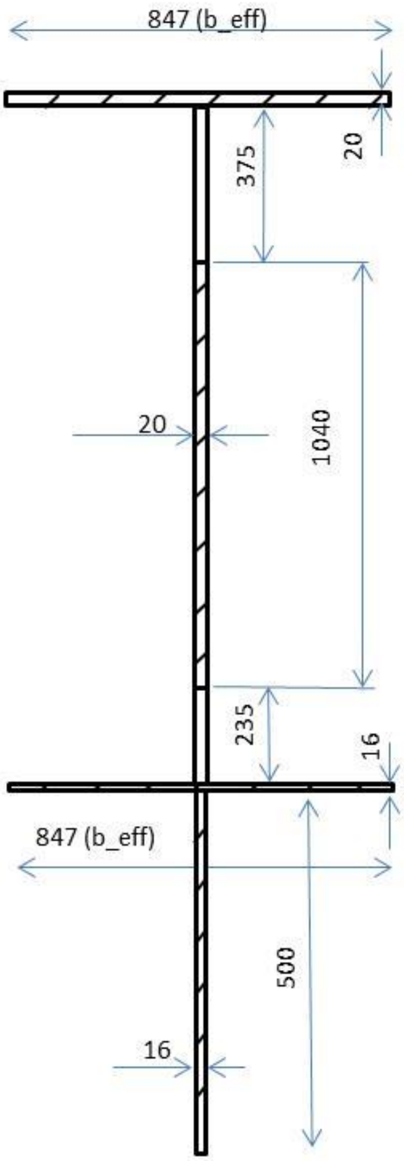
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1528.0*	*32.0*	*0.0*	48896	437	3.90E+07
2	*0.0*	*375.0*	*0.0*	0	0	3.90E+07
3	*20.0*	*1040.0*	*0.0*	20800	20800	3.66E+07
4	*0.0*	*235.0*	*0.0*	0	0	3.66E+07
5	*1528.0*	*16.0*	*0.0*	24448	219	1.51E+07
6	*16.0*	*750.0*	*0.0*	12000	12000	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1528	2448		106144	33456	

Section Properties

Areas:	AX	106144	[mm²]
	AY	73344	[mm²]
	AZ	33456	[mm²]
Dimensions:	Y	1528.0	[mm]
	Z	2448.0	[mm]
	Weight	8.2	[kN/m]
Distances to neutral axis:	ez (From bottom)	1635.4	[mm]
	Z-ez	812.6	[mm]
	ey (From left)	764.0	[mm]
	Y-ey	764.0	[mm]
Section moduli:	Wy,min	4.38E+07	[mm³]
	Wy,max	8.81E+07	[mm³]
	Wz,min	1.87E+07	[mm³]
	Wz,max	1.87E+07	[mm³]
Moments of inertia:	Iy	7.16E+10	[mm^4]
	Iz	1.43E+10	[mm^4]
Torsional constant (torsional resistance):	It	2.26E+07	[mm^4]
Radii of gyration:	ry	821.5	[mm]
	rz	366.7	[mm]

BTBR5



BTBR5

Project	Barge H-541 Typical webframe			
Subject	BTBR5			
Job / Bid no.	Double deck barge			
Date	30-Apr-15		Sheet	1

(◉ millimeters ○ centimeters ○ meters ○ inches)

PLATE GIRDER PROPERTIES

(◉ millimeters ○ centimeters ○ meters ○ inches)

Plategirder Description

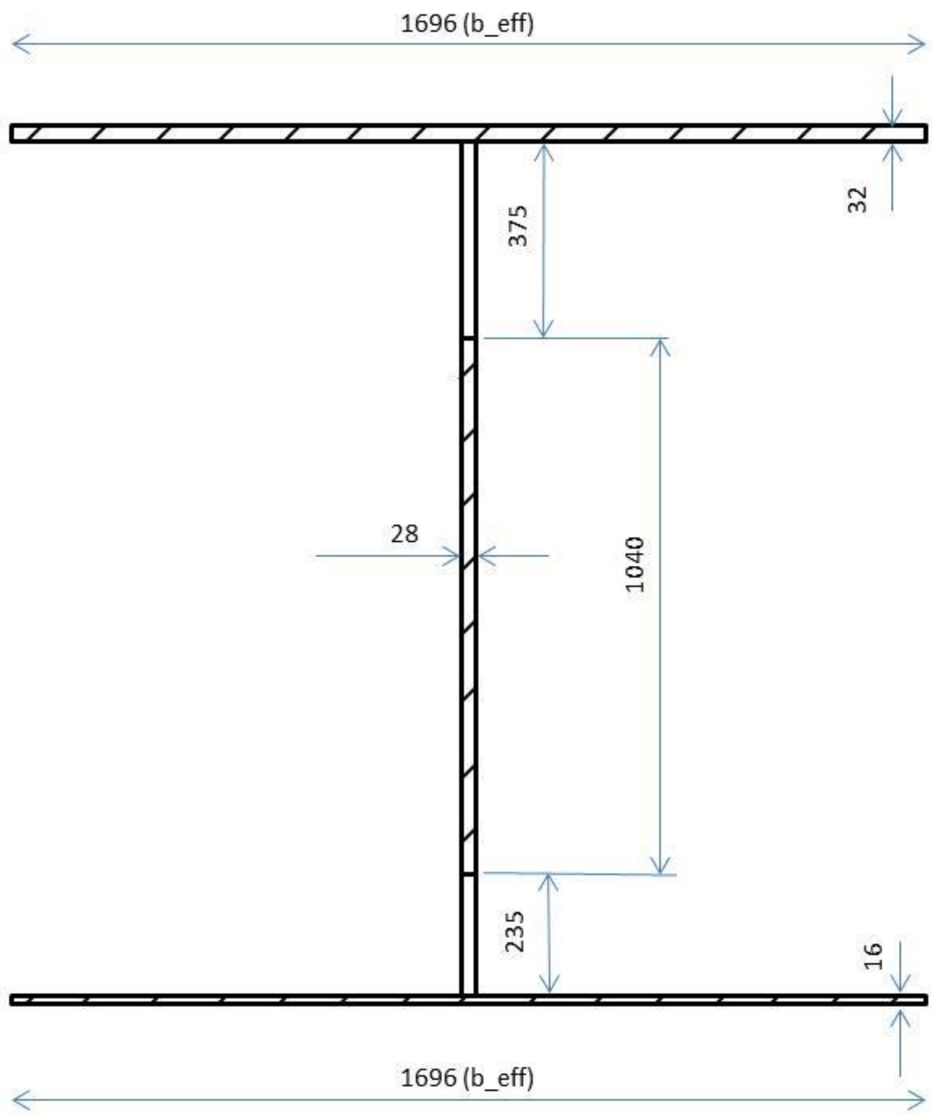
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*847.0*	*20.0*	*0.0*	16940	268	1.62E+07
2	*0.0*	*375.0*	*0.0*	0	0	1.62E+07
3	*20.0*	*1040.0*	*0.0*	20800	20800	1.74E+07
4	*0.0*	*235.0*	*0.0*	0	0	1.74E+07
5	*847.0*	*16.0*	*0.0*	13552	214	7.74E+06
6	*16.0*	*500.0*	*0.0*	8000	8000	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	847	2186		59292	29282	

(◉ KN/m ○ Kg/m ○ mT/m ○ lb/ft ○ lb/inch ○ lb/yard)

Section Properties

Areas:		AX	59292	[mm²]
		AY	30492	[mm²]
		AZ	29282	[mm²]
Dimensions:		Y	847.0	[mm]
		Z	2186.0	[mm]
		Weight	4.6	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1217.4	[mm]
	Z-ez		968.6	[mm]
	ey	(From left)	423.5	[mm]
	Y-ey		423.5	[mm]
Section moduli:		Wy,min	2.63E+07	[mm³]
		Wy,max	3.30E+07	[mm³]
		Wz,min	4.31E+06	[mm³]
		Wz,max	4.31E+06	[mm³]
Moments of inertia:		Iy	3.20E+10	[mm^4]
		Iz	1.82E+09	[mm^4]
Torsional constant (torsional resistance):		It	6.87E+06	[mm^4]
Radii of gyration:		ry	734.4	[mm]
		rz	175.4	[mm]

BTBM1



BTBM1

Project	Barge H-541 Typical webframe				
Subject	BTBM1				
Job / Bid no.	Double deck barge				
Date	13-May-15		Sheet	1	

◉ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

◉ millimeters ○ centimeters ○ meters ○ inches

Plategirder Description

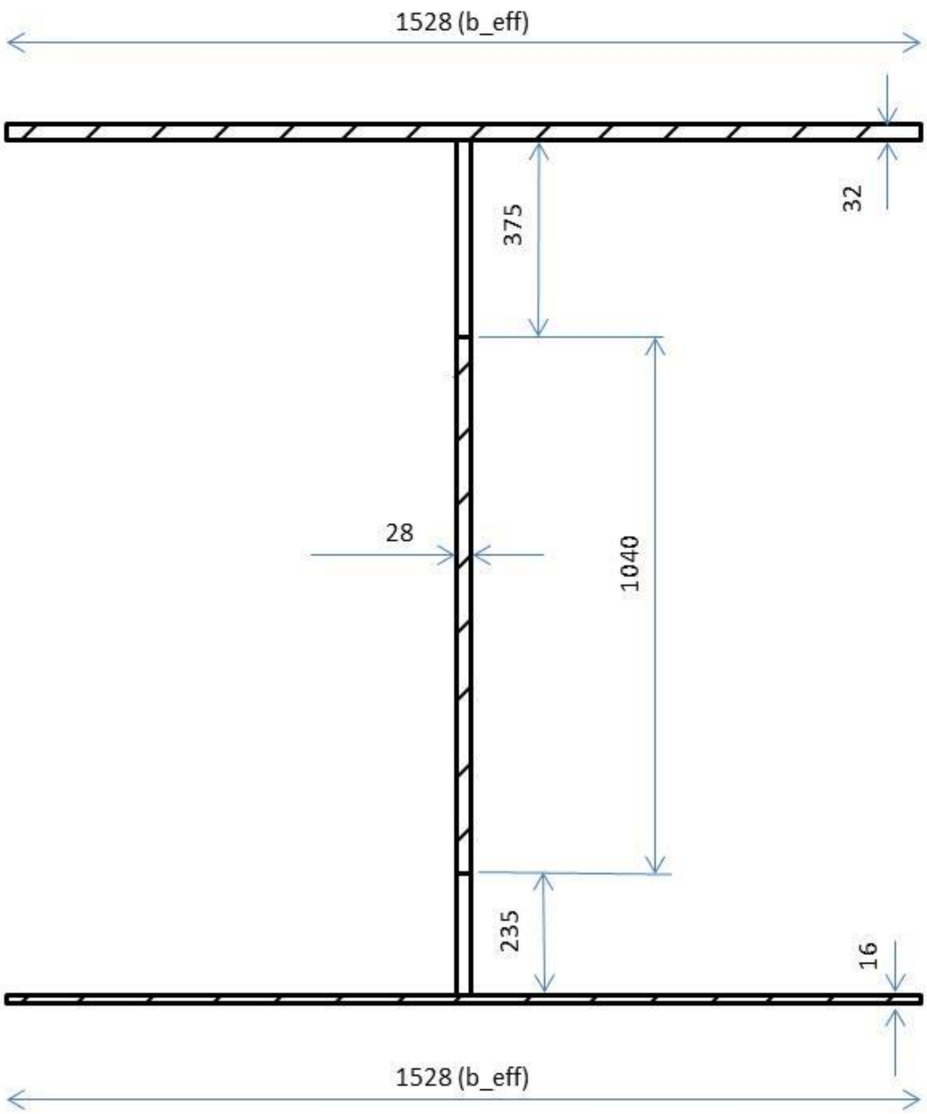
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1696.0	32.0	0.0	54272	565	3.53E+07
2	0.0	375.0	0.0	0	0	3.53E+07
3	28.0	1040.0	0.0	29120	29120	2.78E+07
4	0.0	235.0	0.0	0	0	2.78E+07
5	1696.0	16.0	0.0	27136	282	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1696	1698		110528	29967	

◉ kN/m ○ kg/m ○ lb/ft ○ lb/inch ○ lb/yard

Section Properties

Areas:	AX	110528	[mm²]
	AY	81408	[mm²]
	AZ	29967	[mm²]
Dimensions:	Y	1696.0	[mm]
	Z	1698.0	[mm]
	Weight	8.5	[kN/m]
Distances to neutral axis:	ez (From bottom)	1031.0	[mm]
	Z-ez	667.0	[mm]
	ey (From left)	848.0	[mm]
	Y-ey	848.0	[mm]
Section moduli:	Wy,min	5.43E+07	[mm³]
	Wy,max	8.40E+07	[mm³]
	Wz,min	2.30E+07	[mm³]
	Wz,max	2.30E+07	[mm³]
Moments of inertia:	Iy	5.60E+10	[mm^4]
	Iz	1.95E+10	[mm^4]
Torsional constant (torsional resistance):	It	2.85E+07	[mm^4]
Radii of gyration:	ry	711.8	[mm]
	rz	420.2	[mm]

BTBM3



BTBM3

Project	Barge H-541 Typical webframe		
Subject	BTBM3		
Job / Bid no.	Double deck barge		
Date	13-May-15	Sheet	1

- ◉ millimeters
- ○ centimeters
- ○ meters
- ○ inches

PLATE GIRDER PROPERTIES

- ◉ millimeters
- ○ centimeters
- ○ meters
- ○ inches

Plategirder Description

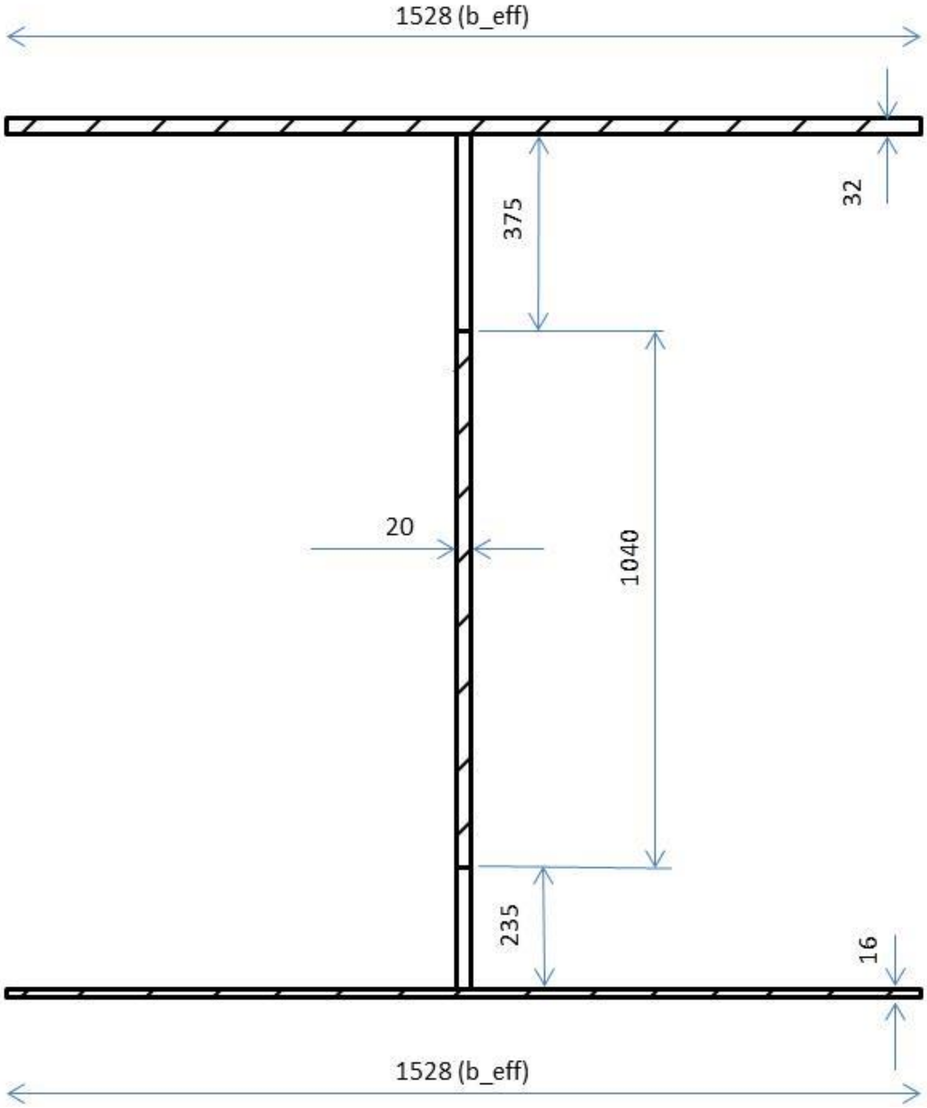
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1528.0*	*32.0*	*0.0*	48896	565	3.22E+07
2	*0.0*	*375.0*	*0.0*	0	0	3.22E+07
3	*28.0*	*1040.0*	*0.0*	29120	29120	2.43E+07
4	*0.0*	*235.0*	*0.0*	0	0	2.43E+07
5	*1528.0*	*16.0*	*0.0*	24448	282	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1528	1698		102464	29967	

- ◉ KN/m
- ○ kg/m
- ○ t/m
- ○ lb/ft
- ○ lb/inch
- ○ lb/yard

Section Properties

Areas:		AX	102464	[mm²]
		AY	73344	[mm²]
		AZ	29967	[mm²]
Dimensions:		Y	1528.0	[mm]
		Z	1698.0	[mm]
		Weight	7.9	[kN/m]
Distances to neutral axis:	ez (From bottom)		1023.7	[mm]
	Z-ez		674.3	[mm]
	ey (From left)		764.0	[mm]
	Y-ey		764.0	[mm]
Section moduli:		Wy,min	4.97E+07	[mm³]
		Wy,max	7.55E+07	[mm³]
		Wz,min	1.87E+07	[mm³]
		Wz,max	1.87E+07	[mm³]
Moments of inertia:		Iy	5.09E+10	[mm^4]
		Iz	1.43E+10	[mm^4]
Torsional constant (torsional resistance):		It	2.64E+07	[mm^4]
Radii of gyration:		ry	704.8	[mm]
		rz	373.2	[mm]

BTBM4



BTBM4

Project	Barge H-541 Typical webframe		
Subject	BTBM4		
Job / Bid no.	Double deck barge		
Date	13-May-15	Sheet	1

◉ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

◉ millimeters ○ centimeters ○ meters ○ inches

Plategirder Description

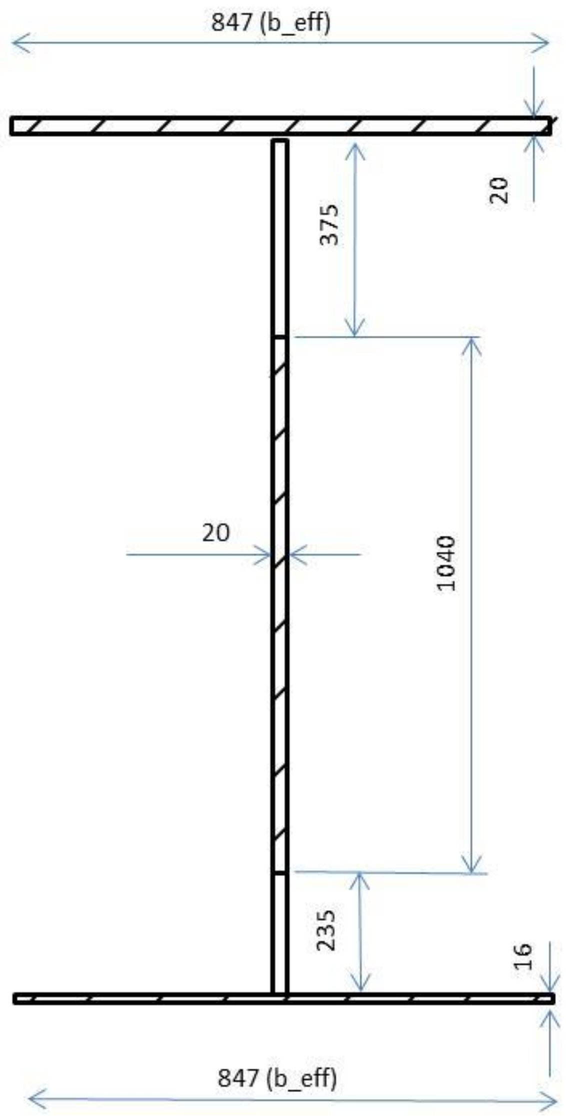
section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	1528.0	32.0	0.0	48896	403	3.11E+07
2	0.0	375.0	0.0	0	0	3.11E+07
3	20.0	1040.0	0.0	20800	20800	2.54E+07
4	0.0	235.0	0.0	0	0	2.54E+07
5	1528.0	16.0	0.0	24448	202	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	1528	1698		94144	21405	

◉ kN/m ○ kg/m ○ lb/ft ○ lb/inch ○ lb/yard

Section Properties

Areas:	AX	94144	[mm²]
	AY	73344	[mm²]
	AZ	21405	[mm²]
Dimensions:	Y	1528.0	[mm]
	Z	1698.0	[mm]
	Weight	7.2	[kN/m]
Distances to neutral axis:	ez (From bottom)	1046.0	[mm]
	Z-ez	652.0	[mm]
	ey (From left)	764.0	[mm]
	Y-ey	764.0	[mm]
Section moduli:	Wy,min	4.74E+07	[mm³]
	Wy,max	7.60E+07	[mm³]
	Wz,min	1.87E+07	[mm³]
	Wz,max	1.87E+07	[mm³]
Moments of inertia:	Iy	4.96E+10	[mm^4]
	Iz	1.43E+10	[mm^4]
Torsional constant (torsional resistance):	It	2.15E+07	[mm^4]
Radii of gyration:	ry	725.6	[mm]
	rz	389.3	[mm]

BTBM5



BTBM5

Project	Barge H-541 Typical webframe		
Subject	BTBM5		
Job / Bid no.	Double deck barge		
Date	30-Apr-15	Sheet	1

Units: ◉ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

Units: ◉ millimeters ○ centimeters ○ meters ○ inches

Weight units: ◉ kN/m ○ kg/m ○ t/m ○ lb/ft ○ lb/inch ○ lb/yard

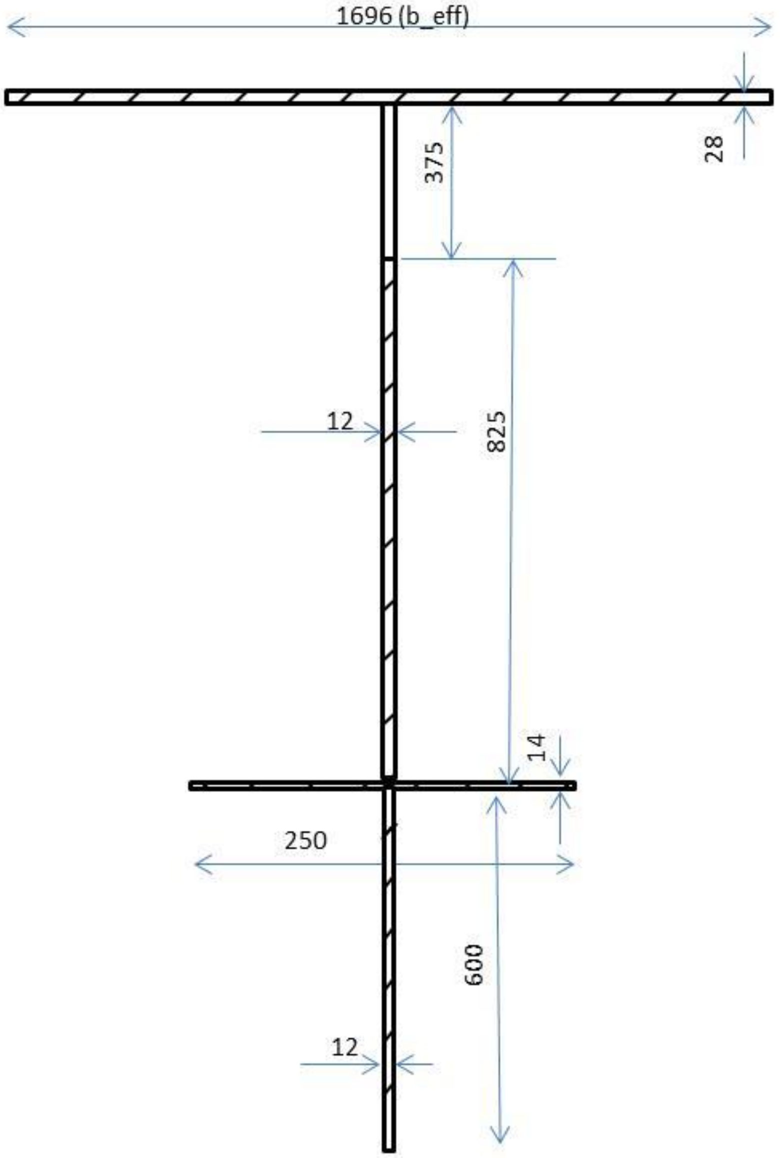
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*847.0*	*20.0*	*0.0*	16940	252	1.37E+07
2	*0.0*	*375.0*	*0.0*	0	0	1.37E+07
3	*20.0*	*1040.0*	*0.0*	20800	20800	1.17E+07
4	*0.0*	*235.0*	*0.0*	0	0	1.17E+07
5	*847.0*	*16.0*	*0.0*	13552	202	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	847	1686		51292	21254	

Section Properties

Areas:		AX	51292	[mm²]
		AY	30492	[mm²]
		AZ	21254	[mm²]
Dimensions:		Y	847.0	[mm]
		Z	1686.0	[mm]
		Weight	3.9	[kN/m]
Distances to neutral axis:	ez	(From bottom)	868.3	[mm]
	Z-ez		817.7	[mm]
	ey	(From left)	423.5	[mm]
	Y-ey		423.5	[mm]
Section moduli:		Wy,min	2.67E+07	[mm³]
		Wy,max	2.83E+07	[mm³]
		Wz,min	4.31E+06	[mm³]
		Wz,max	4.31E+06	[mm³]
Moments of inertia:		Iy	2.32E+10	[mm^4]
		Iz	1.82E+09	[mm^4]
Torsional constant (torsional resistance):		It	6.19E+06	[mm^4]
Radii of gyration:		ry	671.9	[mm]
		rz	188.6	[mm]

BBBR1



BBBR1

Project	Barge H-541		
Subject	BBBR1		
Job / Bid no.	Double deck barge		
Date	30-Apr-15	Sheet	1

PLATE GIRDER PROPERTIES

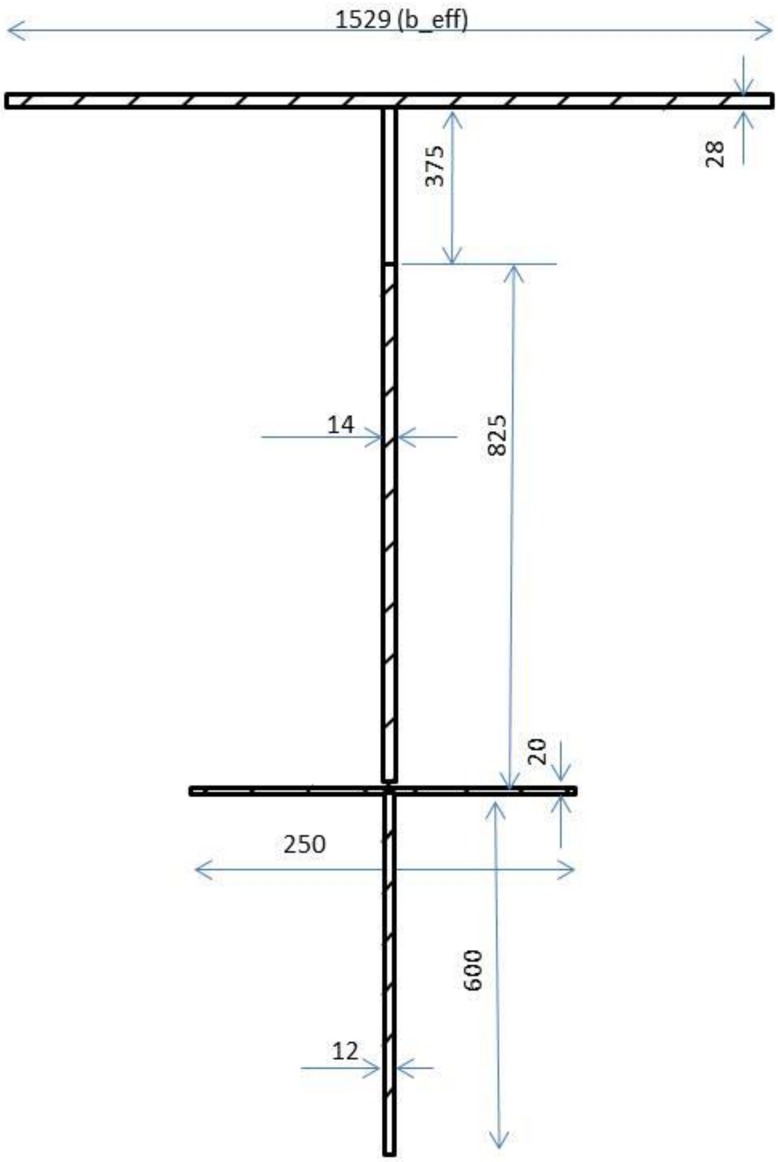
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1696.0*	*28.0*	*0.0*	47488	266	1.62E+07
2	*0.0*	*375.0*	*0.0*	0	0	1.62E+07
3	*12.0*	*825.0*	*0.0*	9900	9900	1.16E+07
4	*250.0*	*14.0*	*0.0*	3500	133	8.55E+06
5	*12.0*	*600.0*	*0.0*	7200	7200	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1696	1842		68088	17499	

Section Properties

Areas:		AX	68088	[mm²]
		AY	50988	[mm²]
		AZ	17499	[mm²]
Dimensions:		Y	1696.0	[mm]
		Z	1842.0	[mm]
		Weight	5.2	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1487.1	[mm]
	Z-ez		354.9	[mm]
	ey	(From left)	848.0	[mm]
	Y-ey		848.0	[mm]
Section moduli:		Wy,min	1.43E+07	[mm³]
		Wy,max	5.99E+07	[mm³]
		Wz,min	1.34E+07	[mm³]
		Wz,max	1.34E+07	[mm³]
Moments of inertia:		Iy	2.13E+10	[mm^4]
		Iz	1.14E+10	[mm^4]
Torsional constant (torsional resistance):		It	1.35E+07	[mm^4]
Radii of gyration:		ry	558.7	[mm]
		rz	409.2	[mm]

BBBR2



BBBR2

Project	Barge H-541			
Subject	BBBR2			
Job / Bid no.	Double deck barge			
Date	13-May-15		Sheet	1

PLATE GIRDER PROPERTIES

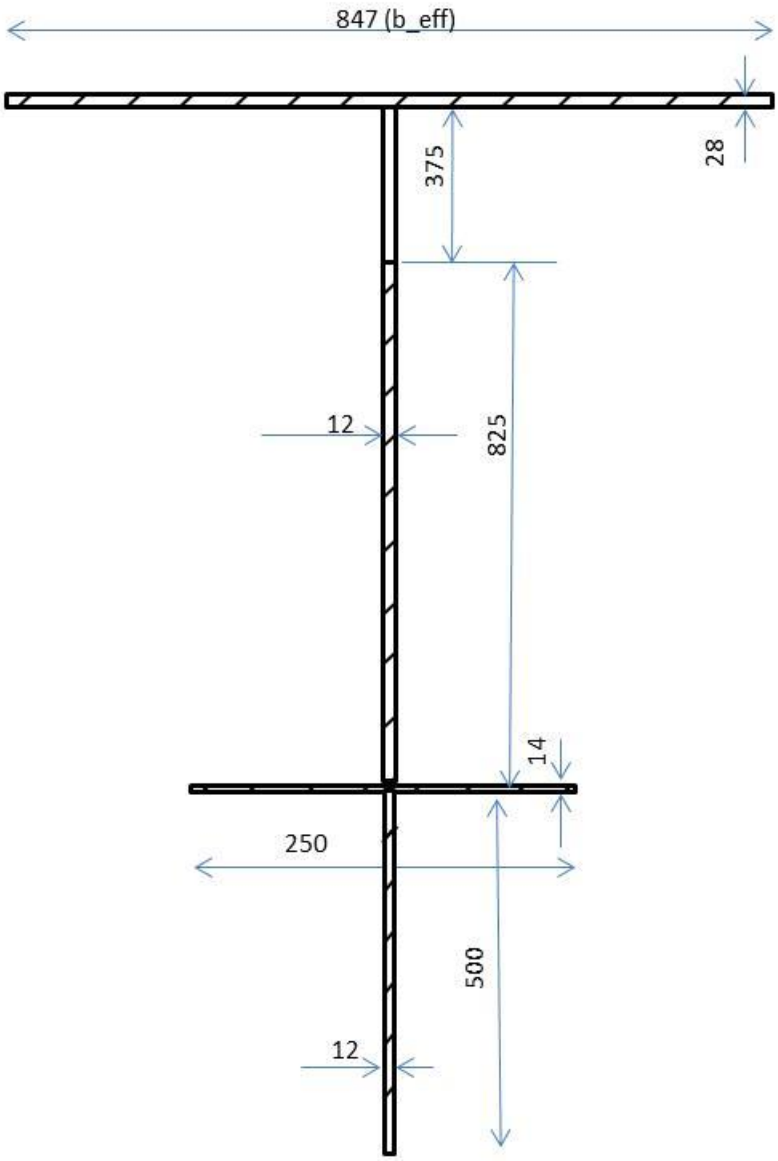
Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	*1529.0*	*28.0*	*0.0*	42812	292	1.70E+07
2	*0.0*	*375.0*	*0.0*	0	0	1.70E+07
3	*14.0*	*825.0*	*0.0*	11550	11550	1.23E+07
4	*250.0*	*20.0*	*0.0*	5000	208	8.19E+06
5	*12.0*	*600.0*	*0.0*	7200	7200	0.00E+00
6	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
7	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
8	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
9	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
10	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
11	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
12	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
13	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
14	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
15	*0.0*	*0.0*	*0.0*	0	0	0.00E+00
	1529	1848		66562	19250	

Section Properties

Areas:	AX	66562	[mm²]
	AY	47812	[mm²]
	AZ	19250	[mm²]
Dimensions:	Y	1529.0	[mm]
	Z	1848.0	[mm]
	Weight	5.1	[kN/m]
Distances to neutral axis:	ez (From bottom)	1437.0	[mm]
	Z-ez	411.0	[mm]
	ey (From left)	764.5	[mm]
	Y-ey	764.5	[mm]
Section moduli:	Wy,min	1.55E+07	[mm³]
	Wy,max	5.41E+07	[mm³]
	Wz,min	1.09E+07	[mm³]
	Wz,max	1.09E+07	[mm³]
Moments of inertia:	Iy	2.22E+10	[mm^4]
	Iz	8.37E+09	[mm^4]
Torsional constant (torsional resistance):	It	1.30E+07	[mm^4]
Radii of gyration:	ry	578.0	[mm]
	rz	354.5	[mm]

BBBR3



BBBR3

Project	Barge H-541			
Subject	BBBR3			
Job / Bid no.	Double deck barge			
Date	30-Apr-15		Sheet	1

Units: ◉ millimeters ○ centimeters ○ meters ○ inches

PLATE GIRDER PROPERTIES

Units: ◉ millimeters ○ centimeters ○ meters ○ inches

Weight units: ◉ KN/m ○ Kg/m ○ mT/m ○ lb/ft ○ lb/inch ○ lb/yard

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	847.0	28.0	0.0	23716	262	1.16E+07
2	0.0	375.0	0.0	0	0	1.16E+07
3	12.0	825.0	0.0	9900	9900	8.50E+06
4	250.0	14.0	0.0	3500	131	5.94E+06
5	12.0	500.0	0.0	6000	6000	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	847	1742		43116	16293	

Section Properties

Areas:		AX	43116	[mm²]
		AY	27216	[mm²]
		AZ	16293	[mm²]
Dimensions:		Y	847.0	[mm]
		Z	1742.0	[mm]
		Weight	3.3	[kN/m]
Distances to neutral axis:	ez	(From bottom)	1239.2	[mm]
	Z-ez		502.8	[mm]
	ey	(From left)	423.5	[mm]
	Y-ey		423.5	[mm]
Section moduli:		Wy,min	1.22E+07	[mm³]
		Wy,max	3.00E+07	[mm³]
		Wz,min	3.39E+06	[mm³]
		Wz,max	3.39E+06	[mm³]
Moments of inertia:		Iy	1.51E+10	[mm^4]
		Iz	1.44E+09	[mm^4]
Torsional constant (torsional resistance):		It	7.19E+06	[mm^4]
Radii of gyration:		ry	591.2	[mm]
		rz	182.5	[mm]

Appendix VI Global Strength

Section properties barge: H541		**Conventional Webframe**											
Frame	13												
Section			**No.**	**b**	**h**	**A each**	**Ix each**	**z**	**A**	**M**	**a**	**Ix**	
				42000	10700					**(A*z)**	**(z-z tot)**		**(A*a^2)**
				[mm]	[mm]	[mm^2]	[10^4 mm^4]	[mm]	[mm^2]	[mm^3]	[mm]	[10^4 mm^4]	[10^4 mm^4]
Plating													
Deck section 1			1	39000	32			10684	1248000	13333632000	5081.8257	10649.6	3222954097
Deck section 2			1	3000	20			10690	60000	641400000	5087.8257	200	155315823.7
Bottom			1	42000	28			14	1176000	16464000	-5588.174	7683.2	3672376547
Sideshell													
Sideshell/ top plate			2	25	1550			9925	77500	769187500	4322.8257	1551614.583	144822872.4
Sideshell/middle section			2	16	6900			5700	220800	1258560000	97.825725	87602400	211302.7847
Sideshell/bottom section 1			2	20	900			1800	36000	64800000	-3802.174	243000	52043505.18
Sideshell/bottom section 2 [bottom]			2	28	1350			675	75600	51030000	-4927.174	1148175	183534470.3
					10700								
C1 Bulkhead @ 15 [m] of CL													
C1 Bulkhead section 1			2	24	3950			8725	189600	1654260000	3122.8257	24651950	184898688.1
C1 Bulkhead section 2 [bottom]			2	16	6750			3375	216000	729000000	-2227.174	82012500	107142593.4
					10700								
C2 Bulkhead @ 9,75 [m] of CL													
C2 Bulkhead section 1			2	24	3950			8725	189600	1654260000	3122.8257	24651950	184898688.1
C2 Bulkhead section 2 [bottom]			2	16	6750			3375	216000	729000000	-2227.174	82012500	107142593.4
					10700								
C3 Bulkhead @ 1,5 [m] off CL													
C3 Bulkhead section 1			2	14	1400			10000	39200	392000000	4397.8257	640266.6667	75816214.75
C3 Bulkhead section 2			2	12	7500			5550	180000	999000000	-52.17427	84375000	48998.78926
C3 Bulkhead section 3 [bottom]			2	14	1800			900	50400	45360000	-4702.174	1360800	111436632.3
					10700								
Stiffening	**b [mm]**	**t [mm]**	**No.**										
Deck section 1	340	14	23		422	6550	7540	10457	150650	1575347050	4854.8257	173420	355071999
Deck section 2	340	14	1.5		422	6550	7540	10469	9825	102857925	4866.8257	11310	23271487.77
Bottom	340	12	27		430	5880	6760	247	158760	39213720	-5355.174	182520	455290205.7
h=2*ex (2 times distance to neutral line)													
SUM									4.29E+06	2.41E+10		3.91E+08	9.04E+09
fy barge =					235	N/mm^2							
fbx allowable =					0.66	fy barge							
fsh allowable =					0.4	fy barge							
h barge =					10700	mm							
z tot (sum M/ sum A) =					5602.174275	mm							
**													
Ix tot (=sum {Ix} + sum {A*a^2}) =					9.43E+09	*10^4 mm^4							
Sx deck (=Ix tot / (h barge - z tot)) =					4.81E+14	*10^3 mm^3							
Sx bottom (=Ix tot / z tot) =					1.68E+07	*10^3 mm^3				Mbx allowable=	2.61E+06	kNm	
											======		
A shear (=sum {A side shell} + sum {A bulkhead}) =					1.49E+06	mm^2				Fsh allowable	1.40E+05	kN	
											======		

Table VI.A Self-made excel sheet in order to obtain the allowable bending moment and allowable shear force for an conventional web frame 13

Section properties barge: H541		Alternative Webframe											
Frame	13												
Section			**No.**	**b**	**h**	**A each**	**Ix each**	**z**	**A**	**M**	**a**	**Ix**	
				42000	10700					**(A*z)**	**(z-z tot)**		**(A*a^2)**
				[mm]	[mm]	[mm^2]	[10^4 mm^4]	[mm]	[mm^2]	[mm^3]	[mm]	[10^4 mm^4]	[10^4 mm^4]
Plating													
Deck section 1			1	39000	32			10684	1248000	13333632000	4560	10650	2594544298
Deck section 2			1	3000	20			10690	60000	641400000	4566	200	125066211
Secondary deck			1	41950	16			9010	671200	6047512000	2886	1432	558873052
Bottom			1	42000	28			14	1176000	16464000	-6110	7683	4390882507
Sideshell													
Sideshell/ top plate			2	25	1550			9925	77500	769187500	3801	1551615	111943183
Sideshell/middle section			2	16	6900			5700	220800	1258560000	-424	87602400	3977634
Sideshell/bottom section 1			2	20	900			1800	36000	64800000	-4324	243000	67322709
Sideshell/bottom section 2 [bottom]			2	28	1350			675	75600	51030000	-5449	1148175	224504482
					10700								
C1 Bulkhead @ 11,25 [m] of CL													
C2 Bulkhead section 1			2	24	3950			8725	189600	1654260000	2601	24651950	128225146
C2 Bulkhead section 2 [bottom]			2	16	6750			3375	216000	729000000	-2749	82012500	163283083
					10700								
C2 Bulkhead @ 1,5 [m] off CL													
C3 Bulkhead section 1			2	14	1400			10000	39200	392000000	3876	640267	58878365
C3 Bulkhead section 2			2	12	7500			5550	180000	999000000	-574	84375000	5939595
C3 Bulkhead section 3 [bottom]			2	14	1800			900	50400	45360000	-5224	1360800	137565482
					10700								
Stiffening	**b [mm]**	**t [mm]**	**No.**										
Deck section 1	340	14	23		422	6550	7540	10457	150650	1575347050	4333	173420	282786697
Deck section 2	340	14	1.5		422	6550	7540	10469	9825	102857925	4345	11310	18544914
Secondary Deck	200	12	23		234	2960	1160	9135	68080	621910800	3011	26680	61704251
Bottom	340	12	27		430	5880	6760	247	158760	39213720	-5877	182520	548424700
h=2*ex (2 times distance to neutral line)													
SUM									4.63E+06	2.83E+10		2.84E+08	9.48E+09
fy barge =					235	N/mm^2							
fbx allowable =					0.66	fy barge							
fsh allowable =					0.4	fy barge							
h barge =					10700	mm							
z tot (sum M/ sum A) =					6124	mm							
**************************************													
Ix tot (=sum {Ix} + sum {A*a^2}) =					9.77E+09	*10^4 mm^4							
Sx deck (=Ix tot / (h barge - z tot)) =					4.47E+14	*10^3 mm^3							
Sx bottom (=Ix tot / z tot) =					1.59E+07	*10^3 mm^3				Mbx allowable =	2.47E+06	kNm	
											======		
A shear (=sum {A side shell} + sum {A bulkhead}) =					1.09E+06	mm^2				Fsh allowable =	1.02E+05	kN	
											======		

Table VI.B Self-made excel sheet in order to obtain the allowable bending moment and allowable shear force for an alternative web frame 13

Appendix VII

A. IPEX Plate Girder Properties sheet

The IPEX spreadsheet is used to calculate a variety of section properties of plate girders. There is a maximum of fifteen sections used in the calculation.
In this spreadsheet there are a couple of dimension of the beams that has to be inserted to calculate the properties:

- Section breadth [mm]
- Section height

Dimensions of all the sections have to be inserted to calculate the properties of the entire cross section of the beam. If all dimensions are inserted, the following properties are calculated:

- Areas
  - AX
  - AY
  - AZ
- Dimensions
  - Y
  - Z
- Weight
- Distance to neutral axis
  - ez
  - Z-ez
  - ey
  - Y-ey
- Section moduli
  - W_y, min
  - W_y, max
  - W_x, min
  - W_x, max
- Moments of inertia
  - I_y
  - I_z
- Torsional constant (torsional resistance)
  - I_t
- Radii of gyration
  - ry
  - rz

Project	PROJECT
Subject	Subject
Job / Bid no.	Job / Bid no.
Date	18-Feb-15
Sheet	1

INPUT: (●) millimeters ( ) centimeters ( ) meters ( ) inches

OUTPUT: (●) millimeters ( ) centimeters ( ) meters ( ) inches

WEIGHT: (●) KN/m ( ) Kg/m ( ) mT/m ( ) lb/ft ( ) lb/inch ( ) lb/yard

OPEN MANUAL

PLATE GIRDER PROPERTIES

Plategirder Description

section no	Section breadth [mm]	Section height [mm]	Offset ey [mm]	Axial area [mm²]	Shear area [mm²]	Statical moment [mm³]
1	100.0	20.0	0.0	2000	500	3.43E+04
2	25.0	60.0	0.0	1500	1500	0.00E+00
3	0.0	0.0	0.0	0	0	0.00E+00
4	0.0	0.0	0.0	0	0	0.00E+00
5	0.0	0.0	0.0	0	0	0.00E+00
6	0.0	0.0	0.0	0	0	0.00E+00
7	0.0	0.0	0.0	0	0	0.00E+00
8	0.0	0.0	0.0	0	0	0.00E+00
9	0.0	0.0	0.0	0	0	0.00E+00
10	0.0	0.0	0.0	0	0	0.00E+00
11	0.0	0.0	0.0	0	0	0.00E+00
12	0.0	0.0	0.0	0	0	0.00E+00
13	0.0	0.0	0.0	0	0	0.00E+00
14	0.0	0.0	0.0	0	0	0.00E+00
15	0.0	0.0	0.0	0	0	0.00E+00
	100	80		3500	2000	

Section Properties

Areas:	AX	3500	[mm²]
	AY	2000	[mm²]
	AZ	2000	[mm²]
Dimensions:	Y	100.0	[mm]
	Z	80.0	[mm]
	Weight	0.3	[kN/m]
Distances to neutral axis:	ez (From bottom)	52.9	[mm]
	Z-ez	27.1	[mm]
	ey (From left)	50.0	[mm]
	Y-ey	50.0	[mm]
Section moduli:	Wy,min	3.57E+04	[mm³]
	Wy,max	6.96E+04	[mm³]
	Wz,min	3.49E+04	[mm³]
	Wz,max	3.49E+04	[mm³]
Moments of inertia:	Iy	1.89E+06	[mm^4]
	Iz	1.74E+06	[mm^4]
Torsional constant (torsional resistance):	It	5.79E+05	[mm^4]
Radii of gyration:	ry	23.2	[mm]
	rz	22.3	[mm]

Note: -Torsional Constant / Resistance is only valid for open girders

Last Revision: May 98

Figure VII.A Example of a plate girders properties IPEX-sheet

B. IPEX Column Capacity Sheet

Project	Barge H-541 Typical Webframe 13		
Subject	Bulkhead Column 2 (@ 8750 mm. off CL)		
Job / Bid no.	v/0003		
Date	22-Nov-99	Sheet	11-3

BULKHEAD COLUMN CAPACITY

BARGE SPECIFICATIONS

Distance (to PS sideshell/bulkhead):	*bps:*	*5250*	[mm]
Distance (to SB sideshell/bulkhead):	*bsb:*	*8250*	[mm]
Transverse webframe spacing:	*l:*	*2500*	[mm]
Barge draught: (80 % DRAUGHT)	*h:*	*5350*	[mm]
Buoyancy reaction force on column:	**Rbuoy:**	**908**	**[kN]**

FRAME PROPERTIES

Distance deck - wanted frame section:	*h1:*	*3064*	[mm]
Distance load - neutral axis:	*e1:*	*542*	[mm]
Distance outer fibre - neutral axis:	*e2:*	*542*	[mm]
Cross section area column:	*A:*	*55182*	[mm²]
Moment of Inertia column:	*Icol:*	*1.50E+10*	[mm^4]
Moment of Inertia deckbeam PS:	*Ideckps:*	*3.13E+10*	[mm^4]
Moment of Inertia deckbeams SB:	*Idecksb:*	*3.26E+10*	[mm^4]
Barge depth:	*H:*	*10700*	[mm]
Yield stress:	*fy:*	*235*	[N/mm²]
Moment reduction factor:	**r:**	**0.12**	

STRESSES

Axial compression stress:	fa:	121.1	[N/mm²]
Maximum bending stress:	fb:	21.8	[N/mm²]
Maximum load on bulkhead column:	**F:**	**9003**	**[kN]**

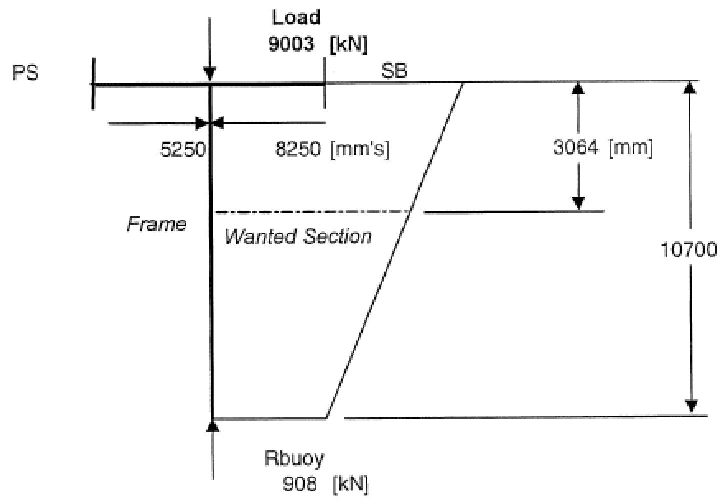
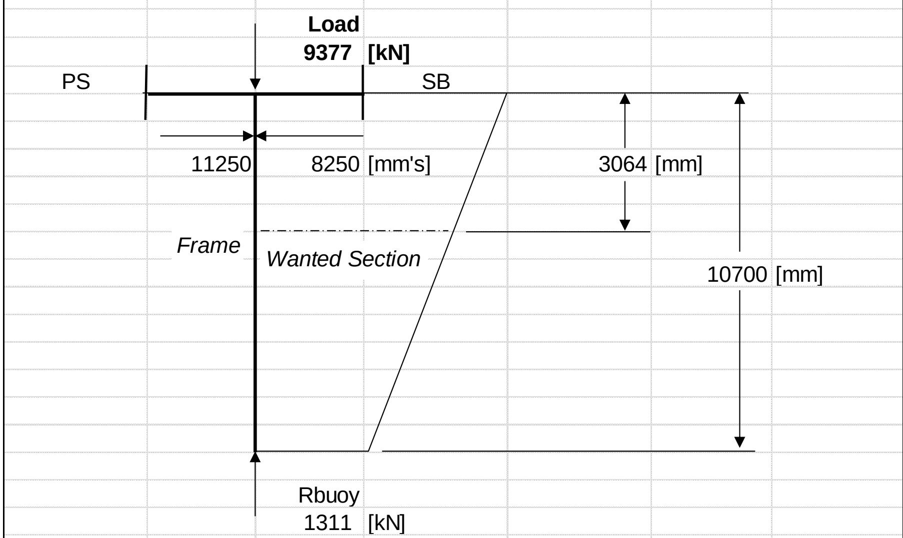


Figure VII.B Bulkhead column capacity sheet conventional web frame

Project	PROJECT		
Subject	Subject		
Job / Bid no.	Job / Bid no.		
Date	########	Sheet	1

BULKHEAD COLUMN CAPACITY

BARGE SPECIFICATIONS				
	Distance (to PS sideshell/bulkhead):	*bps:*	*11250*	[mm]
	Distance (to SB sideshell/bulkhead):	*bsb:*	*8250*	[mm]
	Transverse webframe spacing:	*l:*	*2500*	[mm]
	Barge draught:	*h:*	*5350*	[mm]
Buoyancy reaction force on column:		**Rbuoy:**	**1311**	**[kN]**
FRAME PROPERTIES				
	Distance deck - wanted frame sectio	*h1:*	*3064*	[mm]
	Distance load - neutral axis:	*e1:*	*526*	[mm]
	Distance outer fibre - neutral axis:	*e2:*	*526*	[mm]
	Cross section area column:	*A:*	*58364*	[mm²]
	Moment of Inertia column:	*Icol:*	*1.60E+10*	[mm^4]
	Moment of Inertia deckbeam PS:	*Ideckps:*	*5.93E+10*	[mm^4]
	Moment of Inertia deckbeams SB:	*Idecksb:*	*3.55E+10*	[mm^4]
	Barge depth:	*H:*	*10700*	[mm]
	Yield stress:	*fy:*	*235*	[N/mm²]
	Moment reduction factor:	**r:**	**0.14**	
STRESSES				
	Axial compression stress:	fa:	121.1	[N/mm²]
	Maximum bending stress:	fb:	21.9	[N/mm²]
Maximum load on bulkhead column:		**F:**	**9377**	**[kN]**



Last Revision: May. 98

Figure VII.C Bulkhead column capacity sheet Alternative web frame

C. Specifications Barge

Equipment data H541:

Type of vessel:	*Launch/cargo barge*	
Owner:	*Heerema Shipping 19 B.V.*	
Port of registry:	*Panama*	
Year constructed:	*2000*	
Summer draft:	*8.0m or 25ft.*	
Displacement:	*52994 Tonnes*	
GRT:	*20765*	
NRT:	*6230*	
Light weight:	*11267 Tonnes*	
	(exc. Skid or Launch equipment)	
Max.Allow.Bend.m	*Seagoing*	*178755 T*m*
	Harbour	*250000 T*m*
Midship section modulus	$W_{deck} = 18673\ m^3$	
	$W_{bottom} = 17975\ m^3$	
Max submersion bottom shell	*20 m measured from keel bottom*	

Dimensions:

Length of vessel	$160{,}00\ m$
Breadth	$42{,}00\ m$
Depth	$10{,}70\ m$

Deck capacity:

Deck area	$6760\ m^2$	
Deck load capacity	*Centre part*	$15\ T/m^2$
	Other	$20\ T/m^2$
Max. load capacity	*Main deck (frame 20-44)*	$1250\ T/4m$
	Deck (frame 0-56)	$875\ T/4m$
Max. launch capacity	*20500 Tonnes Jacket*	

Light weight

= 11267 Tonnes

= 110529270 [N]

= (exc. Skid- or Launch equipment)

Tank capacities:

Water ballast tanks: *62000* m^3

(worst case scenario buoyancy the density of seawater is 1020 kg/m3)

$$62000\ [m^3] * 1020\ \left[\frac{kg}{m^3}\right] = 63240000\ [kg]$$

$$63240000\ [kg] * 9{,}81\ \left[\frac{m}{s^2}\right] = \mathbf{620384400}\ [\boldsymbol{N}]$$

Fuel oil tanks: 68 m^3 Cooling water tank

416 m^3

D. Buoyancy

For the purpose of checking if the bottom beams meet with the strength requirements under load of the water pressure the bottom beams have been subjected to a load case.

Barge h·b : 10,70 [m] · 42 [m]
Frame distance: 2,5 [m]

Area of bottom beams per web frame.
$A = 2{,}5 \cdot 42 = 105\ [m]$

$P = \rho \cdot g \cdot h$

$g = 9{,}81\ \left[\frac{m}{s^2}\right]$

$h = 10700\ [mm]$

$\rho = 1020\ \left[\frac{kg}{m^3}\right]$ [3]

$P = 1020 \cdot 9{,}81 \cdot 10{,}70 = 10766.34\ \left[\frac{N}{m^2}\right]$

Pressure · frame distance results in the amount of force per meter over the width of a web frame:
$107066.34 \cdot 2.5 = 267.7\ \left[\frac{kN}{m}\right]$

This distributed load is subjected to the bottom beams on the alternative web frame in SACS model. The unity check end up above 1, which implies the bottom beams are not strong enough.

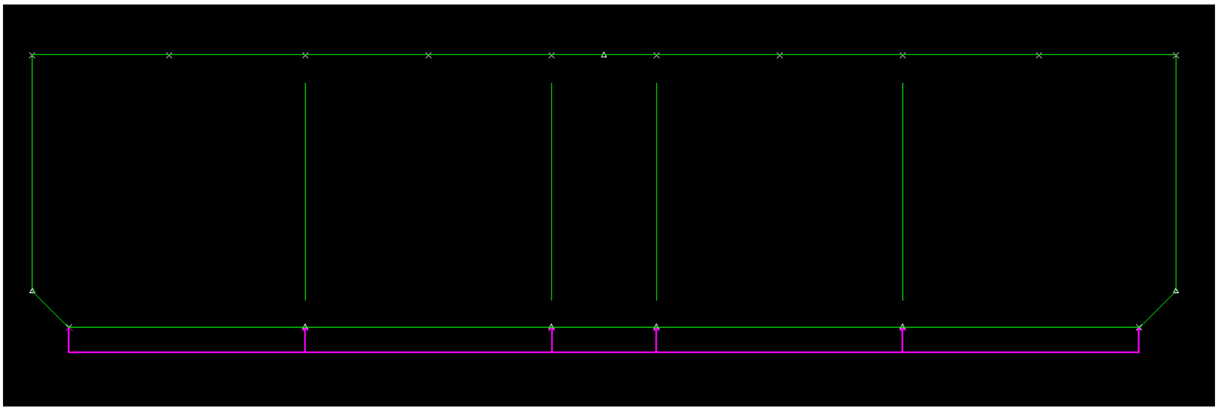
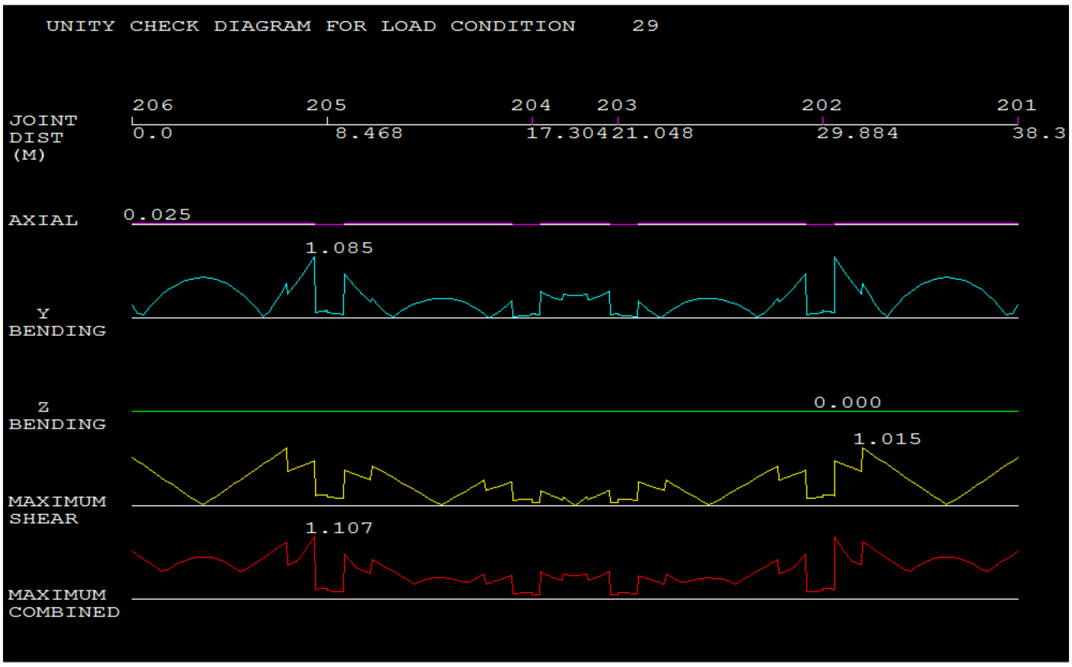


Figure VII.D Distributed force on bottom beams represent the water pressure of the barge when fully submerged.


UNITY CHECK DIAGRAM FOR LOAD CONDITION 29
JOINT
DIST
(M)
206
205
204
203
202
201
0.0
8.468
17.304
21.048
29.884
38.3
AXIAL
0.025
1.085
Y
BENDING
Z
BENDING
0.000
1.015
MAXIMUM
SHEAR
1.107
MAXIMUM
COMBINED

Appendix VIII

A. Reflection competention set

In the plan of approach (hereafter called PvA) is described what competences are expected to be developed during the graduation internship of the student. During this graduation the student will perform the roll of an researcher and designer. In the graduation manual of the Haagse Hogeschool TISD of mechanical engineering is described that the level of the competences have to be at level 3. Level 3 exists out of multiple gradations. In most cases the assignment of the internship is graded: difficult, and independent. The internship of the student at Heerema Marine Contractors will be graded at this level.

The following competences expected to be developed to level 3 during the graduation internship at Heerema Marine contractors:

- Perform a project management
- Execute a research project
- Compiling a product definition: plan of approach and list of demands
- Realizing a functional product of production process
- Realizing a detail design
- Preparing a production process
- Mange or maintain a product or process
- Critical attitude/handling
- Systematic approach in handling problems

This chapter will evaluate the competences, which the student has developed to level 3.

Competences mechanical engineering

1. **Perform a project management**

Performing a project management consists out of several disciplines: organizing, planning, execution and composing a report. In the initial phase of the graduation, the activities were set in consultation with the company supervisors. In order to start the activities considering the research, certain matters had to be arranged (organization). First of all, a planning was made in order to create a clear overview of the activities and their associated timeframes. Activities were discussed in the initial phase of the graduation in order to define the objective of the internship. Activities were linked to deadlines to create a window of time in order to make adjustments in the report, calculations and SACS model. Execution of activities were done individual and therefore can be categorized under level 3. However the results were always evaluated, discussed and checked by the company supervisor in order to obtain valid results. At Heerema Marine Contractors, employees always check each other's work in order to make sure results correct.

2. **Execute a research project**

This graduation can be seen as both a research assignment and a design assignment. During the research current barge designs had to be compared to a self-made design for an alternative web frame 13. In order to be able to make a design, the student was required to obtain certain knowledge about the way Heerema Marine Contractors works and operate. The research can be split into 3 parts. The first part of the research was defining the objective of the assignment. The second part of the research existed out of: gathering information (dimension on ship drawings, methods of calculation) calculations, modeling, organizing data and reporting. The last part existed out of evaluating the results. The results are compared with results of the conventional web frame, and from there on conclusions and recommendations were compiled. All parts (aspects) of this assignment, and the grade of individuality made this competence rise to a level 3.

3. Compiling a product definition: plan of approach and list of demands

Prior to the graduation there have been made agreements on the objective. In the initial phase of the assignment there have been made agreements on what aspect should be researched. From here on a general objective was created. During the graduation the objective kept being defined even more. As result of defining the objective, several demands/requirements which had to be met were compiled. For example: one of the demands was to maintain the same weight for the alternative web frame. This demand can be seen a one of the goals which had to be achieved, and in the thesis is described how this goal is realized.

4. Realizing a functional product or production process

The report, SACS model, Excel sheets, and the hand calculations can be seen as the products, which have been realized during this internship. The SACS model of the conventional web frame 13 was available of the moment the graduation initiated. However in order create the model for an alternative web frame 13, this model is adjusted entirely in order to obtain a valid model, which represented the alternative web frame. This competence can be graded level 3 because of the difficulty of the assignment, the amount of organizing data, and evaluating of the data that was required.

5. Realizing a detail design

During the research a SACS model has been designed for a typical web frame 13. In order to realize this design the program (which the student had never used) had to be mastered. Prior to designing the alternative web frame drawings of the longitudinal bulkheads, side shell, web frames, typical web frame connections, the bottom and deck plan had to be gathered. Information from these drawing was acquired in order to calculate certain properties. Besides obtaining information from drawings, the student had to make drawings for the sections of the beams. These drawing are needed to visualize the plate girders of the alternative beams, which have been implemented in IPEX sheets (plate girder properties).

6. Preparing a production process

This graduation does not really concern a production process. For this competence, the research will be seen as the production process. Preparation concerned getting familiar with calculation methods, IPEX sheet, SACS, and creating a template for the thesis. It was especially important to know what activities needed to be undertaken in order to able to continue the assignment in a structured manner.

7. Manage or maintain a product or process

In this case, the product or process, which has to be maintained/managed, was the SACS model, and the (hand) calculations and the thesis. Changing the SACS model and obtaining correct values was an individual task which took a relatively large amount of time, and effort in order to obtain a model of the alternative web frame. Writing the thesis was a continuous process which has to be maintained daily.

8. Critical attitude/handling

A critical attitude during this research was required in order to make a valid comparison of the conventional web frames and the alternative web frame. The critical attitude was mainly required during the evaluation of the results. An important aspect was to determine of the values of the calculations were realistic. Also understanding what the effects of certain aspects are.

9. Systematic approach in handling problems

The systematic approach in handling problems is mainly applied detailing the alternative web frame in SACS. In preparation to modelling the alternative web frame a variety of activities had to be executed. Designing a SACS model exists out of gathering a lot data, which has to be organized in order to maintain a clear overview. In general organizing and linking certain data to one another was one of the difficulties during this research. Prior to this research the student was ranked level 2 for this competence. However after this graduation internship the student has spent a relatively large amount on creating a structure in the way of executing

	Taakrollen	onderzoeker	ontwerper	adviseur	beheerder	Projectleider	Ondernemer
Competentieset werktuigbouw &hbo algemeen							
Nr.	**Competenties WTB**						
1	Projectmanagement uitvoeren	2	2	-	-	-	-
2	Onderzoeksopdracht uitvoeren	2	2	-	-	-	-
3	Het kunnen opstellen van productdefinitie, pva en pve voor een duurzaam proces	2	2	-	-	-	-
4	Het realiseren van een functioneel duurzaam product of voortbrengingsproces	2	2	-	-	-	-
5	Het realiseren van een detailontwerp voor een duurzaam product of voortbrengingsproces	2	2	-	-	-	-
6	Het realiseren van een prototypemodel van een duurzaam product of voortbrengingsproces	-	-	-	-	-	-
7	Het voorbereiden van een voortbrengingsproces	2	2	-	-	-	-
8	Het produceren van een duurzaam product	3	3	-	-	-	
9	Het beheren of onderhouden van een product of proces	2	2	-	-	-	-
Nr.	**Algemene hbo competenties**						
10	Kritisch handelen (analytisch en probleemoplossend vermogen en het onderbouwen van keuzen, oordeelsvorming)	2	2	-	-	-	-
11	Systematisch een probleem aanpakken (creatieve, plan- en projectmatige werkhouding)	2	2	-	-	-	-
12	Samenwerken (sociaal communicatieve vaardigheden)	3	3	-	-	-	-
13	Persoonlijke en professionele ontwikkeling	3	3	-	-	-	-
14	Zelfverantwoordelijk werken	3	3	-	-	-	-
15	Kunnen functioneren in een internationale en/of multiculturele context	3	3	-	-	-	-