MASTER THESIS

HØGSKOLEN I ÅLESUND
Aalesund University College

TITLE:

STRUCTURE ANALYSIS OF BOW STRUCTURE

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ABSTRACT:

The bow structure presents a significant portion of the hull structure weight, cost and fabrication time. In this thesis, with the purpose of the reduction of the weight, we arrange three of the panel configurations of the ship bow we have definited in different way, changing optimal parameters we have studied such as stiffener direction, stiffener spacing, support member spacing and plate thickness in the bowimpact spreadsheet in Naticus Hull, to find the optimal dimensions of the structure whose results should meet relevant DNV rules, and then simulate the optimal panel in nx to test strengthening enough to resist bow impact pressure.

Lastly, the performances of optimized ship bow structure designs were then compared and it is concluded which configuration is better, and discussion and future work has been made in the last part.

Key words: Bow structure, Stiffened panel. Structure Optimization.

This thesis is submitted for evaluation at Ålesund University College.

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HØGSKOLEN I ÅLESUND

Aalesund University College

MASTER THESIS 2015
FOR
STUD. TECHN. YINGWEI LIU

THSIS TILE: STRUCTURE ANAYLSIS OF BOW STRUTRUE

Here some background information about problem:

This master thesis will deal with structrue optimzation of layout of the stiffened panel on the ship bow. The objective is to evaluate and compare a series of optimum deisgn(different configuration of the stiffened panel in the ship bow) with respect to weight, fabrication and performance.

The performances of optimized ship bow structure designs were then compared and it was concluded which configuration is better, and how it works in the real situation. Furthermore, optimization parameters that play an important role in the weight optimization of ship bow are studied.

Under this circumstance, the objectives of the present work are constituted by the following sub-tasks:

1) Brief description of calculated vessel including structural lay-out and the scantlings of the panels. Review of typical load cases and characteristic action used in the design.

2) Review of relevant characteristic resistance formulation given in DNV for stiffened plates. The theory background for the various requirements shall be explained for BowImpact2008Jan.xls of Rule Check Analysis in the Naticus Hull.

3) On the basis of characteristic action effects supplied by the theory rules of *HULL STRUCTURAL DESIGN SHIPS WITH LENGTH 100 METRES AND ABOVE. January 2008*, determine the dimensions of the stiffened panel. Perform parametric studies where e.g. the plating thickness, spacing of stiffeners and support member length are varied in the BowImpact2008Jan.xls to determine the optimum dimensions of the panel.

4) Develop one of the optimum panel in Finite element analysis in Siemens NX to test the structure strength such as flection and stress, and see if it exceeds the yield strength.

5) Compare and identify weight of each optimum panel to make Conclusions, discussion, and recommendations for further work.

Thesis format

The thesis should be organised in a rational manner to give a clear exposition of results, assessments, and conclusions. The text should be brief and to the point, with a clear language.
Telegraphic language should be avoided.

The thesis shall contain the following elements: A text defining the scope, preface, list of contents, summary, main body of thesis, conclusions with recommendations for further work, list of symbols and acronyms, references and (optional) appendices. All figures, tables and equations shall be numerated.

The supervisors may require that the candidate, in an early stage of the work, presents a written plan for the completion of the work. The plan should include a budget for the use of computer and laboratory resources which will be charged to the department. Overruns shall be reported to the supervisors.

The original contribution of the candidate and material taken from other sources shall be clearly defined. Work from other sources shall be properly referenced using an acknowledged referencing system.

The report shall be submitted in one printed copy, and one electronic as a pdf-file version on a CD.

Thesis supervisor at Aalesund University College: Sollied, Arne Jan

Supervisor

Deadline: May, 29. 2015

PREFACE

This report is the result of the Master Thesis for stud, techn, Yingwei Liu at Aalesund University College. Spring 2015.

The work herein is a new project provided by my supervisor, so the process of performing this thesis is very tough in the starting point, this is due to the experience on learning how to use bowimpact xls, spreadsheet in Nautcis Hull, because there are lots of knowledge, theoretical basis behind the software, and thanks for my supervisor, so that my work can be finished before deadline. And with an agreement with some jobs like expend the size of the panel simulated in the nx has not performed in this thesis, and will be recommended in the future work.

Performance of this thesis, besides essential knowledge about buckling of component structures of the panel, I have a chance to work with practical rules of DNV GL, which I don't have this when I was working in the shipyard in china for one year, and this helps me to get some practical knowledge and understand how to apply for optimal design in this thesis.

During the thesis work, problems were frequently discussed, in particular would like to express a deep sense of gratitude and thanks profusely to Master Thesis supervisor Prof. Sollied, Arne Jan(AAUC) who help me not only knowledge in this thesis, but also gave me method in order to solve a problem in research as well as in real life. And also thanks for Yael Pericard in NX part.

Yingwei Liu

Aalesund University College

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TERMINOLOGY

Symbols

L	rule length in m
B	rule breadth in m
D	rule depth in m
T	rule draught in m
C_B	rule block coefficient
V	maximum service speed in knots on draught T
S	girder span in m.
s	stiffener spacing in m, measured along the plating
l	stiffener span in m, measured along the top flange of the member.
h_0	vertical distance (m) from the waterline at draught T to point considered
K_r	Roll radius of gyration
GM	Metacentric height in m
k	Roll damping parameter in m
TR	Roll period in s
φ	Roll angle in [°]
θ	Pitch angle in [°]
a_B	Common acceleration parameter
C_W	Wave coefficient (reduced)
R	Radius of curvature of shell plating in m
σ	Nominal allowable bending stress in N/mm2 due to lateral pressure
τ	The shear stress, of the web plate for the support members
t	thickness in mm of plating
s	shortest side of plate panel in m
l	longest side of plate panel in m length in m of stiffener, pillar etc.
E	modulus of elasticity of the material $2.06 \cdot 10^5$ N/mm2 for steel
σ_{el}	the ideal elastic (Euler) compressive buckling stress in N/mm2
σ_c	minimum upper yield stress of material in N/mm2, and shall not be taken less than the limit to the yield point
τ_{el}	the ideal elastic (Euler) shear buckling stress in N/mm2

σ_c	the critical compressive buckling stress in N/mm2
τ_c	the critical shear stress in N/mm2
σ_a	calculated actual compressive stress in N/mm2
Z_n	vertical distance in m from the baseline or deckline to the neutral axis of the hull girder, whichever is relevant
Z_a	vertical distance in m from the baseline or deckline to the point in question below or above the neutral axis, respectively
f_1	= material factor = 1.0 for NV-NS steel 1) = 1.08 for NV-27 steel 1) = 1.28 for NV-32 steel 1) = 1.39 for NV-36 steel 1) = 1.47 for NV-40 steel. 1)
η	stability (usage) factor $= \frac{\sigma_a}{\sigma_c} = \frac{\tau_a}{\tau_c}$
n	number of stiffeners located within the span length S
Wyb	section modulus about Y-axial
∂	flare angle
β	waterline to longtidudinal angle
Lw	Welding length

ABBREVIATIONS

FEM	Finite Element Method

1 INTRODUCTION TO THE CALCULATED VESSEL

1.1 Project background

Thin-walled structures are widely used in the maritime industry because they make the structure more cost-effective by offering a desirable strength/weight ratio. Reduction in the structural weight of ships will increase their cargo-carrying efficiency. This increase in efficiency is obtained by either carrying more cargo with the same displacement or by increasing the speed of the ship. Moreover, the substantial decrease in material cost supersedes the higher production costs. One can easily predict that both improvements are also important from a sustainability point of view. Less emission of hazardous gases produced by marine diesel engines and reducing the use of natural resources are the examples of these structures' advantages in terms of sustainability.

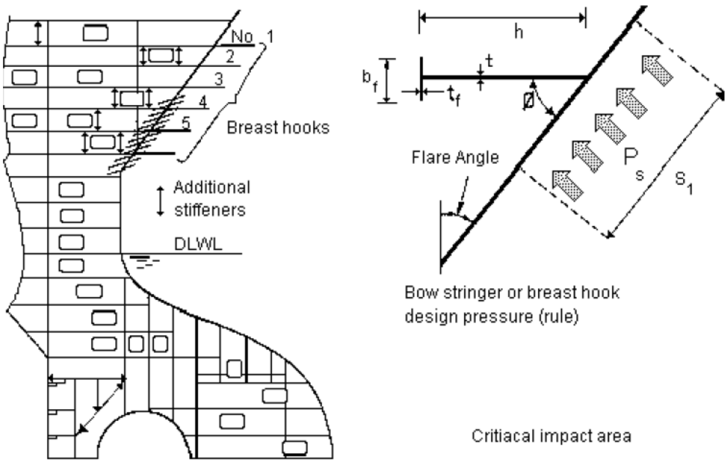


Figure 1.1 Typical Bow region.

Different types of materials such as steel, aluminium, composite and plywood are used structure design. Utilizing alternative materials to produce lightweight in marine structures will lead to weight reduction in.

However, this advantage is overshadowed by the significant manufacturing and material costs. As a result of this, the focus in the marine industry has been shifted toward the structural designs and optimization of panels and ship bow, either by means of modifying the dimensions or utilizing alternative configurations for the panel structures.

In this thesis, a methodology based on Rule Check together with bow impact spreadsheet is presented to investigate the possibility of obtaining weight reductions in ship bow while carrying out rule check and hull structural analysis in the panel according to the DNV Rules for ships and the IACS Common Structural

Rules. This is to be done by BowImpact2008Jan.xls fully integrated in the Nauticus Hull system and share common ship data with the other Nauticus Hull modules.

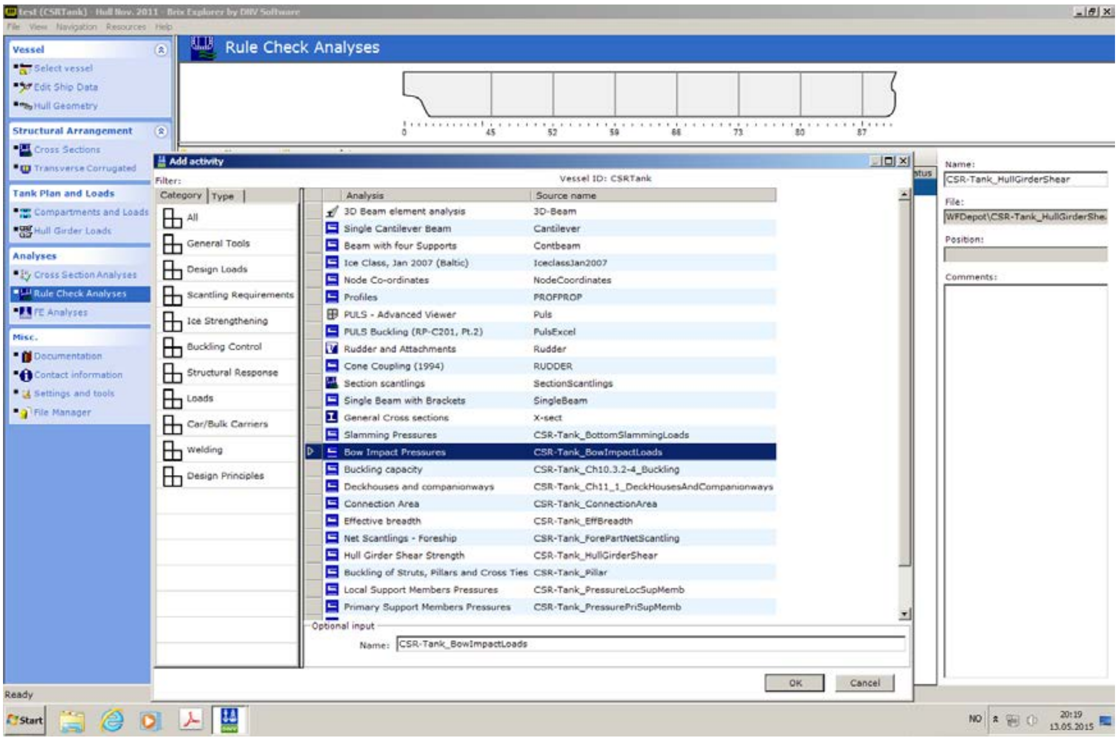


Figure 1.2 BowImpact2008Jan.xls. Windows

1.2 Problem formulation

The structural design of a ships bow is a complex matter. In this context, the term “ship’s bow” refers to the forward 10 percent of the ship’s length above the summer load waterline.

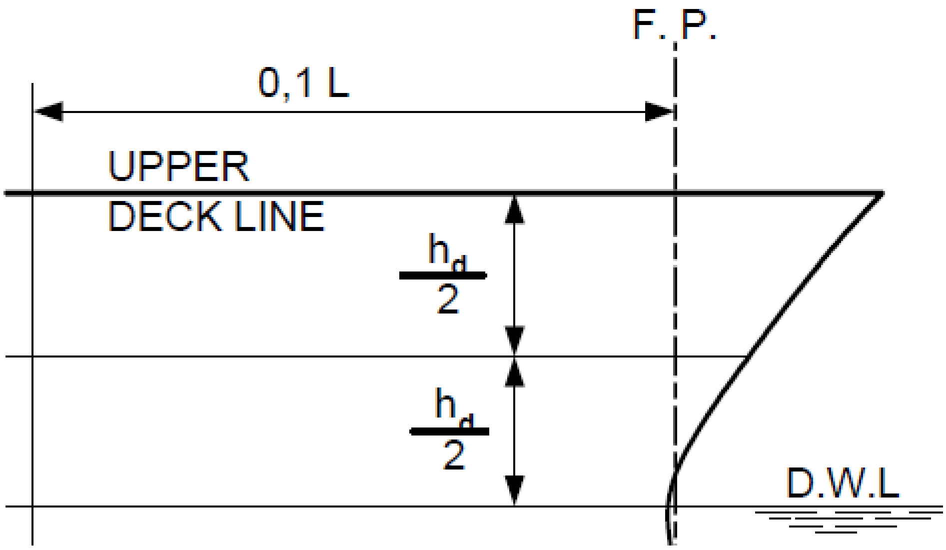


Figure 1.3 Definition of the Ship Bow

The bow structure presents a significant portion of the hull structure weight, cost and fabrication time. In this thesis, we should arrange the panel configuration in different way such as changing optimal parameters stiffener spacing, support members, spacing and plate thickness in order to make bow design balance which should meet relevant DNV rules, and the contributing factors include the additional strengthening required to bow impact pressure and at the same time to save the weight and some practical reasons such as wok space enough to let the shipbuilding works welding or installing such kinds of work.

1.3 Objectives and Scope of Work

The main objective with this thesis is to evaluate and compare a series of optimum design (different configuration of the stiffened panel) with respect to weight, fabrication and performance in the ship bow.

The performances of optimized ship bow structure designs were then compared and it was concluded which configuration is better, and how it works in the real situation. Furthermore, optimization parameters that play an important role in the weight optimization of ship bow are studied.

Under this circumstance, the objectives of the present work are constituted by the following sub-tasks:

1) Brief description of calculated vessel including structural lay-out and the scantlings of the panels. Review of typical load cases and characteristic action used in the design.

2) Review of relevant characteristic resistance formulation given in DNV for stiffened plates. The theory background for the various requirements shall be explained for BowImpact2008Jan.xls of Rule Check Analysis in the Naticus Hull.

3) On the basis of characteristic action effects supplied by the theory rules of *HULL STRUCTURAL DESIGN SHIPS WITH LENGTH 100 METRES AND ABOVE. January 2008*, determine the dimensions of the stiffened panel. Perform parametric studies where e.g. the plating thickness, spacing of stiffeners and support member length are varied in the BowImpact2008Jan.xls to determine the optimum dimensions of the panel.

4) Develop one of the optimum panel in Finite element analysis in Siemens NX to test the structure strength such as flection and stress, and see if it exceeds the yield strength.

5) Compare and identify weight of each optimum panel to make Conclusions and recommendations for further work.

1.4 Assumption

In order to make the simple calculation, radius of curvature of shell plating R is zero, as we know, some shell plating of the ship has a radian which means it is not a plane, but in our calculation, all of the panels are panel.

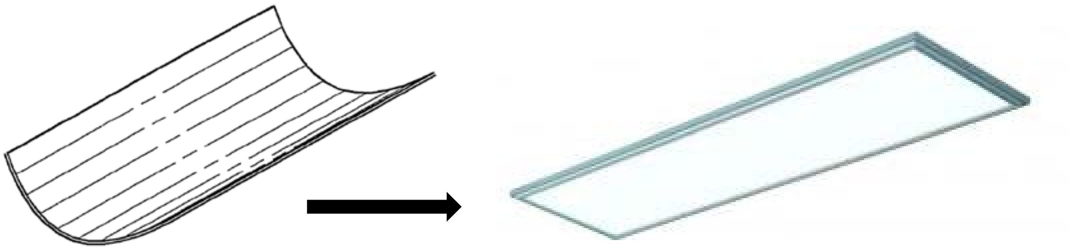


Figure 1.4 Idealization of the curvature of shell plating

2 INTRODUCTION TO THE CACULTED VESSEL

2.1 General

The offshore vessel is built based on the experience data and DNV Rules for ships, and it will be set up as input in BowImpact2008Jan.xls. of the Nauticus hull which is a software package for strength assessment of hull structures.

Table 1 Main data of the calculated vessel

Rule length	L	[m]	120.00
Speed	V	[knots]	16.00
Block coefficient	C_B		0.70
Service area notation			None
Depth	D	[m]	12.00
Draught	T	[m]	7.00
Breadth	B	[m]	24.00
Roll radius of gyration	K_r	[m]	3.96
Metacentric height	GM	[m]	1.68
Roll damping parameter	k		0.8
Roll period	TR	[s]	6.11
Roll angle	φ	[°]	25.40
Pitch angle	θ	[°]	10.24
Common acceleration parameter	a_B		0.50
Wave coefficient (reduced)	C_W		8.34

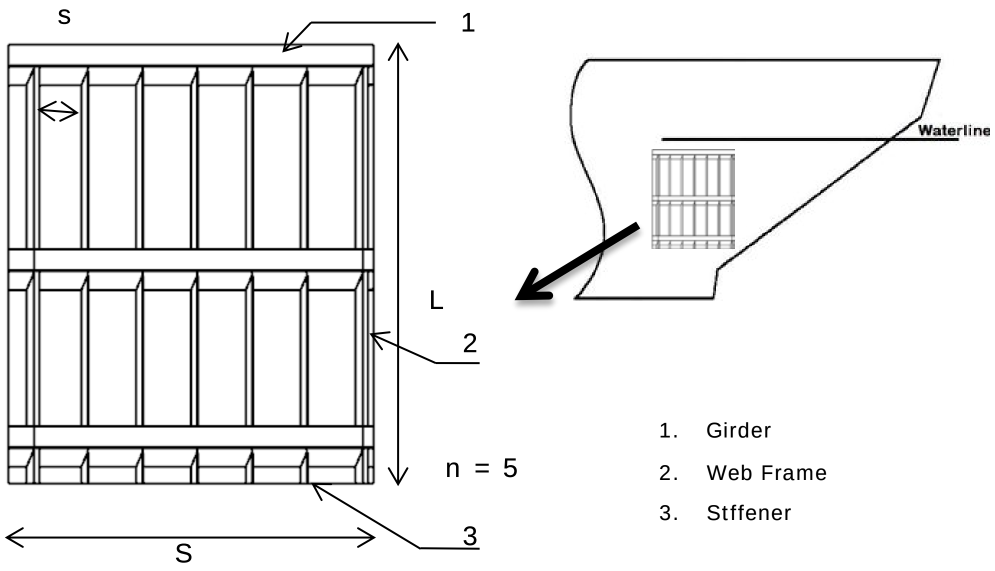


Figure 2.1 Side Views of general layout of stiffened panel in the ship bow.

As we know, the results of weight eveluation should be compared in the kilogram per square meter(kg/m^2), therefore we can definite the dimension of the stiffened panel in the views of the shipbuilding, which could be explained that, from the dimension of the vessel, the distance between tween deck and upper deck is 5 meters, therfore the length(viertical distance) of the panle can be varied from 2 to 5m, and the span of the panel can be equal to the spacing of the frame which is practical estimated from 3m to 6m or more, and the feasibility of the layout will be verified after deisgn.

The diference between stiffened panel of the hull and stiffened panel of the ship bow is the web angle between stiffener and shell also the angle between support members and shell, for the stiffened panel of the hull, this angle is 90 degree, but the web angle φ_w for the stiffened panel of the ship bow is depending on the hull form of the ship bow hul, demonstrated as follows:

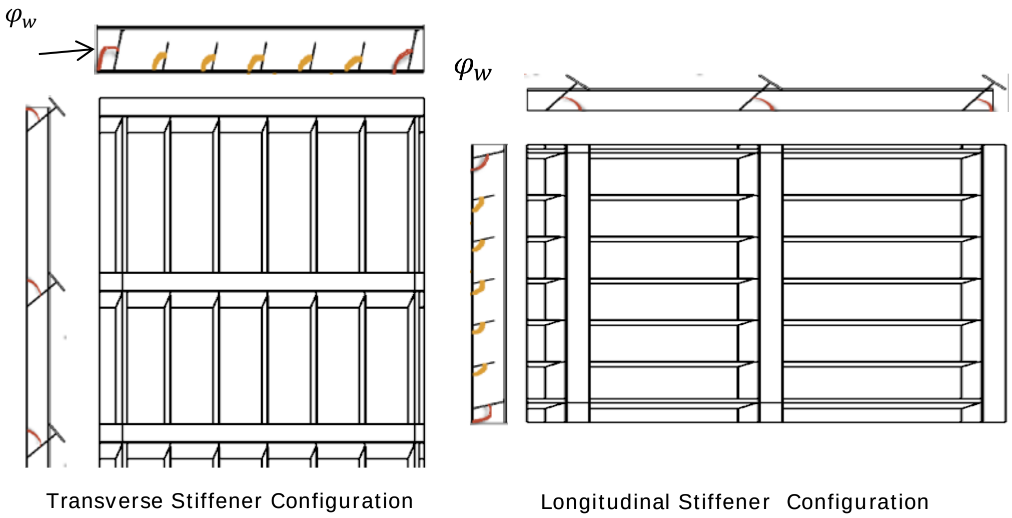


Figure 2.2 Typical two kinds of layout of the stiffened panel on the ship bow.

Because of the time limitation, we make caculation of the general 3 configrations of the stiffened panel in the BowImpact2008Jan.xls, and general dimensions of the panel is shown as follows:

Transverse Stiffener:

1) l = 2.1m, s = 0.50m, 0.55m, 0.60m, 0.65m, and 0.70m.

2) l = 1.4m, s = 0.50m, 0.55m, 0.60m, 0.65m, and 0.70m.

Longitudinal Stiffener:

3) S = 3m, s = 0.50m, 0.55m, 0.60m, 0.65m, and 0.70m.

3 GENERAL THEORETICAL BASIS FOR STIFFENER PLATING BUCKLING

The general theoretical of the requirements in this section applied to design ship's side structure on the ship bow.

The formula are given for plating, stiffeners and girders are based on the structural design principles outlines in the BowImpact2008Jan.xls spreadsheet.

Direct stress calculations based on side structural principles and as outlined in 3.4 will be considered as alternative basis for the scantlings and will be applied in the BUCKLING.xls Sheet in the Nauticus Hull.

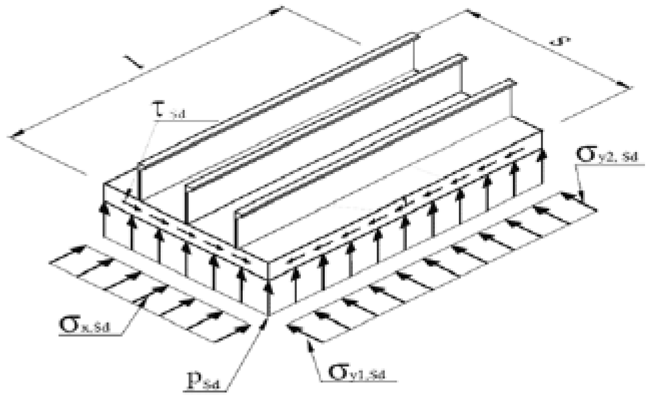


Figure 3.1 Stiffened plate under combined loads

Figure 3.1 shows a stiffened plate under combined loads. $\sigma_{x.Sd}$ is the axial load (considered as the uniformly distributed load); $\sigma_{y1.sd}$ and $\sigma_{y2.sd}$ are the transverse loads (maybe uniformly or linearly distributed loads); τ_{sd} is the shear stress and the above stress values will be identified in the Buckling control in BUCLLING.xls sheet in the Natiucs Hull. And $P_{sl}$is the lateral pressure (this term is constant in BowImpact2008Jan.xls spreadsheet and BUCKLING.xls Sheet.).

Nowadays, there are many available rules, codes and guidelines for buckling design of stiffened panels in the ship structures as well as for the offshore structures .These rules are especially useful in quick design or quick calculation.

However, the simple design rules presently recommended by classification societies will handle the optimum design of stiffened panels in the ship bow, if the designed load is the combinations of the compression in both longitudinal and transverse directions and lateral pressure, see Section 3.4 in this chapter. In this respect, this study proposes a simplified procedure in order to optimize the stiffened plate under these designed loads. The results of this procedure are also then calibrated against numerical analysis which will be carried out in this report. The ultimate goal of this thesis is to develop a robust tool that can give the optimum design of the stiffened plate under this kind of designed load.

3.1 Buckling of stiffened plates

3.1.1 The impact pressure

The impact pressure given in Eq 3.1 applies to areas away from knuckles, anchor bolster etc. that may obstruct the water flow during wave impacts. In way of such obstructions, additional reinforcement of the shell plate by fitting carlings or similar shall generally be considered.

The design bow impact pressure shall be taken as:

$$\mathrm{Psl} = \mathrm{C}(2.2 + \mathrm{Cf})(0{,}4\mathrm{V}\sin\beta + 0{,}6\sqrt{\mathrm{L}})^2 \quad (3.1)$$

C	= 0.18 ($Cw - 0.5h_0$), maximum 1.0
Cw	= wave coefficient as given in Sec.4 B200(Pt3.Ch1)
C_f	= 1.5 tan ($\alpha + \gamma$)
γ	= 0.4 ($\varphi\ cos\beta + \theta\ sin\beta$)
φ, θ	= as given in, in radians, Sec.4 B(Pt3.Ch1)
α	= flare angle in radians taken as the angle between the side plating and a vertical line, measured at the point considered
β	= angle in radians between the waterline and a longitudinal line, measured at the point considered. The flare angle α may normally be taken in accordance with:

$$\tan\alpha = \frac{\mathrm{a1} + \mathrm{a2}}{\mathrm{h_d}}$$

If there is significant difference between a1 and a2, more than one plane between the design waterline and upper deck (forecastle deck if any) may have to be considered.

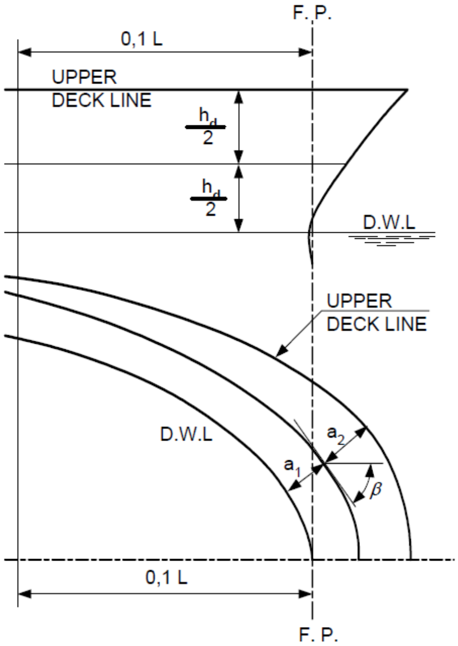


Figure 3.2 Bow region

3.1.2 The thickness of shell plating

The thickness of shell plating in the bow region shall not be less than:

$$t = \frac{13.8 k_a s \sqrt{p_{sl}}}{\sqrt{\sigma_f}} + t_k \quad (3.2)$$

ka	= $(ka1 - 0.25ka2)^2$
kal	= 1.1 in general
	= 1.22 within cylindrical and conical bow shell regions with vertical or radial stiffening. The bow shell shall be considered cylindrical and conical when: $s > R/10$
$ka2$	= s/l , but need not be taken < 0.4, and is not to be taken > 1.0
l	= length of plate field in m
σ_f	= minimum upper yield stress of material in N/mm2 and shall not be taken less than the limit to the yield point given in Sec.2 B201(Pt3.Ch1)
p_{sl}	= as given in Eq 3.1
s	= stiffener spacing in m.

3.2 Buckling of Stiffeners

The plate stiffener is modelled as a beam-column subjected to equivalent axial force and a lateral line load as shown in the following figure.

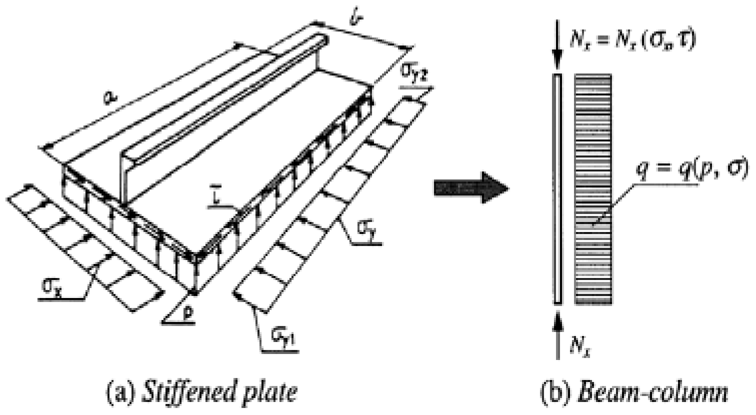


Figure 3.3 Beam- column of the stiffened plate

3.2.1 Shear Area Check

The net effective shear area As of stiffeners supporting the shell plating in the bow region is not to be less than As, as given under:

$$A_s = \frac{125\,\mathrm{l\,s\,p}}{\sigma_f} \quad (cm^2) \qquad (3.3)$$

l = stiffener span in m

p = 0.5 psl but is not to be taken less than 2 p2 as given in (Table B1 Design loads. Pt.3 Ch.1 Sec.6 – Page 52)

p_{sl} = as given in Eq 3.1

σ_f = as defined in Eq 3.2.

3.2.2 Plastic Section Modulus

The net effective plastic section modulus for the stiffener fitted, Zpa, as determined according to in Sec.3 C1005, is not to be less than Zp, given below:

$$Z_p = \frac{160\, s\, l^2\, p}{(1+\frac{n_s}{2})\sigma_f} + \frac{n_s(1-\sqrt{1-(A_s/A_{sa})^2}) \ \ \sin\varphi_\omega\, h_w(h_w+t_p)(t_w-t_k)}{8000} \quad (cm^3) \qquad (3.4)$$

l = stiffener span (m)

h_w = height of stiffener web in mm, see also Fig.3.4

t_f = thickness of flange in mm in general

= 0.0 for flat bar stiffeners

t_k = as given in Sec.2 D200
t_w = web thickness of stiffener in mm.

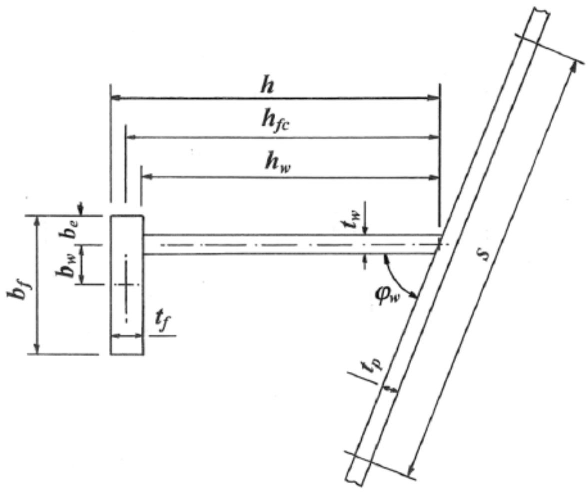


Figure 3.4 Stiffener Cross section

n_s = number of bending effective end supports of stiffener
= 2, 1 or 0
A_s = as given above
A_{sa} = net effective web area in cm^2 of the stiffener fitted, as determined in accordance with. (Sec.3 C1005 Pt.3 Ch.1 Sec.6 – Page 29)
ϕ_w = angle between stiffener web and shell plate

3.2.3 Web Thickness Check

The web thickness of shell stiffeners in lieu of shell stiffeners shall not be less than:

$$t_w = 0{,}025\left(\frac{p\,s\,{h_w}^2}{\sin\varphi_w}\right)^{0{,}33} + t_k \quad (mm) \qquad (3.5)$$

p = as given in 3.3
s = load breadth of considered member in m
φ_w = angle between member web and shell plate
hw = web height.

Or distance in mm between shell plating and the nearest parallel web or breast hook stiffener.

3.3 *Buckling of support members*

Girder systems in the bow shall be designed to have structural continuity especially when the longitudinal girder or stringer should be kept continuity which means the transverse stiffener should be cut off when they meet with longitudinal girder systems.

The main stiffening direction for stringers and web frames, platforms and bulkheads is generally to be parallel to the web direction of the shell stiffeners being supported.

Two-sides girder flanges are generally to be horizontal line and straight between supports in this case can be seen in the Fig 3.5.

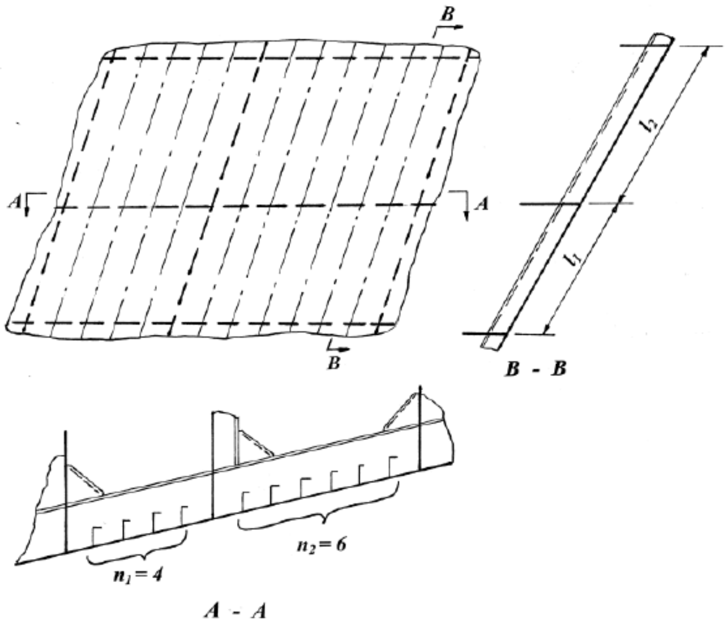


Figure 3.5 Primary member supporting shell stiffeners

3.3.1 Web Thickness fitted

The web thickness of shell stiffeners or breast hooks,stringers and web frames in lieu of shell stiffeners shall not be less than: Eq 3.5.

3.3.2 Section modulus and Web area

The section modulus of primary members supporting shell stiffeners (i.e. stringers and web frames) shall not to be less than:

$$Z = \frac{110S^2 \mathrm{bp} w_k}{\sin \varphi_w \sigma_f} \quad (cm^3) \quad (3.6)$$

The web area at each end support of primary members supporting shell stiffeners shall not to be less than:

$$A = \frac{12.5 \text{nsbp}}{\sin\varphi_w \sigma_f} + \frac{h t_k}{100} \quad (cm^2) \quad (3.7)$$

b = breadth of load area supported by the stringer or web frame in m
= $0.5\,(l_1 + l_2)$, see Fig 3.5.

h = girder height in mm

s = spacing of shell stiffeners in m

S = span of stringer or web frame

φ_w = angle between web and shell plate, see Fig.3.4

p_{sl} = as given in Eq 3.1

σ_f = as defined in Eq 3.2

3.3.3 Shear stress and Normal stress

At the end supports of primary members supporting shell stiffeners, the shear and axial stress response of the web shall to be assessed with respect to web buckling in accordance with Sec.14. In the assessment of the primary member, the shear stress, of the web plate may be taken as:

$$\tau = \frac{600 \text{nsbp}}{\sin\varphi_w h(t_w - t_k)} \quad (N/mm^2) \quad (3.8)$$

The normal stress of the web plate at the face plate may be assumed given by:

$$\sigma = \frac{100 S^2 b p w_k}{\sin\varphi_w Z_f} \quad (N/mm^2) \quad (3.9)$$

Z_f = section modulus in cm^3 of primary member as fitted

t_w = web plate thickness in mm of the primary member as fitted.

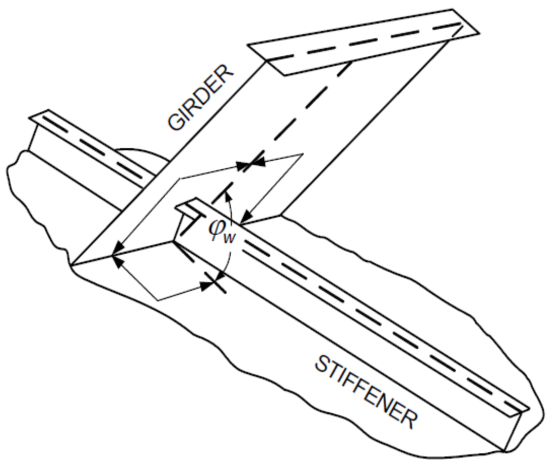


Figure 3.6 The web angle φ_w of stringer or web frames

3.4 Buckling control of support members

3.4.1 Buckling control in the BowImpact2008Jan.xls.

This section covers the requirements for buckling control of

- plating subject to in-plane compressive and or shear stresses
- axially compressed stiffeners and pillars
- panel ultimate strength.

The buckling strength requirements are related to:

- longitudinal hull girder compression and shear stresses based on design values of still water and wave bending moments and shear forces
- axial forces in pillars, supporting bulkheads and panting beams based on the rule loads
- axial and shear forces in primary girders based on the rule loads.

Local plate panels between stiffeners may be subject to uni-axial or bi-axial compressive stresses, in some cases also combined with shear stresses. Methods for calculating the critical buckling stresses for the various load combinations are given below.

Formulae are given for calculating the ideal compressive buckling stress σ_{el}. From this stress the critical buckling stress σ_c may be determined as follows:

$$\sigma_c = \sigma_{el} \text{ when } \sigma_{el} < \frac{\sigma_f}{2} \quad (3.10)$$

$$= \sigma_f \left(1 - \frac{\sigma_f}{4\sigma_{el}}\right) \textit{ when } \sigma_{el} > \frac{\sigma_f}{2} \quad (3.11)$$

Formulae are given for calculating the ideal shear buckling stress τ_{el}. From this stress the critical buckling stress τ_c may be determined as follows:

$$\tau_c = \tau_{el} \text{ when } \tau_{el} < \frac{\tau_f}{2} \quad (3.12)$$

$$= \tau_f \left(1 - \frac{\tau_f}{4\tau_{el}}\right) \textit{ when } \tau_{el} > \frac{\tau_f}{2} \quad (3.13)$$

τ_f = yield stress in shear of material in N/mm2

$= \frac{\tau_f}{\sqrt[3]{3}}$

Plate panel in uni-axial compression

The ideal elastic buckling stress may be taken as:

$$\sigma_{el} = 0.9\mathrm{kE}(\frac{\mathrm{t}-t_k}{1000\mathrm{s}})^2 \quad (N/mm^2) \quad (3.14)$$

For plating with longitudinal stiffeners (in direction of compression stress):

$$\mathrm{k} = \mathrm{k}_l = \frac{8.4}{\varphi+1.1} \quad for\ (0 \leq \varphi \leq 1) \quad (3.15)$$

For plating with transverse stiffeners (perpendicular to compression stress):

$$\mathrm{k} = \mathrm{k}_s = c[1 + (\frac{s}{l})^2]^2 \frac{2.1}{\psi+1.1} \quad for\ (0 \leq \psi \leq 1) \quad (3.16)$$

c = 1.21 when stiffeners are angles or T-sections
= 1.10 when stiffeners are bulb flats
= 1.05 when stiffeners are flat bars
= 1.3 when the plating is supported by floors or deep girders.

ψ ψ is the ratio between the smaller and the larger compressive stress assuming linear variation see Fig.3.7

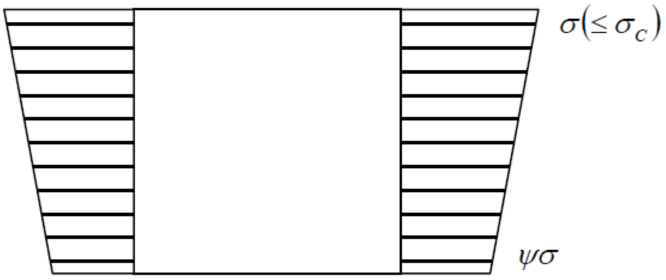


Figure 3.7 Buckling stress correction factor

The above correction factors are not valid for negative ψ-values.
The critical buckling stress is found from Eq. 3.10.

The critical buckling stress calculated in 3.14 shall be related to the actual compressive stresses as follows:

$$\sigma_c \geq \frac{\sigma_a}{\eta} \quad (3.17)$$

σ_a — σ_a calculated compressive stress in plate panels. With linearly varying stress across the plate panel, shall be taken as the largest stress.

In plate panels subject to longitudinal stresses, σ_a is given by:

$$\sigma_{el} = \frac{M_S+M_W}{I_N}(Z_n - Z_a)10^5 \ (N/mm^2) \quad (3.18)$$

= minimum 30 f1 N/mm2 at side

η = 1.0 for deck, single bottom and longitudinally stiffened side plating
= 0.9 for bottom, inner bottom and transversely stiffened side plating
= 1.0 for local plate panels where an extreme load level is applied (e.g. impact pressures)
= 0.8 for local plate panels where a normal load level is applied

M_S = stillwater bending moment as given in Sec.5(Pt3, Ch1)

M_W = wave bending moment as given in Sec.5(Pt3, Ch1)

I_N = moment of inertia in cm4 of the hull girder.

Plate panel in shear

The ideal elastic buckling stress may be taken as:

$$\tau_{el} = 0.9\mathrm{kE}\left(\frac{\mathrm{t}-t_k}{1000\mathrm{s}}\right)^2 \quad (N/mm^2) \quad (3.19)$$

$$k_t = 5.34 + 4\left(\frac{s}{l}\right)^2 \quad (N/mm^2) \quad (3.20)$$

3.4.2 Buckling control in the Buckling sheet

Plate panel in bi-axial compression

For plate panels subject to bi-axial compression the interaction between the longitudinal and transverse buckling strength ratios is given by:

$$\frac{\sigma_{ax}}{\eta_x \sigma_{cx}} - K\frac{\sigma_{ax}\sigma_{ay}}{\eta_x \eta_y \sigma_{cx}\sigma_{cy}} + \left(\frac{\sigma_{ay}}{\eta_y \sigma_{cy}}\right)^n \leq 1 \quad (3.21)$$

σ_{ax} = compressive stress in longitudinal direction (perpendicular to stiffener spacing s)

σ_{ay} = compressive stress in transverse direction (perpendicular

	to the longer side l of the plate panel)
σ_{cx}	= critical buckling stress in longitudinal direction as calculated in **Plate panel in uni-axial compression**
$\sigma_{c\ddot{y}}$	= critical buckling stress in transverse direction as calculated in **Plate panel in uni-axial compression**
n_x, n_x	1.0 for plate panels where the longitudinal stress σ_{al} (as given in 3.17) is incorporated in σ_{ay} or σ_{ax}
K	= $c\beta^a$
c, a	= factor given in following Table 3.1

$$\beta = 1000\frac{s}{t-t_k}\sqrt{\frac{\sigma_f}{E}}$$

n = factor given in the following Table 3.1

Table 3.1 Values for c, a , n

	c	a	n
$1.0 < l/s < 1.5$	0.78	Minus 0.12	1.0
$1.5 \leq l/s < 8$	0.80	0.04	1.2

For plate panels in structures subject to longitudinal stresses, such stresses shall be directly combined with local stresses to the extent they are acting simultaneously and for relevant load conditions. Otherwise combinations based on statistics may be applied.

Plate panel in bi-axial compression and shear

For plate panels subject to bi-axial compression and in addition to in-plane shear stresses the interaction is given by:

$$\frac{\sigma_{ax}}{\eta_x \sigma_{cx} q} - K \frac{\sigma_{ax}\sigma_{ay}}{\eta_x \eta_y \sigma_{cx}\sigma_{cy} q} + \left(\frac{\sigma_{ay}}{\eta_y \sigma_{cy} q}\right)^n \leq 1 \qquad (3.22)$$

$\boldsymbol{\sigma_{ax}}, \boldsymbol{\sigma_{ay}}, \boldsymbol{\sigma_{cx}}, \boldsymbol{\sigma_{cy}}, \boldsymbol{n_x}, \boldsymbol{n_y}$, K and n are given in 3.21

And the theoretical equation in this section will be applied in the Buckling sheet in the Rule Check Analysis, where the calculated results are used to fill in the BowImpact2008Jan.xls.

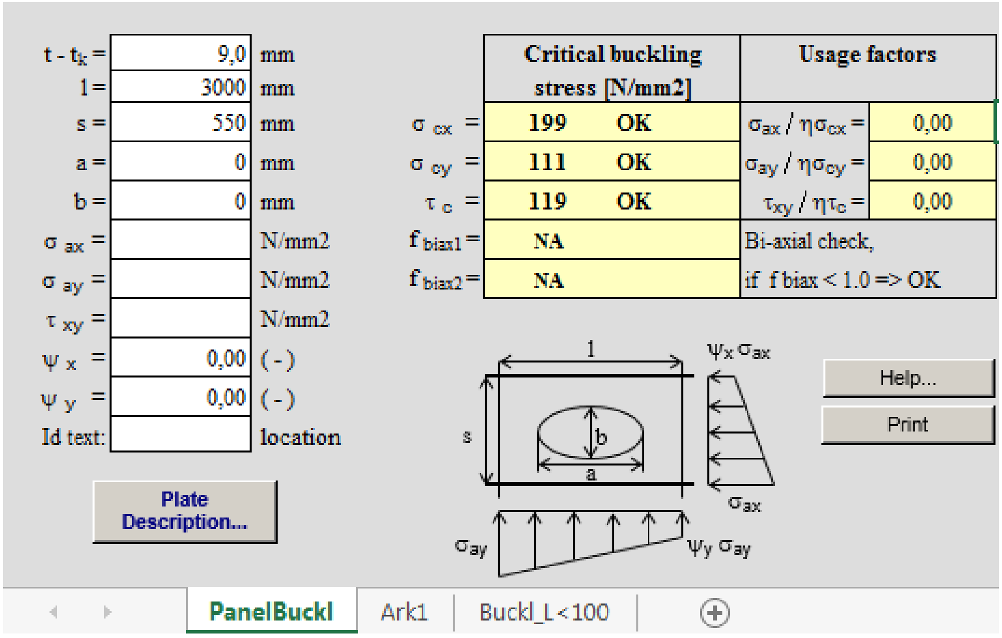


Figure 3.8 Buckling Windows in the Rule Check Analysis of Naticus Hull

4 OPTIMIZING LAYOUT FOR TRASVESE STIFFENED PANEL

4.1 Introudction

The role of stiffeners is proved to be vital in design of ship structures to minimize their weight and cost. Besides, stiffener spacing and plate thickness play an important part with respect to the weight cost for stiffened plate.

In this chapter these above parameters will be varied according to BowImpact2008Jan.xls, spreadsheet. Parametric studies shall be performed where e.g. the spacing of stiffeners and plating thickness are varied. The optimum dimensions of the panel will be determined by reduction of the weight cost and also for the various alternatives.

4.2 Analysis with the BowImpact2008Jan.xls spreadsheet

The design procedure will be explained in the following:

Firstly, we have to define the point which will be known as the load point analysis in the bow region, and the point will be demonstrated by three values like the coordinate of the point (height h_0, flare angle α, waterline to longitudinal angle β)

In this case, we can define any point in the bow as design load, then point ID 1(5,40,20) as shown under:

Location / id			1
Height	h_0	[m]	5,00
Parameters	a_1+a_2	[m]	10,00
	h_d	[m]	5,00
Flare angle	α	[°]	40,0
Flare angle	α	[°]	40,0
ΔX length for calculation of β	ΔX	[m]	
ΔY length for calculation of β	ΔY	[m]	
Waterline to longitudinal angle	β	[°]	20,0
Waterline to longitudinal angle	β	[°]	20,0
Bow impact pressure	p_{sl}	[kN/m^2]	310,8

Figure 4.1 Load points windows

Then the design bow impact pressure Psl is 310.8 kN/m^2.

Secondly the plates which supporting the stiffener and support members will be checked with respect to the specified stiffener spacing and length of plate field according the buckling the plating we discussed in the chapter 3.

Thirdly one of the stiffener has been chosen to install in this panel, then the relevant requirement will be checked if it is ok in the '*Stiffeners sheet* 'which can be seen in detail in the appendix.

Finally support members dimension will be checked and the Optimal dimension of the support member will be described as the section modulus, which will be dealed by the 3D Beam to define the detail dimension of the support member, can be seen under:

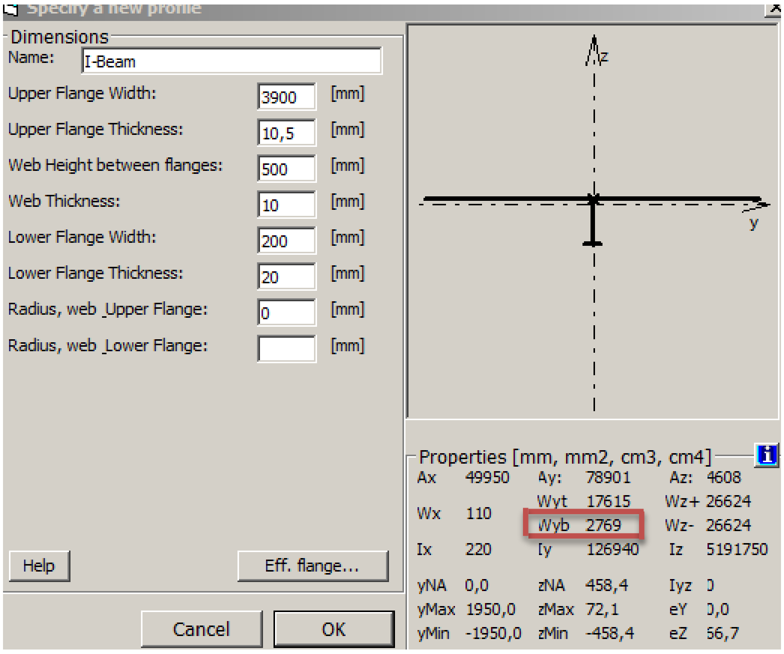


Figure 4.2 Detail dimension description of the support members in 3D beam.

All the setup we have done above in the '*Support member sheet* 'which can be seen in detail in the appendix.

4.2.1 Optimal design for panel with transverse stiffener (n= 5) and stringer spacing l = 2.1m

As we know, we compare the weight per square meter($\mathrm{kg/m^2}$) in the end, therefore keep the stiffener number n and stringer spacing l, then change the spacing of the stiffener s from 0.5m to 0.7m, and also for each spacing of the stiffener, the plating thickness t will be increased by 0.5m from the minimal value, in the end the relevant dimension of stiffener, stringer and web frames will be determined in the BowImpact2008Jan.xls spread sheet.

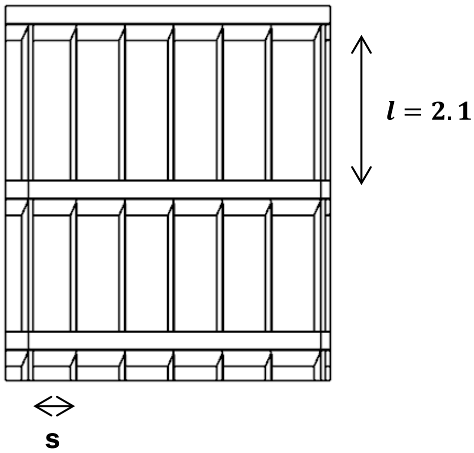


Figure 4.3 Configuration of the panel with n=5 and l=2.1m.

4.2.1.1 Stiffener

The plate thickness will be increased by 0.5m or 1m, then the optimal stiffener is now added on the stiffened panel as well as the dimension of panel is unchanged. And the optimal stiffener dimensions are listed as follows.

Table 4.1 Optimal Dimensional stiffener for varied plate thickness with s=0,5m and $l = 2.1m$

t	[mm]	8	8.5	9	9.5	10
h	[mm]	200	200	200	200	200
bf	[mm]	37	37	37	37	37
tw	[mm]	9	9	9	9	9
tf	[mm]	20.21	20.21	20.21	20.21	20.21

Plating thickness t, Stiffener height h,Flange breadth bf, Web thickness tw, Flange thickness tf,

see the detail stiffener sheet in the Appendix A-1

Table 4.2 Optimal Dimensional stiffener for varied plate thickness with s=0,55m and $l = 2.1m$

t	[mm]	9	9.5	10	10.5	11
h	[mm]	200	200	200	200	200
bf	[mm]	37	37	37	37	37
tw	[mm]	9	9	9	9	9
tf	[mm]	20.21	20.21	20.21	20.21	20.21

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf,

see the detail stiffener sheet in the Appendix A-3

Table 4.3 Optimal Dimensional stiffener for varied plate thickness with s=0,60m and $l = 2.1m$

t	[mm]	10	10.5	11	11.5	12
h	[mm]	200	200	200	200	200
bf	[mm]	37	37	37	37	37
tw	[mm]	9	9	9	9	9
tf	[mm]	20.21	20.21	20.21	20.21	20.21

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix A-5.

Table 4.4 Optimal Dimensional stiffener for varied plate thickness with s=0,65m and l=2.1m

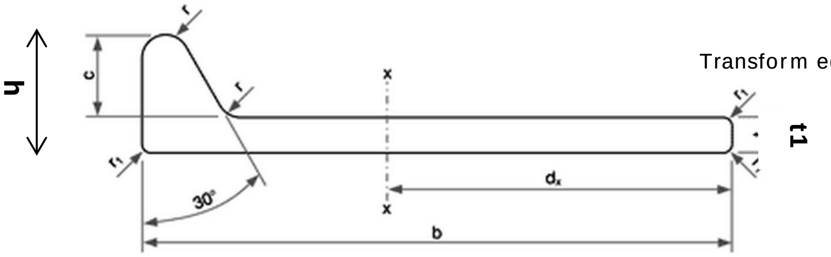
t	[mm]	10.5	11	11.5	12	12.5
h	[mm]	200	200	200	200	200
bf	[mm]	39.5	38	38	38	38
tw	[mm]	11.5	10	10	10	10
tf	[mm]	20.21	20.21	20.21	20.21	20.21

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix A-7

Table 4.5 Optimal Dimensional stiffener for varied plate thickness with s=0,70m and l=2.1m

t	[mm]	11.5	12	12.5	13	13.5
h	[mm]	200	200	200	200	200
bf	[mm]	39.5	39.5	39.5	39.5	39.5
tw	[mm]	11.5	11.5	11.5	11.5	11.5
tf	[mm]	20.21	20.21	20.21	20.21	20.21

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix A-9.



Transform equation:

h= b

t1=tw

bf=c+t1

Figure 4.4 Profile of the stiffener

As we see the symbols between the above tables and the above figure 4.4 have some difference, and there are transform equations between them as seen in Fig 4.4, therefore in order to daft in the NX, it has to be uniformed into the dimension data as shown in the following Table 4.6

Table 4.6 Detial dimensional stiffener

Norminal size	Dimensions				
	b	t1	c	r	A
	mm	mm	mm	mm	cm^2
200x11.5	200	11.5	28	8	28.66
200x10	200	10	28	8	25,66
200x9	200	9	28	8	23,66

Raduis of curvature of corners r_1 for thickness is defined as 3.0mm in accordance with ISO9001

2008(and all the values of the stiffener mentioned in the thesis are the same)

4.2.1.2 Stringer

The stringer which is perpendicular to the stiffener direction also has been optimized based on the certain stiffener dimensions and layout of the panel with respect to varies plate thickness and the optimal dimensions are calculated as following tables.

Table 4.7 Optimal Dimensional stringer for varied plate thickness with s=0,50m and $\boldsymbol{l = 2.1m}$

t	[mm]	8	8.5	9	9.5	10
B	[mm]	500	500	500	500	500
D	[mm]	10	10	10	10	10
A	[mm]	300	300	300	300	250
C	[mm]	14	12	11	9	10

Plate thickness t, Web Height between flanges B, Web Thickness C, Lower Flange Width A, Lower Flange Thickness D. See the detail stringer sheet in the Appendix A-2.

Table 4.8 Optimal Dimensional stringer for varied plate thickness with s=0,55m and $\boldsymbol{l = 2.1m}$

t	[mm]	9	9.5	10	10.5	11
B	[mm]	500	500	500	500	500
D	[mm]	10	10	10	10	10
A	[mm]	300	300	300	300	300
C	[mm]	17	15	13	12	11

Plate thickness t, Web Height between flanges B, Web Thickness C, Lower Flange Width A, Lower Flange Thickness D. See the detail stringer sheet in the Appendix A-4.

Table 4.9 Optimal Dimensional stringer for varied plate thickness with s=0,60m and $\boldsymbol{l = 2.1m}$

t	[mm]	10	10.5	11	11.5	12
B	[mm]	500	500	500	500	500
D	[mm]	11	11	11	11	11
A	[mm]	300	300	300	300	300
C	[mm]	19	17	16	15	14

Plate thickness t, Web Height between flanges B, Web Thickness C, Lower Flange Width A, Lower Flange Thickness D. See the detail stringer sheet in the Appendix A-6.

Table 4.11 Optimal Dimensional stringer for varied plate thickness with s=0,65m and $\boldsymbol{l = 2.1m}$

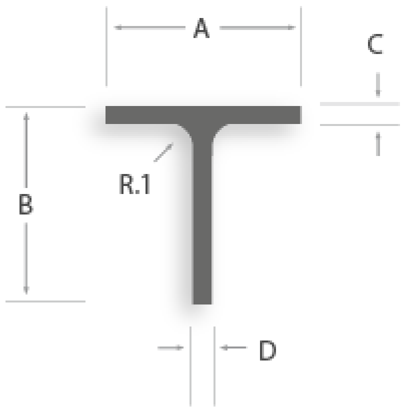
t	[mm]	10.5	11	11.5	12	12.5
B	[mm]	500	500	500	500	500
D	[mm]	12	12	12	12	12
A	[mm]	350	350	300	300	300
C	[mm]	20	18	19	18	17

Plate thickness t, Web Height between flanges B, Web Thickness C, Lower Flange Width A, Lower Flange Thickness D. See the detail stringer sheet in the Appendix A-8.

Table 4.12 Optimal Dimensional stringer for varied plate thickness with s=0,70m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	11.5	12	12.5	13	13.5
B	[mm]	500	500	500	500	500
D	[mm]	13	13	13	13	13
A	[mm]	400	400	350	300	300
C	[mm]	20	18	19	21	20

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-10.



Definition:

Lower Flange Width A

Web Height between flanges B

Web Thickness D

Lower Flange Thickness C

Figure 4.5 Profile of the Stringer.

4.2.1.3 Web Frames

The web frames which is parallel to the stiffener direction also has been optimized based on the certain stiffener dimensions and layout of the panel with respect to varies plate thickness and the optimal dimensions are calculated as following tables.

Table 4.13 Optimal Dimensional web frame for varied plate thickness with s=0,5m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	8	8.5	9	9.5	10
B	[mm]	400	400	400	400	400
D	[mm]	10	10	10	10	10
A	[mm]	20	20	20	20	20
C	[mm]	16	13	11	10	7

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-2.

Table 4.14 Optimal Dimensional web frame for varied plate thickness with s=0,55m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	9	9.5	10	10.5	11
B	[mm]	300	300	300	300	300
D	[mm]	15	15	15	15	15
A	[mm]	50	50	50	50	50
C	[mm]	13	12	11	11	10

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-4.

Table 4.15 Optimal Dimensional web frame for varied plate thickness with s=0,60m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	10	10.5	11	11.5	12
B	[mm]	300	300	300	300	300
D	[mm]	15	15	15	15	15
A	[mm]	60	60	60	60	60
C	[mm]	10	10	9	9	8

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-6.

Table 4.16 Optimal Dimensional web frame for varied plate thickness with s=0,65m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	10.5	13	15	11	11.5
B	[mm]	300	300	300	300	300
D	[mm]	17	17	17	17	17
A	[mm]	40	40	40	40	40
C	[mm]	11	6	5	10	9

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-8.

Table 4.17 Optimal Dimensional web frame for varied plate thickness with s=0,70m and $\boldsymbol{l} = \mathbf{2.1}\boldsymbol{m}$

t	[mm]	11.5	12	12.5	13	13.5
B	[mm]	300	300	300	300	300
D	[mm]	17	17	17	17	17
A	[mm]	30	30	30	30	30
C	[mm]	14	12	11	10	9

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix A-10.

4.2.1.4 Weight Evaluation

From the table 4.1 to table 4.17, the volume of the stiffeners can be summed up then added with plate volume to get total volume of the panel, then multiplied by steel density which is defined as 0.0000078 $\mathbf{kg/m^2}$, finally get the total weight. In order to compare with other configurations, the weight per square meter is calculated and compared in the following figure.

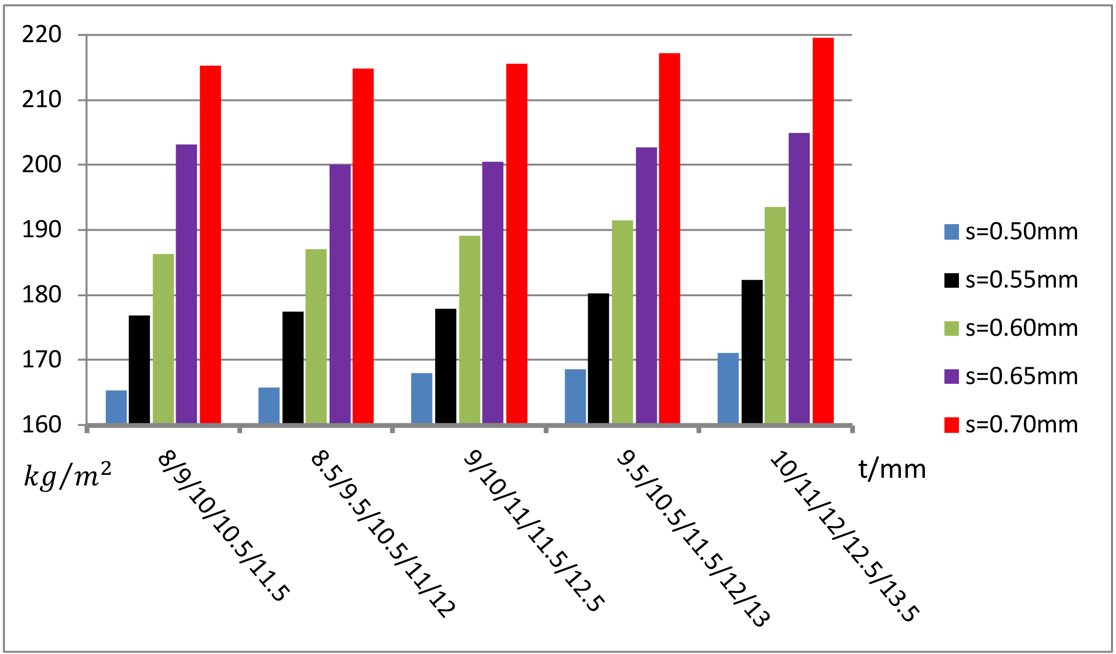


Figure 4.6 Weight Comparison for varied s and plate thickness with transverse stiffener and l=2.1m

From the figure 4.6 we can see the weight increases along with the growth of plate thickness and stiffener spacing. And the minimal weight is 165.3 $\mathbf{kg/m^2}$ when plate thickness is 8mm with s=0.5m and l=2.1m.

4.2.2 Optimal design for panel with transverse stiffener (n=5) and stringer spacing $\boldsymbol{l}$ = 1.4m

It is almost the same as the previous situation, keep the transverse stiffener direction in the vertical way, and stiffener number n = 5, but the stringer spacing now is decreased with $\boldsymbol{l}$ = 1.4, then the spacing between stiffener is varied from 0.5m to 0.7m and at the same time, buckling control for all the support members are performed with growth of the plate thickness.

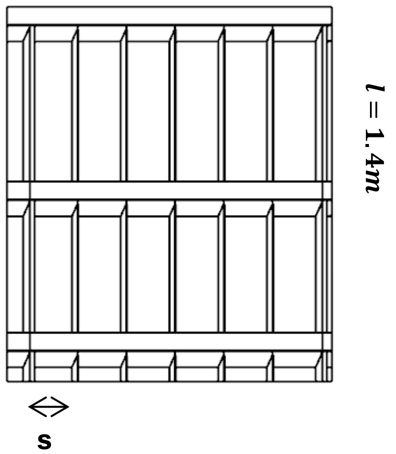


Figure 4.7 Configuration of the panel with n= 5and l=1,4m.

4.2.2.1 Stiffener

When the plate thickness is increased by 0.5m or 1m from the minimal value, the qualified stiffeners will be applied on the stiffened panel according to the Rules mentioned in the buckling of the stiffener sections. And the optimal stiffener dimensions are listed as following tables.

Table 4.14 Optimal Dimensional stiffener for varied plate thickness with s=0,50m and $l = 1.4m$

t	[mm]	8	8.5	9	9.5	10
h	[mm]	140	140	140	140	140
bf	[mm]	26	26	26	26	26
tw	[mm]	7	7	7	7	7
tf	[mm]	13.82	13.82	13.82	13.82	13.82

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix B-1.

Table 4.15 Optimal Dimensional stiffener for varied plate thickness with s=0,55m and $l = 1.4m$

t	[mm]	9	9.5	10	10.5	11
h	[mm]	140	140	140	140	140
bf	[mm]	27	27	27	27	27
tw	[mm]	8	8	8	8	8
tf	[mm]	13.82	13.82	13.82	13.82	13.82

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix B-3.

Table 4.16 Optimal Dimensional stiffener for varied plate thickness with s=0,60m and $l = 1.4m$

t	[mm]	9.5	10	10.5	11	11.5
h	[mm]	140	140	140	140	140
bf	[mm]	28	28	28	27	27
tw	[mm]	9	9	9	8	8
tf	[mm]	13.82	13.82	13.82	13.82	13.82

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix B-5.

Table 4.17 Optimal Dimensional stiffener for varied plate thickness with s=0,65m and $l = 1.4m$

t	[mm]	10	10.5	11	11.5	12
h	[mm]	160	160	140	140	140
bf	[mm]	29	29	28	28	28
tw	[mm]	7	7	9	9	9
tf	[mm]	15.46	15.46	13.82	13.82	13.82

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix B-7.

Table 4.18 Optimal Dimensional stiffener for varied plate thickness with s=0,70m and $l = 1.4m$

t	[mm]	11	11.5	12	12.5	13
h	[mm]	160	160	160	160	140
bf	[mm]	29	29	29	29	28
tw	[mm]	7	7	7	7	9
tf	[mm]	15.46	15.46	15.46	15.46	13.82

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix B-9.

4.2.2.2 Stringer

The dimension of the stringer which is perpendicular to the stiffener direction also has been optimized based on the qualified stiffener dimensions and layout of the panel with respect to varies plate thickness according the buckling control of support members and the optimal dimensions are listed as following tables.

Table 4.19 Optimal Dimensional stringer for varied plate thickness with s=0,50m and $l = 1.4m$

t	[mm]	8	8.5	9	9.5	10
B	[mm]	500	500	500	500	500
D	[mm]	7	7	7	7	7
A	[mm]	200	200	200	200	200
C	[mm]	12	10	9	8	8

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in Appendix B-2.

Table 4.20 Optimal Dimensional stringer for varied plate thickness with s=0,55m and $l = 1.4m$

t	[mm]	9	9.5	10	10.5	11
B	[mm]	500	500	500	500	500
D	[mm]	7	7	7	7	7
A	[mm]	200	200	200	200	200
C	[mm]	14	12	11	11	10

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in Appendix B-4.

Table 4.21 Optimal Dimensional stringer for varied plate thickness with s=0,60m and $l = 1.4m$

t	[mm]	9.5	10	10.5	11	11.5
B	[mm]	500	500	500	500	500
D	[mm]	8	8	8	8	8
A	[mm]	200	200	200	200	200
C	[mm]	17	15	14	13	12

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in Appendix B-6.

Table 4.22 Optimal Dimensional stringer for varied plate thickness with s=0,65m and $l = 1.4m$

t	[mm]	10	10.5	11	11.5	12
B	[mm]	500	500	500	500	500
D	[mm]	8	8	8	8	8
A	[mm]	300	300	300	300	300
C	[mm]	14	13	12	11	11

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in Appendix B-8.

Table 4.23 Optimal Dimensional stringer for varied plate thickness with s=0,70m and $l = 1.4m$

t	[mm]	11	11.5	12	12.5	13
B	[mm]	500	500	500	500	500
D	[mm]	9	9	9	9	9
A	[mm]	300	300	300	300	300
C	[mm]	15	14	13	12	12

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in Appendix B-10.

4.2.2.3 Web Frames

Scantling design of the web frames which are parallel to the stiffener direction are optimized on their dimension, based on the qualified stiffener dimensions and layout of the panel with respect to varies plate thickness, according the buckling control of support members in the chapter 3, the optimal dimensions are seen in the following tables.

Table 4.24 Optimal Dimensional web frame for varied t with s=0,50m and $l = 1.4m$

t	[mm]	8	8.5	9	9.5	10
B	[mm]	250	250	250	250	250
D	[mm]	10	10	10	10	10
A	[mm]	0	0	0	0	0
C	[mm]	0	0	0	0	0

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix B-2.

Table 4.25 Optimal Dimensional web frame for varied t with s=0,55m and $l = 1.4m$

t	[mm]	9	9.5	10	10.5	11
B	[mm]	250	250	250	250	250
D	[mm]	12	12	12	12	12
A	[mm]	0	0	0	0	0
C	[mm]	0	0	0	0	0

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix B-4.

Table 4.26 Optimal Dimensional web frame for varied t with s=0.60m and $l = 1.4m$

t	[mm]	9.5	10	10.5	11	11.5
B	[mm]	250	250	250	250	250
D	[mm]	12	12	12	12	12
A	[mm]	0	0	0	0	0
C	[mm]	0	0	0	0	0

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix B-6.

Table 4.27 Optimal Dimensional web frame for varied t with s=0.65m and $l = 1.4m$

t	[mm]	10	10.5	11	11.5	12
B	[mm]	250	250	250	250	250
D	[mm]	13	13	13	13	13
A	[mm]	0	0	0	0	0
C	[mm]	0	0	0	0	0

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix B-8.

Table 4.28 Optimal Dimensional web frame for varied t with s=0.70m and $l = 1.4m$

t	[mm]	11	11.5	12	12.5	13
B	[mm]	250	250	250	250	250
D	[mm]	14	14	14	14	14
A	[mm]	0	0	0	0	0
C	[mm]	0	0	0	0	0

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix B-10.

From the above table, we have seen that the A and C are zero, which means there is no flange in the T beam for the web frames, in other words, these no flange T beam or I beam still can be sufficient to bear the same strength. The reason of this is that the stringer spacing is too small, which in some extent reduce the bearing stress, and then reduce the requirement of scantling of the web frames.

4.2.2.4 **Weight Evaluation**

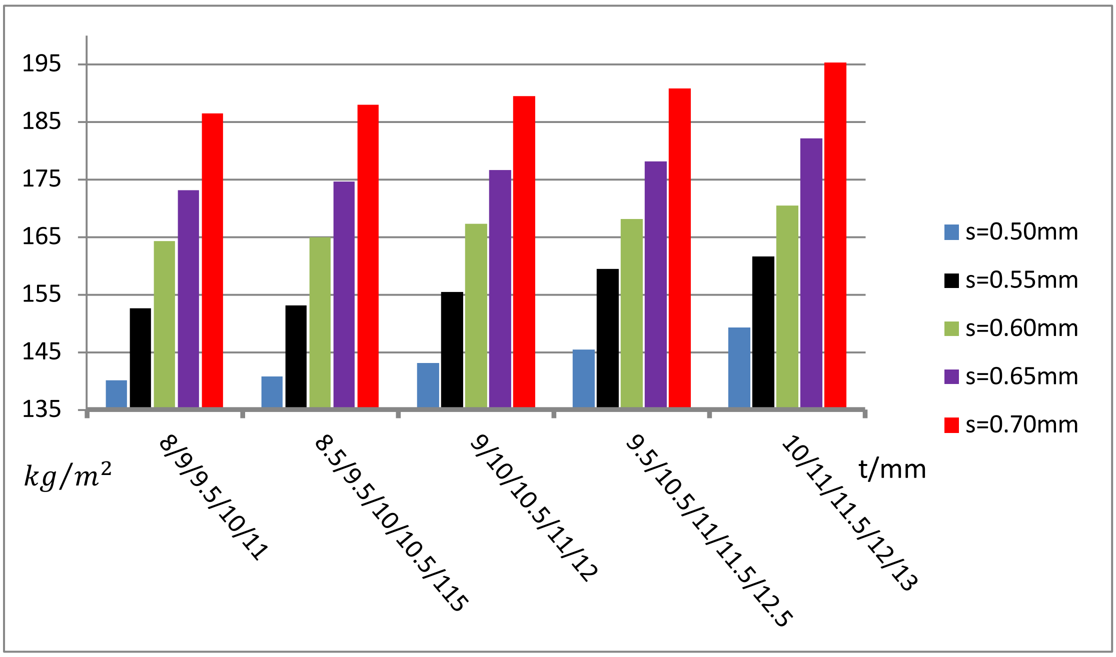


Figure 4.8 Weight Comparison for varied s and plate thickness with transverse stiffener and l=1.4m

From the figure 4.8 we can see the weight increases along with the growth of plate thickness and stiffener spacing. And the minimal weight is 140.2 kg/m^2 when plate thickness is 8mm with s=0.5m and l=1.4m, and comparing with the panel with l=2.1, the weight decrease by 25.1kg/m^2.

5 OPTIMUMLAYOUT FOR LONGTIDINAL STIFFENED PANEL

5.1 *Introduction*

As known, in the maritime industry, it is always discussed that if we change the stiffener direction from vertical or transverse to longitudinal direction, what will happen to the weight in satisfied the strength requirement of DNV rules for all the ships. Therefore the longitudinal stiffener will be introduced in this chapter.

In order to redesign for the longitudinal stiffener or girder, two parameter can be varied that is girder spacing and girder length, however if changing two these parameters in the same time it will be too many possibilities, therefore, keep the girder length l constant and the number of girder n within adjacent to the stringer, then vary the girder spacing. Then do the same process to the configuration with a different girder length l.

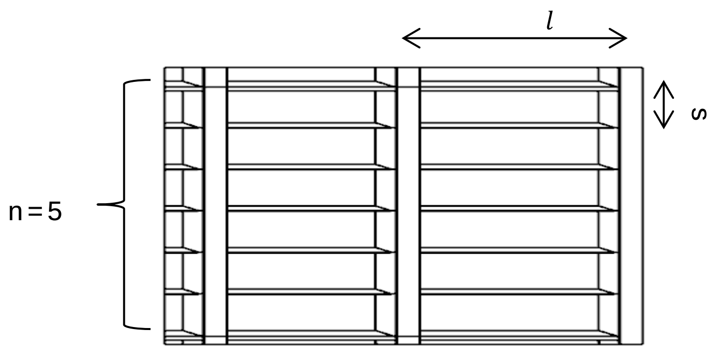


Figure 5.1 Configuration with the longitudinal stiffener direction and stiffener number n=5.

5.1.1 Optimal design for panel with longitudinal stiffener (n=5) and girder length *l* = 3m

5.1.1.1 Stiffener

The plate thickness will be increased by 0.5m or 1m, then the optimal stiffener is now added on the stiffened panel as well as the dimension of panel is unchanged. And the optimal stiffener dimensions are listed as follows.

Table 5.1 Optimal longitudinal stiffener for varied plate thickness with s=0,5m and l=3m

t	[mm]	8	8.5	9	9.5	10
h	[mm]	280	280	280	280	280
bf	[mm]	51	51	52	52	52
tw	[mm]	11	11	12	12	12
tf	[mm]	29.7	29.7	29.7	29.7	29.7

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix C-1.

Table 5.2 Optimal longitudinal stiffener for varied plate thickness with s=0,55m and l=3m

t	[mm]	9	9.5	10	10.5	11
h	[mm]	300	300	300	300	300
bf	[mm]	54	54	54	54	54
tw	[mm]	11	11	11	11	11
tf	[mm]	32.8	32.8	32.8	32.8	32.8

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix C-3.

Table 5.3 Optimal longitudinal stiffener for varied plate thickness with s=0,60m and l=3m

t	[mm]	10	10.5	11	11.5	12
h	[mm]	300	300	300	300	300
bf	[mm]	55	55	55	55	55
tw	[mm]	12	12	12	12	12
tf	[mm]	32.08	32.08	32.08	32.08	32.08

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix C-5.

Table 5.4 Optimal longitudinal stiffener for varied plate thickness with s=0,65m and l=3m

t	[mm]	10.5	11	11.5	12	12.5
h	[mm]	320	300	300	300	300
bf	[mm]	58	56	56	56	56
tw	[mm]	12	13	13	13	13
tf	[mm]	34.45	32.08	32.08	32.08	32.08

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the the Appendix C-7.

Table 5.5 Optimal longitudinal stiffener for varied plate thickness with s=0,70m and l=3m

t	[mm]	11.5	12	12.5	13	13.5
h	[mm]	320	320	320	320	320
bf	[mm]	58	58	58	58	58
tw	[mm]	12	12	12	12	12
tf	[mm]	34.45	34.45	34.45	34.45	34.45

Plating thickness t, Stiffener height h, Flange breadth bf, Web thickness tw, Flange thickness tf, see the detail stiffener sheet in the Appendix C-9.

5.1.2 Stringer

The stringer which is parallel to the stiffener direction also has been optimized based on the certain stiffener dimensions and layout of the panel with respect to varies plate thickness and the optimal dimensions are calculated as following tables.

Table 5.6 Optimal stringer dimension for varied plate thickness with s=0,50m and l=3m.

t	[mm]	8	8.5	9	9.5	10
B	[mm]	500	500	500	500	500
D	[mm]	14	14	14	14	14
A	[mm]	200	200	200	200	200
C	[mm]	12	12	11	11	11

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-2.

Table 5.7 Optimal stringer dimension for varied plate thickness with s=0,55m and l=3m.

t	[mm]	9	9.5	10	10.5	11
B	[mm]	500	500	500	500	500
D	[mm]	15	15	15	15	15
A	[mm]	200	200	200	200	200
C	[mm]	11	11	10	10	10

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-4.

Table 5,8 Optimal stringer dimension for varied plate thickness with s=0,60m and l=3m.

t	[mm]	10	10.5	11	11.5	12
B	[mm]	500	500	500	500	500
D	[mm]	16	16	16	16	16
A	[mm]	200	200	200	200	200
C	[mm]	10	10	9	9	9

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-6.

Table 5.9 Optimal stringer dimension for varied plate thickness with s=0,65m and l=3m.

t	[mm]	10.5	11	11.5	12	12.5
B	[mm]	500	500	500	500	500
D	[mm]	17	17	17	17	17
A	[mm]	200	200	200	200	200
C	[mm]	9	9	9	8	8

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-8.

Table 5.10 Optimal stringer dimension for varied plate thickness with s=0,70m and l=3m.

t	[mm]	11.5	12	12.5	13	13.5
B	[mm]	500	500	500	500	500
D	[mm]	19	19	19	19	19
A	[mm]	100	100	100	100	100
C	[mm]	15	14	14	13	13

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-10.

5.1.3 Web Frames

Scantling design of the web frames which are perendicular to the stiffener direction are optimized, based on the qualified stiffener dimensions and layout of the panel with respect to varies plate thickness, according the buckling control of support members in the chapter 3, the optimal dimensions are seen in the following tables.

Table 5.11 Optimal Web frame dimension for varied plate thickness with s=0,50m and l=3m.

t	[mm]	8	8.5	9	9.5	10
B	[mm]	500	500	500	500	500
D	[mm]	11	11	11	11	11
A	[mm]	300	300	300	300	300
C	[mm]	18	16	13	12	11

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-2.

Table 5.12 Optimal Web frame dimension for varied plate thickness with s=0,55m and l=3m.

t	[mm]	9	9.5	10	10.5	11
B	[mm]	500	500	500	500	500
D	[mm]	13	13	13	13	13
A	[mm]	350	350	350	350	350
C	[mm]	18	16	14	13	11

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-4.

Table 5.13 Optimal Web frame dimension for varied plate thickness with s=0,60m and l=3m.

t	[mm]	10	10.5	11	11.5	12
B	[mm]	500	500	500	500	500
D	[mm]	13	13	13	13	13
A	[mm]	350	350	350	350	350
C	[mm]	20	18	16	15	13

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-6.

Table 2Optimal Web frame dimension for varied plate thickness with s=0,65m and l=3m.

t	[mm]	10.5	11	11.5	12	12.5
B	[mm]	500	500	500	500	500
D	[mm]	14	14	14	14	14
A	[mm]	450	450	450	450	450
C	[mm]	20	18	16	15	14

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-8.

Table 5.15 Optimal Web frame dimension for varied plate thickness with s=0,70m and l=3m.

t	[mm]	11.5	12	12.5	13	13.5
B	[mm]	500	500	500	500	500
D	[mm]	15	15	15	15	15
A	[mm]	500	500	500	500	500
C	[mm]	20	19	17	16	15

Plate thickness t, Web Height between flanges B, Web Thickness D, Lower Flange Width A, Lower Flange Thickness C. See the detail stringer sheet in the Appendix C-10.

5.1.4 Weight Eveluation

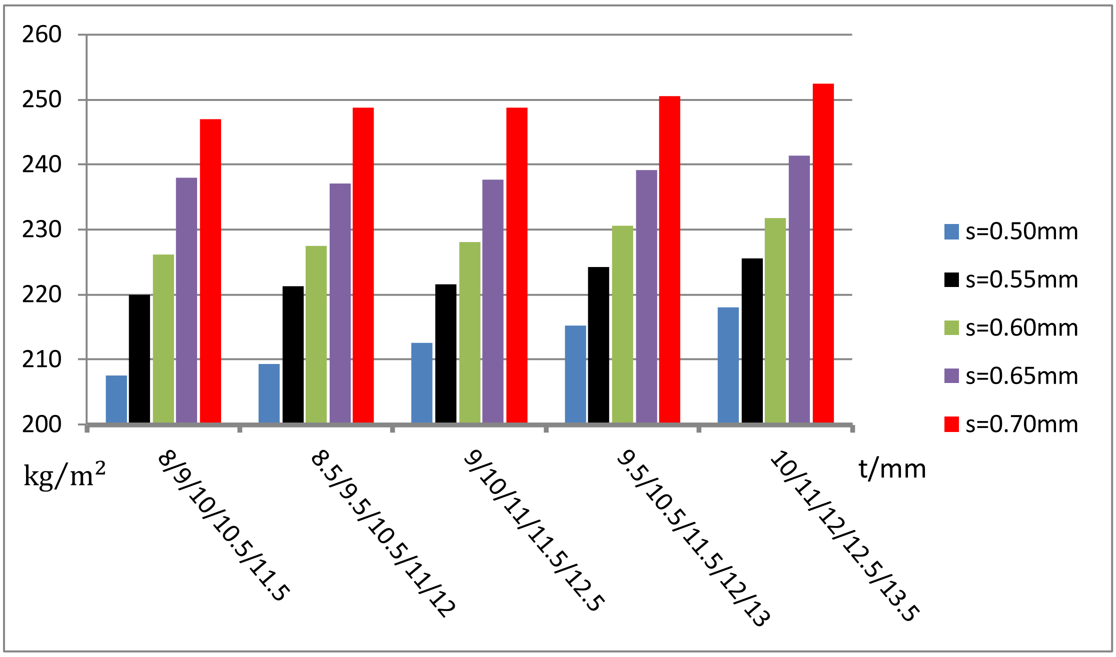


Figure 5.2 Weight Comparison for varied s and plate thickness with longitudinal stiffener and l=3,0m

From the figure 5.2 we can see the weight increases along with the growth of plate thickness and stiffener spacing. And the minimal weight is 140.2 kg/m^2 when plate thickness is 8mm with s=0.5m and l=1.4m, and comparing with the panel with l=2.1, the weight decrease by 25.1kg/m^2.

6 FINITE ELEMENT ANALYSIS

6.1 Simplication

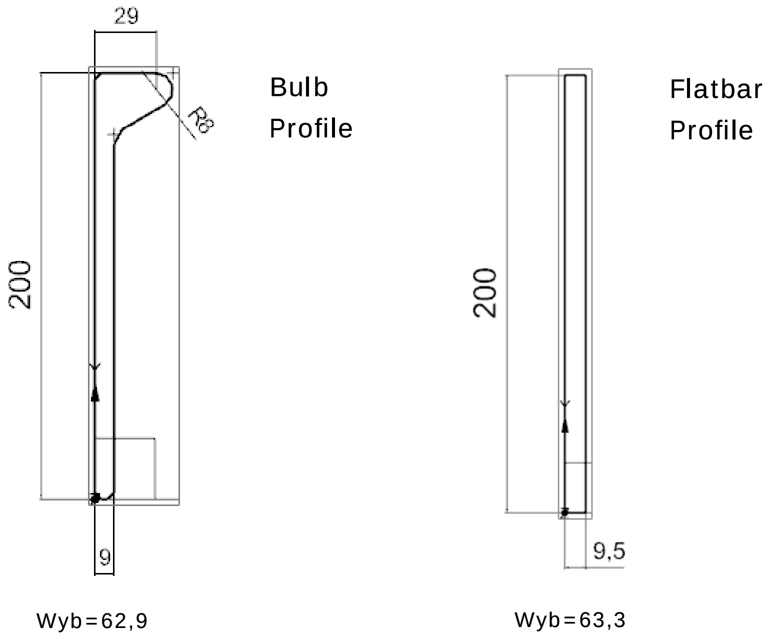


Figure 6.1 Stiffener Simplification in the function of the section modulus.

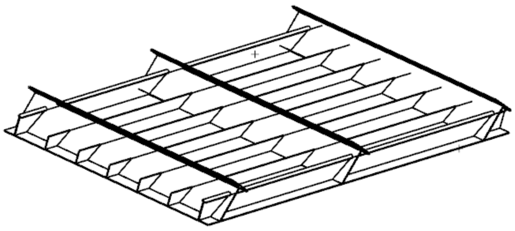
As we seen in the first picture of the bulb flat section, whichis the optimal dimension of stiffener calculated, the second figure is simplified flatbar, which is used to calculated in the FEM Analysis because they have the same section modulus which symbolize that they have the same plastic capacity against amplified forces or stresses in order to strive to ultimately remain below the plastic limit to avoid permanent deformations.

The simplification process is performed because the bending shape in the top of the bulb flat section will make the mesh more fine mesh size to adjust to the sharp edges which will take more time to calculate.

6.2 Model Description

6.2.1 General

One of the configurations of the stiffened panel listed in the above is simulated in NX in this section, which the panel with transverse stiffener and two web frames and three girders, the main dimension of the stiffener panel is shown as follows.



Main Dimension:
n=5
s=0.60mm,
l=2.1m.
∂=40°
β=20°

Figure 6.2 Layout of the model and main dimension.

The optimal dimensions of the plate, stiffener, girder and web frame based on the BowImpact2008Jan.xls are demonstrated as following Table:

Table 6.1 Dimensions of all the components of the model.

Items	Dimension		
Plate	t=10mm, the size of the stiffened panel is decided as more than 3.6m x4.2m		
Stiffener	200mm x 9.5mm, see the details in 6.1 Simplification.		
Girder	Web Height between flanges	[mm]	500
	Web Thickness	[mm]	11
	Lower Flange Width	[mm]	300
	Lower Flange Thickness	[mm]	19
	The span of the girder is depend on the plate size		
Web frame	Web Height between flanges	[mm]	300
	Web Thickness	[mm]	15
	Lower Flange Width	[mm]	60
	Lower Flange Thickness	[mm]	10
	The span of the web frame is depend on the plate size		

6.2.2 FE model Detail and Property

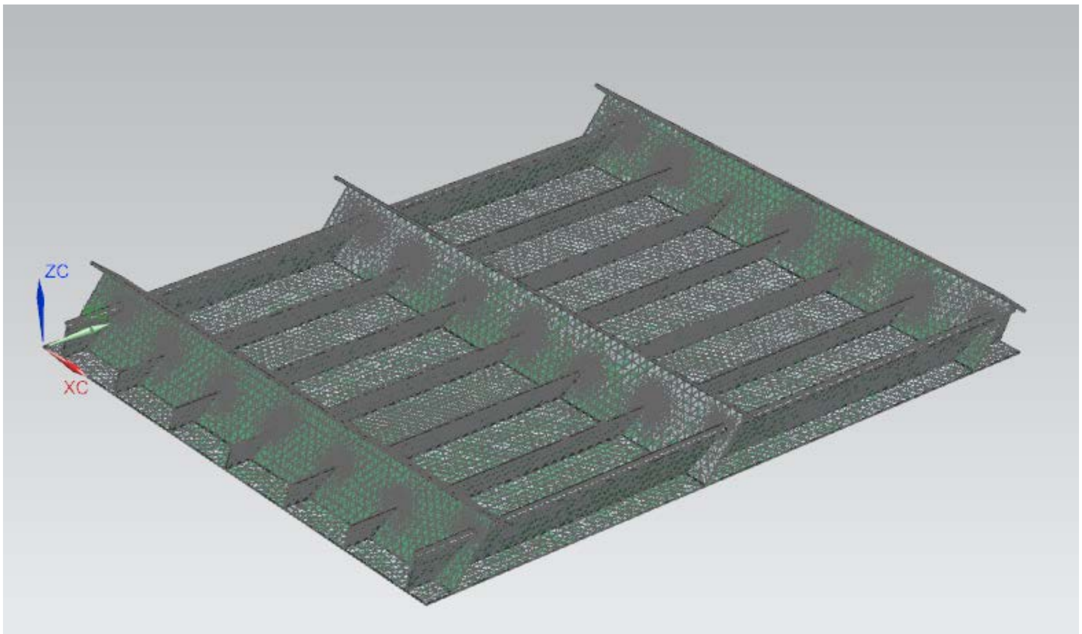


Figure 6.3 FE Model of the stiffened panel with n= 5, s=0.6m and l=2.1m in NX.

Table 6.2 Summary of FE model of the stiffened panel.

Design pressure	310800N/m^2 or variable pressure, see 6.2.4.
Boudary condition	Fixed in all
Material	Name : Steel-Rolled
	Mass Density: 7.85e-006 kg/mm^3
	Young's Modulus: 2.06e+008 mN/mm^2(kPa)
	Poisson's Ratio : 0.3
	Yield Strength : 235000 mN/mm^2(kPa)
	Ultimate Tensile Strength : 340000 mN/mm^2(kPa)
	Mesh Property
Total No. of Nodes	1237537
Total No. of Elements	818145
Elements types used and size	3D Thedrathedral(70mm)

6.2.3 Results of constant pressure

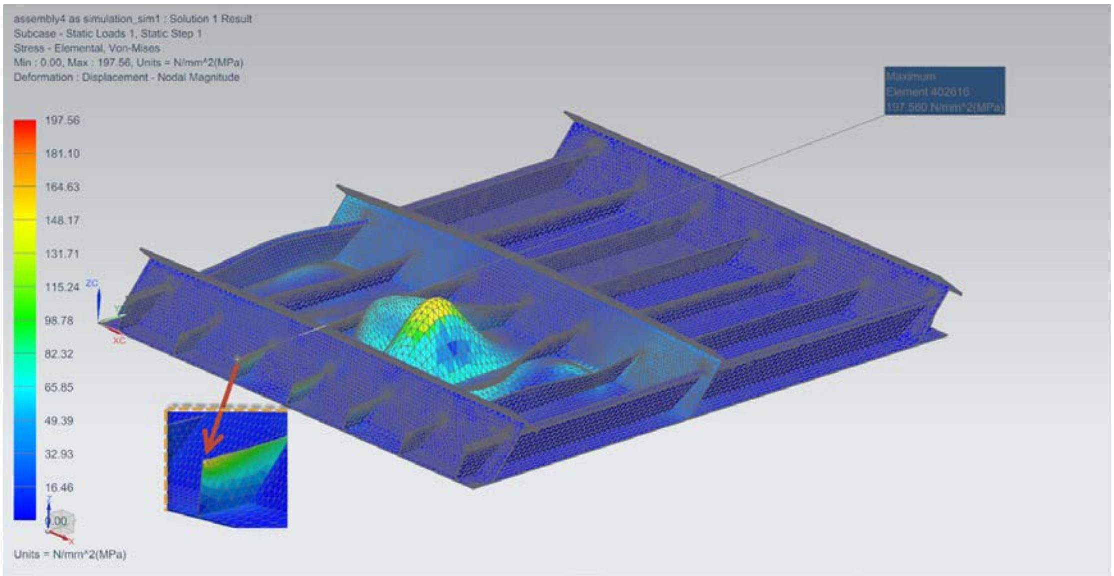


Figure 6.4 Stress Elemental of the stiffened panel with constant pressure.

From the figure 6.4, we have seen that the maximum stress happens in the corner of the stiffener edges which is boundary area, and the value is 197,56 N/mm^2, in the reality, the stiffener is connected or expend to the other stiffener and be welded together, which means the maximum stress here is not possible to happen in the corner, and this situation can be avoided here by expanding the size of the panel into larger one, which maybe can be done in the future work, but anyway, the maximum stress still does not exceed the yield stress 235 N/mm^2. Then we can check other parts as followings.

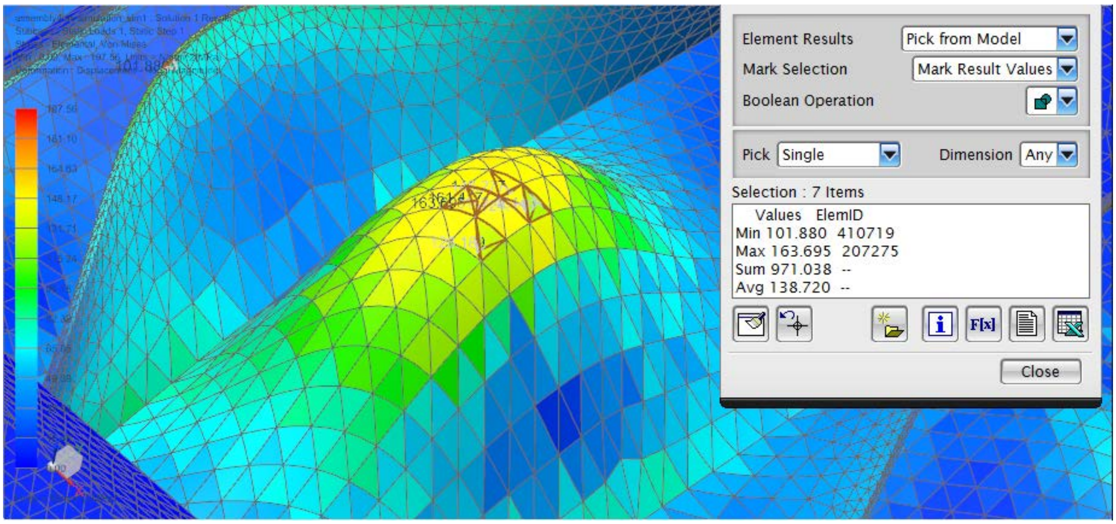


Figure 6.5 Other critical part t of the middle stiffened panel.

From the figure 6.5, the maximum value of stress in this yellow part which indicates the high level of the stress is 163.1 N/mm^2, which does not exceed the yield strength as well, then we can know that the layout of the stiffened panel with s=0.6 and l=2.1 is safe structure for the ship.

6.2.4 Results of variable pressure

In reality, the pressure applied on the bow region can't be constant, it should cover the largest bow impact pressure and lowest bow impact pressure, and the middle pressure applied on the whole bow region simultaneously, in order to simulate the real situation as much as possible, we can split the panel with grid in a proper size, which should be made as fine as possible, but it will can take much more time to calculate, therefore, we can make one situation that make the real situation as much as we can.

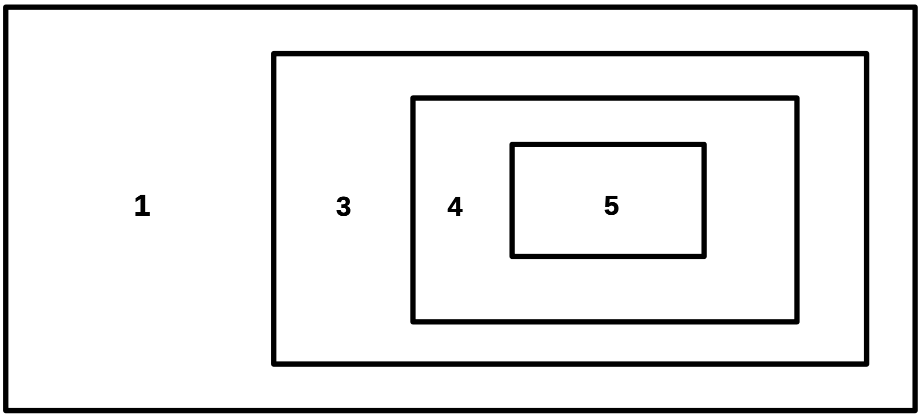


Figure 6.6 Layout of the regional bow impact pressure.

In the same time, as we know, the location of the point is made of three values which is height h_0, flare angle α and waterline to longitudinal angleβ. And for a specified vessel with special hull form of the ship bow, the combination of the three values is certain, but in order to make the problem simple, we keep one coordinate value such as height or flare angle constant and change another value, then compare the bow impact pressure, after that select some of them which is representative can cover the range of the pressure, and add them on the FE model to get results.

Table 6.3 Bow impact pressure of varied point with constant h_0 , α and varied β.

Area ID		1	2	3	4	5	6
h_0	[m]	5.00	5.00	5.00	5.00	5.00	5.00
α	[°]	40.0	40.0	40.0	40.0	40.0	40.0
β	[°]	20.0	35.0	50.0	60.0	75.0	90.0
p_{sl}	[kN/m^2]	310.8	423.0	522.4	572.9	615.8	614.8

See the detail bow impact pressure in all the β in the Appendix D

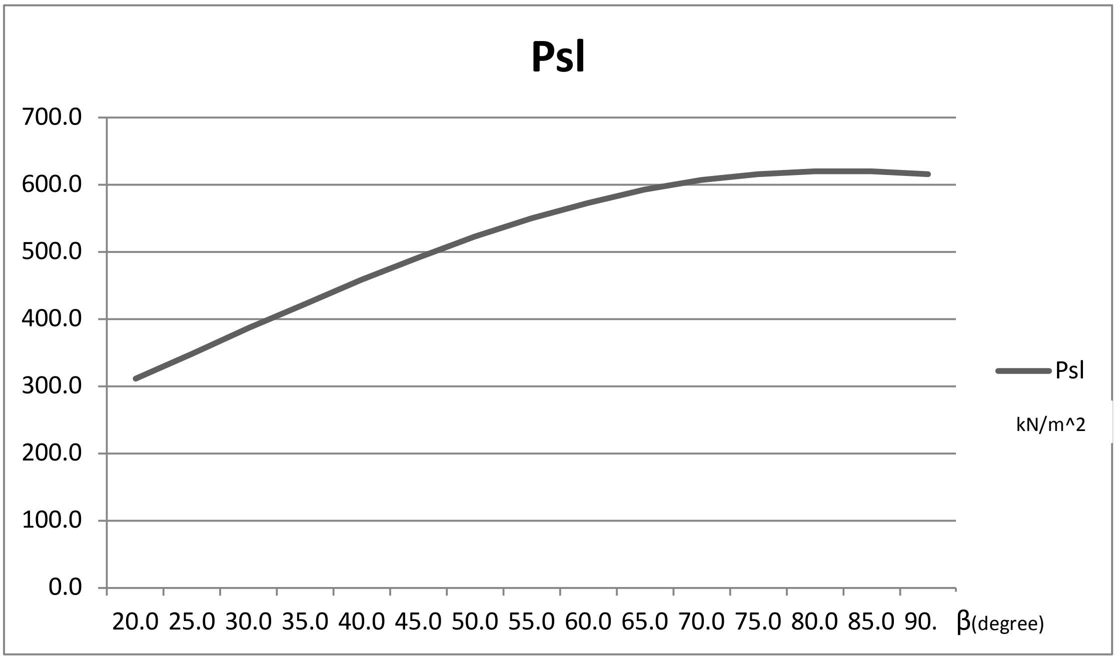


Figure 6.7 Bow impact pressure in all the β with constant $h_0 = 5m$, α=40.

We can see from the table, in this case the maximum bow pressure(615,8 kN/m^2) happens when ≈75°

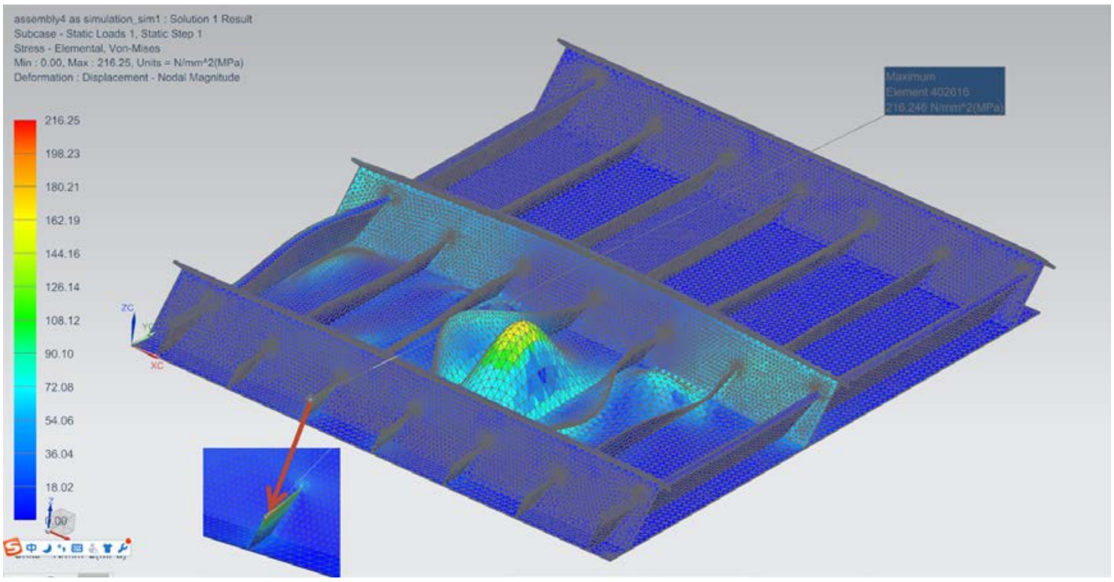


Figure 6.8 Stress Elemental of the stiffened panel with regional pressure.

From the figure we have seen that the maximum stress happens in the corner of the stiffener edges, which is 216,56 N/mm^2, and also the stress in this situation do not have reference value to identify that our structure is no safe, the discussion can be seen in the chapter 7, anyway still it does not exceed the yield strength.

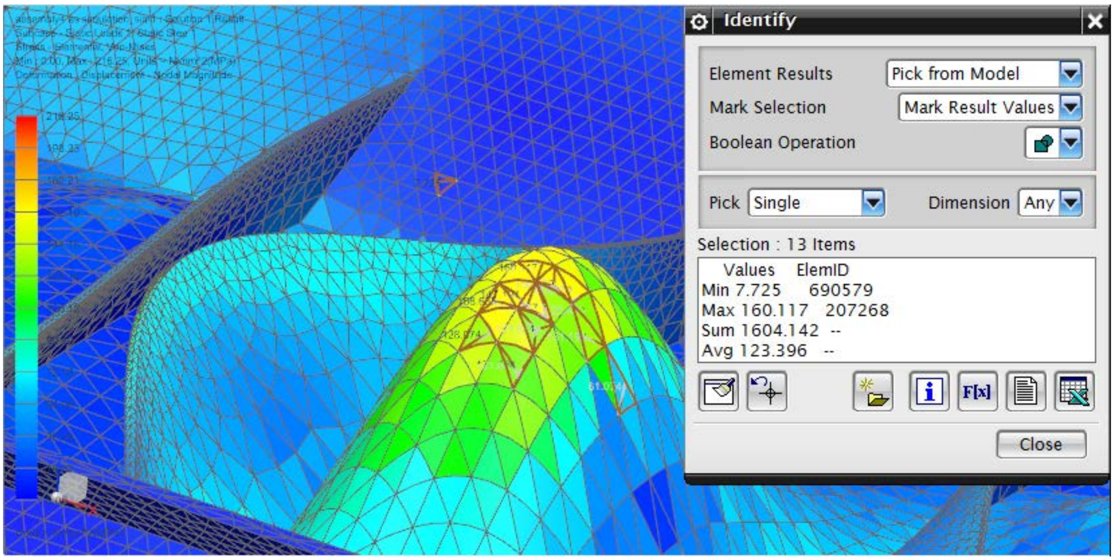


Figure 6.9 Other critical part of the middle stiffened panel.

From the figure 6.9, the maximum value of stress in this yellow part which means the high level of the stress is 160.117 N/mm^2, which does not exceed the yield strength as well, and the results indicates the layout of the stiffened panel with s=0.6 and l=2.1 is safe structure for the ship while applying by the regional pressure.

7 DISUCUSSION-CONCLUSION-FUTRUE WORK

This thesis is focus on the optimization of the stiffened panel in the ship bow by making different configurations, studying optimal parameters, buckling and scantling of the stiffeners e.g. plating structure, shell plate, stringer and web frame in the BowImpact2008Jan.xls.

The conclusion is that we have established a robust tool to optimize the structure such scantling of the supporting structure with respect to different configurations, by reduction of the weight cost, but still which is not enough, and will be discussion in the following.

In addition, from studying the optimized parameter with weight calculated in each situations and configurations, we can make a conclusion that the weight will decrease as we decrease plating thickness within the minimal requirement, and as we made a configuration that can have a smaller grid surrounded by the stiffener and support members, e.g web frames and girder, in other words, as we decease the stiffer spacing, web frame spacing, stringer spacing or the length of support members, the weight per square meter decrease.

Which configuration is better transverse stiffener or longitudinal stiffener?

In order to figure out this problem, we should make a condition that we need to apply both two configurations into one certain size of panel.

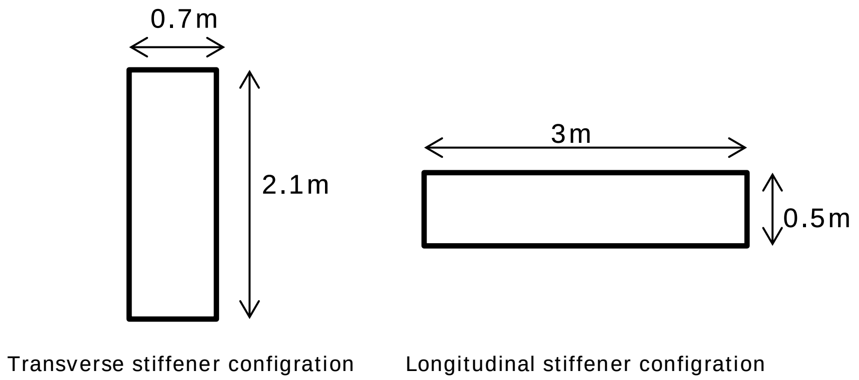


Figure 7.1 Two optional for one specific panel.

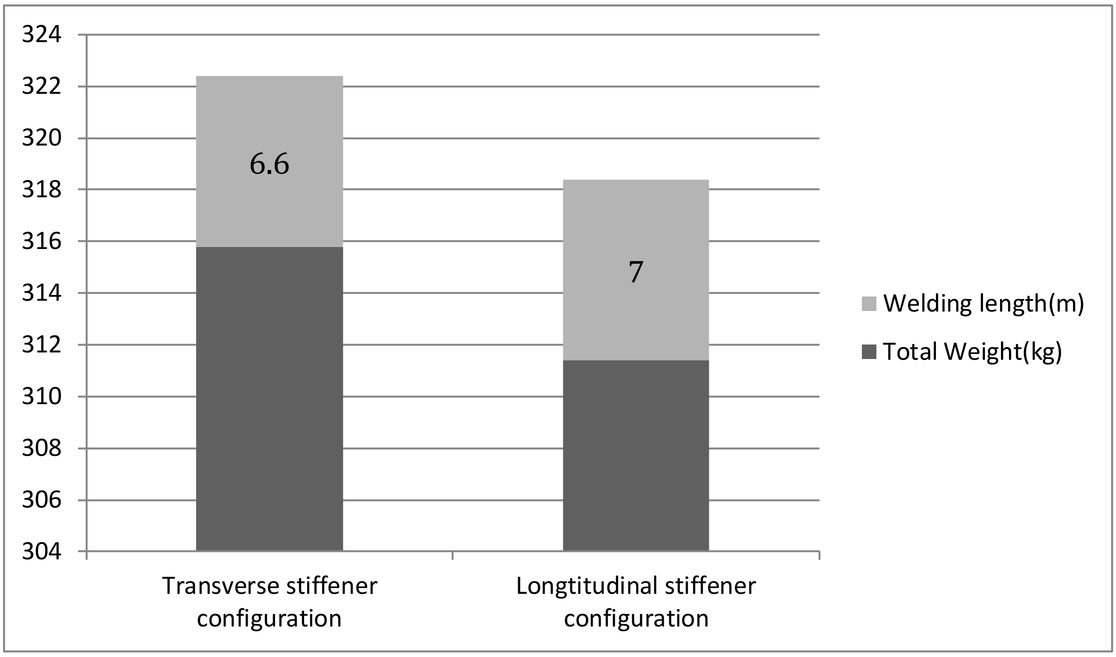


Figure 7.2 Weight comparison between two configurations.

As we calculated, for the transverse stiffener configuration, the area A1 = 1,47 m^2 , the welding length Lw1=6.6m and the weight T1= 315.8 kg, for the longitudinal stiffener configuration the area A2 = 1,5 m^2. T1= 311.4 kg and Lw2=7,0m.

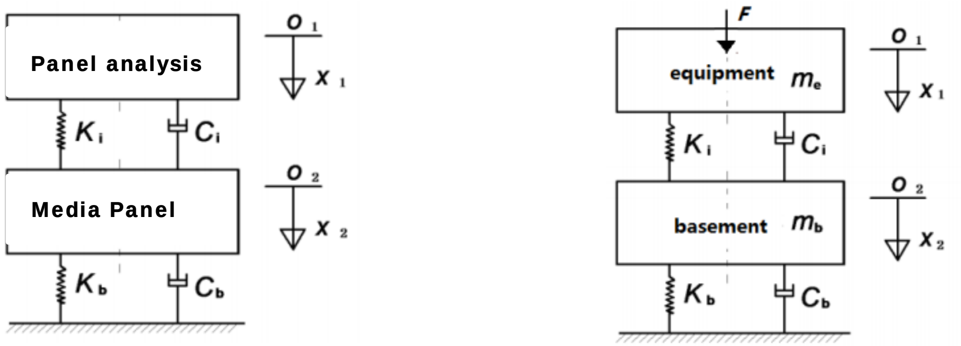
Table 7.1 Comparison between two configurations.

	Weight Cost	Fabration cost	Working Space
Transverse stiffener configration	no	yes	yes

Longitudinal stiffener configration	yes	no	no

Then we can make a conclusion that for consideration of the weight cost, the longitudinal stiffener configuration is better, for consideration of the welding cost(Assumption that the throat thickness is the same), the transverse stiffener configuration is better, but combination of the two factors, we don't which is better, because each configuration has own advantage, it should also be considered as other factors like steel price and fabrication cost for each shipyard, and operational space (stiffener spacing normally)for welding worker in the ship building process as well and maybe some other factors we don't know. Therefore in the future work, we can research on total cost in the function of weight, welding length and other practical reason, which can be seen as a robust tools for designer to make good decision.

Boundary condition in NX is fixed in all the translation and rotation direction, this critical boundary condition is more stringent. But in reality, it would be more complex, based on the principle of structural dynamics[4], a given moving boundary conditions which is the real constraint underwater for the panel can be expressed in the form of mechanical boundary conditions, which indicates that the moving boundary conditions and mechanical boundary conditions are equivalent, and by the meaning of this, most important imply is that we can test our structure in our lab if we can establish a foundation acting like response moving boundary condition.



(a) model with moving boundary condition (b) model with mechanical boundary condition

Figure 7.3 Illustration of the corresponding moving boundary condition underwater.

From the figure we know, the constraint will be increase with the growth motion amplitude, and will change when the object is moving, in other words, the real constraint for the stiffened panel is like the function of the spring, the more effort you pull out, the larger you receive the constraint from the spring and it will change along with the motion of the panel. In order to make our model more like the real situation, one recommended method is to expand the panel in to bigger size, and fixed in all around the model boundary, but trying to decease the effects of our critical boundary condition, then the stress in the middle of the panel will be more close to the actual value, and this work will be recommended in the future work.

The main content of the continue work of this thesis is that we can establish a total cost function which can be in the function of weight, welding length, steel price and fabrication cost and so on, so that we can have intuitive feeling which configuration is better than others and this function can be good for designer to make decision.

And what is more, the model of the stiffened panel can be **simulated in Star CMM+**, the panel can experience different amplitude waves with real variable pressure changing with the time, and the stress in the panel can be analysis.

8 REFERENCE

[1] Veritas D N. DNV Rules for classification of ships[J]. Det Norske Veritas, Høvik, Norway, 2008.

[2] Optimum layout of stiffened panels subjected to lateral pressure and in-plane loads Jørgen Amdahl Trondheim, Norway FALL 2010.

[3] Bulb flats data sheet - Tata Steel in Europe http://www.tatasteeleurope.com/static_files/Downloads/Energy%20and%20Power/TATA%20STEEL%20Bulb%20Flats%20BRO.pdf

[4] Moving boundary similarity method and its application on ship structural borne noise prediction. Fu-zhen PANG1 ; Xu-hong MIAO 2 ; Dong TANG3 ; Hong-bao SONG4 1 Naval Academy of Armament, Beijing 100161, China.

Appendix

Appendix A-Calculated spreadsheet of transverse stiffener (n=5) and stringer spacing l = 2.1m

			Select profile	Select profile	Select profile	Select profile	Select profile	Select profile
Type			Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 180 x 10
Type id			20	20	20	20	20	20
Stiffener height	h	[mm]	200.00	200.00	200.00	200.00	200.00	180.00
Flange breadth	b_f	[mm]	37.00	37.00	37.00	37.00	37.00	35.00
Web thickness	t_w	[mm]	9.00	9.00	9.00	9.00	9.00	10.00
Flange thickness	t_f	[mm]	20.21	20.21	20.21	20.21	20.21	17.84
Stiff. height to centre of flange area	h_{fc}	[mm]						
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	2.10	2.10	2.10	2.10	2.10	2.10
Stiffener spacing	s	[m]	0.50	0.50	0.50	0.50	0.50	0.50
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	8.00	8.50	9.00	9.50	10.00	11.00
Shell to web angle	φ_w	[°]	70.0	70.0	70.0	70.0	70.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0	0
Cross-sectional area of flange	A_f	[mm^2]						
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]						
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]						
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ							
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm^2]	8.7	8.7	8.7	8.7	8.7	8.7
Effective shear area	A_{sa}	[cm^2]	17.6	17.6	17.7	17.7	17.8	17.9
Shear area check			OK	OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm^3]	248	248	248	248	248	248
Effective plastic section modulus	Z_{pa}	[cm^3]	288	290	292	293	295	252
Plastic section modulus check			OK	OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	3.31	3.31	3.31	3.31	3.31	3.09
Web thickness check			OK	OK	OK	OK	OK	OK

Figure A -1 Stiffeners sheet of varied plate thickness with s=0,50m.

Depth of structural member	h	[m]	0.50	0.40	0.50	0.40	0.50	0.40	0.50	0.40	0.50	0.40
Girder height	h_{girder}	[mm]	500.00	400.00	500.00	400.00	500.00	400.00	500.00	400.00	500.00	400.00
The full length of the stiffener to the	l_1	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
adjacent primary member supports	l_2	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	2.10	3.00	2.10	3.00	2.10	3.00	2.10	3.00	2.10
Stiffener spacing	s	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm²]	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Critical buckling stress	σ_c	[Mpa]	111.0	197.0	125.0	201.0	137.0	205.0	147.0	208.0	156.0	211.0
Breadth of shell	s_b	[m]	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Side shell to plate field distance	h_p	[m]	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m²]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm²]	45.3	36.9	45.3	36.9	45.3	36.9	45.3	36.9	45.3	36.9
Effective web area	A_s	[cm²]	50.0	40.0	50.0	40.0	50.0	40.0	50.0	40.0	50.0	40.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm³]	1435.8	573.5	1435.8	573.5	1435.8	573.5	1435.8	573.5	1435.8	573.5
Section modulus as fitted	Z_f	[cm³]	2780.0	627.0	2507.0	610.0	2373.0	599.0	2094.0	594.0	2001.0	581.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-9.75	-4.97	-8.65	-5.09	-7.90	-4.99	-7.36	-4.92	-6.94	-4.85
Web thickness as fitted	t_w	[mm]	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm²	102	104	102	104	102	104	102	104	102	104
Critical shear buckling stress	τ_c	N/mm²	118	118	120	120	122	122	123	123	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm²	110	195	122	201	129	205	146	206	153	211
Critical compressive buckling stress	σ_c	N/mm²	111	197	125	201	137	205	147	208	156	211
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure A-2 Supp. member sheet of varied plate thickness with s=0,50m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener: Type			Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9
Type id			20	20	20	20	20
Stiffener height	h	[mm]	200.00	200.00	200.00	200.00	200.00
Flange breadth	b_f	[mm]	37.00	37.00	37.00	37.00	37.00
Web thickness (Parameters)	t_w	[mm]	9.00	9.00	9.00	9.00	9.00
Flange thickness	t_f	[mm]	20.21	20.21	20.21	20.21	20.21
Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	2.10	2.10	2.10	2.10	2.10
Stiffener spacing	s	[m]	0.60	0.60	0.60	0.60	0.60
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	10.00	10.50	11.00	11.50	12.00
Shell to web angle	φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0
Cross-sectional area of flange	A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ						
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm^2]	10.4	10.4	10.4	10.4	10.4
Effective shear area	A_{sa}	[cm^2]	17.8	17.8	17.8	17.9	17.9
Shear area check			OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm^3]	298	298	298	298	298
Effective plastic section modulus	Z_{pa}	[cm^3]	298	300	303	305	307
Plastic section modulus check			OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	3.51	3.51	3.51	3.51	3.51
Web thickness check			OK	OK	OK	OK	OK

Figure A-3 Stiffeners sheet of varied plate thickness with s=0,55m.

bulkhead measured at right angle to its line of intersection with the shell. In a deck or bulkhead the depth need not be measured further than to the ship's centreline, and need not be taken larger than the length h_m (the distance measured on the side shell between the members which support the deck or bulkhead (see Fig. 4, Pt.3 Ch.1 Sec.7 E110)).

Depth of structural member				0.30	0.50	0.30	0.50	0.30	0.50	0.30	0.50	0.30
Girder height				00.00	500.00	300.00	500.00	300.00	500.00	300.00	500.00	300.00
The full length of the stiffener to the adjacent primary member supports				2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
				2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Stiffeners number within the span				5	5	5	5	5	5	5	5	5
Supp. member's span				2.10	3.30	2.10	3.30	2.10	3.30	2.10	3.30	2.10
Stiffener spacing				0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Yield stress of material				35.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm²]	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Critical buckling stress	σ_c	[Mpa]	119.0	199.0	131.0	202.0	141.0	206.0	150.0	208.0	157.0	211.0
Breadth of shell	s_b	[m]	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Side shell to plate field distance	h_p	[m]	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m²]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm²]	49.9	40.6	49.9	40.6	49.9	40.6	49.9	40.6	49.9	40.6
Effective web area	A_s	[cm²]	50.0	45.0	50.0	45.0	50.0	45.0	50.0	45.0	0.0	45.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	Failed	OK
Minimum section modulus	Z	[cm³]	1737.4	573.5	1737.4	573.5	1737.4	573.5	1737.4	573.5	1737.4	573.5
Section modulus as fitted	Z_f	[cm³]	3224.0	621.0	2950.0	610.0	2673.0	598.0	2537.0	600.0	2399.0	588.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-8.24	-5.09	-7.49	-5.02	-6.95	-4.92	-6.54	-4.87	-6.25	-4.80
Web thickness as fitted	t_w	[mm]	10.00	15.00	10.00	15.00	10.00	15.00	10.00	15.00	10.00	15.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm²	112	102	112	102	112	102	112	102	112	102
Critical shear buckling stress	τ_c	N/mm²	119	119	121	121	122	122	124	124	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm²	115	197	126	201	139	205	146	204	155	208
Critical compressive buckling stress	σ_c	N/mm²	119	199	131	202	141	206	150	208	157	211
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure A-4 Supp. member sheet of varied plate thickness with s=0,55m.

				Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9	Bulb 200 x 9
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	200.00	200.00	200.00	200.00	200.00
	Flange breadth	b_f	[mm]	37.00	37.00	37.00	37.00	37.00
	Web thickness Parameters	t_w	[mm]	9.00	9.00	9.00	9.00	9.00
	Flange thickness	t_f	[mm]	20.21	20.21	20.21	20.21	20.21
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	2.10	2.10	2.10	2.10	2.10
Stiffener spacing		s	[m]	0.60	0.60	0.60	0.60	0.60
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	10.00	10.50	11.00	11.50	12.00
Shell to web angle		φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm²]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m²]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm²]	10.4	10.4	10.4	10.4	10.4
Effective shear area		A_{sa}	[cm²]	17.8	17.8	17.8	17.9	17.9
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm³]	298	298	298	298	298
Effective plastic section modulus		Z_{pa}	[cm³]	298	300	303	305	307
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	3.51	3.51	3.51	3.51	3.51
Web thickness check				OK	OK	OK	OK	OK

Figure A-5 Stiffeners sheet of varied plate thickness with s=0,60m.

Depth of structural member	h	[m]	0.50	0.30	0.50	0.30	0.50	0.30	0.50	0.30	0.50	0.30
Girder height	h_{girder}	[mm]	500.00	300.00	500.00	300.00	500.00	300.00	500.00	300.00	500.00	300.00
The full length of the stiffener to the	l_1	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
adjacent primary member supports	l_2	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.60	2.10	3.60	2.10	3.60	2.10	3.60	2.10	3.60	2.10
Stiffener spacing	s	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Critical buckling stress	σ_c	[Mpa]	126.0	200.0	136.0	203.0	145.0	206.0	152.0	208.0	159.0	211.0
Breadth of shell	s_b	[m]	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Side shell to plate field distance	h_p	[m]	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	54.4	44.3	54.4	44.3	54.4	44.3	54.4	44.3	54.4	44.3
Effective web area	A_a	[cm^2]	55.0	45.0	55.0	45.0	55.0	45.0	55.0	45.0	55.0	45.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2067.6	573.5	2067.6	573.5	2067.6	573.5	2067.6	573.5	2067.6	573.5
Section modulus as fitted	Z_f	[cm^3]	3590.0	616.0	3317.0	618.0	3183.0	603.0	3048.0	605.0	2912.0	590.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-7.11	-4.64	-6.59	-4.58	-6.18	-4.51	-5.90	-4.47	-5.64	-4.40
Web thickness as fitted	t_w	[mm]	11.00	15.00	11.00	15.00	11.00	15.00	11.00	15.00	11.00	15.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	112	111	112	111	112	111	112	111	112	111
Critical shear buckling stress	τ_c	N/mm^2	120	120	121	121	123	123	124	124	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	123	199	133	198	139	203	145	203	152	208
Critical compressive buckling stress	σ_c	N/mm^2	126	200	136	203	145	206	152	208	159	211
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure A-6 Supp. member sheet of varied plate thickness with s=0,60m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener: Type			Bulb 200 x 11.5	Bulb 200 x 10	Bulb 200 x 9	Bulb 200 x 8	Bulb 200 x 11.5
Type id			20	20	20	20	20
Stiffener height	h	[mm]	200.00	200.00	200.00	200.00	200.00
Flange breadth	b_f	[mm]	39.50	38.00	37.00	36.00	39.50
Web thickness	t_w	[mm]	11.50	10.00	9.00	8.00	11.50
Flange thickness	t_f	[mm]	20.21	20.21	20.21	20.21	20.21
Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	2.10	2.10	2.10	2.10	2.10
Stiffener spacing	s	[m]	0.65	0.60	0.55	0.50	0.70
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	10.50	10.00	9.00	8.00	11.50
Shell to web angle	φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0
Cross-sectional area of flange	A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ						
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm^2]	11.3	10.4	9.5	8.7	12.2
Effective shear area	A_{sa}	[cm^2]	22.7	19.7	17.7	15.6	22.9
Shear area check			OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm^3]	323	298	273	248	348
Effective plastic section modulus	Z_{pa}	[cm^3]	351	318	293	269	358
Plastic section modulus check			OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	3.60	3.51	3.41	3.31	3.69
Web thickness check			OK	OK	OK	OK	OK

Parameters

Figure A-7 Stiffeners sheet of varied plate thickness with s=0,65m.

Depth of structural member	h	[m]	0.50	0.30	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	300.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
adjacent primary member supports	l_2	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.90	2.10	3.90	2.10	3.90	2.10	3.90	2.10	3.90	2.10
Stiffener spacing	s	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm²]	28.7	28.7	25.7	25.7	23.7	23.7	25.7	25.7	25.7	25.7
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Critical buckling stress	σ_c	[Mpa]	122.0	198.0	161.0	211.0	180.0	217.0	132.0	201.0	141.0	204.0
Breadth of shell	s_b	[m]	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Side shell to plate field distance	h_p	[m]	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m²]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm²]	58.9	48.0	58.9	48.0	58.9	48.0	58.9	48.0	58.9	48.0
Effective web area	A_a	[cm²]	60.0	51.0	60.0	51.0	60.0	51.0	60.0	51.0	60.0	51.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm³]	2426.6	573.5	2426.6	573.5	2426.6	573.5	2426.6	573.5	2426.6	573.5
Section modulus as fitted	Z_f	[cm³]	4282.0	626.0	3249.0	584.0	2916.0	580.0	3965.0	618.0	3684.0	609.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-8.24	-5.24	-5.56	-3.71	-4.58	-3.28	-6.80	-3.90	-6.36	-3.85
Web thickness as fitted	t_w	[mm]	12.00	17.00	12.00	17.00	12.00	17.00	12.00	17.00	12.00	17.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm²	111	106	111	64	111	64	111	64	111	64
Critical shear buckling stress	τ_c	N/mm²	119	119	125	125	128	128	121	121	122	122
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm²	121	196	160	210	178	211	131	200	141	201
Critical compressive buckling stress	σ_c	N/mm²	122	198	161	211	180	217	132	201	141	204
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure A-8 Supp. member sheet of varied plate thickness with s=0,65m.

				Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 200 x 11.5	Bulb 200 x 11.5	Bulb 200 x 11.5	Bulb 200 x 11.5	Bulb 200 x 11.5
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	200.00	200.00	200.00	200.00	200.00
	Flange breadth	b_f	[mm]	39.50	39.50	39.50	39.50	39.50
	Web thickness Parameters	t_w	[mm]	11.50	11.50	11.50	11.50	11.50
	Flange thickness	t_f	[mm]	20.21	20.21	20.21	20.21	20.21
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	2.10	2.10	2.10	2.10	2.10
Stiffener spacing		s	[m]	0.70	0.70	0.70	0.70	0.70
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	11.50	12.00	12.50	13.00	13.50
Shell to web angle		φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	12.2	12.2	12.2	12.2	12.2
Effective shear area		A_{sa}	[cm^2]	22.9	22.9	23.0	23.0	23.1
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	348	348	348	348	348
Effective plastic section modulus		Z_{pa}	[cm^3]	358	360	363	366	369
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	3.69	3.69	3.69	3.69	3.69
Web thickness check				OK	OK	OK	OK	OK

Figure A-9 Stiffeners sheet of varied plate thickness with s=0,70m.

Depth of structural member	h	[m]	0.50	0.30	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	300.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
adjacent primary member supports	l_2	[m]	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span	S	[m]	4.20	2.10	4.20	2.10	4.20	2.10	4.20	2.10	4.20	2.10
Stiffener spacing Figure	s	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Critical buckling stress	σ_c	[Mpa]	129.0	199.0	137.0	202.0	145.0	204.0	152.0	207.0	158.0	209.0
Breadth of shell	s_b	[m]	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Side shell to plate field distance	h_p	[m]	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	63.5	51.7	63.5	51.7	63.5	51.7	63.5	51.7	63.5	51.7
Effective web area	A_a	[cm^2]	65.0	54.0	65.0	54.0	65.0	54.0	65.0	54.0	65.0	54.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2814.2	573.5	2814.2	573.5	2814.2	573.5	2814.2	573.5	2814.2	573.5
Section modulus as fitted	Z_f	[cm^3]	4846.0	620.0	4482.0	607.0	4225.0	602.0	4060.0	596.0	3927.0	590.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-6.97	-4.24	-6.56	-3.70	-6.20	-3.66	-5.92	-3.61	-5.69	-3.57
Web thickness as fitted	t_w	[mm]	13.00	17.00	13.00	17.00	13.00	17.00	13.00	17.00	13.00	17.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	110	114	110	69	110	69	110	69	110	69
Critical shear buckling stress	τ_c	N/mm^2	120	120	121	121	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	124	198	134	202	142	204	148	206	153	208
Critical compressive buckling stress	σ_c	N/mm^2	129	199	137	202	145	204	152	207	158	209
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure A-10 Supp. member sheet of varied plate thickness with s=0,70m.

Appendix-B Calculated spreadsheet of transverse stiffener (n=5) and stringer spacing l = 1.4m

				Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 140 x 7	Bulb 140 x 7	Bulb 140 x 7	Bulb 140 x 7	Bulb 140 x 7
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	140.00	140.00	140.00	140.00	140.00
	Flange breadth	b_f	[mm]	26.00	26.00	26.00	26.00	26.00
	Web thickness	t_w	[mm]	7.00	7.00	7.00	7.00	7.00
	Flange thickness	t_f	[mm]	13.82	13.82	13.82	13.82	13.82
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	1.40	1.40	1.40	1.40	1.40
Stiffener spacing		s	[m]	0.50	0.50	0.50	0.50	0.50
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	8.00	8.50	9.00	9.50	10.00
Shell to web angle		φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	5.8	5.8	5.8	5.8	5.8
Effective shear area		A_{sa}	[cm^2]	9.7	9.8	9.8	9.8	9.9
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	110	110	110	110	110
Effective plastic section modulus		Z_{pa}	[cm^3]	111	112	113	115	116
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	2.62	2.62	2.62	2.62	2.62
Web thickness check				OK	OK	OK	OK	OK

Parameters

Figure B-11 Stiffeners sheet of varied plate thickness with s=0,50m.

Depth of structural member	h	[m]	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25
Girder height	h_{girder}	[mm]	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00
The full length of the stiffener to the	l_1	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
adjacent primary member supports	l_2	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span	S	[m]	3.00	1.40	3.00	1.40	3.00	1.40	3.00	1.40	3.00	1.40
Stiffener spacing Figure	s	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Critical buckling stress	σ_c	[Mpa]	126.0	197.0	138.0	201.0	149.0	205.0	158.0	208.0	165.0	211.0
Breadth of shell	s_b	[m]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Side shell to plate field distance	h_p	[m]	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	30.2	24.6	30.2	24.6	30.2	24.6	30.2	24.6	30.2	24.6
Effective web area	A_a	[cm^2]	35.0	25.0	35.0	25.0	35.0	25.0	35.0	25.0	35.0	25.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	957.2	169.9	957.2	169.9	957.2	169.9	957.2	169.9	957.2	169.9
Section modulus as fitted	Z_f	[cm^3]	1687.0	210.0	1504.0	211.0	1415.0	212.0	1324.0	213.0	1328.0	213.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-3.98	-2.72	-3.64	-2.66	-3.37	-2.61	-3.18	-2.57	-3.04	-2.54
Web thickness as fitted	t_w	[mm]	7.00	10.00	7.00	10.00	75.00	10.00	7.00	10.00	7.00	10.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	97	111	97	111	9	111	97	111	97	111
Critical shear buckling stress	τ_c	N/mm^2	119	119	121	121	123	123	124	124	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	121	173	136	172	145	171	154	170	154	170
Critical compressive buckling stress	σ_c	N/mm^2	126	197	138	201	149	205	158	208	165	211
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure B-12 Supp. member sheet of varied plate thickness with s=0,50m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener: Type			Bulb 140 x 8	Bulb 140 x 8	Bulb 140 x 8	Bulb 140 x 8	Bulb 140 x 8
Type id			20	20	20	20	20
Stiffener height	h	[mm]	140.00	140.00	140.00	140.00	140.00
Flange breadth	b_f	[mm]	27.00	27.00	27.00	27.00	27.00
Web thickness (Parameters)	t_w	[mm]	8.00	8.00	8.00	8.00	8.00
Flange thickness	t_f	[mm]	13.82	13.82	13.82	13.82	13.82
Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	1.40	1.40	1.40	1.40	1.40
Stiffener spacing	s	[m]	0.55	0.55	0.55	0.55	0.55
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	9.00	9.50	10.00	10.50	11.00
Shell to web angle	φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0
Cross-sectional area of flange	A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ						
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm^2]	6.4	6.4	6.4	6.4	6.4
Effective shear area	A_{sa}	[cm^2]	11.2	11.2	11.3	11.3	11.4
Shear area check			OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm^3]	121	121	121	121	121
Effective plastic section modulus	Z_{pa}	[cm^3]	124	126	128	129	131
Plastic section modulus check			OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	2.70	2.70	2.70	2.70	2.70
Web thickness check			OK	OK	OK	OK	OK

Figure B-13 Stiffeners sheet of varied plate thickness with s=0,55m.

Depth of structural member	h	[m]	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25
Girder height	h_{girder}	[mm]	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00
The full length of the stiffener to the	l_1	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
adjacent primary member supports	l_2	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.30	1.40	3.30	1.40	3.30	1.40	3.30	1.40	3.30	1.40
Stiffener spacing	s	[m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Critical buckling stress	σ_c	[Mpa]	136.0	199.0	146.0	202.0	154.0	206.0	162.0	208.0	168.0	211.0
Breadth of shell	s_b	[m]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Side shell to plate field distance	h_p	[m]	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	33.2	27.1	33.2	27.1	33.2	27.1	33.2	27.1	33.2	27.1
Effective web area	A_a	[cm^2]	35.0	30.0	35.0	30.0	35.0	30.0	35.0	30.0	35.0	30.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	1158.2	169.9	1158.2	169.9	1158.2	169.9	1158.2	169.9	1158.2	169.9
Section modulus as fitted	Z_f	[cm^3]	1888.0	254.0	1704.0	255.0	1614.0	255.0	1619.0	256.0	1527.0	257.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-3.74	-2.72	-3.49	-2.68	-3.30	-2.63	-3.14	-2.60	-3.03	-2.57
Web thickness as fitted	t_w	[mm]	7.00	12.00	7.00	12.00	75.00	12.00	7.00	12.00	7.00	12.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	107	102	107	102	10	102	107	102	107	102
Critical shear buckling stress	τ_c	N/mm^2	120	120	122	122	123	123	124	124	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	131	143	145	142	153	142	153	142	162	141
Critical compressive buckling stress	σ_c	N/mm^2	136	199	146	202	154	206	162	208	168	211
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure B-14 Supp. member sheet of varied plate thickness with s=0,55m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Type			Bulb 140 x 9	Bulb 140 x 9	Bulb 140 x 9	Bulb 140 x 8	Bulb 140 x 8
Type id			20	20	20	20	20
Stiffener height	h	[mm]	140.00	140.00	140.00	140.00	140.00
Flange breadth	b_f	[mm]	28.00	28.00	28.00	27.00	27.00
Web thickness	t_w	[mm]	9.00	9.00	9.00	8.00	8.00
Flange thickness	t_f	[mm]	13.82	13.82	13.82	13.82	13.82
Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	1.40	1.40	1.40	1.40	1.40
Stiffener spacing	s	[m]	0.60	0.60	0.60	0.60	0.60
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	9.50	10.00	10.50	11.00	11.50
Shell to web angle	φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0
Cross-sectional area of flange	A_f	[mm²]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ						
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm²]	6.9	6.9	6.9	6.9	6.9
Effective shear area	A_{sa}	[cm²]	12.6	12.7	12.7	11.4	11.4
Shear area check			OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm³]	132	132	132	132	132
Effective plastic section modulus	Z_{pa}	[cm³]	137	139	141	133	135
Plastic section modulus check			OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	2.78	2.78	2.78	2.78	2.78
Web thickness check			OK	OK	OK	OK	OK

Figure B-15 Stiffeners sheet of varied plate thickness with s=0,60m.

Depth of structural member	h	[m]	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25
Girder height	h_{girder}	[mm]	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00
The full length of the stiffener to the	l_1	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
adjacent primary member supports	l_2	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span (Figure)	S	[m]	3.60	1.40	3.60	1.40	3.60	1.40	3.60	1.40	3.60	1.40
Stiffener spacing	s	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle (Figure)	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm²]	15.2	15.2	15.2	15.2	15.2	15.2	13.8	13.8	13.8	13.8
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Critical buckling stress	σ_c	[Mpa]	134.0	196.0	144.0	200.0	152.0	203.0	160.0	206.0	166.0	208.0
Breadth of shell	s_b	[m]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Side shell to plate field distance	h_p	[m]	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m²]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm²]	36.3	29.6	36.3	29.6	36.3	29.6	36.3	29.6	36.3	29.6
Effective web area	A_a	[cm²]	40.0	30.0	40.0	30.0	40.0	30.0	40.0	30.0	40.0	30.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm³]	1378.4	169.9	1378.4	169.9	1378.4	169.9	1378.4	169.9	1378.4	169.9
Section modulus as fitted	Z_f	[cm³]	2240.0	255.0	2059.0	256.0	1971.0	257.0	1882.0	258.0	1792.0	259.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-3.84	-2.79	-3.57	-2.74	-3.39	-2.70	-2.87	-2.39	-2.77	-2.37
Web thickness as fitted	t_w	[mm]	8.00	12.00	8.00	12.00	8.00	12.00	8.00	12.00	8.00	12.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm²	102	111	102	111	102	111	102	111	102	111
Critical shear buckling stress	τ_c	N/mm²	119	119	121	121	122	122	124	124	125	125
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm²	131	142	143	142	149	141	156	141	164	140
Critical compressive buckling stress	σ_c	N/mm²	134	196	144	200	152	203	160	206	166	208
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure B-16 Supp. member sheet of varied plate thickness with s=0,60m.

Stiffener				Select profile	Select profile	Select profile	Select profile	Select profile
	Type			Bulb 160 x 7	Bulb 160 x 7	Bulb 140 x 9	Bulb 140 x 9	Bulb 140 x 9
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	160.00	160.00	140.00	140.00	140.00
	Flange breadth	b_f	[mm]	29.00	29.00	28.00	28.00	28.00
	Web thickness (Parameters)	t_w	[mm]	7.00	7.00	9.00	9.00	9.00
	Flange thickness	t_f	[mm]	15.46	15.46	13.82	13.82	13.82
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	1.40	1.40	1.40	1.40	1.40
Stiffener spacing		s	[m]	0.65	0.65	0.65	0.65	0.65
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	10.00	10.50	11.00	11.50	12.00
Shell to web angle		φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	7.5	7.5	7.5	7.5	7.5
Effective shear area		A_{sa}	[cm^2]	11.2	11.2	12.8	12.8	12.9
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	143	143	143	143	143
Effective plastic section modulus		Z_{pa}	[cm^3]	157	159	144	146	149
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	3.12	3.12	2.85	2.85	2.85
Web thickness check				OK	OK	OK	OK	OK

Figure B-17 Stiffeners sheet of varied plate thickness with s=0,65m.

Depth of structural member	h	[m]	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25
Girder height	h_{girder}	[mm]	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00
The full length of the stiffener to the	l_1	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
adjacent primary member supports	l_2	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span	S	[m]	3.90	1.40	3.90	1.40	3.90	1.40	3.90	1.40	3.90	1.40
Stiffener spacing Figure	s	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	14.6	14.6	14.6	14.6	15.2	15.2	15.2	15.2	15.2	15.2
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Critical buckling stress	σ_c	[Mpa]	134.0	194.0	143.0	198.0	151.0	201.0	158.0	204.0	165.0	206.0
Breadth of shell	s_b	[m]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Side shell to plate field distance	h_p	[m]	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	39.3	32.0	39.3	32.0	39.3	32.0	39.3	32.0	39.3	32.0
Effective web area	A_a	[cm^2]	40.0	32.5	40.0	32.5	40.0	32.5	40.0	32.5	40.0	32.5
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	1617.7	169.9	1617.7	169.9	1617.7	169.9	1617.7	169.9	1617.7	169.9
Section modulus as fitted	Z_f	[cm^3]	2637.0	277.0	2502.0	278.0	2367.0	279.0	2229.0	280.0	2235.0	281.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-3.34	-1.98	-3.13	-1.94	-3.10	-2.01	-2.97	-1.99	-2.84	-1.97
Web thickness as fitted	t_w	[mm]	8.00	13.00	8.00	13.00	8.00	13.00	8.00	13.00	8.00	13.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	111	111	111	111	111	111	111	111	111	111
Critical shear buckling stress	τ_c	N/mm^2	119	119	120	120	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	131	131	138	131	146	130	155	130	155	129
Critical compressive buckling stress	σ_c	N/mm^2	134	194	143	198	151	201	158	204	165	206
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure B-18 Supp. member sheet of varied plate thickness with s=0,65m.

				Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 160 x 7	Bulb 160 x 7	Bulb 160 x 7	Bulb 160 x 7	Bulb 140 x 9
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	160.00	160.00	160.00	160.00	140.00
	Flange breadth	b_f	[mm]	29.00	29.00	29.00	29.00	28.00
	Web thickness Parameters	t_w	[mm]	7.00	7.00	7.00	7.00	9.00
	Flange thickness	t_f	[mm]	15.46	15.46	15.46	15.46	13.82
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	1.40	1.40	1.40	1.40	1.40
Stiffener spacing		s	[m]	0.70	0.70	0.70	0.70	0.70
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	11.00	11.50	12.00	12.50	13.00
Shell to web angle		φ_w	[°]	70.0	70.0	70.0	70.0	70.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	8.1	8.1	8.1	8.1	8.1
Effective shear area		A_{sa}	[cm^2]	11.2	11.3	11.3	11.3	12.9
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	154	154	154	154	154
Effective plastic section modulus		Z_{pa}	[cm^3]	163	165	168	170	156
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	3.20	3.20	3.20	3.20	2.92
Web thickness check				OK	OK	OK	OK	OK

Figure B-19 Stiffeners sheet of varied plate thickness with s=0,70m.

Depth of structural member	h	[m]	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.50	0.25
Girder height	h_{girder}	[mm]	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00	500.00	250.00
The full length of the stiffener to the	l_1	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
adjacent primary member supports	l_2	[m]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	4.20	1.40	4.20	1.40	4.20	1.40	4.20	1.40	4.20	1.40
Stiffener spacing	s	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm²]	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	15.2	15.2
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Critical buckling stress	σ_c	[Mpa]	143.0	196.0	151.0	199.0	158.0	202.0	164.0	204.0	169.0	207.0
Breadth of shell	s_b	[m]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Side shell to plate field distance	h_p	[m]	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m²]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m²]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m²]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm²]	42.3	34.5	42.3	34.5	42.3	34.5	42.3	34.5	42.3	34.5
Effective web area	A_a	[cm²]	45.0	35.0	45.0	35.0	45.0	35.0	45.0	35.0	45.0	35.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm³]	1876.2	169.9	1876.2	169.9	1876.2	169.9	1876.2	169.9	1876.2	169.9
Section modulus as fitted	Z_f	[cm³]	2856.0	301.0	2723.0	302.0	2587.0	303.0	2451.0	304.0	2457.0	305.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-2.86	-1.76	-2.71	-1.74	-2.59	-1.71	-2.50	-1.69	-2.54	-1.77
Web thickness as fitted	t_w	[mm]	9.00	14.00	9.00	14.00	9.00	14.00	9.00	14.00	9.00	14.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm²	106	111	106	111	106	111	106	111	106	111
Critical shear buckling stress	τ_c	N/mm²	120	120	121	121	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm²	140	121	147	120	155	120	164	119	163	119
Critical compressive buckling stress	σ_c	N/mm²	143	196	151	199	158	202	164	204	169	207
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure B-20 Supp. member sheet of varied plate thickness with s=0,70m.

Appendix C-Calculated spreadsheet of longitudinal stiffener (n=5) and stringer spacing l = 3m

Stiffener				Select profile	Select profile	Select profile	Select profile	Select profile
	Type			Bulb 280 x 11	Bulb 280 x 11	Bulb 280 x 12	Bulb 280 x 12	Bulb 280 x 12
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	280.00	280.00	280.00	280.00	280.00
	Flange breadth	b_f	[mm]	51.00	51.00	52.00	52.00	52.00
	Web thickness Parameters	t_w	[mm]	11.00	11.00	12.00	12.00	12.00
	Flange thickness	t_f	[mm]	29.70	29.70	29.70	29.70	29.70
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	3.00	3.00	3.00	3.00	3.00
Stiffener spacing		s	[m]	0.50	0.50	0.50	0.50	0.50
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	8.00	8.50	9.00	9.50	10.00
Shell to web angle		φ_w	[°]	50.0	50.0	50.0	50.0	50.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	12.4	12.4	12.4	12.4	12.4
Effective shear area		A_{sa}	[cm^2]	24.3	24.3	26.6	26.6	26.7
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	622	622	622	622	622
Effective plastic section modulus		Z_{pa}	[cm^3]	687	690	730	644	646
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	4.40	4.40	4.40	4.40	4.40
Web thickness check				OK	OK	OK	OK	OK

Figure C-21 Stiffeners sheet of varied plate thickness with s=0,50m.

Depth of structural member	h	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
adjacent primary member supports	l_2	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffener spacing	s	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	42.7	42.7	42.7	42.7	45.5	45.5	45.5	45.5	45.5	45.5
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Critical buckling stress	σ_c	[Mpa]	197.0	105.0	201.0	119.0	205.0	131.0	208.0	142.0	211.0	151.0
Breadth of shell	s_b	[m]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Side shell to plate field distance	h_p	[m]	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	64.7	52.8	64.7	52.8	64.7	52.8	64.7	52.8	64.7	52.8
Effective web area	A_a	[cm^2]	70.0	55.0	70.0	55.0	70.0	55.0	70.0	55.0	70.0	55.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2051.2	1672.1	2051.2	1672.1	2051.2	1672.1	2051.2	1672.1	2051.2	1672.1
Section modulus as fitted	Z_f	[cm^3]	2234.0	3461.0	2243.0	3186.0	2157.0	2765.0	2164.0	2628.0	2170.0	2490.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-9.52	-18.40	-9.47	-16.23	-9.93	-15.75	-9.79	-14.53	-9.65	-13.67
Web thickness as fitted	t_w	[mm]	14.00	11.00	14.00	11.00	14.00	11.00	14.00	11.00	14.00	11.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	104	108	104	108	104	108	104	108	104	108
Critical shear buckling stress	τ_c	N/mm^2	118	118	120	120	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	196	103	195	112	203	129	202	136	202	143
Critical compressive buckling stress	σ_c	N/mm^2	197	105	201	119	205	131	208	142	211	151
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure C-22 Supp. member sheet of varied plate thickness with s=0,50m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener: Type			Bulb 300 x 11	Bulb 300 x 11	Bulb 300 x 11	Bulb 300 x 11	Bulb 300 x 11
Type id			20	20	20	20	20
Stiffener height	h	[mm]	300.00	300.00	300.00	300.00	300.00
Flange breadth	b_f	[mm]	54.00	54.00	54.00	54.00	54.00
Web thickness (Parameters)	t_w	[mm]	11.00	11.00	11.00	11.00	11.00
Flange thickness	t_f	[mm]	32.08	32.08	32.08	32.08	32.08
Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span	l	[m]	3.00	3.00	3.00	3.00	3.00
Stiffener spacing	s	[m]	0.55	0.55	0.55	0.55	0.55
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness	t_p	[mm]	9.00	9.50	10.00	10.50	11.00
Shell to web angle	φ_w	[°]	50.0	50.0	50.0	50.0	50.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.	n_s		0	0	0	0	0
Cross-sectional area of flange	A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005	β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005	γ						
as defined in Pt.3 Ch.1 Sec.3 C1005	γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area	A_s	[cm^2]	13.6	13.6	13.6	13.6	13.6
Effective shear area	A_{sa}	[cm^2]	26.0	26.1	26.1	26.2	26.2
Shear area check			OK	OK	OK	OK	OK
Minimum plastic section modulus	Z_p	[cm^3]	684	684	684	684	684
Effective plastic section modulus	Z_{pa}	[cm^3]	725	728	730	733	736
Plastic section modulus check			OK	OK	OK	OK	OK
Minimum web thickness	t_w	[mm]	4.75	4.75	4.75	4.75	4.75
Web thickness check			OK	OK	OK	OK	OK

Figure C-23 Stiffeners sheet of varied plate thickness with s=0,55m.

Depth of structural member	h	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
adjacent primary member supports	l_2	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	3.30	3.00	3.30	3.00	3.30	3.00	3.30	3.00	3.30
Stiffener spacing	s	[m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Side shell stiffener direction angle	φ_s	[°]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Critical buckling stress	σ_c	[Mpa]	199.0	111.0	202.0	124.0	206.0	135.0	208.0	144.0	211.0	152.0
Breadth of shell	s_b	[m]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Side shell to plate field distance	h_p	[m]	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	71.2	58.1	71.2	58.1	71.2	58.1	71.2	58.1	71.2	58.1
Effective web area	A_a	[cm^2]	75.0	60.0	75.0	60.0	75.0	60.0	75.0	60.0	75.0	60.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2051.2	2023.3	2051.2	2023.3	2051.2	2023.3	2051.2	2023.3	2051.2	2023.3
Section modulus as fitted	Z_f	[cm^3]	2238.0	4047.0	2245.0	3660.0	2157.0	3334.0	2163.0	3174.0	2169.0	2844.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-9.01	-17.38	-8.88	-15.56	-8.70	-14.29	-8.62	-13.40	-8.50	-12.69
Web thickness as fitted	t_w	[mm]	15.00	12.00	15.00	12.00	15.00	12.00	15.00	12.00	15.00	12.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	107	109	107	109	107	109	107	109	107	109
Critical shear buckling stress	τ_c	N/mm^2	119	119	120	120	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	196	107	195	118	203	130	203	136	202	152
Critical compressive buckling stress	σ_c	N/mm^2	199	111	202	124	206	135	208	144	211	152
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure C-24 Supp. member sheet of varied plate thickness with s=0,55m.

Stiffener				Select profile	Select profile	Select profile	Select profile	Select profile
	Type			Bulb 300 x 12	Bulb 300 x 12	Bulb 300 x 12	Bulb 300 x 12	Bulb 300 x 12
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	300.00	300.00	300.00	300.00	300.00
	Flange breadth	b_f	[mm]	55.00	55.00	55.00	55.00	55.00
	Web thickness Parameters	t_w	[mm]	12.00	12.00	12.00	12.00	12.00
	Flange thickness	t_f	[mm]	32.08	32.08	32.08	32.08	32.08
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	3.00	3.00	3.00	3.00	3.00
Stiffener spacing		s	[m]	0.60	0.60	0.60	0.60	0.60
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	10.00	10.50	11.00	11.50	12.00
Shell to web angle		φ_w	[°]	50.0	50.0	50.0	50.0	50.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	14.9	14.9	14.9	14.9	14.9
Effective shear area		A_{sa}	[cm^2]	28.5	28.5	28.6	28.6	28.7
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	746	746	746	746	746
Effective plastic section modulus		Z_{pa}	[cm^3]	768	770	773	776	779
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	4.88	4.88	4.88	4.88	4.88
Web thickness check				OK	OK	OK	OK	OK

Figure C-25 Stiffeners sheet of varied plate thickness with s=0,60m.

Depth of structural member	h	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
adjacent primary member supports	l_2	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	3.60	3.00	3.60	3.00	3.60	3.00	3.60	3.00	3.60
Stiffener spacing	s	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Side shell stiffener direction angle	φ_s	[°]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Critical buckling stress	σ_c	[Mpa]	200.0	117.0	203.0	128.0	206.0	137.0	208.0	146.0	211.0	158.0
Breadth of shell	s_b	[m]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Side shell to plate field distance	h_p	[m]	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	77.7	63.3	77.7	63.3	77.7	63.3	77.7	63.3	77.7	63.3
Effective web area	A_a	[cm^2]	80.0	65.0	80.0	65.0	80.0	65.0	80.0	65.0	80.0	65.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2051.2	2407.9	2051.2	2407.9	2051.2	2407.9	2051.2	2407.9	2051.2	2407.9
Section modulus as fitted	Z_f	[cm^3]	2219.0	4432.0	2227.0	4107.0	2139.0	3778.0	2145.0	3617.0	2157.0	3285.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-8.72	-16.07	-8.59	-14.69	-8.47	-13.72	-8.38	-12.88	-8.26	-11.90
Web thickness as fitted	t_w	[mm]	16.00	13.00	16.00	13.00	16.00	13.00	16.00	13.00	16.00	13.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	110	110	110	110	110	110	110	110	110	110
Critical shear buckling stress	τ_c	N/mm^2	119	119	121	121	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	197	116	197	125	205	136	204	142	203	157
Critical compressive buckling stress	σ_c	N/mm^2	200	117	203	128	206	137	208	146	211	158
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure C-26 Supp. member sheet of varied plate thickness with s=0,60m.

			Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 320 x 12	Bulb 300 x 13	Bulb 300 x 13	Bulb 300 x 13	Bulb 300 x 13
Stiffener	Type id			20	20	20	20	20
Stiffener	Stiffener height	h	[mm]	320.00	300.00	300.00	300.00	300.00
Stiffener	Flange breadth	b_f	[mm]	58.00	56.00	56.00	56.00	56.00
Stiffener	Web thickness Parameters	t_w	[mm]	12.00	13.00	13.00	13.00	13.00
Stiffener	Flange thickness	t_f	[mm]	34.45	32.08	32.08	32.08	32.08
Stiffener	Stiff. height to centre of flange area	h_{fc}	[mm]					
Stiffener	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	3.00	3.00	3.00	3.00	3.00
Stiffener spacing		s	[m]	0.65	0.65	0.65	0.65	0.65
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	10.50	11.00	11.50	12.00	12.50
Shell to web angle		φ_w	[°]	50.0	50.0	50.0	50.0	50.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	16.1	16.1	16.1	16.1	16.1
Effective shear area		A_{sa}	[cm^2]	30.4	31.0	31.0	31.1	31.1
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	808	808	808	808	808
Effective plastic section modulus		Z_{pa}	[cm^3]	903	811	814	817	821
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	5.23	5.02	5.02	5.02	5.02
Web thickness check				OK	OK	OK	OK	OK

Figure C-27 Stiffeners sheet of varied plate thickness with s=0,65m.

Depth of structural member	h	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
adjacent primary member supports	l_2	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	3.90	3.00	3.90	3.00	3.90	3.00	3.90	3.00	3.90
Stiffener spacing	s	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	54.3	54.3	52.8	52.8	52.8	52.8	52.8	52.8	52.8	52.8
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Critical buckling stress	σ_c	[Mpa]	198.0	111.0	201.0	122.0	204.0	132.0	206.0	140.0	209.0	148.0
Breadth of shell	s_b	[m]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Side shell to plate field distance	h_p	[m]	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	84.2	68.6	84.2	68.6	84.2	68.6	84.2	68.6	84.2	68.6
Effective web area	A_s	[cm^2]	85.0	70.0	85.0	70.0	85.0	70.0	85.0	70.0	85.0	70.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2051.2	2825.9	2051.2	2825.9	2051.2	2825.9	2051.2	2825.9	2051.2	2825.9
Section modulus as fitted	Z_f	[cm^3]	2231.0	5444.0	2237.0	5029.0	2243.0	4611.0	2153.0	4405.0	2158.0	4197.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-8.87	-17.35	-8.47	-15.34	-8.34	-14.18	-8.26	-13.37	-8.14	-12.65
Web thickness as fitted	t_w	[mm]	17.00	14.00	17.00	14.00	17.00	14.00	17.00	14.00	17.00	14.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	112	111	112	111	112	111	112	111	112	111
Critical shear buckling stress	τ_c	N/mm^2	118	118	120	120	121	121	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	196	111	196	120	195	131	204	137	203	144
Critical compressive buckling stress	σ_c	N/mm^2	198	111	201	122	204	132	206	140	209	148
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure C-28 Supp. member sheet of varied plate thickness with s=0,65m.

				Select profile	Select profile	Select profile	Select profile	Select profile
Stiffener	Type			Bulb 320 x 12	Bulb 320 x 12	Bulb 320 x 12	Bulb 320 x 12	Bulb 320 x 12
	Type id			20	20	20	20	20
	Stiffener height	h	[mm]	320.00	320.00	320.00	320.00	320.00
	Flange breadth	b_f	[mm]	58.00	58.00	58.00	58.00	58.00
	Web thickness Parameters	t_w	[mm]	12.00	12.00	12.00	12.00	12.00
	Flange thickness	t_f	[mm]	34.45	34.45	34.45	34.45	34.45
	Stiff. height to centre of flange area	h_{fc}	[mm]					
	Stiff. height to centre of flange area	h_{fc}	[mm]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Stiffener span		l	[m]	3.00	3.00	3.00	3.00	3.00
Stiffener spacing		s	[m]	0.70	0.70	0.70	0.70	0.70
Yield stress of material		σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0
Plate thickness		t_p	[mm]	11.50	12.00	12.50	13.00	13.50
Shell to web angle		φ_w	[°]	50.0	50.0	50.0	50.0	50.0
Corrosion addition		t_k	[mm]	0.00	0.00	0.00	0.00	0.00
Stiff. bending end supp.		n_s		0	0	0	0	0
Cross-sectional area of flange		A_f	[mm^2]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_w	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		b_e	[mm]					
as defined in Pt.3 Ch.1 Sec.3 C1005		β		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.3 C1005		γ						
as defined in Pt.3 Ch.1 Sec.3 C1005		γ		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
as defined in Pt.3 Ch.1 Sec.7 E105		p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4
Sea pressure above summer load waterline		p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1
Minimum shear area		A_s	[cm^2]	17.4	17.4	17.4	17.4	17.4
Effective shear area		A_{sa}	[cm^2]	30.5	30.5	30.6	30.6	30.7
Shear area check				OK	OK	OK	OK	OK
Minimum plastic section modulus		Z_p	[cm^3]	870	870	870	870	870
Effective plastic section modulus		Z_{pa}	[cm^3]	912	915	918	922	926
Plastic section modulus check				OK	OK	OK	OK	OK
Minimum web thickness		t_w	[mm]	5.36	5.36	5.36	5.36	5.36
Web thickness check				OK	OK	OK	OK	OK

Figure C-29 Stiffeners sheet of varied plate thickness with s=0,70m.

Depth of structural member	h	[m]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Girder height	h_{girder}	[mm]	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
The full length of the stiffener to the	l_1	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
adjacent primary member supports	l_2	[m]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Stiffeners number within the span	n	[]	5	5	5	5	5	5	5	5	5	5
Supp. member's span Figure	S	[m]	3.00	4.20	3.00	4.20	3.00	4.20	3.00	4.20	3.00	4.20
Stiffener spacing	s	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Yield stress of material	σ_F	[Mpa]	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0	235.0
Shell to web angle Figure	φ_w	[°]	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0	50.0	70.0
Corrosion addition	t_k	[mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Section modulus corrosion factor	w_k		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Parallel or Perpendicular	Dir		Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Side shell stiffener direction angle	φ_s	[°]	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00	50.00	70.00
Net cross-sectional area of stiffeners	A_{ns}	[cm^2]	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3
Spacing of stiffeners fitted on the stinger	s_w	[m]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Critical buckling stress	σ_c	[Mpa]	199.0	117.0	202.0	126.0	204.0	135.0	207.0	143.0	209.0	149.0
Breadth of shell	s_b	[m]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Side shell to plate field distance	h_p	[m]	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.4
as defined in Pt.3 Ch.1 Sec.7 E110	p	[kN/m^2]	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4	155.4
as defined in Pt.3 Ch.1 Sec.7 E111	p	[kN/m^2]	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3	124.3
Sea pressure above summer load waterline	p_2	[kN/m^2]	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Minimum web area	A	[cm^2]	90.6	73.9	90.6	73.9	90.6	73.9	90.6	73.9	90.6	73.9
Effective web area	A_a	[cm^2]	95.0	75.0	95.0	75.0	95.0	75.0	95.0	75.0	95.0	75.0
Web area check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum section modulus	Z	[cm^3]	2051.2	3277.4	2051.2	3277.4	2051.2	3277.4	2051.2	3277.4	2051.2	3277.4
Section modulus as fitted	Z_f	[cm^3]	2233.0	6017.0	2193.0	5793.0	2198.0	5327.0	2158.0	5098.0	2163.0	4868.0
Section modulus check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Minimum web thickness	t	[mm]	-8.12	-15.26	-8.00	-14.17	-7.92	-13.23	-7.81	-12.49	-7.73	-11.98
Web thickness as fitted	t_w	[mm]	19.00	15.00	19.00	15.00	19.00	15.00	19.00	15.00	19.00	15.00
Web thickness check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Shear stress	τ	N/mm^2	108	111	108	111	108	111	108	111	108	111
Critical shear buckling stress	τ_c	N/mm^2	119	119	120	120	122	122	123	123	124	124
Shear stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Normal stress	σ	N/mm^2	196	116	200	121	199	131	203	137	203	144
Critical compressive buckling stress	σ_c	N/mm^2	199	117	202	126	204	135	207	143	209	149
Normal stress check			OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure C-30 Supp. member sheet of varied plate thickness with s=0,70m.

Appendix D-Bow impact pressure in all the waterline to longitudinal angle β.

Location / id			1														
Height	h_0	[m]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	a_1+a_2	[m]	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	h_d	[m]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Flare angle	α	[°]	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Flare angle	α	[°]	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
ΔX length for calculation of β	ΔX	[m]															
ΔY length for calculation of β	ΔY	[m]															
Waterline to longitudinal angle	β	[°]	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0
Waterline to longitudinal angle	β	[°]	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0
Bow impact pressure	p_{sl}	[kN/m^2]	310.8	348.4	386.1	423.0	458.4	491.8	522.4	549.6	572.9	591.9	606.3	615.8	620.4	620.0	614.8

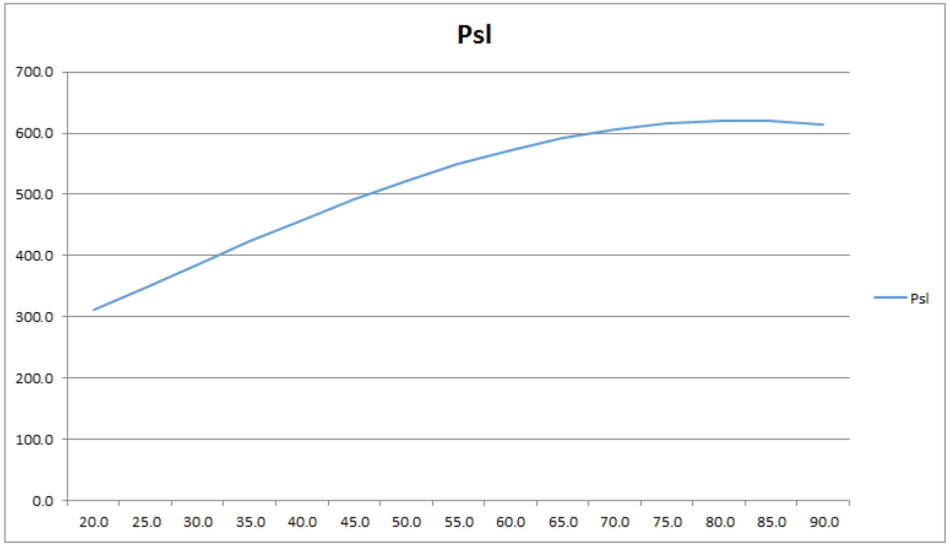


Figure D Bow impact pressure in all the waterline to longitudinal angle β, with constant $h_0 = 5m$, α=40degee.