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MASTER'S THESIS

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Abstract

This master thesis is written at the University of Stavanger in collaboration with the Department of Mechanical and Structural Engineering and Materials Science.

All subsea modules for subsea processing highly require integrated supporting frame structure that can support during lifting, transportation, installation and decommissioning. In principle the subsea module supporting structures should be designed such that it can withstand the critical design phase. Failure of the subsea module supporting structures is directly associated with the main subsea module /unit.

This work presents a literature study on lifting, transportation, installation and decommissioning phases. The project has developed different supporting structure STAAD models to study how the structural integrity will be responded to different design phases. The subsea modules for each case study are taking from Åsgard compact subsea compression system for smaller gas fields. The data for the pump module, cooler module and compressor module are based on AkerSolutions and Statoil presentations. The main objective of this thesis is to investigate the critical design phase for the subsea supporting structures and make some guide lines on how to document structural integrity during concept and final engineering stages.

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I owe my deepest gratitude to my main supervisor, Prof. Sudath Siriwardane, for his excellent encouragement, guidance and support from scratch to the final level of writing my master thesis.

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Lastly, I offer my regards and blessings to my beloved wife Saba Tsahaye and children, for their love, patience, encouragement and support for all aspects until the completion of the project.

Berhane Yohannes.

Stavanger, June 14, 2016.

Table of contents

List of Figures

List of Tables

List of Symbols

Latin symbols

a_x : Transverse acceleration due to roll and sway.

a_y : Transverse acceleration due to pitch and surge.

a_{zmax} : Maximum transverse acceleration due to gravity and heave.

a_{zmin} : Minimum transverse acceleration due to gravity and heave.

d : Diameter.

E : Modulus of elasticity.

F : Design load for lifting.

F_{Air} : Lift load in air.

F_H : Horizontal load.

$F_{HI(air)}$: Horizontal design impact load during air lift.

$F_{HI(sub)}$: Horizontal design impact load during subsea/offshore lift.

$F_{HIR(air)}$: Reduced horizontal design impact load during air lift.

$F_{HIR(sub)}$: Reduced horizontal design impact load during subsea/offshore lift.

F_{TEST}: Test load.

F_{Sub} : Lift load Subsea.

$F_{V\,max}$: Maximum vertical load.

$F_{V\,min}$: Minimum vertical load.

F_{VI}: Vertical design impact load.

f_y : Minimum yield strength.

G : Shear modulus.

g : gravitational acceleration.

H : Height.

L : Length.

M : Mass.

$M_{y,Ed}$: Maximum moment about y-y axis.

$M_{z,Ed}$: Maximum moment about z-z axis.

$\Delta M_{y,Ed}$: Moment due to the shift of the centroidal axis about y-y axis.

$\Delta M_{z,Ed}$: Moment due to the shift of the centroidal axis about z-z axis.

N_{Ed} : Compression force.

t : Thickness.

W : Width.

Greek symbols

χ_y : Reduction factor due to flexural buckling about y-y axis.

χ_z : Reduction factor due to flexural buckling about z-z axis.

χ_{LT} : Reduction factor due to lateral torsional buckling.

k_{yy} : Interaction factor about y-y axis.

k_{yz} : Interaction factor about y-z axis.

k_{zy} : Interaction factor about z-y axis.

k_{zz} : Interaction factor about z-z axis.

ρ : Density.

ν : Poisson's Ratio.

α : Coefficient of thermal expansion.

γ_M : Material factor for resistance of cross-section.

σ_x : Normal stress in X direction.

σ_{by} : Bending stresses in y direction.

σ_{bz} : Bending stresses in z direction.

τ_x : Shear stress in x direction.

τ_y : Shear stress in y direction.

τ_z : Shear stress in z direction.

Abbreviations

A: Accidental loads.

ALS: Axial limit state.

CF : Contingency factor.

COG: Center of gravity.

D: Deformation loads.

DAF: Dynamic amplification factor.

Des: Description.

DF: Design factor.

Dia: Diameter.

DNV: Det Norske Veritas.

E: Environmental loads.

EC3: Eurocode 3.

FLS: Fatigue limit state.

i.e.: That is.

IF: Impact factor.

kg/m^3: Kilogram per cubic meter.

kN: Kilo Newton (1000 Newton).

kN/m: Kilo Newton per meter.

L: Live loads.

LC: Load combinations.

LF: Total load factor.

m: Meter.

Max: Maximum.

Min: Minimum.

MGW: Maximum Gross Weight (mass).

mm: Millimeter.

N/A : Not applicable.

No: Number.

P: Permanent loads.

PLS: Progressive collapse limit state.

PO: portable offshore unit.

PSA: Petroleum Safety Authority.

R30: Operational class 30.

R45: Operational class 45.

R60: Operational class 60.

SCS : Subsea compression system.

SKL: Skew load factor.

SLS: Serviceability limit state.

Thick: Thickness.

ULS: Ultimate limit state.

UR: Utilization ratios.

1. Introduction

1.1 General

It has been a common practice that oil and gas industries has been using the advantage subsea technology than surface production platforms in case of deeper water. Subsea development in deeper water become a key toward cost effective with optimal oil recovery. In order to achieve the subsea production, subsea modules or products are required. All subsea modules; like subsea gas compressor, pumps, umbilical termination, control system, subsea pig launcher, power and processing unit and the like; require integrated supporting frame structure that can support during lifting, transportation, installation and decommissioning. Any failure of the subsea module supporting structures have direct impact on the main subsea module /unit and this failure can induce stress on the main subsea module. Therefore it is very important to document the structural integrity of the subsea module supporting structures before installation and operation subsea. As the above subsea module integrated supporting structures are very critical unit, normally protection structure with roof panels are provided to ensure protection against both dropped objects and trawling. Considering this situation only ULS condition will be evaluated during the analyses of the subsea module supporting structures. The protection structure shall not have any physical contact with the subsea module supporting structure and hence deformation after trawl impact or dropped object will be self-contained by the protection structure. It is unlikely event that the contained subsea module supporting structure will be damaged by accident, therefore ALS condition is required for protection structure but not for subsea module supporting structure.

It is common to utilize the advantage of tubular steel cross-section for structures exposed to hydrodynamic forces and hence the same cross-sections will be adopted to model the subsea module supporting structures.

In general the subsea module supporting structure should be designed such that it can withstand all design phases. I.e. in-place, load out, sea transportation, offshore lifting, operations and retrieval.

Different oil and gas companies have different approaches to document the above. Even though most oil and gas companies have the competence to perform analyses for all the above listed phases, some used to document part of the above. These differences could be due to the following reasons:

- Minimize engineering hours by performing analyses for only some selected phases.
- Have extensive experience on similar projects and presume critical design phase.
- No strict guidelines.

1.2 Objective

The main objective of this thesis is to study and document the critical design phase for subsea module supporting structures during concept and final engineering phases. The objective of this thesis can in brief be described as follows:

- Perform analyses for different type of subsea module supporting structures at different design phases that includes in-place, lifting in air, transportation, offshore lifting, operation and retrieval.
- Identify which one of the design phases and analyses give maximum utilization ratios.
- Summarize the results of the analyses.
- Set guidelines on critical design phase and advice how to document the structural integrity of the supporting structure during concept and detail engineering design stages.
- Draw conclusions and recommendations.

1.3 Scope

The scope of the thesis is limited to the following points:

- Even though supporting structures for some of the above mentioned subsea modules will be considered in this project, the outcome of the analyses are expected to generalize any type of subsea module supporting structures which lie on the same class of operation.
- Only ULS conditions are evaluated during the analyses of the subsea module supporting structures.
- It is not feasible to check deflection in case of lifting. It is only a matter of psychological limit. It is crucial that the deflection of primary frame structure should not affect other integrated parts like piping, lifting points, equipment which are supported to it and so on.
- SLS check is not performed for transportation phase. The main goal of this thesis is to determine the critical design phase from all design phases based on ULS.
- Analyses for only the primary frame of subsea module steel supporting structures are carried out in order to document the structural capacity at different stages of design phases.
- Impact loads may occur during lift or lowering of structure and these are document based on DNV standards and requirements.
- Only critical design phases are analyzed and documented in order to reduce the load combinations.
- Present, review and discuss on structural analyses results for each respective case.

1.4 Methodology

- The primary supporting steel frame structures are modelled by beam elements in Staad.Pro.
- Staad.Pro is mainly used for analyses and its code check is only used to identify the hot-spots and associated load combinations. Colbeam EC3 and manual calculations are used for stability and yielding check.
- Tubular steel cross-sections are used to model the frame of subsea module supporting structures.
- Different subsea module supporting structures are considered in the analyses and are categorized as small (case A), medium (case B) and large (case C) supporting structures based on total maximum weight. Refer section 5. Structural design philosophy below for details.

1.5 Thesis organization

The following are to be undertaken in this thesis work:

Chapter 1 Gives an overview of the thesis title definition, general description, objective, scope, methodology and organization of the thesis work.

Chapter 2 Discusses the regulations, codes and standards.

Chapter 3 Deals with the design basis. This includes limit state, load categories and factors and material properties.

Chapter 4 Covers the different types of design phases. These includes in place, lifting, transportation, landing and operational phase.

Chapter 5 Discusses structural design philosophy.

Chapter 6 Addresses basic loads and load combinations.

Chapter 7 Covers global analyses for different cases of subsea module supporting structures.

Chapter 8 Discusses summary results.

Chapter 9 Provides the conclusions and recommendations from the study.

2. Regulations, codes and standards

The thesis shall be executed in accordance with the codes and standards listed in this project work. According to petroleum safety authority (Petroleum Safety Authority Norway, 2016), the Norwegian regulation hierarchy is as follows:

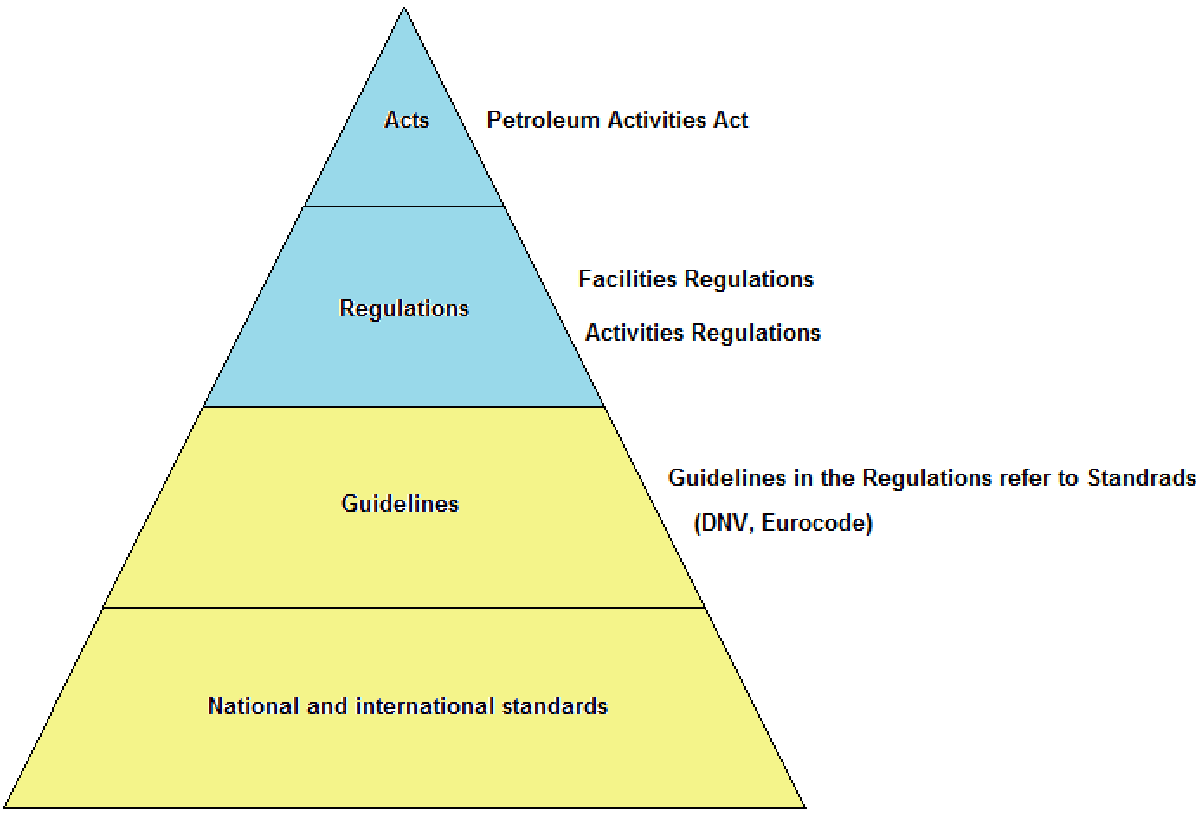

Figure 1: Order of precedence (Petroleum Safety Authority Norway, 2016).

2.1 Statuary regulations

The regulations intended for design and exploitation of petroleum resources are mentioned below (Petroleum Safety Authority Norway, 2016):

- Petroleum Safety Authority Norway (PSA) : Regulations for loads, load effects and resistance
- Petroleum Safety Authority Norway (PSA) : Regulations for structural design of load bearing structures

2.2 National and international codes and standards

Regulations are rather general and functional, in guidelines one can find references to other standards. Hence here are listed the codes and standards which are used for this project work.

- DNV standard for certification No. 2.7-3: Portable offshore structures ,2011.
- DNV Rules for Planning and Execution of Marine Operations, 1996.
- Euro code 3 EN 1993-1-1: Design of steel structures, 2005.

3. Design basis

3.1 Limit state design

In a limit state design, the design of the structure is checked for all groups of limit states to ensure that the safety margin between the maximum loads and the weakest possible resistance of the structure is large enough and that the fatigue damage is tolerable (Bai, 2015).

Limit state is categorized into four during strength verification according to part 1. chapter 4 section 3.2 (DNV, January 1996):

The Ultimate Limit State (ULS), related to the maximum load carrying capacity like yielding limit and buckling limit state.

The Serviceability Limit State (SLS), related to limits regarding structural behavior under specified conditions of service or treatment like deflection limit state, vibration limit states related to human limits.

The Progressive Collapse Limit State (PLS/ALS), related to the maximum load carrying capacity under the assumption that local damage is unavoidable, or that certain parts of the structure have been damaged or removed.

The Fatigue Limit State (FLS), related to the capacity of the structure to resist accumulated effect of repeated loading.

Only ULS condition is considered during the analyses of the subsea module supporting structures as described above in section 1.3 Scope.

3.2 Load categories and factors

The following actions shall be combined in ULS conditions.

According to part 1 chapter 4 section 3.2 (DNV, January 1996), the two load conditions for ULS a and ULS b are given in Table 1 below are considered:

Table 1: Action factors for ULS (DNV, January 1996).

Load combination	Load categories				
	P	L	D	E	A
ULS a	1.3	1.3	N/A	0.7	N/A
ULS b	1.0	1.0	N/A	1.3	N/A

According to part 1. chapter 3 section 3.1 (DNV, January 1996), Load categories P,L,D,E and A are defined as follows:

P	Permanent Loads	These are static loads which will not be moved or removed during the phase considered like weight of structures, weight of permanent ballast and equipment that cannot be removed, internal/external hydrostatic pressure of permanent nature and permanent buoyancy

L	Live Loads	Loads that can be moved, removed or added like operation of cranes, loads from alongside vessels, differential ballasting, operational impact loads and stored materials, equipment or liquids
D	Deformation Loads	Loads associated with deformations. Such loads may be Installation or set down tolerance, structural restraints between structures, differential settlements and temperature
E	Environmental Loads	These are all loads caused by environmental phenomena like winds, waves, current, storm surge, tide and ice
A	Accidental Loads	These are loads associated with exceptional or unexpected events or conditions like collision from vessels, dropped objects, loss of hydrostatic stability, flooding and loss of internal pressure.

3.3 Material properties

As mentioned in section 1.3 Scope, only primary frames of subsea module steel supporting structure are evaluated . These primary structural elements are made of carbon steel and are essential to the overall integrity of the subsea unit.

3.3.1 Material strength and constants

The yield strength to be applied in the structural strength analyses are according to Eurocode 3 (CEN, 2005) given below in Table 2:

Table 2: Steel yield strength (CEN, 2005).

Standard	Steel Grade	Type	Min. yield strength, f_y [N/mm^2]
EN 10210-1	S355NH	Hot finished tubular	t ≤ 40 mm: 355 40 mm < t ≤ 80 mm: 335

The following material constant properties for structural steel design will be used in the analyses:

Modulus of elasticity: $E = 2.1 \times 10^{11}$ N/m^2 (210 000 N/mm^2)

Shear modulus: $G = 0.8 \times 10^{11}$ N/m^2 (80 000 N/mm^2)

Density: $\rho = 7850$ kg/m^3

Poisson's Ratio: $\nu = 0.3$

Coefficient of thermal expansion: $\alpha = 1.2 \times 10^{-5}$ per ^{0}C

3.3.2 Material factors

According to part 1 chapter 4 section 4 (DNV, January 1996), The following material partial safety factors; γ_M ; for steel structures to be applied to the characteristic values of resistance in the analyses and limit states are as follows:

ULS: Material factor for resistance of cross-section, $\gamma_M = 1.15$

3.3.3 ULS usage factor and code checks

For the main steel members of the structure covered by this thesis , the maximum allowable usage factor (utilization ratio) is 1.0.

Note that Staad.Pro code check is used only to identify “hot-spots” and the associated load combinations . Code checks are done manually with the help of colbeam EC3 (buckling) and excel sheet (vonmises).

Code checking of the steel structure are performed for both yielding and stability.

- Vonmises yield criterion for elastic verification of tubular section at 3 points is checked as follows:

$$\frac{\sqrt{((\sigma_x+\sigma_{by}+\sigma_{bz})^2+3(\tau_x+\tau_y+\tau_z)^2)}}{f_y}\times\gamma_m \leq 1$$

where:

σ_x = The design value of normal stress in X direction at the point of consideration

σ_{by} , σ_{bz} = The design value of bending stresses in y and z directions at the point of consideration

τ_x , τ_y , τ_z = The design value of shear stresses in x, y and z directions at the point of consideration

f_y = The minimum yield strength

γ_M = Material factor for resistance of cross-section

- Buckling check for members subjected to combined bending and axial compression is evaluated according to Eurocode 3 (CEN, 2005) section 6.3.3:

i) About y-y axis

$$\left(\frac{N_{Ed}}{\frac{\chi_y N_{Rk}}{\gamma_M}}\right)+k_{yy}\left(\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_M}}\right)+k_{yz}\left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_M}}\right)\leq 1$$

ii) About z-z axis

$$\left(\frac{N_{Ed}}{\frac{\chi_z N_{Rk}}{\gamma_M}}\right)+k_{zy}\left(\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_M}}\right)+k_{zz}\left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_M}}\right)\leq 1$$

where:

N_{Ed} , $M_{y,Ed}$, $M_{z,Ed}$ = The design values of the compression force and the maximum moments about y-y and z-z axis

$\Delta M_{y,Ed}$, $\Delta M_{z,Ed}$ = The moments due to the shift of the centroidal axis (zero for class 1,2 and 3)

χ_y and χ_z = The reduction factors due to flexural buckling ,given in Eurocode 3 section 6.3.1 (CEN, 2005)

χ_{LT} = The reduction factor due to lateral torsional buckling, given in Eurocode 3 section 6.3.2 (CEN, 2005). NO LTB for closed cross-sections (i.e. χ_{LT} = 1.0)

k_{yy} , k_{yz} , k_{zy} , k_{zz} = The interaction factors (Refer Eurocode 3 annex A or B)

4. Design phases

The particularity of subsea structures unlike onshore structures is that cannot be constructed in the final location. Generally subsea structures are constructed in a factory or quay then lifted load out to vessel, sea fastened, offshore transported, lifted off and installed at the predetermined location. Hence the integrated supporting frame structure of subsea modules shall be designed to withstand all loads from critical design phase. In order to document the critical design phase, the integrity of subsea module supporting structures shall be checked during in place, lift load out, transportation, lifting/installation and in-situ conditions.

The integrated supporting frame structures under study shall be classified as portable offshore unit. PO, which is defined as a package or unit intended for repeated or single offshore transportation and installation/lifting (DNV, May 2011).

4.1 In place phase

Subsea modules are used to be constructed and tested in a factory with favorable or sheltered conditions. All the loads associated with in place analysis are permanent in nature namely static self-weight of supporting frame structure and weight of subsea module. Therefore in place analysis is not critical compared with other types of analyses.

4.2 Lifting phase

Normally offshore lifting operations used to be carried out by vessels. Small subsea modules up to 70 tonnes can be installed through a moon pool where as large modules can be installed by crane vessels. In this project work, all lifting operations are considered to be carried out by crane vessel.

Offshore lift encompasses the stages from where a subsea structure is lifted from deck with the crane vessel , deployed through the water surface and landed on the seabed.

During lift off, it is normal to expect impact loads. These loads occur due to the relative velocities between the transport vessel deck and the hanging load. Even though it is not feasible to calculate the impact loads accurately, the horizontal impact load, during lifting off, mentioned below in section 4.2.3 Horizontal impact during air lift and section 4.2.4 Horizontal impact during offshore lift are considered to be adequate according to DNV 2.7-3 section 3.6 (DNV, May 2011).

Lifting phase covers the following:

- Lift from deck of vessel
- Lift in air
- Lift through splash zone
- Lowering
- Landing
- Recovery to deck

With deeper waters and harsh environment, offshore lifting operations are demanding and complex. For a successful operation of offshore lift, it is crucial to understand all the phases of lift and weather criteria. In this project , Portable Offshore Units with operation class R30 are designed according to criteria set by DNV 2.7-3 (DNV, May 2011).

4.2.1 Air lifting

According to DNV 2.7-3 section 3.5 (DNV, May 2011), the design load for all supporting structures in the subsea module for air lifting is as follows :

$$F_{Air} = DF \times MGW \times g$$

where :

F_{Air} = Lift load, $[kN]$, in air

DF = Design factor

MGW = Maximum Gross Weight (mass)

g = Gravitational acceleration

The design factor, DF, is defined according to the Operational Class and MGW as shown below in Table 3 (DNV, May 2011):

Table 3: Design Factors, DF, (DNV, May 2011).

Operational Class	DF for $MGW < 50$ tonnes	DF for $MGW \geq 50$ tonnes
R60	$1.4 + 0.8 \times \sqrt{50/MGW}$	2.2
R45	$1.4 + 0.6 \times \sqrt{50/MGW}$	2.0
R30	$1.4 + 0.4 \times \sqrt{50/MGW}$	1.8

Note that the Operational Class for a PO unit can be selected based on the type of PO units; type A, B, C, D and E; risk and MGW as input according to DNV 2.7-3 sections 1 and 3 (DNV, May 2011).

4.2.2 Subsea lifting

Subsea lifting is critical mainly when it is through splash zone . This phase occurs when the object being lifted starts to get submerged. In this phase the module can be partly submerged during one wave period. This means that the lowest part of the object can be submerged by the wave crest, at the same time the upper part of the object be free of water. During this phase snap loads are great concern. Therefor lifting with cranes equipped with heave compensation system is beneficial as snap loads are avoided. Most offshore cranes are equipped with heave compensation system today and this system avoids heave movements being transferred from the vessel to the main wire.

The design load for all supporting structures in the subsea module for subsea lifting is set according to DNV 2.7-3 section 3.11 (DNV, May 2011).

$$F_{Sub} = 2.5 \times MGW \times g$$

where :

F_{Sub} = Lift load, $[kN]$, Subsea

MGW = Maximum Gross Weight (mass)

g = Gravitational acceleration

According to DNV 2.7-3 section 3.11 (DNV, May 2011),the total design factor is 2.5. This total factor includes a Dynamic Amplification Factor of 2.0. The above mentioned total design factor is considered to be conservative including when lifting through splash zone and further lowering. During installation, it is crucial to verify that lift should not be subjected to a DAF value higher than specified DAF during the base design.

The total design factor of 2.5 consists of the following:

- Dynamic Amplification Factor, DAF = 2.0
- Partly submerged weight = 0.9 × MGW
- General design factor = 1.4

4.2.3 Horizontal impact during air lift

According to DNV 2.7-3 (DNV, May 2011), the impact force may act in any horizontal direction on the corners of the PO unit. This can happen during lifting off or recovery phase. On all sides of the PO unit, the load is considered to act perpendicular to the surface. The primary members shall be capable of withstanding a local horizontal impact at any point. Note that the impact stress shall be combined with the lifting stress based on the MGW of the PO unit. The static equivalent horizontal force on the primary members in the corners of the supporting structure in any direction as given according to DNV 2.7-3 section 3.6 (DNV, May 2011) as follows:

- For operational class R30 (corner posts and bottom beams):

$$F_{HI(air)} = 0.05 \times F_{TEST}$$

- Reduced design load for end or side structure and upper edge:

$$F_{HIR(air)} = 0.6 \times F_{HI(air)}$$

where :

$F_{HI(air)}$ = Horizontal design impact load during air lift, $[kN]$

F_{TEST} =Test load, $[kN]$, given below in Table 4

$F_{HIR(air)}$ = Reduced horizontal design impact load during air lift, $[kN]$

‘

4.2.4 Horizontal impact during offshore lift

During offshore lifting, the structure is lowered alone and considered as single transportation and hence 50% of F_{HI} and F_{HIR} are applied as follows according to DNV 2.7-3 (DNV, May 2011):

- For operational class R30 (corner posts and bottom beams) :

$$F_{HI(sub)} = 0.025 \times F_{TEST}$$

- For end/side structure and top beams :

$$F_{HIR(sub)} = 0.6 \times F_{HI(sub)}$$

where :

$F_{HI(sub)}$ = Horizontal design impact load during subsea/offshore lift, $[kN]$

F_{TEST} =Test load, $[kN]$, given below in Table 4

$F_{HIR(sub)}$ = Reduced horizontal design impact load during subsea/offshore lift, $[kN]$

Table 4: Total test load for all point lifting test (DNV, May 2011).

MGW	$Test\ Load\ [kN]$
$MGW \leq$ 25 tonnes	$Minimum\ of\ F\ and\ 2.5 \times MGW\ \times g$
$25 < MGW \leq 50\ tonnes$	$[1 - 0.01 \times (MGW - 25) \times F$
$MGW >$ 50 tonnes	$0.75 \times F$

Note that the $F = F_{Air}$ *during air lifting and* $F = F_{Sub}$ *during subsea lifting*

4.3 Transportation phase

The design condition is based on unrestricted (i.e. any weather) transportation in any waters on any suitable vessel. As no actual transport vessel motion data is available, conservative dynamic accelerations is adopted as described in DNV 2.7-3 (DNV, May 2011).

The horizontal and vertical loads due to vessel motions in case of sea transportation phase are as follows (DNV, May 2011):

$$F_H = MGW \times g$$

$$F_{V\,max} = 1.3 \times MGW \times g$$

$$F_{V\,min} = 0.7 \times MGW \times g$$

where :

F_H = Horizontal load

$F_{V\,max}$ = Maximum vertical load

$F_{V\,min}$ = Minimum vertical load

MGW = Maximum Gross Weight (mass)

g = Gravitational acceleration

From the above formulas, the vessel accelerations in all directions can be written as follows:

a_x : Transverse acceleration due to roll and sway $1 \times g$

a_y : Transverse acceleration due to pitch and surge $1 \times g$

a_{zmax} : Maximum transverse acceleration due to gravity and heave $1.3 \times g$

a_{zmin} : Minimum transverse acceleration due to gravity and heave $0.7 \times g$

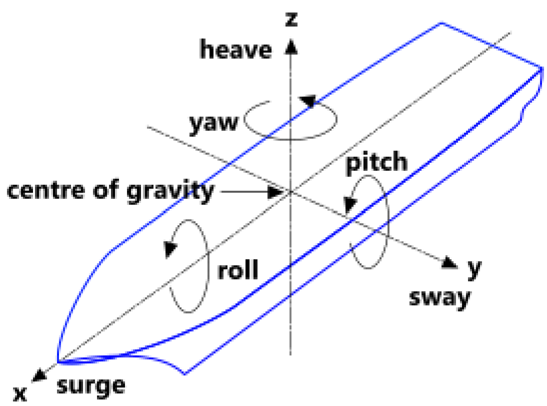

Figure 2: Vessel motion at sea.

4.4 Landing phase

During landing or set down, the bottom outer edge of the supporting structure may hit if the subsea module is landed on a surface which is not flat. These impact loads; resulted from relative movement between the transport vessel deck and hanging load; occur randomly and are very short duration. According to DNV 2.7-3 section 3.6 (DNV, May 2011),the static equivalent vertical force acting on any point that could hit if the PO unit is set down on a not flat surface is defined as follows:

$$F_{VI} = 0.08 \times F$$

where :

F_{VI} = Vertical design impact load, $[kN]$

F = Design load, $[kN]$, for lifting. Basically this is the design load during further lowering but for conservative design the lift load during splash zone is taken. I.e. F_{Sub}

4.5 In-situ/Operational phase

The subsea module shall be protected against both dropped objects and trawling by using protection structure with roof panels .The protection structure shall not have any physical contact with the subsea module supporting structure and deformation after trawl impact or dropped object will be self-contained by the protection structure. Besides it is assumed that the subsea module experience minimum currents loads and wave loads. Therefore operational phase is not critical to consider in this project.

5. Structural design philosophy

5.1 General

The subsea module supporting frame structures are analyzed by using a design software called STAAD.Pro 2003. Colbeam EC3 and Excel sheet are used for design check i.e. buckling and yield check. Different types of global analyses, for three cases, are performed namely air lifting, transportation, subsea lifting and landing.

The following three case studies listed below in Table 5 are considered and documented in this project work:

Table 5: Case and categories based on maximum gross weight.

Case	Subsea module-Maximum Gross Weight	Categories/Module name	Remarks
A	40	Small/Pump	Operation class A
B	100	Medium/Cooler	Operation class A
C	120	Large/Compressor	Operation class A

5.2 Computer model description

The primary supporting frame structures for all modules under consideration are modeled by beam elements in STAAD Pro. Bracing elements in beams are moment released in ends where applicable. The structural configuration used during the analyses is almost similar with the CAD drawings gathered from AkerSolutions (AkerSolutions, 2016) and Statoil (Statoil, 2016). The weight of the main equipment is applied as subsea module weight and the lifting point is adjusted according to the COG of the model.

5.3. Boundary conditions

The global coordinate system adopted during the analyses of the supporting structures for all cases is as shown below in Figure 3.

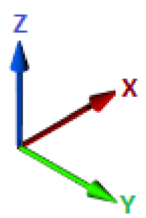

Figure 3: Global coordinate system.

5.3.1 Air and subsea lifting analyses

The hook point during lifting analyses is fixed in all translational directions and free in all rotational directions. Other supports to be given in such a way that they will avoid singularity, but giving very small reaction forces. The support conditions; for pump, cooler and compressor ; during lifting analyses are as given below in Table 6:

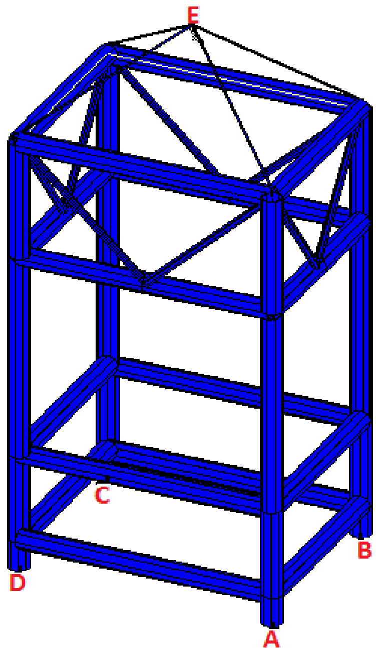

Figure 4: Pump model lifting.

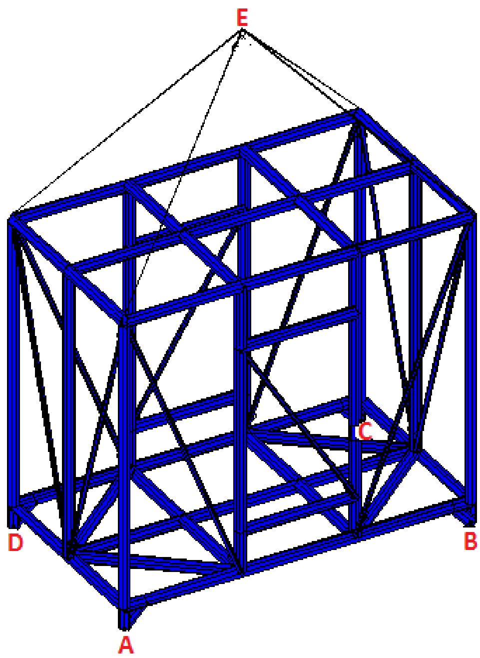

Figure 5: Cooler model lifting.

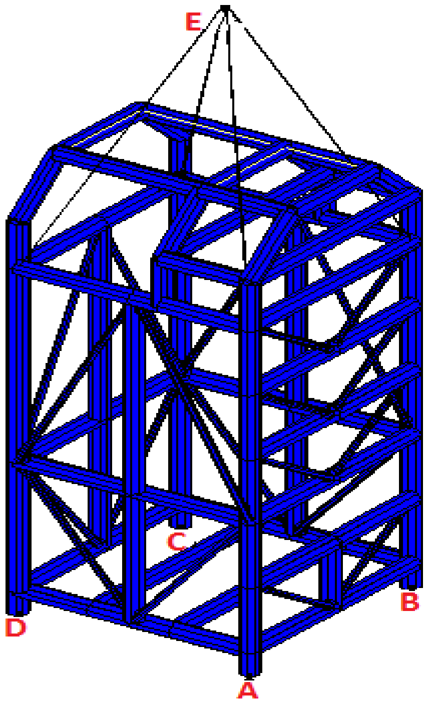

Figure 6: Compressor model lifting.

Table 6: Boundary conditions for lifting analyses

Support	Translation			Rotation		
	X	Y	Z	X	Y	Z
A	10kN/m	10kN/m	Free	Free	Free	Free
B	10kN/m	10kN/m	Free	Free	Free	Free
C	10kN/m	10kN/m	Free	Free	Free	Free
D	10kN/m	10kN/m	Free	Free	Free	Free
E	Fixed	Fixed	Fixed	Free	Free	Free

5.3.2 Transportation analyses

The frame structure of the pump, cooler and compressor rests on 4 supports on the barge. The support conditions during transportation analyses are given below in Table 7:

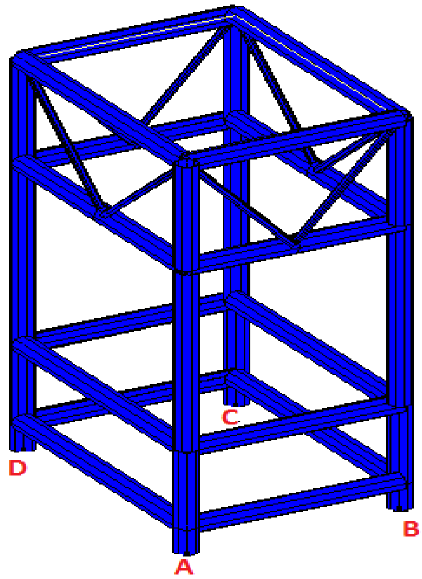

Figure 7: Pump model transport.

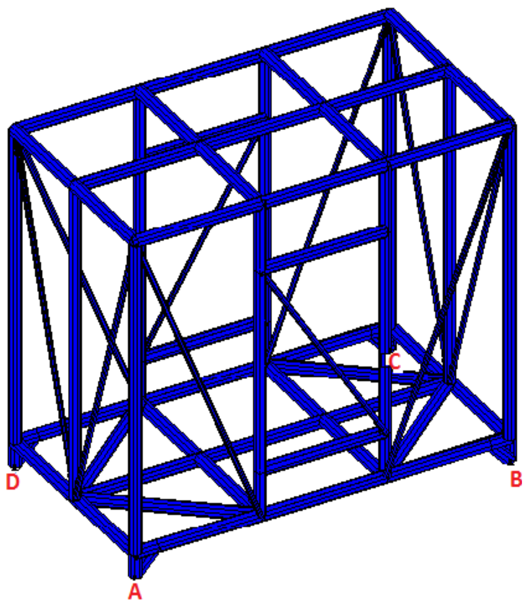

Figure 8: Cooler model transport.

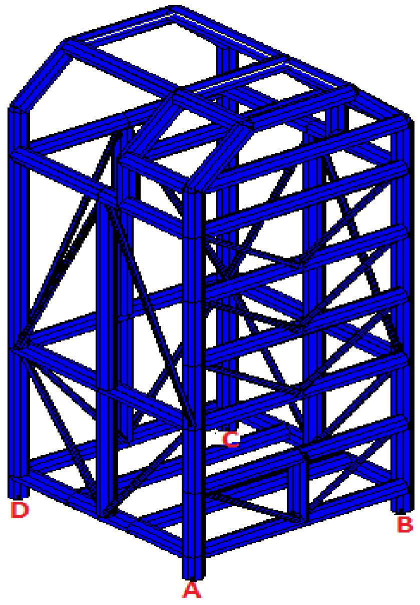

Figure 9: Compressor model transport.

Table 7: Boundary conditions for transportation analyses

Support	Translation			Rotation		
	X	Y	Z	X	Y	Z
A	Fixed	Fixed	Fixed	Free	Free	Free
B	Fixed	Fixed	Fixed	Free	Free	Free
C	Fixed	Fixed	Fixed	Free	Free	Free
D	Fixed	Fixed	Fixed	Free	Free	Free

5.3.3 Landing analyses

For landing analyses, it is assumed that the bottom frame structure interfaces the bottom surface on two supports. This is conservative approach as only two instead of four supports are considered. The two supports; namely A and B; takes translational in Z direction while C and D takes all translations in x and y directions. Refer below in Table 8 for the support conditions for landing analyses of pump, cooler and compressor models:

Table 8: Boundary conditions for landing analyses

Support	Translation			Rotation		
	X	Y	Z	X	Y	Z
A	Free	Free	Fixed	Free	Free	Free
B	Free	Free	Fixed	Free	Free	Free
C	Fixed	Fixed	Free	Free	Free	Free
D	Fixed	Fixed	Free	Free	Free	Free

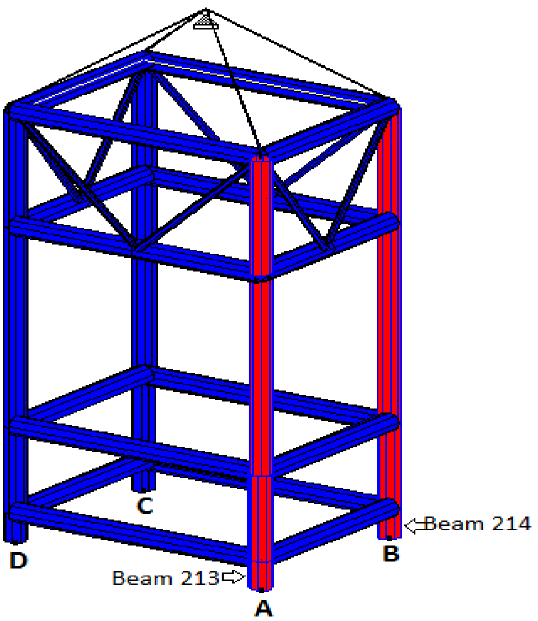

Figure 10: Pump model landing.

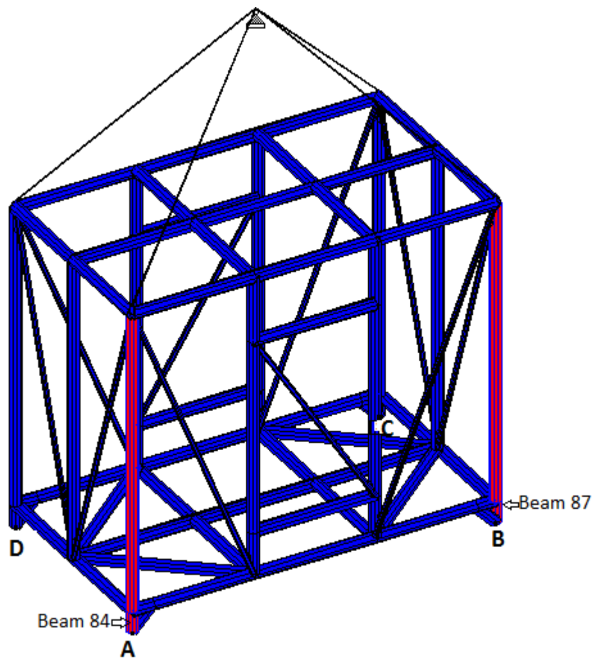

Figure 11: Cooler model landing

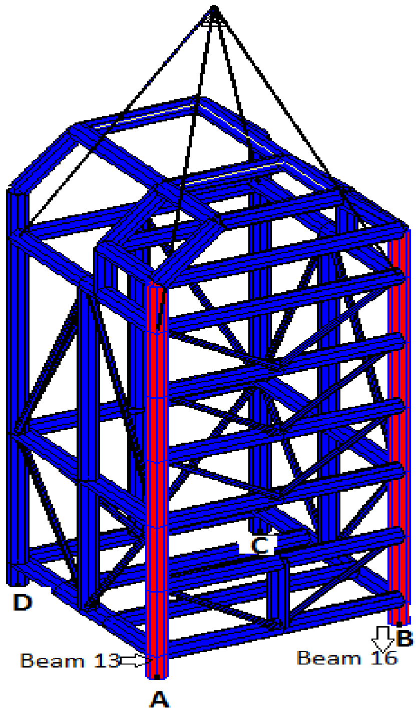

Figure 12: Compressor model landing.

6. Basic loads and load combinations

6.1 General

All basic loads which are used as an input during the analyses are under the category defined above in section 3.2 Load categories and factors. The weights of the different subsea modules under consideration are based on the reported weights from drawings of AkerSolutions (AkerSolutions, 2016) and Statoil (Statoil, 2016). Self-weight of the supporting frame structure is generated by STAAD. Pro.

6.2 Basic loads

6.2.1 Static self-weight

The static self-weights of the frame structures for different subsea modules are generated by the software as follows:

A material density, ρ, of 7850 kg/m^3 is applied for generating steel mass. Contingency Factor, CF, of 10% is taken for weight inaccuracy and the gravity loads of STAAD generated structural mass , M, are F_Z and is given as below:

$$F_Z = -CF \times g \times \sum M_i = -1.10 \times M \times g$$

Note that the direction of the load is downwards.

6.2.2 Static subsea module weight

The static self-weights of the subsea modules are based on the reported weights from drawings of AkerSolutions (AkerSolutions, 2016) and Statoil (Statoil, 2016).These weights include all types of weights that are permanent in nature. The direction of the load is downwards.

6.2.3 Dynamic self-weight

The dynamic self-weight is the self-weight of the supporting frame structure in X, Y and Z directions. This dynamic self-weight is the result of the vessel motion in roll, pitch and heave that occurs during transportation phase.

6.2.4 Dynamic subsea module weight

The dynamic subsea module weight is the self-weight of the unit in X, Y and Z directions. This dynamic module self-weight is the result of the vessel motion in roll, pitch and heave that occurs during transportation phase.

6.3 Load combinations

Load combinations, based on basic loads, for different type of analyses are given below as load combinations.

6.3.1 In place analyses

As mentioned above in section 4.1 In place phase, in place analysis is not critical compared with other types of analyses as loads only associated with static weights are present.

6.3.2 Transportation analyses

During transportation analyses, the roll and pitch are assumed to pass through the center of floatation and heave is parallel to the global vertical axis. According to DNV 2.7-3 section 3.7 (DNV, May 2011), the horizontal design load due to vessel motions in any direction should be combined with both maximum and minimum vertical loads.

The most sever combinations of roll ± heave and pitch ± heave is also documented for ULS a and ULS b. Refer below Table 9 and Table 10 for the transportation load combinations.

Table 9: Load combinations-Transportation analyses

Load combinations - transportation analyses	**Basic loads**											
	1. Static self-weight	**2**. Static subsea module weight	**3**. Dynamic self-weight in +X direction	**4**. Dynamic self-weight in +Y direction	**5**. Dynamic self-weight in +Z direction	**6**. Dynamic subsea module weight in +X direction	**7**. Dynamic subsea module weight in +Y direction	**8**. Dynamic subsea module weight in +Z direction	**9**. Dynamic self-weight in -X direction	**10**. Dynamic self-weight in -Y direction	**11**. Dynamic subsea module weight in -X direction	**12**. Dynamic subsea module weight in -Y direction
LC1. Transportation roll, max.Z	1.3	1.3	1.0			1.0						
LC2. Transportation roll, min.Z	0.7	0.7	1.0			1.0						
LC3. Transportation pitch, max.Z	1.3	1.3		1.0			1.0					
LC4. Transportation pitch, min. Z	0.7	0.7		1.0			1.0					
LC5. Transportation -roll, max.Z	1.3	1.3							1.0		1.0	
LC6. Transportation -roll, min.Z	0.7	0.7							1.0		1.0	
LC7. Transportation -pitch, max.Z	1.3	1.3								1.0		1.0
LC8. Transportation -pitch, min.Z	0.7	0.7								1.0		1.0

Table 10: Load combinations ULS a and ULS b- Transportation analyses

ULS a and ULS b- transportation analyses	**Basic loads**											
	1. Static self-weight	**2**. Static subsea module weight	**3**. Dynamic self-weight in +X direction	**4**. Dynamic self-weight in +Y direction	**5**. Dynamic self-weight in +Z direction	**6**. Dynamic subsea module weight in +X direction	**7**. Dynamic subsea module weight in +Y direction	**8**. Dynamic subsea module weight in +Z direction	**9**. Dynamic self-weight in -X direction	**10**. Dynamic self-weight in -Y direction	**11**. Dynamic subsea module weight in -X direction	**12**. Dynamic subsea module weight in -Y direction
LC9. ULS a, roll + heave	1.3	1.3	0.7		-0.7	0.7		-0.7				
LC10. ULS a, roll - heave	1.3	1.3	0.7		0.7	0.7		0.7				
LC11. ULS a, -roll + heave	1.3	1.3			-0.7			-0.7	0.7		0.7	
LC12. ULS a, -roll - heave	1.3	1.3			0.7			0.7	0.7		0.7	
LC13. ULS a, pitch + heave	1.3	1.3		0.7	-0.7		0.7	-0.7				
LC14. ULS a, pitch - heave	1.3	1.3		0.7	0.7		0.7	0.7				
LC15. ULS a, -pitch + heave	1.3	1.3			-0.7			-0.7		0.7		0.7
LC16. ULS a, -pitch - heave	1.3	1.3			0.7			0.7		0.7		0.7
LC17. ULS b, roll + heave	1.0	1.0	1.3		-1.3	1.3		-1.3				
LC18. ULS b, roll - heave	1.0	1.0	1.3		1.3	1.3		1.3				
LC19. ULS b, -roll + heave	1.0	1.0			-1.3			-1.3	1.3		1.3	
LC20. ULS b, -roll - heave	1.0	1.0			1.3			1.3	1.3		1.3	
LC21. ULS b, pitch + heave	1.0	1.0		1.3	-1.3		1.3	-1.3				
LC22. ULS b, pitch - heave	1.0	1.0		1.3	1.3		1.3	1.3				
LC23. ULS b, -pitch + heave	1.0	1.0			-1.3			-1.3		1.3		1.3
LC24. ULS b, -pitch - heave	1.0	1.0			1.3			1.3		1.3		1.3

6.3.2 Lifting analyses

According to DNV 2.7-3 section 3.5 (DNV, May 2011), the load combination for lifting analyses is based on the static self-weight of the supporting frame structure and the subsea module. The static weights are then enhanced by the design factor (DF) and skew load factor (SKL) .

- For air lifting, the design factor (DF) for different types of operational class is given in Table 3 above.

- For subsea lifting, a total design factor (DF) of 2.5 is considered to be conservative design including for lifting through splash zone and further lowering as mentioned above in section 4.2.2 Subsea lifting. Lifting through splash zone is often the most critical phase of offshore lifting operation as we often experience largest hydrodynamic loads.

The total load factor includes the design factor (DF) and skew load factor (SKL) according to DNV 2.7-3 section 3.5 (DNV, May 2011). Skew load factor (SKL), design factor (DF) and total load factor (LF) for 4 slings for air and subsea lifting are given below in Table 11 and Table 12 respectively. The load combinations for air and subsea lifting based on total load factor are given below in Table 13. For both above lifting analyses, horizontal impact force in air and subsea are accounted for as mentioned above in section 4.2.3 Horizontal impact during air lift and 4.2.4 Horizontal impact during offshore lift.

Table 11: SKL, DF and LF-Air lifting analyses

Sling sets	SKL	DF	LF	Remarks
4 leg sling	1.25	1.8	2.25	*Operational Class R30*

Table 12: SKL, DF and LF-Subsea lifting analyses

Sling sets	SKL	DF	LF	Remarks
4 leg sling	1.25	2.5	3.12	*Lifting through splash zone and operational class R30*

From good engineering practice, It is recommended to consider the following points during lifting:

- ✓ Angles less than 45 degrees with the horizontal are not recommended during lifting. Angles below 30 degrees should be avoided whenever possible.
- ✓ Lifting points should be higher than COG to avoid risk of overturning.

Table 13: Load combinations-Lifting analyses

Load combinations-Lifting analyses	Basic loads		Remarks
	1. Static self-weight	**2**. Static subsea module weight	
LC25. Air lifting	2.25	2.25	*-Horizontal impact forces as mentioned above in 4.2.3 will be added to LC25*
LC26. Subsea lifting	3.12	3.12	*-Horizontal impact forces as mentioned above in section 4.2.4 will be added to LC26*

6.3.3 Landing analyses

The frame shall be capable of withstanding an impact from landing. Landing capacity is checked according to vertical impact formula as given above in section 4.4 Landing phase. It is assumed that the analysis is elastic analysis and stress free when the structure interacts with the surface. Therefore stresses resulted from lowering (lift only) of the structure do not need to be combined with the stresses due to impact loads, but horizontal impact with the protection structure can occur during lowering of the module and this impact force is accounted during analysis.

To determine the load combination for the vertical design impact load, the design load for further lowering is required to be estimated first as shown in section 4.4 Landing phase above. A total design factor (DF) of 2.5 is considered to be conservative design even for further lowering as mentioned above in section 4.2.2 Subsea lifting. The Skew load factor (SKL), design factor (DF), vertical impact factor (IF) and total load factor (LF) for 4 sling sets are given below in Table 14. The load combination for landing based on total load factor is given below in Table 15.

Table 14: SKL, DF, IF and LF for landing

Sling sets	SKL	DF	IF	LF
4 leg sling	1.25	2.5	0.08	0.25

Table 15: Load combination-Landing analyses

Load combinations-Landing analysis	Basic loads		Remarks
	13. Static self-weight	**14.** Static subsea module weight	
LC27. Landing (F_{VI})	0.25	0.25	*-To be applied on the corner posts of the structure* *-Horizontal impact forces as mentioned above in section 4.2.4 will be added to LC27*

6.3.4 In-situ/Operational analyses

During operational phase the subsea module can experience currents loads, while wave loads are minimum. As mentioned in section 4.5 In-situ/Operational phase above, the unit shall be protected by protection structure with roof panels. It is assumed that operational analysis is not critical compared with other types of analyses.

6.3.5 Recovery analyses

Recovery is under category subsea lifting as mentioned above in section 4.2 Lifting phase. It is already mentioned that lifting through splash zone is critical. Therefore it is not required to document recovery analysis as lifting analysis through splash zone is already documented.

7. Global analyses

7.1 General

The Gas Booster system can be arranged with up to four parallel compressor trains on one subsea template. Åsgard Subsea Compression System (SCS) compressor trains comprises multiphase gas cooler, separator, compressor, subsea power and control units and pump according to AkerSolutions (AkerSolutions, 2016).

The subsea module supporting frame structures namely pump (case A), cooler (case B) and compressor (case C) are modelled by beam elements in Staad.Pro.

Code check is performed manually as discussed above in section 3.3.3 ULS usage factor and code checks.

7.2 Operational classes

The operational classes for a PO units can be selected based on the type of PO units; type A, B, C, D and E; risk and MGW as input according to DNV 2.7-3 sections 1.1.5 and 3.3 (DNV, May 2011).

The pump module, cooler module and compressor module have $\mathrm{MGW} > 25$ tonnes and the risk is considered as high because they are main subsea units and failure of these units have great impact on overall subsea production system. According to DNV 2.7-3 section 1.1.5 (DNV, May 2011), the type of PO units (modules) are under category A. Therefore the selection of the operational class for all above mentioned units can be done according to DNV 2.7-3 section 3.3.4 , table 3.3 (DNV, May 2011)

- ✓ Type of structure **A**
- ✓ Risk **High**
- ✓ $MGW > \mathbf{25}$ **tonnes**

Based on DNV 2.7-3 table 3.3 (DNV, May 2011), the operational class suited for the pump module, cooler module and compressor module is R30. The identification **DNV 2.7-3 R30-Subsea** applies to all modules mentioned above.

7.3 Cross-sectional properties and classes

7.3.1 Cross-sectional properties

The profile and cross-sectional properties used for the pump and compressor model are given below in Table 16 and for cooler model are in Table 17 respectively.

Table 16: Cross-sectional properties for pump and compressor model

Des.	Profile dimensions		Section properties					
	Dia.(d) mm	Thick. (t) mm	Ax (mm^2)	Ay (mm^2)	Az (mm^2)	Iy/Iz $(10^6 mm^4)$	Ix $(10^6 mm^4)$	Wel,y $(10^4 mm^3)$
Posts	324	16	15482	7741	7741	184.1	368.2	113.6
Beams	324	16	15482	7741	7741	184.1	368.2	113.6
Braces	114	6	2036	1018	1018	2.977	5.955	5.223

Table 17: Cross-sectional properties for cooler model

Des.	Profile dimensions		Section properties					
	Dia.(d) mm	Thick. (t) mm	Ax (mm^2)	Ay (mm^2)	Az (mm^2)	Iy/Iz $(10^6 mm^4)$	Ix $(10^6 mm^4)$	Wel,y $(10^4 mm^3)$
Posts	273	16	12918	6459	6459	107.1	214.1	78.44
Beams	273	16	12918	6459	6459	107.1	214.1	78.44
Braces	114	6	2036	1018	1018	2.977	5.955	5.223

7.3.2 Cross-section class

With reference to EC3 ,Part 1-1 – Sect. 5.6 – Table 5.2 (sheet 3 of 3) (CEN, 2005): “Tubular sections subjected to bending and/or compression” the cross-section class for all models used during the analyses are given below in Table 18:

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0.81$$

Table 18: Tubular cross-section class

Class	Factor	Diameter to thickness ratio	Criteria for cross-section class	Remarks
1	$50\varepsilon^2 = 50 \times 0.81^2 = 32.81$	$\frac{d}{t} = \frac{324}{16} = 20.25$	$\frac{d}{t} \leq 50\varepsilon^2$	*All posts, beams and braces for pump, cooler and compressor model are cross-section class 1*
	$50\varepsilon^2 = 50 \times 0.81^2 = 32.81$	$\frac{d}{t} = \frac{273}{16} = 17.06$	$\frac{d}{t} \leq 50\varepsilon^2$	
	$50\varepsilon^2 = 50 \times 0.81^2 = 32.81$	$\frac{d}{t} = \frac{114}{6} = 19.00$	$\frac{d}{t} \leq 50\varepsilon^2$	

7.4 Case A-Pump module

According to the document accessed from AkerSolutions (AkerSolutions, 2016), the main dimensions of the pump module are $4\ (L) \times 3(W) \times 7(H)$ m and the total dry weight (static module weight) of the module is 30. The CAD model of the pump is shown below in Figure 13. Refer below in Table 19 for the weights that are used for the analyses of the pump model.

Table 19: Total weight for pump model

Description	Load [kN]	Remarks
Pump Module	294.3	*Pump module weight 30 tonnes*
Structural steel weight	131.9	*Self-weight with 10% inaccuracy. Taken from STAAD analysis*
Total weight	426	$426\ kN \approx 40\ tonnes\ (MGW)$

Figure 13: Pump CAD model.

7.4.1 Pump transportation analysis-Results

Highly utilized members are shown below in Figure 14. Refer in Table 20 below for the maximum utilization ratios due to buckling and yielding of posts, beams and braces during transportation analysis of pump model. Other information like detail manual code checks (Colbeam and excel checks),Staad input loads , reaction forces, reference drawings can be seen from the enclosed attachments in appendices.

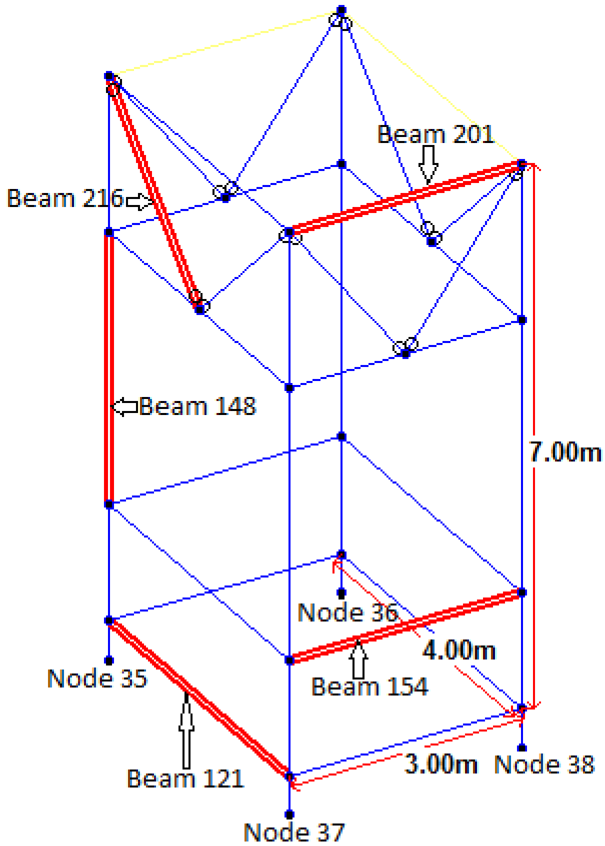

Figure 14: Highly utilized members for pump-transportation analysis

Table 20: Pump transportation analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
121	Bottom beam	Tube 324x16	0.25	0.55	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
148	Corner post	Tube 324x16	0.39	0.72	
154	Intermediate beam	Tube 324x16	0.34	**0.74**	
201	Top beam	Tube 324x16	N /A	0.05	
216	Brace	Tube 114x6	0.48	0.33	

7.4.2 Pump air lifting analysis-Results

Utilization ratios for only selected critical members, as shown in Figure 15 below, are evaluated. The maximum utilization ratios are obtained from the combined stress of lifting and horizontal impact during airlifting as described in section 6.3.2 Lifting analyses. Refer Table 21 below for the maximum utilization ratios due to buckling and yielding of posts, beams and braces during air lifting analysis of pump model. Other information like horizontal impact calculations during air lift, detail manual code checks (Colbeam and excel checks), Staad input loads for air lifting and reaction forces can be seen from the enclosed attachments in appendices.

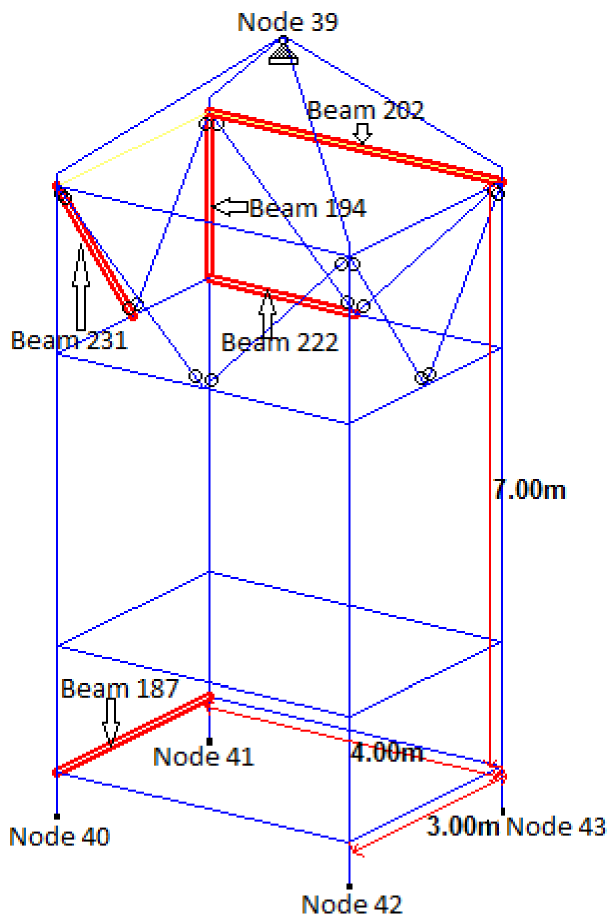

Figure 15: Highly utilized members for pump-Air lifting analysis

Table 21: Pump air lifting and horizontal impact analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
187	Bottom beam	Tube 324x16	N /A	0.52	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
194	Corner post	Tube 324x16	N /A	**0.56**	
202	Top beam	Tube 324x16	0.04	0.32	
222	Intermediate beam	Tube 324x16	N /A	0.52	
231	Brace	Tube 114x6	N /A	0.01	

7.4.3 Pump subsea lifting analysis-Results

Refer below in Table 22 for the maximum utilization ratios, for the pump subsea lifting, from the analyses and calculations:

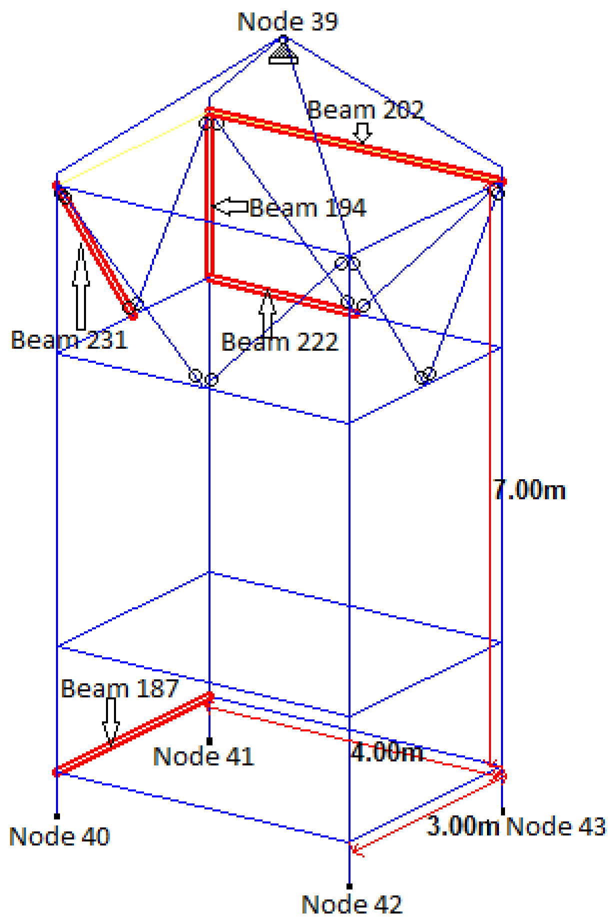

Figure 16: Highly utilized members for pump-Offshore/subsea lifting analysis

Table 22: Pump offshore lifting and horizontal impact analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
187	Bottom beam	Tube 324x16	N /A	0.36	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
194	Corner post	Tube 324x16	N /A	0.43	
202	Top beam	Tube 324x16	0.06	0.23	
222	Intermediate beam	Tube 324x16	N /A	0.37	
231	Brace	Tube 114x6	N /A	0.01	

7.4.4 Pump landing analysis-Results

For landing analysis, the pump structure is supported at two corners and the supporting conditions are stated above in section 5.3.3 Landing analyses. The maximum utilization factors for the critical members, specified above in Figure 10, are given below in Table 23:

Table 23: Pump landing analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
213	Corner post	Tube 324x16	N /A	0.36	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
214	Corner post	Tube 324x16	N /A	0.36	

7.5 Case B- Cooler module

The main dimensions of the cooler module are $5\ (L) \times 9(W) \times 7(H)$ m. The total dry weight (static module weight) of the module is 75 tonnes (AkerSolutions, 2016). The CAD model of the cooler is shown below in Figure 17. Refer below in Table 24 for the weights that are used for the analyses of the cooler model.

Table 24: Total weight for cooler model

Description	**Load [kN]**	**Remarks**
Cooler Module	735.8	*Cooler module weight 75 tonnes*
Structural steel weight	227.9	*Self-weight with 10% inaccuracy. Taken from STAAD analysis*
Total weight	964	$964\ kN \approx 100\ tonnes\ (MGW)$

Figure 17: Cooler CAD model.

7.5.1 Cooler transportation analysis-Results

Refer below in Table 25 for the maximum utilization ratios, for the cooler model transportation analysis , from the analyses and calculations:

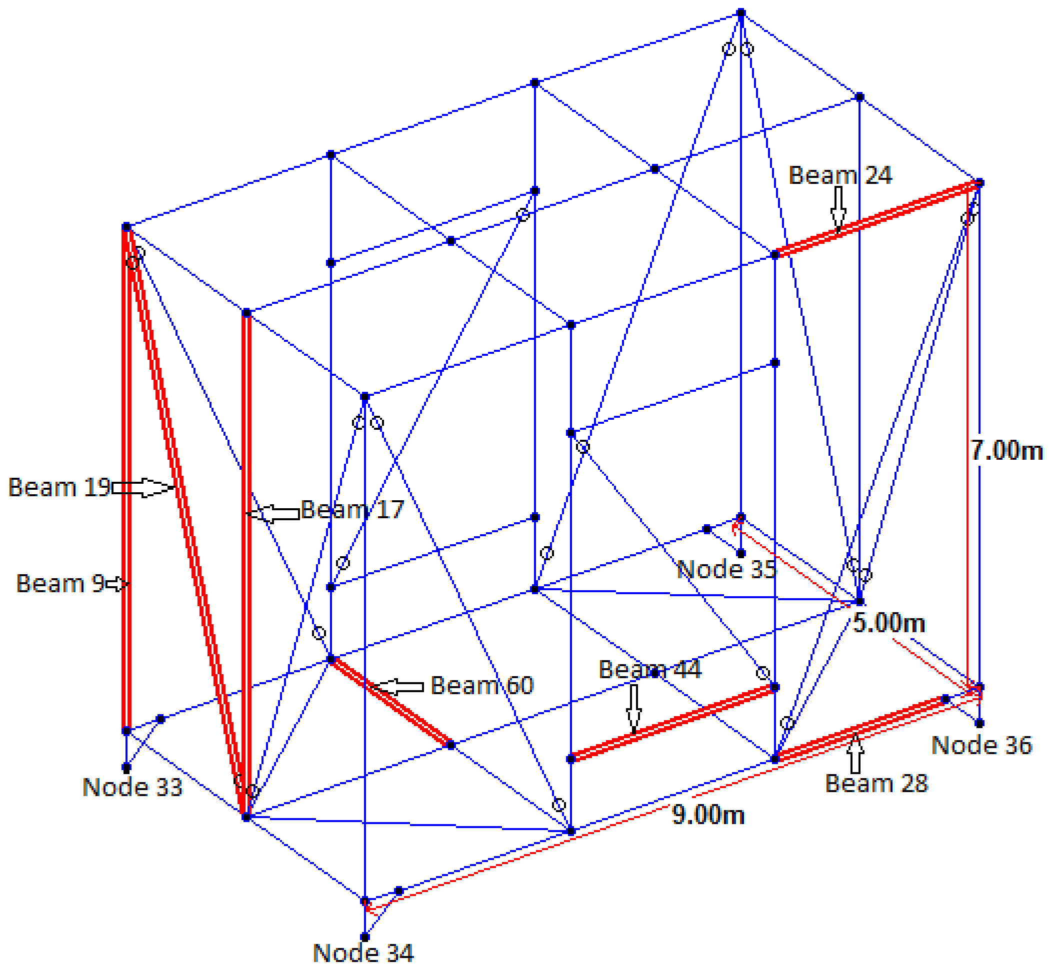

Figure 18: Highly utilized members for cooler-transportation analysis

Table 25: Cooler transportation analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
9	Corner post	Tube 273x16	0.19	0.21	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
17	Middle post	Tube 273x16	N /A	0.18	
19	Brace	Tube 114x6	**0.42**	0.06	
24	Top beam	Tube 273x16	0.07	0.12	
28	Bottom beam	Tube 273x16	0.18	0.34	
44	Intermediate beam	Tube 273x16	0.04	0.07	
60	Bottom middle beam	Tube 273x16	N /A	0.38	

7.5.2 Cooler air lifting analysis-Results

The maximum utilization factors for the cooler model air lifting analysis are shown below in Table 26:

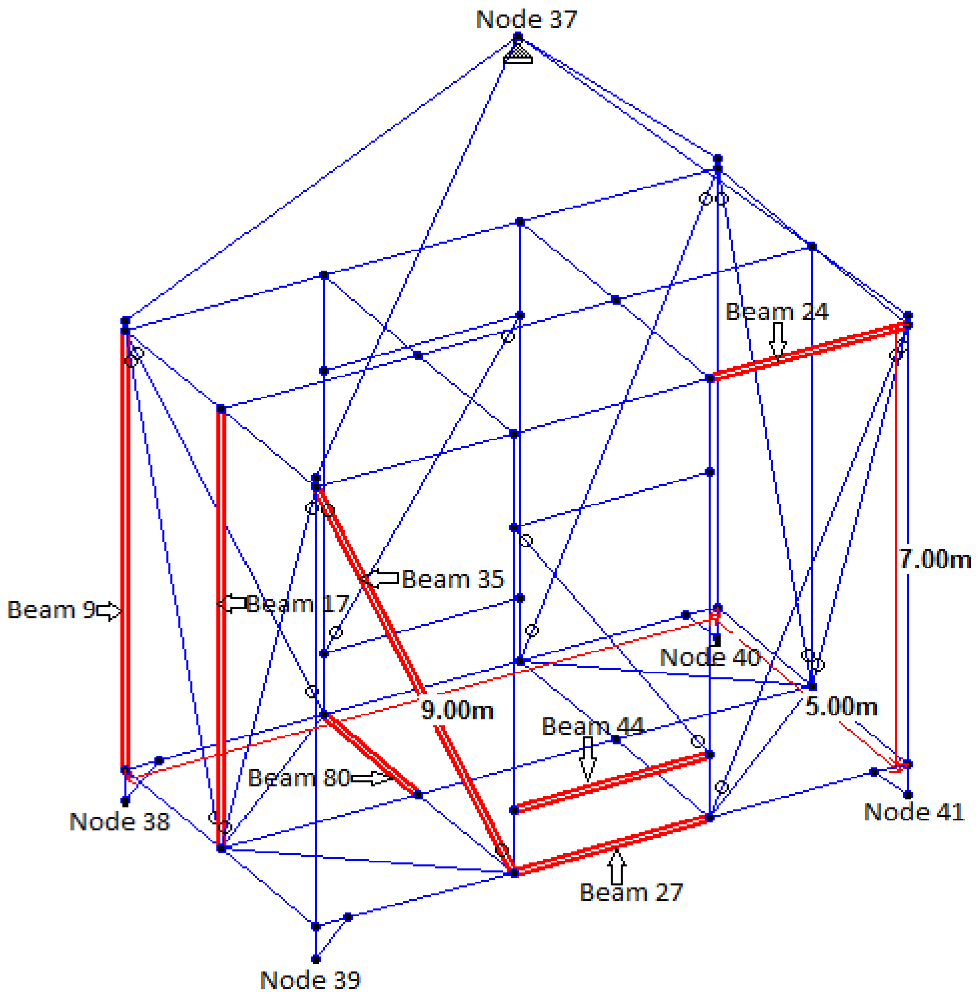

Figure 19: Highly utilized members for cooler-Air lifting analysis

Table 26: Cooler air lifting analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
9	Corner post	Tube 273x16	N /A	0.28	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
17	Middle post	Tube 273x16	0.15	0.30	
24	Top beam	Tube 114x6	0.25	0.29	
27	Bottom beam	Tube 273x16	N /A	0.14	
35	Brace	Tube 273x16	N /A	0.51	
44	Intermediate beam	Tube 273x16	0.03	0.08	
80	Bottom middle beam	Tube 273x16	N /A	**0.65**	

7.5.3 Cooler subsea lifting analysis-Results

The maximum utilization factors for the cooler model subsea/offshore lifting analysis are shown below in Table 27:

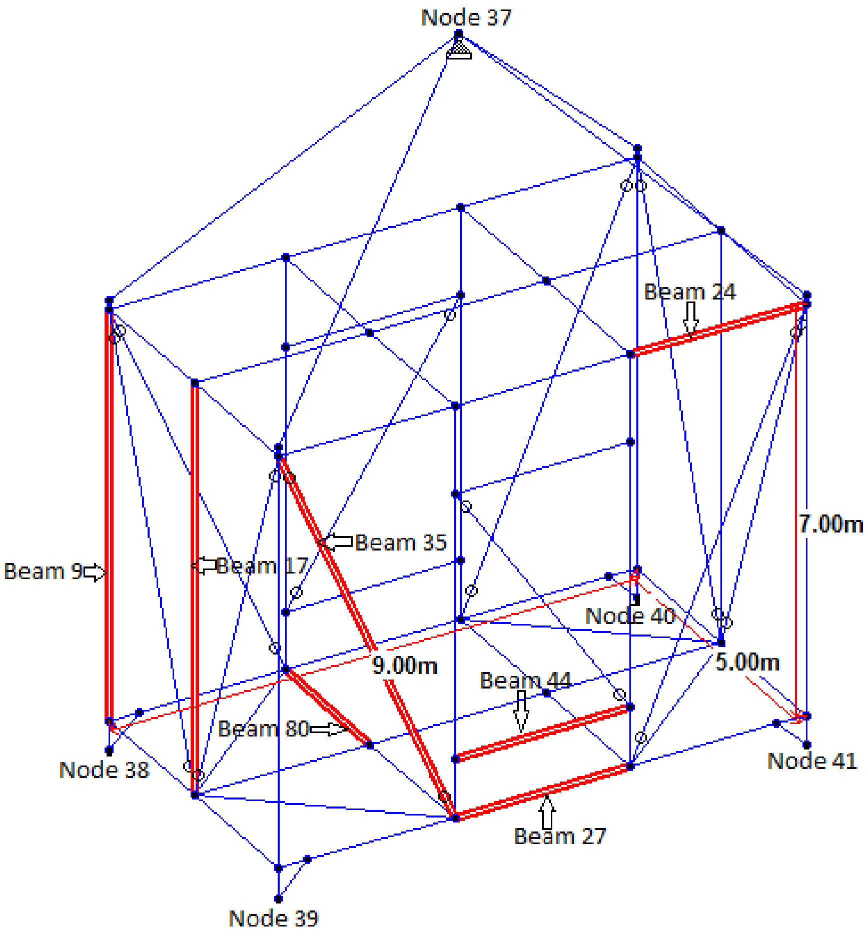

Figure 20: Highly utilized members for cooler-Offshore/subsea lifting analysis

Table 27: Cooler offshore lifting analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
9	Corner post	Tube 273x16	N /A	0.37	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
17	Middle post	Tube 273x16	0.21	0.40	
24	Top beam	Tube 114x6	0.35	0.40	
27	Bottom beam	Tube 273x16	N /A	0.17	
35	Brace	Tube 273x16	N /A	0.71	
44	Intermediate beam	Tube 273x16	0.04	0.07	
80	Bottom middle beam	Tube 273x16	N /A	**0.90**	

7.5.4 Cooler landing analysis-Results

The maximum utilization factors for landing analysis of cooler model, members specified above in Figure 11, are given below in Table 28:

Table 28: Cooler landing analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
84	Corner post	Tube 273x16	N /A	0.06	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
87	Corner post	Tube 273x16	N /A	0.06	

7.6 Case C- Compressor module

The main dimensions of the compressor module are $4\ (L) \times 4(W) \times 7(H)$ m. The total dry weight (static module weight) of the module is 100 tonnes (AkerSolutions, 2016). The CAD model of the compressor is shown below in Figure 21. Refer below in Table 29 for the weights that are used for the analyses of the compressor model.

Table 29: Total weight for compressor model

Description	**Load [kN]**	**Remarks**
Compressor Module	981	*Compressor module weight 100 tonnes*
Structural steel weight	232	*Self-weight with 10% inaccuracy. Taken from STAAD analysis*
Total weight	1,213	$1{,}213\ kN \approx 120\ tonnes\ (MGW)$

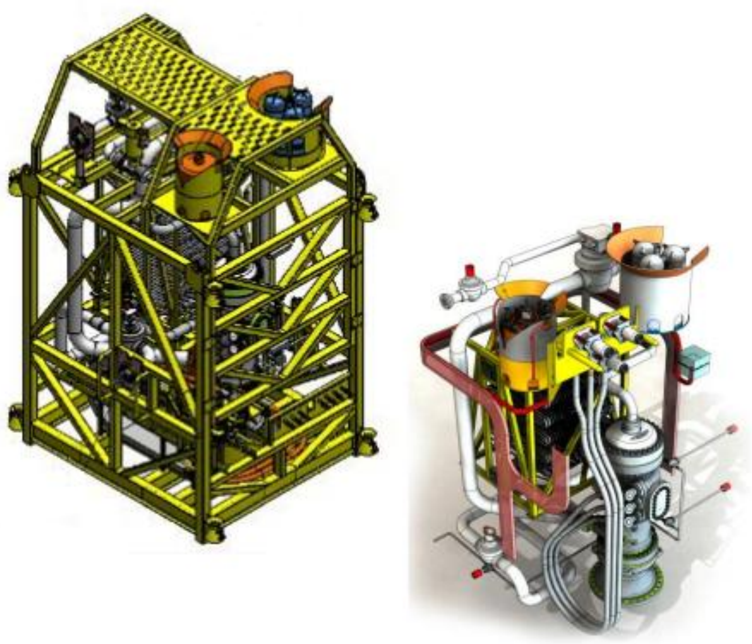

Figure 21: Compressor CAD model

7.6.1 Compressor transportation analysis-Results

The maximum utilization factors for compressor transportation analysis are given below in Table 30:

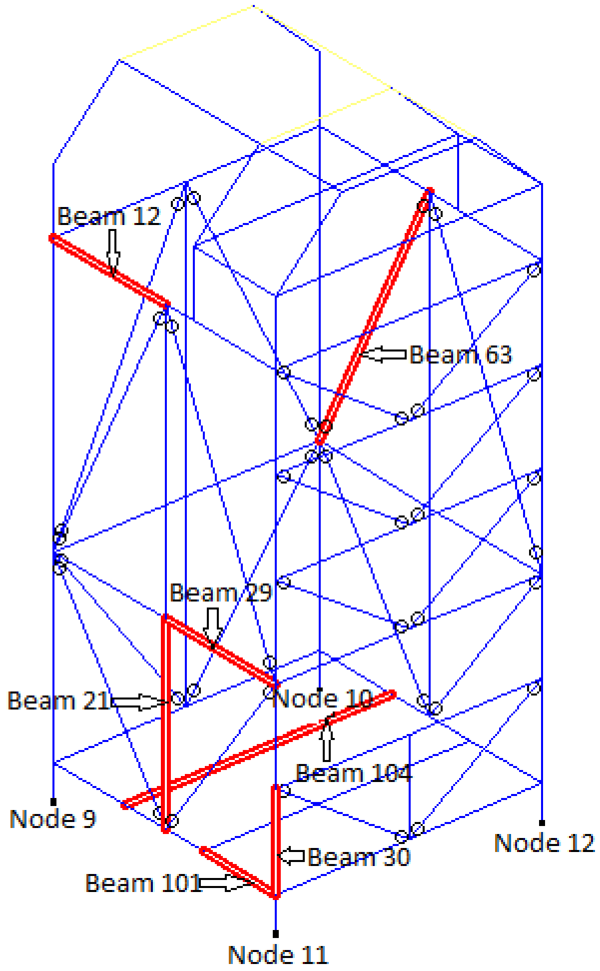

Figure 22: Highly utilized members for compressor-transportation analysis

Table 30: Compressor transportation analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
12	Top beam	Tube 324x16	N /A	0.08	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
21	Middle post	Tube 324x16	N /A	0.25	
29	Intermediate beam	Tube 324x16	0.09	0.15	
30	Corner post	Tube 324x16	0.24	0.34	
63	Brace	Tube 114x6	**0.52**	0.17	
101	Bottom beam	Tube 324x16	0.17	0.34	
104	Bottom middle beam	Tube 324x16	N /A	0.27	

7.6.2 Compressor air lifting analysis-Results

Refer below in Table 31 for the maximum utilization factors for the compressor model air lifting analysis.

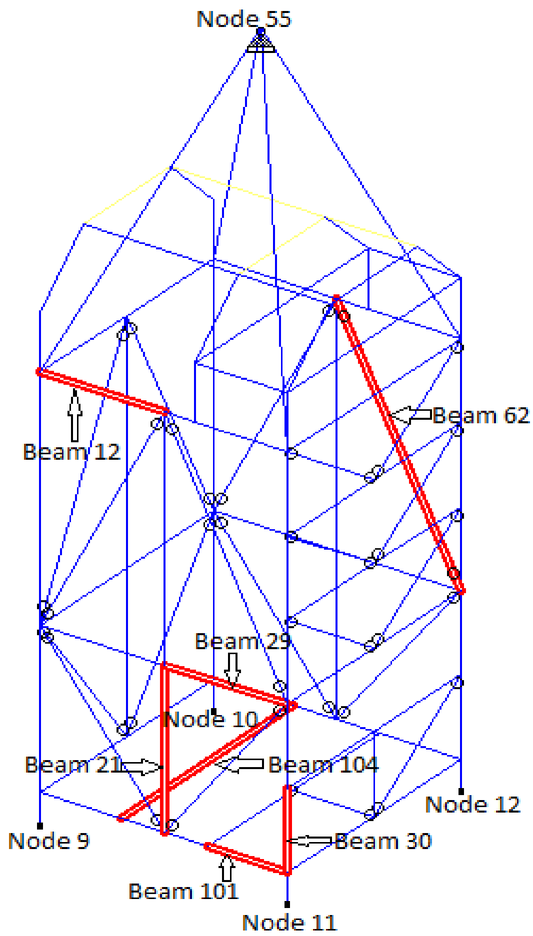

Figure 23: Highly utilized members for compressor-Air lifting analysis

Table 31: Compressor air lifting analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
12	Top beam	Tube 324x16	0.13	0.23	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
21	Middle post	Tube 324x16	N /A	0.43	
29	Intermediate beam	Tube 324x16	0.11	0.22	
30	Corner post	Tube 324x16	N /A	0.35	
62	Brace	Tube 114x6	0.34	0.11	
101	Bottom beam	Tube 324x16	N /A	**0.46**	
104	Bottom middle beam	Tube 324x16	N /A	**0.46**	

7.6.3 Compressor subsea lifting analysis-Results

The maximum utilization factors for the compressor model subsea/offshore lifting analysis are shown below in Table 32:

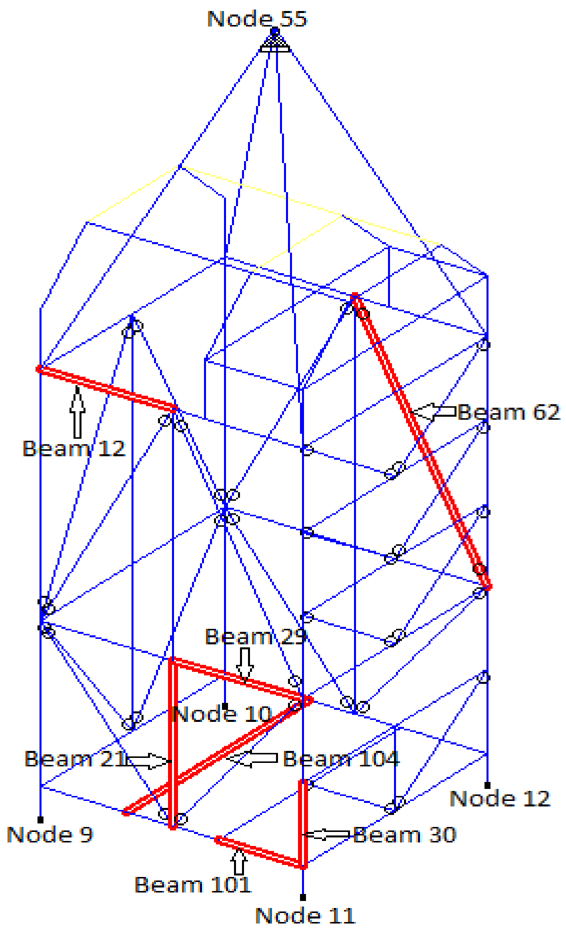

Figure 24: Highly utilized members for compressor-Offshore/subsea lifting analysis

Table 32: Compressor offshore lifting analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
12	Top beam	Tube 324x16	0.18	0.31	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
21	Middle post	Tube 324x16	N /A	0.58	
29	Intermediate beam	Tube 324x16	0.15	0.28	
30	Corner post	Tube 324x16	N /A	0.46	
62	Brace	Tube 114x6	0.47	0.16	
101	Bottom beam	Tube 324x16	N /A	0.59	
104	Bottom middle beam	Tube 324x16	N /A	**0.89**	

7.6.4 Compressor landing analysis-Results

The maximum utilization factors for landing analysis of compressor model, members specified above in Figure 12 , are given below in Table 33:

Table 33: Compressor landing analysis-Results UR buckling/yielding

Beam No.	Beam description	Beam profile (d.t)mm	UR Buckling	UR Yielding	Remarks
13	Corner post	Tube 324x16	N /A	0.06	*Refer Appendix C and Appendix D for detail calculations for yielding and buckling respectively*
16	Corner post	Tube 324x16	N /A	0.06	

8. Summary results and discussions

8.1 General

Analyses were conducted on each established case study and Table 34,Table 35 and Table 36 below summarizes the maximum utilization ratios.

8.2 Summary results for Case A:Pump module

Refer in Table 34 below for the maximum utilization ratios for pump module for different design phases:

Table 34: Pump module maximum UR

Subsea module	Identification	Type of PO Unit	Design phase	Maximum UR	Ranking
Pump ($MGW \approx 40\ tonnes$)	DNV 2.7-3 R30-Subsea	A	Transportation	**0.74**	1
			Air lifting	0.56	2
			Subsea/offshore lifting	0.43	3
			Landing	0.36	4

8.3 Summary results for Case B:Cooler module

Refer in Table 35 below for the maximum utilization ratios for cooler module for different design phases:

Table 35: Cooler module maximum UR

Subsea module	Identification	Type of PO Unit	Design phase	Maximum UR	Ranking
Cooler ($MGW \approx 100\ tonnes$)	DNV 2.7-3 R30-Subsea	A	Transportation	0.42	3
			Air lifting	0.65	2
			Subsea/offshore lifting	**0.90**	1
			Landing	0.06	4

8.4 Summary results for Case C:Compressor module

Refer in Table 36 below for the maximum utilization ratios for compressor module for different design phases:

Table 36: Compressor module maximum UR

Subsea module	Identification	Type of PO Unit	Design phase	Maximum UR	Ranking
Compressor ($MGW \approx 120\ tonnes$)	DNV 2.7-3 R30-Subsea	A	Transportation	0.52	2
			Air lifting	0.46	3
			Subsea/offshore lifting	**0.89**	1
			Landing	0.06	4

9. Conclusions and recommendations

9.1 General

The conclusions are mainly based on the three cases conducted during the analyses. The main input data during the analyses that decide the type of operational class are maximum gross weight ,type of PO unit and risk.

9.2 Conclusion

From the detail analyses conducted, It can be generally summarized that the critical design phase are transport for small subsea supporting structures and offshore lifting for medium and large subsea module supporting structures respectively. From good engineering practice, it is crucial to think about safety and economic analysis during concept phase so as to optimize engineering man-hours. Therefore from the analyses conducted with respect to three cases, it can be concluded that transport phase is the critical design phase for small structures and should be checked during concept phase and similarly offshore lifting should be evaluated for medium and large subsea module supporting structures.

During final engineering stage, it is necessary to provide detail analyses and complete design drawings with sufficient details. At this stage it important to document all the necessary critical design phases. From the analyses conducted and engineering judgments, design phases like air lifting, transport and offshore lift are critical and should be all evaluated and documented for small, medium and large subsea supporting structures. The following conclusions are summarized in Table 37 below as guidelines on which critical design phase/phases to be documented when structural integrity of subsea supporting structures are evaluated during concept and final engineering stages based on the analyses conducted for each case study :

Table 37: Guidelines on critical design phase/phases for subsea module supporting structures

Identification	Type of PO Unit	PO weight	Categories	Concept phase Critical design phase	Detail engineering phase Critical design phases
DNV 2.7-3 R30-Subsea	A	$25 < MGW \leq 50$ *tonnes*	Small	Transportation	✓ Air lifting ✓ Transportation ✓ Offshore lifting
		$50 < MGW \leq 100$ *tonnes*	Medium	Offshore lifting	✓ Air lifting ✓ Transportation ✓ Offshore lifting
		$100 < MGW \leq 150$ *tonnes*	Large	Offshore lifting	✓ Air lifting ✓ Transportation ✓ Offshore lifting

9.3 Recommendation for further work

In principle, subsea module supporting structures should be designed such that they can withstand all design phases. I.e. in-place, load out, sea transportation, offshore lifting, operations and retrieval. Even though there are no simple guidelines on how to document the structural integrity of subsea supporting structures as of today, it is recommended to set such guidelines to minimize engineering hours by performing analyses for only some selected phases without breaching the goal of health, safety and environment. This Thesis recommends for further studies for subsea module supporting structures with maximum gross weight (PO weight) greater than specified above and operational classes R60, R45 type A, B, C, D, E and class R30 type B, C, D and E according to operational class classifications given by DNV 2.7-3 (DNV, May 2011).

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Appendix A: Impact calculation during lifting

Appendix A1: Impact calculation during air lifting-Case A: Pump module

Total pump model weight, as given above in Table 19, is 40 tonnes.

As given in section 4.2.3 Horizontal impact during air lift -Table 4 above, test load for pump model (40 tonnes) during air lifting is as follows:

for *25<MGW≤50 tonnes,* test load , $F_{TEST} = [1 - 0.01 \times (MGW - 25) \times F_{Air}$
$\rightarrow F_{Air} = 2.25 \times MGW \times g$

$F_{Air} = 2.25 \times 426 \approx 960\ kN$

$\rightarrow F_{TEST} = [1 - 0.01 \times (MGW - 25) \times F_{Air}$

$F_{TEST} = [1 - 0.01 \times (40 - 25) \times 960 \approx 14{,}256\ kN$

a) For corner posts and bottom beams :

$\rightarrow F_{HI(air)} = 0.05 \times F_{TEST}$

$F_{HI(air)} = 0.05 \times 14{,}256 \approx 713\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(air)} = 0.6 \times F_{HI(air)}$

$F_{HIR(air)} = 0.6 \times 713 \approx 428\ kN$

$\boldsymbol{F_{HI(air)} \approx 713\ kN}$ -To be applied on corner posts , bottom beams and intermediate beams during air lift of pump module

$\boldsymbol{F_{HIR(air)} \approx 428\ kN}$-To be applied on end/side structure and top beams during air lift of pump module

Appendix A2: Impact calculation during offshore lifting-Case A: Pump module

Total pump model weight, as given above in Table 19, is 40 tonnes.

As given in section 4.2.4 Horizontal impact during offshore lift-Table 4 above, test load for pump model (40 tonnes) during offshore lifting is as follows:

for *25<MGW≤50 tonnes,* test load , $F_{TEST} = [1 - 0.01 \times (MGW - 25) \times F_{Sub}$

$\rightarrow F_{Sub} = 3.12 \times MGW \times g$

$F_{Sub} = 3.12 \times 426 \approx 1329\ kN$

$\rightarrow F_{TEST} = [1 - 0.01 \times (MGW - 25) \times F_{Sub}$

$F_{TEST} = [1 - 0.01 \times (40 - 25) \times 1329 \approx 19{,}736\ kN$

During offshore lifting, the structure is lowered alone and considered as single transportation and hence 50% of F_{HI} and F_{HIR} are applied as follows:

a) For corner posts and bottom beams :

$\rightarrow F_{HI(sub)} = 0.5 \times 0.05 \times F_{TEST}$

$F_{HI(sub)} = 0.025 \times 19{,}736 \approx 493\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(sub)} = 0.6 \times F_{HIsub}$

$F_{HIR(sub)} = 0.6 \times 493 \approx 296kN$

$\boldsymbol{F_{HI(sub)}} \approx \mathbf{493\ kN}$-To be applied on corner posts , bottom beams and intermediate beams during *offshore lift* of pump module

$\boldsymbol{F_{HIR(sub)}} \approx \mathbf{296kN}$-To be applied on end/side structure and top beams during offshore lift of pump module

Appendix A3: Impact calculation during air lifting-Case B: Cooler module

Total cooler model weight, as given above in Table 24, is 100 tonnes.

As given in section 4.2.3 Horizontal impact during air lift-Table 4 above, test load for cooler model (100 tonnes) during air lifting is as follows:

for $MGW > $ 50 tonnes, test load , $F_{TEST} = 0.75 \times F_{Air}$

$\rightarrow F_{Air} = 2.25 \times MGW \times g$

$F_{Air} = 2.25 \times 964 \approx 2{,}169\ kN$

$\rightarrow F_{TEST} = 0.75 \times F_{Air}$

$F_{TEST} = 0.75 \times 2{,}169 \approx 1{,}627\ kN$

a) For corner posts and bottom beams :

$\rightarrow F_{HI(air)} = 0.05 \times F_{TEST}$

$F_{HI(air)} = 0.05 \times 1{,}627 \approx 81\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(air)} = 0.6 \times F_{HI(air)}$

$F_{HIR(air)} = 0.6 \times 81 \approx 49\ kN$

$\boldsymbol{F_{HI(air)} \approx 81\ kN}$ -To be applied on corner posts , bottom beams and intermediate beams during air lift of cooler module

$\boldsymbol{F_{HIR(air)} \approx 49\ kN}$-To be applied on end/side structure and top beams during air lift of cooler module

Appendix A4: Impact calculation during offshore lifting-Case B: Cooler module

Total cooler model weight, as given above in Table 24, is 100 tonnes.

As given in section 4.2.4 Horizontal impact during offshore lift-Table 4 above, test load for cooler model (100 tonnes) during offshore lifting is as follows:

for $MGW >$ 50 tonnes, test load , $F_{TEST} = 0.75 \times F_{Sub}$

$\rightarrow F_{Sub} = 3.12 \times MGW \times g$

$F_{Sub} = 3.12 \times 964 \approx 3{,}008\ kN$

$\rightarrow F_{TEST} = 0.75 \times F_{Sub}$

$F_{TEST} = 0.75 \times 3{,}008 \approx 2{,}256\ kN$

During offshore lifting, the structure is lowered alone and considered as single transportation and hence 50% of F_{HI} and F_{HIR} are applied as follows:

a) For corner posts and bottom beams :

$\rightarrow F_{HI(sub)} = 0.5 \times 0.05 \times F_{TEST}$

$F_{HI(sub)} = 0.025 \times 2{,}256 \approx 56\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(sub)} = 0.6 \times F_{HI(sub)}$

$F_{HIR(sub)} = 0.6 \times 56 \approx 34\ kN$

$\boldsymbol{F_{HI(sub)} \approx 56\ kN}$-To be applied on corner posts , bottom beams and intermediate beams during offshore lift of cooler module

$\boldsymbol{F_{HIR(sub)} \approx 34\ kN}$-To be applied on end/side structure and top beams during offshore lift of cooler module

Appendix A5: Impact calculation during air lifting-Case C: Compressor module

Total compressor model weight, as given above in Table 29, is 120 tonnes.

As given in section 4.2.3 Horizontal impact during air lift-Table 4 above, test load for compressor model (120 tonnes) during air lifting is as follows:

for $MGW >$ 50 tonnes, test load , $F_{TEST} = 0.75 \times F_{Air}$

$\rightarrow F_{Air} = 2.25 \times MGW \times g$

$F_{Air} = 2.25 \times 1{,}213 \approx 2{,}729\ kN$

$\rightarrow F_{TEST} = 0.75 \times F_{Air}$

$F_{TEST} = 0.75 \times 2{,}729 \approx 2{,}047\ kN$

a) For corner posts and bottom beams :

$\rightarrow F_{HI(air)} = 0.05 \times F_{TEST}$

$F_{HI(air)} = 0.05 \times 2{,}047 \approx 102\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(air)} = 0.6 \times F_{HI(air)}$

$F_{HIR(air)} = 0.6 \times 102 \approx 61\ kN$

$\boldsymbol{F_{HI(air)} \approx 102\ kN}$ -To be applied on corner posts , bottom beams and intermediate beams during air lift of compressor module

$\boldsymbol{F_{HIR(air)} \approx 61\ kN}$-To be applied on end/side structure and top beams during air lift of compressor module

Appendix A_6: Impact calculation during offshore lifting-Case C: Compressor module

Total compressor model weight, as given above in Table 29, is 120 tonnes.

As given in section 4.2.4 Horizontal impact during offshore lift-Table 4 above, test load for compressor model (120 tonnes) during offshore lifting is as follows:

for $MGW > 50$ tonnes, test load , $F_{TEST} = 0.75 \times F_{Sub}$

$\rightarrow F_{Sub} = 3.12 \times MGW \times g$

$F_{Sub} = 3.12 \times 1{,}213 \approx 3{,}785\ kN$

$\rightarrow F_{TEST} = 0.75 \times F_{Sub}$

$F_{TEST} = 0.75 \times 3{,}785 \approx 2{,}839\ kN$

During offshore lifting, the structure is lowered alone and considered as single transportation and hence 50% of F_{HI} and F_{HIR} are applied as follows:

a) For corner posts and bottom beams :

$\rightarrow F_{HI(sub)} = 0.5 \times 0.05 \times F_{TEST}$

$F_{HI(sub)} = 0.025 \times 2{,}839 \approx 71\ kN$

b) For end/side structure and top beams :

$\rightarrow F_{HIR(sub)} = 0.6 \times F_{HI(sub)}$

$F_{HIR(sub)} = 0.6 \times 71 \approx 43\ kN$

$\boldsymbol{F_{HI(sub)} \approx 71\ kN}$-To be applied on corner posts , bottom beams and intermediate beams during offshore lift of compressor module

$\boldsymbol{F_{HIR(sub)} \approx 43\ kN}$-To be applied on end/side structure and top beams during offshore lift of compressor module

Appendix B: Landing impact calculations during offshore lifting

Appendix B_1: Landing calculation during offshore lifting-Case A: Pump module

As given in section 6.3.3 Landing analyses above, the total factor for landing load combination; LC27; is 0.25.

Therefore,

$\mathbf{LC27}.\,\text{Landing}(F_{VI}) = \ 0.25 \times (\text{Static self weight pump} + \text{Static subsea module weight pump})$

Total static pump model weight, as given above in Table 19, is 426kN.

$\rightarrow F_{VI} = 0.25 \times 426$

$F_{VI} \approx 107kN$

According to section 5.3.3 above, the structure is modeled in such a way that the bottom of the frame structure interfaces the bottom surface on two supports. Hence the total calculated load above is divided on two supports, i.e.

$\boldsymbol{F_{VI}} \approx \mathbf{54\ kN}$ -To be applied on corner post of pump model as compression force (in X direction) and horizontal impact of $\boldsymbol{F_{HI(sub)}} \approx \mathbf{493\ kN}$ in Y or Z direction as calculated above in Appendix A_2: Impact calculation during offshore lifting-Case A: Pump module.

Appendix B2: Landing calculation during offshore lifting-Case B: Cooler module

As given in section 6.3.3 Landing analyses above, the total factor for landing load combination; LC27; is 0.25.

Therefore,

$$\mathbf{LC27}.\,\text{Landing}(F_{VI}) = 0.25 \times (\text{Static self weight cooler} + \text{Static subsea module weight cooler})$$

Total static cooler model weight, as given above in Table 24, is 964kN.

$$\rightarrow F_{VI} = 0.25 \times 964$$

$$F_{VI} \approx 241kN$$

According to section 5.3.3 above, the structure is modeled in such a way that the bottom of the frame structure interfaces the bottom surface on two supports. Hence the total calculated load above is divided on two supports, i.e.

$\boldsymbol{F_{VI} \approx 121\ kN}$ -To be applied on corner post as compression force of cooler model (in X direction) and horizontal impact of $\boldsymbol{F_{HI(sub)} \approx 56\ kN}$ in Y or Z direction as calculated above in Appendix A_4: Impact calculation during offshore lifting-Case B: Cooler module.

Appendix B3: Landing calculation during offshore lifting-Case C: Compressor module

As given in section 6.3.3 Landing analyses above, the total factor for landing load combination; LC27; is 0.25.

Therefore,

$\mathbf{LC27}.\,\text{Landing}(F_{VI}) = 0.25 \times (\text{Self weight compressor} + \text{Subsea module weight compressor})$

Total static compressor model weight, as given above in Table 29, is 1,213kN.

$\rightarrow F_{VI} = 0.25 \times 1{,}213$

$F_{VI} \approx 303kN$

According to section 5.3.3 above, the structure is modeled in such a way that the bottom of the frame structure interfaces the bottom surface on two supports. Hence the total calculated load above is divided on two supports, i.e.

$\boldsymbol{F_{VI} \approx 152\ kN}$ -To be applied on corner post as compression force of compressor model (in X direction) and horizontal impact of $\boldsymbol{F_{HI(sub)} \approx 71\ kN}$ in Y or Z direction as calculated above in Appendix A_6: Impact calculation during offshore lifting-Case C: Compressor module.

Appendix C: Von Mises yield criteria calculations

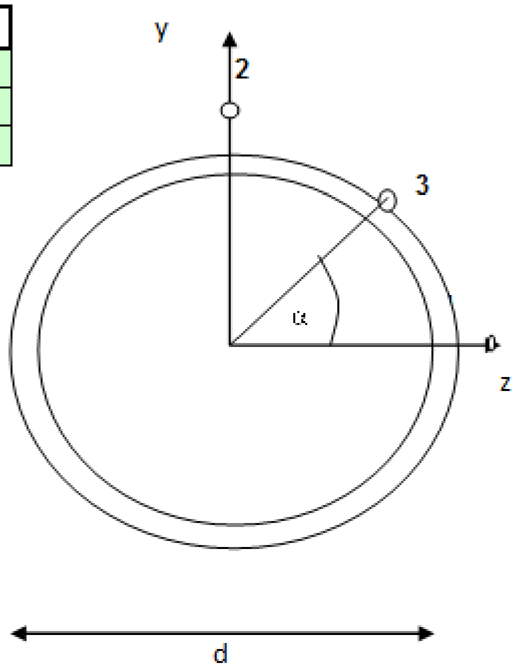
Appendix C1: Von Mises yield criteria for air lifting and horizontal impact- Case A: Pump module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	187
Descrip.	Bottom end beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.570	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	2.5	kN
Fy	6.5	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	4.9	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.2	0.0	0.0	0.0	0.8	0.0	**1.5**
Point 2	0.2	0.0	4.1	0.0	0.0	0.0	**4.3**
Point 3	0.2	4.1		0.0	0.8		**4.5**
Utilisation:							0.01

$* Apply, F_{HI} \approx 713\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	713.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	92.1	**159.5**
Point 3	0.0	0.0		0.0	92.1		**159.5**
Utilisation:							0.52

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	0.2	0.0	0.0	0.0	0.8	0.0	**1.5**
Point 2	0.2	0.0	4.1	0.0	0.0	92.1	**159.6**
Point 3	0.2	4.1		0.0	92.9		**161.0**
Utilisation:							0.52

INPUT LOADS

1.0 -End forces from Staad analysis for pump module air lift

Pump module air lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
187	3	1	-2.498	2.378	0.000	0.001	-0.006	-1.273
		2	2.498	6.471	-0.000	-0.001	0.005	-4.867

2.0 -Horizontal impact loads

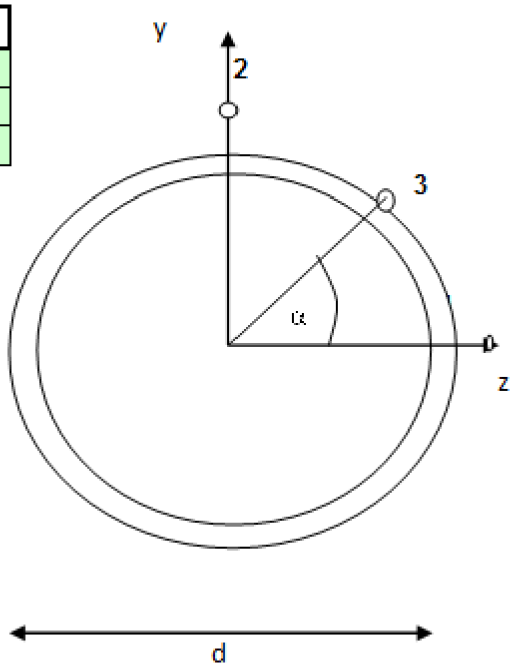
Refer attached calcaulations for horizontal impact loads during air lifting for pump module

$F_{HI} \approx 713\ kN$ *-To be applied on corner posts , bottom beams and intermediate beams*

$F_{HIR} \approx 428\ kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	194
Descrip.	Corner post
Analysis:	Air lift and horizontal impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.587	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR AIR LIFT		
Fx	63.0	kN
Fy	15.5	kN
Fz	24.1	kN
Mx	0.2	kNm
My	38.3	kNm
Mz	25.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	4.1	32.1	0.0	0.1	2.0	0.0	**36.3**
Point 2	4.1	0.0	21.3	0.1	0.0	3.1	**26.0**
Point 3	4.1	38.5		0.1	3.7		**43.1**
Utilisation:							**0.14**

$* Apply, F_{HI} \approx 713\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	713.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	92.1	**159.5**
Point 3	0.0	0.0		0.0	92.1		**159.5**
Utilisation:							**0.52**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	4.1	32.1	0.0	0.1	2.0	0.0	**36.3**
Point 2	4.1	0.0	21.3	0.1	0.0	95.2	**167.0**
Point 3	4.1	38.5		0.1	95.8		**171.5**
Utilisation:							**0.56**

INPUT LOADS

1.0 -End forces from Staad analysis for pump module air lift

Pump module air lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
194	3	34	-57.121	15.477	24.097	-0.236	-9.873	5.458
		6	63.020	-15.477	-24.097	0.236	-38.321	25.496

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for pump module

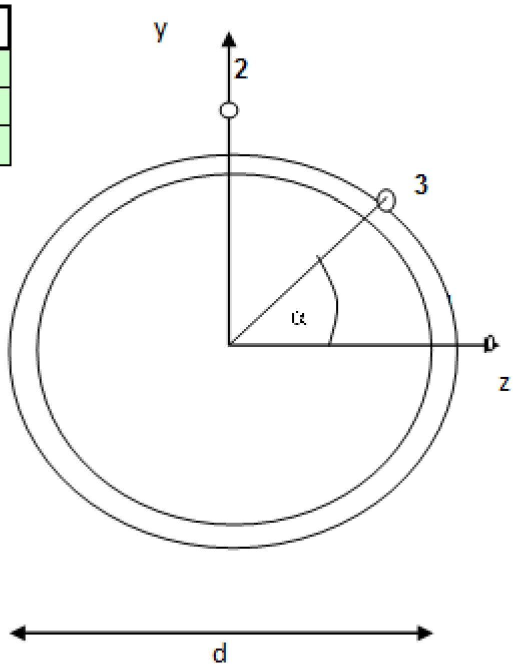
$F_{HI} \approx 713\ kN$ *-To be applied on corner posts , bottom beams and intermediate beams*

$F_{HIR} \approx 428\ kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	202
Descrip.	Top beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.525	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR AIR LIFT		
Fx	115.2	kN
Fy	5.9	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.4	kNm
Mz	8.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	7.4	0.3	0.0	0.0	0.8	0.0	**7.9**
Point 2	7.4	0.0	7.3	0.0	0.0	0.0	**14.7**
Point 3	7.4	7.3		0.0	0.8		**14.8**
Utilisation:							0.05

$* \, Apply, F_{HIR} \approx 428 \; kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	428.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	55.3	**95.8**
Point 3	0.0	0.0		0.0	55.3		**95.8**
Utilisation:							0.31

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	7.4	0.3	0.0	0.0	0.8	0.0	7.9
Point 2	7.4	0.0	7.3	0.0	0.0	55.3	96.9
Point 3	7.4	7.3		0.0	56.1		98.2
Utilisation:							0.32

INPUT LOADS

1.0 -End forces from Staad analysis for pump module air lift

Pump module air lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
202	3	8	115.186	5.899	0.000	0.000	-0.404	-8.730
		6	-115.186	5.899	-0.000	-0.000	0.404	8.730

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for pump module

$F_{HI} \approx 713\ kN$ *-To be applied on corner posts , bottom beams and intermediate beams*

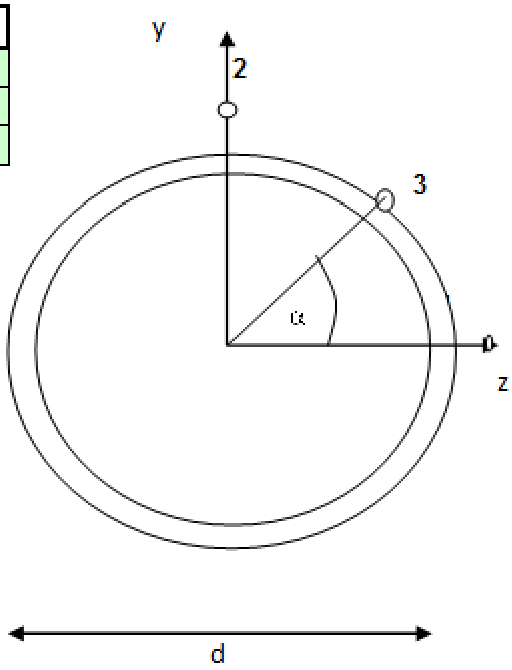
$F_{HIR} \approx 428\ kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	222
Descrip.	Intermediate beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.558	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	24.8	kN
Fy	7.8	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.1	kNm
Mz	7.4	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.6	0.1	0.0	0.0	1.0	0.0	**2.4**
Point 2	1.6	0.0	6.2	0.0	0.0	0.0	**7.8**
Point 3	1.6	6.2		0.0	1.0		**8.0**
Utilisation:							0.03

$* \, Apply \, , F_{HI} \approx 713 \; kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	713.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	92.1	**159.5**
Point 3	0.0	0.0		0.0	92.1		**159.5**
Utilisation:							0.52

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	1.6	0.1	0.0	0.0	1.0	0.0	**2.4**
Point 2	1.6	0.0	6.2	0.0	0.0	92.1	**159.7**
Point 3	1.6	6.2		0.0	93.1		**161.5**
Utilisation:							0.52

INPUT LOADS

1.0 -End forces from Staad analysis for pump module air lift

Pump module air lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
222	3	46	-24.765	-1.891	-0.000	-0.000	-0.098	-2.296
		34	24.765	7.790	0.000	0.000	0.098	-7.385

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for pump module

$F_{HI} \approx 713\ kN$ *-To be applied on corner posts , bottom beams and intermediate beams*

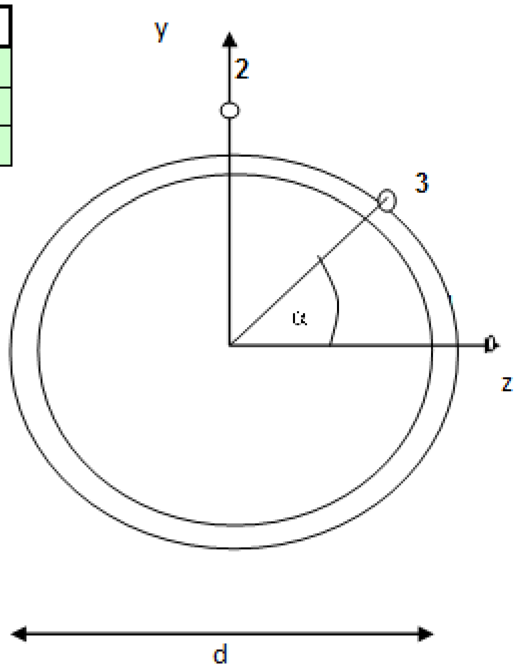
$F_{HIR} \approx 428\ kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	231
Descrip.	Brace
Analysis:	Air lifting

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	5.4	kN
Fy	0.3	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY (Braces take no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.7	0.0	0.0	0.0	0.3	0.0	**2.7**
Point 2	2.7	0.0	0.0	0.0	0.0	0.0	**2.7**
Point 3	2.7	0.0		0.0	0.3		**2.7**
Utilisation:							**0.01**

INPUT LOADS

1.0 -End forces from Staad analysis for pump module air lift

Pump module air lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
231	3	5	4.628	0.306	-0.000	0.000	0.000	0.000
		47	-5.443	0.306	0.000	0.000	0.000	0.000

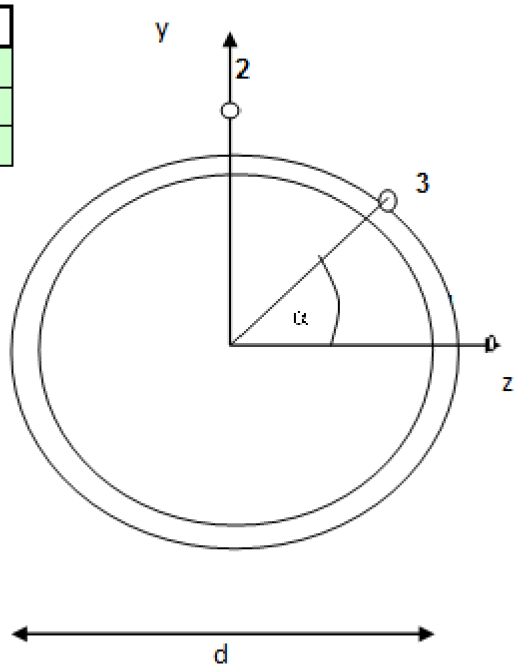
Appendix C2: Von Mises yield criteria for offshore lifting and horizontal impact-Case A: Pump module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	187
Descrip.	Bottom side beam
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.570	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	3.5	kN
Fy	9.0	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	6.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.2	0.0	0.0	0.0	1.2	0.0	**2.0**
Point 2	0.2	0.0	5.6	0.0	0.0	0.0	**5.9**
Point 3	0.2	5.6		0.0	1.2		**6.2**
Utilisation:							0.02

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	493.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

$* \, Apply, F_{HIsub} \approx 493 \, kN$

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	63.7	**110.3**
Point 3	0.0	0.0		0.0	63.7		**110.3**
Utilisation:							0.36

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	0.2	0.0	0.0	0.0	1.2	0.0	**2.0**
Point 2	0.2	0.0	5.6	0.0	0.0	63.7	**110.5**
Point 3	0.2	5.6		0.0	64.8		**112.5**
Utilisation:							0.36

INPUT LOADS

1.0 -End forces from Staad analysis for pump module offshore lift

Pump module offshore lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
187	3	1	-3.464	3.297	0.000	0.001	-0.008	-1.766
		2	3.464	8.973	-0.000	-0.001	0.007	-6.748

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for pump module

$F_{HIsub} \approx 493\ kN$ *-To be applied on corner posts, bottom beams and intermediate beams*

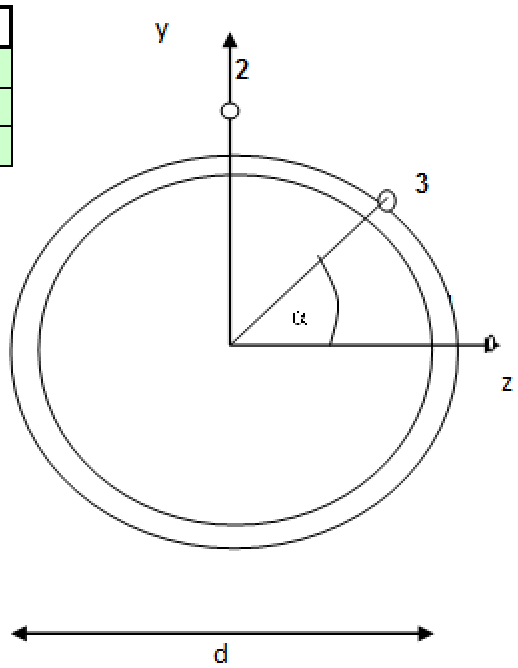
$F_{HIRsub} \approx 296 kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	194
Descrip.	Corner post
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.587	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	87.4	kN
Fy	21.5	kN
Fz	33.4	kN
Mx	0.3	kNm
My	53.1	kNm
Mz	35.4	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	5.6	44.5	0.0	0.1	2.8	0.0	**50.4**
Point 2	5.6	0.0	29.6	0.1	0.0	4.3	**36.1**
Point 3	5.6	53.4		0.1	5.1		**59.7**
Utilisation:							**0.19**

$* \, Apply \, , F_{HIsub} \approx 493 \; kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	493.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	63.7	**110.3**
Point 3	0.0	0.0		0.0	63.7		**110.3**
Utilisation:							**0.36**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	5.6	44.5	0.0	0.1	2.8	0.0	50.4
Point 2	5.6	0.0	29.6	0.1	0.0	68.0	123.2
Point 3	5.6	53.4		0.1	68.8		133.2
Utilisation:							0.43

INPUT LOADS

1.0 -End forces from Staad analysis for pump module offshore lift

Pump module offshore lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
194	3	34	-79.208	21.461	33.414	-0.327	-13.691	7.568
		6	87.388	-21.461	-33.414	0.327	-53.138	35.354

2.0 -Horizontal impact loads

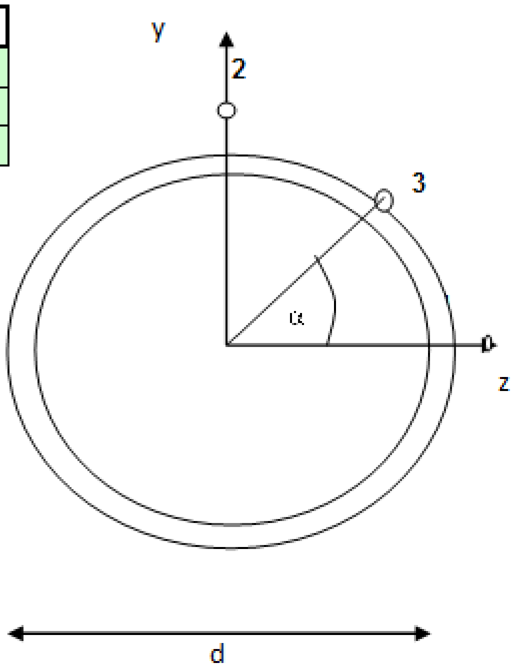
Refer attached calcaulations for horizontal impact loads during offshore lifting for pump module

$F_{HIsub} \approx 493\ kN$ *- To be applied on corner posts , bottom beams and intermediate beams*

$F_{HIRsub} \approx 296 kN$ *- To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	202
Descrip.	Top beam
Analysis:	Offshore lift and horizon.impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.524	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	159.7	kN
Fy	8.2	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.6	kNm
Mz	12.1	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	10.3	0.5	0.0	0.0	1.1	0.0	**10.9**
Point 2	10.3	0.0	10.1	0.0	0.0	0.0	**20.4**
Point 3	10.3	10.1		0.0	1.1		**20.5**
Utilization:							**0.07**

* Apply, $F_{HIRsub} \approx 296kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	296.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	38.2	**66.2**
Point 3	0.0	0.0		0.0	38.2		**66.2**
Utilization:							**0.21**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	10.3	0.5	0.0	0.0	1.1	0.0	**10.9**
Point 2	10.3	0.0	10.1	0.0	0.0	38.2	**69.3**
Point 3	10.3	10.1		0.0	39.3		**71.1**
Utilization:							0.23

INPUT LOADS

1.0 -End forces from Staad analysis for pump module offshore lift

Pump module offshore lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
202	3	8	159.724	8.180	0.000	0.000	-0.561	-12.105
		6	-159.724	8.180	-0.000	-0.000	0.561	12.105

2.0 -Horizontal impact loads

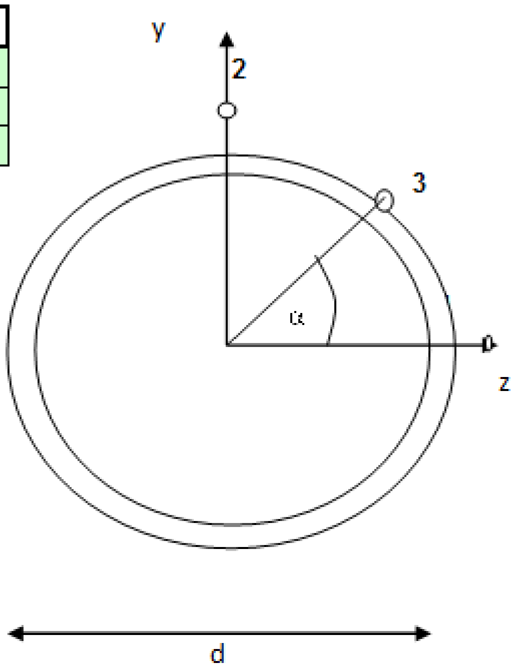
Refer attached calcaulations for horizontal impact loads during offshore lifting for pump module

$F_{HIsub} \approx 493\ kN$ *-To be applied on corner posts , bottom beams and intermediate beams*

$F_{HIRsub} \approx 296kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	222
Descrip.	Intermidate beam
Analysis:	Offshore lift and horizon.impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.558	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	34.3	kN
Fy	10.8	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.1	kNm
Mz	10.2	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.2	0.1	0.0	0.0	1.4	0.0	**3.4**
Point 2	2.2	0.0	8.6	0.0	0.0	0.0	**10.8**
Point 3	2.2	8.6		0.0	1.4		**11.1**
Utilization:							0.04

$* \, Apply, F_{HIsub} \approx 493 \, kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	493.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	63.7	**110.3**
Point 3	0.0	0.0		0.0	63.7		**110.3**
Utilization:							0.36

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	2.2	0.1	0.0	0.0	1.4	0.0	**3.4**
Point 2	2.2	0.0	8.6	0.0	0.0	63.7	**110.8**
Point 3	2.2	8.6		0.0	65.1		**113.2**
Utilization:							0.37

INPUT LOADS

1.0 -End forces from Staad analysis for pump module offshore lift

Pump module offshore lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
222	3	46	-34.340	-2.623	-0.000	-0.000	-0.136	-3.184
		34	34.340	10.803	0.000	0.000	0.136	-10.241

2.0 -Horizontal impact loads

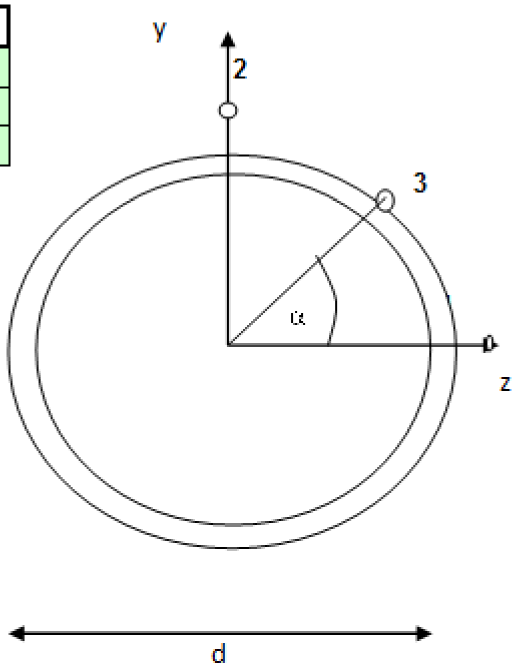
Refer attached calcaulations for horizontal impact loads during offshore lifting for pump module

$F_{HIsub} \approx 493\ kN$ *-To be applied on corner posts, bottom beams and intermediate beams*

$F_{HIRsub} \approx 296kN$ *-To be applied on end/side structure and top beams*

VON MISES YIELD CRITERION

GENERAL	
Beam No.	231
Descrip.	Brace
Analysis:	Offshore lifting



SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	7.5	kN
Fy	0.4	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: $[(\sigma_x + \sigma_{by} + \sigma_{bz})^2 + 3(\tau_x + \tau_y + \tau_z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY (Braces take no impact)							
	σ_{x1}	σ_{by1}	σ_{bz1}	τ_{x1}	τ_{y1}	τ_{z1}	σ_{e1}
Point 1	3.7	0.0	0.0	0.0	0.4	0.0	3.8
Point 2	3.7	0.0	0.0	0.0	0.0	0.0	3.7
Point 3	3.7	0.0		0.0	0.4		3.8
Utilisation:							0.01

INPUT LOADS

1.0 -End forces from Staad analysis for pump module offshore lift

Pump module offshore lifting.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
231	3	5	6.418	0.424	-0.000	0.000	0.000	0.000
		47	-7.548	0.424	0.000	0.000	0.000	0.000

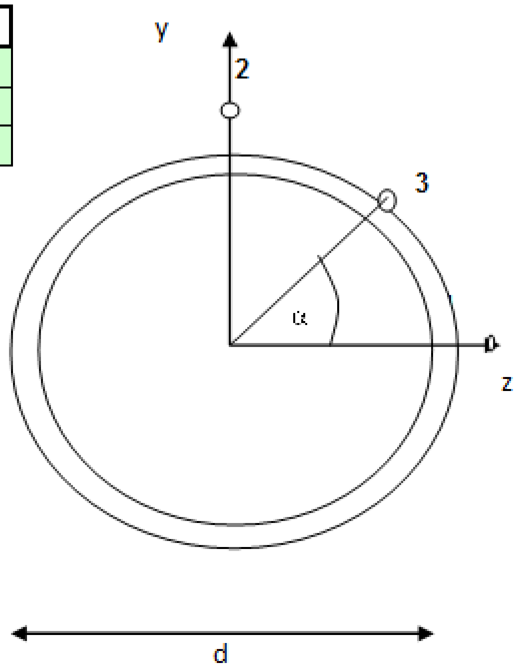
Appendix C3: Von Mises yield criteria for transportation-Case A: Pump module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	121
Descrip.	Bottom beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.566	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	4.4	kN
Fy	104.7	kN
Fz	0.4	kN
Mx	0.0	kNm
My	0.9	kNm
Mz	201.2	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.3	0.7	0.0	0.0	13.5	0.0	**23.5**
Point 2	0.3	0.0	168.3	0.0	0.0	0.1	**168.6**
Point 3	0.3	168.3		0.0	13.5		**170.2**
Utilisation:							**0.55**

INPUT LOADS

1.0 -End forces from Staad analysis for pump module transport analysis

Pump transport.std - Beam End Force

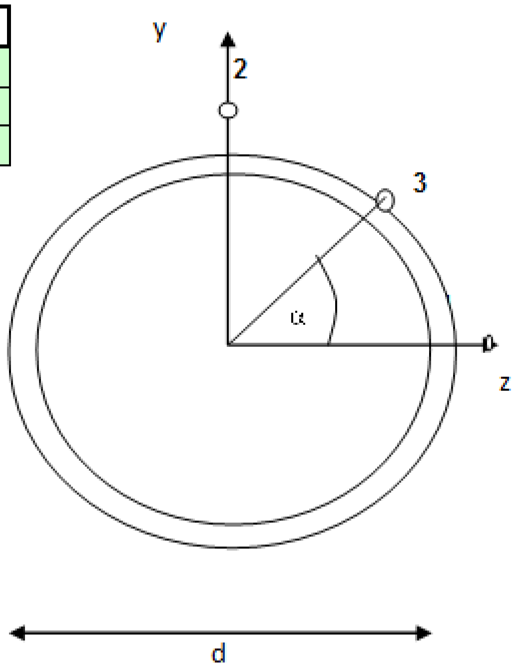
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
121	33	1	-2.408	-92.681	0.437	0.002	-0.873	-193.688
		3	-4.409	104.741	-0.437	-0.002	-0.874	-201.156

VON MISES YIELD CRITERION

GENERAL	
Beam No.	148
Descrip.	Corner post
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.011	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	441.6	kN
Fy	1.1	kN
Fz	124.0	kN
Mx	0.0	kNm
My	231.3	kNm
Mz	2.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	28.5	193.5	0.0	0.0	0.1	0.0	222.0
Point 2	28.5	0.0	2.1	0.0	0.0	16.0	41.3
Point 3	28.5	193.5		0.0	16.0		223.8
Utilisation:							0.72

INPUT LOADS

1.0 -End forces from Staad analysis for pump module transport analysis

Pump transport.std - Beam End Force

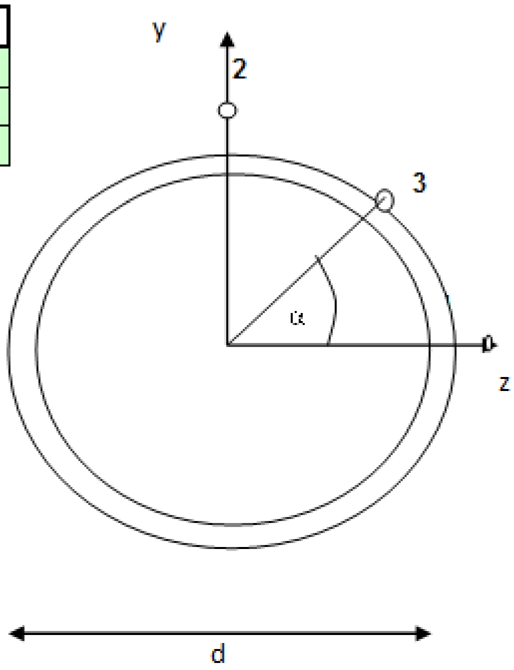
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
148	35	19	441.635	-1.105	124.044	-0.003	-192.401	-1.379
		33	-431.082	1.105	-118.080	0.003	-231.316	-2.489

VON MISES YIELD CRITERION

GENERAL	
Beam No.	154
Descrip.	Intermidate beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.564	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	3.1	kN
Fy	182.5	kN
Fz	1.2	kN
Mx	0.1	kNm
My	1.8	kNm
Mz	269.0	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.2	1.5	0.0	0.0	23.6	0.0	**40.9**
Point 2	0.2	0.0	225.0	0.0	0.0	0.2	**225.2**
Point 3	0.2	225.0		0.0	23.6		**228.9**
Utilisation:							0.74

INPUT LOADS

1.0 -End forces from Staad analysis for pump module transport analysis

Pump transport.std - Beam End Force

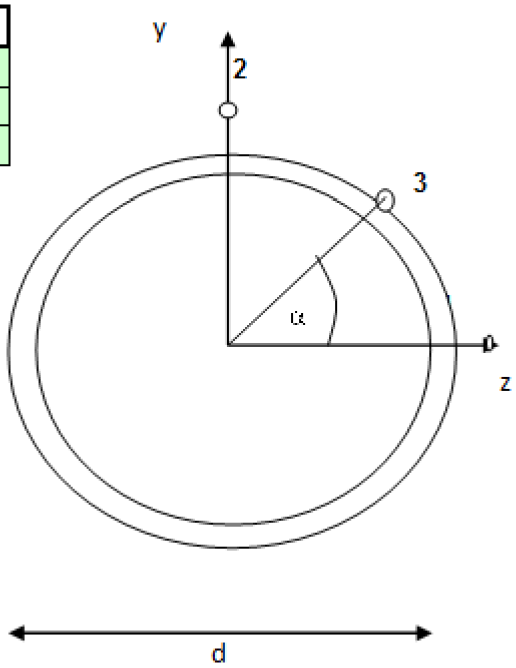
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
154	29	20	-2.007	-173.437	1.185	-0.051	-1.777	-264.891
		21	-3.105	182.482	-1.185	0.051	-1.776	-268.988

VON MISES YIELD CRITERION

GENERAL	
Beam No.	201
Descrip.	Top beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.561	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	3.7	kN
Fy	16.1	kN
Fz	0.1	kN
Mx	0.1	kNm
My	0.2	kNm
Mz	19.4	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.2	0.2	0.0	0.0	2.1	0.0	**3.7**
Point 2	0.2	0.0	16.2	0.0	0.0	0.0	**16.4**
Point 3	0.2	16.2		0.0	2.1		**16.8**
Utilisation:							0.05

INPUT LOADS

1.0 -End forces from Staad analysis for pump module transport analysis

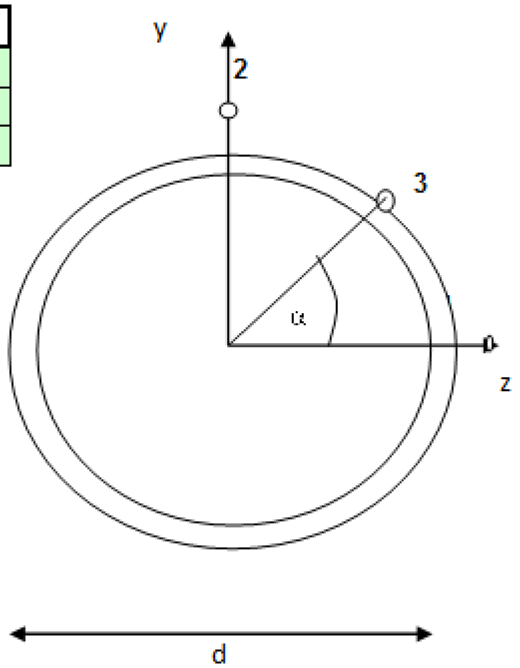
Pump transport.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
201	29	7	-3.660	-7.102	0.105	-0.104	-0.180	-15.514
		8	-1.452	16.147	-0.105	0.104	-0.135	-19.360

VON MISES YIELD CRITERION

GENERAL	
Beam No.	216
Descrip.	Brace
Analysis:	Transport analysis

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR TRANSPORT		
Fx	208.0	kN
Fy	0.3	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	102.2	0.0	0.0	0.0	0.3	0.0	**102.2**
Point 2	102.2	0.0	0.0	0.0	0.0	0.0	**102.2**
Point 3	102.2	0.0		0.0	0.3		**102.2**
Utilisation:							0.33

INPUT LOADS

1.0 -End forces from Staad analysis for pump module transport analysis

Pump transport.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
216	34	5	207.668	-0.290	0.000	0.000	0.000	0.000
		39	-208.030	-0.290	0.000	0.000	0.000	0.000

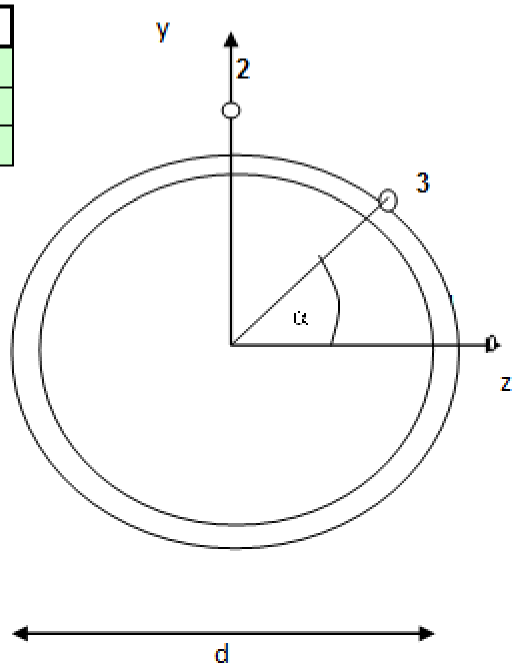
Appendix C4: Von Mises yield criteria for air lifting and horizontal impact-Case B:Cooler module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	9
Descrip.	Corner post
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.061	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	96.8	kN
Fy	14.5	kN
Fz	8.5	kN
Mx	0.6	kNm
My	30.0	kNm
Mz	53.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	7.5	36.0	0.0	0.4	2.2	0.0	**43.8**
Point 2	7.5	0.0	64.5	0.4	0.0	1.3	**72.0**
Point 3	7.5	73.8		0.4	2.6		**81.5**
Utilization:							0.26

$* Apply, F_{HI} \approx 81\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	81.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	12.5	**21.7**
Point 3	0.0	0.0		0.0	12.5		**21.7**
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	7.5	36.0	0.0	0.4	2.2	0.0	**43.8**
Point 2	7.5	0.0	64.5	0.4	0.0	13.9	**76.1**
Point 3	7.5	73.8		0.4	15.1		**85.7**
Utilization:							0.28

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
9	3	1	-79.602	-14.506	8.519	0.633	-30.014	-47.834
		5	96.835	14.506	-8.519	-0.633	-29.622	-53.710

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for cooler module

$F_{HI} \approx 81\ kN$ -To be applied on corner posts , bottom beams and intermediate beams during air lift of cooler module

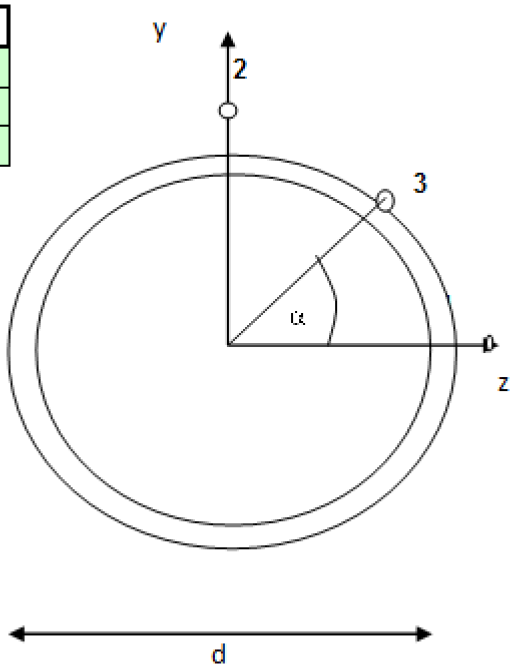
$F_{HIR} \approx 49\ kN$ -To be applied on end/side structure and top beams during air lift of cooler module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	17
Descrip.	Middel corner post
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.571	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	15.7	kN
Fy	16.6	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	72.2	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.2	0.0	0.0	0.0	2.6	0.0	4.6
Point 2	1.2	0.0	86.6	0.0	0.0	0.0	87.8
Point 3	1.2	86.6		0.0	2.6		87.9
Utilization:							0.28

$* \ Apply, F_{HI} \approx 81 \ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	81.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	12.5	21.7
Point 3	0.0	0.0		0.0	12.5		21.7
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	1.2	0.0	0.0	0.0	2.6	0.0	**4.6**
Point 2	1.2	0.0	86.6	0.0	0.0	12.5	**90.5**
Point 3	1.2	86.6		0.0	15.1		**91.7**
Utilization:							**0.30**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
17	3	10	15.730	-16.616	-0.002	0.015	0.012	-72.166
		9	1.504	16.616	0.002	-0.015	0.005	-44.145

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for cooler module

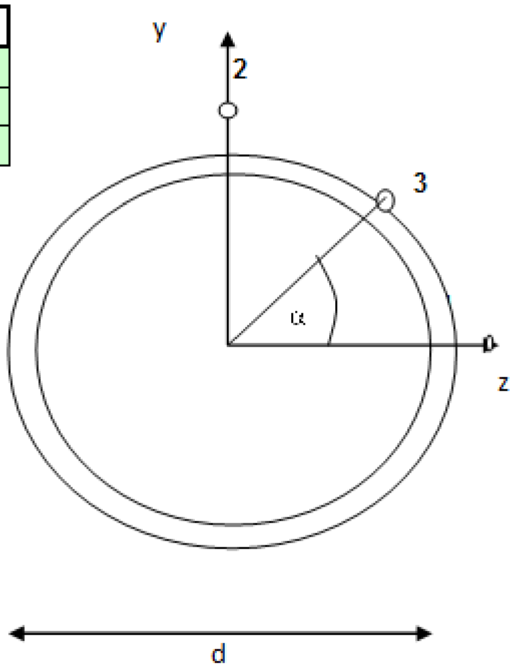
$F_{HI} \approx 81\ kN$ -To be applied on corner posts , bottom beams and intermediate beams
$F_{HIR} \approx 49\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	24
Descrip.	Top beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.143	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	670.1	kN
Fy	8.6	kN
Fz	6.4	kN
Mx	13.7	kNm
My	11.5	kNm
Mz	25.3	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	51.9	13.9	0.0	8.2	1.3	0.0	**67.8**
Point 2	51.9	0.0	30.4	8.2	0.0	1.0	**83.8**
Point 3	51.9	33.4		8.2	1.7		**87.0**
Utilization:							0.28

$* \text{Apply}, F_{HIR} \approx 49\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	49.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	7.6	**13.1**
Point 3	0.0	0.0		0.0	7.6		**13.1**
Utilization:							0.04

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	51.9	13.9	0.0	8.2	1.3	0.0	67.8
Point 2	51.9	0.0	30.4	8.2	0.0	8.6	87.3
Point 3	51.9	33.4		8.2	9.2		90.5
Utilization:							0.29

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
24	3	14	670.138	-1.243	6.362	13.688	-7.546	-25.324
		7	-670.138	8.629	-6.362	-13.688	-11.542	10.515

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for cooler module

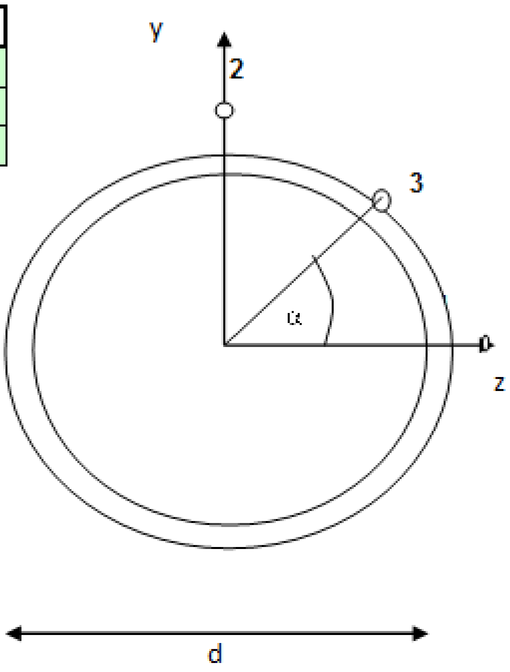
$F_{HI} \approx 81\ kN$ -To be applied on corner posts , bottom beams and intermediate beams
$F_{HIR} \approx 49\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	27
Descrip.	Bottom beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.547	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	184.6	kN
Fy	44.1	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.3	kNm
Mz	12.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	14.3	0.4	0.0	0.0	6.8	0.0	18.8
Point 2	14.3	0.0	15.0	0.0	0.0	0.0	29.3
Point 3	14.3	15.0		0.0	6.8		31.6
Utilization:							0.10

$* Apply, F_{HI} \approx 81\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	81.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	12.5	21.7
Point 3	0.0	0.0		0.0	12.5		21.7
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	14.3	0.4	0.0	0.0	6.8	0.0	**18.8**
Point 2	14.3	0.0	15.0	0.0	0.0	12.5	**36.5**
Point 3	14.3	15.0		0.0	19.4		**44.6**
Utilization:							**0.14**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
27	3	17	-184.615	44.063	0.006	-0.043	-0.296	12.494
		18	184.615	43.795	-0.006	0.043	0.278	-12.091

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for cooler module

$F_{HI} \approx 81\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

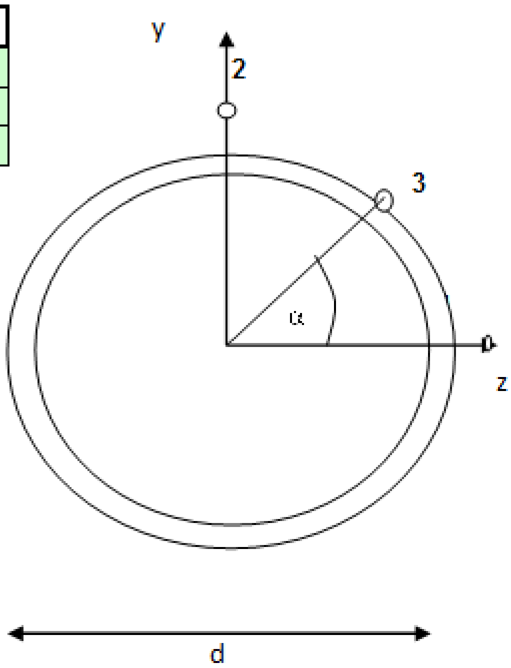
$F_{HIR} \approx 49\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	35
Descrip.	Brace
Analysis:	Air lifting

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	319.8	kN
Fy	0.6	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY (Braces take no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	157.1	0.0	0.0	0.0	0.6	0.0	**157.1**
Point 2	157.1	0.0	0.0	0.0	0.0	0.0	**157.1**
Point 3	157.1	0.0		0.0	0.6		**157.1**
Utilisation:							0.51

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

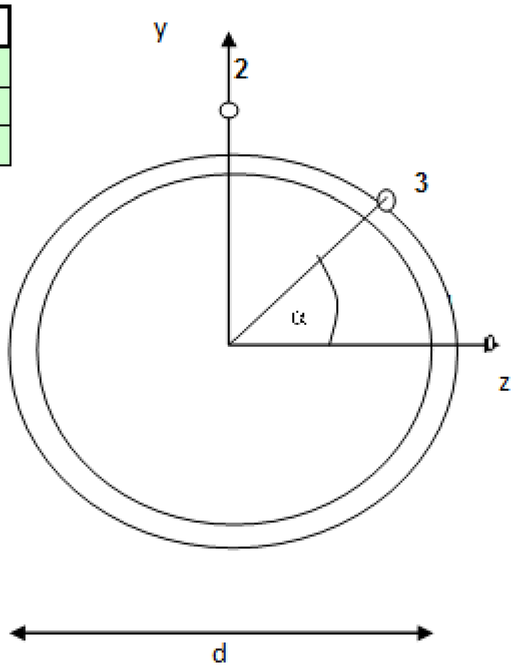
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
35	3	6	-319.809	0.611	0.000	0.000	0.000	0.000
		17	316.957	0.611	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	44
Descrip.	Intermidate beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.525	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	55.8	kN
Fy	3.8	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.2	kNm
Mz	3.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	4.3	0.2	0.0	0.0	0.6	0.0	4.6
Point 2	4.3	0.0	4.1	0.0	0.0	0.0	8.5
Point 3	4.3	4.1		0.0	0.6		8.5
Utilization:							0.03

* $Apply, F_{HI} \approx 81\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	81.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	12.5	21.7
Point 3	0.0	0.0		0.0	12.5		21.7
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	4.3	0.2	0.0	0.0	0.6	0.0	4.6
Point 2	4.3	0.0	4.1	0.0	0.0	12.5	23.3
Point 3	4.3	4.1		0.0	13.1		24.3
Utilization:							0.08

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
44	3	23	55.789	3.842	-0.008	-0.020	-0.134	3.450
		24	-55.789	3.544	0.008	0.020	0.158	-3.002

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting for cooler module

$F_{HI} \approx 81\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

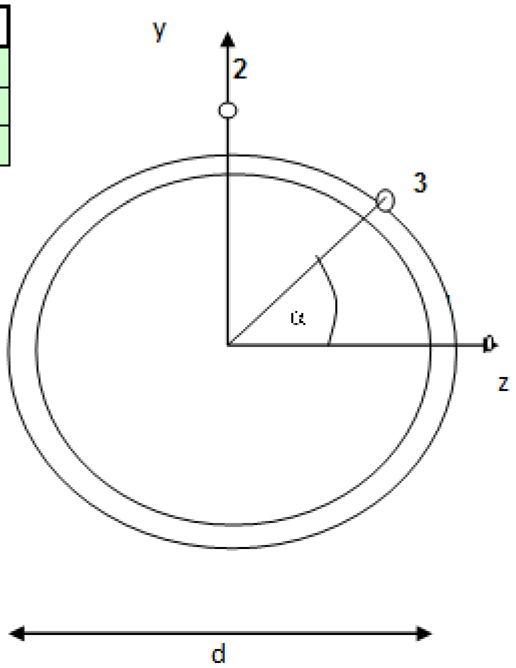
$F_{HIR} \approx 49\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	80
Descrip.	Bottom middel beam
Analysis:	Air lifting

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.563	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	21.7	kN
Fy	159.1	kN
Fz	0.9	kN
Mx	18.9	kNm
My	1.3	kNm
Mz	157.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY (Bot. mid.beam takes no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.7	1.6	0.0	11.4	24.6	0.0	**62.4**
Point 2	1.7	0.0	189.1	11.4	0.0	0.1	**191.8**
Point 3	1.7	189.1		11.4	24.6		**200.7**
Utilization:							**0.65**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module air lift

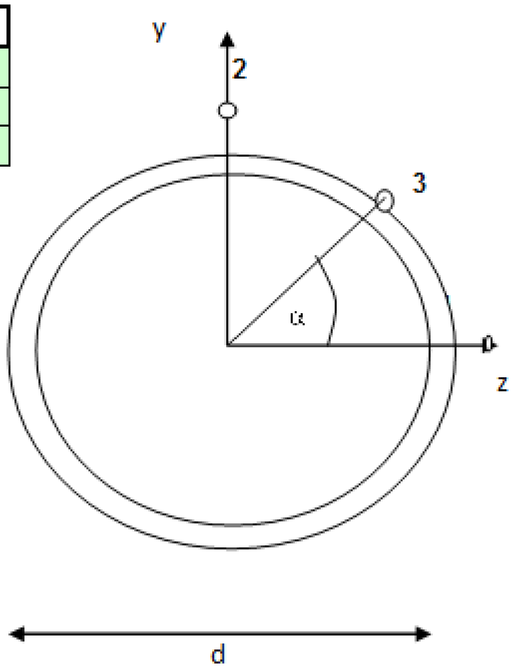
Air lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
80	3	20	-21.661	159.099	0.908	18.930	-0.965	109.570
		31	21.661	-49.480	-0.908	-18.930	-1.306	157.541

Appendix C5: Von Mises yield criteria for offshore lifting and horizontal impact-Case B:Cooler module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	9
Descrip.	Corner post
Analysis:	Offshore lift and horizon.impact



SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.061	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	134.3	kN
Fy	20.1	kN
Fz	11.8	kN
Mx	0.9	kNm
My	41.6	kNm
Mz	74.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	10.4	50.0	0.0	0.5	3.1	0.0	**60.7**
Point 2	10.4	0.0	89.4	0.5	0.0	1.8	**99.9**
Point 3	10.4	102.4		0.5	3.6		**113.0**
Utilisation:							**0.37**

$* Apply, F_{HIsub} \approx 56\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	56.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	8.7	**15.0**
Point 3	0.0	0.0		0.0	8.7		**15.0**
Utilisation:							**0.05**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	10.4	50.0	0.0	0.5	3.1	0.0	**60.7**
Point 2	10.4	0.0	89.4	0.5	0.0	10.5	**101.6**
Point 3	10.4	102.4		0.5	12.3		**115.0**
Utilisation:							0.37

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
9	3	1	-110.381	-20.115	11.814	0.878	-41.619	-66.330
		5	134.278	20.115	-11.814	-0.878	-41.076	-74.477

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for cooler module

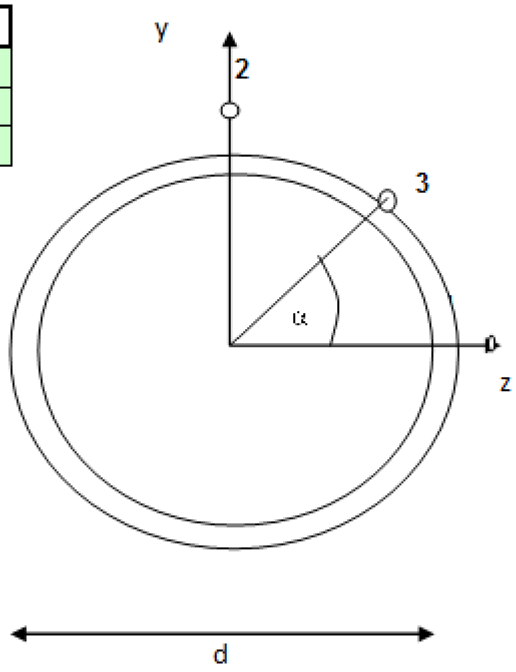
$F_{HIsub} \approx 56\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

$F_{HIRsub} \approx 34\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	17
Descrip.	Middel corner post
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.571	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	21.8	kN
Fy	23.0	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	100.1	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.7	0.0	0.0	0.0	3.6	0.0	**6.4**
Point 2	1.7	0.0	120.1	0.0	0.0	0.0	**121.8**
Point 3	1.7	120.1		0.0	3.6		**121.9**
Utilization:							0.40

$* Apply, F_{HIsub} \approx 56\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	56.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	8.7	**15.0**
Point 3	0.0	0.0		0.0	8.7		**15.0**
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	1.7	0.0	0.0	0.0	3.6	0.0	6.4
Point 2	1.7	0.0	120.1	0.0	0.0	8.7	122.7
Point 3	1.7	120.1		0.0	12.2		123.6
Utilization:							0.40

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
17	3	10	21.812	-23.041	-0.003	0.021	0.017	-100.070
		9	2.085	23.041	0.003	-0.021	0.007	-61.215

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for cooler module

$F_{HIsub} \approx 56\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

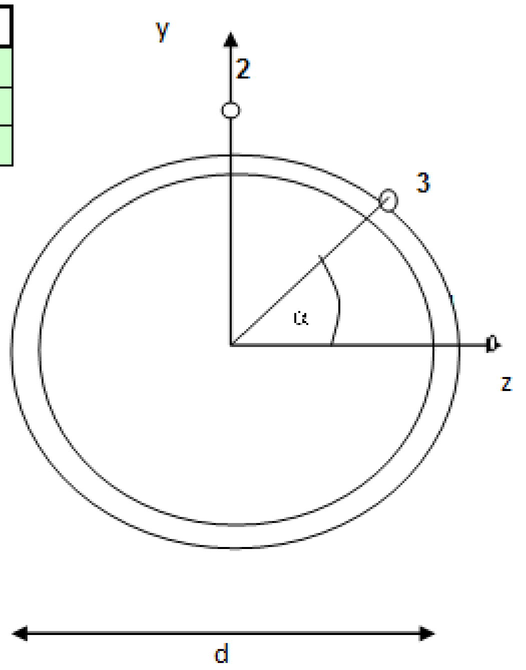
$F_{HIRsub} \approx 34\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	24
Descrip.	Top beam
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.143	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	929.3	kN
Fy	12.0	kN
Fz	8.8	kN
Mx	19.0	kNm
My	16.0	kNm
Mz	35.1	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	71.9	19.2	0.0	11.4	1.9	0.0	**94.0**
Point 2	71.9	0.0	42.1	11.4	0.0	1.4	**116.2**
Point 3	71.9	46.3		11.4	2.3		**120.6**
Utilization:							0.39

$* \mathit{Apply}, F_{HIRsub} \approx 34\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	34.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	5.3	**9.1**
Point 3	0.0	0.0		0.0	5.3		**9.1**
Utilization:							0.03

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	71.9	19.2	0.0	11.4	1.9	0.0	**94.0**
Point 2	71.9	0.0	42.1	11.4	0.0	6.6	**118.3**
Point 3	71.9	46.3		11.4	7.6		**122.7**
Utilization:							**0.40**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
24	3	14	929.258	-1.724	8.823	18.981	-10.463	-35.115
		7	-929.258	11.966	-8.823	-18.981	-16.004	14.581

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for cooler module

$F_{HIsub} \approx 56\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

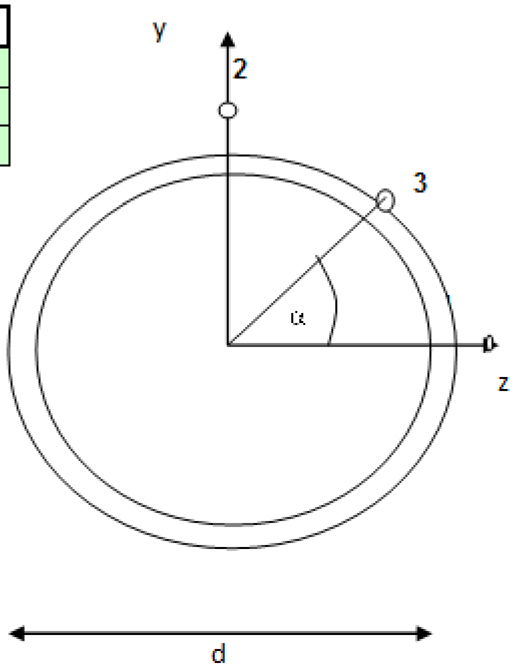
$F_{HIRsub} \approx 34\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	35
Descrip.	Brace
Analysis:	Offshore lifting

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	443.5	kN
Fy	0.8	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY (Braces take no impact)

	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	217.8	0.0	0.0	0.0	0.8	0.0	**217.8**
Point 2	217.8	0.0	0.0	0.0	0.0	0.0	**217.8**
Point 3	217.8	0.0		0.0	0.8		**217.8**
Utilisation:							**0.71**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

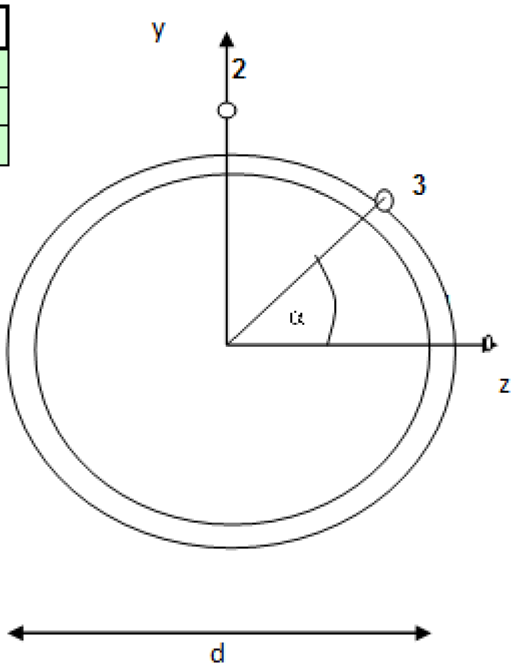
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
35	3	6	-443.468	0.847	0.000	0.000	0.000	0.000
		17	439.514	0.847	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	27
Descrip.	Bottom beam
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.547	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	256.0	kN
Fy	61.1	kN
Fz	0.0	kN
Mx	0.1	kNm
My	0.4	kNm
Mz	17.3	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	19.8	0.5	0.0	0.0	9.5	0.0	26.1
Point 2	19.8	0.0	20.8	0.0	0.0	0.0	40.6
Point 3	19.8	20.8		0.0	9.5		43.8
Utilization:							0.14

$* Apply, F_{HIsub} \approx 56\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	56.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	8.7	15.0
Point 3	0.0	0.0		0.0	8.7		15.0
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	19.8	0.5	0.0	0.0	9.5	0.0	26.1
Point 2	19.8	0.0	20.8	0.0	0.0	8.7	43.3
Point 3	19.8	20.8		0.0	18.1		51.4
Utilization:							0.17

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
27	3	17	-256.000	61.101	0.008	-0.060	-0.410	17.325
		18	256.000	60.729	-0.008	0.060	0.385	-16.766

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for cooler module

$F_{HIsub} \approx 56\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

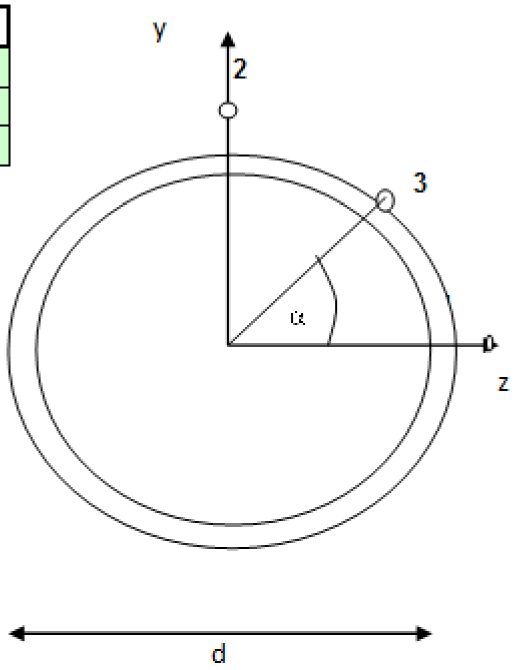
$F_{HIRsub} \approx 34\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	44
Descrip.	Intermidate beam
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.525	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	77.4	kN
Fy	5.3	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.2	kNm
Mz	4.8	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	6.0	0.3	0.0	0.0	0.8	0.0	**6.4**
Point 2	6.0	0.0	5.7	0.0	0.0	0.0	**11.7**
Point 3	6.0	5.7		0.0	0.8		**11.8**
Utilization:							0.04

$* Apply, F_{HIsub} \approx 56\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	56.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	8.7	**15.0**
Point 3	0.0	0.0		0.0	8.7		**15.0**
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	6.0	0.3	0.0	0.0	0.8	0.0	**6.4**
Point 2	6.0	0.0	5.7	0.0	0.0	8.7	**19.1**
Point 3	6.0	5.7		0.0	9.5		**20.2**
Utilization:							0.07

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
44	3	23	77.360	5.328	-0.011	-0.027	-0.186	4.784
		24	-77.360	4.914	0.011	0.027	0.219	-4.163

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for cooler module

$F_{HIsub} \approx 56\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

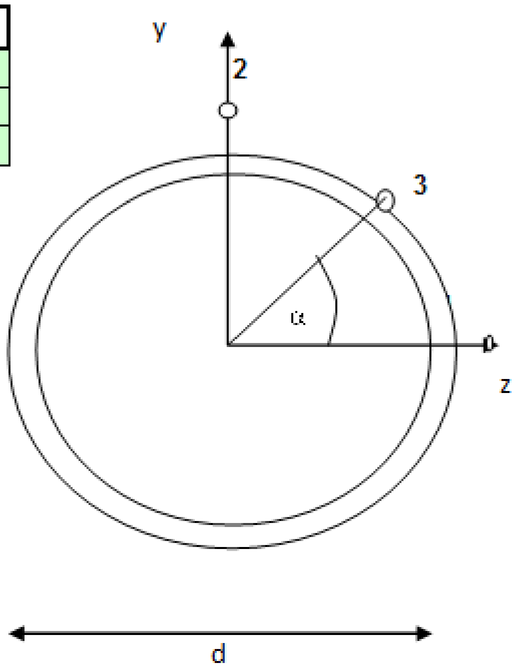
$F_{HIRsub} \approx 34\ kN$ -To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	80
Descrip.	Bottom middel beam
Analysis:	Offshore lifting

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.563	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	30.0	kN
Fy	220.6	kN
Fz	1.3	kN
Mx	26.3	kNm
My	1.8	kNm
Mz	218.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFF. LIFTING ONLY (Bot. mid.beam takes no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.3	2.2	0.0	15.8	34.2	0.0	86.6
Point 2	2.3	0.0	262.2	15.8	0.0	0.2	265.9
Point 3	2.3	262.2		15.8	34.2		278.3
Utilisation:							0.90

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module offshore lift

Offshore lift cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
80	3	20	-30.037	220.618	1.260	26.250	-1.338	151.937
		31	30.037	-68.612	-1.260	-26.250	-1.811	218.457

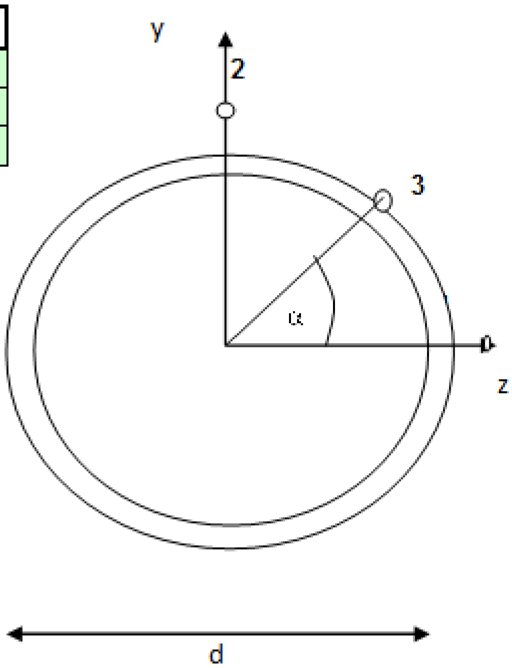
Appendix C6: Von Mises yield criteria for transportation-Case B:Cooler module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	9
Descrip.	Corner post
Analysis:	Transport analysis

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.374	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	286.5	kN
Fy	12.6	kN
Fz	2.0	kN
Mx	0.1	kNm
My	7.1	kNm
Mz	35.3	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	22.2	8.5	0.0	0.1	1.9	0.0	30.9
Point 2	22.2	0.0	42.4	0.1	0.0	0.3	64.6
Point 3	22.2	43.2		0.1	2.0		65.5
Utilization:							0.21

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

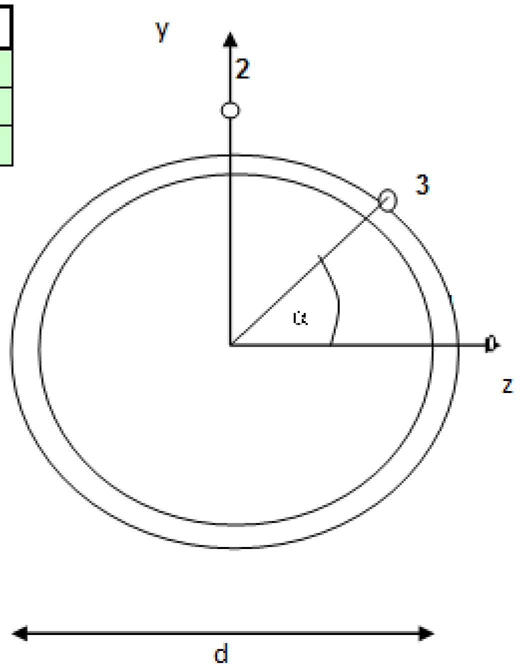
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
9	31	1	286.470	-12.582	1.964	0.148	-7.061	-35.331
		5	-268.854	2.625	-1.964	-0.148	-6.686	-17.893

VON MISES YIELD CRITERION

GENERAL	
Beam No.	17
Descrip.	Middel post
Analysis:	Transport analysis

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.571	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	9.7	kN
Fy	13.1	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	45.8	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.7	0.0	0.0	0.0	2.0	0.0	3.6
Point 2	0.7	0.0	55.0	0.0	0.0	0.0	55.7
Point 3	0.7	55.0		0.0	2.0		55.8
Utilization:							0.18

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

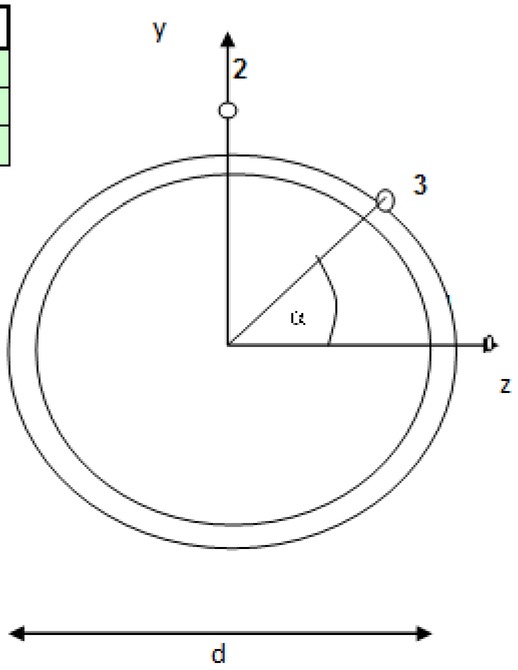
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
17	17	10	0.291	-13.117	0.001	0.006	-0.003	-45.817
		9	9.666	5.458	-0.001	-0.006	-0.008	-19.197

VON MISES YIELD CRITERION

GENERAL	
Beam No.	19
Descrip.	Brace
Analysis:	Transport analysis

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	37.6	kN
Fy	0.9	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	18.5	0.0	0.0	0.0	0.9	0.0	**18.5**
Point 2	18.5	0.0	0.0	0.0	0.0	0.0	**18.5**
Point 3	18.5	0.0		0.0	0.9		**18.5**
Utilisation:							0.06

INPUT LOADS

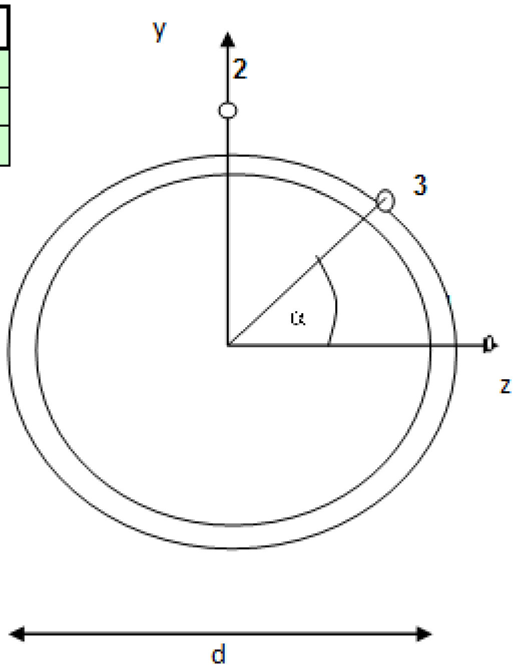
1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
19	34	5	37.376	-0.892	0.000	0.000	0.000	0.000
		10	-37.584	-0.892	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	24
Descrip.	Top beam
Analysis:	Transport analysis



SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.431	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR TRANSPORT		
Fx	74.9	kN
Fy	17.9	kN
Fz	1.9	kN
Mx	5.0	kNm
My	3.3	kNm
Mz	23.4	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	5.8	4.0	0.0	3.0	2.8	0.0	**14.0**
Point 2	5.8	0.0	28.1	3.0	0.0	0.3	**34.4**
Point 3	5.8	28.4		3.0	2.8		**35.6**
Utilization:							**0.12**

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

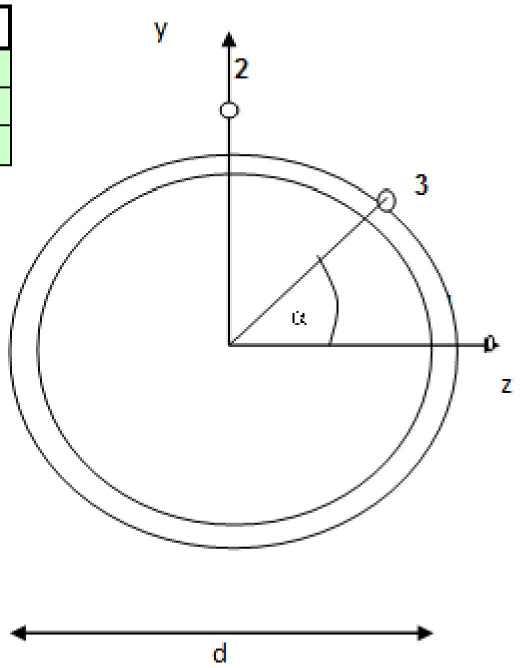
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
24	21	14	72.644	-11.314	1.896	4.981	-2.387	-23.423
		7	-74.942	17.879	-1.896	-4.981	-3.302	-20.366

VON MISES YIELD CRITERION

GENERAL	
Beam No.	28
Descrip.	Bottom beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.566	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	72.6	kN
Fy	62.3	kN
Fz	0.2	kN
Mx	15.7	kNm
My	0.4	kNm
Mz	78.8	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	5.6	0.5	0.0	9.4	9.6	0.0	**33.6**
Point 2	5.6	0.0	94.5	9.4	0.0	0.0	**101.5**
Point 3	5.6	94.5		9.4	9.6		**105.5**
Utilization:							0.34

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

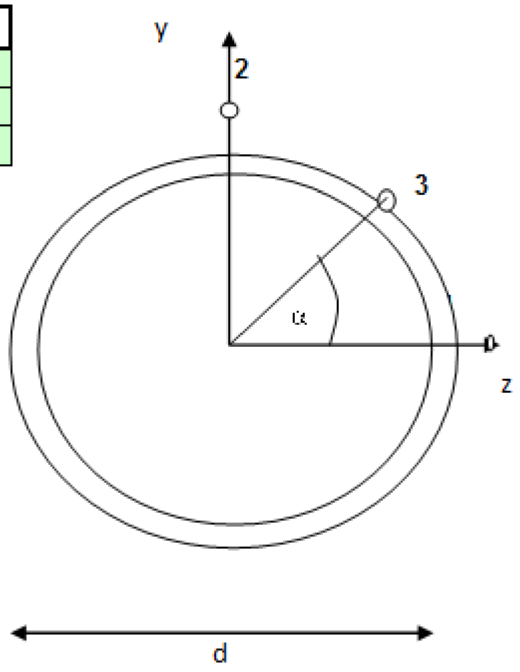
Transport cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
28	31	18	72.598	-37.263	-0.177	-15.711	0.052	-39.580
		38	-69.042	62.289	0.177	15.711	0.389	-78.757

VON MISES YIELD CRITERION

GENERAL	
Beam No.	44
Descrip.	Intermidate beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.565	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR TRANSPORT		
Fx	54.9	kN
Fy	10.3	kN
Fz	0.0	kN
Mx	0.2	kNm
My	0.1	kNm
Mz	13.3	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	$\sigma x1$	$\sigma by1$	$\sigma bz1$	$\tau x1$	$\tau y1$	$\tau z1$	$\sigma e1$
Point 1	4.3	0.1	0.0	0.1	1.6	0.0	5.3
Point 2	4.3	0.0	16.0	0.1	0.0	0.0	20.2
Point 3	4.3	16.0		0.1	1.6		20.4
Utilization:							0.07

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

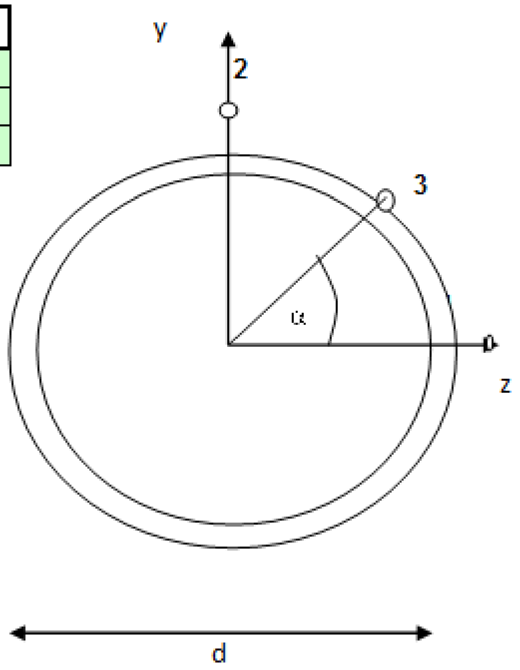
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
44	31	23	54.942	10.320	0.003	0.201	-0.080	13.307
		24	-50.674	-2.770	-0.003	-0.201	0.072	6.328

VON MISES YIELD CRITERION

GENERAL	
Beam No.	60
Descrip.	Bottom middel beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.562	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	2.2	kN
Fy	95.7	kN
Fz	0.6	kN
Mx	10.1	kNm
My	0.8	kNm
Mz	93.6	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS

	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.2	1.0	0.0	6.1	14.8	0.0	**36.2**
Point 2	0.2	0.0	112.3	6.1	0.0	0.1	**113.0**
Point 3	0.2	112.3		6.1	14.8		**118.1**
Utilization:							0.38

INPUT LOADS

1.0 -End forces from Staad analysis for cooler module transport analysis

Transport cooler.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
60	27	20	-0.295	95.732	-0.574	10.133	0.826	67.903
		31	2.210	-30.482	0.574	-10.133	0.610	93.554

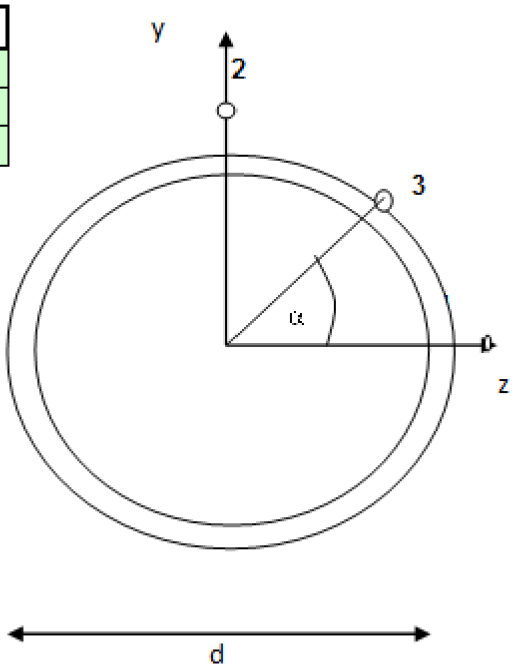
Appendix C7: Von Mises yield criteria for air lifting and horizontal impact-Case C:Compressor module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	12
Descrip.	Top beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.441	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	219.2	kN
Fy	59.3	kN
Fz	4.5	kN
Mx	3.1	kNm
My	8.0	kNm
Mz	61.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY

	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	14.2	6.7	0.0	1.3	7.7	0.0	26.0
Point 2	14.2	0.0	51.0	1.3	0.0	0.6	65.3
Point 3	14.2	51.5		1.3	7.7		67.4
Utilization:							0.22

$* \, Apply, F_{HIR} \approx 61 \, kN$

MEMBER FORCES FOR IMPACT

Fx	0.0	kN
Fy	0.0	kN
Fz	61.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY

	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	7.9	13.6
Point 3	0.0	0.0		0.0	7.9		13.6
Utilization:							0.04

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	14.2	6.7	0.0	1.3	7.7	0.0	**26.0**
Point 2	14.2	0.0	51.0	1.3	0.0	8.5	**67.3**
Point 3	14.2	51.5		1.3	15.6		**71.8**
Utilization:							0.23

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
12	3	5	219.243	59.344	-4.487	-3.144	7.986	51.810
		13	-219.243	-53.445	4.487	3.144	0.989	60.979

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting of compressor module

$F_{HI(air)} \approx 102\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

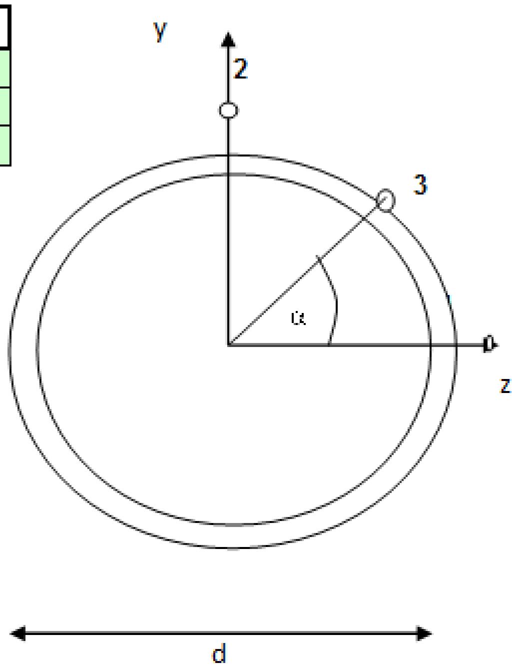
$F_{HIR(air)} \approx 61\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	21
Descrip.	Middel post
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.550	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	327.0	kN
Fy	53.1	kN
Fz	1.8	kN
Mx	0.1	kNm
My	2.6	kNm
Mz	127.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	21.1	2.2	0.0	0.0	6.9	0.0	**26.2**
Point 2	21.1	0.0	106.2	0.0	0.0	0.2	**127.3**
Point 3	21.1	106.2		0.0	6.9		**127.9**
Utilization:							**0.41**

$* \, Apply, F_{HI} \approx 102 \, kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	102.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	13.2	**22.8**
Point 3	0.0	0.0		0.0	13.2		**22.8**
Utilization:							**0.07**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	21.1	2.2	0.0	0.0	6.9	0.0	**26.2**
Point 2	21.1	0.0	106.2	0.0	0.0	13.4	**129.5**
Point 3	21.1	106.2		0.0	20.0		**132.0**
Utilization:							0.43

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
21	3	16	-326.967	-53.128	1.830	0.078	-2.542	-21.791
		14	318.709	53.128	-1.830	-0.078	-2.581	-126.967

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting of compressor module

$F_{HI(air)} \approx 102\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

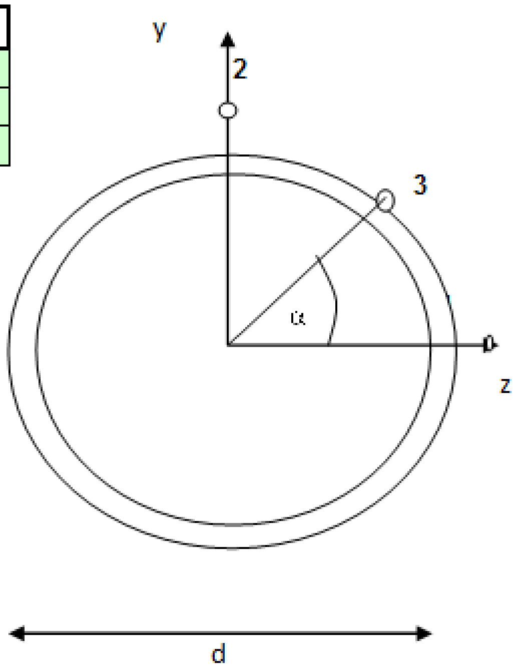
$F_{HIR(air)} \approx 61\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	29
Descrip.	Intermidate beam
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.925	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	77.5	kN
Fy	48.9	kN
Fz	27.7	kN
Mx	6.5	kNm
My	35.7	kNm
Mz	47.3	kNm

Von Mises: $[(\sigma x + \sigma by + \sigma bz)^2 + 3(\tau x + \tau y + \tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY

	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	5.0	29.8	0.0	2.7	6.3	0.0	38.2
Point 2	5.0	0.0	39.6	2.7	0.0	3.6	45.9
Point 3	5.0	49.5		2.7	7.3		57.2
Utilization:							0.19

$* Apply, F_{HI} \approx 102\ kN$

MEMBER FORCES FOR IMPACT

Fx	0.0	kN
Fy	0.0	kN
Fz	102.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY

	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	13.2	22.8
Point 3	0.0	0.0		0.0	13.2		22.8
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	5.0	29.8	0.0	2.7	6.3	0.0	38.2
Point 2	5.0	0.0	39.6	2.7	0.0	16.8	55.9
Point 3	5.0	49.5		2.7	20.4		67.7
Utilization:							0.22

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
29	3	16	77.499	-42.952	-27.696	6.451	35.661	-47.287
		17	-77.499	48.851	27.696	-6.451	19.732	-44.517

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting of compressor module

$F_{HI(air)} \approx 102\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

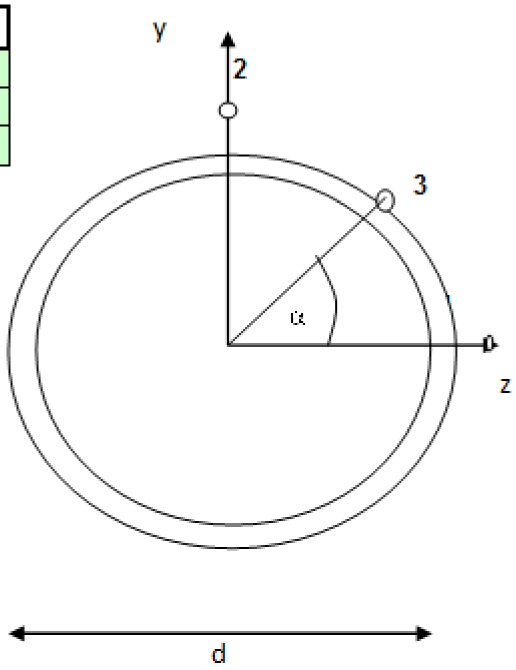
$F_{HIR(air)} \approx 61\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	30
Descrip.	Corner post
Analysis:	Air lift and horizontal impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.032	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	213.9	kN
Fy	84.2	kN
Fz	29.4	kN
Mx	1.2	kNm
My	51.1	kNm
Mz	85.5	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	13.8	42.8	0.0	0.5	10.9	0.0	59.9
Point 2	13.8	0.0	71.6	0.5	0.0	3.8	85.7
Point 3	13.8	83.4		0.5	11.5		99.4
Utilization:							0.32

$* Apply, F_{HI} \approx 102\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	102.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	13.2	22.8
Point 3	0.0	0.0		0.0	13.2		22.8
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	13.8	42.8	0.0	0.5	10.9	0.0	**59.9**
Point 2	13.8	0.0	71.6	0.5	0.0	17.0	**90.6**
Point 3	13.8	83.4		0.5	24.7		**106.6**
Utilization:							0.35

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
30	3	22	-213.885	-84.221	29.413	1.208	9.968	-32.365
		3	209.756	84.221	-29.413	-1.208	-51.145	-85.544

2.0 -Horizontal impact loads

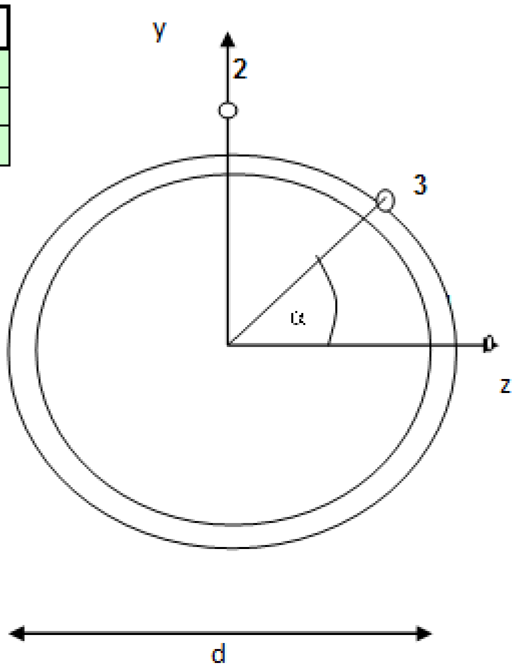
Refer attached calcaulations for horizontal impact loads during air lifting of compressor module

$F_{HI(air)} \approx 102\ kN$ -To be applied on corner posts , bottom beams and intermediate beams
$F_{HIR(air)} \approx 61\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	62
Descrip.	Brace
Analysis:	Air lifting

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR AIR LIFT		
Fx	71.3	kN
Fy	0.4	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY (Braces take no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	35.0	0.0	0.0	0.0	0.4	0.0	35.0
Point 2	35.0	0.0	0.0	0.0	0.0	0.0	35.0
Point 3	35.0	0.0		0.0	0.4		35.0
Utilisation:							0.11

INPUT LOADS

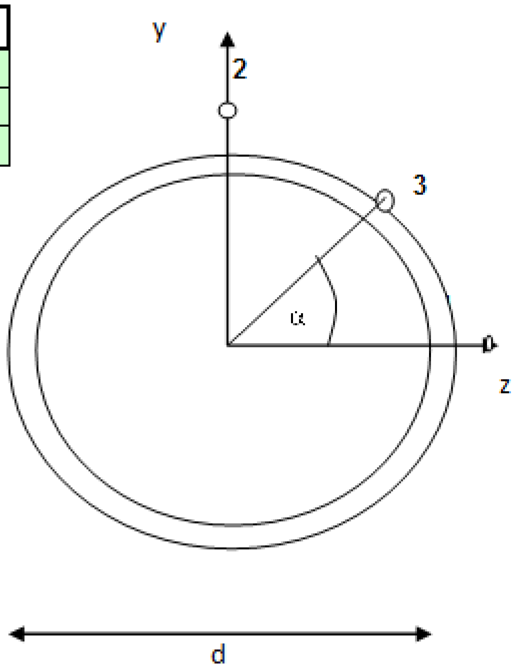
1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
62	3	31	69.573	0.407	0.000	0.000	0.000	0.000
		20	-71.284	0.407	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	101
Descrip.	Bottom beam
Analysis:	Air lift and horizontal impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.510	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR AIR LIFT		
Fx	24.6	kN
Fy	148.3	kN
Fz	2.6	kN
Mx	84.5	kNm
My	5.5	kNm
Mz	90.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.6	4.6	0.0	35.4	19.2	0.0	94.6
Point 2	1.6	0.0	75.9	35.4	0.0	0.3	99.1
Point 3	1.6	76.0		35.4	19.2		122.2
Utilization:							0.40

* Apply , $F_{HI} \approx 102\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	102.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	13.2	22.8
Point 3	0.0	0.0		0.0	13.2		22.8
Utilization:							0.07

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	1.6	4.6	0.0	35.4	19.2	0.0	**94.6**
Point 2	1.6	0.0	75.9	35.4	0.0	13.5	**114.7**
Point 3	1.6	76.0		35.4	32.3		**140.6**
Utilization:							**0.46**

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
101	3	52	-24.630	-86.194	-2.606	-84.539	5.531	-90.667
		3	24.630	148.301	2.606	84.539	-2.143	-61.754

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during air lifting of compressor module

$F_{HI(air)} \approx 102\ kN$ -To be applied on corner posts , bottom beams and intermediate beams

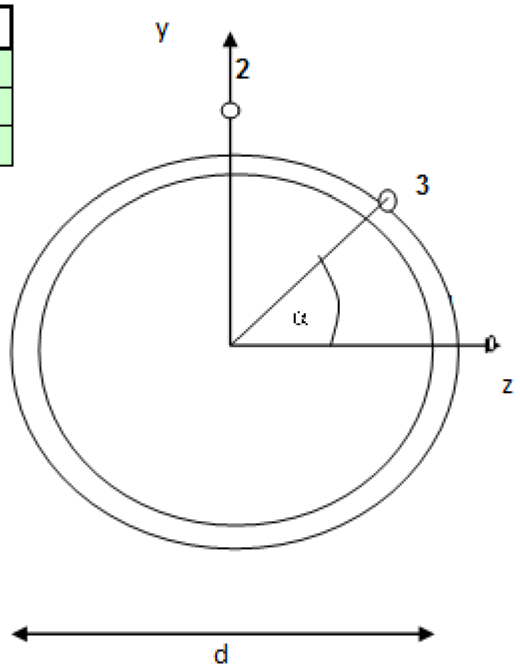
$F_{HIR(air)} \approx 61\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	104
Descrip.	Bottom middel beam
Analysis:	Air lifting

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.561	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR AIR LIFT		
Fx	23.5	kN
Fy	315.4	kN
Fz	0.0	kN
Mx	0.0	kNm
My	1.4	kNm
Mz	147.4	kNm

Von Mises: $[(\sigma x+\sigma by+\sigma bz)^2+3(\tau x+\tau y+\tau z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR AIR LIFTING ONLY (Bot. mid.beam takes no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	1.5	1.2	0.0	0.0	40.7	0.0	**70.6**
Point 2	1.5	0.0	123.3	0.0	0.0	0.0	**124.8**
Point 3	1.5	123.3		0.0	40.7		**143.4**
Utilization:							**0.46**

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module air lift

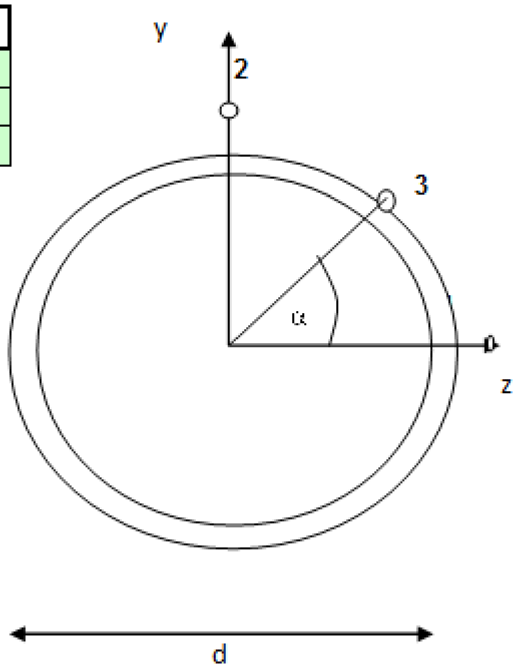
Air lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
104	3	51	-23.496	315.368	0.000	0.000	-1.380	147.387
		54	23.496	315.368	-0.000	-0.000	1.380	-147.387

Appendix C8: Von Mises yield criteria for offshore lifting and horizontal impact- Case C:Compressor module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	12
Descrip.	Top beam
Analysis:	Offshore lift and horizon.impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.441	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	304.0	kN
Fy	82.3	kN
Fz	6.2	kN
Mx	4.4	kNm
My	11.1	kNm
Mz	84.6	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	19.6	9.3	0.0	1.8	10.6	0.0	**36.1**
Point 2	19.6	0.0	70.7	1.8	0.0	0.8	**90.5**
Point 3	19.6	71.3		1.8	10.7		**93.5**
Utilization:							0.30

$* \, Apply, F_{HIRsub} \approx 43 \, kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	43.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	5.6	**9.6**
Point 3	0.0	0.0		0.0	5.6		**9.6**
Utilization:							0.03

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	19.6	9.3	0.0	1.8	10.6	0.0	**36.1**
Point 2	19.6	0.0	70.7	1.8	0.0	6.4	**91.5**
Point 3	19.6	71.3		1.8	16.2		**96.2**
Utilization:							0.31

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
12	3	5	304.018	82.290	-6.222	-4.360	11.073	71.843
		13	-304.018	-74.110	6.222	4.360	1.371	84.557

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for compressor module

$F_{HI(sub)} \approx 71\ kN$-To be applied on corner posts , bottom beams and intermediate

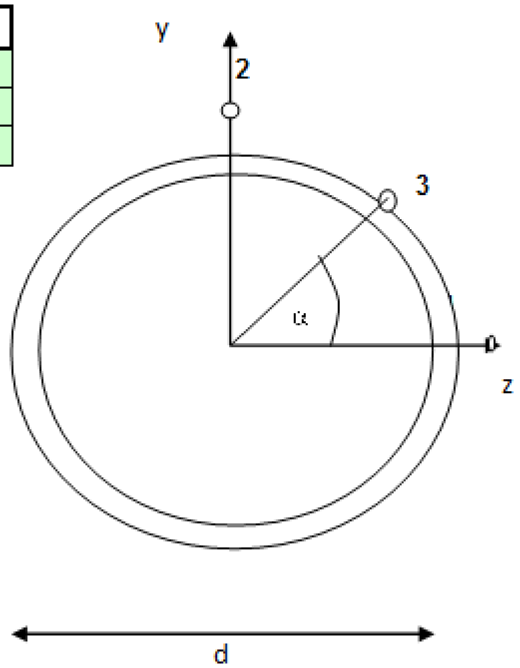
$F_{HIR(sub)} \approx 43\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	21
Descrip.	Middel post
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.550	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	453.4	kN
Fy	73.7	kN
Fz	2.5	kN
Mx	0.1	kNm
My	3.6	kNm
Mz	176.1	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	29.3	3.0	0.0	0.0	9.5	0.0	**36.3**
Point 2	29.3	0.0	147.3	0.0	0.0	0.3	**176.6**
Point 3	29.3	147.3		0.0	9.5		**177.4**
Utilization:							0.57

$* Apply, F_{HIsub} \approx 71\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	71.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	9.2	**15.9**
Point 3	0.0	0.0		0.0	9.2		**15.9**
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	29.3	3.0	0.0	0.0	9.5	0.0	36.3
Point 2	29.3	0.0	147.3	0.0	0.0	9.5	177.4
Point 3	29.3	147.3		0.0	18.7		179.6
Utilization:							0.58

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
21	3	16	-453.394	-73.671	2.537	0.108	-3.525	-30.217
		14	441.942	73.671	-2.537	-0.108	-3.579	-176.062

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for compressor module

$F_{HI(sub)} \approx 71\ kN$-To be applied on corner posts , bottom beams and intermediate

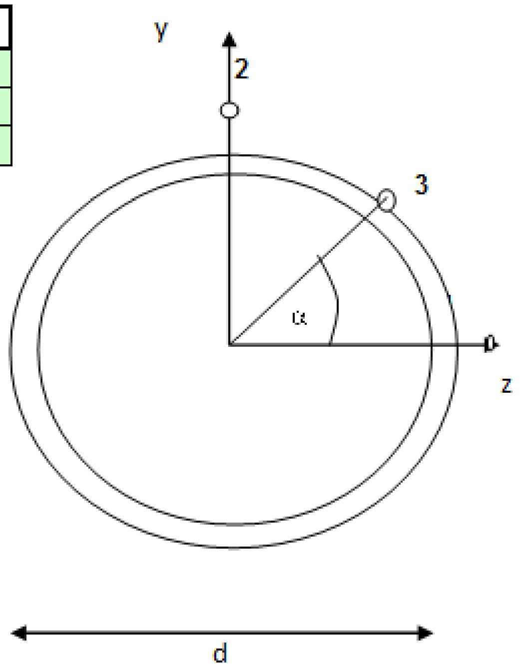
$F_{HIR(sub)} \approx 43\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	29
Descrip.	Intermidate beam
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.925	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	107.5	kN
Fy	67.7	kN
Fz	38.4	kN
Mx	8.9	kNm
My	49.4	kNm
Mz	65.6	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	6.9	41.4	0.0	3.7	8.8	0.0	52.9
Point 2	6.9	0.0	54.9	3.7	0.0	5.0	63.6
Point 3	6.9	68.7		3.7	10.1		79.3
Utilization:							0.26

$* Apply, F_{HIsub} \approx 71\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	71.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Point 2	0.0	0.0	0.0	0.0	0.0	9.2	15.9
Point 3	0.0	0.0		0.0	9.2		15.9
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT

	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	6.9	41.4	0.0	3.7	8.8	0.0	**52.9**
Point 2	6.9	0.0	54.9	3.7	0.0	14.1	**69.1**
Point 3	6.9	68.7		3.7	19.2		**85.5**
Utilization:							**0.28**

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
29	3	16	107.465	-59.561	-38.405	8.946	49.449	-65.571
		17	-107.465	67.741	38.405	-8.946	27.362	-61.731

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for compressor module

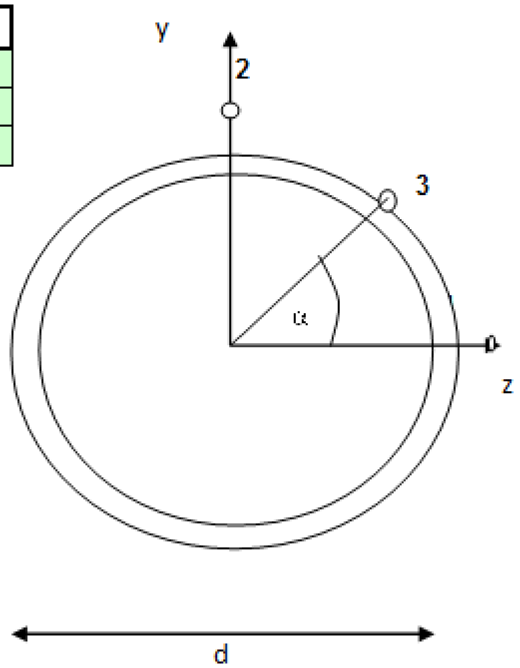
$F_{HI(sub)} \approx 71\ kN$-To be applied on corner posts , bottom beams and intermediate

$F_{HIR(sub)} \approx 43\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	30
Descrip.	Corner post
Analysis:	Offshore lift and horizon.impact

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.032	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4



MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	296.6	kN
Fy	116.8	kN
Fz	40.8	kN
Mx	1.7	kNm
My	70.9	kNm
Mz	118.6	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	19.2	59.3	0.0	0.7	15.1	0.0	**83.1**
Point 2	19.2	0.0	99.2	0.7	0.0	5.3	**118.8**
Point 3	19.2	115.6		0.7	16.0		**137.8**
Utilization:							**0.45**

$* \, Apply, F_{HIsub} \approx 71\ kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	71.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	9.2	**15.9**
Point 3	0.0	0.0		0.0	9.2		**15.9**
Utilization:							**0.05**

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	19.2	59.3	0.0	0.7	15.1	0.0	**83.1**
Point 2	19.2	0.0	99.2	0.7	0.0	14.4	**121.3**
Point 3	19.2	115.6		0.7	25.2		**142.0**
Utilization:							0.46

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
30	3	22	-296.588	-116.786	40.785	1.675	13.822	-44.880
		3	290.862	116.786	-40.785	-1.675	-70.922	-118.621

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for compressor module

$F_{HI(sub)} \approx 71\ kN$-To be applied on corner posts , bottom beams and intermediate

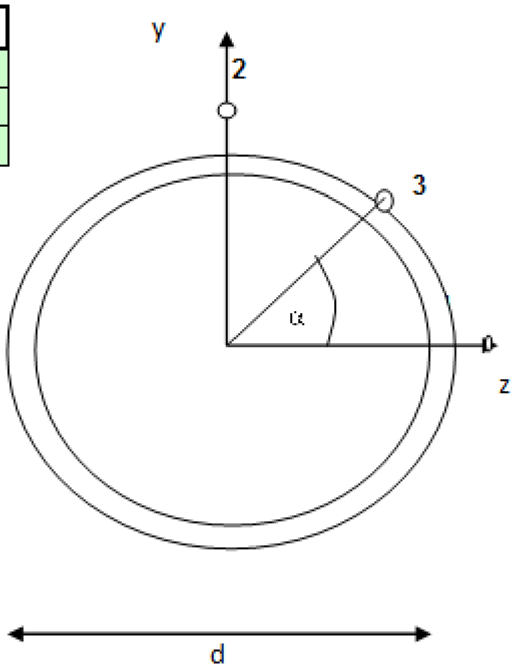
$F_{HIR(sub)} \approx 43\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	62
Descrip.	Brace
Analysis:	Offshore lifting

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	98.8	kN
Fy	0.6	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY (Braces take no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	48.6	0.0	0.0	0.0	0.6	0.0	48.6
Point 2	48.6	0.0	0.0	0.0	0.0	0.0	48.6
Point 3	48.6	0.0		0.0	0.6		48.6
Utilisation:							0.16

INPUT LOADS

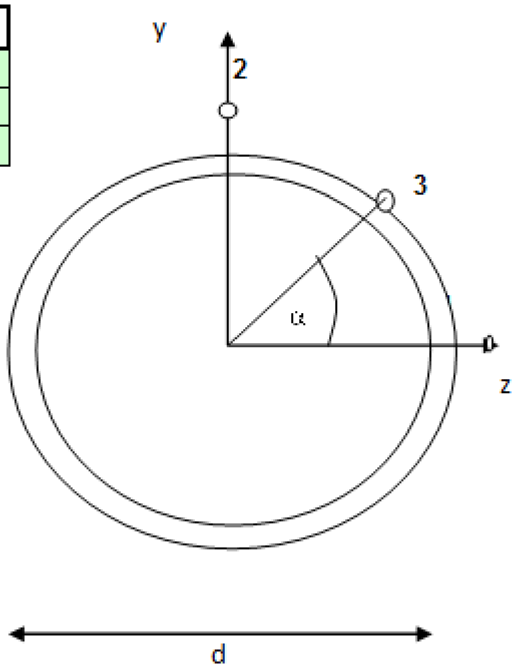
1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
62	3	31	96.475	0.565	0.000	0.000	0.000	0.000
		20	-98.848	0.565	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	101
Descrip.	Bottom beam
Analysis:	Offshore lift and horizon.impact



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.510	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	34.2	kN
Fy	205.6	kN
Fz	3.6	kN
Mx	117.2	kNm
My	7.7	kNm
Mz	125.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING ONLY							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.2	6.4	0.0	49.0	26.6	0.0	**131.2**
Point 2	2.2	0.0	105.2	49.0	0.0	0.5	**137.4**
Point 3	2.2	105.4		49.0	26.6		**169.5**
Utilization:							0.55

$* \, Apply, F_{HIsub} \approx 71 \, kN$

MEMBER FORCES FOR IMPACT		
Fx	0.0	kN
Fy	0.0	kN
Fz	71.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

STRESS CALCULATIONS AND UTILIZATION FOR HORIZONTAL IMPACT ONLY							
	σx2	σby2	σbz2	τx2	τy2	τz2	σe2
Point 1	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Point 2	0.0	0.0	0.0	0.0	0.0	9.2	**15.9**
Point 3	0.0	0.0		0.0	9.2		**15.9**
Utilization:							0.05

*** According to DNV 2.7.3 section 3.6.2 , the impact stress are combined with lifting stress**

STRESS CALCULATIONS AND UTILIZATION FOR OFFSHORE LIFTING AND HORIZONTAL IMPACT							
	σx12	σby12	σbz12	τx12	τy12	τz12	σe
Point 1	2.2	6.4	0.0	49.0	26.6	0.0	**131.2**
Point 2	2.2	0.0	105.2	49.0	0.0	9.6	**147.9**
Point 3	2.2	105.4		49.0	35.7		**182.0**
Utilization:							0.59

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
101	3	52	-34.153	-119.522	-3.614	-117.227	7.670	-125.725
		3	34.153	205.644	3.614	117.227	-2.971	-85.633

2.0 -Horizontal impact loads

Refer attached calcaulations for horizontal impact loads during offshore lifting for compressor module

$F_{HI(sub)} \approx 71\ kN$-To be applied on corner posts , bottom beams and intermediate

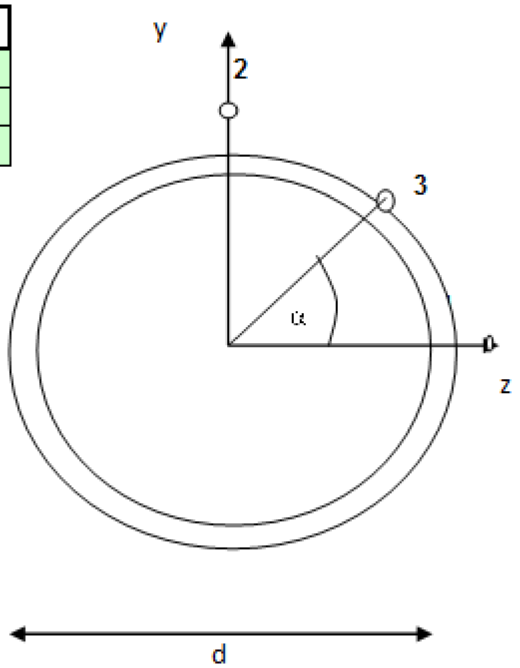
$F_{HIR(sub)} \approx 43\ kN$-To be applied on end/side structure and top beams

VON MISES YIELD CRITERION

GENERAL	
Beam No.	104
Descrip.	Bottom middel beam
Analysis:	Offshore lifting

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	1.561	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR OFFSHOR.LIFT		
Fx	32.6	kN
Fy	437.3	kN
Fz	0.0	kN
Mx	0.0	kNm
My	1.9	kNm
Mz	204.4	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR OFF. LIFTING ONLY (Bot. mid.beam takes no impact)							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.5	2.3	0.0	0.0	67.7	0.0	117.4
Point 2	2.5	0.0	245.3	0.0	0.0	0.0	247.8
Point 3	2.5	245.3		0.0	67.7		274.2
Utilisation:							0.89

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module offshore lift

offshore lift compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
104	3	51	-32.582	437.311	0.000	0.000	-1.914	204.377
		54	32.582	437.311	-0.000	-0.000	1.914	-204.377

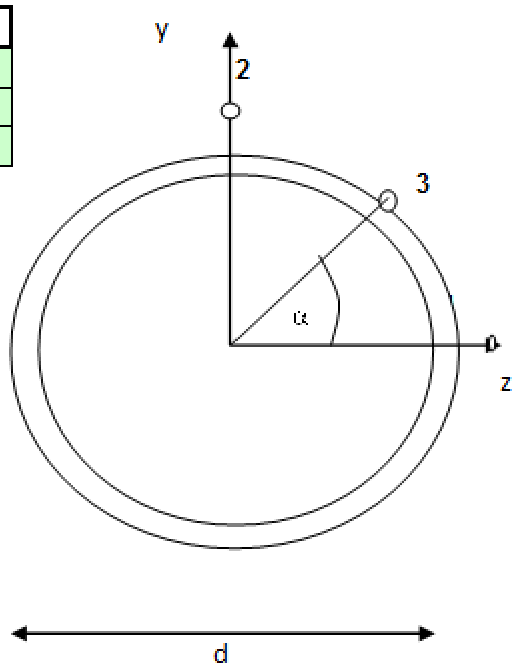
Appendix C9: Von Mises yield criteria for transportation-Case C:Compressor module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	12
Descrip.	Top beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.379	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	22.8	kN
Fy	27.9	kN
Fz	2.9	kN
Mx	0.1	kNm
My	5.2	kNm
Mz	26.9	kNm

Von Mises: $[(\sigma_x + \sigma_{by} + \sigma_{bz})^2 + 3(\tau_x + \tau_y + \tau_z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS

	σ_{x1}	σ_{by1}	σ_{bz1}	τ_{x1}	τ_{y1}	τ_{z1}	σ_{e1}
Point 1	1.5	4.4	0.0	0.0	3.6	0.0	**8.6**
Point 2	1.5	0.0	22.5	0.0	0.0	0.4	**24.0**
Point 3	1.5	22.9		0.0	3.6		**25.2**
Utilization:							**0.08**

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

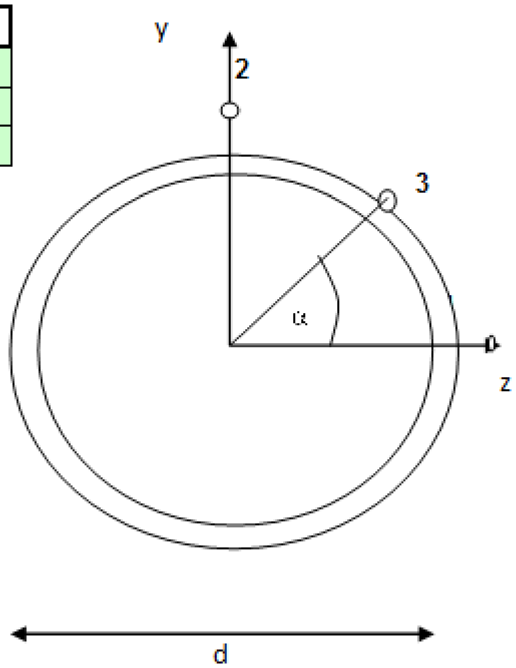
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
12	35	5	-19.369	27.902	-2.901	-0.061	5.226	26.929
		13	22.777	-21.872	2.901	0.061	0.576	22.844

VON MISES YIELD CRITERION

GENERAL	
Beam No.	21
Descrip.	Middel post
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.557	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	136.8	kN
Fy	34.9	kN
Fz	0.6	kN
Mx	1.4	kNm
My	1.1	kNm
Mz	81.2	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	8.8	0.9	0.0	0.6	4.5	0.0	**13.1**
Point 2	8.8	0.0	67.9	0.6	0.0	0.1	**76.8**
Point 3	8.8	67.9		0.6	4.5		**77.3**
Utilization:							0.25

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

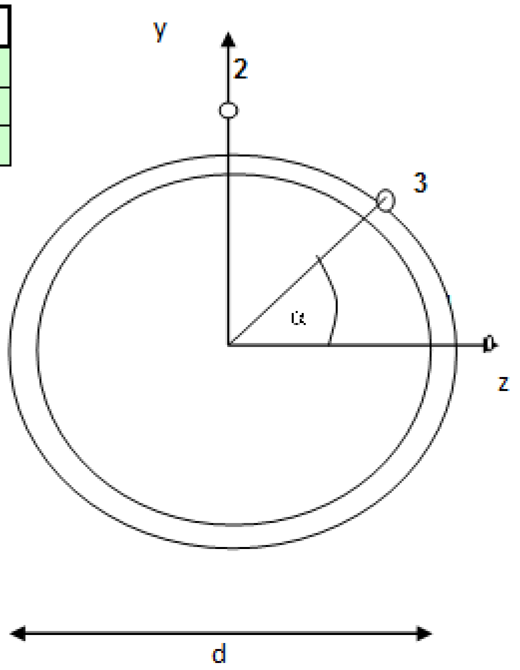
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
21	17	16	-136.817	-31.236	-0.619	1.358	0.637	-11.430
		14	132.046	34.907	0.619	-1.358	1.095	-81.170

VON MISES YIELD CRITERION

GENERAL	
Beam No.	29
Descrip.	Intermidate beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.259	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	39.1	kN
Fy	44.0	kN
Fz	10.7	kN
Mx	3.2	kNm
My	15.4	kNm
Mz	47.7	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	2.5	12.9	0.0	1.3	5.7	0.0	**19.6**
Point 2	2.5	0.0	39.9	1.3	0.0	1.4	**42.7**
Point 3	2.5	41.9		1.3	5.9		**46.1**
Utilization:							**0.15**

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

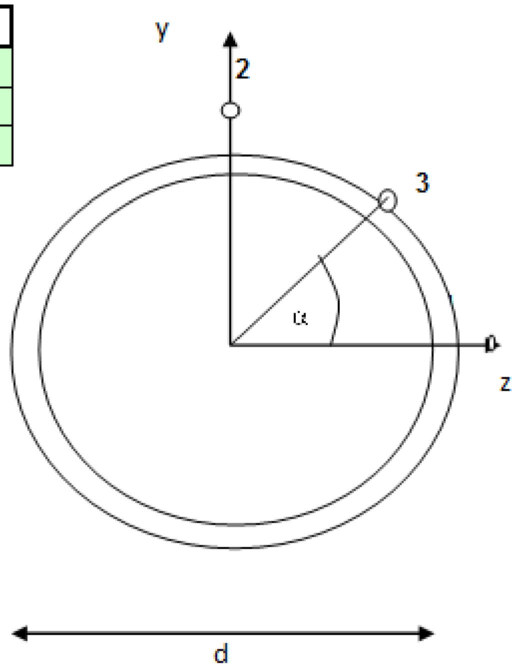
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
29	33	16	35.732	-37.973	-10.732	3.172	15.361	-34.308
		17	-39.140	44.003	10.732	-3.172	6.102	-47.669

VON MISES YIELD CRITERION

GENERAL	
Beam No.	30
Descrip.	Corner post
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.365	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	391.2	kN
Fy	69.2	kN
Fz	11.3	kN
Mx	2.7	kNm
My	18.8	kNm
Mz	89.9	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS

	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	25.3	15.7	0.0	1.1	8.9	0.0	**44.5**
Point 2	25.3	0.0	75.2	1.1	0.0	1.5	**100.6**
Point 3	25.3	76.9		1.1	9.1		**103.6**
Utilization:							0.34

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

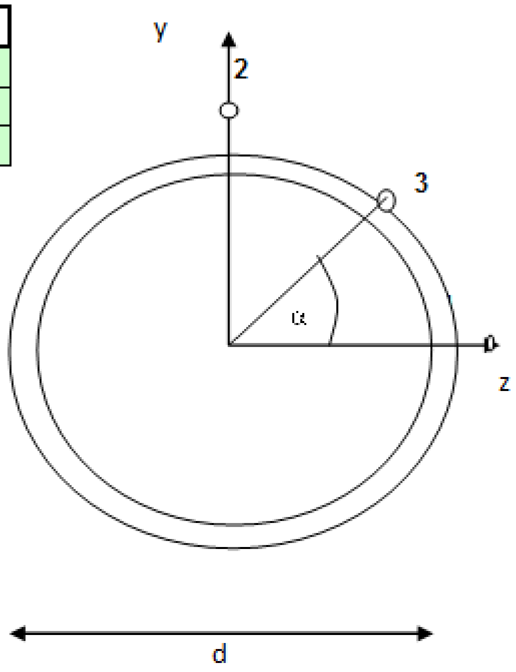
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
30	31	22	386.954	-66.863	11.334	2.651	2.941	-5.348
		3	-391.175	69.248	-11.334	-2.651	-18.809	-89.930

VON MISES YIELD CRITERION

GENERAL	
Beam No.	63
Descrip.	Braces
Analysis:	Transport analysis

SECTION PROPERTIES		
d	114.0	mm
t	6.0	mm
r	54	mm
α	0.785	rad
Ax	2036	mm2
Ay	1018	mm2
Az	1018	mm2
Iy	2.977E+06	mm4
Iz	2.977E+06	mm4
Ix	5.955E+06	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	109.8	kN
Fy	0.1	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	54.0	0.0	0.0	0.0	0.1	0.0	54.0
Point 2	54.0	0.0	0.0	0.0	0.0	0.0	54.0
Point 3	54.0	0.0		0.0	0.1		54.0
Utilization:							0.17

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

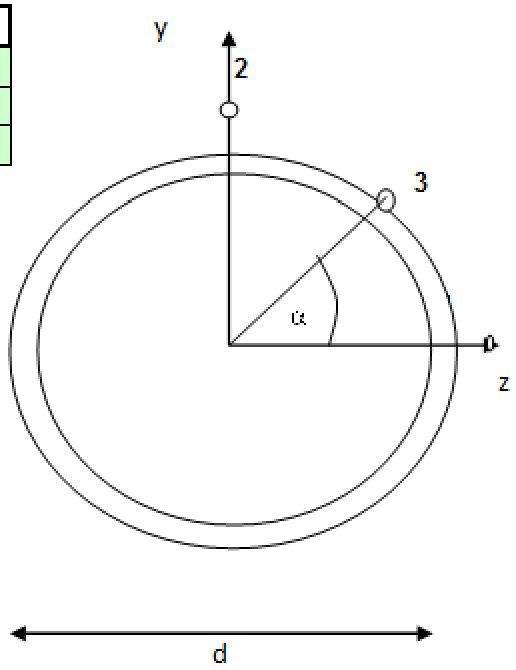
Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
63	35	31	107.627	-0.078	0.000	0.000	0.000	0.000
		30	-109.847	-0.078	-0.000	0.000	0.000	0.000

VON MISES YIELD CRITERION

GENERAL	
Beam No.	101
Descrip.	Bottom beam
Analysis:	Transport analysis

SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.547	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR TRANSPORT		
Fx	18.9	kN
Fy	117.8	kN
Fz	3.7	kN
Mx	41.2	kNm
My	2.5	kNm
Mz	105.7	kNm

Von Mises: $[(\sigma_x + \sigma_{by} + \sigma_{bz})^2 + 3(\tau_x + \tau_y + \tau_z)^2]^{(1/2)}$

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σ_{x1}	σ_{by1}	σ_{bz1}	τ_{x1}	τ_{y1}	τ_{z1}	σ_{e1}
Point 1	1.2	2.1	0.0	17.2	15.2	0.0	**56.3**
Point 2	1.2	0.0	88.5	17.2	0.0	0.5	**94.8**
Point 3	1.2	88.5		17.2	15.2		**105.9**
Utilization:							0.34

INPUT LOADS

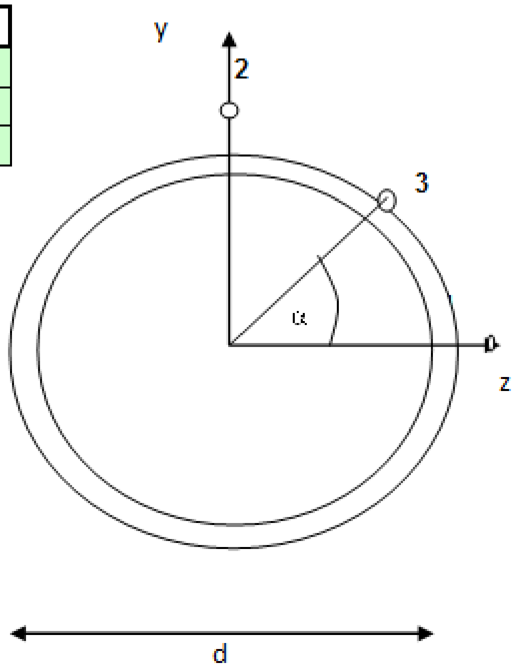
1.0 -End forces from Staad analysis for compressor module transport analysis

Transport compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
101	35	52	18.873	-88.012	-3.716	-41.187	2.481	-28.072
		3	-16.658	117.831	3.716	41.187	2.350	-105.726

VON MISES YIELD CRITERION

GENERAL	
Beam No.	104
Descrip.	Bottom middel beam
Analysis:	Transport analysis



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	1.543	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR TRANSPORT		
Fx	8.7	kN
Fy	184.0	kN
Fz	1.8	kN
Mx	0.0	kNm
My	2.5	kNm
Mz	87.8	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	0.6	2.1	0.0	0.0	23.8	0.0	**41.3**
Point 2	0.6	0.0	73.5	0.0	0.0	0.2	**74.1**
Point 3	0.6	73.5		0.0	23.8		**84.8**
Utilization:							0.27

INPUT LOADS

1.0 -End forces from Staad analysis for compressor module transport analysis

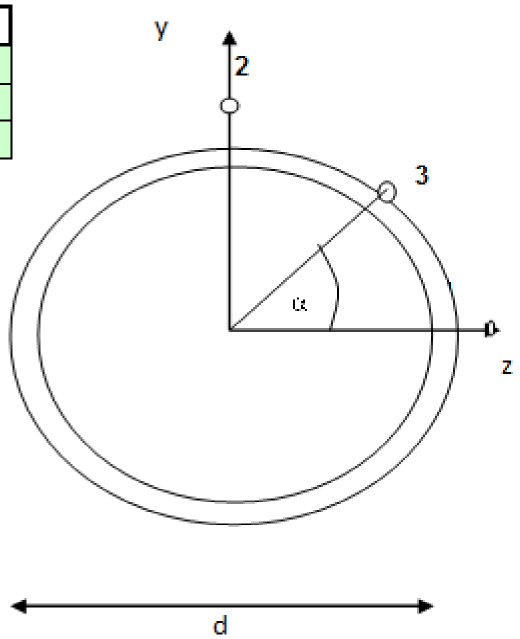
Transport compressor.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
104	27	51	-8.697	184.048	1.835	0.000	-2.460	87.844
		54	8.697	184.048	1.835	-0.000	2.460	-87.844

Appendix C_{10}: Von Mises yield criteria for landing-Case A:Pump module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	212-213-214-215
Descrip.	Corner post
Analysis:	Landing analysis pump model



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.785	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR Lading		
Fx	54.0	kN
Fy	493.0	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	3.5	0.0	0.0	0.0	63.7	0.0	**110.4**
Point 2	3.5	0.0	0.0	0.0	0.0	0.0	**3.5**
Point 3	3.5	0.0		0.0	63.7		**110.4**
Utilisation:							0.36

INPUT LOADS-Pump model

$F_{VI} \approx 54\ kN$ -To be applied on corner post as compression force (in X direction) and horizontal impact of $F_{HI(sub)} \approx 493\ kN$ in Y or Z direction

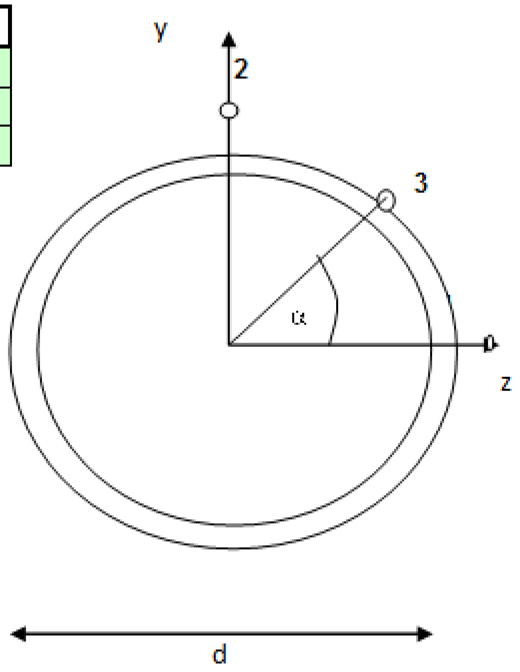
Appendix C_{11}: Von Mises yield criteria for landing-Case B:Cooler module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	84-85-86-87
Descrip.	Corner post
Analysis:	Landing analysis cooler model

SECTION PROPERTIES		
d	273.0	mm
t	16.0	mm
r	128.5	mm
α	0.785	rad
Ax	12918	mm2
Ay	6459	mm2
Az	6459	mm2
Iy	1.071E+08	mm4
Iz	1.071E+08	mm4
Ix	2.141E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-



MEMBER FORCES FOR Lading		
Fx	121.0	kN
Fy	56.0	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx + σby + σbz)^2 + 3(τx + τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	9.4	0.0	0.0	0.0	8.7	0.0	17.7
Point 2	9.4	0.0	0.0	0.0	0.0	0.0	9.4
Point 3	9.4	0.0		0.0	8.7		17.7
Utilisation:							0.06

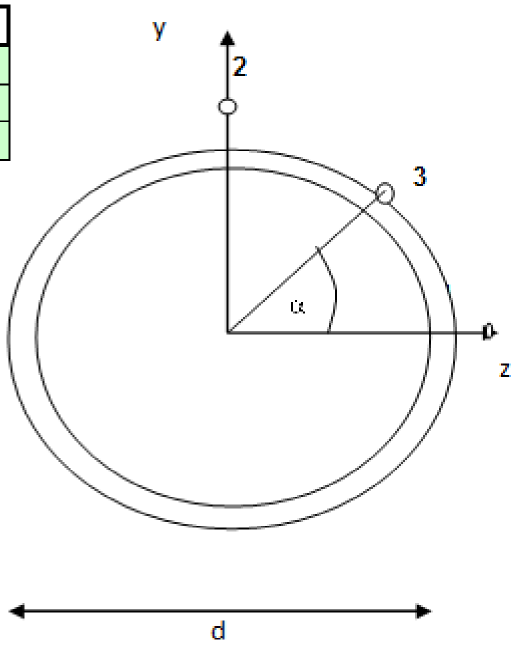
INPUT LOADS-Cooler model

$F_{VI} \approx 121\ kN$ -To be applied on corner post as compression force of cooler model (in X direction) and horizontal impact of $F_{HI(sub)} \approx 56\ kN$ in Y or Z direction

Appendix C12: Von Mises yield criteria for landing-Case C:Compressor module

VON MISES YIELD CRITERION

GENERAL	
Beam No.	13-14-15-16
Descrip.	Corner post
Analysis:	Landing analysis compressor mod.



SECTION PROPERTIES		
d	324.0	mm
t	16.0	mm
r	154	mm
α	0.785	rad
Ax	15482	mm2
Ay	7741	mm2
Az	7741	mm2
Iy	1.841E+08	mm4
Iz	1.841E+08	mm4
Ix	3.682E+08	mm4

MATERIAL		
fy	355.0	N/mm2
γm	1.15	-

MEMBER FORCES FOR Lading		
Fx	152.0	kN
Fy	71.0	kN
Fz	0.0	kN
Mx	0.0	kNm
My	0.0	kNm
Mz	0.0	kNm

Von Mises: [(σx+ σby + σbz)^2 + 3(τx+ τy + τz)^2]^(1/2)

STRESS CALCULATIONS AND UTILIZATION FOR TRANSPORT ANALYSIS							
	σx1	σby1	σbz1	τx1	τy1	τz1	σe1
Point 1	9.8	0.0	0.0	0.0	9.2	0.0	18.7
Point 2	9.8	0.0	0.0	0.0	0.0	0.0	9.8
Point 3	9.8	0.0		0.0	9.2		18.7
Utilisation:							0.06

INPUT LOADS-Compressor model

$F_{VI} \approx 152\ kN$ -To be applied on corner post as compression force of cooler model (in X direction) and horizontal impact of $F_{HI(sub)} \approx 71\ kN$ in Y or Z direction

Appendix D: Colbeam EC3 calculations

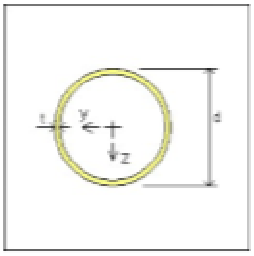
Appendix D1: Colbeam EC3 calculations for air lift Case A:Pump module

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Air lift analysis Pump module 40 tonnes Identification: Beam No.187	Page: 1/1 Date: 4/15/2016 Time: 10:34
File: new file		

General:

Material: S355 NH/NLH   fy = 355 MPa   E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

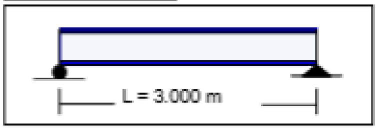
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

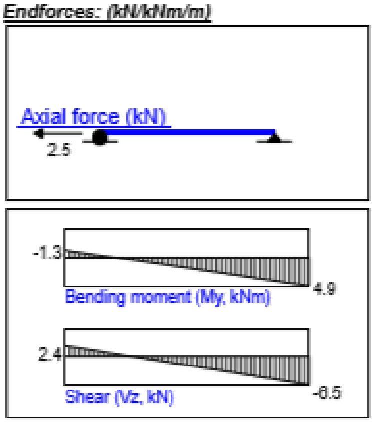
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 4.9/469.0 = 0.01 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 4.9/469.0 = 0.01 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 6.5/1756.6 = 0.00 < 1.0 (1.00L; Ch 6.2.6)

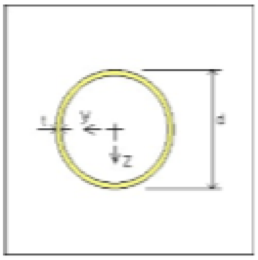
Colbeam EC3 - User defined	Project: Air lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.194	Date: 4/15/2016 Time: 10:41	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:			
d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

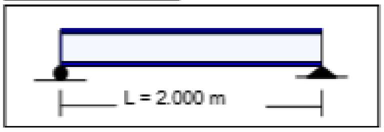
Section property:			
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

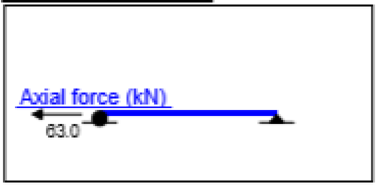
Cross Section Class: 1/2/2 N/My/M

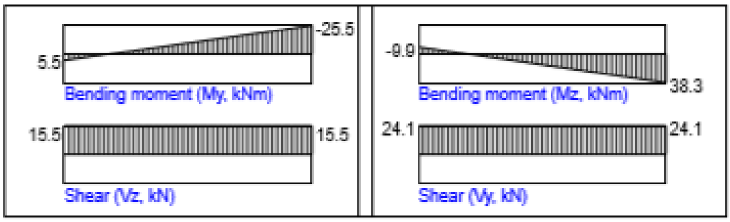
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = Mz,Ed/Mz,Rd = 38.3/469.0 = 0.08 < 1.0 (1.00L; Ch 6.2.5)

IR = Mz,Ed/MN,z,Rd = 38.3/468.7 = 0.08 < 1.0 (1.00L; Ch 6.2.9)

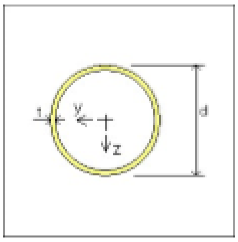
IR = Vy,Ed/Vy,Rd = 24.1/1756.6 = 0.01 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 202	Date: 4/14/2016 Time: 12:16	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

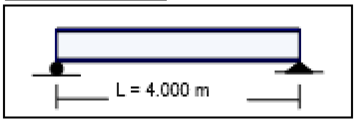
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

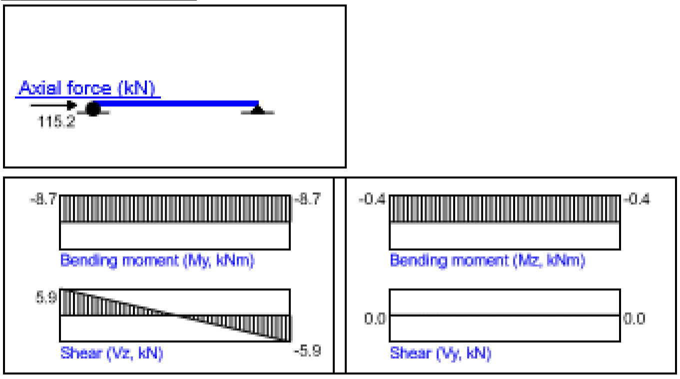
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.48	0.48
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 115.2/4779.2 = **0.02** < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 8.7/468.1 = **0.02** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 5.9/1756.6 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

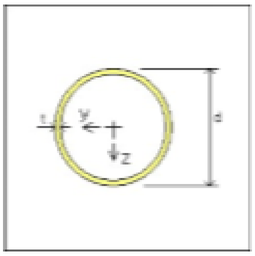
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 115.2/4446.2+1.00*8.7/(1.00*469.0)+0.60*0.4/469.0 = **0.04** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 115.2/4446.2+0.60*8.7/(1.00*469.0)+1.00*0.4/469.0 = **0.04** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Air lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.222	Date: 4/15/2016 Time: 10:38	
File: new file			

General:

Material:	S355 NH/NLH	fy =	355 MPa	E =	210000.0 MPa
gm0/gm1 =	1.15/1.15				

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

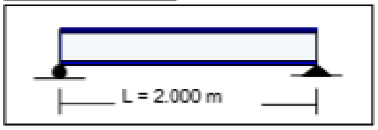
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

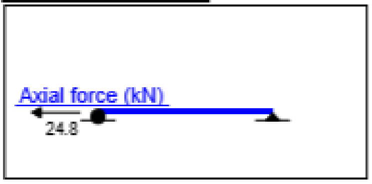
Cross Section Class: 1/2/2 N/My/Mz

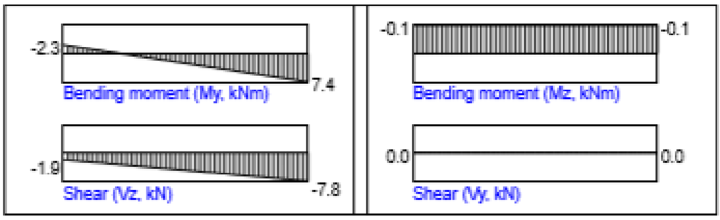
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

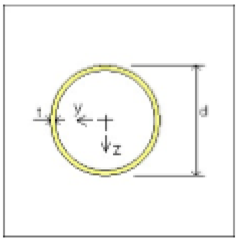
IR = My,Ed/My,Rd = 7.4/469.0 = **0.02** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 7.4/468.9 = **0.02** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 7.8/1756.6 = **0.00** < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 231	Date: 4/14/2016 Time: 12:21	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

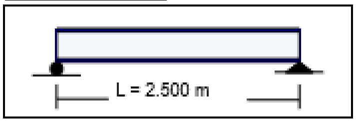
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

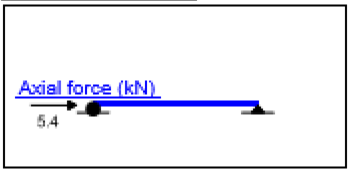
Cross Section Class: 1/2/2 N/My/Mz

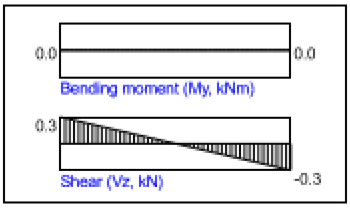
N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.86	0.86
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 5.4/628.4 = **0.01** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.3/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

No Buckling, ref ch 6.3.1.2 (4); lamdaby/lamdabz<=0.2 or Ned/Ncry<=0.04; Ned/Ncry<=0.04 = =

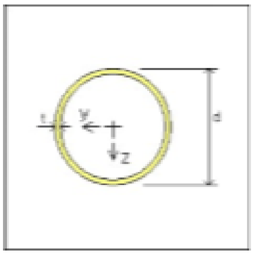
Appendix D2: Colbeam EC3 calculations for offshore lift Case A:Pump module

Colbeam EC3 - User defined	Project: Offshore lift analysis Pump module 40 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.187	Date: 4/15/2016 Time: 10:43
File: new file		

General:

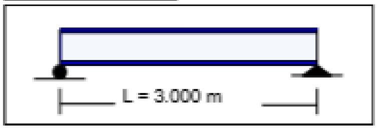
Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 324x16 (Hot finished)

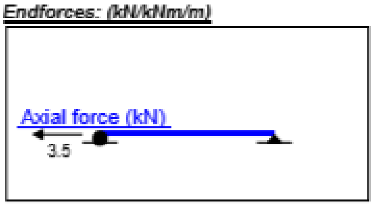


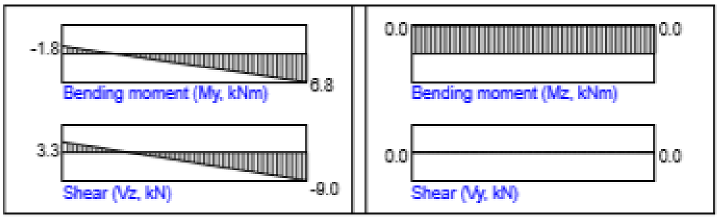
Dimensions and weight:			Section property:			Capacity:		
d	=	324.0 mm	A	=	15482 mm2	Cross Section Class: 1/2/2 N/My/Mz		
t	=	16.0 mm	Ix	=	3.682E+8 mm4	N,Rd	=	4779.2 kN
g	=	121.5 kg/m	Iy	=	1.841E+8 mm4	My,Rd	=	469.0 kNm
S	=	1.018 m2/m	Wel,y	=	1.136E+6 mm3	Vc,z,Rd	=	1756.6 kN
			Wpl,y	=	1.519E+6 mm3			

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

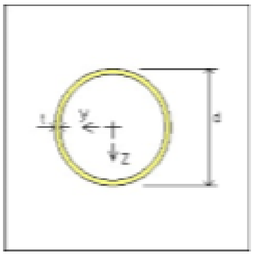
IR = My,Ed/My,Rd = 6.8/469.0 = 0.01 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 6.8/469.0 = 0.01 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 9.0/1756.6 = 0.01 < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.194	Date: 4/15/2016	
		Time: 10:48	
File: new file			

General:

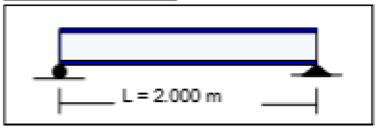
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)

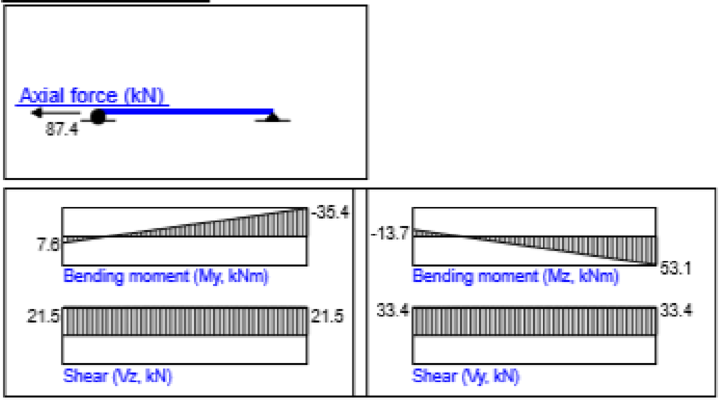


Dimensions and weight:				Section property:				Capacity:			
d	=	324.0	mm	A	=	15482	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	3.682E+8	mm4	N,Rd	=	4779.2	kN
g	=	121.5	kg/m	Iy	=	1.841E+8	mm4	My,Rd	=	469.0	kNm
S	=	1.018	m2/m	Wel,y	=	1.136E+6	mm3	Vc,z,Rd	=	1756.6	kN
				Wpl,y	=	1.519E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

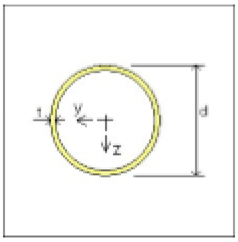
IR = Mz,Ed/Mz,Rd = 53.1/469.0 = 0.11 < 1.0 (1.00L; Ch 6.2.5)
IR = Mz,Ed/MN,z,Rd = 53.1/468.4 = 0.11 < 1.0 (1.00L; Ch 6.2.9)
IR = Vy,Ed/Vy,Rd = 33.4/1756.6 = 0.02 < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Pump module 40 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 202	Date: 4/14/2016 Time: 12:32
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:			
d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

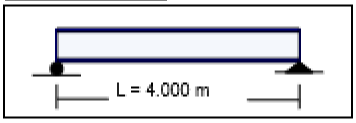
Section property:			
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

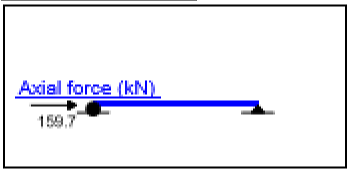
Cross Section Class: 1/2/2 N/My/Mz

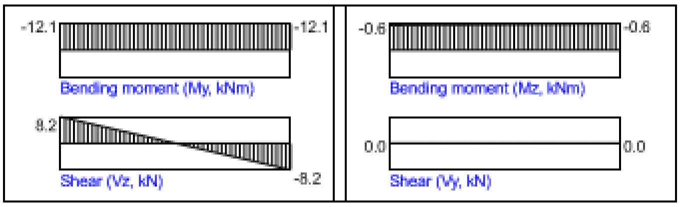
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.48	0.48
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 159.7/4779.2 = **0.03** < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 12.1/467.5 = **0.03** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 8.2/1756.6 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

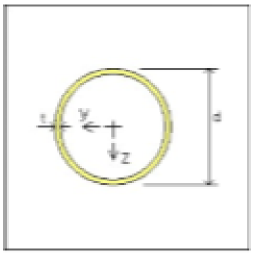
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 159.7/4446.2+1.00*12.1/(1.00*469.0)+0.59*0.6/469.0 = **0.06** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 159.7/4446.2+0.60*12.1/(1.00*469.0)+0.98*0.6/469.0 = **0.05** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Offshore lift analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.222	Date: 4/15/2016	
		Time: 10:45	
File: new file			

General:

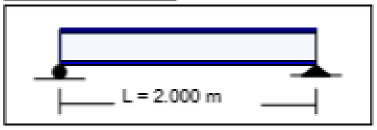
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)

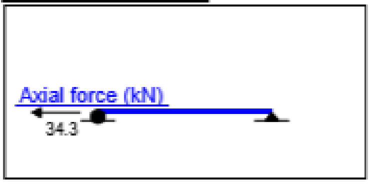


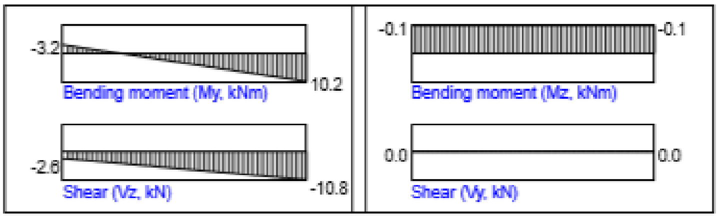
Dimensions and weight:				Section property:				Capacity:			
d	=	324.0	mm	A	=	15482	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	3.682E+8	mm4	N,Rd	=	4779.2	kN
g	=	121.5	kg/m	Iy	=	1.841E+8	mm4	My,Rd	=	469.0	kNm
S	=	1.018	m2/m	Wel,y	=	1.136E+6	mm3	Vc,z,Rd	=	1756.6	kN
				Wpl,y	=	1.519E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 10.2/469.0 = **0.02** < 1.0 (1.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 10.2/468.9 = **0.02** < 1.0 (1.00L; Ch 6.2.9)

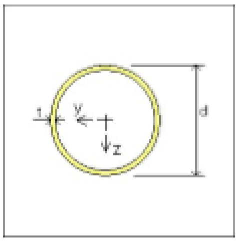
IR = Vz,Ed/Vz,Rd = 10.8/1756.6 = **0.01** < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Pump module 40 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 231	Date: 4/14/2016 Time: 12:37
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

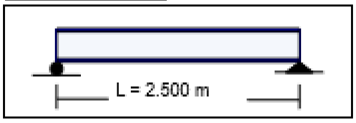
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

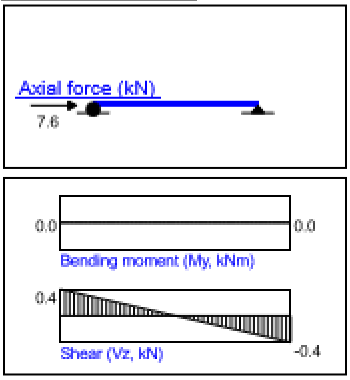
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.86	0.86
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 7.6/628.4 = **0.01** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.4/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

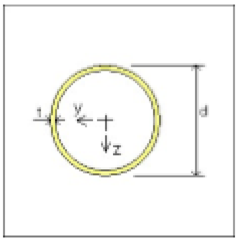
No Buckling, ref ch 6.3.1.2 (4); lamdaby/lamdabz<=0.2 or Ned/Ncry<=0.04; Ned/Ncry<=0.04 = =

Appendix D3: Colbeam EC3 calculations for transportation Case A:Pump module

Colbeam EC3 - User defined	Project: Transport analysis Pump module 40 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 121	Date: 4/14/2016 Time: 11:3
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)

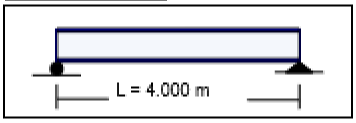


Dimensions and weight:
d = 324.0 mm
t = 16.0 mm
g = 121.5 kg/m
S = 1.018 m2/m

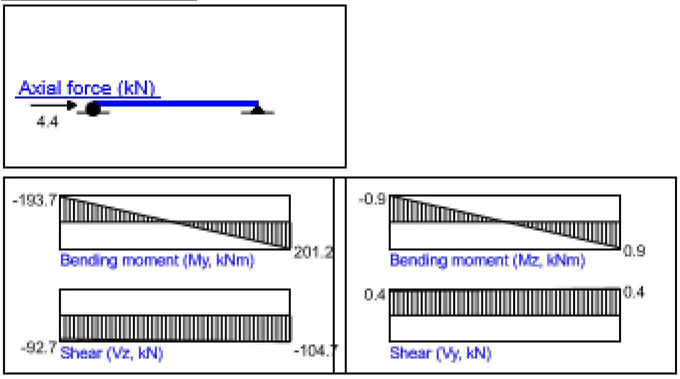
Section property:
A = 15482 mm2
Ix = 3.682E+8 mm4
Iy = 1.841E+8 mm4
Wel,y = 1.136E+6 mm3
Wpl,y = 1.519E+6 mm3

Capacity:
Cross Section Class: 1/2/2 N/My/Mz
N,Rd = 4779.2 kN
My,Rd = 469.0 kNm
Vc,z,Rd = 1756.6 kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.48	0.48
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

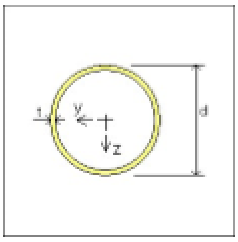
SECTION CONTROL:
IR = My,Ed/My,Rd = 201.2/469.0 = **0.43** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 201.2/469.0 = **0.43** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 104.7/1756.6 = **0.06** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 4.4/4446.2+0.59*201.2/(1.00*469.0)+0.35*0.9/469.0 = **0.25** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 4.4/4446.2+0.35*201.2/(1.00*469.0)+0.59*0.9/469.0 = **0.15** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Pump module 40 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 148	Date: 4/14/2016 Time: 12:3
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)

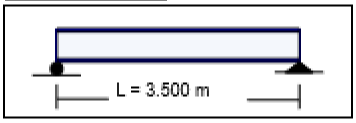


Dimensions and weight:
d = 324.0 mm
t = 16.0 mm
g = 121.5 kg/m
S = 1.018 m2/m

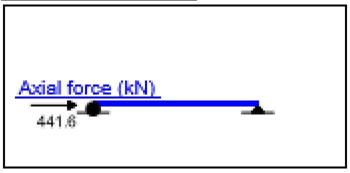
Section property:
A = 15482 mm2
Ix = 3.682E+8 mm4
Iy = 1.841E+8 mm4
Wel,y = 1.136E+6 mm3
Wpl,y = 1.519E+6 mm3

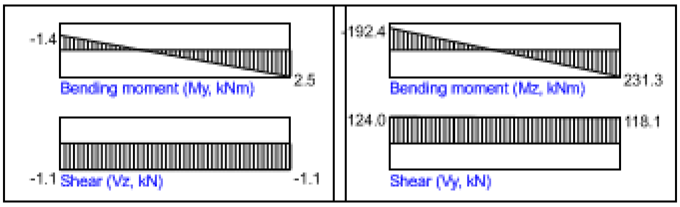
Capacity:
Cross Section Class: 1/2/2 N/My/Mz
N,Rd = 4779.2 kN
My,Rd = 469.0 kNm
Vc,z,Rd = 1756.6 kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.42	0.42
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = Mz,Ed/Mz,Rd = 231.3/469.0 = 0.49 < 1.0 (1.00L; Ch 6.2.5)
IR = Mz,Ed/MN,z,Rd = 231.3/460.8 = 0.50 < 1.0 (1.00L; Ch 6.2.9)
IR = Vy,Ed/Vy,Rd = 124.0/1756.6 = 0.07 < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

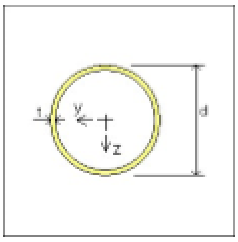
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 441.6/4527.9+0.64*2.5/(1.00*469.0)+0.35*231.3/469.0 = 0.27 < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 441.6/4527.9+0.39*2.5/(1.00*469.0)+0.59*231.3/469.0 = 0.39 < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Transport analysis Pump module 40 tonnes Identification: Beam No. 154	Page: 1/1 Date: 4/14/2016 Time: 11:27
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

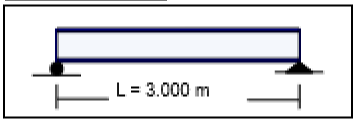
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

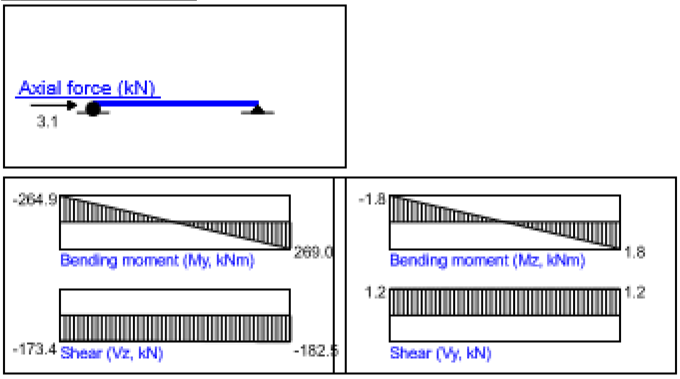
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:

		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.36	0.36
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 269.0/469.0 = **0.57** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 269.0/469.0 = **0.57** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 182.5/1756.6 = **0.10** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

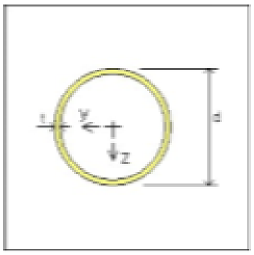
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 3.1/4602.4+0.58*269.0/(1.00*469.0)+0.35*1.8/469.0 = **0.34** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 3.1/4602.4+0.35*269.0/(1.00*469.0)+0.58*1.8/469.0 = **0.20** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.201	Date: 4/15/2016 Time: 10:2	
File: new file			

General:

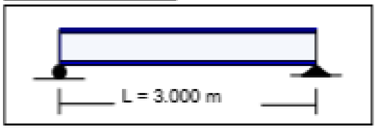
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0	MPa
gm0/gm1 =	1.15/1.15								

Profile: Tube 324x16 (Hot finished)

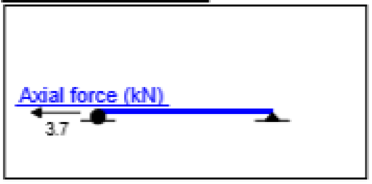


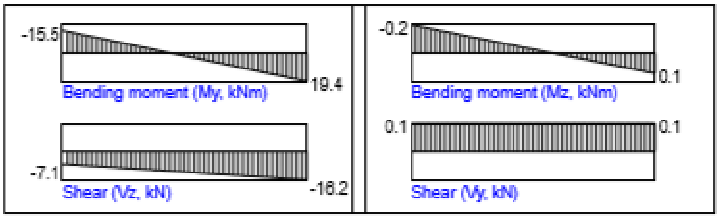
Dimensions and weight:				Section property:				Capacity:			
								Cross Section Class: 1/2/2 N/My/Mz			
d	=	324.0	mm	A	=	15482	mm2	N,Rd	=	4779.2	kN
t	=	16.0	mm	Ix	=	3.682E+8	mm4	My,Rd	=	469.0	kNm
g	=	121.5	kg/m	Iy	=	1.841E+8	mm4	Vc,z,Rd	=	1756.6	kN
S	=	1.018	m2/m	Wel,y	=	1.136E+6	mm3				
				Wpl,y	=	1.519E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

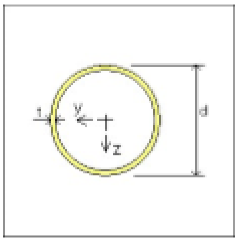
SECTION CONTROL:

IR = My,Ed/My,Rd = 19.4/469.0 = 0.04 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 19.4/469.0 = 0.04 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 16.2/1756.6 = 0.01 < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Transport analysis Pump module 40 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No. 216	Date: 4/14/2016 Time: 12:6	
File: new file			

General:
Material: S355 NH/NLH   fy = 355 MPa   E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 114x6 (Hot finished)



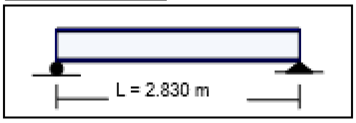
Dimensions and weight:			
d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:			
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

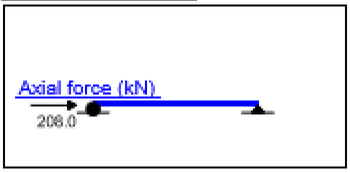
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

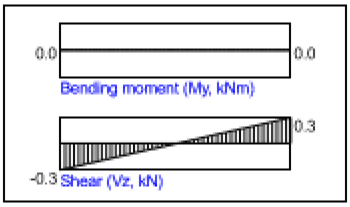
N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.97	0.97
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 208.0/628.4 = **0.33** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.3/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd = 208.0/432.1 = **0.48** < 1.0 (Ch 6.3.1)
IR = NEd/Nb,z,Rd = 208.0/432.1 = **0.48** < 1.0 (Ch 6.3.1)

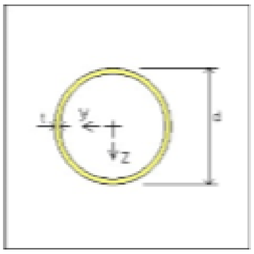
Appendix D4: Colbeam EC3 calculations for air lift Case B:Cooler module

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Air lift analysis Cooler module 100 tonnes Identification: Beam No.9	Page: 1/1 Date: 4/15/2016 Time: 14:10
File: new file		

General:

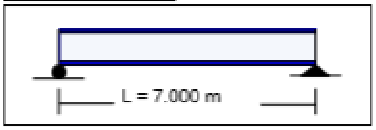
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 273x16 (Hot finished)

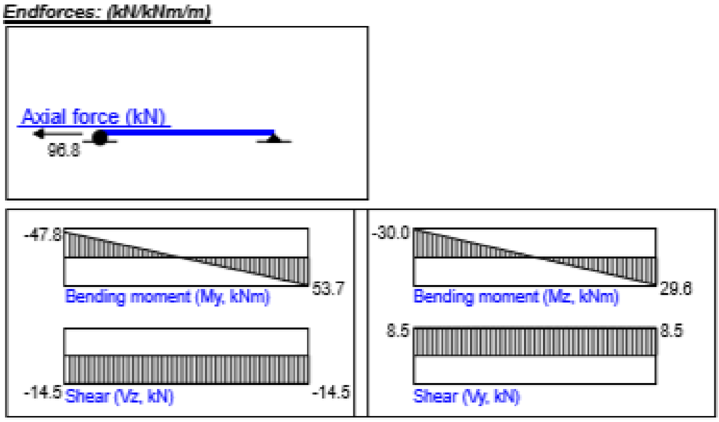


Dimensions and weight:				Section property:				Capacity:			
d	=	273.0	mm	A	=	12918	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	2.141E+8	mm4	N,Rd	=	3987.8	kN
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	My,Rd	=	326.6	kNm
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3	Vc,z,Rd	=	1465.7	kN
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 53.7/326.6 = 0.16 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 53.7/326.1 = 0.16 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 14.5/1465.7 = 0.01 < 1.0 (0.00L; Ch 6.2.6)

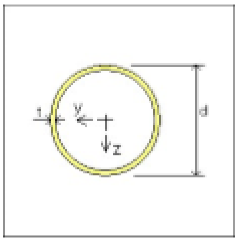
Colbeam EC3 - User defined	Project: Air lift analysis Cooler module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.17	Date: 4/15/2016 Time: 14:13
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:			
d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

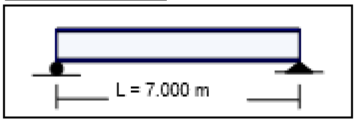
Section property:			
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

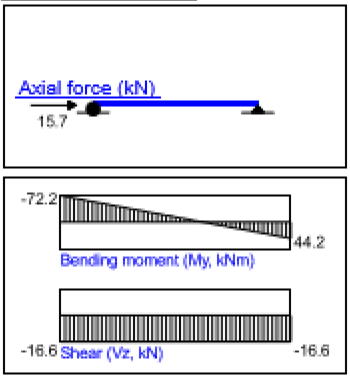
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.01	1.01
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 72.2/326.6 = **0.22** < 1.0 (0.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 72.2/326.6 = **0.22** < 1.0 (0.00L; Ch 6.2.9)

IR = Vz,Ed/Vz,Rd = 16.6/1465.7 = **0.01** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) = 15.7/2636.7+0.66*72.2/(1.00*326.6) = **0.15** < 1.0 (Ch 6.3.3)

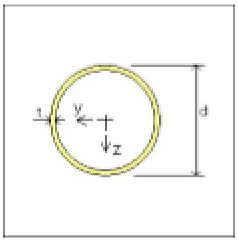
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) = 15.7/2636.7+0.40*72.2/(1.00*326.6) = **0.09** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Air lift analysis Cooler Module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.24	Date: 4/15/2016 Time: 19:26	
File: new file			

General:

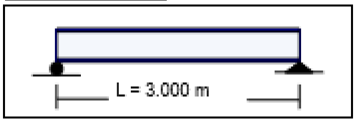
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0	MPa
gm0/gm1 =	1.15/1.15								

Profile: Tube 273x16 (Hot finished)

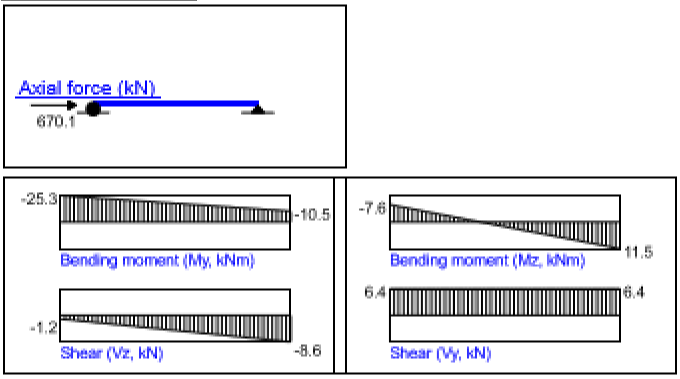


Dimensions and weight:				Section property:				Capacity:			
d	=	273.0	mm	A	=	12918	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	2.141E+8	mm4	N,Rd	=	3987.8	kN
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	My,Rd	=	326.6	kNm
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3	Vc,z,Rd	=	1465.7	kN
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 670.1/3987.8 = **0.17** < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 25.3/310.9 = **0.08** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 8.6/1465.7 = **0.01** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

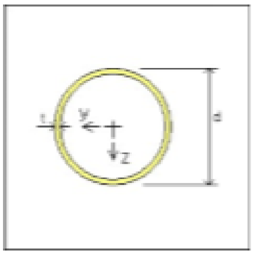
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 670.1/3765.9+0.83*25.3/(1.00*326.6)+0.36*11.5/326.6 = **0.25** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 670.1/3765.9+0.50*25.3/(1.00*326.6)+0.60*11.5/326.6 = **0.24** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Air lift analysis Cooler module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.27	Date: 4/15/2016 Time: 13:7	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:

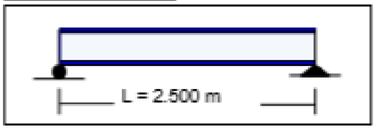
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

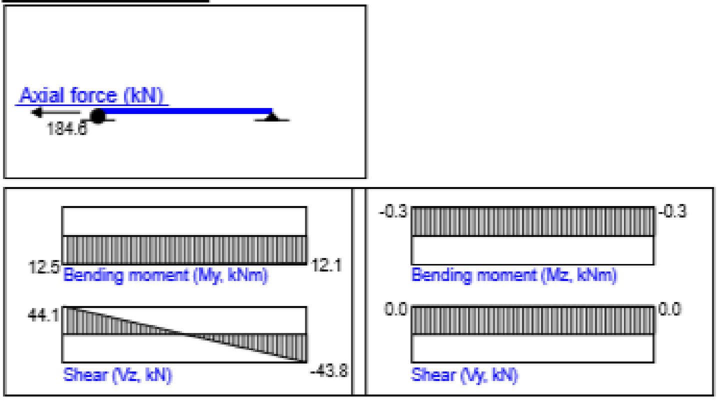
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

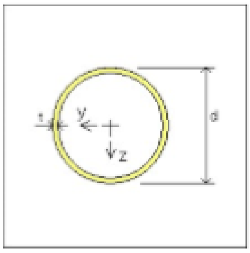
IR = NEd/NRd = -184.6/3987.8 = 0.05 < 1.0 (0.50L; Ch 6.2.3)
IR = My,Ed/MN,y,Rd = 12.5/324.9 = 0.04 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 44.1/1465.7 = 0.03 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Cooler Module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.35	Date: 4/15/2016 Time: 19:29	
File: new file			

General:

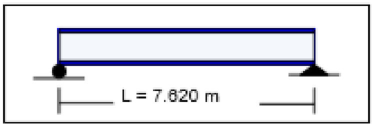
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0	MPa
gm0/gm1 =	1.15/1.15								

Profile: Tube 114x6 (Hot finished)

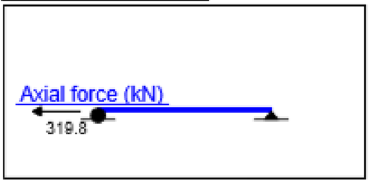


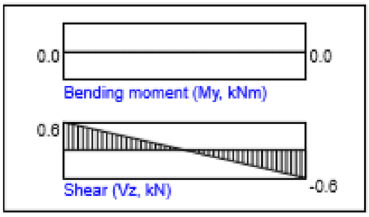
Dimensions and weight:				Section property:				Capacity:			
								Cross Section Class: 1/2/2 N/My/Mz			
d	=	114.0	mm	A	=	2036	mm2	N,Rd	=	628.4	kN
t	=	6.0	mm	Ix	=	5.955E+6	mm4	My,Rd	=	21.6	kNm
g	=	16.0	kg/m	Iy	=	2.977E+6	mm4	Vc,z,Rd	=	231.0	kN
S	=	0.358	m2/m	Wel,y	=	5.223E+4	mm3				
				Wpl,y	=	7.006E+4	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = -319.8/628.4 = **0.51** < 1.0 (0.50L; Ch 6.2.3)

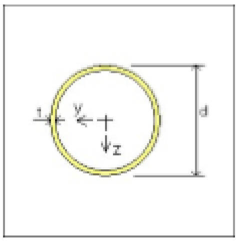
IR = Vz,Ed/Vz,Rd = 0.6/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Cooler Module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.44	Date: 4/15/2016 Time: 19:24	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:

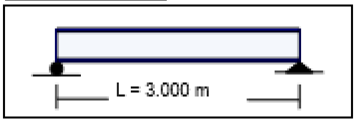
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

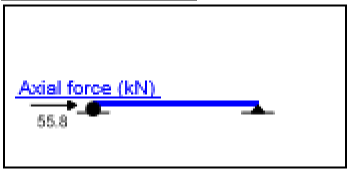
Cross Section Class: 1/2/2 N/My/Mz

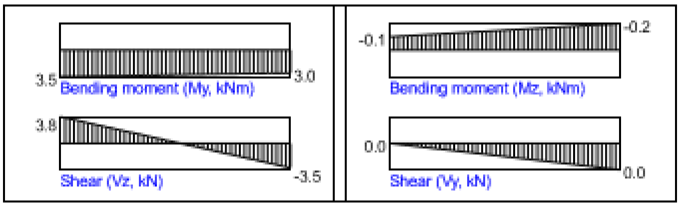
N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 55.8/3987.8 = **0.01** < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 3.5/326.4 = **0.01** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 3.8/1465.7 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

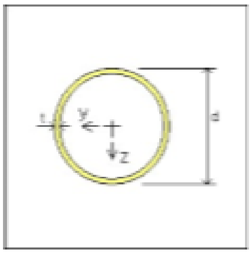
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 55.8/3765.9+0.97*3.5/(1.00*326.6)+0.53*0.2/326.6 = **0.03** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 55.8/3765.9+0.58*3.5/(1.00*326.6)+0.89*0.2/326.6 = **0.02** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Air lift analysis Cooler module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.80	Date: 4/15/2016 Time: 12:58	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:

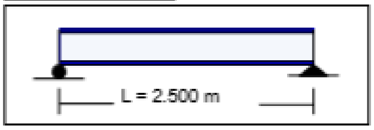
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

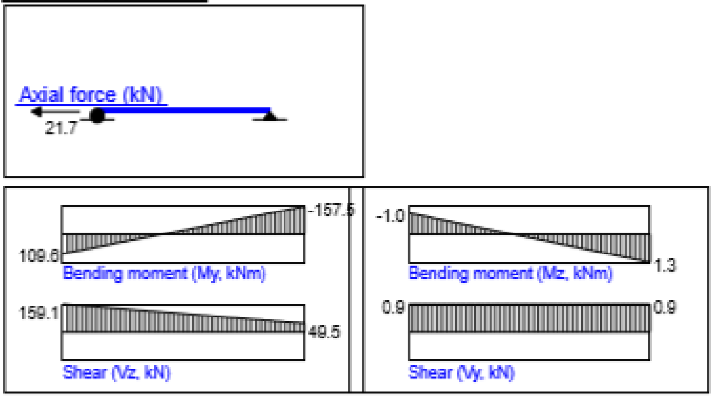
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 157.5/326.6 = 0.48 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 157.5/326.6 = 0.48 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 159.1/1465.7 = 0.11 < 1.0 (0.00L; Ch 6.2.6)

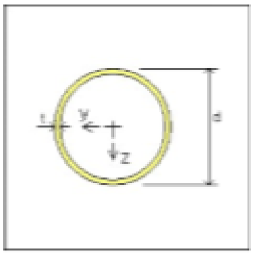
Appendix D5: Colbeam EC3 calculations for offshore lift Case B:Cooler module

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Offshore lift analysis Cooler Module 100 tonnes Identification: Beam No.9	Page: 1/1 Date: 4/15/2016 Time: 20:14
File: new file		

General:

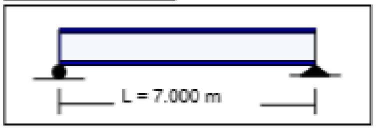
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 273x16 (Hot finished)

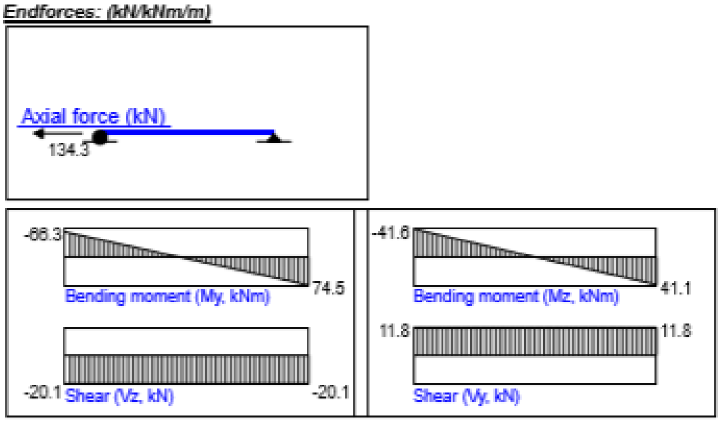


Dimensions and weight:				Section property:				Capacity:			
d	=	273.0	mm	A	=	12918	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	2.141E+8	mm4	N,Rd	=	3987.8	kN
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	My,Rd	=	326.6	kNm
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3	Vc,z,Rd	=	1465.7	kN
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

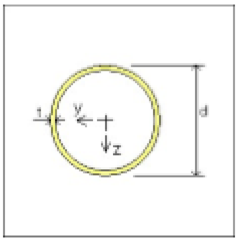
IR = My,Ed/My,Rd = 74.5/326.6 = 0.23 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 74.5/325.6 = 0.23 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 20.1/1465.7 = 0.01 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.17	Date: 4/15/2016 Time: 20:19	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:

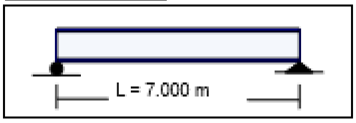
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

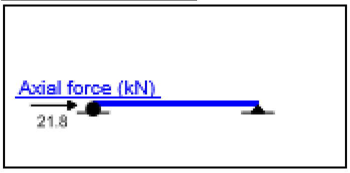
Cross Section Class: 1/2/2 N/My/Mz

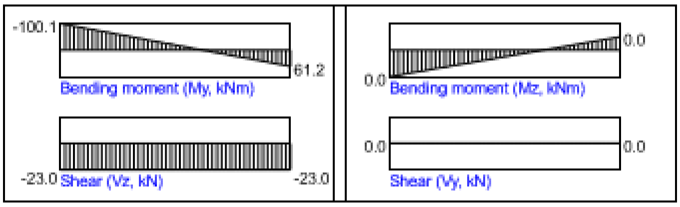
N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.01	1.01
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 100.1/326.6 = **0.31** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 100.1/326.6 = **0.31** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 23.0/1465.7 = **0.02** < 1.0 (0.00L; Ch 6.2.6)

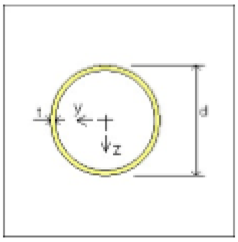
BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 21.8/2636.7+0.66*100.1/(1.00*326.6)+0.41*0.0/326.6 = **0.21** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 21.8/2636.7+0.40*100.1/(1.00*326.6)+0.68*0.0/326.6 = **0.13** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.24	Date: 4/15/2016 Time: 20:24
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

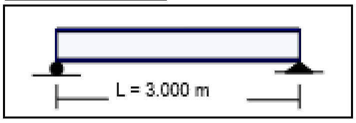
Section property:

A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

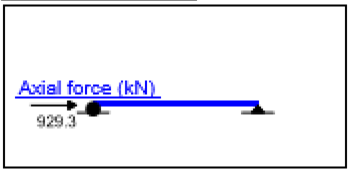
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

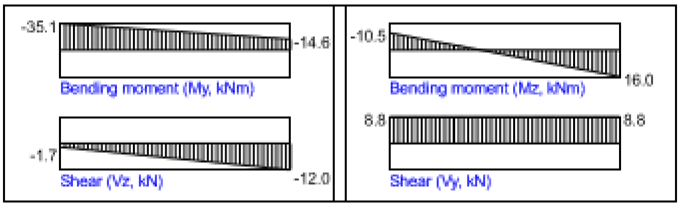
N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:

		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:
IR = NEd/NRd = 929.3/3987.8 = 0.23 < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 35.1/299.2 = 0.12 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 12.0/1465.7 = 0.01 < 1.0 (1.00L; Ch 6.2.6)

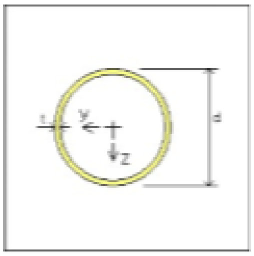
BUCKLING CONTROL:
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 929.3/3765.9+0.82*35.1/(1.00*326.6)+0.35*16.0/326.6 = 0.35 < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 929.3/3765.9+0.49*35.1/(1.00*326.6)+0.58*16.0/326.6 = 0.33 < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.27	Date: 4/15/2016 Time: 20:11	
File: new file			

General:

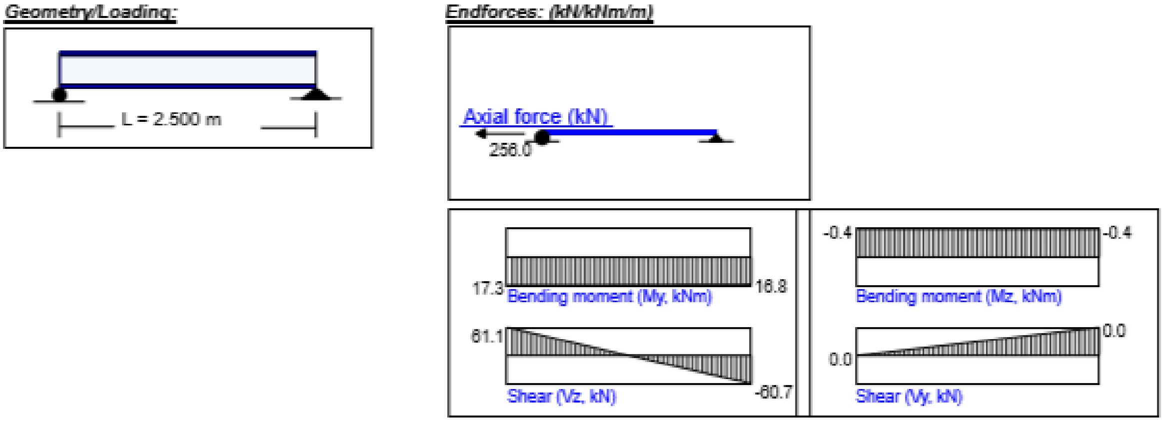
Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:			Section property:			Capacity:		
d	=	273.0 mm	A	=	12918 mm2	Cross Section Class: 1/2/2 N/My/Mz		
t	=	16.0 mm	Ix	=	2.141E+8 mm4	N,Rd	=	3987.8 kN
g	=	101.4 kg/m	Iy	=	1.071E+8 mm4	My,Rd	=	326.6 kNm
S	=	0.858 m2/m	Wel,y	=	7.844E+5 mm3	Vc,z,Rd	=	1465.7 kN
			Wpl,y	=	1.058E+6 mm3			

Geometry/Loading: **Endforces: (kN/kNm/m)**



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

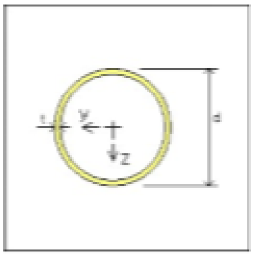
IR = NEd/NRd = -256.0/3987.8 = 0.06 < 1.0 (0.50L; Ch 6.2.3)
IR = My,Ed/MN,y,Rd = 17.3/323.6 = 0.05 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 61.1/1465.7 = 0.04 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonn es	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.35	Date: 4/15/2016 Time: 20:26
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

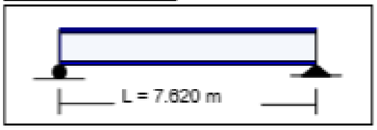
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

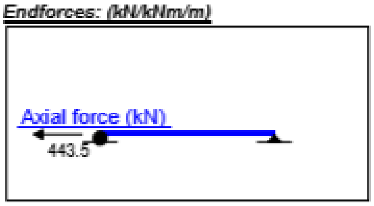
Cross Section Class: 1/2/2 N/My/Mz

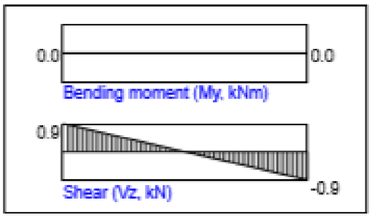
N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = -443.5/628.4 = 0.71 < 1.0 (0.50L; Ch 6.2.3)

IR = Vz,Ed/Vz,Rd = 0.9/231.0 = 0.00 < 1.0 (0.00L; Ch 6.2.6)

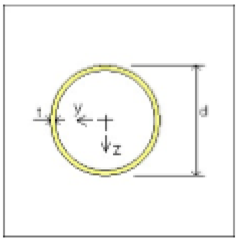
Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.44	Date: 4/15/2016 Time: 20:22
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

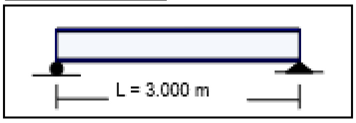
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)

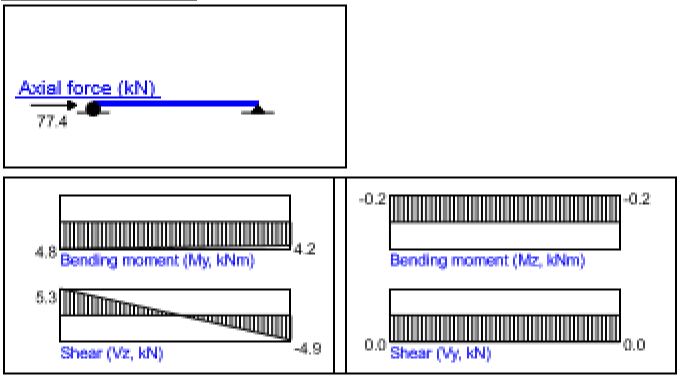


Dimensions and weight:				Section property:				Capacity:			
d	=	273.0	mm	A	=	12918	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	2.141E+8	mm4	N,Rd	=	3987.8	kN
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	My,Rd	=	326.6	kNm
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3	Vc,z,Rd	=	1465.7	kN
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 77.4/3987.8 = **0.02** < 1.0 (0.50L; Ch 6.2.4)
IR = My,Ed/MN,y,Rd = 4.8/326.2 = **0.01** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 5.3/1465.7 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 77.4/3765.9+0.97*4.8/(1.00*326.6)+0.60*0.2/326.6 = **0.04** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 77.4/3765.9+0.58*4.8/(1.00*326.6)+1.00*0.2/326.6 = **0.03** < 1.0 (Ch 6.3.3)

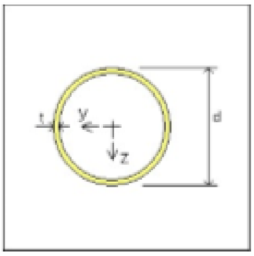
Colbeam EC3 - User defined	Project: Offshore lift analysis Cooler Module 100 tonn es	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.80	Date: 4/15/2016 Time: 20:8
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:			
d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:			
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

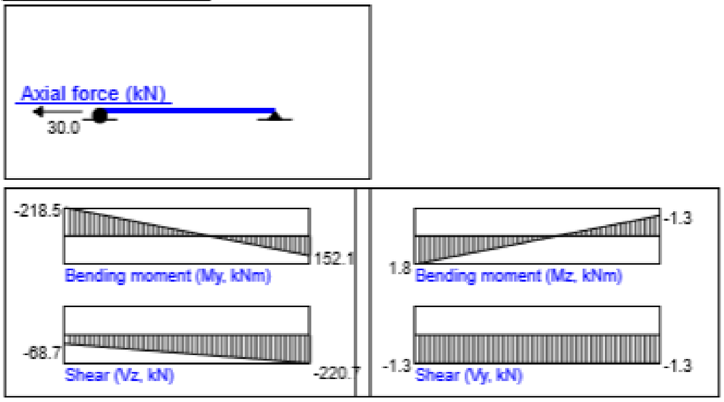
Capacity:

Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:

Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 218.5/326.6 = **0.67** < 1.0 (0.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 218.5/326.6 = **0.67** < 1.0 (0.00L; Ch 6.2.9)

IR = Vz,Ed/Vz,Rd = 220.7/1465.7 = **0.15** < 1.0 (1.00L; Ch 6.2.6)

Appendix D6: Colbeam EC3 calculations for transportation Case B:Cooler module

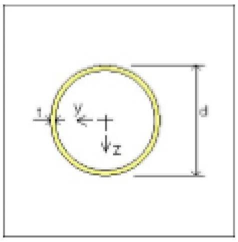
Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Transport analysis Cooler module 100 tonnes		Page: 1/1
	Identification: Beam No.9	Date: 4/15/2016 Time: 12:45	
File: new file			

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:

d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:

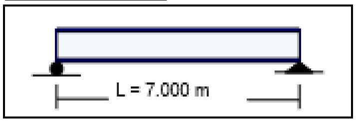
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

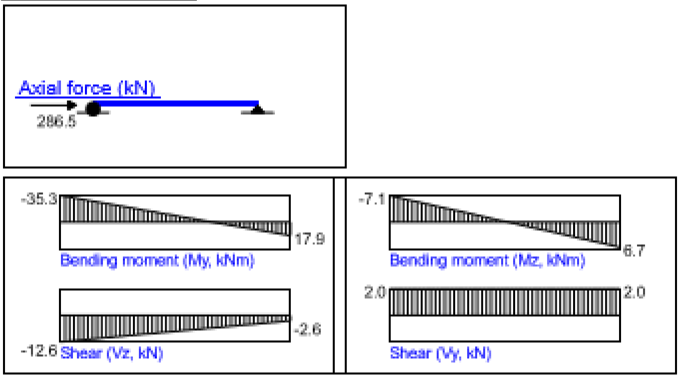
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.01	1.01
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 35.3/326.6 = **0.11** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 35.3/322.9 = **0.11** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 12.6/1465.7 = **0.01** < 1.0 (0.00L; Ch 6.2.6)

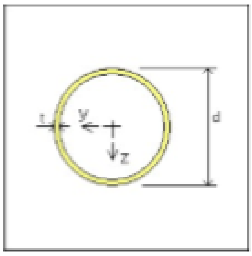
BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 286.5/2636.7+0.68*35.3/(1.00*326.6)+0.34*7.1/326.6 = **0.19** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 286.5/2636.7+0.41*35.3/(1.00*326.6)+0.57*7.1/326.6 = **0.17** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Transport analysis Cooler module 100 tonnes Identification: Beam No.17	Page: 1/1 Date: 4/15/2016 Time: 12:48
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



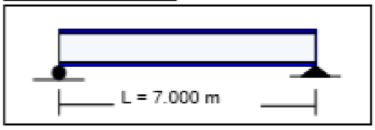
Dimensions and weight:			
d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:			
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

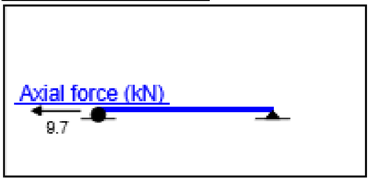
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

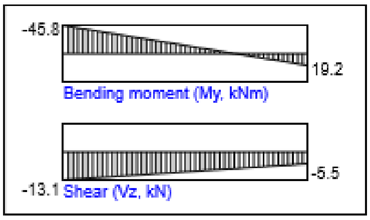
N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

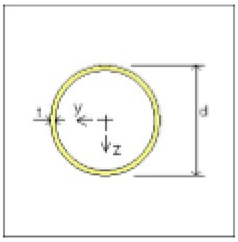
IR = My,Ed/My,Rd = 45.8/326.6 = 0.14 < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 45.8/326.6 = 0.14 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 13.1/1465.7 = 0.01 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Transport analysis Cooler module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.19	Date: 4/15/2016 Time: 12:55
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

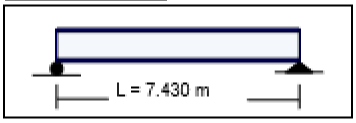
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

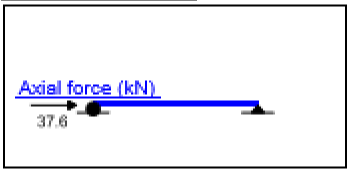
Cross Section Class: 1/2/2 N/My/Mz

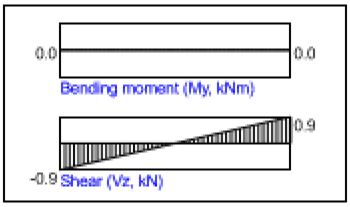
N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	2.54	2.54
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 37.6/628.4 = **0.06** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.9/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

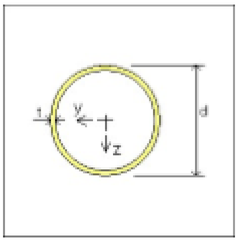
BUCKLING CONTROL:

IR = NEd/Nb,y,Rd = 37.6/89.3 = **0.42** < 1.0 (Ch 6.3.1)
IR = NEd/Nb,z,Rd = 37.6/89.3 = **0.42** < 1.0 (Ch 6.3.1)

Colbeam EC3 - User defined	Project: Transport analysis Cooler module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.24	Date: 4/15/2016 Time: 12:53
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



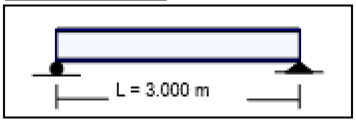
Dimensions and weight:			
d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

Section property:			
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

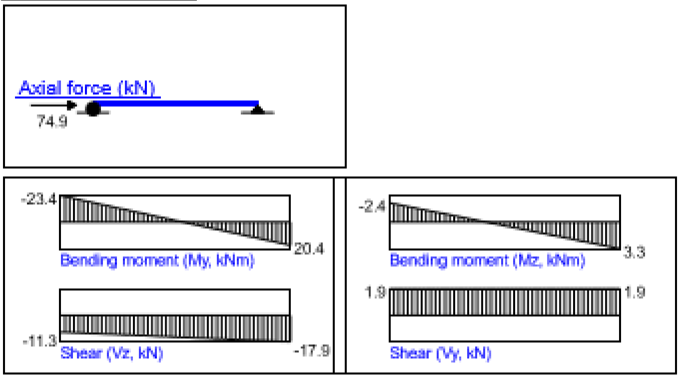
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 23.4/326.6 = **0.07** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 23.4/326.3 = **0.07** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 17.9/1465.7 = **0.01** < 1.0 (1.00L; Ch 6.2.6)

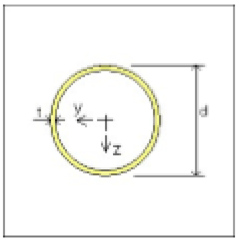
BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 74.9/3765.9+0.60*23.4/(1.00*326.6)+0.38*3.3/326.6 = **0.07** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 74.9/3765.9+0.36*23.4/(1.00*326.6)+0.63*3.3/326.6 = **0.05** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Cooler module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.28	Date: 4/15/2016 Time: 12:42
File: new file		

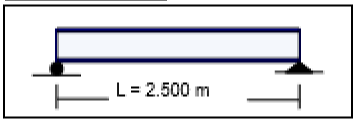
General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)

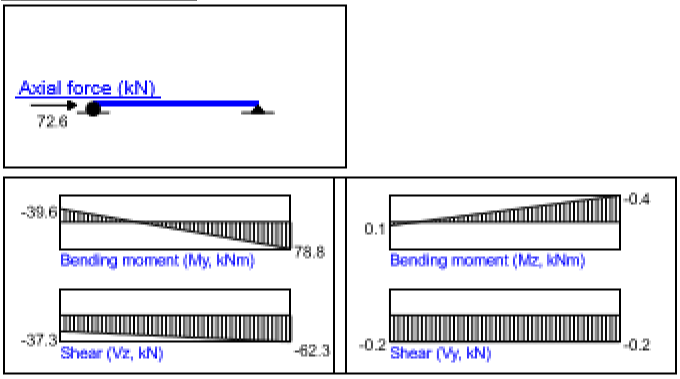


Dimensions and weight:				Section property:				Capacity:			
d	=	273.0	mm	A	=	12918	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	2.141E+8	mm4	N,Rd	=	3987.8	kN
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	My,Rd	=	326.6	kNm
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3	Vc,z,Rd	=	1465.7	kN
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.36	0.36
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 78.8/326.6 = **0.24** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 78.8/326.3 = **0.24** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 62.3/1465.7 = **0.04** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

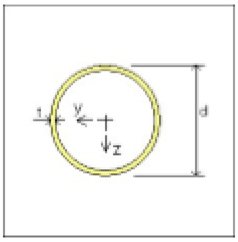
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 72.6/3841.0+0.68*78.8/(1.00*326.6)+0.45*0.4/326.6 = **0.18** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 72.6/3841.0+0.41*78.8/(1.00*326.6)+0.76*0.4/326.6 = **0.12** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Cooler module 100 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.44	Date: 4/15/2016 Time: 12:50	
File: new file			

General:

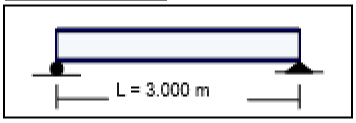
Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 273x16 (Hot finished)

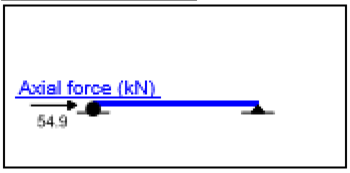


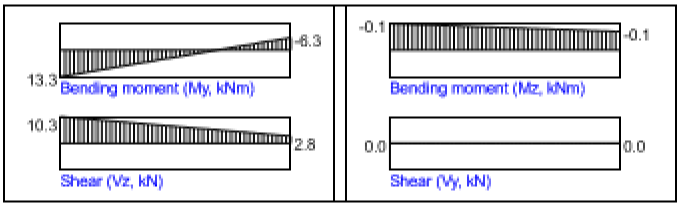
Dimensions and weight:				Section property:				Capacity:			
								Cross Section Class: 1/2/2 N/My/Mz			
d	=	273.0	mm	A	=	12918	mm2	N,Rd	=	3987.8	kN
t	=	16.0	mm	Ix	=	2.141E+8	mm4	My,Rd	=	326.6	kNm
g	=	101.4	kg/m	Iy	=	1.071E+8	mm4	Vc,z,Rd	=	1465.7	kN
S	=	0.858	m2/m	Wel,y	=	7.844E+5	mm3				
				Wpl,y	=	1.058E+6	mm3				

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.43	0.43
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 13.3/326.6 = **0.04** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 13.3/326.4 = **0.04** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 10.3/1465.7 = **0.01** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 54.9/3765.9+0.69*13.3/(1.00*326.6)+0.56*0.1/326.6 = **0.04** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 54.9/3765.9+0.41*13.3/(1.00*326.6)+0.93*0.1/326.6 = **0.03** < 1.0 (Ch 6.3.3)

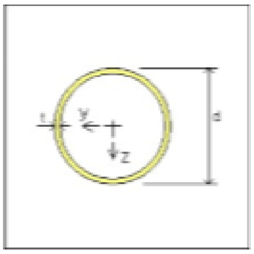
Colbeam EC3 - User defined	Project: Transport analysis Cooler module 100 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.60	Date: 4/15/2016 Time: 12:39
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 273x16 (Hot finished)



Dimensions and weight:			
d	=	273.0	mm
t	=	16.0	mm
g	=	101.4	kg/m
S	=	0.858	m2/m

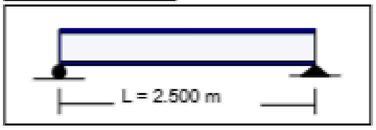
Section property:			
A	=	12918	mm2
Ix	=	2.141E+8	mm4
Iy	=	1.071E+8	mm4
Wel,y	=	7.844E+5	mm3
Wpl,y	=	1.058E+6	mm3

Capacity:

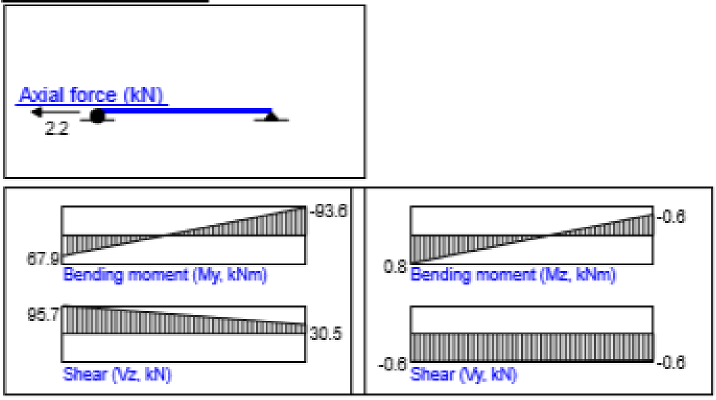
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	3987.8	kN
My,Rd	=	326.6	kNm
Vc,z,Rd	=	1465.7	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 93.6/326.6 = 0.29 < 1.0 (1.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 93.6/326.6 = 0.29 < 1.0 (1.00L; Ch 6.2.9)

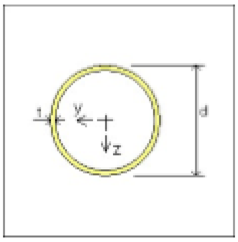
IR = Vz,Ed/Vz,Rd = 95.7/1465.7 = 0.07 < 1.0 (0.00L; Ch 6.2.6)

Appendix D7: Colbeam EC3 calculations for air lift Case C:Compressor module

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Air lift analysis Compressor module 120 tonne s Identification: Beam No.12	Page: 1/1 Date: 4/17/2016 Time: 17:1
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



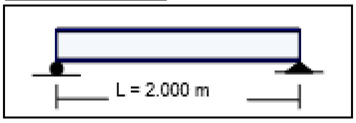
Dimensions and weight:			
d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:			
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

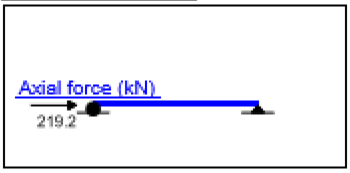
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

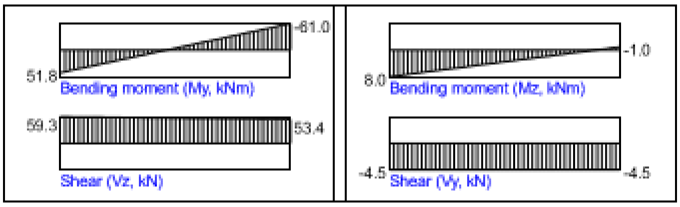
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.24	0.24
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:
IR = My,Ed/My,Rd = 61.0/469.0 = 0.13 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 61.0/466.5 = 0.13 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 59.3/1756.6 = 0.03 < 1.0 (0.00L; Ch 6.2.6)

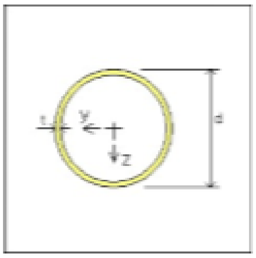
BUCKLING CONTROL:
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 219.2/4736.9+0.59*61.0/(1.00*469.0)+0.45*8.0/469.0 = 0.13 < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 219.2/4736.9+0.36*61.0/(1.00*469.0)+0.74*8.0/469.0 = 0.11 < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Air lift analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.21	Date: 4/17/2016 Time: 18:54
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

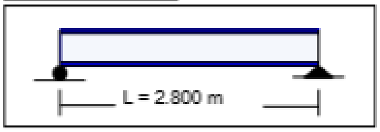
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

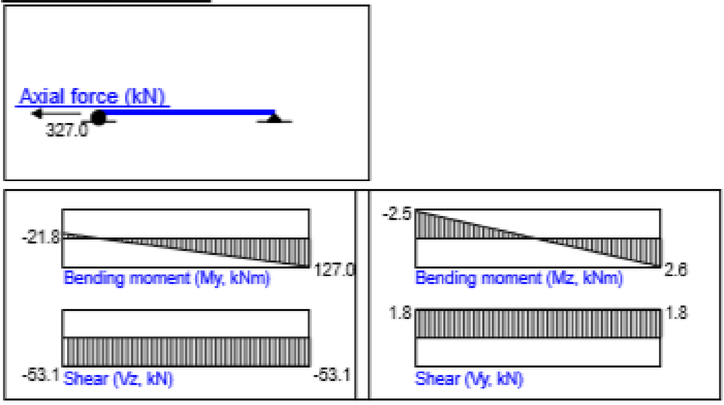
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

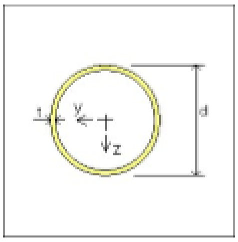
IR = My,Ed/My,Rd = 127.0/469.0 = 0.27 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 127.0/464.1 = 0.27 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 53.1/1756.6 = 0.03 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.29	Date: 4/17/2016 Time: 16:56
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

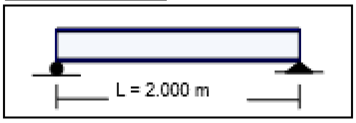
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

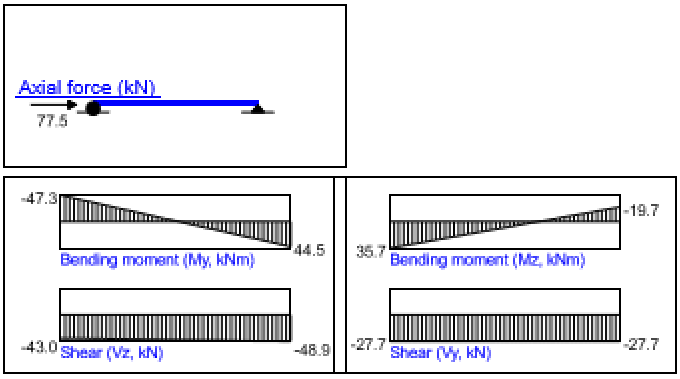
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.24	0.24
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 47.3/469.0 = **0.10** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 47.3/468.5 = **0.10** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 48.9/1756.6 = **0.03** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

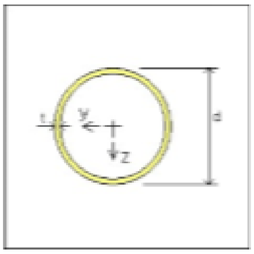
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 77.5/4736.9+0.59*47.3/(1.00*469.0)+0.40*35.7/469.0 = **0.11** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 77.5/4736.9+0.35*47.3/(1.00*469.0)+0.67*35.7/469.0 = **0.10** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Air lift analysis Compressor module 120 tonne s Identification: Beam No.30	Page: 1/1 Date: 4/17/2016 Time: 16:52
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:			
d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

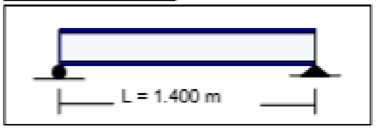
Section property:			
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

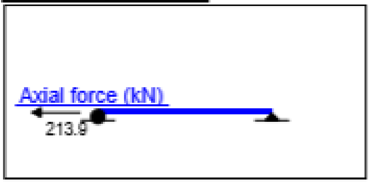
Cross Section Class: 1/2/2 N/My/Mz

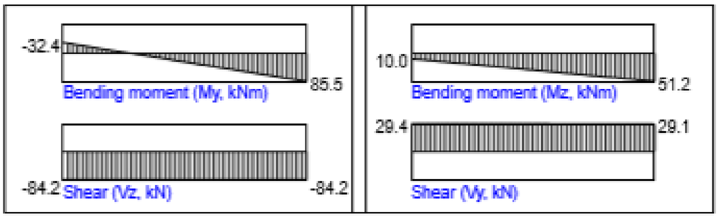
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

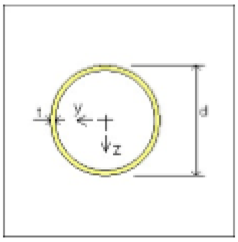
IR = My,Ed/My,Rd = 85.5/469.0 = 0.18 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 85.5/466.6 = 0.18 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 84.2/1756.6 = 0.05 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Air lift analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.62	Date: 4/17/2016 Time: 17:30
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

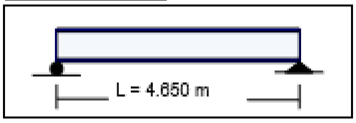
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

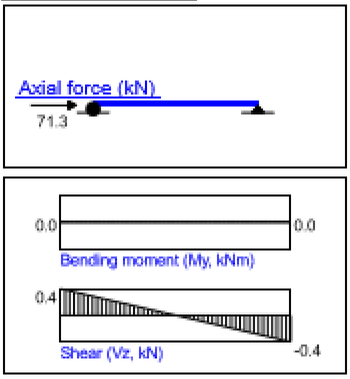
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.59	1.59
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 71.3/628.4 = **0.11** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.4/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd = 71.3/211.4 = **0.34** < 1.0 (Ch 6.3.1)
IR = NEd/Nb,z,Rd = 71.3/211.4 = **0.34** < 1.0 (Ch 6.3.1)

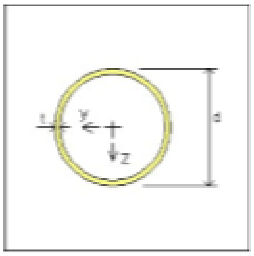
Colbeam EC3 - User defined	Project: Air lift analysis Compressor module 120 tonne s	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.101	Date: 4/17/2016 Time: 16:49
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

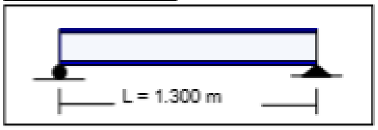
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)

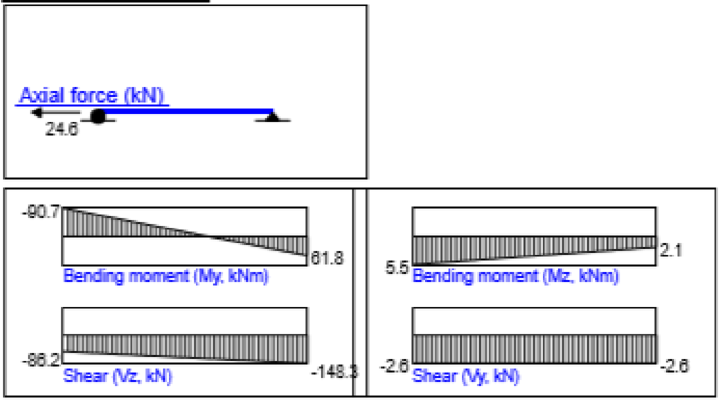


Dimensions and weight:			Section property:			Capacity:		
d	=	324.0 mm	A	=	15482 mm2	Cross Section Class: 1/2/2 N/My/Mz		
t	=	16.0 mm	Ix	=	3.682E+8 mm4	N,Rd	=	4779.2 kN
g	=	121.5 kg/m	Iy	=	1.841E+8 mm4	My,Rd	=	469.0 kNm
S	=	1.018 m2/m	Wel,y	=	1.136E+6 mm3	Vc,z,Rd	=	1756.6 kN
			Wpl,y	=	1.519E+6 mm3			

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 90.7/469.0 = 0.19 < 1.0 (0.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 90.7/468.9 = 0.19 < 1.0 (0.00L; Ch 6.2.9)

IR = Vz,Ed/Vz,Rd = 148.3/1756.6 = 0.08 < 1.0 (1.00L; Ch 6.2.6)

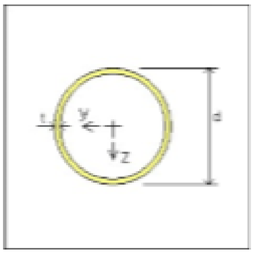
Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Air lift analysis Compressor module 120 tonne s	Page: 1/1
	Identification: Beam No.104	Date: 4/17/2016 Time: 16:43
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

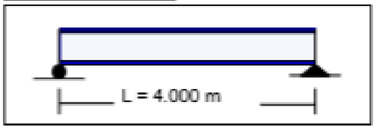
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

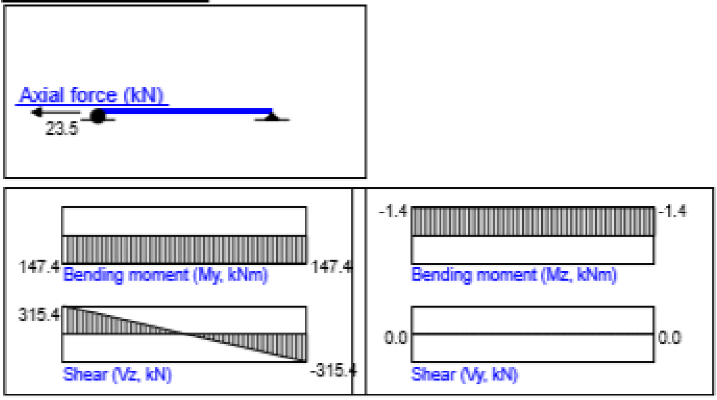
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 147.4/469.0 = 0.31 < 1.0 (0.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 147.4/468.9 = 0.31 < 1.0 (0.00L; Ch 6.2.9)

IR = Vz,Ed/Vz,Rd = 315.4/1756.6 = 0.18 < 1.0 (0.00L; Ch 6.2.6)

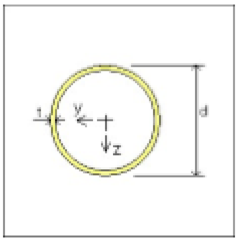
Appendix D8: Colbeam EC3 calculations for offshore lift Case C:Compressor module

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.12	Date: 4/17/2016 Time: 17:48
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

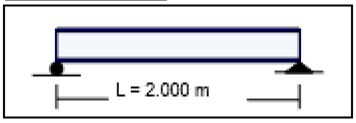
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

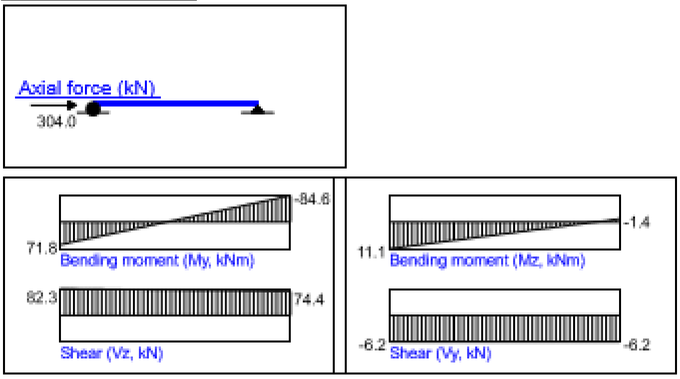
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:

		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.24	0.24
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 84.6/469.0 = 0.18 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 84.6/464.6 = 0.18 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 82.3/1756.6 = 0.05 < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

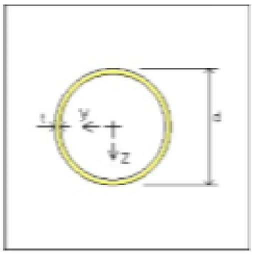
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 304.0/4736.9+0.59*84.6/(1.00*469.0)+0.44*11.1/469.0 = 0.18 < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 304.0/4736.9+0.35*84.6/(1.00*469.0)+0.74*11.1/469.0 = 0.15 < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.21	Date: 4/17/2016 Time: 17:42	
File: new file			

General:

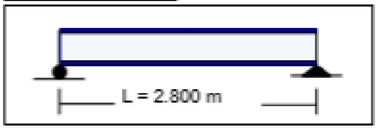
Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 324x16 (Hot finished)

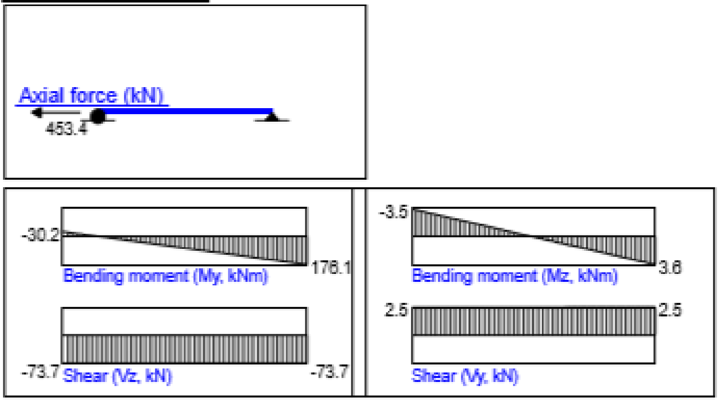


Dimensions and weight:			Section property:			Capacity:		
d	=	324.0 mm	A	=	15482 mm2	Cross Section Class: 1/2/2 N/My/Mz		
t	=	16.0 mm	Ix	=	3.682E+8 mm4	N,Rd	=	4779.2 kN
g	=	121.5 kg/m	Iy	=	1.841E+8 mm4	My,Rd	=	469.0 kNm
S	=	1.018 m2/m	Wel,y	=	1.136E+6 mm3	Vc,z,Rd	=	1756.6 kN
			Wpl,y	=	1.519E+6 mm3			

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

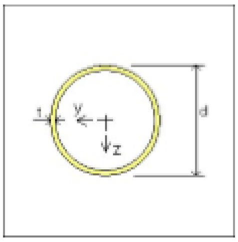
IR = My,Ed/My,Rd = 176.1/469.0 = 0.38 < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 176.1/460.4 = 0.38 < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 73.7/1756.6 = 0.04 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.29	Date: 4/17/2016 Time: 17:46	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

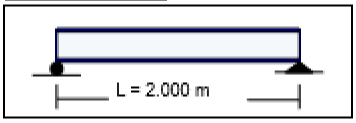
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

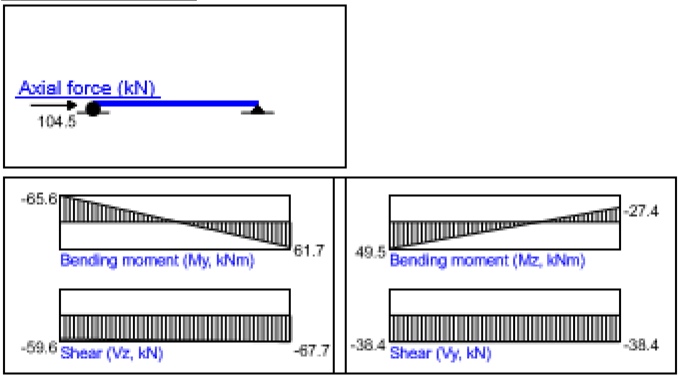
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.24	0.24
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 65.6/469.0 = **0.14** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 65.6/468.3 = **0.14** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 67.7/1756.6 = **0.04** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 104.5/4736.9+0.58*65.6/(1.00*469.0)+0.40*49.5/469.0 = **0.15** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 104.5/4736.9+0.35*65.6/(1.00*469.0)+0.67*49.5/469.0 = **0.14** < 1.0 (Ch 6.3.3)

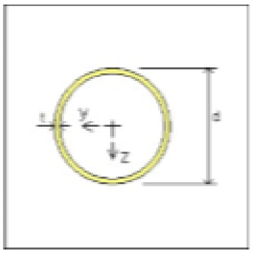
Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Offshore lift analysis Compressor module 120 tonnes Identification: Beam No.30	Page: 1/1 Date: 4/17/2016 Time: 17:40
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa

gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

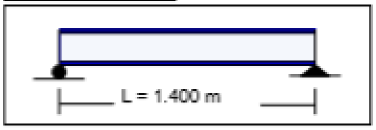
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

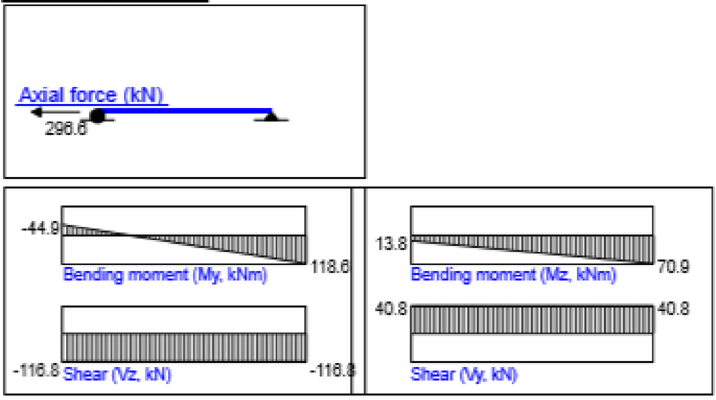
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 118.6/469.0 = 0.25 < 1.0 (1.00L; Ch 6.2.5)

IR = My,Ed/MN,y,Rd = 118.6/464.8 = 0.26 < 1.0 (1.00L; Ch 6.2.9)

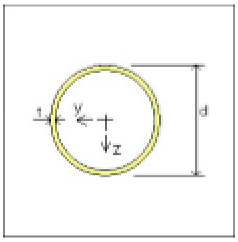
IR = Vz,Ed/Vz,Rd = 116.8/1756.6 = 0.07 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.62	Date: 4/17/2016 Time: 17:50	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0	MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

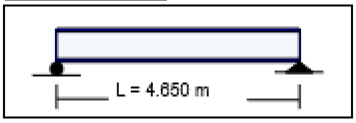
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

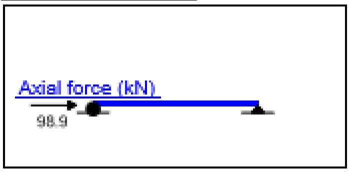
Cross Section Class: 1/2/2 N/My/Mz

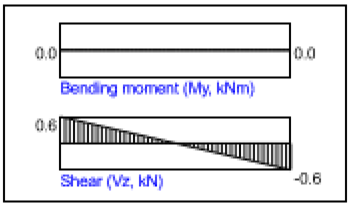
N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Buckling parameters:

		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.59	1.59
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 98.9/628.4 = **0.16** < 1.0 (0.50L; Ch 6.2.4)
IR = Vz,Ed/Vz,Rd = 0.6/231.0 = **0.00** < 1.0 (0.00L; Ch 6.2.6)

BUCKLING CONTROL:

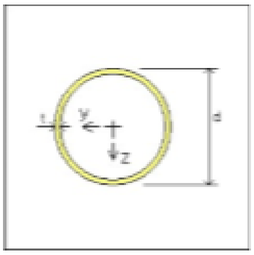
IR = NEd/Nb,y,Rd = 98.9/211.4 = **0.47** < 1.0 (Ch 6.3.1)
IR = NEd/Nb,z,Rd = 98.9/211.4 = **0.47** < 1.0 (Ch 6.3.1)

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.101	Date: 4/17/2016 Time: 17:37	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

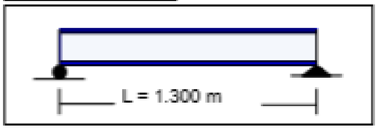
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

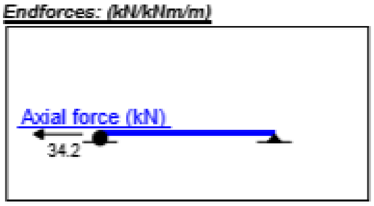
Cross Section Class: 1/2/2 N/My/Mz

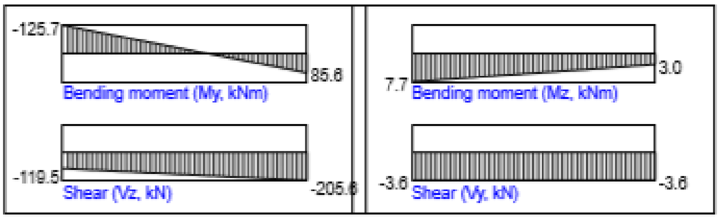
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

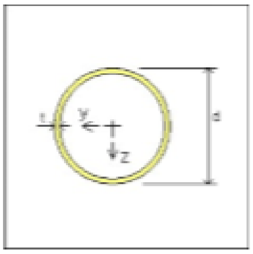
IR = My,Ed/My,Rd = 125.7/469.0 = 0.27 < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 125.7/468.9 = 0.27 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 205.6/1756.6 = 0.12 < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Offshore lift analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.104	Date: 4/17/2016 Time: 17:35
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355 MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15						

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

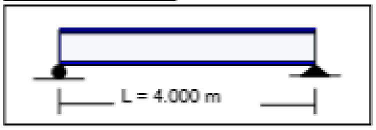
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

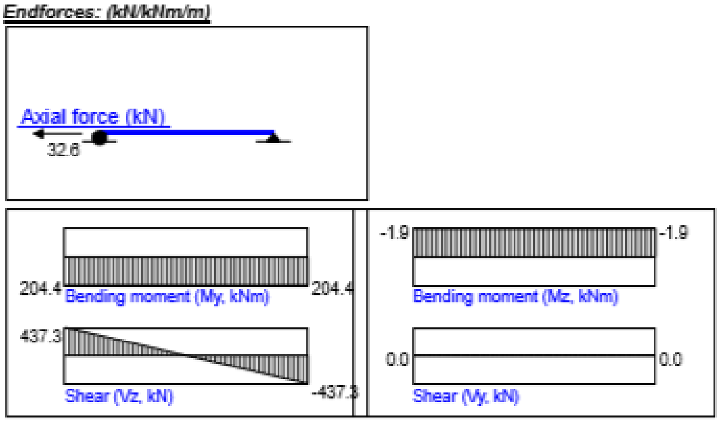
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 204.4/469.0 = 0.44 < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 204.4/468.9 = 0.44 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 437.3/1756.6 = 0.25 < 1.0 (0.00L; Ch 6.2.6)

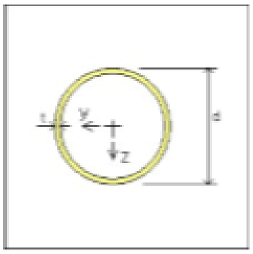
Appendix D9: Colbeam EC3 calculations for transportation Case C:Compressor module

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Transport analysis Compressor module 120 tonnes Identification: Beam No.12	Page: 1/1 Date: 4/17/2016 Time: 16:36
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

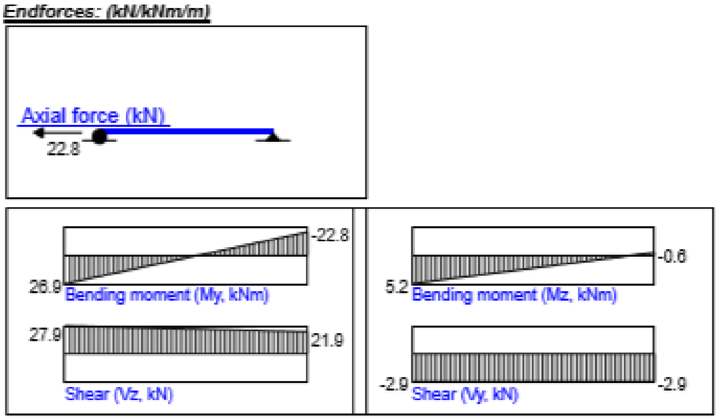
Profile: Tube 324x16 (Hot finished)



Dimensions and weight:				Section property:				Capacity:			
d	=	324.0	mm	A	=	15482	mm2	Cross Section Class: 1/2/2 N/My/Mz			
t	=	16.0	mm	Ix	=	3.682E+8	mm4	N,Rd	=	4779.2	kN
g	=	121.5	kg/m	Iy	=	1.841E+8	mm4	My,Rd	=	469.0	kNm
S	=	1.018	m2/m	Wel,y	=	1.136E+6	mm3	Vc,z,Rd	=	1756.6	kN
				Wpl,y	=	1.519E+6	mm3				

Geometry/Loading:

Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

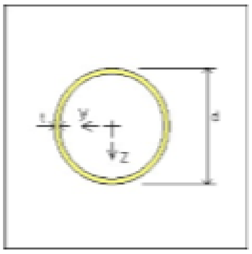
SECTION CONTROL:

IR = My,Ed/My,Rd = 26.9/469.0 = 0.06 < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 26.9/468.9 = 0.06 < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 27.9/1756.6 = 0.02 < 1.0 (0.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Transport analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.21	Date: 4/17/2016 Time: 16:31	
File: new file			

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

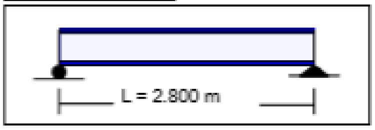
Section property:

A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

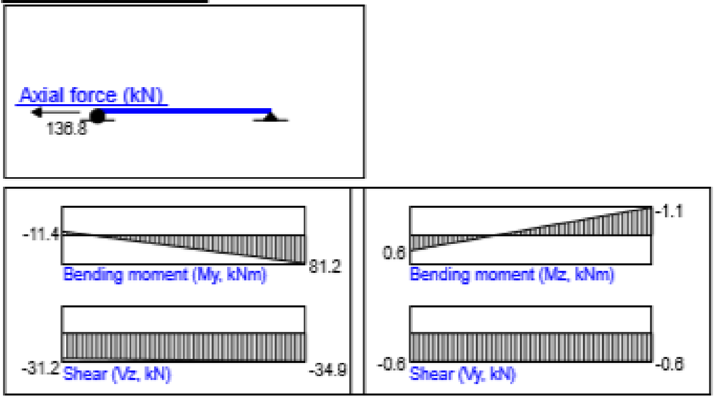
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

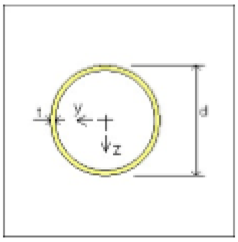
SECTION CONTROL:

IR = My,Ed/My,Rd = 81.2/469.0 = **0.17** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 81.2/467.9 = **0.17** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 34.9/1756.6 = **0.02** < 1.0 (1.00L; Ch 6.2.6)

Colbeam EC3 - User defined	Project: Transport analysis Compressor module 120 tonnes	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.29	Date: 4/17/2016 Time: 16:34
File: new file		

General:
Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 324x16 (Hot finished)



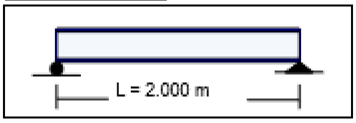
Dimensions and weight:			
d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:			
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

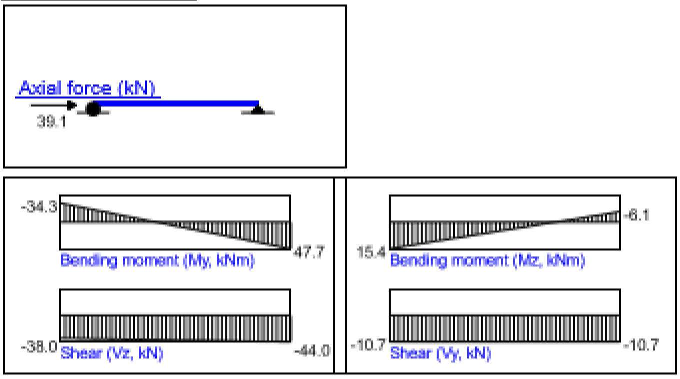
Capacity:
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.24	0.24
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 47.7/469.0 = **0.10** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 47.7/468.8 = **0.10** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 44.0/1756.6 = **0.03** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

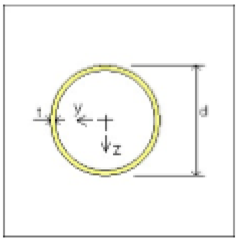
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 39.1/4736.9+0.64*47.7/(1.00*469.0)+0.42*15.4/469.0 = **0.09** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 39.1/4736.9+0.38*47.7/(1.00*469.0)+0.70*15.4/469.0 = **0.07** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Compressor module 120 tonn es	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Identification: Beam No.30	Date: 4/17/2016 Time: 16:28
File: new file		

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

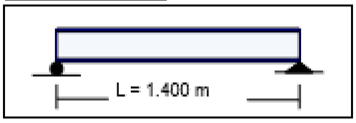
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

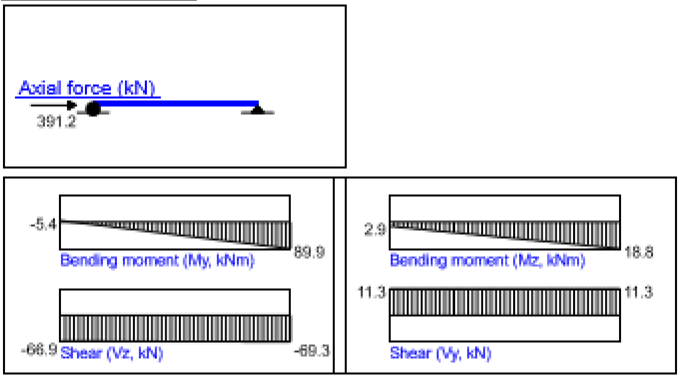
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:

		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.17	0.17
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 89.9/469.0 = **0.19** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 89.9/462.3 = **0.19** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 69.3/1756.6 = **0.04** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

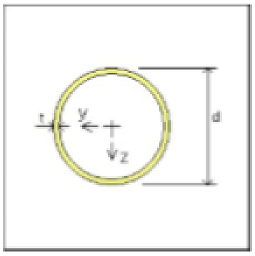
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 391.2/4779.2+0.74*89.9/(1.00*469.0)+0.47*18.8/469.0 = **0.24** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 391.2/4779.2+0.44*89.9/(1.00*469.0)+0.78*18.8/469.0 = **0.20** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Compressor module 120 tonn es	Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7	Identification: Beam No.63	Date: 4/17/2016
Copyright (C) 2010-2012 StruProg AB		Time: 16:39
File: new file		

General:

Material: S355 NH/NLH fy = 355 MPa E = 210000.0 MPa
gm0/gm1 = 1.15/1.15

Profile: Tube 114x6 (Hot finished)



Dimensions and weight:

d	=	114.0	mm
t	=	6.0	mm
g	=	16.0	kg/m
S	=	0.358	m2/m

Section property:

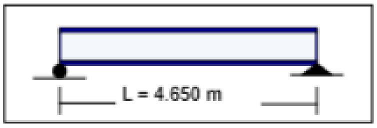
A	=	2036	mm2
Ix	=	5.955E+6	mm4
Iy	=	2.977E+6	mm4
Wel,y	=	5.223E+4	mm3
Wpl,y	=	7.006E+4	mm3

Capacity:

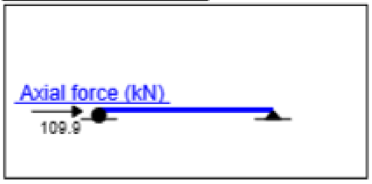
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	628.4	kN
My,Rd	=	21.6	kNm
Vc,z,Rd	=	231.0	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	1.59	1.59
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = NEd/NRd = 109.9/628.4 = 0.17 < 1.0 (0.50L; Ch 6.2.4)

BUCKLING CONTROL:

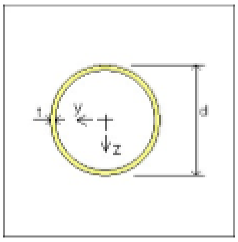
IR = NEd/Nb,y,Rd = 109.9/211.4 = 0.52 < 1.0 (Ch 6.3.1)
IR = NEd/Nb,z,Rd = 109.9/211.4 = 0.52 < 1.0 (Ch 6.3.1)

Colbeam EC3 - User defined Member Design Program incl updates until Feb 2012 Version 1.1.7 Copyright (C) 2010-2012 StruProg AB	Project: Transport analysis Compressor module 120 tonn es		Page: 1/1
	Identification: Beam No.101	Date: 4/17/2016 Time: 16:25	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

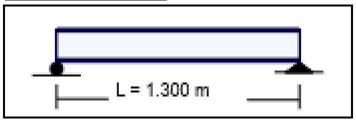
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

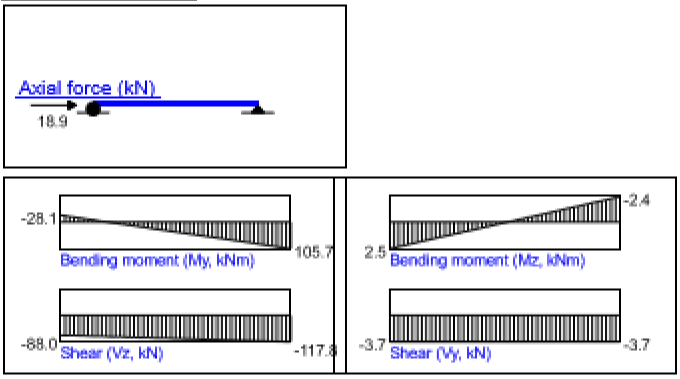
Cross Section Class: 1/2/2 N/My/Mz

N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)



Buckling parameters:		Y-axis	Z-axis
Buckling length factor		1.00	1.00
Buckling Curve		a	a
Slenderness	lamda =	0.16	0.16
Interaction factors kij:	Method 1		

Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 105.7/469.0 = **0.23** < 1.0 (1.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 105.7/468.9 = **0.23** < 1.0 (1.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 117.8/1756.6 = **0.07** < 1.0 (1.00L; Ch 6.2.6)

BUCKLING CONTROL:

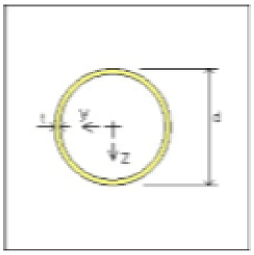
IR = NEd/Nb,y,Rd + kyy*My,Ed/(xLT*My,Rd) + kyz*Mz,Ed/Mz,Rd = 18.9/4779.2+0.73*105.7/(1.00*469.0)+0.35*2.5/469.0 = **0.17** < 1.0 (Ch 6.3.3)
IR = NEd/Nb,z,Rd + kzy*My,Ed/(xLT*My,Rd) + kzz*Mz,Ed/Mz,Rd = 18.9/4779.2+0.44*105.7/(1.00*469.0)+0.59*2.5/469.0 = **0.11** < 1.0 (Ch 6.3.3)

Colbeam EC3 - User defined	Project: Transport analysis Compressor module 120 tonnes		Page: 1/1
Member Design Program incl updates until Feb 2012 Version 1.1.7	Identification: Beam No.104	Date: 4/17/2016	
		Time: 16:23	
File: new file			

General:

Material:	S355 NH/NLH	fy	=	355	MPa	E	=	210000.0 MPa
gm0/gm1 =	1.15/1.15							

Profile: Tube 324x16 (Hot finished)



Dimensions and weight:

d	=	324.0	mm
t	=	16.0	mm
g	=	121.5	kg/m
S	=	1.018	m2/m

Section property:

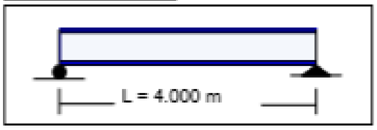
A	=	15482	mm2
Ix	=	3.682E+8	mm4
Iy	=	1.841E+8	mm4
Wel,y	=	1.136E+6	mm3
Wpl,y	=	1.519E+6	mm3

Capacity:

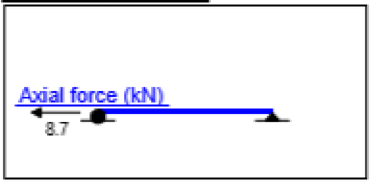
Cross Section Class: 1/2/2 N/My/Mz

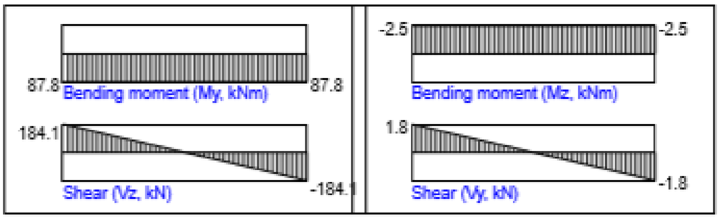
N,Rd	=	4779.2	kN
My,Rd	=	469.0	kNm
Vc,z,Rd	=	1756.6	kN

Geometry/Loading:



Endforces: (kN/kNm/m)





Lateral buckling parameters:

Governing Loadcase: Basic loads: G + Q1 + Q2

SECTION CONTROL:

IR = My,Ed/My,Rd = 87.8/469.0 = **0.19** < 1.0 (0.00L; Ch 6.2.5)
IR = My,Ed/MN,y,Rd = 87.8/469.0 = **0.19** < 1.0 (0.00L; Ch 6.2.9)
IR = Vz,Ed/Vz,Rd = 184.1/1756.6 = **0.10** < 1.0 (0.00L; Ch 6.2.6)

Appendix E: Staad.Pro input

Appendix E1: Staad.Pro input for air lifting Case A:Pump module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME PUMP MODULE 40 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 19-03-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 3 0 0; 3 0 0 4; 4 3 0 4; 5 0 7 0; 6 3 7 0; 7 0 7 4; 8 3 7 4;
19 0 1.5 0; 20 0 1.5 4; 21 3 1.5 4; 22 3 1.5 0; 27 0 5 4; 28 3 5 4; 33 0 5 0;
34 3 5 0; 35 0 7.15 0; 36 3 7.15 0; 37 0 7.15 4; 38 3 7.15 4; 39 1.58 8.73 2;
40 0 -0.5 0; 41 3 -0.5 0; 42 0 -0.5 4; 43 3 -0.5 4; 44 0 5 2; 45 1.5 5 4;
46 3 5 2; 47 1.5 5 0;
MEMBER INCIDENCES
121 1 3; 122 2 4; 147 1 19; 148 19 33; 149 20 3; 150 21 4; 151 22 2; 152 19 20;
153 22 21; 154 20 21; 155 19 22; 156 22 34; 163 20 27; 164 21 28; 165 27 7;
166 28 8; 187 1 2; 188 3 4; 189 33 5; 194 34 6; 200 5 7; 201 7 8; 202 8 6;
203 6 5; 204 35 5; 205 36 6; 206 38 8; 207 37 7; 208 36 39; 209 38 39;
210 35 39; 211 37 39; 212 1 40; 213 3 42; 214 4 43; 215 2 41; 216 33 44;
217 27 45; 218 28 46; 219 34 47; 220 44 27; 221 45 28; 222 46 34; 223 47 33;
224 5 44; 225 7 44; 226 7 45; 227 8 45; 228 8 46; 229 6 46; 230 6 47; 231 5 47;
ELEMENT INCIDENCES SHELL
31 5 7 8 6;
*******************************************************************************
ELEMENT PROPERTY
*******************************************************************************
*Cover and side steel plate thickness. Steel plate design is not performed
*******************************************************************************
31 THICKNESS 0.015
*******************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*******************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 1.2e-005
DAMP 0.03
```

```
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
*************************************************************************************
*Hollow section steel property
*************************************************************************************
MEMBER PROPERTY EUROPEAN
224 TO 231 TABLE ST PIPE OD 0.1143 ID 0.1017
121 122 147 TO 156 163 TO 166 187 TO 189 194 200 TO 203 212 TO 222 -
223 TABLE ST PIPE OD 0.3239 ID 0.2919
MEMBER PROPERTY EUROPEAN
208 TO 211 TABLE ST PIPE OD 0.02 ID 0
MEMBER PROPERTY EUROPEAN
204 TO 207 PRIS YD 0.02 ZD 0.01
CONSTANTS
BETA 45 MEMB 204 206
BETA 315 MEMB 205 207
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 208 TO 211
SUPPORTS
*************************************************************************************
*Boundary conditions for air lifting analysis set according to section 5.3.1
*************************************************************************************
39 PINNED
40 TO 43 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
*************************************************************************************
*BASIC LOADS
*************************************************************************************
MEMBER TENSION
208 TO 211
MEMBER RELEASE
*************************************************************************************

*************************************************************************************
*Braces released for moment
*************************************************************************************
224 TO 231 START MX MY MZ
224 TO 231 END MX MY MZ
LOAD 1 STATIC SELFWEIGHT
*************************************************************************************
* Static selfweight with 10% weight inaccuracy
*************************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
*************************************************************************************
*Total static pump module weight 30 tonnes (294.3kN)
*Applied on plate 4*3 (294.3/(4*3))= 24.525kN/m2
*************************************************************************************
ELEMENT LOAD
31 PR GY -24.525 -2 -1.5 2 1.5
*************************************************************************************
*LOAD COMBINATIONS-AIR LIFTING ANALYSIS
*************************************************************************************
LOAD COMB 3 LC25.AIR LIFTING
1 2.25 2 2.25
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E_2: Staad.Pro input for offshore lifting Case A:Pump module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME PUMP MODULE 40 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 19-03-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 3 0 0; 3 0 0 4; 4 3 0 4; 5 0 7 0; 6 3 7 0; 7 0 7 4; 8 3 7 4;
19 0 1.5 0; 20 0 1.5 4; 21 3 1.5 4; 22 3 1.5 0; 27 0 5 4; 28 3 5 4; 33 0 5 0;
34 3 5 0; 35 0 7.15 0; 36 3 7.15 0; 37 0 7.15 4; 38 3 7.15 4; 39 1.58 8.73 2;
40 0 -0.5 0; 41 3 -0.5 0; 42 0 -0.5 4; 43 3 -0.5 4; 44 0 5 2; 45 1.5 5 4;
46 3 5 2; 47 1.5 5 0;
MEMBER INCIDENCES
121 1 3; 122 2 4; 147 1 19; 148 19 33; 149 20 3; 150 21 4; 151 22 2; 152 19 20;
153 22 21; 154 20 21; 155 19 22; 156 22 34; 163 20 27; 164 21 28; 165 27 7;
166 28 8; 187 1 2; 188 3 4; 189 33 5; 194 34 6; 200 5 7; 201 7 8; 202 8 6;
203 6 5; 204 35 5; 205 36 6; 206 38 8; 207 37 7; 208 36 39; 209 38 39;
210 35 39; 211 37 39; 212 1 40; 213 3 42; 214 4 43; 215 2 41; 216 33 44;
217 27 45; 218 28 46; 219 34 47; 220 44 27; 221 45 28; 222 46 34; 223 47 33;
224 5 44; 225 7 44; 226 7 45; 227 8 45; 228 8 46; 229 6 46; 230 6 47; 231 5 47;
ELEMENT INCIDENCES SHELL
31 5 7 8 6;
**********************************************************************************
ELEMENT PROPERTY
**********************************************************************************
*Cover and side steel plate thickness. Steel plate design is not performed
**********************************************************************************
31 THICKNESS 0.015
**********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
**********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 1.2e-005
DAMP 0.03
*******************************************************************************
```

```
*********************************************************************************
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
************************************************************************************
*Hollow section steel property
************************************************************************************
MEMBER PROPERTY EUROPEAN
224 TO 231 TABLE ST PIPE OD 0.1143 ID 0.1017
121 122 147 TO 156 163 TO 166 187 TO 189 194 200 TO 207 212 TO 222 -
223 TABLE ST PIPE OD 0.3239 ID 0.2919
MEMBER PROPERTY EUROPEAN
208 TO 211 TABLE ST PIPE OD 0.02 ID 0
MEMBER PROPERTY EUROPEAN
204 TO 207 PRIS YD 0.02 ZD 0.01
CONSTANTS
BETA 45 MEMB 204 206
BETA 315 MEMB 205 207
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 208 TO 211
SUPPORTS
************************************************************************************
*Boundary conditions for offshore lifting analysis set according to section 5.3.1
************************************************************************************
39 PINNED
40 TO 43 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
************************************************************************************
*BASIC LOADS
************************************************************************************
MEMBER TENSION
208 TO 211
MEMBER RELEASE
************************************************************************************

************************************************************************************
*Braces released for moment
************************************************************************************
224 TO 231 START MX MY MZ
224 TO 231 END MX MY MZ
LOAD 1 STATIC SELFWEIGHT
************************************************************************************
* Static selfweight with 10% weight inaccuracy
************************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
************************************************************************************
*Total static pump module weight 30 tonnes (294.3kN)
*Applied on plate 4*3 (294.3/(4*3))= 24.525kN/m2
************************************************************************************
ELEMENT LOAD
31 PR GY -24.525 -2 -1.5 2 1.5
************************************************************************************
*LOAD COMBINATIONS-OFFSHORE/SUBSEA LIFTING ANALYSIS
************************************************************************************
LOAD COMB 3 LC26.SUBSEA LIFTING
1 3.12 2 3.12
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E3: Staad.Pro input for transportation Case A:Pump module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME PUMP MODULE 40 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 19-0316
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 3 0 0; 3 0 0 4; 4 3 0 4; 5 0 7 0; 6 3 7 0; 7 0 7 4; 8 3 7 4;
19 0 1.5 0; 20 0 1.5 4; 21 3 1.5 4; 22 3 1.5 0; 27 0 5 4; 28 3 5 4; 33 0 5 0;
34 3 5 0; 35 0 -0.5 0; 36 3 -0.5 0; 37 0 -0.5 4; 38 3 -0.5 4; 39 0 5 2;
40 1.5 5 4; 41 3 5 2; 42 1.5 5 0;
MEMBER INCIDENCES
121 1 3; 122 2 4; 147 1 19; 148 19 33; 149 20 3; 150 21 4; 151 22 2; 152 19 20;
153 22 21; 154 20 21; 155 19 22; 156 22 34; 163 20 27; 164 21 28; 165 27 7;
166 28 8; 187 1 2; 188 3 4; 189 33 5; 194 34 6; 200 5 7; 201 7 8; 202 8 6;
203 6 5; 204 1 35; 205 3 37; 206 4 38; 207 2 36; 208 33 39; 209 27 40;
210 28 41; 211 34 42; 212 39 27; 213 40 28; 214 41 34; 215 42 33; 216 5 39;
217 7 39; 218 7 40; 219 8 40; 220 8 41; 221 6 41; 222 6 42; 223 5 42;
ELEMENT INCIDENCES SHELL
31 5 7 8 6;
**********************************************************************************
ELEMENT PROPERTY
**********************************************************************************
*Cover and side steel plate thickness. Steel plate design is not performed
**********************************************************************************
31 THICKNESS 0.015
**********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
**********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
END DEFINE MATERIAL
**********************************************************************************
```

```
***************************************************************************************
*Hollow section steel property
***************************************************************************************
MEMBER PROPERTY EUROPEAN
216 TO 223 TABLE ST PIPE OD 0.1143 ID 0.1017
121 122 147 TO 156 163 TO 166 187 TO 189 194 200 TO 214 -
215 TABLE ST PIPE OD 0.3239 ID 0.2919
CONSTANTS
MATERIAL STEEL ALL
SUPPORTS
***************************************************************************************
*Boundary conditions for transportaion analysis set according to section 5.3.2
***************************************************************************************
35 TO 38 FIXED BUT MX MY MZ
***************************************************************************************
*BASIC LOADS
***************************************************************************************
MEMBER RELEASE
***************************************************************************************
*Braces released for moment
***************************************************************************************
216 TO 223 START MX MY MZ
216 TO 223 END MX MY MZ
LOAD 1 STATIC SELFWEIGHT
***************************************************************************************
* Static selfweight with 10% weight inaccuracy
***************************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
***************************************************************************************
```

```
LOAD 2 STATIC SUBSEA MODULE WEIGHT
***************************************************************************************
*Total static pump module weight 30 tonnes (294.3kN)
*Applied on plate 4*3 (294.3/(4*3))= 24.525kN/m2
***************************************************************************************
ELEMENT LOAD
31 PR GY -24.525 -2 -1.5 2 1.5
LOAD 3 DYNAMIC SELFWEIGHT IN +X DIRECTION
SELFWEIGHT X 1.1
LOAD 4 DYNAMIC SELFWEIGHT IN +Z DIRECTION
SELFWEIGHT Z 1.1
LOAD 5 DYNAMIC SELFWEIGHT IN +Y DIRECTION
SELFWEIGHT Y 1.1
LOAD 6 DYNAMIC SUBSEA MODULE WEIGHT IN +X DIRECTION
***************************************************************************************
*Total pump module weight 30 tonnes =294.3kN
***************************************************************************************
ELEMENT LOAD
31 PR GX 294.3 0 0
LOAD 7 DYNAMIC SUBSEA MODULE WEIGHT IN +Z DIRECTION
ELEMENT LOAD
31 PR GZ 294.3 0 0
LOAD 8 DYNAMIC SUBSEA MODULE WEIGHT IN +Y DIRECTION
ELEMENT LOAD
31 PR GY 294.3 0 0
LOAD 9 DYNAMIC SELFWEIGHT IN -X DIRECTION
SELFWEIGHT X -1.1
LOAD 10 DYNAMIC SELFWEIGHT IN -Z DIRECTION
SELFWEIGHT Z -1.1
LOAD 11 DYNAMIC SUBSEA MODULE WEIGHT IN -X DIRECTION
***************************************************************************************
*Total pump module weight 30 tonnes =294.3kN
***************************************************************************************
ELEMENT LOAD
31 PR GX -294.3 0 0
LOAD 12 DYNAMIC SUBSEA MODULE WEIGHT IN -Z DIRECTION
ELEMENT LOAD
31 PR GZ -294.3 0 0
***************************************************************************************
```

```
*LOAD COMBINATIONS-TRANSPORTATION ANALYSIS
*******************************************************************************
LOAD COMB 13 LC1.TRANSPORTATION ROLL, MAX.Z
1 1.3 2 1.3 3 1.0 6 1.0
LOAD COMB 14 LC2.TRANSPORTATION ROLL, MIN.Z
1 0.7 2 0.7 3 1.0 6 1.0
LOAD COMB 15 LC3.TRANSPORTATION PITCH, MAX.Z
1 1.3 2 1.3 4 1.0 7 1.0
LOAD COMB 16 LC4.TRANSPORTATION PITCH, MIN.Z
1 0.7 2 0.7 4 1.0 7 1.0
LOAD COMB 17 LC5.TRANSPORTATION -ROLL, MAX.Z
1 1.3 2 1.3 9 1.0 11 1.0
LOAD COMB 18 LC6.TRANSPORTATION -ROLL, MIN.Z
1 0.7 2 0.7 9 1.0 11 1.0
LOAD COMB 19 LC7.TRANSPORTATION -PITCH, MAX.Z
1 1.3 2 1.3 10 1.0 12 1.0
LOAD COMB 20 LC8.TRANSPORTATION -PITCH, MIN.Z
1 0.7 2 0.7 10 1.0 12 1.0
*******************************************************************************
*LOAD COMBINATIONS-ULSa TRANSPORTATION ANALYSIS
*******************************************************************************
LOAD COMB 21 LC9.ULS A,ROLL+HEAVE
1 1.3 2 1.3 3 0.7 5 -0.7 6 0.7 8 -0.7
LOAD COMB 22 LC10.ULS A,ROLL-HEAVE
1 1.3 2 1.3 3 0.7 5 0.7 6 0.7 8 0.7
LOAD COMB 23 LC11.ULS A,-ROLL+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 9 0.7 11 0.7
LOAD COMB 24 LC12.ULS A,-ROLL-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 9 0.7 11 0.7
LOAD COMB 25 LC13.ULS A,PITCH+HEAVE
1 1.3 2 1.3 4 0.7 5 -0.7 7 0.7 8 -0.7
LOAD COMB 26 LC14.ULS A,PITCH-HEAVE
1 1.3 2 1.3 4 0.7 5 0.7 7 0.7 8 0.7
LOAD COMB 27 LC15.ULS A,-PITCH+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 10 0.7 12 0.7
LOAD COMB 28 LC16.ULS A,-PITCH-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 10 0.7 12 0.7
*******************************************************************************

*LOAD COMBINATIONS-ULSb TRANSPORTATION ANALYSIS
*******************************************************************************
LOAD COMB 29 LC17.ULS B,ROLL+HEAVE
1 1.0 2 1.0 3 1.3 5 -1.3 6 1.3 8 -1.3
LOAD COMB 30 LC18.ULS B,ROLL-HEAVE
1 1.0 2 1.0 3 1.3 5 1.3 6 1.3 8 1.3
LOAD COMB 31 LC19.ULS B,-ROLL+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 9 1.3 11 1.3
LOAD COMB 32 LC20.ULS B,-ROLL-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 9 1.3 11 1.3
LOAD COMB 33 LC21.ULS B,PITCH+HEAVE
1 1.0 2 1.0 4 1.3 5 -1.3 7 1.3 8 -1.3
LOAD COMB 34 LC22.ULS B,PITCH-HEAVE
1 1.0 2 1.0 4 1.3 5 1.3 7 1.3 8 1.3
LOAD COMB 35 LC23.ULS B,-PITCH+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 10 1.3 12 1.3
LOAD COMB 36 LC24.ULS B,-PITCH-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 10 1.3 12 1.3
PERFORM ANALYSIS
LOAD LIST 13 TO 36
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
FINISH
```

Appendix E4: Staad.Pro input for air lifting Case B: Cooler module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COOLER MODULE 100 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 04-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 0 5; 3 9 0 0; 4 9 0 5; 5 0 7 0; 6 0 7 5; 7 9 7 5; 8 9 7 0;
9 0 7 2.5; 10 0 0 2.5; 11 9 0 2.5; 12 9 7 2.5; 13 3 7 5; 14 6 7 5; 15 6 7 0;
16 3 7 0; 17 3 0 5; 18 6 0 5; 19 6 0 0; 20 3 0 0; 21 3 5.5 5; 22 6 5.5 5;
23 3 1 5; 24 6 1 5; 25 6 5.5 0; 26 3 5.5 0; 27 6 1 0; 28 3 1 0; 29 3 7 2.5;
30 6 7 2.5; 31 3 0 2.5; 32 6 0 2.5; 33 0 7.15 0; 34 0 7.15 5; 35 9 7.15 5;
36 9 7.15 0; 37 4.5 11.65 2.5; 38 0 -0.5 0; 39 0 -0.5 5; 40 9 -0.5 0;
41 9 -0.5 5; 42 0.5 0 5; 43 8.5 0 5; 44 8.5 0 0; 45 0.5 0 0;
*******************************************************************************
MEMBER INCIDENCES
1 1 10; 2 2 42; 3 4 11; 4 3 44; 5 5 9; 6 6 13; 7 7 12; 8 8 15; 9 1 5; 10 2 6;
11 3 8; 12 4 7; 13 9 6; 14 10 2; 15 11 3; 16 12 8; 17 10 9; 18 11 12; 19 5 10;
20 6 10; 21 8 11; 22 7 11; 23 13 14; 24 14 7; 25 15 16; 26 16 5; 27 17 18;
28 18 43; 29 19 20; 30 20 45; 31 16 26; 32 15 25; 33 13 21; 34 14 22; 35 6 17;
36 7 18; 37 8 19; 38 5 20; 39 21 23; 40 22 24; 41 21 22; 42 23 17; 43 24 18;
44 23 24; 45 21 24; 46 25 27; 47 26 28; 48 25 26; 49 27 19; 50 28 20; 51 27 28;
52 25 28; 53 16 29; 54 15 30; 55 29 13; 56 30 14; 57 9 29; 58 29 30; 59 30 12;
64 10 31; 65 31 32; 66 32 11; 67 10 17; 68 10 20; 70 11 18; 71 11 19; 72 34 6;
73 33 5; 74 36 8; 75 35 7; 76 33 37; 77 34 37; 78 36 37; 79 35 37; 80 20 31;
81 31 17; 82 19 32; 83 32 18; 84 2 39; 85 1 38; 86 3 40; 87 4 41; 88 42 17;
89 42 39; 90 43 4; 91 43 41; 92 44 19; 93 44 40; 94 45 1; 95 45 38;
*******************************************************************************
*********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
```

```
********************************************************************************
* Dummy slings for lifting with density 0
********************************************************************************
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
*********************************************************************************
*Hollow section steel property
*********************************************************************************
MEMBER PROPERTY EUROPEAN
1 TO 18 23 TO 34 39 TO 44 46 TO 51 53 TO 59 64 TO 68 70 71 80 TO 94 -
95 TABLE ST PIPE OD 0.273 ID 0.241
19 TO 22 35 TO 38 45 52 TABLE ST PIPE OD 0.1143 ID 0.1017
MEMBER PROPERTY EUROPEAN
76 TO 79 TABLE ST PIPE OD 0.02 ID 0
MEMBER PROPERTY EUROPEAN
72 TO 75 PRIS YD 0.02 ZD 0.1
CONSTANTS
BETA 45 MEMB 73 75
BETA 315 MEMB 72 74
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 76 TO 79
*********************************************************************************
*Braces released for moment
*********************************************************************************
MEMBER RELEASE
19 TO 22 35 TO 38 45 52 START MX MY MZ
19 TO 22 35 TO 38 45 52 END MX MY MZ
SUPPORTS
*********************************************************************************
*Boundary conditions for air lifting analysis set according to section 5.3.1
*********************************************************************************
37 PINNED
38 TO 41 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
*********************************************************************************

*********************************************************************************
*BASIC LOADS
*********************************************************************************
LOAD 1 STATIC SELFWEIGHT
*********************************************************************************
* Static selfweight with 10% weight inaccuracy
*********************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
*******************************************************************************
*Total static cooler module weight 75 tonnes (735.75kN)
*This load is distributed on Area 5 x 9, hence (735.75/(5x9))= 16.35kN/m2
*******************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -16.35 XRANGE 0 9 ZRANGE 0 5
*********************************************************************************
*LOAD COMBINATIONS-AIR LIFTING ANALYSIS
*********************************************************************************
LOAD COMB 3 LC25.AIR LIFTING
1 2.25 2 2.25
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E5: Staad.Pro input for offshore lifting Case B: Cooler module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COOLER MODULE 100 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 04-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 0 5; 3 9 0 0; 4 9 0 5; 5 0 7 0; 6 0 7 5; 7 9 7 5; 8 9 7 0;
9 0 7 2.5; 10 0 0 2.5; 11 9 0 2.5; 12 9 7 2.5; 13 3 7 5; 14 6 7 5; 15 6 7 0;
16 3 7 0; 17 3 0 5; 18 6 0 5; 19 6 0 0; 20 3 0 0; 21 3 5.5 5; 22 6 5.5 5;
23 3 1 5; 24 6 1 5; 25 6 5.5 0; 26 3 5.5 0; 27 6 1 0; 28 3 1 0; 29 3 7 2.5;
30 6 7 2.5; 31 3 0 2.5; 32 6 0 2.5; 33 0 7.15 0; 34 0 7.15 5; 35 9 7.15 5;
36 9 7.15 0; 37 4.5 11.65 2.5; 38 0 -0.5 0; 39 0 -0.5 5; 40 9 -0.5 0;
41 9 -0.5 5; 42 0.5 0 5; 43 8.5 0 5; 44 8.5 0 0; 45 0.5 0 0;
*********************************************************************************
MEMBER INCIDENCES
1 1 10; 2 2 42; 3 4 11; 4 3 44; 5 5 9; 6 6 13; 7 7 12; 8 8 15; 9 1 5; 10 2 6;
11 3 8; 12 4 7; 13 9 6; 14 10 2; 15 11 3; 16 12 8; 17 10 9; 18 11 12; 19 5 10;
20 6 10; 21 8 11; 22 7 11; 23 13 14; 24 14 7; 25 15 16; 26 16 5; 27 17 18;
28 18 43; 29 19 20; 30 20 45; 31 16 26; 32 15 25; 33 13 21; 34 14 22; 35 6 17;
36 7 18; 37 8 19; 38 5 20; 39 21 23; 40 22 24; 41 21 22; 42 23 17; 43 24 18;
44 23 24; 45 21 24; 46 25 27; 47 26 28; 48 25 26; 49 27 19; 50 28 20; 51 27 28;
52 25 28; 53 16 29; 54 15 30; 55 29 13; 56 30 14; 57 9 29; 58 29 30; 59 30 12;
64 10 31; 65 31 32; 66 32 11; 67 10 17; 68 10 20; 70 11 18; 71 11 19; 72 34 6;
73 33 5; 74 36 8; 75 35 7; 76 33 37; 77 34 37; 78 36 37; 79 35 37; 80 20 31;
81 31 17; 82 19 32; 83 32 18; 84 2 39; 85 1 38; 86 3 40; 87 4 41; 88 42 17;
89 42 39; 90 43 4; 91 43 41; 92 44 19; 93 44 40; 94 45 1; 95 45 38;
*********************************************************************************
*********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
```

```
********************************************************************************
* Dummy slings for lifting with density 0
********************************************************************************
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
***********************************************************************************
*Hollow section steel property
***********************************************************************************
MEMBER PROPERTY EUROPEAN
1 TO 18 23 TO 34 39 TO 44 46 TO 51 53 TO 59 64 TO 68 70 71 80 TO 94 -
95 TABLE ST PIPE OD 0.273 ID 0.241
19 TO 22 35 TO 38 45 52 TABLE ST PIPE OD 0.1143 ID 0.1017
MEMBER PROPERTY EUROPEAN
76 TO 79 TABLE ST PIPE OD 0.02 ID 0
MEMBER PROPERTY EUROPEAN
72 TO 75 PRIS YD 0.02 ZD 0.1
CONSTANTS
BETA 45 MEMB 73 75
BETA 315 MEMB 72 74
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 76 TO 79
***********************************************************************************
*Braces released for moment
***********************************************************************************
MEMBER RELEASE
19 TO 22 35 TO 38 45 52 START MX MY MZ
19 TO 22 35 TO 38 45 52 END MX MY MZ
SUPPORTS
***********************************************************************************
*Boundary conditions for lifting analysis set according to section 5.3.1
***********************************************************************************
37 PINNED
38 TO 41 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
***********************************************************************************

***********************************************************************************
*BASIC LOADS
***********************************************************************************
LOAD 1 STATIC SELFWEIGHT
***********************************************************************************
* Static selfweight with 10% weight inaccuracy
***********************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
*********************************************************************************
*Total static cooler module weight 75 tonnes (735.75kN)
*This load is distributed on Area 5 x 9, hence (735.75/(5x9))= 16.35kN/m2
*********************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -16.35 XRANGE 0 9 ZRANGE 0 5
***********************************************************************************
*LOAD COMBINATIONS-SUBSEA LIFTING ANALYSIS
***********************************************************************************
LOAD COMB 3 LC26.SUBSEA LIFTING
1 3.12 2 3.12
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E_6: Staad.Pro input for transportation Case B: Cooler module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COOLER MODULE 100 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 04-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0 0 5; 3 9 0 0; 4 9 0 5; 5 0 7 0; 6 0 7 5; 7 9 7 5; 8 9 7 0;
9 0 7 2.5; 10 0 0 2.5; 11 9 0 2.5; 12 9 7 2.5; 13 3 7 5; 14 6 7 5; 15 6 7 0;
16 3 7 0; 17 3 0 5; 18 6 0 5; 19 6 0 0; 20 3 0 0; 21 3 5.5 5; 22 6 5.5 5;
23 3 1 5; 24 6 1 5; 25 6 5.5 0; 26 3 5.5 0; 27 6 1 0; 28 3 1 0; 29 3 7 2.5;
30 6 7 2.5; 31 3 0 2.5; 32 6 0 2.5; 33 0 -0.5 0; 34 0 -0.5 5; 35 9 -0.5 0;
36 9 -0.5 5; 37 0.5 0 5; 38 8.5 0 5; 39 8.5 0 0; 40 0.5 0 0;
**********************************************************************************
MEMBER INCIDENCES
1 1 10; 2 2 37; 3 4 11; 4 3 39; 5 5 9; 6 6 13; 7 7 12; 8 8 15; 9 1 5; 10 2 6;
11 3 8; 12 4 7; 13 9 6; 14 10 2; 15 11 3; 16 12 8; 17 10 9; 18 11 12; 19 5 10;
20 6 10; 21 8 11; 22 7 11; 23 13 14; 24 14 7; 25 15 16; 26 16 5; 27 17 18;
28 18 38; 29 19 20; 30 20 40; 31 16 26; 32 15 25; 33 13 21; 34 14 22; 35 6 17;
36 7 18; 37 8 19; 38 5 20; 39 21 23; 40 22 24; 41 21 22; 42 23 17; 43 24 18;
44 23 24; 45 21 24; 46 25 27; 47 26 28; 48 25 26; 49 27 19; 50 28 20; 51 27 28;
52 25 28; 53 16 29; 54 15 30; 55 29 13; 56 30 14; 57 9 29; 58 29 30; 59 30 12;
60 20 31; 61 19 32; 62 31 17; 63 32 18; 64 10 31; 65 31 32; 66 32 11; 67 10 17;
68 10 20; 70 11 18; 71 11 19; 72 1 33; 73 2 34; 74 4 36; 75 3 35; 76 37 17;
77 38 4; 78 39 19; 79 40 1; 80 37 34; 81 38 36; 82 39 35; 83 40 33;
**********************************************************************************
**********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
**********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
END DEFINE MATERIAL
```

```
*************************************************************************************
*Hollow section steel property
*************************************************************************************
CONSTANTS
MATERIAL STEEL MEMB 1 TO 68 70 TO 83
MEMBER PROPERTY EUROPEAN
1 TO 18 23 TO 34 39 TO 44 46 TO 51 53 TO 68 70 TO 82 -
83 TABLE ST PIPE OD 0.273 ID 0.241
19 TO 22 35 TO 38 45 52 TABLE ST PIPE OD 0.1143 ID 0.1017
*************************************************************************************
*Braces released for moment
*************************************************************************************
MEMBER RELEASE
19 TO 22 35 TO 38 45 52 START MX MY MZ
19 TO 22 35 TO 38 45 52 END MX MY MZ
SUPPORTS
*************************************************************************************
*Boundary conditions for transportaion analysis set according to section 5.3.2
*************************************************************************************
33 TO 36 FIXED BUT MX MY MZ
*************************************************************************************
*BASIC LOADS
*************************************************************************************
LOAD 1 STATIC SELFWEIGHT
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
***********************************************************************************
*Total static cooler module weight 75 tonnes (735.75kN)
*This load is distributed on Area 5 x 9, hence (735.75/(5x9))= 16.35kN/m2
***********************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -16.35 XRANGE 0 9 ZRANGE 0 5
LOAD 3 DYNAMIC SELFWEIGHT IN +X DIRECTION
SELFWEIGHT X 1.1
LOAD 4 DYNAMIC SELFWEIGHT IN +Z DIRECTION
SELFWEIGHT Z 1.1
LOAD 5 DYNAMIC SELFWEIGHT IN +Y DIRECTION
SELFWEIGHT Y 1.1
LOAD 6 DYNAMIC SUBSEA MODULE WEIGHT IN +X DIRECTION
JOINT LOAD
1 TO 4 FX -183.94
```

```
LOAD 7 DYNAMIC SUBSEA MODULE WEIGHT IN +Z DIRECTION
JOINT LOAD
1 TO 4 FZ -183.94
LOAD 8 DYNAMIC SUBSEA MODULE WEIGHT IN +Y DIRECTION
JOINT LOAD
1 TO 4 FY -183.94
LOAD 9 DYNAMIC SELFWEIGHT IN -X DIRECTION
SELFWEIGHT X -1.1
LOAD 10 DYNAMIC SELFWEIGHT IN -Z DIRECTION
SELFWEIGHT Z -1.1
LOAD 11 DYNAMIC SUBSEA MODULE WEIGHT IN -X DIRECTION
JOINT LOAD
1 TO 4 FX 183.94
LOAD 12 DYNAMIC SUBSEA MODULE WEIGHT IN -Z DIRECTION
JOINT LOAD
1 TO 4 FZ 183.94
*************************************************************************************
*LOAD COMBINATIONS-TRANSPORTATION ANALYSIS
*************************************************************************************
LOAD COMB 13 LC1.TRANSPORTATION ROLL, MAX.Z
1 1.3 2 1.3 3 1.0 6 1.0
LOAD COMB 14 LC2.TRANSPORTATION ROLL, MIN.Z
1 0.7 2 0.7 3 1.0 6 1.0
LOAD COMB 15 LC3.TRANSPORTATION PITCH, MAX.Z
1 1.3 2 1.3 4 1.0 7 1.0
LOAD COMB 16 LC4.TRANSPORTATION PITCH, MIN.Z
1 0.7 2 0.7 4 1.0 7 1.0
LOAD COMB 17 LC5.TRANSPORTATION -ROLL, MAX.Z
1 1.3 2 1.3 9 1.0 11 1.0
LOAD COMB 18 LC6.TRANSPORTATION -ROLL, MIN.Z
1 0.7 2 0.7 9 1.0 11 1.0
LOAD COMB 19 LC7.TRANSPORTATION -PITCH, MAX.Z
1 1.3 2 1.3 10 1.0 12 1.0
LOAD COMB 20 LC8.TRANSPORTATION -PITCH, MIN.Z
1 0.7 2 0.7 10 1.0 12 1.0
```

```
*******************************************************************************
*LOAD COMBINATIONS-ULSa TRANSPORTATION ANALYSIS
*******************************************************************************
LOAD COMB 21 LC9.ULS A,ROLL+HEAVE
1 1.3 2 1.3 3 0.7 5 -0.7 6 0.7 8 -0.7
LOAD COMB 22 LC10.ULS A,ROLL-HEAVE
1 1.3 2 1.3 3 0.7 5 0.7 6 0.7 8 0.7
LOAD COMB 23 LC11.ULS A,-ROLL+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 9 0.7 11 0.7
LOAD COMB 24 LC12.ULS A,-ROLL-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 9 0.7 11 0.7
LOAD COMB 25 LC13.ULS A,PITCH+HEAVE
1 1.3 2 1.3 4 0.7 5 -0.7 7 0.7 8 -0.7
LOAD COMB 26 LC14.ULS A,PITCH-HEAVE
1 1.3 2 1.3 4 0.7 5 0.7 7 0.7 8 0.7
LOAD COMB 27 LC15.ULS A,-PITCH+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 10 0.7 12 0.7
LOAD COMB 28 LC16.ULS A,-PITCH-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 10 0.7 12 0.7
*******************************************************************************
*LOAD COMBINATIONS-ULSb TRANSPORTATION ANALYSIS
*******************************************************************************
LOAD COMB 29 LC17.ULS B,ROLL+HEAVE
1 1.0 2 1.0 3 1.3 5 -1.3 6 1.3 8 -1.3
LOAD COMB 30 LC18.ULS B,ROLL-HEAVE
1 1.0 2 1.0 3 1.3 5 1.3 6 1.3 8 1.3
LOAD COMB 31 LC19.ULS B,-ROLL+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 9 1.3 11 1.3
LOAD COMB 32 LC20.ULS B,-ROLL-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 9 1.3 11 1.3
LOAD COMB 33 LC21.ULS B,PITCH+HEAVE
1 1.0 2 1.0 4 1.3 5 -1.3 7 1.3 8 -1.3
LOAD COMB 34 LC22.ULS B,PITCH-HEAVE
1 1.0 2 1.0 4 1.3 5 1.3 7 1.3 8 1.3
LOAD COMB 35 LC23.ULS B,-PITCH+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 10 1.3 12 1.3
LOAD COMB 36 LC24.ULS B,-PITCH-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 10 1.3 12 1.3

PERFORM ANALYSIS
LOAD LIST 13 TO 36
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
FINISH
```

Appendix E7: Staad.Pro input for air lifting Case C: Compressor module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COMPRESSOR MODULE 120 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 07-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 4 0 0; 3 0 0 4; 4 4 0 4; 5 0 7 0; 6 4 7 0; 7 0 7 4; 8 4 7 4;
9 0 -0.5 0; 10 4 -0.5 0; 11 0 -0.5 4; 12 4 -0.5 4; 13 0 7 2; 14 0 0 2;
15 0 2.8 0; 16 0 2.8 2; 17 0 2.8 4; 18 4 5.6 4; 19 4 4.2 4; 20 4 2.8 4;
21 4 1.4 4; 22 0 1.4 4; 23 0 5.6 4; 24 0 4.2 4; 25 2 0 4; 26 2 1.4 4;
27 2 2.8 4; 28 2 4.2 4; 29 2 5.6 4; 30 4 2.8 0; 31 4 7 2; 32 4 0 2; 33 4 2.8 2;
34 2 0 0; 35 2 2.8 0; 36 2 7 0; 37 0 8 0; 38 4 8 0; 39 0 8 4; 40 4 8 4;
41 1 9 4; 42 3 9 4; 43 0 7 2.5; 44 4 7 2.5; 45 0 8 2.5; 46 4 8 2.5; 47 1 9 2.5;
48 3 9 2.5; 49 1 9 0; 50 3 9 0; 51 0 0 1.3; 52 0 0 2.7; 53 4 0 2.7; 54 4 0 1.3;
55 2 12.5 2.17;
********************************************************************************
MEMBER INCIDENCES
1 3 25; 2 4 53; 3 2 34; 4 1 51; 5 7 23; 6 5 15; 7 8 18; 8 6 30; 9 7 8; 10 8 44;
11 6 36; 12 5 13; 13 3 11; 14 1 9; 15 2 10; 16 4 12; 17 13 43; 18 14 52;
19 13 16; 20 15 1; 21 16 14; 23 17 22; 24 18 19; 25 19 20; 26 20 21; 27 21 4;
28 15 16; 29 16 17; 30 22 3; 31 23 24; 32 24 17; 33 21 26; 34 20 27; 35 19 28;
36 18 29; 37 13 15; 38 13 17; 39 15 14; 40 17 14; 41 25 4; 42 26 22; 43 26 25;
44 21 25; 45 22 25; 46 27 17; 47 19 27; 48 24 27; 49 28 24; 50 18 28; 51 23 28;
52 29 23; 53 8 29; 54 7 29; 55 30 2; 56 20 33; 57 31 6; 58 32 54; 59 33 30;
60 31 33; 61 33 32; 62 31 20; 63 31 30; 64 30 32; 65 20 32; 66 30 35; 67 34 1;
68 35 15; 69 36 5; 70 15 34; 71 30 34; 72 36 30; 73 36 15; 74 39 7; 75 40 8;
76 38 6; 77 37 5; 78 39 40; 79 41 42; 80 43 7; 81 44 31; 82 45 43; 83 46 44;
84 45 46; 85 47 48; 87 49 50; 88 49 37; 89 50 38; 90 41 39; 91 42 40; 92 47 45;
93 48 46; 94 45 39; 95 49 47; 96 47 41; 97 50 48; 98 48 42; 99 46 40;
100 51 14; 101 52 3; 102 53 32; 103 54 2; 104 51 54; 105 52 53; 108 34 35;
109 35 36; 110 5 55; 111 6 55; 112 7 55; 113 8 55;
ELEMENT INCIDENCES SHELL
106 49 47 48 50; 107 47 41 42 48;
********************************************************************************
```

```
*****************************************************************************
ELEMENT PROPERTY
*****************************************************************************
*15 mm Cover steel plate.Steel plate design is not performed
*****************************************************************************
106 107 THICKNESS 0.015
*****************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*****************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
**************************************************************************
* Dummy slings for lifting with density 0
**************************************************************************
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
*****************************************************************************
*Hollow section steel property
*****************************************************************************
MEMBER PROPERTY EUROPEAN
1 TO 21 23 TO 36 41 TO 43 46 49 52 55 TO 61 66 TO 69 74 TO 85 87 TO 105 108 -
109 TABLE ST PIPE OD 0.3239 ID 0.2919
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 72 -
73 TABLE ST PIPE OD 0.1143 ID 0.1017
MEMBER PROPERTY EUROPEAN
110 TO 113 TABLE ST PIPE OD 0.02 ID 0
CONSTANTS
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 110 TO 113
*****************************************************************************
```

```
********************************************************************************
*Braces released for moment
********************************************************************************
MEMBER RELEASE
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 START MX MY MZ
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 END MX MY MZ
SUPPORTS
********************************************************************************
*Boundary conditions for air lifting analysis set according to section 5.3.1
********************************************************************************
9 TO 12 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
55 PINNED
********************************************************************************
*BASIC LOADS
********************************************************************************
LOAD 1 STATIC SELFWEIGHT
********************************************************************************
* Static selfweight with 10% weight inaccuracy
********************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
******************************************************************************
*Total static compressor module weight 100 tonnes (981kN)
*This load is distributed on Area 4 x 4, hence (981/(4x4))= 61.3kN/m2
******************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -61.3 XRANGE 0 4 ZRANGE 0 4
********************************************************************************
*LOAD COMBINATIONS-AIR LIFTING ANALYSIS
********************************************************************************
LOAD COMB 3 LC25.AIR LIFTING
1 2.25 2 2.25
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E8: Staad.Pro input for offshore lifting Case C: Compressor module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COMPRESSOR MODULE 120 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 07-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 4 0 0; 3 0 0 4; 4 4 0 4; 5 0 7 0; 6 4 7 0; 7 0 7 4; 8 4 7 4;
9 0 -0.5 0; 10 4 -0.5 0; 11 0 -0.5 4; 12 4 -0.5 4; 13 0 7 2; 14 0 0 2;
15 0 2.8 0; 16 0 2.8 2; 17 0 2.8 4; 18 4 5.6 4; 19 4 4.2 4; 20 4 2.8 4;
21 4 1.4 4; 22 0 1.4 4; 23 0 5.6 4; 24 0 4.2 4; 25 2 0 4; 26 2 1.4 4;
27 2 2.8 4; 28 2 4.2 4; 29 2 5.6 4; 30 4 2.8 0; 31 4 7 2; 32 4 0 2; 33 4 2.8 2;
34 2 0 0; 35 2 2.8 0; 36 2 7 0; 37 0 8 0; 38 4 8 0; 39 0 8 4; 40 4 8 4;
41 1 9 4; 42 3 9 4; 43 0 7 2.5; 44 4 7 2.5; 45 0 8 2.5; 46 4 8 2.5; 47 1 9 2.5;
48 3 9 2.5; 49 1 9 0; 50 3 9 0; 51 0 0 1.3; 52 0 0 2.7; 53 4 0 2.7; 54 4 0 1.3;
55 2 12.5 2.17;
*************************************************************************************
MEMBER INCIDENCES
1 3 25; 2 4 53; 3 2 34; 4 1 51; 5 7 23; 6 5 15; 7 8 18; 8 6 30; 9 7 8; 10 8 44;
11 6 36; 12 5 13; 13 3 11; 14 1 9; 15 2 10; 16 4 12; 17 13 43; 18 14 52;
19 13 16; 20 15 1; 21 16 14; 23 17 22; 24 18 19; 25 19 20; 26 20 21; 27 21 4;
28 15 16; 29 16 17; 30 22 3; 31 23 24; 32 24 17; 33 21 26; 34 20 27; 35 19 28;
36 18 29; 37 13 15; 38 13 17; 39 15 14; 40 17 14; 41 25 4; 42 26 22; 43 26 25;
44 21 25; 45 22 25; 46 27 17; 47 19 27; 48 24 27; 49 28 24; 50 18 28; 51 23 28;
52 29 23; 53 8 29; 54 7 29; 55 30 2; 56 20 33; 57 31 6; 58 32 54; 59 33 30;
60 31 33; 61 33 32; 62 31 20; 63 31 30; 64 30 32; 65 20 32; 66 30 35; 67 34 1;
68 35 15; 69 36 5; 70 15 34; 71 30 34; 72 36 30; 73 36 15; 74 39 7; 75 40 8;
76 38 6; 77 37 5; 78 39 40; 79 41 42; 80 43 7; 81 44 31; 82 45 43; 83 46 44;
84 45 46; 85 47 48; 87 49 50; 88 49 37; 89 50 38; 90 41 39; 91 42 40; 92 47 45;
93 48 46; 94 45 39; 95 49 47; 96 47 41; 97 50 48; 98 48 42; 99 46 40;
100 51 14; 101 52 3; 102 53 32; 103 54 2; 104 51 54; 105 52 53; 108 34 35;
109 35 36; 110 5 55; 111 6 55; 112 7 55; 113 8 55;
ELEMENT INCIDENCES SHELL
106 49 47 48 50; 107 47 41 42 48;
*************************************************************************************
```

```
*****************************************************************************************
ELEMENT PROPERTY
*****************************************************************************************
*15 mm Cover steel plate.Steel plate design is not performed
*****************************************************************************************
106 107 THICKNESS 0.015
*****************************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*****************************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
**************************************************************************************
* Dummy slings for lifting with density 0
**************************************************************************************
ISOTROPIC SLINGS
E 2.1e+008
POISSON 0.3
DENSITY 0.0001
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
*****************************************************************************************
*Hollow section steel property
*****************************************************************************************
MEMBER PROPERTY EUROPEAN
1 TO 21 23 TO 36 41 TO 43 46 49 52 55 TO 61 66 TO 69 74 TO 85 87 TO 105 108 -
109 TABLE ST PIPE OD 0.3239 ID 0.2919
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 72 -
73 TABLE ST PIPE OD 0.1143 ID 0.1017
MEMBER PROPERTY EUROPEAN
110 TO 113 TABLE ST PIPE OD 0.02 ID 0
CONSTANTS
MATERIAL STEEL ALL
MATERIAL SLINGS MEMB 110 TO 113
*****************************************************************************************
```

```
*************************************************************************************
*Braces released for moment
*************************************************************************************
MEMBER RELEASE
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 START MX MY MZ
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 END MX MY MZ
SUPPORTS
*************************************************************************************
*Boundary conditions for air lifting analysis set according to section 5.3.1
*************************************************************************************
9 TO 12 FIXED BUT FY MX MY MZ KFX 10 KFZ 10
55 PINNED
*************************************************************************************
*BASIC LOADS
*************************************************************************************
LOAD 1 STATIC SELFWEIGHT
*************************************************************************************
* Static selfweight with 10% weight inaccuracy
*************************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
***********************************************************************************
*Total static compressor module weight 100 tonnes (981kN)
*This load is distributed on Area 4 x 4, hence (981/(4x4))= 61.3kN/m2
***********************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -61.3 XRANGE 0 4 ZRANGE 0 4
*************************************************************************************
*LOAD COMBINATIONS-SUBSEA LIFTING ANALYSIS
*************************************************************************************
LOAD COMB 3 LC26.SUBSEA LIFTING
1 3.12 2 3.12
PERFORM ANALYSIS
LOAD LIST 3
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
PRINT CG
FINISH
```

Appendix E9: Staad.Pro input for transportation Case C: Compressor module

```
STAAD SPACE
START JOB INFORMATION
JOB NAME COMPRESSOR MODULE 120 tonnes
ENGINEER NAME Yohannes
ENGINEER DATE 07-Apr-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 4 0 0; 3 0 0 4; 4 4 0 4; 5 0 7 0; 6 4 7 0; 7 0 7 4; 8 4 7 4;
9 0 -0.5 0; 10 4 -0.5 0; 11 0 -0.5 4; 12 4 -0.5 4; 13 0 7 2; 14 0 0 2;
15 0 2.8 0; 16 0 2.8 2; 17 0 2.8 4; 18 4 5.6 4; 19 4 4.2 4; 20 4 2.8 4;
21 4 1.4 4; 22 0 1.4 4; 23 0 5.6 4; 24 0 4.2 4; 25 2 0 4; 26 2 1.4 4;
27 2 2.8 4; 28 2 4.2 4; 29 2 5.6 4; 30 4 2.8 0; 31 4 7 2; 32 4 0 2; 33 4 2.8 2;
34 2 0 0; 35 2 2.8 0; 36 2 7 0; 37 0 8 0; 38 4 8 0; 39 0 8 4; 40 4 8 4;
41 1 9 4; 42 3 9 4; 43 0 7 2.5; 44 4 7 2.5; 45 0 8 2.5; 46 4 8 2.5; 47 1 9 2.5;
48 3 9 2.5; 49 1 9 0; 50 3 9 0; 51 0 0 1.3; 52 0 0 2.7; 53 4 0 2.7; 54 4 0 1.3;
*******************************************************************************
MEMBER INCIDENCES
1 3 25; 2 4 53; 3 2 34; 4 1 51; 5 7 23; 6 5 15; 7 8 18; 8 6 30; 9 7 8; 10 8 44;
11 6 36; 12 5 13; 13 3 11; 14 1 9; 15 2 10; 16 4 12; 17 13 43; 18 14 52;
19 13 16; 20 15 1; 21 16 14; 23 17 22; 24 18 19; 25 19 20; 26 20 21; 27 21 4;
28 15 16; 29 16 17; 30 22 3; 31 23 24; 32 24 17; 33 21 26; 34 20 27; 35 19 28;
36 18 29; 37 13 15; 38 13 17; 39 15 14; 40 17 14; 41 25 4; 42 26 22; 43 26 25;
44 21 25; 45 22 25; 46 27 17; 47 19 27; 48 24 27; 49 28 24; 50 18 28; 51 23 28;
52 29 23; 53 8 29; 54 7 29; 55 30 2; 56 20 33; 57 31 6; 58 32 54; 59 33 30;
60 31 33; 61 33 32; 62 31 20; 63 31 30; 64 30 32; 65 20 32; 66 30 35; 67 34 1;
68 35 15; 69 36 5; 70 15 34; 71 30 34; 72 36 30; 73 36 15; 74 39 7; 75 40 8;
76 38 6; 77 37 5; 78 39 40; 79 41 42; 80 43 7; 81 44 31; 82 45 43; 83 46 44;
84 45 46; 85 47 48; 87 49 50; 88 49 37; 89 50 38; 90 41 39; 91 42 40; 92 47 45;
93 48 46; 94 45 39; 95 49 47; 96 47 41; 97 50 48; 98 48 42; 99 46 40;
100 51 14; 101 52 3; 102 53 32; 103 54 2; 104 51 54; 105 52 53; 108 34 35;
109 35 36;
ELEMENT INCIDENCES SHELL
106 49 47 48 50; 107 47 41 42 48;
*******************************************************************************
ELEMENT PROPERTY
*******************************************************************************
*15 mm Cover steel plate.Steel plate design is not performed
*******************************************************************************
106 107 THICKNESS 0.015
```

```
*********************************************************************************
* Material constant properties set according to section 3.3.1 of project work
*********************************************************************************
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.1e+008
POISSON 0.3
DENSITY 77
ALPHA 6.5e-006
DAMP 0.03
END DEFINE MATERIAL
*********************************************************************************
*Hollow section steel property
*********************************************************************************
CONSTANTS
MATERIAL STEEL MEMB 1 TO 21 23 TO 85 87 TO 109
MEMBER PROPERTY EUROPEAN
1 TO 21 23 TO 36 41 TO 43 46 49 52 55 TO 61 66 TO 69 74 TO 85 87 TO 105 108 -
109 TABLE ST PIPE OD 0.3239 ID 0.2919
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 72 -
73 TABLE ST PIPE OD 0.1143 ID 0.1017
*********************************************************************************
*Braces released for moment
*********************************************************************************
MEMBER RELEASE
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 START MX MY MZ
37 TO 40 44 45 47 48 50 51 53 54 62 TO 65 70 TO 73 END MX MY MZ
SUPPORTS
*********************************************************************************
*Boundary conditions for transportaion analysis set according to section 5.3.2
*********************************************************************************
9 TO 12 FIXED BUT MX MY MZ
*********************************************************************************
```

```
*******************************************************************************
*BASIC LOADS
*******************************************************************************
LOAD 1 STATIC SELFWEIGHT
*******************************************************************************
* Static selfweight with 10% weight inaccuracy
*******************************************************************************
SELFWEIGHT Y -1.1
LOAD 2 STATIC SUBSEA MODULE WEIGHT
*****************************************************************************
*Total static compressor module weight 100 tonnes (981kN)
*This load is distributed on Area 4 x 4, hence (981/(4x4))= 61.3kN/m2
*****************************************************************************
FLOOR LOAD
YRANGE 0 0 FLOAD -61.3 XRANGE 0 4 ZRANGE 0 4
LOAD 3 DYNAMIC SELFWEIGHT IN +X DIRECTION
SELFWEIGHT X 1.1
LOAD 4 DYNAMIC SELFWEIGHT IN +Z DIRECTION
SELFWEIGHT Z 1.1
LOAD 5 DYNAMIC SELFWEIGHT IN +Y DIRECTION
SELFWEIGHT Y 1.1
LOAD 6 DYNAMIC SUBSEA MODULE WEIGHT IN +X DIRECTION
JOINT LOAD
1 TO 4 FX -245.3
LOAD 7 DYNAMIC SUBSEA MODULE WEIGHT IN +Z DIRECTION
JOINT LOAD
1 TO 4 FZ -245.3
LOAD 8 DYNAMIC SUBSEA MODULE WEIGHT IN +Y DIRECTION
JOINT LOAD
1 TO 4 FY -245.3
LOAD 9 DYNAMIC SELFWEIGHT IN -X DIRECTION
SELFWEIGHT X -1.1
LOAD 10 DYNAMIC SELFWEIGHT IN -Z DIRECTION
SELFWEIGHT Z -1.1
LOAD 11 DYNAMIC SUBSEA MODULE WEIGHT IN -X DIRECTION
JOINT LOAD
1 TO 4 FX 245.3
LOAD 12 DYNAMIC SUBSEA MODULE WEIGHT IN -Z DIRECTION
JOINT LOAD
1 TO 4 FZ 245.3
```

```
*LOAD COMBINATIONS-TRANSPORTATION ANALYSIS
*************************************************************************************
LOAD COMB 13 LC1.TRANSPORTATION ROLL, MAX.Z
1 1.3 2 1.3 3 1.0 6 1.0
LOAD COMB 14 LC2.TRANSPORTATION ROLL, MIN.Z
1 0.7 2 0.7 3 1.0 6 1.0
LOAD COMB 15 LC3.TRANSPORTATION PITCH, MAX.Z
1 1.3 2 1.3 4 1.0 7 1.0
LOAD COMB 16 LC4.TRANSPORTATION PITCH, MIN.Z
1 0.7 2 0.7 4 1.0 7 1.0
LOAD COMB 17 LC5.TRANSPORTATION -ROLL, MAX.Z
1 1.3 2 1.3 9 1.0 11 1.0
LOAD COMB 18 LC6.TRANSPORTATION -ROLL, MIN.Z
1 0.7 2 0.7 9 1.0 11 1.0
LOAD COMB 19 LC7.TRANSPORTATION -PITCH, MAX.Z
1 1.3 2 1.3 10 1.0 12 1.0
LOAD COMB 20 LC8.TRANSPORTATION -PITCH, MIN.Z
1 0.7 2 0.7 10 1.0 12 1.0
*************************************************************************************
*LOAD COMBINATIONS-ULSa TRANSPORTATION ANALYSIS
*************************************************************************************
LOAD COMB 21 LC9.ULS A,ROLL+HEAVE
1 1.3 2 1.3 3 0.7 5 -0.7 6 0.7 8 -0.7
LOAD COMB 22 LC10.ULS A,ROLL-HEAVE
1 1.3 2 1.3 3 0.7 5 0.7 6 0.7 8 0.7
LOAD COMB 23 LC11.ULS A,-ROLL+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 9 0.7 11 0.7
LOAD COMB 24 LC12.ULS A,-ROLL-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 9 0.7 11 0.7
LOAD COMB 25 LC13.ULS A,PITCH+HEAVE
1 1.3 2 1.3 4 0.7 5 -0.7 7 0.7 8 -0.7
LOAD COMB 26 LC14.ULS A,PITCH-HEAVE
1 1.3 2 1.3 4 0.7 5 0.7 7 0.7 8 0.7
LOAD COMB 27 LC15.ULS A,-PITCH+HEAVE
1 1.3 2 1.3 5 -0.7 8 -0.7 10 0.7 12 0.7
LOAD COMB 28 LC16.ULS A,-PITCH-HEAVE
1 1.3 2 1.3 5 0.7 8 0.7 10 0.7 12 0.7

*************************************************************************************
*LOAD COMBINATIONS-ULSb TRANSPORTATION ANALYSIS
*************************************************************************************
LOAD COMB 29 LC17.ULS B,ROLL+HEAVE
1 1.0 2 1.0 3 1.3 5 -1.3 6 1.3 8 -1.3
LOAD COMB 30 LC18.ULS B,ROLL-HEAVE
1 1.0 2 1.0 3 1.3 5 1.3 6 1.3 8 1.3
LOAD COMB 31 LC19.ULS B,-ROLL+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 9 1.3 11 1.3
LOAD COMB 32 LC20.ULS B,-ROLL-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 9 1.3 11 1.3
LOAD COMB 33 LC21.ULS B,PITCH+HEAVE
1 1.0 2 1.0 4 1.3 5 -1.3 7 1.3 8 -1.3
LOAD COMB 34 LC22.ULS B,PITCH-HEAVE
1 1.0 2 1.0 4 1.3 5 1.3 7 1.3 8 1.3
LOAD COMB 35 LC23.ULS B,-PITCH+HEAVE
1 1.0 2 1.0 5 -1.3 8 -1.3 10 1.3 12 1.3
LOAD COMB 36 LC24.ULS B,-PITCH-HEAVE
1 1.0 2 1.0 5 1.3 8 1.3 10 1.3 12 1.3
PERFORM ANALYSIS
LOAD LIST 13 TO 36
PRINT MEMBER FORCES
PRINT SUPPORT REACTION
FINISH
```

Appendix F: Staad.Pro output reaction forces

Appendix F$_1$: Air/offshore lifting reaction forces-Case A: Pump module

Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	39	1.143	131.851	0.000	Refer Figure 15 /Figure 16 above for node numbers.
	40	-0.286	0.000	0.000	
	41	-0.286	0.000	0.000	
	42	-0.286	0.000	0.000	
	43	-0.286	0.000	0.000	
Static subsea module weight	39	2.551	294.300	0.000	
	40	-0.638	0.000	0.000	
	41	-0.638	0.000	0.000	
	42	-0.638	0.000	0.000	
	43	-0.638	0.000	0.000	

Appendix F$_2$: Transportation reaction forces-Case A: Pump module

Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	35	0.882	32.960	1.587	Refer Figure 14 above for node numbers.
	36	-0.882	32.960	1.587	
	37	0.882	32.960	-1.587	
	38	-0.882	32.960	-1.587	
Static subsea module weight	35	0.031	73.575	0.022	
	36	-0.031	73.575	0.022	
	37	0.031	73.575	-0.022	
	38	-0.031	73.575	-0.022	

Appendix F3: Air/offshore lifting reaction forces-Case B: Cooler module

Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	37	0.000	227.908	0.000	Refer Figure 19/Figure 20 above for node numbers.
	38	0.001	0.000	0.000	
	39	0.001	0.000	0.000	
	40	-0.001	0.000	0.000	
	41	-0.001	0.000	0.000	
Static subsea module weight	37	0.000	735.750	0.000	
	38	0.005	0.000	0.004	
	39	0.005	0.000	-0.004	
	40	-0.005	0.000	0.004	
	41	-0.005	0.000	-0.004	

Appendix F4: Transportation reaction forces-Case B: Cooler module

Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	33	19.447	57.161	7.387	Refer Figure 18 above for node numbers.
	34	19.297	56.742	-7.303	
	35	-19.297	56.742	7.303	
	36	-19.447	57.161	-7.387	
Static subsea module weight	33	91.379	183.882	51.936	
	34	91.418	183.993	-51.959	
	35	-91.418	183.993	51.959	
	36	-91.379	183.882	-51.936	

Appendix F_5: Air/offshore lifting reaction forces-Case C: Compressor module

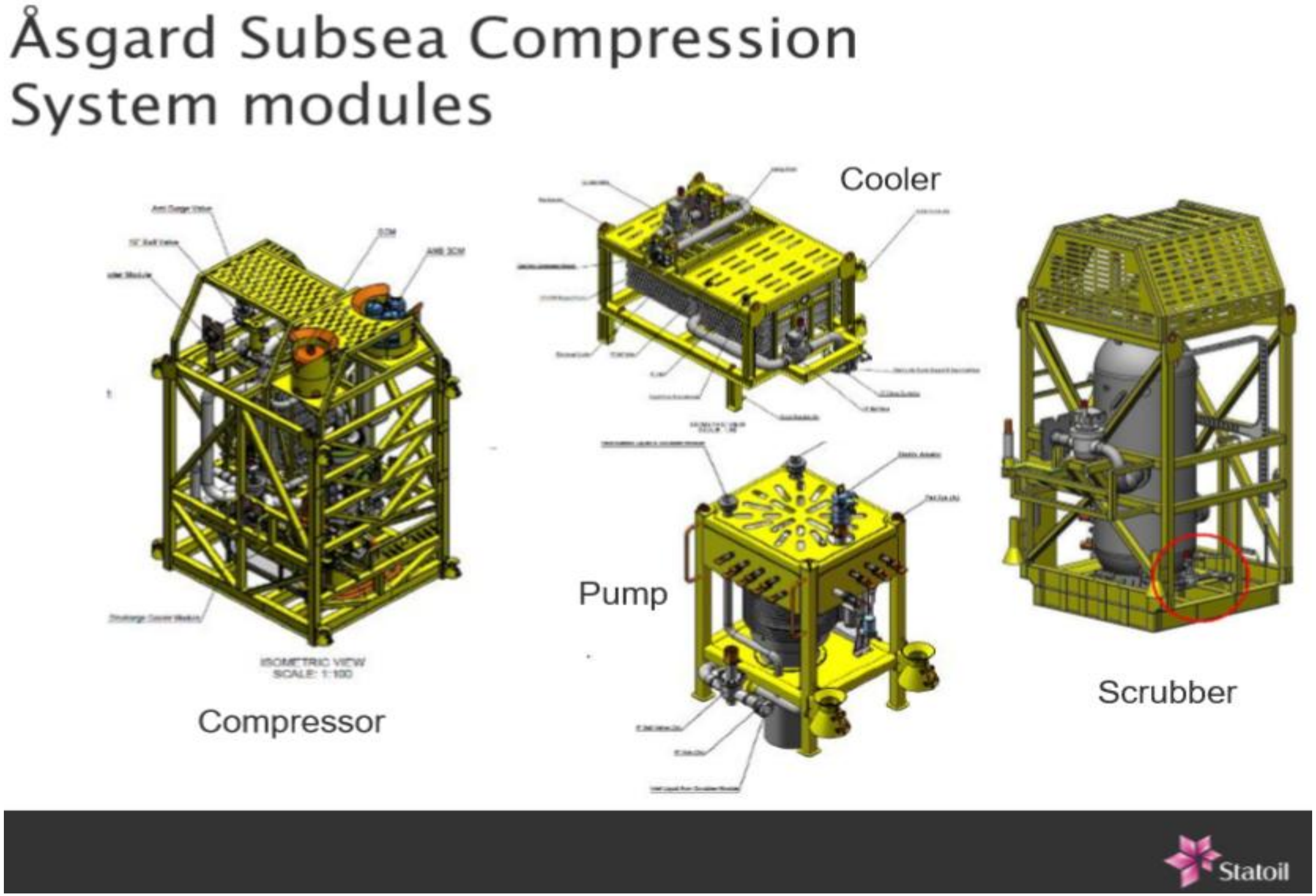
Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	9	0.000	0.000	0.020	Refer Figure 23/Figure 24 above for node numbers.
	10	0.000	0.000	0.020	
	11	0.000	0.000	0.020	
	12	0.000	0.000	0.020	
	55	0.000	232.082	-0.080	
Static subsea module weight	9	0.002	0.000	-3.204	
	10	-0.003	0.000	-3.204	
	11	0.003	0.000	-3.209	
	12	-0.003	0.000	-3.209	
	55	0.001	980.800	12.826	

Appendix F_6: Transportation reaction forces-Case C: Compressor module

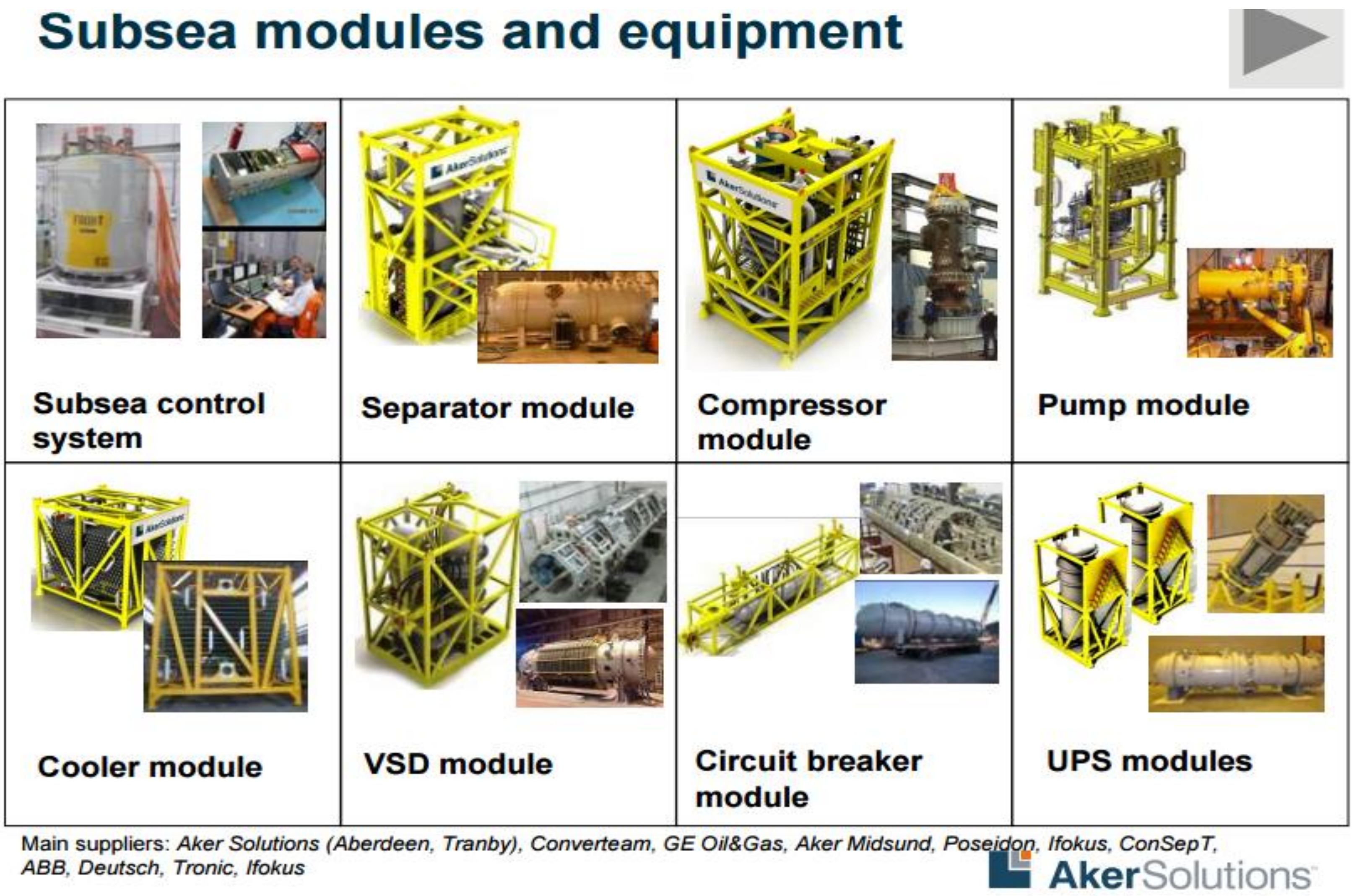
Load	Node	Force -X (kN)	Force-Y(kN)	Force-Z(kN)	Remarks
Static self-weight	9	3.626	52.959	4.472	Refer Figure 22 above for node numbers.
	10	-3.626	52.959	4.472	
	11	2.656	63.082	-4.472	
	12	-2.656	63.082	-4.472	
Static subsea module weight	9	61.931	245.200	53.071	
	10	-61.931	245.200	53.071	
	11	59.111	245.200	-53.071	
	12	-59.111	245.200	-53.071	

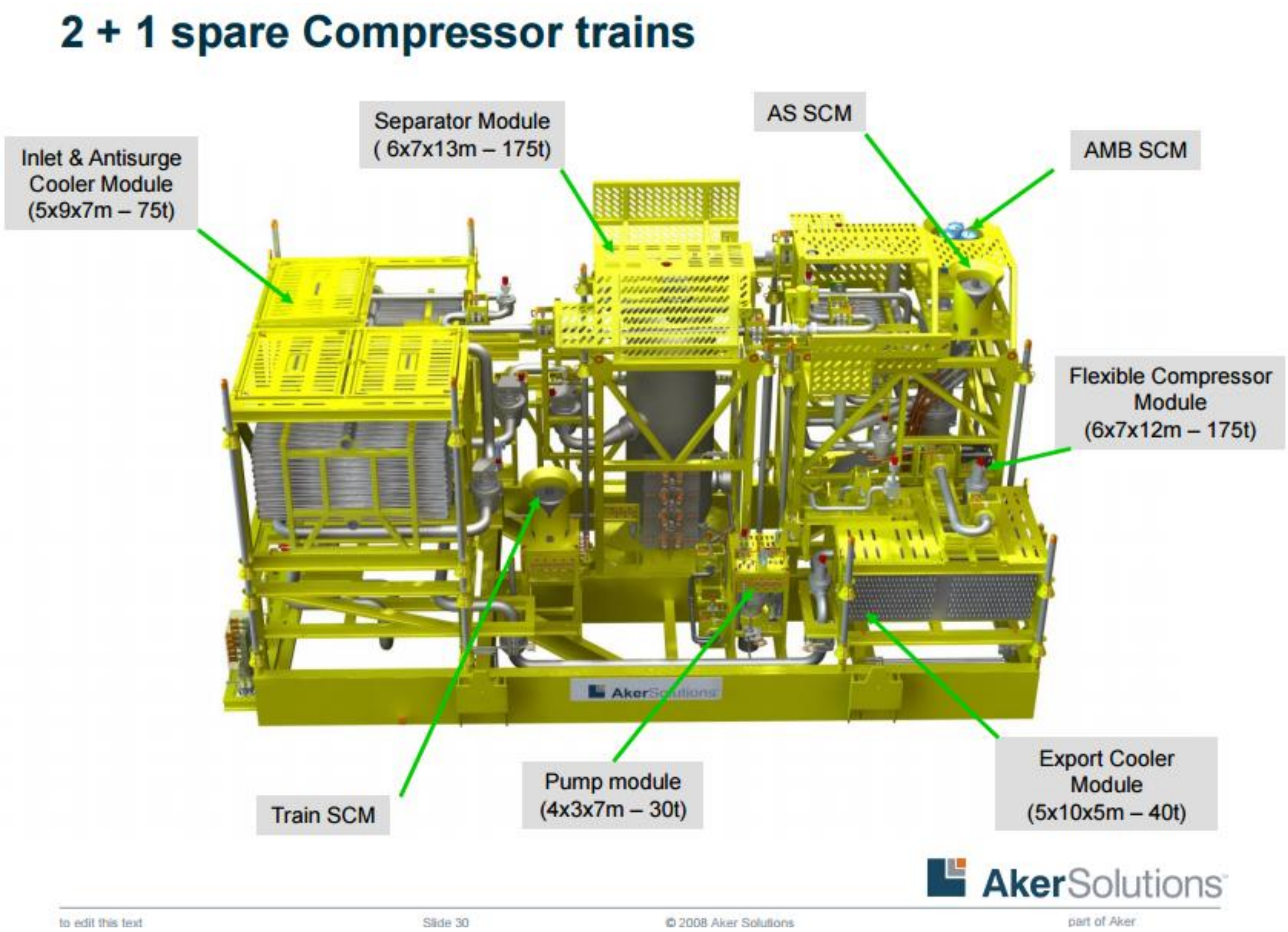
Appendix G: Reference drawings

Appendix G_1: Reference drawings from Statoil presentations



Appendix G2: Reference drawings from AkerSolutions presentations




2 + 1 spare Compressor trains
Inlet & Antisurge Cooler Module (5x9x7m – 75t)
Separator Module (6x7x13m – 175t)
AS SCM
AMB SCM
Flexible Compressor Module (6x7x12m – 175t)
Train SCM
Pump module (4x3x7m – 30t)
Export Cooler Module (5x10x5m – 40t)
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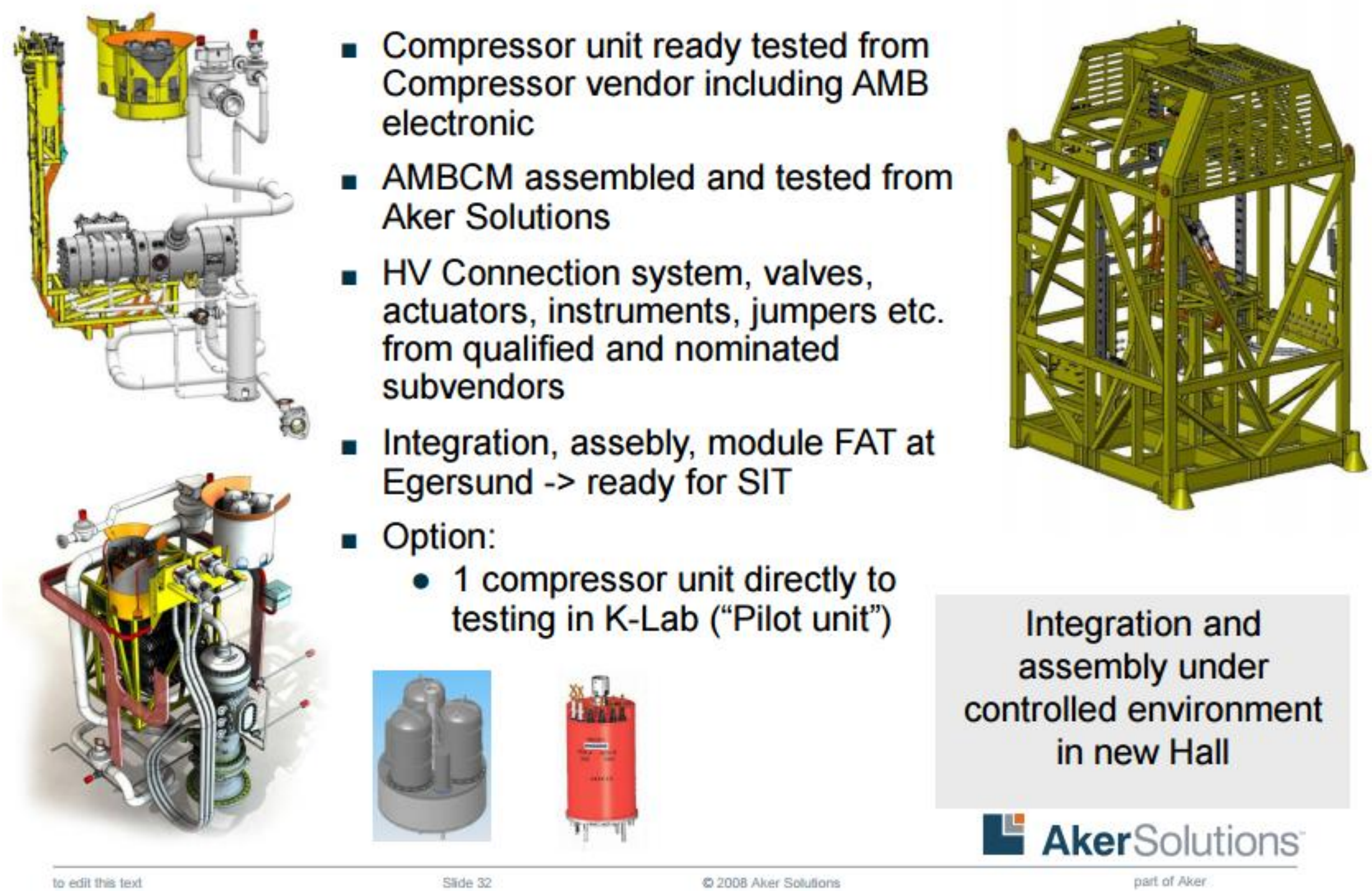
Compressor unit ready tested from Compressor vendor including AMB electronic
AMBCM assembled and tested from Aker Solutions
HV Connection system, valves, actuators, instruments, jumpers etc. from qualified and nominated subvendors
Integration, assebly, module FAT at Egersund -> ready for SIT
Option:
1 compressor unit directly to testing in K-Lab ("Pilot unit")
Integration and assembly under controlled environment in new Hall
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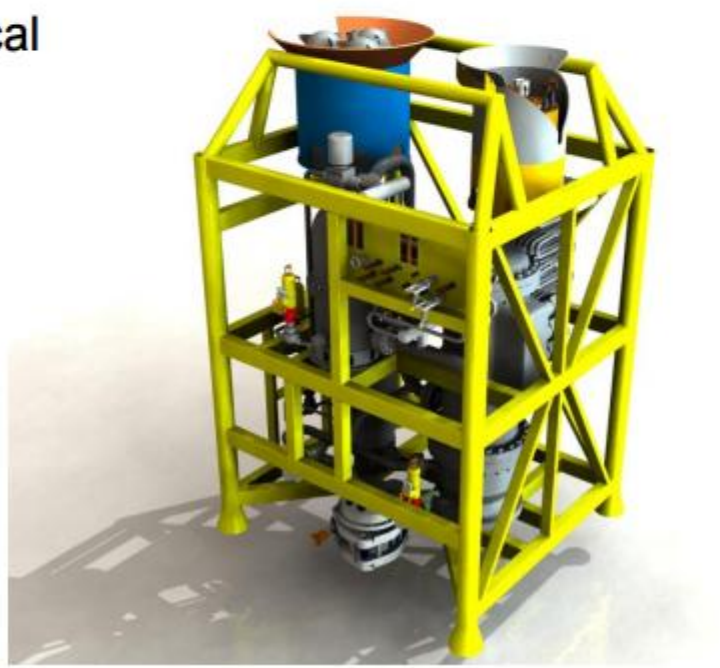
Compact Compression
Aker Solutions Subsea GasBooster

- 6 MW unit
- Minimised number of mechanical and electrical connections
- Separately retrievable control module and actuators
- Compact and low weight



Footprint: 4 m x 4 m
Height: 7 m
Weight: 100 tonnes

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