Base Load Power Hub (BLPH)

CAISSON FRAME – In service, Lifting and Transportation Design Report

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 PROJECT LOCATION

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

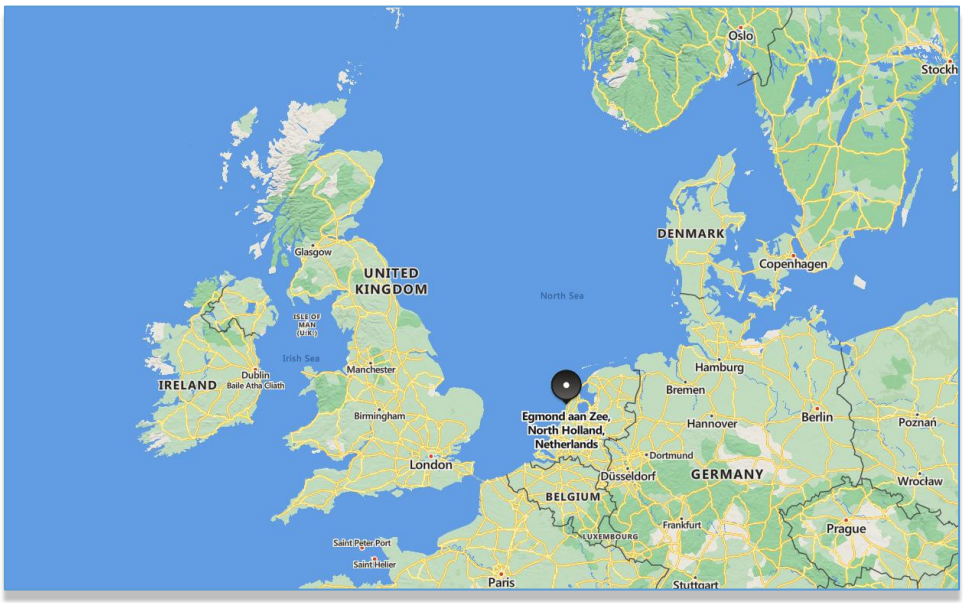


Figure 1.1 - HOLLANDSE KUST NOORD WIND PARK Location Map

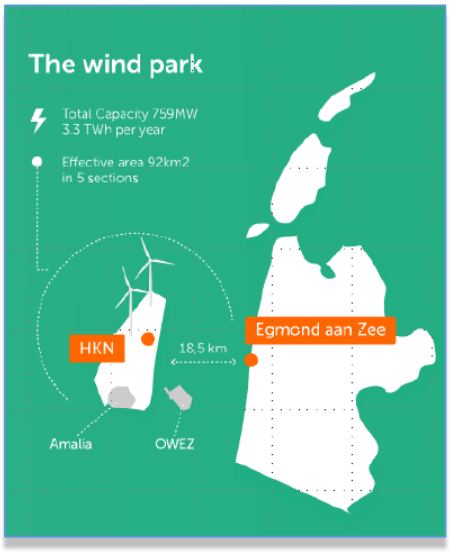


Figure 1.2 - Wind Park Details

The wind farm consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 PROJECT CONCEPT

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

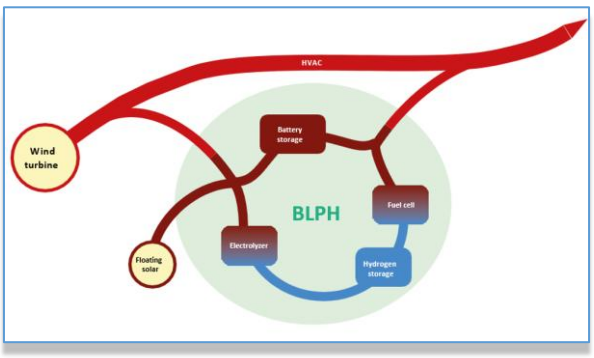


Figure 1.3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

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2 DOCUMENT SCOPE

The objective of this report is to present the results of the checks performed on caisson frame structure during is-service, lifting and transportation phases.

Caisson frame load-out analysis is performed in a dedicated report, Ref. /24/.

The analysis has been performed in compliance with the requirements, criteria and parameters reported in the Structural Design Premises, Ref./19/.

Structural Code checks are performed according to EN ISO 19902 for tubular members and tubular joints, Ref./6/, and according to Eurocode 3 for non-tubular structural elements, Ref./8/.

Structural analyses have been carried out using the structural analysis program SACS, the proprietary software developed by Bentley, Ref. /33/.

The International System of Units (SI) has been used in all engineering assessments and calculations.

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3 REFERENCES

3.1 CODES AND STANDARDS

Doc. No.	Description
/1/ BS EN ISO 19900	General requirements for offshore structures - 2019
/2/ BS EN ISO 19901-1	Specific requirements for offshore structures - Part 1: Metocean design and operating considerations - 2015
/3/ BS EN ISO 19901-3	Specific requirements for offshore structures – Part 3: Topsides structure - 2014
/4/ BS EN ISO 19901-5	Specific requirements for offshore structures – Part 5: Weight Management - 2021
/5/ BS EN ISO 19901-6	Specific requirements for offshore structures – Part 6: Marine Operations – 2009
/6/ BS EN ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures – 2020
/7/ ISO 19906:2019	Petroleum and natural gas industries – Arctic offshore structures
/8/ EN 1993-1-1	Design of steel structures - Part 1-1: General rules and rules for buildings
/9/ EN 1993-1-5	Design of steel structures - Part 1-5: Plated structural elements
/10/ DNV-ST-N001	DNV GL - Marine operation and marine warranty - 2021
/11/ DNV-ST-0145	DNV, Offshore substations
/12/ DNV-RP-C201	DNV, Buckling Strength of Plated Structures, October 2010.
/13/ DNV-RP-C208	DNV, Determination of structural capacity by non-linear finite element analysis methods, September 2021.
/14/ DNV-ST-0126	Support structures for wind turbine, 2018
/15/ DNV-RP-C205	Environmental conditions and Environmental loads, 2019

3.2 COMPANY SPECIFICATIONS

Doc. No.	Description
/16/ DEP 37.19.00.12	Gen - Offshore Topsides Structures
/17/ DEP 37.19.00.30	Gen - Fixed Steel Offshore Structures (Adoption of IOGP S-631-11, Amendments / Supplements to ISO 19902:2020).

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/18/ DEP 37.81.10.19	Gen - Marine Operations Requirements – Loadout, Transportation and Installation of Offshore Structures (Amendments / Supplements to ISO 19901-6)

3.3 PROJECT DOCUMENTS

Doc. No.	Description
/19/ 123A90-DDL-ST-SP-90017	Structural Design Basis
/20/ 123A90-DDL-MD-RE-01006	Monthly Weight Report
/21/ 123A90-DDL-ST-SP-90018	Structural Material Specification for Topside and TP
/22/ 123A90-DDL-ST-RE-90000	BLPH Platform – In service Analysis
/23/ 123A90-DDL-ST-TN-90119	Evaluating ISO and DNV approaches
/24/ 123A90-DDL-ST-RE-90014	Caisson Frame – Loadout Analysis
/25/ 123A90-DDL-ST-DD-90094	Caisson frame – Elevations
/26/ 123A90-DDL-ST-DD-90095	Caisson frame - Details
/27/ 123A90-DDL-ST-DD-90096	Caisson frame - Details
/28/ 123A90-DDL-TI-DD-99015	BLPH Platform – Barge Layout

3.4 OTHER DOCUMENTS

Doc. No.	Description
/29/ K559–2254-ST-PHI-001	BLPH Structural Topsides Design & Installation Philosophy, Rev.1, 09 December 2022
/30/ K559–2254-ST-REP-001	BLPH Structural Topsides and Transition Piece Design and Analysis Report, Rev.0, 27 February 2023
/31/ 144671-VOOW-TF-ENG-REP-1052	Wave Loads and Effects for BLPH
/32/ 144671-VOOW-TF-ENG-REP-1401	Design Report: Boat Landing and Ladder

3.5 SOFTWARE

Doc. No.	Description
/33/ SACS	Structural Analysis Computer System – BENTLEY Inc- v15

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4 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY)	Crosswind
CONTRACTOR (CTR)	ROSETTI MARINO S.p.A.
PROJECT	HOLLANDSE KUST NOORD WIND PARK Project
T&I CONTRACTOR	DEME
ALS	Accidental Limit State
BESS	BATTERY ENERGY STORAGE SYSTEM
BG	Box Girder
BLPH	Base Load Power Hub
BL	Boat Landing
CL	Concentrated Load
CF	Caisson Frame
CoG	Centre of Gravity
CW	CrossWind
DAF	Dynamic Amplification Factor
DLB	Ductility Level Blast
DNV	Det Norske Veritas
DP	Dynamic Positioning
El.	Elevation
EPCI	Engineering Procurement Construction and Installation
FEED	Front End Engineering Design
FEA	Finite Element Analysis
FEM	Finite Element Method
HAT	Highest Astronomical Tide
HKN	Hollandse Kust Noord
ICCP	Impressed Current Corrosion Protection
LAT	Lowest Astronomical Tide
LRFD	Load and Resistance Factor Design

MSL	Mean Sea Level
NTE	Not-to-Exceed
OD	Outside Diameter
PAU	Pre-Assembled Unit (H2 Vessels)
PG	Plate Girder
SHL	Static Hook Load
T&I	Transport & Installation
ToS	Top of Steel
UC	Unity Check
UDL	Uniformly Distributed Load
VM	Von Mises
VMS	Von Mises Stress
WTG	Wind Turbine Generator
W2W	Walk to Work

Table 4.1 - Definitions and Abbreviations

5 SUMMARY AND CONCLUSIONS

The analyses performed show that the Caisson Frame, as configured, can withstand the maximum loads can be experienced during in-service, Lifting and Transportation.

Checks are executed according to the criteria imposed by ISO code 19902, Ref. /6/, Eurocode 3, Ref./8/ and DNV-ST-N001, Ref. /10/.

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6 CAISSON FRAME DESCRIPTION

The caisson frame is designed to structurally connect n.2 seawater lift caissons and n.1 brine discharge caisson to the Monopile CW70.

The monopile is supplied with N. 6 stubs for support of the caisson frame. These are arranged in pairs at N. 3 elevations (El. +14.5m LAT, El. +7m LAT and El. 0.00m LAT) and cannot be modified or moved as monopile CW70 is already installed in the wind farm. All the supports will be surveyed offshore prior to proceed with caisson loadout.

The support concept is that the CF form a structure similar to the boat landing frame, that has been successfully installed by Van Oord on monopile.

The brine caisson is "piggy-backed" off the CF. it is positioned on the outside of the CF and terminates 6m above the inlet to the seawater lift pump caissons. This to avoid, as far as possible, cross-contamination of waste brine water being dumped overboard with fresh seawater drawn for electrolysis.

The seawater lift caissons contain submersible pumps, so the caissons must be vertical.

As the caissons extend to the topside, dedicated caisson structure is foreseen welded to TP.

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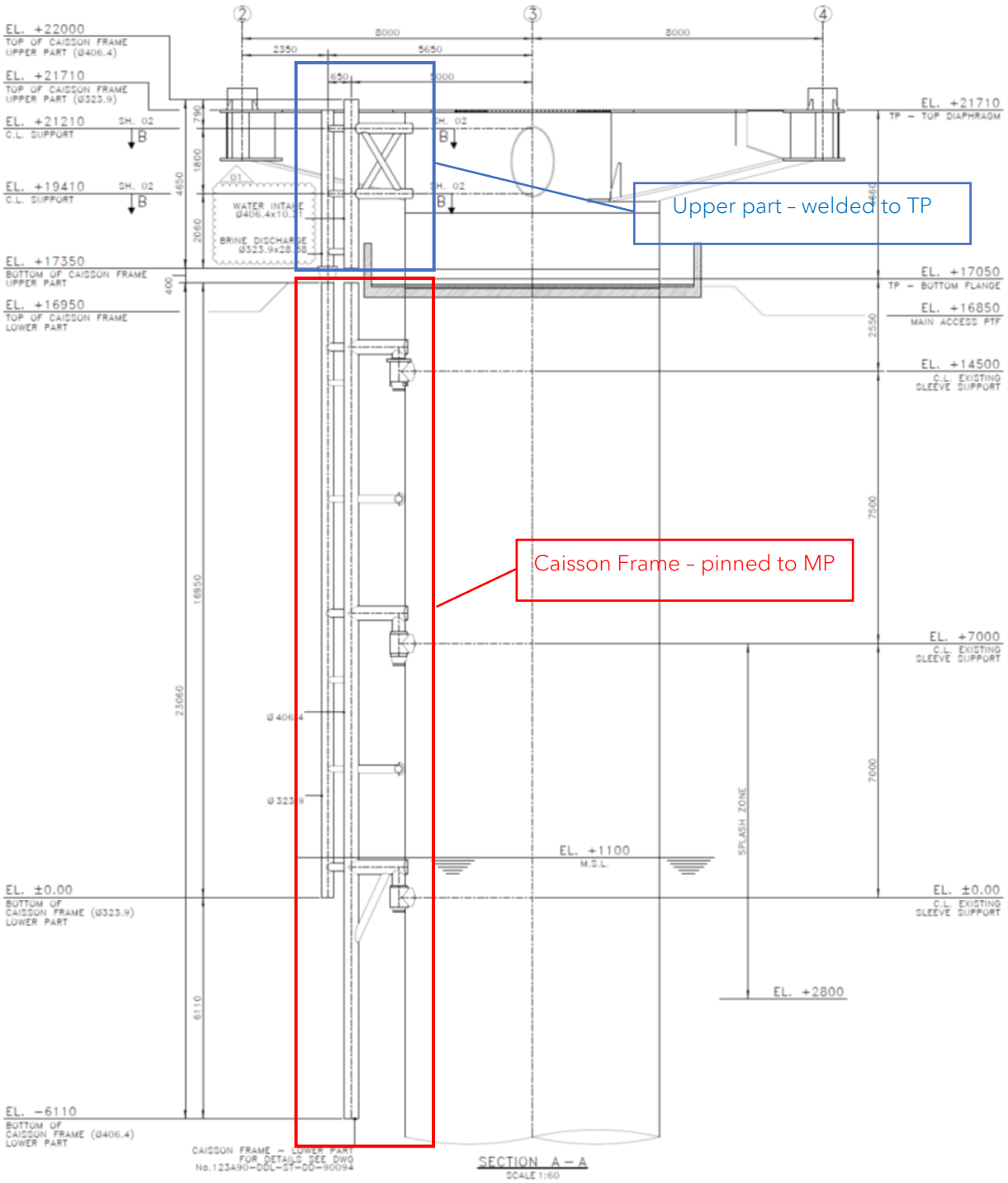


Figure 6.1 – CF assembly

7 DESIGN DATA

Design Data are herein collected according to ref. /19/.

7.1 DESIGN LIFE

Despite the operational life of the platform is 2 years, a total design life of 25.5 years is required, as per following Table 7.1, from ref. /19/.

Description	Mode	Duration (years)
Construction Phase	Monopile Only	2.5
Operational Life	Monopile + Topsides	2.0
Non-Operational Life[1]	Monopile + Topsides	21.0
Total Design Life		25.5
Note: Topside assumed to be decommissioned and removed after 2 years, although this will be reviewed by CW.		

Table 7.1- Design Life

The monopile installation has been completed in 2023, with removal and decommissioning planned for 2048.

7.2 DATUM

Elevations are refenced to LAT unless noted otherwise.

7.3 WATER LEVELS

Mean Sea Level (MSL) is 1.1 m above LAT, Sea Level Rise (SLR) is: SLR= maximum 0.3 m by 2050 (>25 years), ref. /19/. Maximum and minimum water levels for a range of return periods are provided in Table 7.2.

Extreme Water Level	Return period						
	1	2	5	10	50	100	1,000
Max	3.2	3.4	3.5	3.7	4.0	4.1	4.5
Min	-0.5	-0.6	-0.7	-0.8	-1.0	-1.1	-1.4

Table 7.2 - Extreme Water Levels including Storm Surge

7.4 MARINE GROWTH

Table 7.3 shows the recommended maximum marine growth according to Ref. /19/.

Level [m] LAT		Thickness	Density
From	To	[mm]	[mm]

HAT	LAT	150	1325
LAT	-6.0	150-50	1325
-6.0	Seabed	50	1325

Table 7.3- Marine Growth

7.5 SPLASH ZONE

External splash zone:

- Upper limit external splash zone = +7.0 [m] LAT;
- Lower limit external splash zone = -2.8 [m] LAT.

Internal splash zone:

- Upper limit internal splash zone = +3.6 [m] LAT;
- Lower limit internal splash zone = -0.6 [m] LAT.

7.6 CORROSION ALLOWANCE

No corrosion thickness allowance shall be added to any Topside and Transition piece structure above interface level at el.+17.05, as painting and coating system shall provide necessary protection.

Corrosion allowance for zones that are subjective to coating damages (such as the boat landing fenders and upper side of ladder rungs) shall be taken as 0.3 mm/year. A corrosion allowance of 10mm will be considered for caissons design and check.

7.7 WIND DATA

Omni-Directional wind speed data are reported in Table 7.4 , from Ref. /19/.

Averaging Time	Return period (years)						
	1	2	5	10	50	100	1000
1hr	31.8	33.4	35.1	36.4	39.1	40.1	43.4
10 min	33.7	35.5	37.4	38.8	41.7	42.9	46.5
3s	39.4	41.6	44.1	45.9	49.7	51.1	56.0

Table 7.4 - Omni-Directional Wind velocities [m/s] at 125 m MSL

Wind speeds are provided at 125m MSL. Wind speeds at any specified averaging time or elevation, will be calculated according to following equations, Ref./2/:

$U(z, t) = U(z) * [1 - 0.41 * Iu(z) * \ln(t/t0)]$

U(z) = 1-hour mean wind speed given by:

U(z) = U0 * [1 + C * ln(z/zr)]

C = $0.0573 * (1 + 0.15 * U0)^{1/2}$

Iu = $0.06 * [1 + 0.043 * U0] * (z/zr)^{-0.22}$

U0 = 1-hour average at the reference elevation, zr

zr = 10 m above sea level.

Directional exceedance data for wind is presented in Figure 7.1. The wind predominantly blows from the south- west.

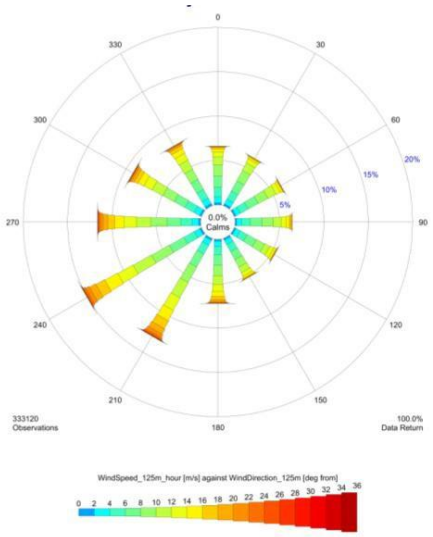


Figure 7.1 - Mean Hourly Wind Speed Distribution at 125 m MSL

7.8 BATHYMETRY

The area consists of a static and a dynamic bathymetry, where the dynamic part consists of moving sand banks and dunes:

- Lowest Seabed Level: this is the lowest possible seabed level during the lifetime of the wind park until 2048;
- Highest Seabed Level: This is the highest possible seabed level during the lifetime of the wind park until 2048;
- Best Estimate Bathymetry (BEB): This is the best estimate seabed level during the lifetime of the wind park until 2048. The BEB is expected to have, on average, the smallest overall error.

The seabed levels (water depths) in 2023 (installation) to 2048 (decommissioning) are shown in Table 7.5.

Year	Lowest Seabed	Highest Seabed	Best Estimate
2023	-21.6	-20.0	-21.0
2048	-22.2	-20.0	-21.4

Table 7.5 - Seabed Level (m) relative to LAT

7.9 WAVES AND CURRENT

7.9.1 NORMAL SEA STATE (NSS)

Significant wave height with recurrence period of 1 year and associated peak period are:

- Hs,1y = 5.6m;
- Tp = 10.0s.

The omnidirectional the most severe Normal Sea State (NSS) as shown in Table 7.6 is provided and will be considered in structural analyses.

Hs [m]	Tp [s]	WL [m]	V_{Cavg} [m/s]	$V_{c;SWL}$ [m/s]
6.44	10.17	2.47	0.30	0.99

V_{Cavg} = total depth averaged current (tidal + wind)
$V_{c;SWL}$ = total current (tidal + wind) at Still Water Level

Table 7.6 – Most severe NSS load case for omni-directional wave

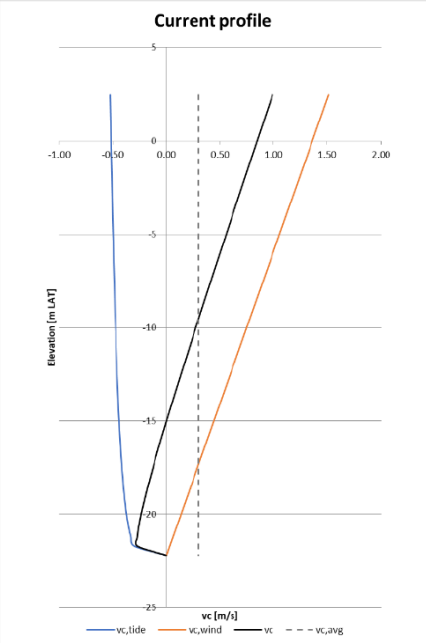


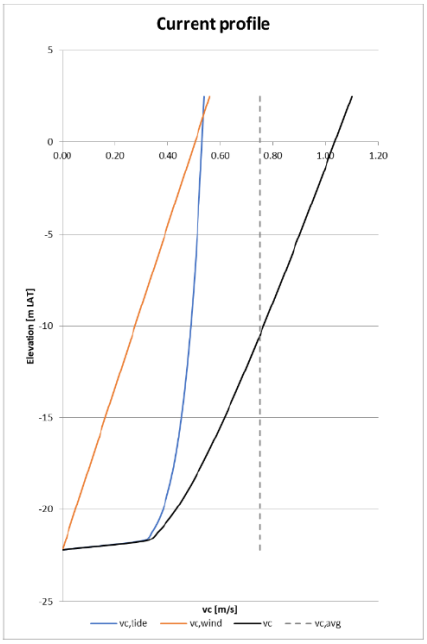
Table 7.7 - Current profile for NSS for $v_{wind,2hr,125\,[m]\,MSL}$ = 35 m/s:

7.9.2 EXTREME SEA STATE (ESS)

The omnidirectional Extreme Sea State (ESS) as shown in Table 7.6 is provided and will be considered in structural analyses.

RP [years]	Hs [m]	Tp [s]	WLmin [m]	WLmax [m]	V_{Cavg} [m/s]	V_{CSWL} [m/s]	H_{mp} [m]	T_{Hmp_min} [s]	T_{Hmp_avg} [s]	T_{Hmp_max} [s]
50	7.3	11.5	2.5	3.6	0.75	1.1	14.0	10.54	11.71	12.88
100	7.6	11.8	2.5	3.6	0.75	1.1	14.5	10.70	11.89	13.08
Vcavg = total depth averaged current (tidal + wind) Vc;SWL = total current (tidal + wind) at Still Water Level										

Table 7.8 – ESS load cases



ESS100yr

Table 7.9 -Current profile for ESS (100 yr)

7.10 DRAG AND INERTIA COEFFICIENTS

Hydrodynamic coefficients for unshielded circular cylinders as per ISO code, Ref./6/, is given in Table 7.10.

Surface of component	Cd	Cm
smooth	0,65	1,6
rough	1,05	1,2

Table 7.10 - Drag and Inertia Coefficients

Ref. /31/ presents the calculation of the values Cd and Cd, according to DNV-RP-C205 code, Ref. /15/, considering the presence of the monopile.

8 MATERIALS

8.1 STRUCTURAL STEEL

For the structural analyses, steel types and grades to be used for the platform structures are summarised in Table 8.1 and specified in Ref. /21/. The material selection criteria are based on the requirements of ISO 19906:2019, ISO 19902:2020 and ISO 19901-3:2014. The materials are in accordance with the EN standard 10225:2019 and 10025:2019 and are suitable for plates, rolled sections and welded / seamless tubulars.

			EN10025-3	ISO EN 19902:2020						
Design Class	**Complexity**	**SQL**	**Hot rolled bar**	**Plates and Welded Tubular**	**Sections**	**SMLS pipes**	**THK**	**CVN inpact test**	**Material Designation**	**List of Options (EN10225-1 to -4) & EN10025-3**
DC1 TP to monopile flange connection	High	**I (Z properties)**	EN 10025 S420 NL	NA	NA	NA	t > 50	-40	DC1-I-420-40_Z	1, 2, 3, 4, 6, 12, 18, 24, 30
DC1 Complex lift-nodes and element connection to topside, Lift points, main complex joints	High	**I (Z properties)**	NA	EN 10225 S420 QLO / ML	NA	NA	25 < t <= 50	-40	DC1-I-420-40_Z DC1-I-460-40_Z	2, 7, 8, 11, 12, 17, 18
							t > 50	-40		
DC2 simple joints, primary deck girders and beams of Topside and TP, column and diagonal to lift points, main columns, Davit crane support, Bolts	Low	**II**	NA	EN 10225 S420 QLO / MLO	NA	NA	t < = 12	0	NA	-
							12 < t <= 25	-20	DC2-II-420-20 / DC2-II-460-20	2, 7, 8, 11 17 for t > 40mm
							25 < t <= 50	-40	DC2-II-420-40 DC2-II-460-40	
							t > 50	-40		
DC3 all other columns and diagonals, stiffeners, Secondary deck beams, Grillage and sea fastening	High	**II**	NA	EN 10225 S355 NLO / MLO	EN 10025 S355 MLO	EN 10225 S355 NLHHO / QLHHO API 5L X52	t < = 12	0	DC3-II-355-0 / DC3-II-X52-0	2, 7, 8 11 for plate 17 for t > 40mm
							12 < t <= 25	-20	DC3-II-355-20 / DC3-II-X52-20	
							25 < t <= 50	-40	DC3-II-355-40 / DC3-II-X52-40	
							t > 50	-40		
DC4 Equipment and vessel supports, modules supports, equipment fixing bolts	Low	**III**	NA	EN 10025 S355 J2	EN 10025 S355 J2	API 5L X52 EN 10210 S355 J2H	t < = 12	0	DC4-III-355-0 / DC4-III-X52-0 / DC4-III-X60-0	-
							12 < t <= 25	0		
DC5 floor plating, grating, Walkways, stairs, handrails	Any	**IV**	NA	EN 10025 S235 JR EN 10025 S275 J0 EN 10025 S355 J0	EN 10025 S235 JR EN 10025 S275 J0 EN 10025 S355 J0	API 5L Gr.B EN 10210 S235 JRH / EN 10210 S275 J0H / EN 10210 S355 J0H	t < = 12	10	DC5-IV-235-10 / DC5-IV-275-10 / DC5-IV-355-10 / DC5-IV-GRB-10	-
							12 < t <= 25	10		

Table 8.1 - Material Selection, Ref /21/

Mechanical properties for structural materials are presented in Table 8.2, Table 8.3 and Table 8.4.

- Young's Modulus = 205000 N/mm^2
- Density = 7850 kg/m^3
- Poisson's Ratio = 0.3

Thickness (mm)	Min. Tensile Strength (N/mm2)	Min. Yield Strength (N/mm2)	Steel Type (1)
t ≤ 16	500	420	I & II
16 < t ≤ 40	500	400	I & II

40 < t ≤ 63	480	390	I & II
63 < t ≤ 100	480	380	I & II
Note: 1) Type I steel has Z (through the thickness) properties.			

Table 8.2 – Mechanical properties of Plates

Thickness (mm)	Min. Tensile Strength (N/mm²)	Min. Yield Strength (N/mm2)	Steel Type
t ≤ 20	460	355	III
20 < t ≤ 40	460	345	III

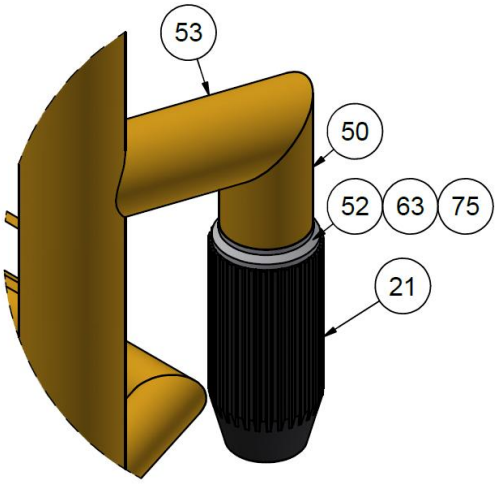
Table 8.3 – Mechanical properties of Structural Seamless Tubulars

Thickness (mm)	Min. Tensile Strength (N/mm2)	Min. Yield Strength (N/mm2)	Steel Type
t ≤ 16	460/360	355/275	IV
16 < t ≤ 40	460	345	IV

Table 8.4 – Mechanical properties for Structural Sections

8.2 NEOPRENE FOR PINS

The pins are surrounded by a layer of neoprene with a toothed shape. This ensures lateral restrain without compromising the ease of installation. Selected material is Polyurethane shore A80°. The solution adopted in Boat landing installation is therefore here repeated. See following picture:



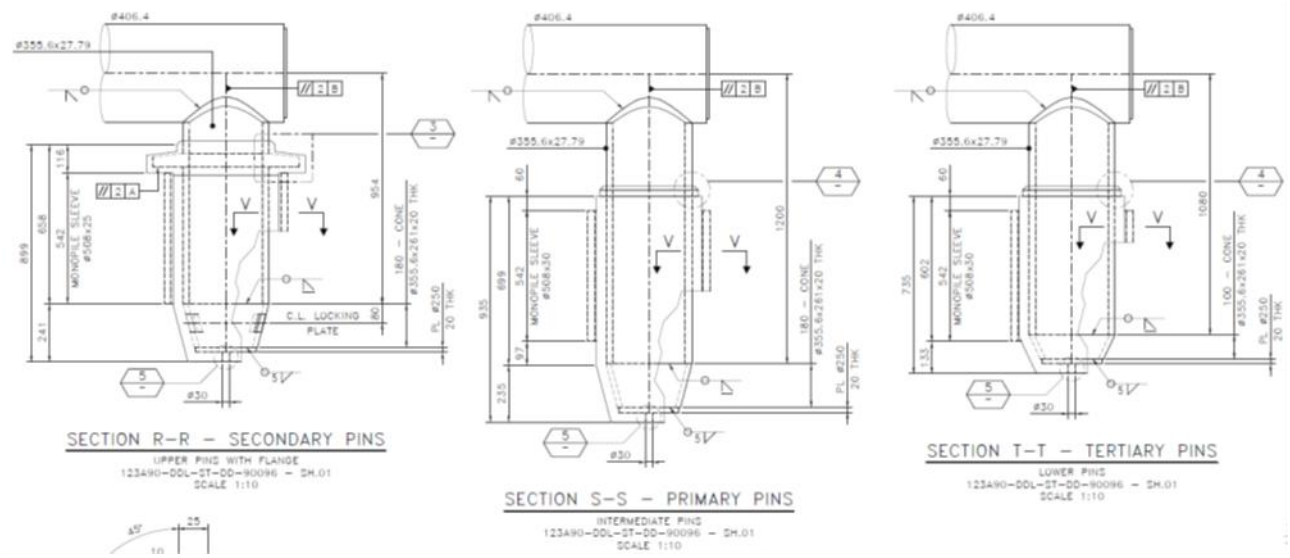


Figure 8.1 – Pin cover detail

9 DESIGN CRITERIA AND REQUIREMENTS

9.1 GENERAL

Structures in SOW is designed in accordance with limit states approach of ISO codes 19901 and 19902, Refs./2/, /3/and /6/. For non-tubular sections, Eurocode, Ref./8/, is adopted.
Member forces and moments derived from the global analyses are used for checking member strength and stability, and joint strength.

The general requirement of ISO code, ref./6/, is that, for the structure as a whole and for each component, the following is satisfied:

$$R_d = \frac{R_k}{\gamma_M} > \gamma_F F_r = F_d$$

Where:

- R_d is the design resistance;
- R_k is the characteristic resistance;
- γ_M is the partial resistance factor reported in section 9.2;
- F_d is the design value of action;
- F_r is the characteristic value of action;
- γ_F is the partial action factor.

Design according to the provisions for load and resistance factor design (LRFD) of EC3, ref. /8/, shall be performed in accordance with following equation:

$$R_u \leq \phi R_n$$

Where:

- R_u = required strength using LRFD load combinations
- R_n = nominal strength
- ϕ = resistance factor reported in Sec.9.2
- ϕ Rn = design strength.

9.2 PARTIAL RESISTANCE FACTORS

9.2.1 PARTIAL RESISTANCE FACTORS FOR TUBULAR SECTIONS

The partial resistance factors for tubular sections from ISO 19902, Ref./6/, are listed below.

Resistance factor	Value	Definition
$\gamma_{R,t}$	1.05	Partial resistance factor for axial tensile strength
$\gamma_{R,c}$	1.18	Partial resistance factor for axial compressive strength
$\gamma_{R,b}$	1.05	Partial resistance factor for bending strength
$\gamma_{R,v}$	1.05	Partial resistance factor for shear strength
$\gamma_{R,h}$	1.25	Partial resistance factor for hoop buckling strength

Table 9.1- Resistance Factors for Tubular Sections

9.2.2 PARTIAL RESISTANCE FACTORS FOR NON-TUBULAR SECTIONS

Referring to ISO 19901-3, Ref./3/, section 8, to be consistent with ISO 19900 inherent the level of safety, a "building code correspondence factor" is to be applied to the AISC partial factors.

The partial resistance factors for non-tubular sections from Eurocode 3, Ref./8/, are listed below.

Resistance factor	Value	Definition
Resistance of members and cross sections		
γ_{M0}	1.10	Cross-section resistance to excessive yield strain including local buckling
γ_{M1}	1.10	Resistance of unstable elements measured during element inspection
γ_{M2}	1.25	Tensile cross-section resistance to mechanical breakdown
Resistance of connections		
γ_{M2}	1.25	Bolts, rivets, pins, welds and slabs on supporting surface
γ_{M3}	1.25	Sliding resistance at Ultimate Limit State Category C
$\gamma_{M3,SER}$	1.10	Sliding resistance at Serviceability Limit State
γ_{M4}	1.10	Injection bolt collapse resistance
γ_{M5}	1.10	Resistance of connections in open lattice trusses

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$\gamma_{M6,SER}$	1.00	Resistance of pins at Serviceability Limit State
γ_{M7}	1.10	Preload of high strength bolts

Table 9.2- Resistance for Non-Tubular Section

9.2.3 PARTIAL RESISTANCE FACTORS FOR TUBULAR JOINTS CHECK

The partial resistance factors for tubular joints checks are provided in following table.

Resistance factor	Value	Definition
$\gamma_{R,j}$	1.05	Partial resistance factor for joints
$\gamma_{z,j}$	1.17	Additional partial resistance factor for members during joint pre-strain collapse

Table 9.3 - Resistance Factors for Tubular Joints

9.3 PARTIAL ACTION FACTORS

9.3.1 PARTIAL ACTION FACTORS FOR IN-SERVICE ANALYSIS

Partial action factors to be applied for the operating conditions in compliance with ISO codes are reported in Table 9.4.

Load combination		Dead load		Live load		Environmental load	Wave dynamics
		G1	G2	Q1	Q2	Eo / Ee	Do / De
		$\gamma_{f,G1}$	$\gamma_{f,G2}$	$\gamma_{f,Q1}$	$\gamma_{f,Q2}$	$\gamma_{f,Eo}$ / $\gamma_{f,Ee}$	$\gamma_{f,D}$
Operating Gravity / Buoyancy		1.3	1.3	1.5	1.5	-	-
Extreme Storm (100 years)	Max Compression	1.0	1.0	1.0	-	1.35	1.25
	Max Tension	0.9	0.9	0.8	-	1.35	1.25

Table 9.4 – Partial Action Factors for the In-Service Analysis

9.3.2 PARTIAL ACTION FACTORS FOR PRE-SERVICE ANALYSIS

Partial Action Factors for Pre-Service analysis (e.g. Lifting, Transportation, Load-out) conditions are shown in Table 9.5 with reference to three design situations, according to ISO 19902, Ref./6/. where:

- G_T are the permanent actions during the transient situation;
- Q_T are the variable actions during the transient situation;
- T represents the actions from the transient situation being considered.

SITUATION	ACTION		
	Permanent (GT)	**Variable (QT)**	Transient (T)
1	1.3	1.3	1.0
2	1.1	1.1	1.35
3	0.95	0.9	1.35

Table 9.5 – Partial action factors for Pre-service Analyses

9.4 ACCEPTANCE CRITERIA

The maximum member Unity Check (UC) will be less than unity.

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10 CF – IN SERVICE ANALYSIS

The BLPH platform has n.2 seawater caissons and n.1 brine water disposal caisson. Details are given in following table 10.1:

Caisson ID	Type	OD (mm)	Thk (mm)	Top El. (m) LAT	Bottom El. (m) LAT
C1	Seawater Lift	406.4	36.53	16.95	-6.0
C2	Seawater Lift	406.4	36.53	16.95	-6.0
C3	Brine Water disposal	323.9	28.58	16.95	0.0

Table 10.1 – Caisson details

Caisson pipes are then connected in a lattice structure to provide strength during lifting and in service conditions. The seawater lift pumps are submersible, and the caisson can accommodate a pump of 12" diameter with 6" string equipped with suitable spacers.

The SACS model of CF has been created including members, joints and supports.

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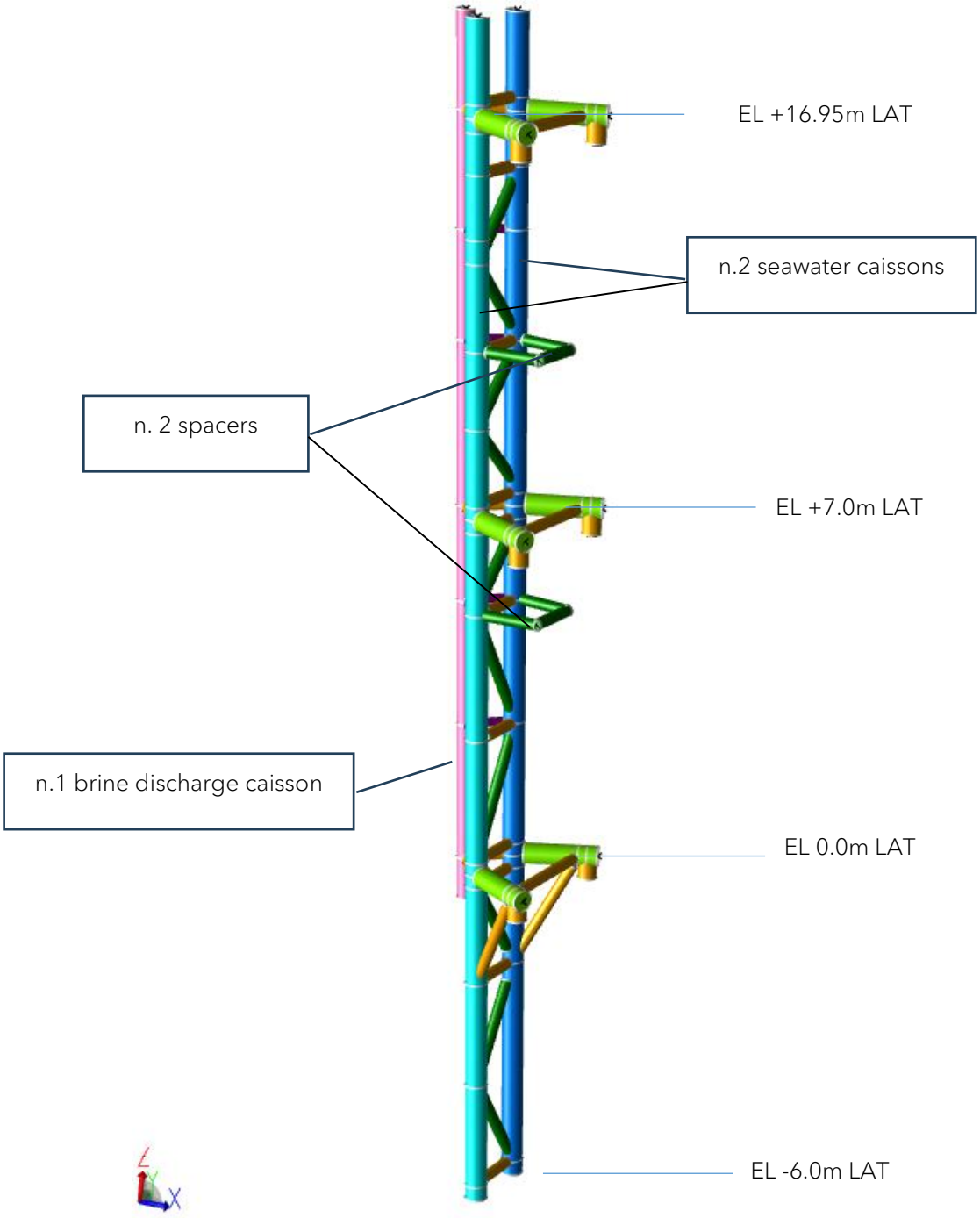


Figure 10.1 – CF SACS model 3D view

10.1 REFERENCE SYSTEM

The SACS ref. system is located at monopile center and at LAT.

10.2 BOUNDARY CONDITIONS

The top pair of CF supports (El +16.95 LAT) are considered hanger flanges, hence they support axial load in addition to both shears. There are two other pairs of supports at El. +7.0m and El. +0.0m LAT.
All these supports are on monopile and intermediate and lower supports are modelled as pinned laterally with vertical release.

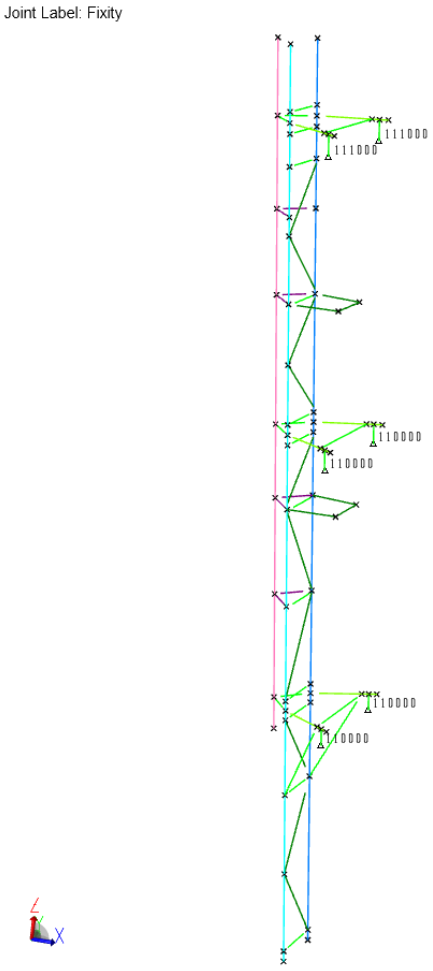


Figure 10.2 – Caisson frame fixities

Restrains at	EL: +16.95m LAT	(111000) – hanger flanges
	EL: +7.00m LAT	(110000)
	EL: +0.00m LAT	(110000)

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It is noted that these supports are "gapped" and therefore can rattle, but gap is necessary to allow for fabrication tolerances when installing the CF offshore.
It is the same system successfully used for boat landing and access ladder installation on the North side of monopile.

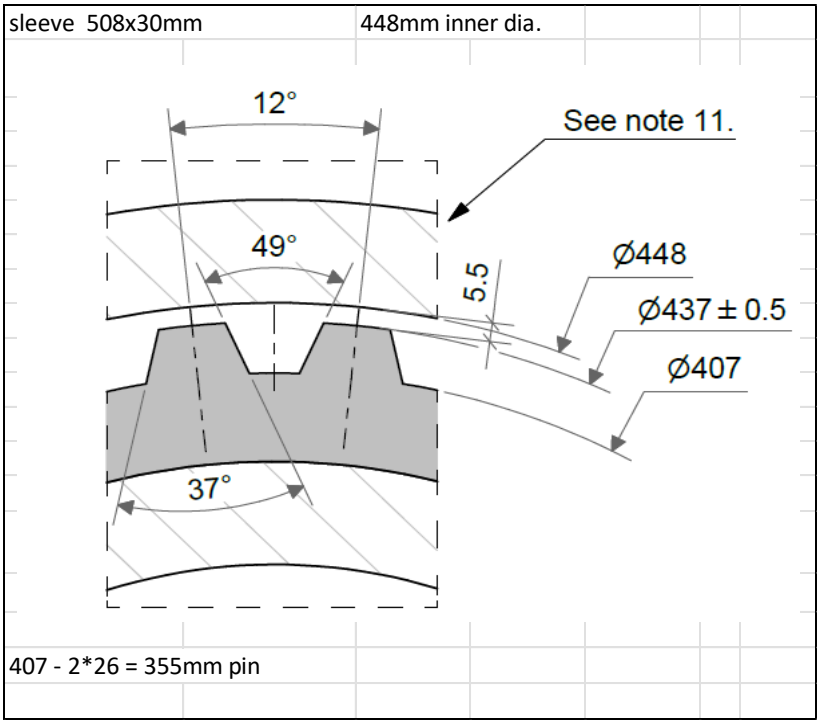


Figure 10.3 – pin-stub interface and GAP

10.3 LOADS CASES

10.3.1 PERMANENT ACTIONS

Caisson frame self-weight as modelled and additional 20% of not modeled weights (e.g. pins and polyurethane guide). The weights of the inner 6" string and pump are not insisting on CF.

10.3.2 VARIABLE LOADS

Ref. document "144671-VOOW-TF-ENG-REP-1052 Wave Loads and Effects for BLPH", ref /31/ that summarizes in easily readable table the design data given in section 7.

TIDE + SURGE

Table 6-3 Extreme total high and low water level at HKN2018 relative to LAT (taken from DHI, 2019).

Location	Parameter	Return period						
		1-yr	2yr	5yr	10yr	50yr	100yr	1000yr
HKN-2018	Total high water level (m LAT)[16]	3.2	3.4	3.5	3.7	4.0	4.1	4.5
		-0.5	-0.6	-0.7	-0.8	-1.0	-1.1	-1.4

Table 10.2 – Ref. Table 7.3 above

CURRENT

7.3. Extreme current speeds

Table 7-1 gives the extreme current speeds at the surface for 7 return periods at Hollandse Kust Noord as computed by (DHI, 2019).

Table 7-1 Extreme omni-directional currents (m/s) at Hollandse Kust Noord (taken from DHI, 2019)

Parameter	Return period						
	1-yr	2-yr	5-yr	10-yr	50-yr	100-yr	1000-yr
Surface current	1.5	1.5	1.6	1.6	1.7	1.7	1.8
Near-bed current[17]	0.8	0.8	0.8	0.8	0.9	0.9	0.9
Depth-averaged current	1.0	1.0	1.1	1.1	1.1	1.2	1.2

Table 10.3 – ref. Table 7.10 above

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WAVES

Table 5-1 Extreme omnidirectional Hs, Hmp, Cmp and EWL at HKN-2018 (from DHI, 2019)

Parameter	Return period					
	1-yr	5-yr	10-yr	50-yr	100-yr	1000-yr
Hs	5.6	6.4	6.7	7.3	7.6	8.4
Hmp	10.4	12.0	12.6	14.0	14.5	16.2
$T_{Hmp,\ lower}$	9.2	9.8	10.1	10.5	10.7	11.2
T_{Hmp} [13]	10.3	10.9	11.2	11.7	11.9	12.5
$T_{Hmp,\ upper}$	11.3	12.0	12.3	12.9	13.1	13.7
Cmp	6.6	7.7	8.2	9.2	9.6	10.9
Tp [14]	10.0	10.9	11.1	11.5	11.8	12.2
T_z [15]	7.4	8.0	8.2	8.6	8.8	9.2
EWL (LAT)	9.1	10.5	11.1	12.3	12.7	14.3
Extreme duration (hr)	1	1	1	1	1	1

Individual wave height

crest height

Table 10.4 – ref. Table 7.10 above

10.3.2.1 Wave theory selection

Considering the min and max water depth associated to min and max wave period the more appropriate wave theory results Stream function, order 9-11.

WDmin = 20m +4.1m

WDmax = 22.2m+4.1m

100yrsr - Tmin - WDmin						
Dir	Tmin [s]	Hmax [m]	dmin [m]	H/gT_{app}^2	d/gT_{app}^2	Wave Theory
0	10.70	14.50	24.10	0.0129	0.0215	
45	10.70	14.50	24.10	0.0129	0.0215	
90	10.70	14.50	24.10	0.0129	0.0215	

100yrsr - Tmin - WDmax						
Dir	Tmin [s]	Hmax [m]	dmax [m]	H/gT_{app}^2	d/gT_{app}^2	Wave Theory
0	10.70	14.50	26.30	0.0129	0.0234	
45	10.70	14.50	26.30	0.0129	0.0234	
90	10.70	14.50	26.30	0.0129	0.0234	

100yrsr - Tmax - WDmin						
Dir	Tmax [s]	Hmax [m]	dmin [m]	H/gT_{app}^2	d/gT_{app}^2	Wave Theory
0	13.10	14.50	24.10	0.0086	0.0143	
30	13.10	14.5	24.10	0.0086	0.0143	
60	13.10	14.5	24.10	0.0086	0.0143	

100yrsr - Tmax - WDmax						
Dir	Tmax [s]	Hmax [m]	dmax [m]	H/gT_{app}^2	d/gT_{app}^2	Wave Theory
0	13.10	14.5	26.30	0.0086	0.0156	
45	13.10	14.5	26.30	0.0086	0.0156	
90	13.10	14.5	26.30	0.0086	0.0156	

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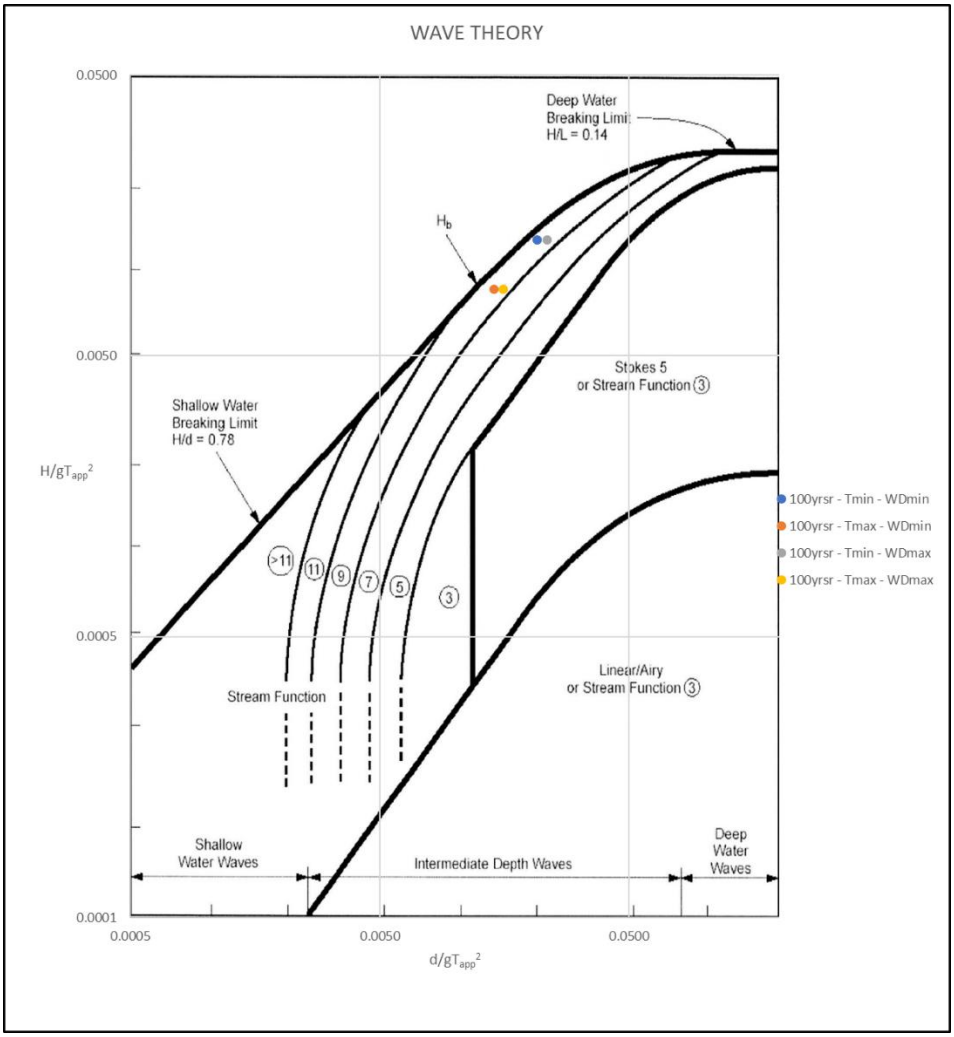


Figure 10.4 – Recommended wave theory

10.3.2.2 Wave enhancement

According to document /30/, FEED design, the presence of monopile affects the magnitude and direction of the water flowing around it on the appurtenances. This influence extends out from the monopile surface at least two diameters, see fig. 10.5. The velocity enhancement values are based on the assumption of potential flow, e.g. no flow separation, turbulence or vortex shedding occurs around the monopile. Clearly it is unrealistic, but the assumption is conservative.

The maximum flow enhancement occurs on a plane perpendicular to the flow, where the velocity enhancement can double the freestream velocity.

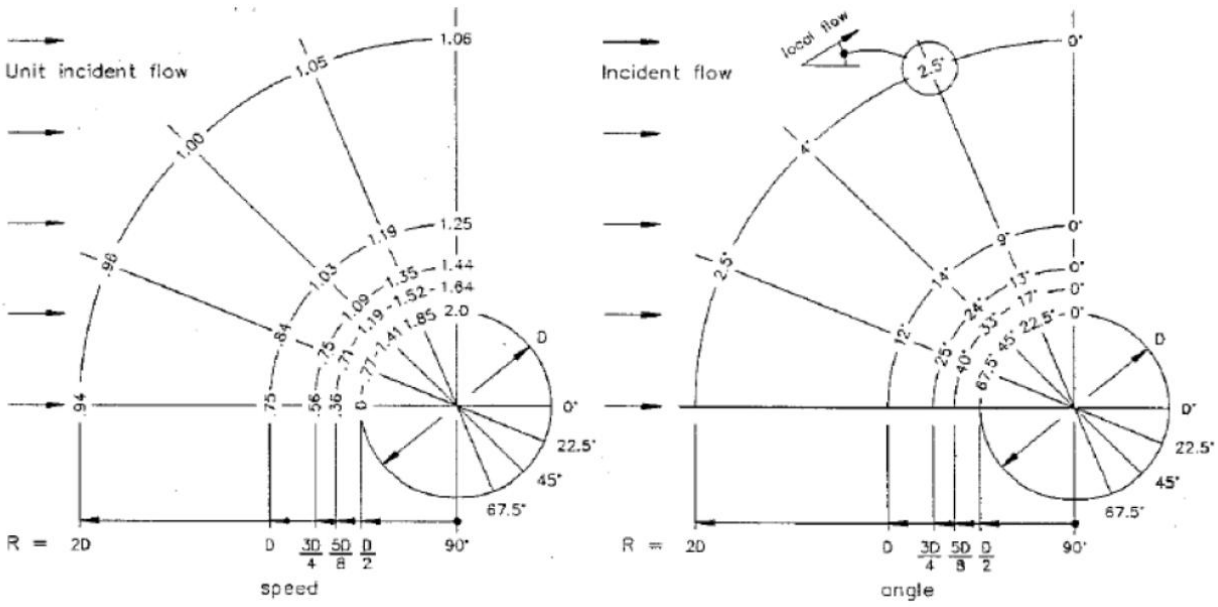


Figure 10.5 – Velocity enhancement

The flow is stopped on a "stagnation" point at the surface of the monopile, on a plane parallel to the flow direction. This is shown in the following figures.

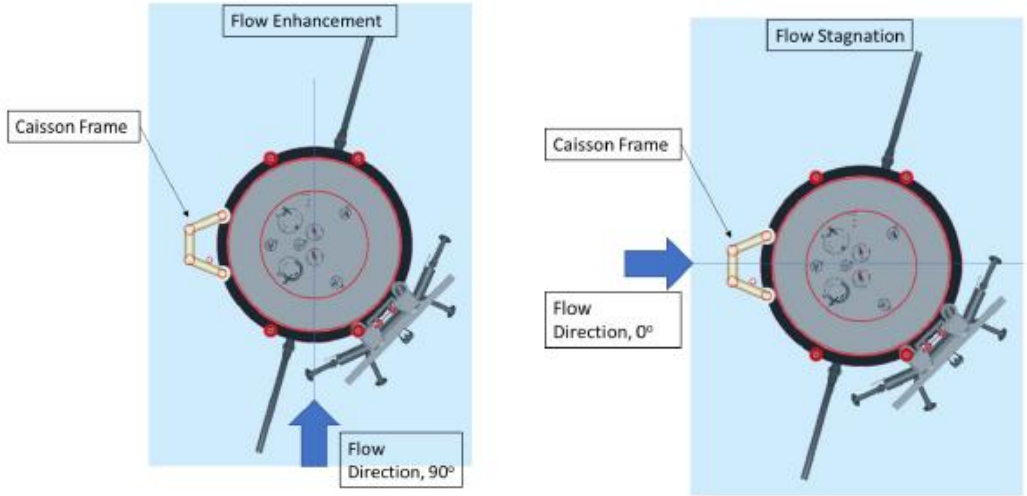


Figure 10.6 – Flow enhancement and stagnation

monopile diameter			7	m		
distance from center MP to center main Caisson			5	m		
			@45	@90		
3*D/4 =	5.250	m	1.090	1.440		
5*D/8 =	4.375	m	1.190	1.640		
interpolation	5.031	m	1.115	1.490	enhancement factors:	

Table 10.5 – Enhancement factor calculation

From the above table, the values to be considered as enhancement factors at distance 5m from MP centre line are assumed equal respectively to 1.12 and 1.50.

10.3.2.3 Cd and Cm calculation

The values of Cd and Cm have been modified to consider the presence of the monopile, according with the factors given in Ref. /15/.

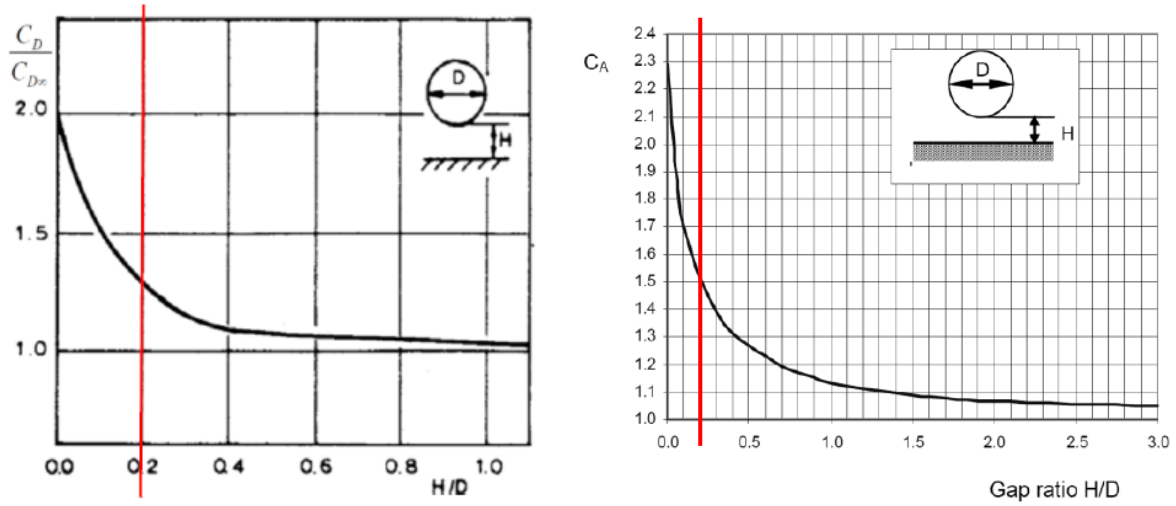


Figure 10.7 – Correction for Cd (left side) and for Cm (right side)

Where: D = 7m, H = 1.5m (GAP), and therefore H/D = 0.20.

In conclusion, values Cd = 1.300 and Cm = 1.600 were assumed for both smooth and rough profiles.

10.4 LOAD COMBINATIONS

Load combination for extreme variable load conditions are reported in the next table:

- MIN WD -24.10m LAT

ID	Self Weight	Min period T=10.7s			Max period T=13.1s		
		Wave + current @0deg incoming	Wave + current @45deg incoming	Wave + current @90deg incoming	Wave + current @0deg incoming	Wave + current @45deg incoming	Wave + current @90deg incoming
LC01	1.00	1.35	-	-	-	-	-
LC02	1.00	-	1.35	-	-	-	-
LC03	1.00	-	-	1.35	-	-	-
LC04	1.00	-	-	-	1.35	-	-
LC05	1.00	-	-	-	-	1.35	-
LC06	1.00	-	-	-	-	-	1.35

Table 10.6 – ULS Load combinations – SET 1

- MAX WD -26.3m LAT

ID	Self Weight	Min period T=10.7s			Max period T=13.1s		
		Wave + current @0deg incoming	Wave + current @45deg incoming	Wave + current @90deg incoming	Wave + current @0deg incoming	Wave + current @45deg incoming	Wave + current @90deg incoming
LC07	1.00	1.35	-	-	-	-	-
LC08	1.00	-	1.35	-	-	-	-
LC09	1.00	-	-	1.35	-	-	-
LC10	1.00	-	-	-	1.35	-	-
LC11	1.00	-	-	-	-	1.35	-
LC12	1.00	-	-	-	-	-	1.35

Table 10.7 – ULS Load combinations – SET 2

10.5 ANALYSIS RESULTS

10.5.1 WAVES VELOCITY CALCULATION

The 100-years return period flow enhanced wave plus current velocity has been calculated as follows:

- Calculate wave velocity using stream function theory with wave 14.5m height, wave period 10.7sec and 13.1sec and water depth -22.1m LAT and -26.3m LAT
- Add 100-years return period current velocity. The surface current velocity has been stretched into the wave crest.
- Factor the combined wave + current velocity by the flow enhancement factor for direction 45° and 90°, as calculated in section 10.3.2.2.

velocity profile (min. WD)

LAT	WAVE HEIGHT	min. T=10.7sec			LAT	WAVE HEIGHT	max. T=13.1sec		
		EN00	EN45 (1.120)	EN90 (1.500)			EM00	EM45 (1.120)	EM90 (1.500)
14.62	34.62	11.424	12.795	17.136	15.03	35.03	11.022	12.345	16.533
14.32	34.32	11.247	12.597	16.871	14.72	34.72	10.882	12.188	16.323
13.85	33.85	10.982	12.300	16.473	14.25	34.25	10.666	11.946	15.999
13.20	33.2	10.626	11.901	15.939	13.60	33.6	10.376	11.621	15.564
12.39	32.39	10.203	11.427	15.305	12.78	32.78	10.027	11.230	15.041
11.41	31.41	9.728	10.895	14.592	11.79	31.79	9.632	10.788	14.448
10.27	30.27	9.218	10.324	13.827	10.63	30.63	9.202	10.306	13.803
8.95	28.95	8.687	9.729	13.031	9.30	29.3	8.749	9.799	13.124
7.46	27.46	8.150	9.128	12.225	7.80	27.8	8.284	9.278	12.426
5.81	25.81	7.618	8.532	11.427	6.13	26.13	7.819	8.757	11.729
3.99	23.99	7.102	7.954	10.653	4.29	24.29	7.361	8.244	11.042
2.00	22	6.610	7.403	9.915	2.27	22.27	6.921	7.752	10.382
-0.16	19.84	6.149	6.887	9.224	0.09	20.09	6.504	7.284	9.756
-2.49	17.51	5.724	6.411	8.586	-2.27	17.73	6.116	6.850	9.174
-4.99	15.01	5.341	5.982	8.012	-4.80	15.2	5.762	6.453	8.643
-7.65	12.35	5.001	5.601	7.502	-7.50	12.5	5.447	6.101	8.171
-10.49	9.51	4.711	5.276	7.067	-10.37	9.63	5.175	5.796	7.763
-13.49	6.51	4.472	5.009	6.708	-13.41	6.59	4.950	5.544	7.425
-16.66	3.34	4.291	4.806	6.437	-16.62	3.38	4.777	5.350	7.166
-20.00	0	4.174	4.675	6.261	-20.00	0	4.664	5.224	6.996

Table 10.8 – Velocity profile with min. WD

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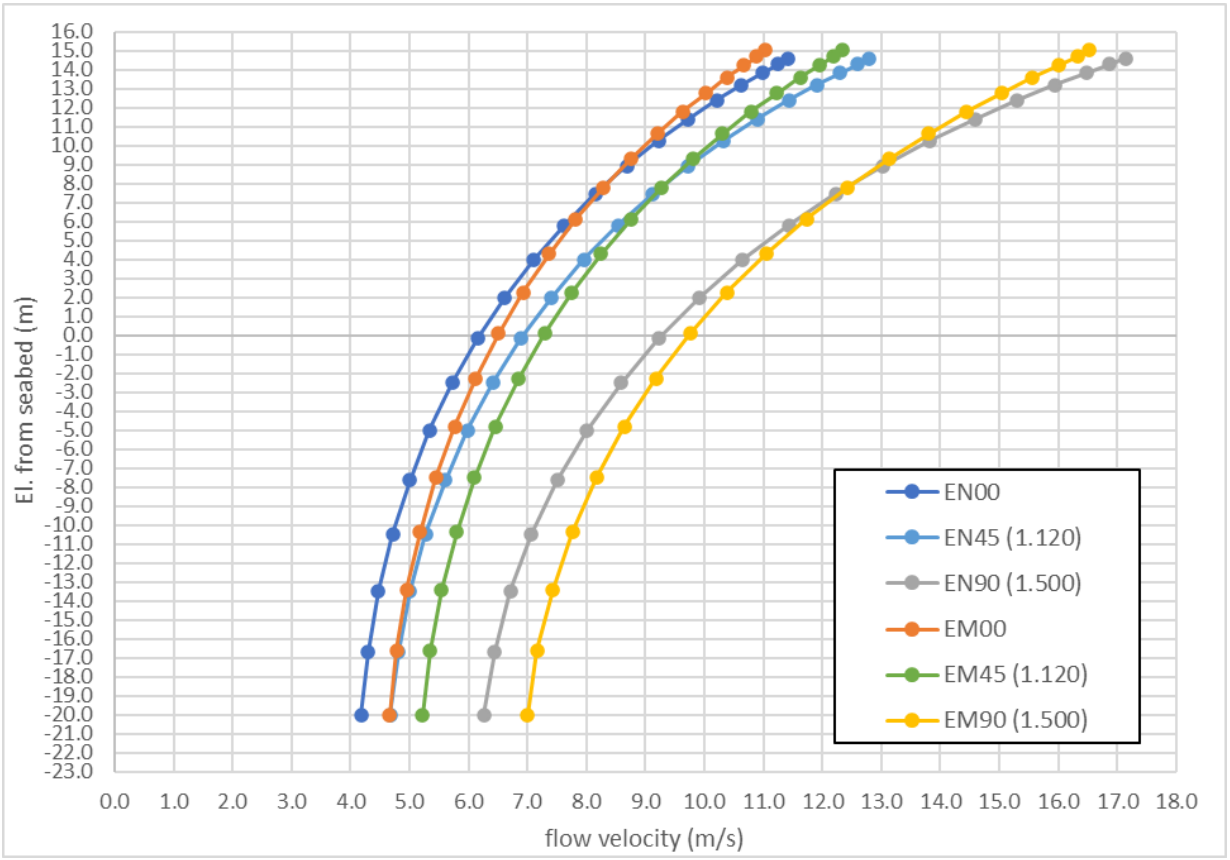


Figure 10.8 – Flow velocity with min WD

velocity profile (max WD)

LAT	WAVE HEIGHT	min. T=10.7sec			LAT	WAVE HEIGHT	max. T=13.1sec		
		EN00	EN45 (1.120)	EN90 (1.500)			EM00	EM45 (1.120)	EM90 (1.500)
14.23	36.43	10.427	11.678	15.641	14.64	36.84	10.117	11.331	15.176
13.93	36.13	10.291	11.526	15.437	14.34	36.54	10.008	11.209	15.012
13.44	35.64	10.079	11.288	15.119	13.85	36.05	9.832	11.012	14.748
12.78	34.98	9.790	10.965	14.685	13.18	35.38	9.594	10.745	14.391
11.94	34.14	9.441	10.574	14.162	12.33	34.53	9.304	10.420	13.956
10.92	33.12	9.045	10.130	13.568	11.30	33.5	8.972	10.049	13.458
9.72	31.92	8.613	9.647	12.920	10.09	32.29	8.608	9.641	12.912
8.34	30.54	8.157	9.136	12.236	8.70	30.9	8.219	9.205	12.329
6.78	28.98	7.690	8.613	11.535	7.12	29.32	7.817	8.755	11.726
5.04	27.24	7.222	8.089	10.833	5.36	27.56	7.410	8.299	11.115
3.12	25.32	6.762	7.573	10.143	3.42	25.62	7.006	7.847	10.509
1.03	23.23	6.318	7.076	9.477	1.30	23.5	6.613	7.407	9.920
-1.25	20.95	5.898	6.606	8.847	-1.00	21.2	6.237	6.985	9.356
-3.71	18.49	5.506	6.167	8.259	-3.48	18.72	5.885	6.591	8.828
-6.34	15.86	5.149	5.767	7.724	-6.15	16.05	5.560	6.227	8.340
-9.15	13.05	4.831	5.411	7.247	-9.00	13.2	5.269	5.901	7.904
-12.15	10.05	4.556	5.103	6.834	-12.02	10.18	5.015	5.617	7.523
-15.32	6.88	4.328	4.847	6.492	-15.23	6.97	4.802	5.378	7.203
-18.67	3.53	4.153	4.651	6.230	-18.63	3.57	4.637	5.193	6.956
-22.20	0	4.038	4.523	6.057	-22.20	0	4.526	5.069	6.789

Table 10.9 – Velocity profile with max. WD

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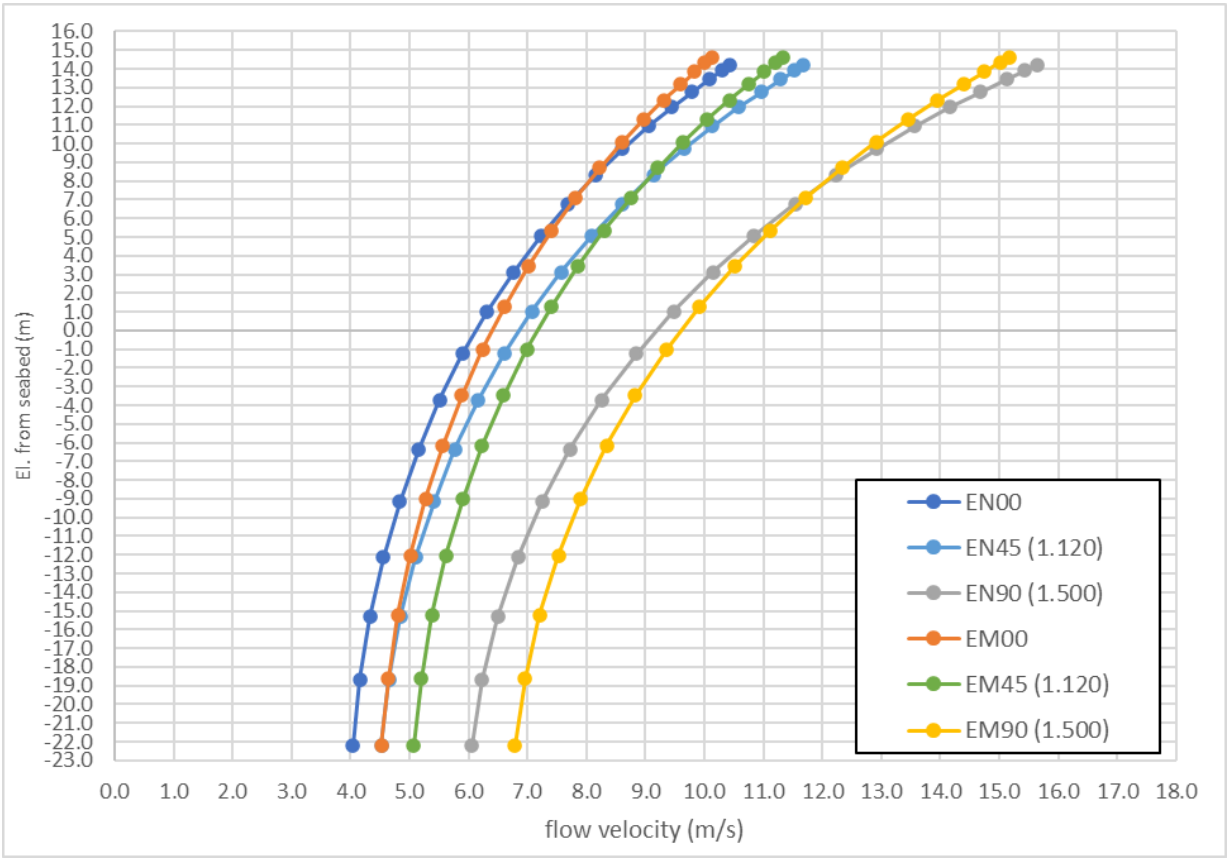


Figure 10.9 – Flow velocity with max WD

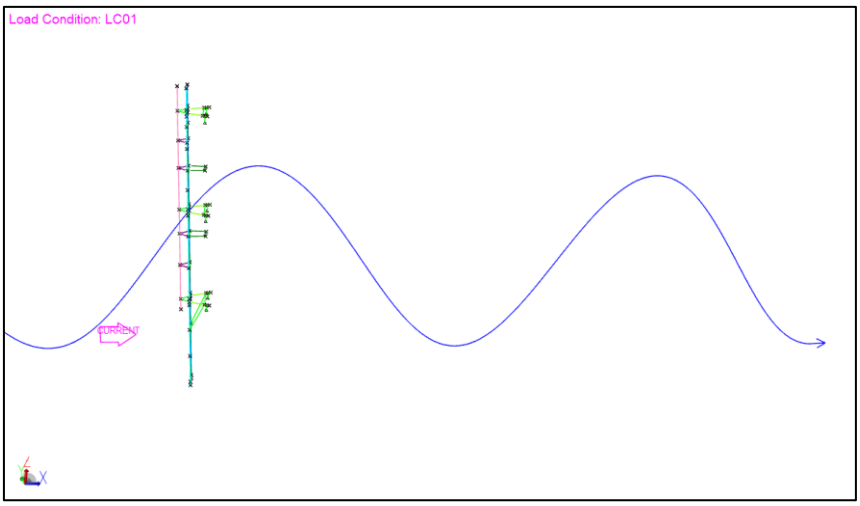


Figure 10.10 – Load combination LC01 – incoming wave at 0deg

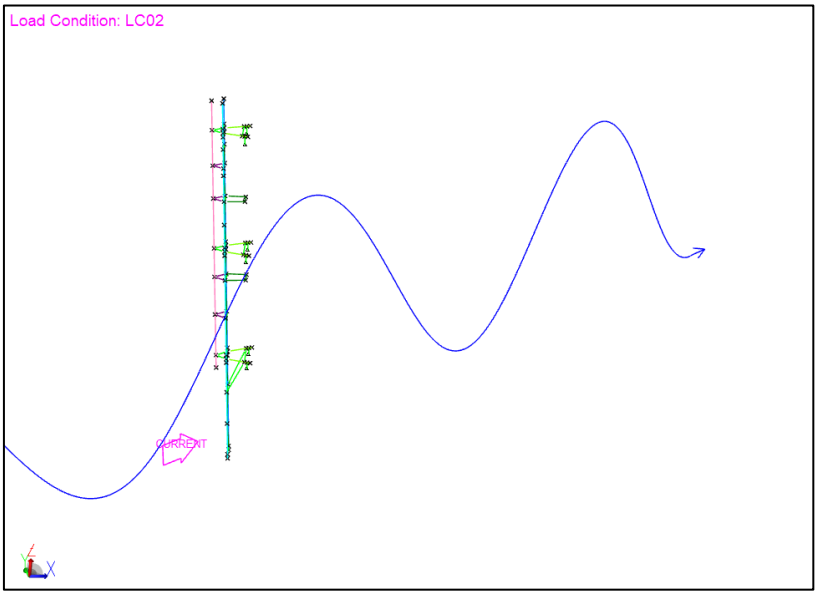


Figure 10.11 – Load combination LC02 – incoming wave at 45deg

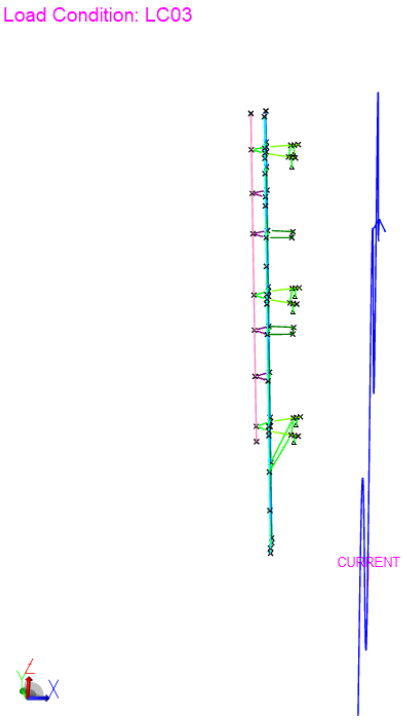


Figure 10.12 – Load combination LC03 – incoming wave at 90deg

10.5.2 BASE REACTIONS

The base reactions at structural origin are reported in the following tables:

@MIN WD:

********** SEASTATE LOAD CASE CENTER REPORT **********
RELATIVE TO STRUCTURAL ORIGIN

LOAD CASE	LOAD LABEL	********* X - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Y - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Z - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)
1	DEAZ	0.00				0.00				-255.00	-4.96	-0.00	6.63
2	EM00	1628.96	-5.02	-0.00	5.63	-0.30	-5.00	90.98	14.10	-210.17	-4.91	-0.00	5.25
3	EM45	1292.33	-5.02	-0.03	5.80	1203.09	-5.02	-0.04	5.77	-228.34	-4.89	0.01	5.69
4	EM90	1.00	-4.52	-68.92	-1.33	2282.56	-5.01	0.00	5.75	-214.22	-4.91	0.03	6.32
5	EN00	1590.06	-5.02	-0.00	5.93	COUPLE				-224.95	-4.90	-0.00	5.37
6	EN45	1194.25	-5.03	-0.03	5.74	1115.05	-5.03	-0.05	5.71	-204.25	-4.93	0.02	5.70
7	EN90	1.08	-4.53	-61.09	-1.53	2161.25	-5.02	0.00	5.86	-219.84	-4.90	0.02	6.35
8	DEAC	0.00				0.00				-51.00	-4.96	-0.00	6.63
9	LC01	2146.58	-5.02	-0.00	5.93	COUPLE				-609.69	-4.93	-0.00	6.00
10	LC02	1612.24	-5.03	-0.03	5.74	1505.32	-5.03	-0.05	5.71	-581.75	-4.94	0.01	6.19
11	LC03	1.46	-4.53	-61.09	-1.53	2917.69	-5.02	0.00	5.86	-602.78	-4.93	0.01	6.49
12	LC04	2199.10	-5.02	-0.00	5.63	-0.41	-5.00	90.98	14.10	-589.74	-4.93	-0.00	5.96
13	LC05	1744.64	-5.02	-0.03	5.80	1624.17	-5.02	-0.04	5.77	-614.26	-4.92	0.01	6.15
14	LC06	1.36	-4.52	-68.92	-1.33	3081.46	-5.01	0.00	5.75	-595.20	-4.93	0.02	6.48

Table 10.10 – Base reactions at min WD

@MAX WD:

********** SEASTATE LOAD CASE CENTER REPORT **********
RELATIVE TO STRUCTURAL ORIGIN

LOAD CASE	LOAD LABEL	********* X - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Y - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Z - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)
1	DEAZ	0.00				0.00				-256.23	-4.96	-0.00	6.62
2	EM00	1507.40	-5.02	-0.00	5.28	-0.24	-5.00	107.04	14.15	-212.00	-4.91	-0.00	5.35
3	EM45	1179.76	-5.02	-0.03	5.32	1101.92	-5.02	-0.04	5.32	-226.96	-4.89	0.01	5.74
4	EM90	0.99	-4.51	-66.64	-1.15	2093.60	-5.01	0.00	5.32	-213.29	-4.91	0.03	6.36
5	EN00	1466.52	-5.02	-0.00	5.51	COUPLE				-225.05	-4.90	-0.00	5.44
6	EN45	1104.78	-5.02	-0.03	5.36	1035.49	-5.02	-0.04	5.39	-238.54	-4.89	0.01	5.83
7	EN90	1.08	-4.52	-58.26	-1.28	1995.87	-5.01	0.00	5.44	-218.48	-4.91	0.03	6.37
8	DEAC	0.00				0.00				-51.25	-4.96	-0.00	6.62
9	LC07	1979.80	-5.02	-0.00	5.51	COUPLE				-611.29	-4.93	-0.00	6.03
10	LC08	1491.46	-5.02	-0.03	5.36	1397.91	-5.02	-0.04	5.39	-629.51	-4.92	0.00	6.22
11	LC09	1.46	-4.52	-58.26	-1.28	2694.42	-5.01	0.00	5.44	-602.42	-4.93	0.01	6.50
12	LC10	2034.99	-5.02	-0.00	5.28	-0.33	-5.00	107.04	14.15	-593.68	-4.93	-0.00	6.01
13	LC11	1592.67	-5.02	-0.03	5.32	1487.59	-5.02	-0.04	5.32	-613.88	-4.92	0.01	6.18
14	LC12	1.33	-4.51	-66.64	-1.15	2826.36	-5.01	0.00	5.32	-595.42	-4.93	0.02	6.49

Table 10.11 – Base reactions at max WD

10.5.3 SUPPORT REACTION FORCES

Maximum supports reactions at TP elevation, +16.95m LAT (joints FX20 and FX21), at intermediate El. +7.0m (joints FX10 and FX11) and at sea level 0.0m LAT (joints FX00 and FX01) are reported here after with reference to factored Load Combinations.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	********** KN ********** FORCE(X)	FORCE(Y)	FORCE(Z)	********** KN-M ********** MOMENT(X)	MOMENT(Y)	MOMENT(Z)
FX00	LC01	-450.082	-139.588	0.000	0.000	0.000	0.000
	LC02	-676.568	-431.533	0.000	0.000	0.000	0.000
	LC03	-619.681	-619.166	0.000	0.000	0.000	0.000
	LC04	-495.859	-155.337	0.000	0.000	0.000	0.000

	LC05	-748.504	-477.732	0.000	0.000	0.000	0.000
	LC06	-679.876	-680.830	0.000	0.000	0.000	0.000
FX01	LC01	-455.256	140.945	0.000	0.000	0.000	0.000
	LC02	-19.986	-218.287	0.000	0.000	0.000	0.000
	LC03	621.787	-614.180	0.000	0.000	0.000	0.000
	LC04	-501.399	156.579	0.000	0.000	0.000	0.000
	LC05	-26.485	-237.445	0.000	0.000	0.000	0.000
	LC06	681.965	-675.691	0.000	0.000	0.000	0.000
FX10	LC01	-451.146	-70.826	0.000	0.000	0.000	0.000
	LC02	-656.260	-345.720	0.000	0.000	0.000	0.000
	LC03	-631.106	-574.313	0.000	0.000	0.000	0.000
	LC04	-435.805	-68.421	0.000	0.000	0.000	0.000
	LC05	-662.741	-350.920	0.000	0.000	0.000	0.000
	LC06	-634.361	-576.745	0.000	0.000	0.000	0.000
FX11	LC01	-447.499	68.428	0.000	0.000	0.000	0.000
	LC02	-48.230	-239.415	0.000	0.000	0.000	0.000
	LC03	525.479	-555.801	0.000	0.000	0.000	0.000
	LC04	-431.862	65.866	0.000	0.000	0.000	0.000
	LC05	-40.329	-244.385	0.000	0.000	0.000	0.000
	LC06	530.139	-558.375	0.000	0.000	0.000	0.000
FX20	LC01	-171.491	-88.830	305.231	0.000	0.000	0.000
	LC02	-279.775	-215.453	321.834	0.000	0.000	0.000
	LC03	-305.838	-347.271	371.995	0.000	0.000	0.000
	LC04	-166.924	-86.103	295.077	0.000	0.000	0.000
	LC05	-327.091	-242.238	349.983	0.000	0.000	0.000
	LC06	-321.165	-364.159	379.091	0.000	0.000	0.000
FX21	LC01	-171.105	90.020	304.457	0.000	0.000	0.000
	LC02	68.586	-54.911	259.911	0.000	0.000	0.000
	LC03	407.901	-206.951	230.786	0.000	0.000	0.000
	LC04	-167.248	87.825	294.658	0.000	0.000	0.000
	LC05	60.517	-71.450	264.273	0.000	0.000	0.000
	LC06	421.944	-225.651	216.109	0.000	0.000	0.000

Table 10.12 – Supports reactions at min WD

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X) (KN)	FORCE(Y) (KN)	FORCE(Z) (KN)	MOMENT(X) (KN-M)	MOMENT(Y) (KN-M)	MOMENT(Z) (KN-M)
FX00	LC07	-443.769	-138.041	0.000	0.000	0.000	0.000
	LC08	-662.993	-422.967	0.000	0.000	0.000	0.000
	LC09	-609.081	-609.389	0.000	0.000	0.000	0.000
	LC10	-484.056	-152.133	0.000	0.000	0.000	0.000
	LC11	-729.950	-466.323	0.000	0.000	0.000	0.000
	LC12	-661.796	-663.405	0.000	0.000	0.000	0.000
FX01	LC07	-448.987	139.374	0.000	0.000	0.000	0.000
	LC08	-20.816	-212.172	0.000	0.000	0.000	0.000
	LC09	611.093	-604.551	0.000	0.000	0.000	0.000
	LC10	-489.577	153.339	0.000	0.000	0.000	0.000
	LC11	-27.054	-230.917	0.000	0.000	0.000	0.000
	LC12	663.811	-658.472	0.000	0.000	0.000	0.000
FX10	LC07	-420.680	-66.029	0.000	0.000	0.000	0.000
	LC08	-614.958	-321.136	0.000	0.000	0.000	0.000
	LC09	-585.893	-531.296	0.000	0.000	0.000	0.000
	LC10	-406.717	-64.017	0.000	0.000	0.000	0.000
	LC11	-616.161	-324.995	0.000	0.000	0.000	0.000
	LC12	-588.735	-533.054	0.000	0.000	0.000	0.000
FX11	LC07	-417.295	63.685	0.000	0.000	0.000	0.000
	LC08	-51.466	-219.815	0.000	0.000	0.000	0.000
	LC09	480.363	-512.102	0.000	0.000	0.000	0.000
	LC10	-403.073	61.502	0.000	0.000	0.000	0.000
	LC11	-41.794	-224.826	0.000	0.000	0.000	0.000
	LC12	484.570	-514.080	0.000	0.000	0.000	0.000
FX20	LC07	-124.632	-84.359	306.030	0.000	0.000	0.000

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	LC08	-216.621	-193.737	335.030	0.000	0.000	0.000
	LC09	-232.879	-288.566	343.195	0.000	0.000	0.000
	LC10	-125.609	-82.399	297.085	0.000	0.000	0.000
	LC11	-246.770	-203.339	333.728	0.000	0.000	0.000
	LC12	-247.025	-297.820	348.353	0.000	0.000	0.000
FX21	LC07	-124.435	85.569	305.259	0.000	0.000	0.000
	LC08	75.403	-28.078	294.477	0.000	0.000	0.000
	LC09	334.933	-148.510	259.224	0.000	0.000	0.000
	LC10	-125.950	84.038	296.592	0.000	0.000	0.000
	LC11	69.060	-37.190	280.144	0.000	0.000	0.000
	LC12	347.842	-159.520	247.059	0.000	0.000	0.000

Table 10.13 – Supports reactions at max WD

El. (LAT)	joint	Max Reactions [kN]			description
		X-dir	Y-dir	Z-dir	Load condition / wave direction / WD / period
0.0	FX00	-748.5	-681	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX01	682	-676	-	LC06 / 90deg / min WD / max T
+7.0	FX10	-663	-577	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX11	530	-558	-	LC06 / 90deg / min WD / max T
+14.5	FX20	-327	-364	380	LC05 & LC06 / 45 & 90deg / min WD / max T LC06 / 90deg / min WD / max T
	FX21	422	-226	305	LC06 / 90deg / min WD / max T LC07 / 0deg / max WD / min T

Table 10.14 – Summary table of support reactions

It can be observed that the governing case for lateral force is with incoming wave perpendicular to caisson frame with wave velocity enhanced and associated with minimum WD and max period.

These reactions have been compared with the MP sleeves resistance, see Appendix E.

10.6 STRUCTURAL CHECKS

The results of the performed analysis in terms of members' Unity Check (UC) and Joints' Punching Shear Unity Checks are detailed in the following sections.

10.6.1 ULS MEMBER CHECKS

All members were checked according to ISO 19902 and Eurocode 3, Ref./6/and /8/, respectively for tubular and non-tubular elements. Members' code checks are reported in the following and show that the structure can withstand all In-Service load combinations, with utilization factors below 1.0.

The maximum UC value is equal to 0.73 on support pins at EL. 0.0m LAT for load combination LC06. Maximum member UC are reported in following SACS excerpt and figures.

@MIN WD:

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
FX00- S00	CFA	0.731	LC06	0.4	0.07	-220.15	-222.48	-679.88	-664.62	7.8	7.8	0.674	LC05	0.666	LC03
FX01- S01	CFA	0.730	LC06	0.4	0.07	-218.49	223.16	681.96	-659.66	7.8	7.8	0.664	LC03	0.398	LC04

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 999.00

** NO UNITY CHECKS IN THIS GROUP **

Maximum UC per member's group are reported in following SACS excerpt.

* * * M E M B E R G R O U P S U M M A R Y * * *
ISO 19902:2007 / EC3:2005
(EN 1993-1-1:2005/NA NONE)

GRUP ID	CRITICAL MEMBER	LOAD COND	MAX. UNITY CHECK	DIST FROM END M	* APPLIED STRESSES * AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	*** ALLOWABLE STRESSES *** AXIAL N/MM2	EULER N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	CRIT COND	EFFECTIVE LENGTHS KLY M	EFFECTIVE LENGTHS KLZ M	CM * VALUES * Y	CM * VALUES * Z
CFA	FX00- S00	LC06	0.73	0.4	0.1	-220.1	-222.5	.3E+03	.3E+05	.4E+03	.4E+03	TN+BN	0.87	0.87	0.85	0.85
CFB	S00- T00	LC06	0.57	0.2	-37.1	-188.2	24.5	283.9	4322.2	428.6	428.6	ACBI	2.80	0.16	0.85	0.85
CS1	800- 900	LC05	0.33	0.2	-11.2	44.6	-116.1	283.9	672.1	434.6	434.6	ACBI	7.00	7.00	0.85	0.85
CS2	801- 901	LC04	0.32	0.2	-0.3	-24.2	-137.7	283.9	672.1	434.6	434.6	ACBI	7.00	7.00	0.85	0.85
CS3	202- 402	LC01	0.30	0.0	-31.9	-0.3	-87.2	292.4	4780.8	456.0	456.0	ACBI	2.16	2.16	0.85	0.85
TR1	201- 202	LC01	0.54	0.0	-7.3	238.0	-2.5	.3E+03	.4E+05	.5E+03	.5E+03	ACBI	0.52	0.52	0.85	0.85
TR2	801- 700	LC06	0.37	0.0	71.8	-65.4	10.5	328.6	1341.7	439.3	439.3	TN+BN	2.65	2.65	0.85	0.85
TR3	501- 502	LC01	0.39	0.0	-0.2	-178.2	5.2	.3E+03	.2E+05	.5E+03	.5E+03	ACBI	0.55	0.55	0.85	0.85

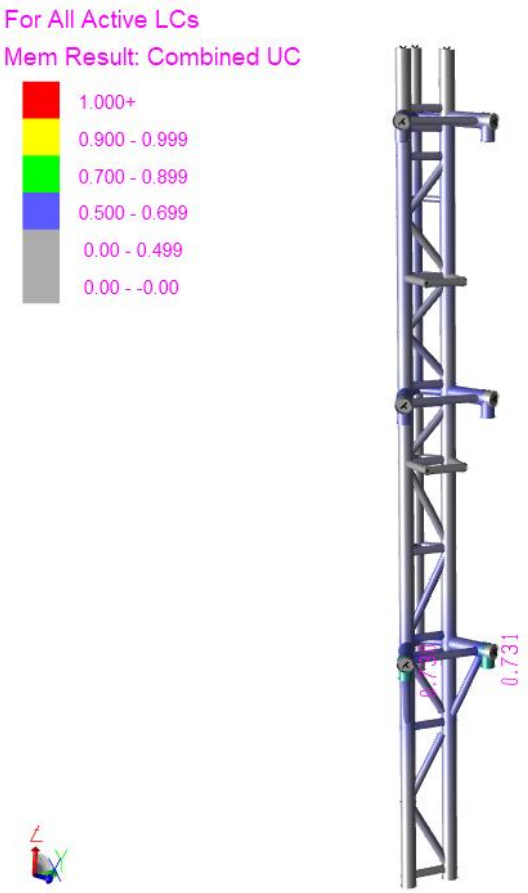


Figure 10.13 – Max UCs @ min. WD

@MAX WD:

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
FX00- S00	CFA	0.712	LC12	0.4	0.07	-214.52	-216.56	-661.80	-647.68	7.8	7.8	0.658	LC11	0.655	LC09
FX01- S01	CFA	0.711	LC12	0.4	0.07	-212.93	217.22	663.81	-642.89	7.8	7.8	0.653	LC09	0.389	LC10

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 999.00

** NO UNITY CHECKS IN THIS GROUP **

Maximum UC per member's group are reported in following SACS excerpt.

* * * M E M B E R G R O U P S U M M A R Y * * *

ISO 19902:2007 / EC3:2005

(EN 1993-1-1:2005/NA NONE)

GRUP ID	CRITICAL MEMBER	LOAD COND	MAX. UNITY CHECK	DIST FROM END M	* APPLIED STRESSES * AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	*** ALLOWABLE STRESSES *** AXIAL N/MM2	EULER N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	CRIT COND	EFFECTIVE LENGTHS KLY M	KLZ M	CM * VALUES * Y	Z
CFA	FX00- S00	LC12	0.71	0.4	0.1	-214.5	-216.6	.3E+03	.3E+05	.4E+03	.4E+03	TN+BN	0.87	0.87	0.85	0.85
CFB	S00- T00	LC12	0.56	0.2	-36.2	-183.3	23.9	283.9	4322.2	428.6	428.6	ACBI	2.80	0.16	0.85	0.85
CS1	800- 900	LC11	0.32	0.2	-11.0	43.7	-114.2	283.9	672.1	434.6	434.6	ACBI	7.00	7.00	0.85	0.85
CS2	801- 901	LC10	0.32	0.2	-0.3	-23.7	-135.6	283.9	672.1	434.6	434.6	ACBI	7.00	7.00	0.85	0.85
CS3	202- 402	LC07	0.28	0.0	-30.3	-0.3	-79.6	292.4	4780.8	456.0	456.0	ACBI	2.16	2.16	0.85	0.85
TR1	201- 202	LC07	0.52	0.0	-6.3	230.5	-3.4	.3E+03	.4E+05	.5E+03	.5E+03	ACBI	0.52	0.52	0.85	0.85
TR2	801- 700	LC12	0.36	0.0	70.3	-63.2	10.4	328.6	1341.7	439.3	439.3	TN+BN	2.65	2.65	0.85	0.85
TR3	501- 502	LC07	0.37	0.0	-0.4	-169.5	4.4	.3E+03	.2E+05	.5E+03	.5E+03	ACBI	0.55	0.55	0.85	0.85

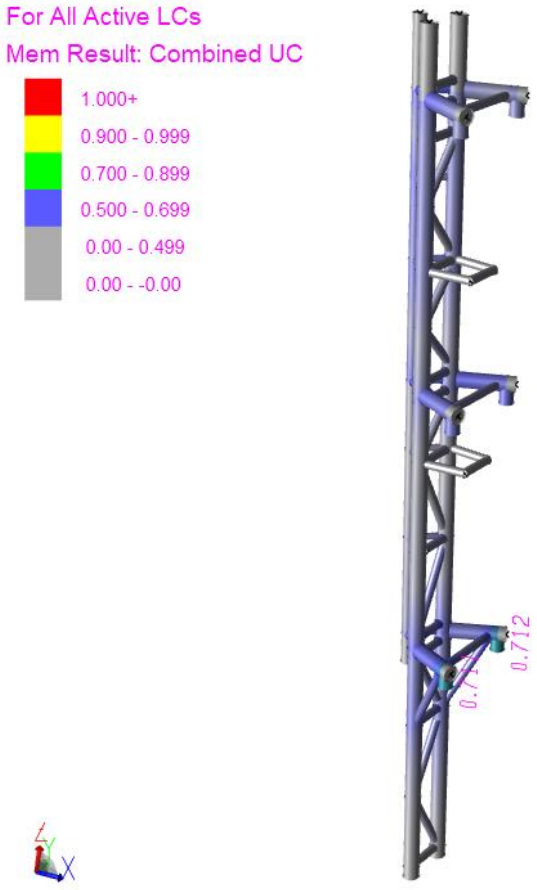


Figure 10.14 – Max UCs @ max WD

10.6.2 ULS JOINT CHECKS

All tubular joints punching shear checks and strength checks are detailed in following SACS excerpt according to ISO19902, ref./6/.

@MIN WD:

* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS		
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
S00	38.640	2.096	335.000	0.705	0.825	38.640	2.096	335.000	0.705	0.825	FX00	LC06
S01	38.640	2.096	335.000	0.699	0.818	38.640	2.096	335.000	0.699	0.818	FX01	LC06
T00	38.640	2.096	335.000	0.611	0.714	38.640	2.096	335.000	0.611	0.714	1100	LC06
T01	38.640	2.096	335.000	0.547	0.640	38.640	2.096	335.000	0.547	0.640	1101	LC06
901	38.640	2.653	335.000	0.468	0.548	38.640	2.653	335.000	0.468	0.548	T01	LC06
900	38.640	2.653	335.000	0.460	0.538	38.640	2.653	335.000	0.460	0.538	T00	LC06

@MAX WD:

* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS		
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
S00	38.640	2.096	335.000	0.649	0.759	38.640	2.096	335.000	0.649	0.759	FX00	LC12
S01	38.640	2.096	335.000	0.643	0.753	38.640	2.096	335.000	0.643	0.753	FX01	LC12
T00	38.640	2.096	335.000	0.586	0.686	38.640	2.096	335.000	0.586	0.686	1100	LC12
T01	38.640	2.096	335.000	0.525	0.614	38.640	2.096	335.000	0.525	0.614	1101	LC12
901	38.640	2.653	335.000	0.456	0.534	38.640	2.653	335.000	0.456	0.534	T01	LC12
900	38.640	2.653	335.000	0.448	0.524	38.640	2.653	335.000	0.448	0.524	T00	LC12

10.6.3 JOINT DEFLECTION

The maximum deflection happens at the bottom joints (El -6m) in cantilever.

@MIN WD:

***************** MAXIMUM JOINT DEFLECTION REPORT *****************

LOAD CASE	*** X-DIRECTION *** JOINT	DEFLECTION CM	*** Y-DIRECTION *** JOINT	DEFLECTION CM	*** Z-DIRECTION *** JOINT	DEFLECTION CM
LC01	1201	4.2628	1100	-0.0128	TS13	-1.1434
LC02	1201	3.2297	1201	0.6443	TS12	-1.1780
LC03	101	-0.9008	1201	1.2079	TS12	-1.0189
LC04	1201	4.9556	1100	-0.0139	TS13	-1.0919
LC05	1201	3.7814	1201	0.7553	TS12	-1.1981
LC06	101	-0.8879	1201	1.4245	TS12	-1.0065

@MAX WD:

LC07	1201	4.2518	1100	-0.0127	TS12	-1.1036
LC08	1201	3.1909	1201	0.6486	TS12	-1.1844
LC09	101	-0.8945	1201	1.2315	TS12	-0.9825
LC10	1201	4.8982	1100	-0.0137	TS12	-1.0627
LC11	1201	3.7394	1201	0.7569	TS12	-1.1589
LC12	101	-0.8834	1201	1.4275	TS12	-0.9716

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11 CF – LIFTING ANALYSIS

11.1 STRUCTURAL MODEL

The software SACS™, ref./33/, is used for the lifting analysis of CF. The structural model of the CF is shown here below and it is based on in-service analysis, ref. to section 10.

CF is assumed to be installed using single hook.

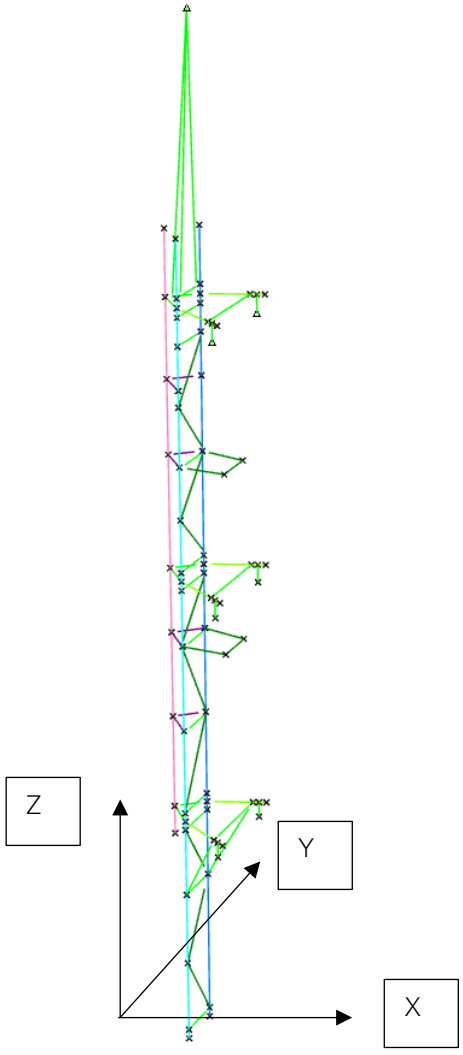


Figure 11.1 – CF SACS structural model

The SACS reference system is in the centre of the caisson water intake pipes, Z is measured from 0.0 LAT.

11.1.1 Boundary Conditions

The CF is vertically suspended from 3 pad-eyes joints located at el. +15.200 LAT with 3 slings to lift point.

Horizontal (isostatic) restrains have been applied to avoid numerical instability.

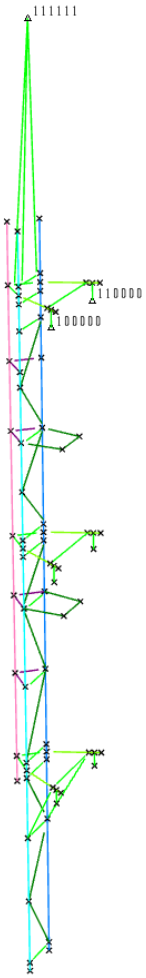


Figure 11.2 - CF fixity

JOINT ID	Fixity	Comment
FX20	110000	Fixed in X and Y
FX21	100000	Fixed in X
HK00	111111	Hook point (CoG nominal position)

Table 11.1 – TP restraints

Trial lift will be carried out in yard for the definition of third sling length and for the verticality check of CF structure. The slings are modeled with elements having axial stiffness only and are considered of Sling type and modelled according to section 16.2.6.11 of Ref. /10/.

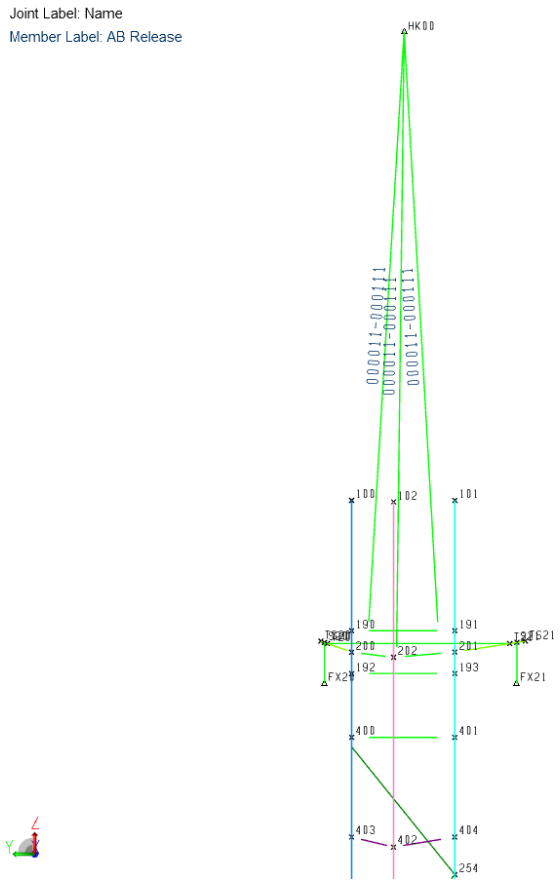


Figure 11.3 - Lifting Analysis – SACS Model – Sling Release

11.2 BASIC LOAD COMBINATIONS

Basic Load cases and load combinations have been combined together to define the final Load Combinations to be used in the lifting global analysis, according to Partial Action Factor as per sec. 9.2.

11.2.1 Lift Coefficients

The following lift factors will be applied following the DNV code, Ref./10/, and in accordance with Structural Design basis, Ref./19/:

Weight contingency factor as Ref./10/, sec. 16.2.2.1	1.10
DAF for the gross weight 300<W<1000 T, Ref./10/, Sect 16.2.5	1+0.25*√(100/SHL) = 1.50

SKL = 1.00 using 3 slings converging in 1 point.

11.2.2 Consequence Factor

Consequence factor		Coefficients		
Description		Lifting points	Other elements	Other elements
Consequence Factors as per Ref./10/, section 16.2.2.1	Lift points, spreader bars	1.30		
	Non-redundant members framing into the lift point.			
	Load transferring redundant members framing directly into the lift point.		1.15	
	All other members of the lifted structure			1.00

Table 11.2 - Lift total factors for ULS lifting analyses

11.3 LOAD COMBINATIONS

The lifting combination 1001 is generated applying the lift coefficients listed in section 11.2.1 to the C000 combination. On top of that, the dead load factor 1.30 as per ISO 19902 and ISO 19901-6 is applied.

Note, structure is all checked considering CF = 1.30.

LOAD COMB	LOAD CASE	notes
	C000	
1001	1.30*(1.10*1.50) = 2.15	SLU combination
2001	1.30*(1.10*1.50)*1.30 = 2.80	With CF

Table 11.3 - Load Combinations

Following excerpt from SACS output provide the Load Combinations resultants, with contingency, DAF, SKL and ULS factor included:

```
                    TECON - BLPH CAISSON FRAME LIFTING

                                        ************* SEASTATE LOAD CASE CENTER REPORT *************
                                                      RELATIVE TO STRUCTURAL ORIGIN
LOAD  LOAD      ********* X - DIRECTION *********    ********* Y - DIRECTION *********    ********* Z - DIRECTION *********
CASE  LABEL     FORCE       X         Y         Z      FORCE       X         Y         Z      FORCE       X         Y         Z
                  (KN)      (M)       (M)       (M)      (KN)      (M)       (M)       (M)      (KN)      (M)       (M)       (M)

1  DEAZ        -0.00                                    0.00                                  -279.44     0.06     -0.00     12.77
2  DEAC        -0.00                                    0.00                                   -55.89     0.06     -0.00     12.77
```

3	C000	-0.00			0.00			-335.33	0.06	-0.00	12.77
4	1001	-0.00			0.00			-720.96	0.06	-0.00	12.77

And also including theCF = 1.30:

		********** SEASTATE LOAD CASE CENTER REPORT **********											
		RELATIVE TO STRUCTURAL ORIGIN											
LOAD CASE	LOAD LABEL	******** X - DIRECTION ********				******** Y - DIRECTION ********				******** Z - DIRECTION ********			
		FORCE (KN)	X (M)	Y (M)	Z (M)	FORCE (KN)	X (M)	Y (M)	Z (M)	FORCE (KN)	X (M)	Y (M)	Z (M)
5	2001	-0.00				0.00				-938.92	0.06	-0.00	12.77

Table 11.4 - Load Combinations center report

11.4 ANALYSIS RESULTS

This section presents the results of the performed Lifting analysis in terms of:

- Joints reactions
- Definition of the lifting slings design loads
- Definition of the lifting padeye design load
- Structural checks of members
- Structural checks of tubular connections.

11.4.1 Joints Reactions

The Hooks joint reactions are detailed in the next tables:

		SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS					
		********** KN **********			********** KN-M **********		
JOINT NUMBER	LOAD CASE	FORCE(X)	FORCE(Y)	FORCE(Z)	MOMENT(X)	MOMENT(Y)	MOMENT(Z)
HK00	C000	-0.163	0.056	335.329	0.000	0.000	0.000
	1001	-0.350	0.120	720.961	0.000	0.000	0.000
	2001	-0.455	0.156	938.925	0.000	0.000	0.000

Table 11.5 – Fixed hooks Joint reactions

And the reactions at the restrained joints (used to delete numerical instability):

		SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS					
		********** KN **********			********** KN-M **********		
JOINT NUMBER	LOAD CASE	FORCE(X)	FORCE(Y)	FORCE(Z)	MOMENT(X)	MOMENT(Y)	MOMENT(Z)
FX20	C000	0.053	-0.056	0.000	0.000	0.000	0.000
	1001	0.113	-0.120	0.000	0.000	0.000	0.000
	2001	0.148	-0.156	0.000	0.000	0.000	0.000
FX21	C000	0.110	0.000	0.000	0.000	0.000	0.000
	1001	0.236	0.000	0.000	0.000	0.000	0.000
	2001	0.308	0.000	0.000	0.000	0.000	0.000

Table 11.6 – Restrains reactions

11.4.2 Lifting Slings Internal Actions

The lifting slings internal actions are presented in the following tables:

- Table 11.7 shows the slings internal actions.
- Table 11.8 summarizes the max forces (including CF = 1.30), to be used for padeye design.

SACS-IV SYSTEM MEMBER FORCES AND MOMENTS

MEMBER NUMBER	MEMBER END	GROUP ID	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
190-HK00	HK00		1001	281.07	-0.00	-0.33	0.00	0.00	0.00
191-HK00	HK00		1001	283.13	0.00	-0.33	0.00	0.00	0.00
202-HK00	HK00		1001	158.17	-0.00	-0.39	0.00	0.00	0.00

Table 11.7 – Slings internal actions (ULS)

MEMBER NUMBER	MEMBER END	GROUP ID	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
190-HK00	HK00		2001	366.05	-0.00	-0.43	0.00	0.00	0.00
191-HK00	HK00		2001	368.72	0.00	-0.43	0.00	0.00	0.00
202-HK00	HK00		2001	205.98	-0.00	-0.51	0.00	0.00	0.00

Table 11.8 – Padeyes design loads

11.4.3 Structural Checks

The results of the performed analysis in terms of members' Unity Check (UC) and Joints' Punching Shear Unity Checks are detailed in the following.

11.4.3.1 Member checks

All members were checked according to ISO 19902, Ref./6/ for tubular elements.

11.4.3.2 Members framing into lifting points: CF = 1.30

Members' code checks are reported in the following and show that the structure can withstand all load combinations, with utilization factors below 1.0.

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

** NO UNITY CHECKS IN THIS GROUP **

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 999.00

** NO UNITY CHECKS IN THIS GROUP **

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Maximum UC per member's group are reported in following SACS excerpt.

```
                                    * * *  M E M B E R   G R O U P   S U M M A R Y  * * *
                                                ISO 19902:2007 / EC3:2005
                                          (EN 1993-1-1:2005/NA NONE)
                                MAX.  DIST                                                                                  EFFECTIVE      CM
GRUP CRITICAL LOAD              UNITY FROM    * APPLIED STRESSES *     *** ALLOWABLE STRESSES ***     CRIT                LENGTHS     * VALUES *
 ID    MEMBER  COND             CHECK END     AXIAL BEND-Y BEND-Z      AXIAL  EULER BEND-Y BEND-Z    COND          KLY    KLZ     Y     Z
                                       M       N/MM2  N/MM2  N/MM2      N/MM2  N/MM2  N/MM2  N/MM2                    M      M

CFA FX21- S21 2001              0.00  0.5       0.1    0.0    0.1     .3E+03 .3E+05 .4E+03 .4E+03   TN+BN         1.00   1.00   0.85   0.85

CFB  T21- 201 2001              0.01  1.0       0.1   -5.1    1.4      319.0 4578.0  437.7  437.7   TN+BN         2.80   1.22   0.85   0.85

CS1  190- 200 2001              0.08  0.0       7.9   16.9   19.7      319.0 2695.7  443.5  443.5   TN+BN         3.60   3.60   0.85   0.85

CS2  191- 201 2001              0.08  0.0       7.9  -16.8   19.8      319.0 2695.7  443.5  443.5   TN+BN         3.60   3.60   0.85   0.85

CS3  202- 402 2001              0.02  2.2       0.9   -0.5    6.8      328.6 4780.8  456.0  456.0   TN+BN         2.16   2.16   0.85   0.85

SL0  191-HK00 2001              0.11  4.1      46.7    7.2    0.0      476.2   32.6  807.7  807.7   TN+BN         6.91   6.91   0.85   0.85

TR1  200- 202 2001              0.07  0.5      -1.0  -28.8    0.8     .3E+03 .4E+05 .5E+03 .5E+03   SHEAR         0.52   0.52   0.85   0.85

TR2 0036-0037 2001              0.02  0.0       0.0   -7.4   -0.0      328.6 1785.7  453.9  453.9   TN+BN         2.40   2.40   0.85   0.85

TR3  403- 402 2001              0.03  0.5       0.1  -12.9    4.3     .3E+03 .2E+05 .5E+03 .5E+03   TN+BN         0.55   0.55   0.85   0.85
```

11.4.3.3 Members not directly framing into lifting points: consequence factor of 1.15

All the elements have been verified with CF 1.30.

11.4.3.4 Other members: consequence factor of 1.00

All the elements have been verified with CF 1.30.

11.4.4 Uls Joint Checks

All tubular joints punching shear checks and strength checks are detailed in following SACS excerpt and provide utilization factors lower than 1.0, according to ISO19902, ref./6/. All the verifications were performed against combination with CF = 1.3.

```
                                        * * J O I N T   C A N   S U M M A R Y * *
                                                (UNITY CHECK ORDER)
      ***************** ORIGINAL ******************   ************ LOAD DESIGN ************   *** STRENGTH ANALYSIS ****
                                          LOAD    STRN                                    LOAD    STRN    BRACE   LOAD
JOINT DIAMETER THICKNESS  YLD STRS        UC      UC     DIAMETER THICKNESS  YLD STRS     UC      UC      JOINT   CASE
        (CM)      (CM)      (N/MM2)                          (CM)      (CM)      (N/MM2)

  191   40.640    3.653    335.000     0.018   0.021      40.640    3.653    335.000    0.018     0.021     190    2001
  190   40.640    3.653    335.000     0.017   0.020      40.640    3.653    335.000    0.017     0.020     191    2001
  192   40.640    3.653    335.000     0.015   0.018      40.640    3.653    335.000    0.015     0.018     193    2001
  193   40.640    3.653    335.000     0.015   0.018      40.640    3.653    335.000    0.015     0.018     192    2001
```

11.5 UPENDING ANALYSIS

Upending of CF is planned to be performed over the deck of cargo barge, rotating around the CF tip and CF lifting padeyes using 2 cranes.
The critical conditions are at 0deg rotation and at 45deg.

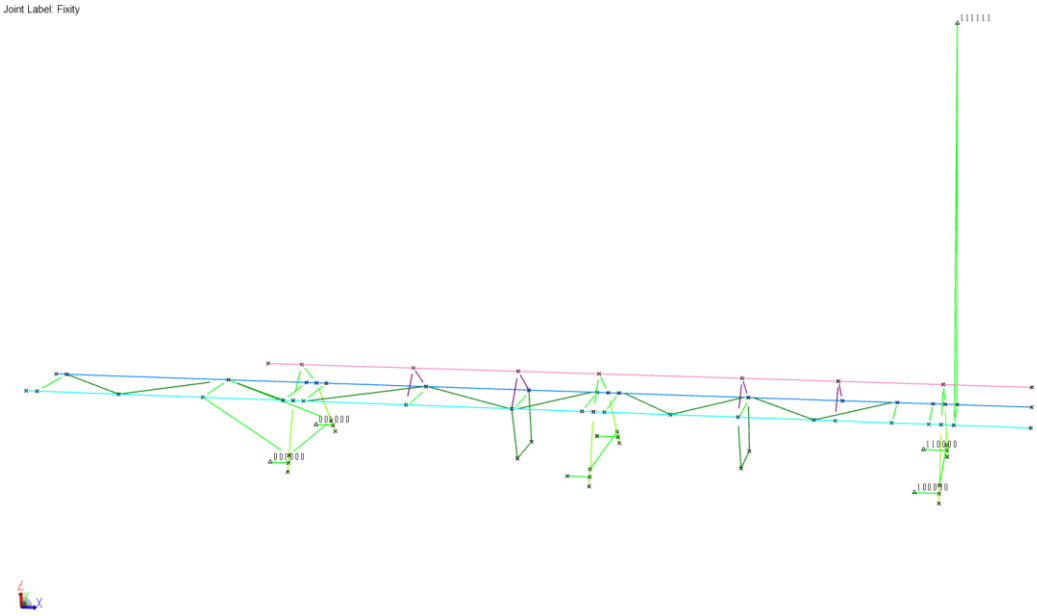


Figure 11.4 – CF at 0deg and fixities

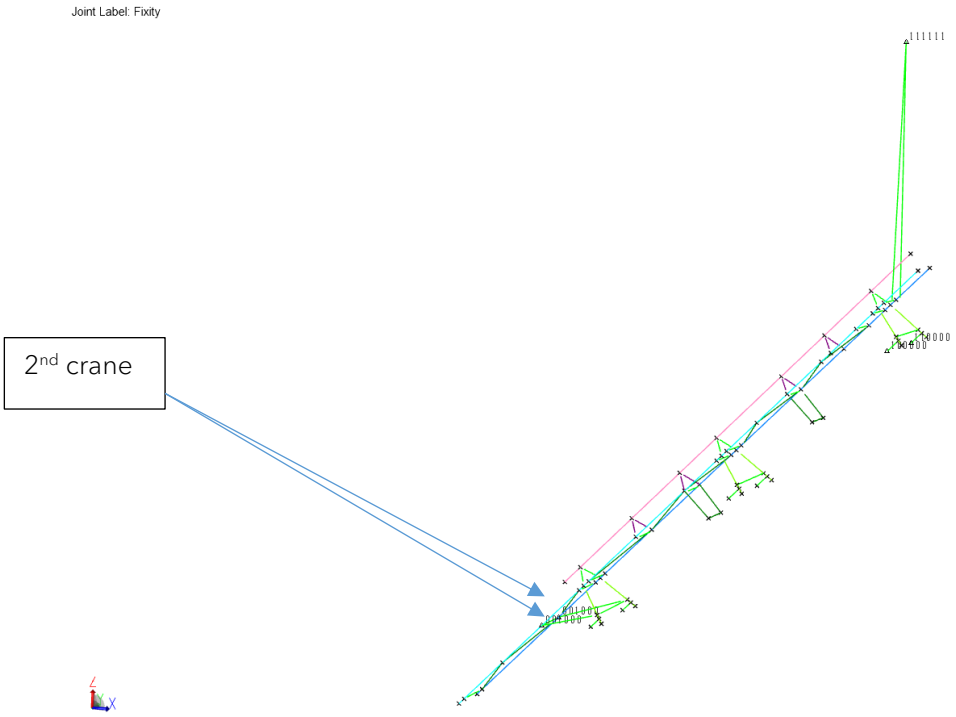


Figure 11.5 – CF at 45deg and fixities

Only two slings were considered (third one is slack) at CF head. Lift coefficient same of section 11.2.1 and load combination taken equal to the ones indicated in section 11.3.

11.5.1 Joints Reactions

The Hooks joint reactions are detailed in the next tables:

@ 0 deg.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
FX00	C000	0.000	0.000	98.217	0.000	0.000	0.000
	1001	0.000	0.000	211.168	0.000	0.000	0.000
	2001	0.000	0.000	275.010	0.000	0.000	0.000
FX01	C000	0.000	0.000	98.579	0.000	0.000	0.000
	1001	0.000	0.000	211.946	0.000	0.000	0.000
	2001	0.000	0.000	276.023	0.000	0.000	0.000
FX20	C000	0.000	-0.001	0.000	0.000	0.000	0.000
	1001	0.000	-0.001	0.000	0.000	0.000	0.000
	2001	0.001	-0.002	0.000	0.000	0.000	0.000
FX21	C000	-0.000	0.000	0.000	0.000	0.000	0.000
	1001	-0.000	0.000	0.000	0.000	0.000	0.000
	2001	-0.001	0.000	0.000	0.000	0.000	0.000
HK00	C000	-0.000	0.001	134.818	0.000	0.000	0.000
	1001	-0.000	0.001	289.859	0.000	0.000	0.000
	2001	-0.000	0.002	377.490	0.000	0.000	0.000

Table 11.9 – Joint reactions

@ 45 deg.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
1100	C000	0.000	0.000	88.054	0.000	0.000	0.000
	1001	0.000	0.000	189.317	0.000	0.000	0.000
	2001	0.000	0.000	246.553	0.000	0.000	0.000
1101	C000	0.000	0.000	88.720	0.000	0.000	0.000
	1001	0.000	0.000	190.749	0.000	0.000	0.000
	2001	0.000	0.000	248.417	0.000	0.000	0.000
FX20	C000	-0.000	-0.003	0.000	0.000	0.000	0.000
	1001	-0.000	-0.007	0.000	0.000	0.000	0.000
	2001	-0.000	-0.009	0.000	0.000	0.000	0.000
FX21	C000	0.000	0.000	0.000	0.000	0.000	0.000
	1001	0.001	0.000	0.000	0.000	0.000	0.000
	2001	0.001	0.000	0.000	0.000	0.000	0.000
HK00	C000	-0.000	0.003	154.915	0.000	0.000	0.000
	1001	-0.000	0.007	333.068	0.000	0.000	0.000
	2001	-0.001	0.009	433.762	0.000	0.000	0.000

Table 11.10 – Joint reactions

11.5.2 Lifting Slings Internal Actions

The lifting slings internal actions are presented in the following tables:

@ 0 deg.

SACS-IV SYSTEM MEMBER FORCES AND MOMENTS

MEMBER NUMBER	MEMBER END	GROUP ID	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
190-HK00	HK00		1001	145.09	0.00	-0.31	0.00	0.00	0.00
191-HK00	HK00		1001	145.11	-0.00	-0.31	0.00	0.00	0.00

Table 11.11 – Slings internal actions (ULS)

@ 45 deg.

SACS-IV SYSTEM MEMBER FORCES AND MOMENTS

MEMBER NUMBER	MEMBER END	GROUP ID	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
190-HK00	HK00		1001	166.66	0.00	-0.31	0.00	0.00	0.00
191-HK00	HK00		1001	166.80	-0.00	-0.31	0.00	0.00	0.00

Table 11.12 – Slings internal actions (ULS)

11.5.3 Structural Checks

The results of the performed analysis in terms of members' Unity Check (UC) and Joints' Punching Shear Unity Checks are detailed in the following.

11.5.3.1 Member checks

All members were checked according to ISO 19902, Ref./6/ for tubular elements and considering Consequence factor = 1.30.

11.5.3.2 Members framing into lifting points: CF = 1.30

Members' code checks are reported in the following and show that the structure can withstand all load combinations, with utilization factors below 1.0.

@ 0 deg.

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

** NO UNITY CHECKS IN THIS GROUP **

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 999.00

** NO UNITY CHECKS IN THIS GROUP **

Maximum UC per member's group are reported in following SACS excerpt.

* * * M E M B E R G R O U P S U M M A R Y * * *
ISO 19902:2007 / EC3:2005
(EN 1993-1-1:2005/NA NONE)

GRUP ID	CRITICAL MEMBER	LOAD COND	MAX. UNITY CHECK	DIST FROM END M	* APPLIED STRESSES * AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	*** ALLOWABLE STRESSES *** AXIAL N/MM2	EULER N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	CRIT COND	EFFECTIVE LENGTHS KLY M	KLZ M	CM * VALUES * Y	Z
CFA	FX01- S01	2001	0.13	0.4	0.0	0.0	-55.3	.3E+03	.4E+05	.4E+03	.4E+03	BEND	0.87	0.87	0.85	0.85
CFB	S01- T01	2001	0.10	0.2	-6.7	-34.3	5.7	283.9	4578.0	437.7	437.7	ACBI	2.80	0.16	0.85	0.85
CS1	800- 900	2001	0.15	0.2	2.6	18.1	-61.8	319.0	713.0	443.5	443.5	TN+BN	7.00	7.00	0.85	0.85
CS2	801- 901	2001	0.16	0.2	2.9	-19.9	-63.9	319.0	713.0	443.5	443.5	TN+BN	7.00	7.00	0.85	0.85
CS3	602- 652	2001	0.20	0.0	-29.7	0.8	46.5	292.4	6576.0	456.0	456.0	ACBI	1.84	1.84	0.85	0.85
TR1	200- 202	2001	0.26	0.0	-3.7	112.5	10.8	.3E+03	.4E+05	.5E+03	.5E+03	ACBI	0.52	0.52	0.85	0.85
TR2	801- 700	2001	0.06	0.0	1.2	2.0	-27.7	328.6	1467.4	453.9	453.9	TN+BN	2.65	2.65	0.85	0.85
TR3	700- 702	2001	0.51	0.0	-2.6	-227.6	-1.6	.3E+03	.2E+05	.5E+03	.5E+03	ACBI	0.55	0.55	0.85	0.85

<u>@ 45 deg.</u>

* * * M E M B E R G R O U P S U M M A R Y * * *
ISO 19902:2007 / EC3:2005
(EN 1993-1-1:2005/NA NONE)

GRUP ID	CRITICAL MEMBER	LOAD COND	MAX. UNITY CHECK	DIST FROM END M	* APPLIED STRESSES * AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	*** ALLOWABLE STRESSES *** AXIAL N/MM2	EULER N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	CRIT COND	EFFECTIVE LENGTHS KLY M	KLZ M	CM * VALUES * Y	Z
CFA	FX21- S21	2001	0.00	0.5	0.1	0.0	0.3	.3E+03	.3E+05	.4E+03	.4E+03	SHEAR	1.00	1.00	0.85	0.85
CFB	901- T01	2001	0.06	0.0	-0.7	-26.8	1.0	283.9	4578.0	437.7	437.7	ACBI	2.80	1.22	0.85	0.85
CS1	550- 600	2001	0.13	0.2	12.7	-1.1	40.7	319.0	621.1	443.5	443.5	TN+BN	7.50	7.50	0.85	0.85
CS2	551- 601	2001	0.13	0.2	12.4	3.5	38.4	319.0	621.1	443.5	443.5	TN+BN	7.50	7.50	0.85	0.85
CS3	702- 902	2001	0.25	2.7	-26.3	-1.2	-75.0	292.4	3036.0	456.0	456.0	ACBI	2.71	2.71	0.85	0.85
TR1	901- 902	2001	0.45	0.0	-4.5	-200.4	-2.8	.3E+03	.4E+05	.5E+03	.5E+03	ACBI	0.52	0.52	0.85	0.85
TR2	0035- 700	2001	0.05	0.0	4.4	-4.9	13.9	328.6	1470.3	453.9	453.9	TN+BN	2.64	2.64	0.85	0.85
TR3	700- 702	2001	0.40	0.5	4.5	176.3	5.7	.3E+03	.2E+05	.5E+03	.5E+03	TN+BN	0.55	0.55	0.85	0.85

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12 CF – TRANSPORTATION ANALYSIS

The CF is to be transported on 300 ft Barge and loaded out by yard crane on barge STB side aligned with the barge longitudinal axis.

The analysis in transportation conditions include permanent and transient actions as accelerations from barge motions, according to design data.

The transportation analysis is performed considering a two steps analysis with different restraint conditions, in order to ensure that the whole mass is reacted by the grillages only and the dynamic loads by grillages and by sea-fastening suitably designed for horizontal loads.

Partial action factors for pre-service analyses as per Table 9.4 will be considered and sixteen (16) basic combinations of inertia loads are therefore defined for each design situation (± Pitch ± Heave ± Wind and ± R ± H ± Wind). Wind action is negligible considering the location of CF on deck. The inertia forces are calculated considering the accelerations according to DNV criteria, Ref./10/.

Transportation analysis is performed in accordance with DNV-ST-N001, Ref./10/.

12.1 DESIGN DATA

Design loads considered for the transportation include wind loads and transient actions from barge motions as per data reported in the following from Design Basis, Ref./19/.

12.1.1 Wind Data

Ref section 7.7.

12.1.2 Motion Criteria

Motion criteria are defined according to DNV for unrestricted world-wide tows, ref. /10/, for 300ft standard barge and to Design Basis, ref. /19/.

Item	Amplitude	Period
Roll	20 degrees	10 seconds
Pitch	12.5 degrees	10 seconds
Heave	0.20 g	

Table 12.1 - DNV Default Motion Criteria

12.2 TRANSPORTATION ARRANGEMENT

The CF is to be transported on 300ft cargo barge supported by barge deck using grillage beams. The position of CF is shown in figure 12.1.

The 300ft barge (P-MAK) is characterized by following main dimensions:

- Length: 91.5m
- Breadth: 27.40m
- Side height: 6.10m

The centre of rotation is assumed to be at the centre of the barge at water level.

The barge motion axes are defined as follows:

- the pitch axis (barge transverse axis) corresponds to the model Y-axis;
- the roll axis (barge longitudinal axis) corresponds to the model X-axis;

An overview of the transportation layout is shown in the following figure from Ref./28/.

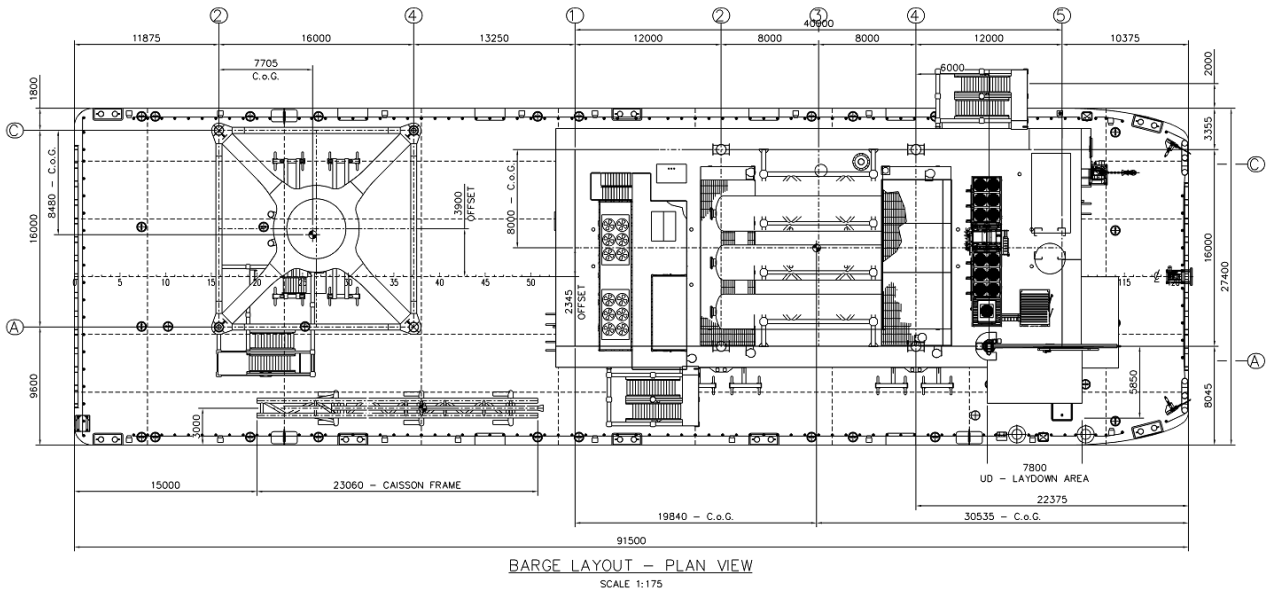


Figure 12.1 – Transportation Arrangement – Side and Plan views

12.2.1 Coordinate System

The model geometry is referred to a right-handed orthogonal Cartesian coordinate system with the origin located at CF brine discharge tip.

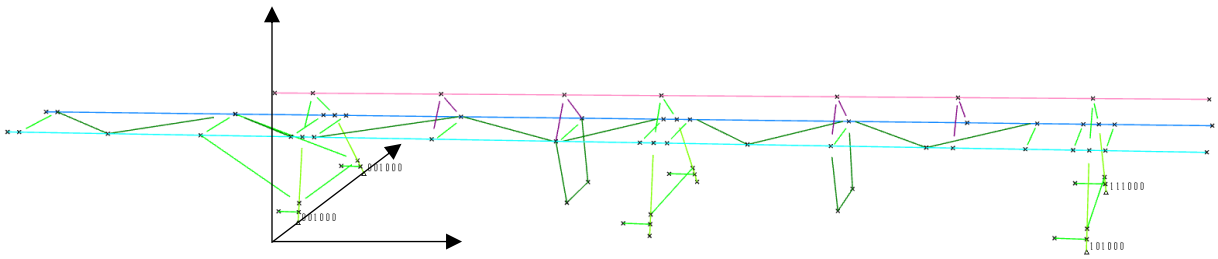


Figure 12.2 – CF Structural Model – Ref. system

12.3 ANALYSIS PROCEDURE

The calculation procedure adopted for transportation analysis is aimed at obtaining the correct distribution on supports of static (dead weight) and transportation loads (inertia forces due to barge motion) properly accounting for grillage and lateral restraints loading sequence.

The distribution of dead weight at the cargo set-up on barge is calculated excluding the lateral restrain contributions of grillage and sea fastenings that are activated in a second phase to resist the transportation transient loads only.

The above loading sequence is therefore analysed by two separate computer runs, with different constraint conditions and applied loads. The actual loads distribution is obtained by suitably combining the two analyses by means of the Combine module of SACS. To ensure the full compatibility and the superposition of the two analyses, the processed models are identical, only loads and constraints are different.

In accordance with the above-described procedure, the transportation analysis is performed through the following three steps.

STEP 1

A first analysis is performed considering the CF supported in correspondence of the lower grillage. Permanent and variable loads are applied to model.

1 digit means fixed, 0 means free.

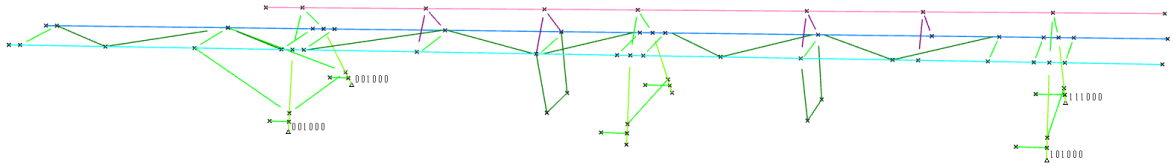


Figure 12.3 – STEP 1 - Restraints scheme

STEP 2

In this analysis the horizontal restraint provided by grillage and sea-fastening are made effective as per following restraint configuration: Only transient loads are considered in Step 2 analysis.

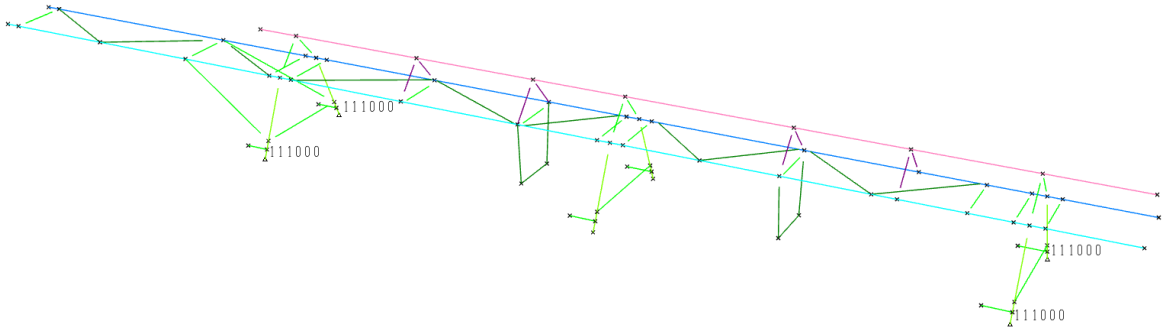


Figure 12.4 - STEP 2 - Restraints scheme

STEP 3

The two analyses above described are superimposed by SACS Combine module. Permanent and variable loads from analysis step 1 and transient loads from analysis step 2 are included and suitably combined. Base reactions and resulting internal forces and stress in structural members are evaluated and processed for the structural checks of the structures.

12.4 LOAD COMBINATIONS

Basic Load cases and load combination have been combined together to define the design Load Combinations to be used in the transportation analysis, according to Partial Action Factor as per sec.9.3.2.

A total of 24 load combinations, according to ISO 19902 Transportation Design Situations, have been defined as per following tables.

TRANSPORTATION LOAD COMBINATIONS - DESIGN SITUATION 1									
LOAD COMB.	LOAD CASES								
	C000	+P+H	+P-H	-P+H	-P-H	+R+H	+R-H	-R+H	-R-H
C101	1.30	1.00							
C102	1.30		1.00						
C103	1.30			1.00					
C104	1.30				1.00				
C105	1.30					1.00			
C106	1.30						1.00		
C107	1.30							1.00	
C108	1.30								1.00

Table 12-2- Transportation Load Combinations – Design situation 1

TRANSPORTATION LOAD COMBINATIONS - DESIGN SITUATION 2									
LOAD COMB.	LOAD CASES								
	C000	+P+H	+P-H	-P+H	-P-H	+R+H	+R-H	-R+H	-R-H
C201	1.10	1.35							
C202	1.10		1.35						
C203	1.10			1.35					
C204	1.10				1.35				
C205	1.10					1.35			
C206	1.10						1.35		
C207	1.10							1.35	
C208	1.10								1.35

Table 12-3 - Transportation Load Combinations – Design situation 2

TRANSPORTATION LOAD COMBINATIONS - DESIGN SITUATION 3									
LOAD COMB.	LOAD CASES								
	C000	+P+H	+P-H	-P+H	-P-H	+R+H	+R-H	-R+H	-R-H
C301	0.90	1.35							
C302	0.90		1.35						
C303	0.90			1.35					
C304	0.90				1.35				
C305	0.90					1.35			
C306	0.90						1.35		
C307	0.90							1.35	
C308	0.90								1.35

Table 12-4 - Transportation Load Combinations – Design situation 3

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12.5 ANALYSIS RESULTS

This section presents the results of the performed Transportation analysis in terms of:

- Reaction forces at barge deck and internal forces of dummy elements at TP-Upper grillage connections.
- Structural checks of structural members and plates;
- Structural checks of tubular connections.

12.5.1 Reaction Forces

Base reactions at supporting points (grillages) are reported in the following paragraphs for the two preliminary analyses (STEP 1 and 2) and final Transportation configuration (STEP 3).

12.5.1.1 Transportation Conditions - base reaction forces at barge deck

Maximum and minimum base reaction forces in transportation phase are reported in the following tables. Reactions are read in global reference system. Maximum and minimum reactions' envelope is reported in following table.

JOINT	Rx [kN]				Ry [kN]				Rz [kN]			
	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND
T02	0	DEAZ	0	DEAZ	0	DEAZ	0	DEAZ	100	C000	17	DEAC
T03	0	DEAZ	0	DEAZ	0	DEAZ	0	DEAZ	100	C000	17	DEAC
TS20	0	DEAZ	0	DEAZ	0	DEAZ	0	DEAZ	60	C000	10	DEAC
TS21	0	DEAZ	0	DEAZ	0	DEAZ	0	DEAZ	60	C000	10	DEAC

Table 12-5 – base reaction forces in Transportation Conditions – STEP 1 Permanent Loads – Summary Envelope

Base reaction forces for all load combinations are reported in following SACS excerpt with reference to STEP 1 analysis.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X)	FORCE(Y)	FORCE(Z)	MOMENT(X)	MOMENT(Y)	MOMENT(Z)
		********** KN **********			********** KN-M **********		
T02	DEAZ	0.000	0.000	83.488	0.000	0.000	0.000
	DEAC	0.000	0.000	16.698	0.000	0.000	0.000
	C000	0.000	0.000	100.186	0.000	0.000	0.000
T03	DEAZ	0.000	0.000	83.711	0.000	0.000	0.000
	DEAC	0.000	0.000	16.742	0.000	0.000	0.000
	C000	0.000	0.000	100.454	0.000	0.000	0.000
TS20	DEAZ	0.000	0.000	49.807	0.000	0.000	0.000
	DEAC	0.000	0.000	9.961	0.000	0.000	0.000
	C000	0.000	0.000	59.769	0.000	0.000	0.000
TS21	DEAZ	-0.000	0.000	49.870	0.000	0.000	0.000
	DEAC	-0.000	0.000	9.974	0.000	0.000	0.000
	C000	-0.000	0.000	59.843	0.000	0.000	0.000

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12.5.1.2 Reaction Forces due to Transportation Transient Loads only (STEP 2)

Maximum and minimum reactions' envelope is reported in following table.

JOINT	Rx [kN]				Ry [kN]				Rz [kN]			
	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND
T02	27	-P+H	-22	+P+H	38	+R-H	-46	-R+H	100	CHCK	-47	+R-H
T03	28	-P+H	-22	+P+H	60	+R+H	-52	-R-H	100	CHCK	-78	-R-H
TS20	21	-P-H	-27	+P+H	24	+R-H	-29	-R+H	60	CHCK	-30	+R-H
TS21	21	-P-H	-27	+P+H	37	+R+H	-32	-R-H	60	CHCK	-48	-R-H

Table 12-6 – base reaction forces in Transportation Conditions – STEP 2 Transient Loads – Summary Envelope

Base reaction forces at barge deck for all load combinations are reported in following SACS excerpt with reference to STEP 2 analysis.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
T02	+P+H	-21.633	3.716	-7.637	0.000	0.000	0.000
	+P-H	-21.003	20.789	-45.414	0.000	0.000	0.000
	+R+H	7.227	34.731	-24.585	0.000	0.000	0.000
	+R-H	0.162	38.319	-47.439	0.000	0.000	0.000
	-P+H	27.444	-19.328	42.002	0.000	0.000	0.000
	-P-H	13.586	-0.863	1.554	0.000	0.000	0.000
	-R+H	-2.904	-46.344	50.150	0.000	0.000	0.000
	-R-H	-8.570	-15.729	-2.287	0.000	0.000	0.000
	CHCK	16.934	-45.500	100.156	0.000	0.000	0.000
T03	+P+H	-21.705	-3.708	-7.660	0.000	0.000	0.000
	+P-H	-21.313	-20.816	-45.563	0.000	0.000	0.000
	+R+H	2.566	59.565	80.368	0.000	0.000	0.000
	+R-H	-3.417	29.056	27.805	0.000	0.000	0.000
	-P+H	27.759	19.350	42.138	0.000	0.000	0.000
	-P-H	13.588	0.851	1.558	0.000	0.000	0.000
	-R+H	1.936	-47.928	-54.717	0.000	0.000	0.000
	-R-H	-5.340	-51.690	-77.696	0.000	0.000	0.000
	CHCK	17.639	45.589	100.486	0.000	0.000	0.000
TS20	+P+H	-26.889	-4.232	9.177	0.000	0.000	0.000
	+P-H	-13.472	6.863	-15.511	0.000	0.000	0.000
	+R+H	3.991	22.255	-16.341	0.000	0.000	0.000
	+R-H	8.041	23.858	-29.555	0.000	0.000	0.000
	-P+H	20.906	-4.961	11.341	0.000	0.000	0.000
	-P-H	21.109	4.870	-10.677	0.000	0.000	0.000
	-R+H	-8.443	-29.094	31.606	0.000	0.000	0.000
	-R-H	0.618	-10.555	-0.136	0.000	0.000	0.000
	CHCK	-17.440	-26.793	59.801	0.000	0.000	0.000
TS21	+P+H	-26.829	4.224	9.182	0.000	0.000	0.000
	+P-H	-13.543	-6.836	-15.514	0.000	0.000	0.000
	+R+H	-13.785	37.095	49.592	0.000	0.000	0.000
	+R-H	-4.786	18.599	17.845	0.000	0.000	0.000
	-P+H	20.951	4.939	11.341	0.000	0.000	0.000
	-P-H	21.045	-4.858	-10.679	0.000	0.000	0.000
	-R+H	9.411	-30.278	-34.324	0.000	0.000	0.000
	-R-H	13.293	-31.857	-47.541	0.000	0.000	0.000
	CHCK	-17.133	26.704	59.812	0.000	0.000	0.000

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12.5.1.3 Reaction Forces in Transportation Conditions (STEP 3)

Maximum and minimum reactions' envelope is reported in following table.

JOINT	Rx [kN]				Ry [kN]				Rz [kN]			
	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND	MAX	LCOND	MIN	LCOND
T02	37	C203	-29	C201	52	C206	-63	C207	180	C107	26	C306
T03	37	C203	-29	C201	80	C205	-70	C208	219	C205	-14	C308
TS20	28	C204	-36	C201	32	C206	-39	C207	109	C107	14	C306
TS21	28	C204	-36	C201	50	C205	-43	C208	133	C205	-10	C308

Table 12-7 – base reaction forces in Transportation Conditions – STEP 3 – Summary Envelope

Base reaction forces at barge deck for all load combinations are reported in following SACS excerpt with reference to STEP 3 analysis, final transportation configuration.

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
T02	C101	-21.633	3.716	122.605	0.000	0.000	0.000
	C102	-21.003	20.789	84.828	0.000	0.000	0.000
	C103	27.444	-19.328	172.244	0.000	0.000	0.000
	C104	13.586	-0.863	131.796	0.000	0.000	0.000
	C105	7.227	34.731	105.657	0.000	0.000	0.000
	C106	0.162	38.319	82.803	0.000	0.000	0.000
	C107	-2.904	-46.344	180.392	0.000	0.000	0.000
	C108	-8.570	-15.729	127.955	0.000	0.000	0.000
	C201	-29.204	5.017	99.894	0.000	0.000	0.000
	C202	-28.354	28.065	48.896	0.000	0.000	0.000
	C203	37.050	-26.093	166.907	0.000	0.000	0.000
	C204	18.342	-1.165	112.302	0.000	0.000	0.000
	C205	9.757	46.886	77.015	0.000	0.000	0.000
	C206	0.219	51.731	46.162	0.000	0.000	0.000
	C207	-3.920	-62.565	177.907	0.000	0.000	0.000
	C208	-11.570	-21.234	107.117	0.000	0.000	0.000
	C301	-29.204	5.017	79.857	0.000	0.000	0.000
	C302	-28.354	28.065	28.859	0.000	0.000	0.000
	C303	37.050	-26.093	146.870	0.000	0.000	0.000
	C304	18.342	-1.165	92.265	0.000	0.000	0.000
	C305	9.757	46.886	56.977	0.000	0.000	0.000
	C306	0.219	51.731	26.125	0.000	0.000	0.000
	C307	-3.920	-62.565	157.870	0.000	0.000	0.000
	C308	-11.570	-21.234	87.080	0.000	0.000	0.000
T03	C101	-21.705	-3.708	122.930	0.000	0.000	0.000
	C102	-21.313	-20.816	85.027	0.000	0.000	0.000
	C103	27.759	19.350	172.728	0.000	0.000	0.000
	C104	13.588	0.851	132.148	0.000	0.000	0.000
	C105	2.566	59.565	210.958	0.000	0.000	0.000
	C106	-3.417	29.056	158.395	0.000	0.000	0.000
	C107	1.936	-47.928	75.873	0.000	0.000	0.000
	C108	-5.340	-51.690	52.894	0.000	0.000	0.000
	C201	-29.302	-5.006	100.158	0.000	0.000	0.000
	C202	-28.773	-28.101	48.989	0.000	0.000	0.000
	C203	37.475	26.123	167.386	0.000	0.000	0.000
	C204	18.344	1.149	112.603	0.000	0.000	0.000
	C205	3.465	80.413	218.996	0.000	0.000	0.000
	C206	-4.613	39.225	148.036	0.000	0.000	0.000
	C207	2.614	-64.702	36.631	0.000	0.000	0.000
	C208	-7.209	-69.782	5.610	0.000	0.000	0.000
	C301	-29.302	-5.006	80.067	0.000	0.000	0.000
	C302	-28.773	-28.101	28.898	0.000	0.000	0.000
	C303	37.475	26.123	147.295	0.000	0.000	0.000
	C304	18.344	1.149	92.512	0.000	0.000	0.000
	C305	3.465	80.413	198.905	0.000	0.000	0.000
	C306	-4.613	39.225	127.946	0.000	0.000	0.000

	C307	2.614	-64.702	16.540	0.000	0.000	0.000
	C308	-7.209	-69.782	-14.481	0.000	0.000	0.000
TS20	C101	-26.889	-4.232	86.877	0.000	0.000	0.000
	C102	-13.472	6.863	62.188	0.000	0.000	0.000
	C103	20.906	-4.961	89.041	0.000	0.000	0.000
	C104	21.109	4.870	67.023	0.000	0.000	0.000
	C105	3.991	22.255	61.358	0.000	0.000	0.000
	C106	8.041	23.858	48.145	0.000	0.000	0.000
	C107	-8.443	-29.094	109.305	0.000	0.000	0.000
	C108	0.618	-10.555	77.564	0.000	0.000	0.000
	C201	-36.300	-5.713	78.135	0.000	0.000	0.000
	C202	-18.187	9.265	44.805	0.000	0.000	0.000
	C203	28.223	-6.698	81.057	0.000	0.000	0.000
	C204	28.497	6.575	51.332	0.000	0.000	0.000
	C205	5.388	30.044	43.685	0.000	0.000	0.000
	C206	10.855	32.208	25.847	0.000	0.000	0.000
	C207	-11.398	-39.276	108.414	0.000	0.000	0.000
	C208	0.834	-14.250	65.562	0.000	0.000	0.000
	C301	-36.300	-5.713	66.181	0.000	0.000	0.000
	C302	-18.187	9.265	32.851	0.000	0.000	0.000
	C303	28.223	-6.698	69.103	0.000	0.000	0.000
	C304	28.497	6.575	39.378	0.000	0.000	0.000
	C305	5.388	30.044	31.731	0.000	0.000	0.000
	C306	10.855	32.208	13.893	0.000	0.000	0.000
	C307	-11.398	-39.276	96.460	0.000	0.000	0.000
	C308	0.834	-14.250	53.609	0.000	0.000	0.000
TS21	C101	-26.829	4.224	86.978	0.000	0.000	0.000
	C102	-13.543	-6.836	62.282	0.000	0.000	0.000
	C103	20.951	4.939	89.137	0.000	0.000	0.000
	C104	21.045	-4.858	67.117	0.000	0.000	0.000
	C105	-13.785	37.095	127.388	0.000	0.000	0.000
	C106	-4.786	18.599	95.642	0.000	0.000	0.000
	C107	9.411	-30.278	43.472	0.000	0.000	0.000
	C108	13.293	-31.857	30.255	0.000	0.000	0.000
	C201	-36.219	5.702	78.223	0.000	0.000	0.000
	C202	-18.282	-9.229	44.884	0.000	0.000	0.000
	C203	28.284	6.668	81.138	0.000	0.000	0.000
	C204	28.411	-6.559	51.411	0.000	0.000	0.000
	C205	-18.609	50.079	132.777	0.000	0.000	0.000
	C206	-6.461	25.108	89.919	0.000	0.000	0.000
	C207	12.705	-40.876	19.490	0.000	0.000	0.000
	C208	17.945	-43.007	1.647	0.000	0.000	0.000
	C301	-36.219	5.702	66.255	0.000	0.000	0.000
	C302	-18.282	-9.229	32.915	0.000	0.000	0.000
	C303	28.284	6.668	69.169	0.000	0.000	0.000
	C304	28.411	-6.559	39.442	0.000	0.000	0.000
	C305	-18.609	50.079	120.808	0.000	0.000	0.000
	C306	-6.461	25.108	77.950	0.000	0.000	0.000
	C307	12.705	-40.876	7.522	0.000	0.000	0.000
	C308	17.945	-43.007	-10.322	0.000	0.000	0.000

Table 12-8 - Reaction Forces in Transportation Conditions

12.5.2 Structural Checks

The results of the performed analysis in terms of structural elements' Unity Check (UC) and Joints' Punching Shear Unity Checks are detailed in the following.

12.5.2.1 Member Checks

All members were checked according to ISO 19902, Ref./6/. Members' code checks are reported in the following and show that the structure can withstand Transportation load combinations, with utilization factors below 1.0.

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

```
                    ** NO UNITY CHECKS IN THIS GROUP **

                      SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                  GROUP III - UNITY CHECKS GREATER THAN    0.90 AND LESS THAN  999.00

                    ** NO UNITY CHECKS IN THIS GROUP **
```

Maximum UCs per member's group are reported in following SACS excerpt.

```
                          * * *  M E M B E R   G R O U P   S U M M A R Y  * * *

                                    ISO 19902:2020 / EC3:2005

                                                                                                                                EFFECTIVE      CM
GRUP CRITICAL LOAD  MAX.  DIST    * APPLIED STRESSES *     *** ALLOWABLE STRESSES ***    CRIT      LENGTHS     * VALUES *
 ID   MEMBER  COND UNITY FROM     AXIAL BEND-Y BEND-Z     AXIAL  EULER BEND-Y BEND-Z    COND      KLY    KLZ     Y      Z
       CHECK  END                                                                                  M      M
                  M      N/MM2   N/MM2   N/MM2     N/MM2   N/MM2   N/MM2   N/MM2

CFA FX21- S21 C105  0.00   0.5      0.0    -0.1     0.2    .3E+03 .3E+05 .4E+03 .4E+03   SHEAR     1.00   1.00   0.85   0.85
CFB  901- T01 C203  0.10   0.0     -3.6    44.5    -1.2     283.9 4578.0  437.7  437.7   ACBI      2.80   1.22   0.85   0.85
CS1  800- 900 C203  0.13   0.2     -1.3     8.5   -55.5     283.9  713.0  443.5  443.5   ACBI      7.00   7.00   0.85   0.85
CS2  801- 901 C203  0.13   0.2     -1.3    -8.7   -57.6     283.9  713.0  443.5  443.5   ACBI      7.00   7.00   0.85   0.85
CS3  602- 652 C103  0.09   0.0    -10.6     0.3    29.7     288.1 6576.0  456.0  456.0   ACBI      1.84   1.84   0.85   0.85
TR1  201- 202 C203  0.13   0.0     -2.5    58.0     0.3    .3E+03 .4E+05 .5E+03 .5E+03   ACBI      0.52   0.52   0.85   0.85
TR2  801- 700 C205  0.06   0.0     -6.9     2.0   -20.5     273.3 1467.4  453.9  453.9   ACBI      2.65   2.65   0.85   0.85
TR3  700- 702 C103  0.29   0.0     -3.7  -131.7     1.5    .3E+03 .2E+05 .5E+03 .5E+03   ACBI      0.55   0.55   0.85   0.85
```

12.5.2.2 ULS Joint Checks

All tubular joints punching shear checks and strength checks are detailed in following SACS excerpt and provide utilization factors lower than 1.0, according to ISO19902, ref./6/.

```
                                  * * J O I N T   C A N   S U M M A R Y * *

                                          (UNITY CHECK ORDER)

      ***************** ORIGINAL ******************   ************ LOAD DESIGN ***********   *** STRENGTH ANALYSIS ****

                                          LOAD    STRN                                    LOAD    STRN    BRACE   LOAD
JOINT DIAMETER THICKNESS  YLD STRS        UC      UC      DIAMETER THICKNESS  YLD STRS    UC      UC      JOINT   CASE
        (CM)      (CM)      (N/MM2)                         (CM)      (CM)      (N/MM2)

  901  40.640    3.653    335.000    0.039   0.046     40.640    3.653    335.000    0.039     0.046    T01    C205
  T00  40.640    3.096    335.000    0.036   0.042     40.640    3.096    335.000    0.036     0.042    1100   C103
  T01  40.640    3.096    335.000    0.035   0.041     40.640    3.096    335.000    0.035     0.041    1101   C103
  900  40.640    3.653    335.000    0.034   0.040     40.640    3.653    335.000    0.034     0.040    T00    C207
```

APPENDIX A – MEMBER GROUP AND SECTION PROPERTIES

****** SEASTATE INITIAL GROUP DESCRIPTION ******

GROUP LABEL	SECTION LABEL	***** AREAS ***** CONST. (CM**2)	DISPL. (CM)	** DIAMETERS ** Y (CM)	Z (CM)	* SECTION * TYPE	* MATL. * LENGTH (TONNE/M**3)	DENSITY	* JOINT * THICK (M.)	FLOOD	** DRAG AND INERTIA COEFFICIENTS ** CDY	CDZ	CMY	CMZ	CDT	CMT
CFA		285.67	989.80	35.50	35.50	TUB	7.849	0.000	NO	1.30	1.30	1.60	1.60	0.00	0.00	
CFB		365.17	1297.17	40.64	40.64	TUB	7.849	0.000	NO	1.30	1.30	1.60	1.60	0.00	0.00	
CS1		424.47	1297.17	40.64	40.64	TUB	7.849	0.000	YES	1.30	1.30	1.60	1.60	0.00	0.00	
CS2		424.47	1297.17	40.64	40.64	TUB	7.849	0.000	YES	1.30	1.30	1.60	1.60	0.00	0.00	
CS3		265.16	823.97	32.39	32.39	TUB	7.849	0.000	YES	1.30	1.30	1.60	1.60	0.00	0.00	
TR1		141.75	377.03	21.91	21.91	TUB	7.849	0.000	NO	1.30	1.30	1.60	1.60	0.00	0.00	
TR2		115.21	377.03	21.91	21.91	TUB	7.849	0.000	NO	1.30	1.30	1.60	1.60	0.00	0.00	
TR3		69.05	222.46	16.83	16.83	TUB	7.849	0.000	NO	1.30	1.30	1.60	1.60	0.00	0.00	

TUBULAR MEMBER PROPERTIES

JOINT GRP	M/S	WALL THICK M	OUTSIDE THICK CM	E DIAM. CM	G 1000 KN/CM2	AXIAL 1000 KN/CM2	AREA CM**2	***** MOMENTS OF INERTIA **** X-X CM**4	Y-Y CM**4	Z-Z CM**4	YIELD STRESS KN/CM2	KY	KZ	SHEAR AREA CM**2	RING SPACE M	SECT TAPER LENG M
CFA	1	0.00	2.779	35.50	20.5	7.7	285.67	77016.	38508.	38508.	33.5	1.0	1.0	142.84	0.00	0.00
CFB	1	0.00	3.096	40.64	20.5	7.7	365.17	0.12956E+06	64778.	64778.	33.5	1.0	1.0	182.58	0.00	0.00
CS1	1	0.00	3.653	40.64	20.5	7.7	424.47	0.14659E+06	73295.	73295.	33.5	1.0	1.0	212.24	0.00	0.00
CS2	1	0.00	3.653	40.64	20.5	7.7	424.47	0.14659E+06	73295.	73295.	33.5	1.0	1.0	212.24	0.00	0.00
CS3	1	0.00	2.858	32.39	20.5	7.7	265.16	58356.	29178.	29178.	34.5	1.0	1.0	132.58	0.00	0.00
TR1	1	0.00	2.222	21.91	20.5	7.7	137.43	13488.	6743.9	6743.9	34.5	1.0	1.0	68.72	0.00	0.00
TR2	1	0.00	1.826	21.91	20.5	7.7	115.21	11714.	5857.2	5857.2	34.5	1.0	1.0	57.61	0.00	0.00
TR3	1	0.00	1.427	16.83	20.5	7.7	69.053	4130.9	2065.4	2065.4	34.5	1.0	1.0	34.53	0.00	0.00

****** SEASTATE GLOBAL CORROSION ZONE DESCRIPTION ******

ZONES LISTED ARE IN THE GLOBAL Z DIRECTION

**** ZONE ***** BOTTOM (M)	TOP	VARY TYPE	CORROSION TYPE	*** CORROSION *** BOTTOM (CM)	TOP	*** THICKNESS RANGE *** MIN (CM)	MAX	MIN CORR THICK	**** MEMBER **** LOADING DIMENSIONS
-2.800	5.000	CONSTANT	FIXED	1.000	1.000	1.0	100.0	1.000	CORRODED

****** SEASTATE GLOBAL MARINE GROWTH ZONE DESCRIPTION ******

MUDLINE ELEVATION = -20.00(M)

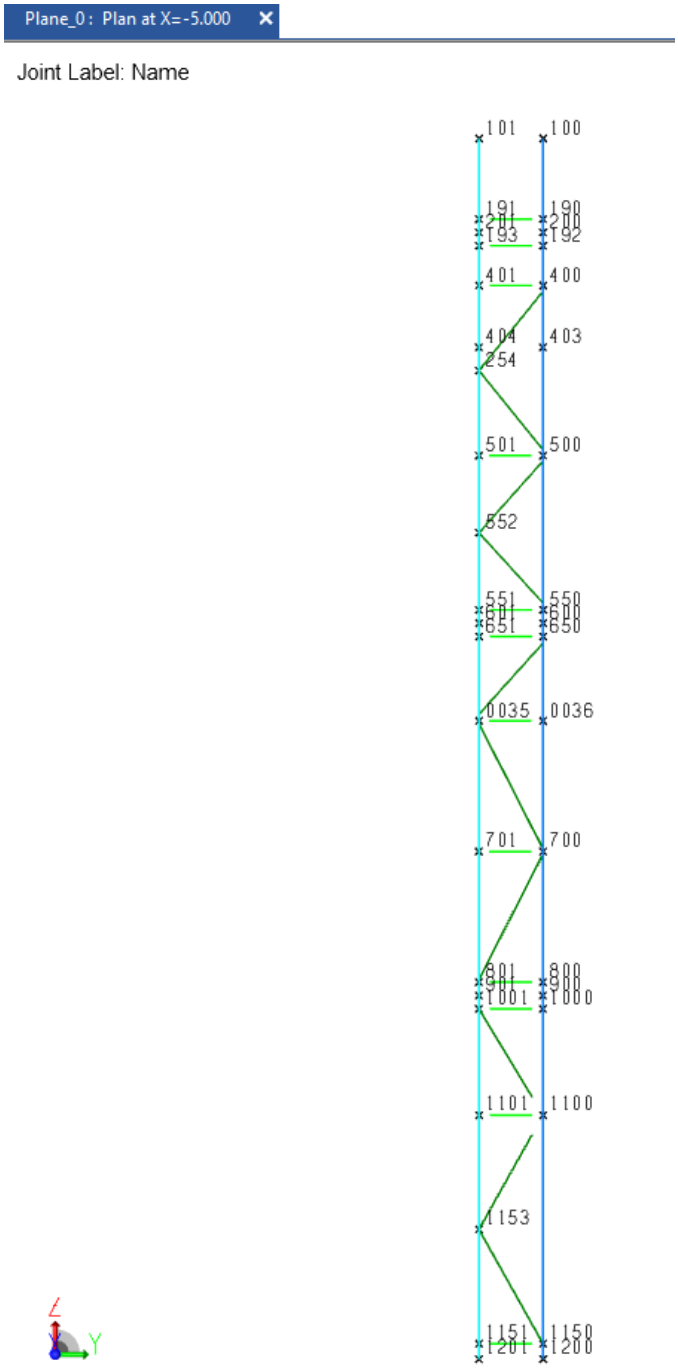
***** M A R I N E G R O W T H *****

ZONE ABOVE MUDLINE FROM (M)	TO	THICKNESS (CM)	DENSITY TON/CUM	CD	CM	ROUGHNESS HEIGHT (CM)	TYPE
0.00	14.0	5.000	1.33	0.000	0.000	0.000	CONSTANT
14.00	16.0	6.667	1.33	0.000	0.000	0.000	CONSTANT
16.00	18.0	10.000	1.33	0.000	0.000	0.000	CONSTANT
18.00	20.0	13.334	1.33	0.000	0.000	0.000	CONSTANT
20.00	25.1	15.000	1.33	0.000	0.000	0.000	CONSTANT

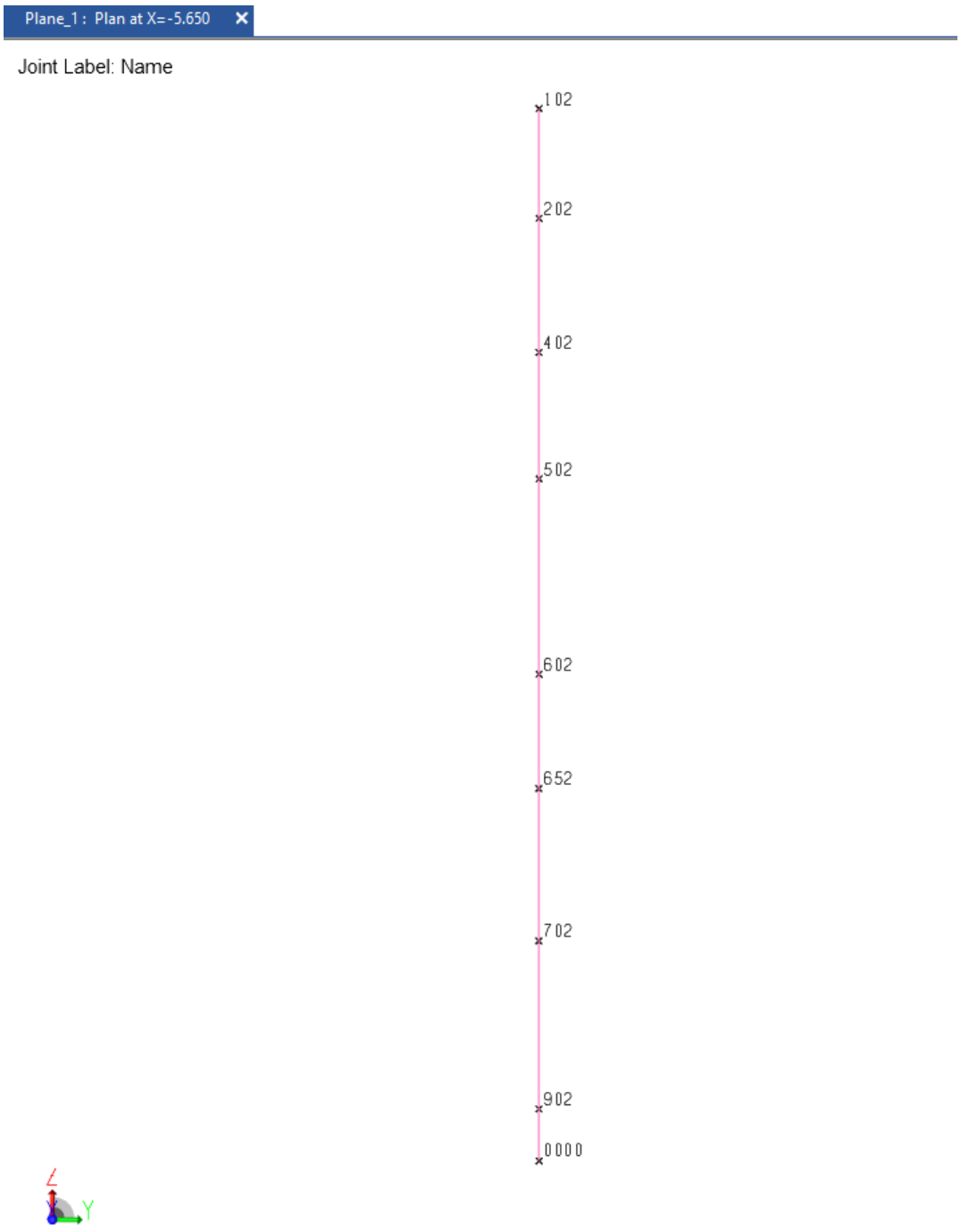
****** SEASTATE DRAG AND INERTIA COEFFICIENTS TABLE ******

MEMBER DIAMETER (CM)	********** CLEAN CYLINDERS ********** * DRAG COEFFICIENTS * NORMAL	AXIAL	* INERTIA COEFFICIENTS * NORMAL	AXIAL	********** FOULED CYLINDERS ********** * DRAG COEFFICIENTS * NORMAL	AXIAL	* INERTIA COEFFICIENTS * NORMAL	AXIAL
1.00	1.3000	0.0000	1.6000	0.0000	1.3000	0.0000	1.6000	0.0000
900.00	1.3000	0.0000	1.6000	0.0000	1.3000	0.0000	1.6000	0.0000

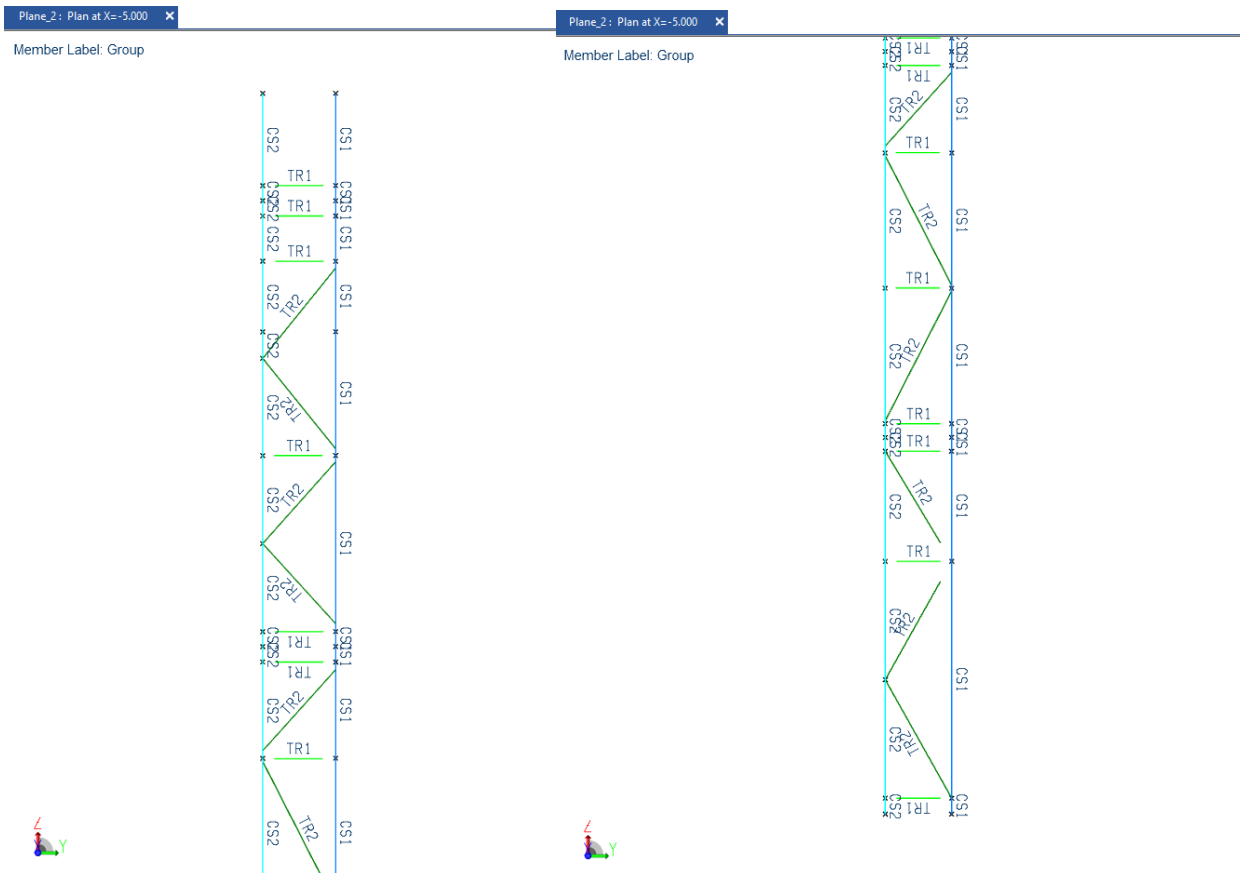
APPENDIX B – WIREFRAME SCHEMES



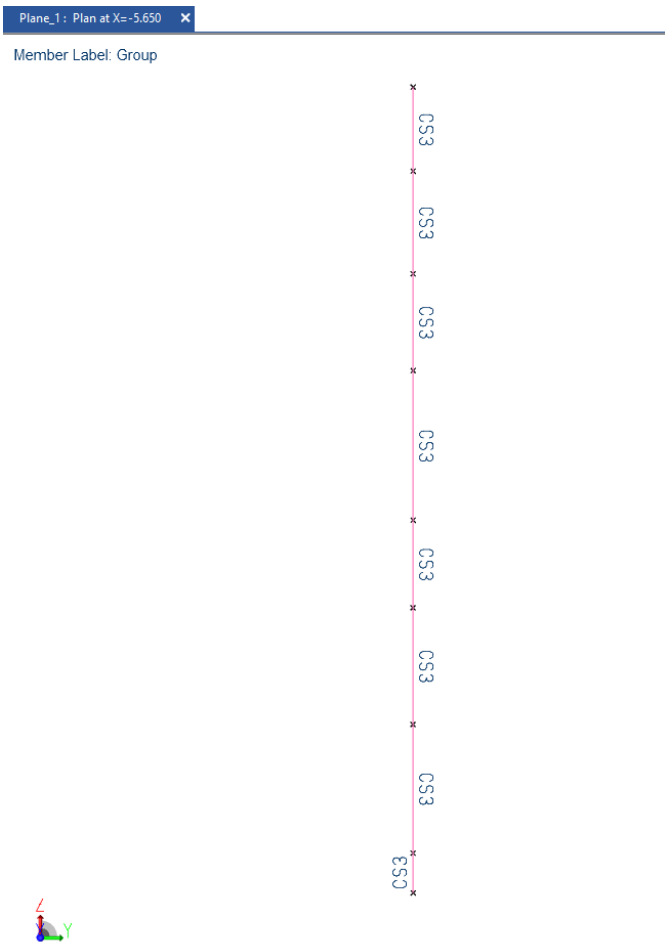
Seawater caissons frame – joints name



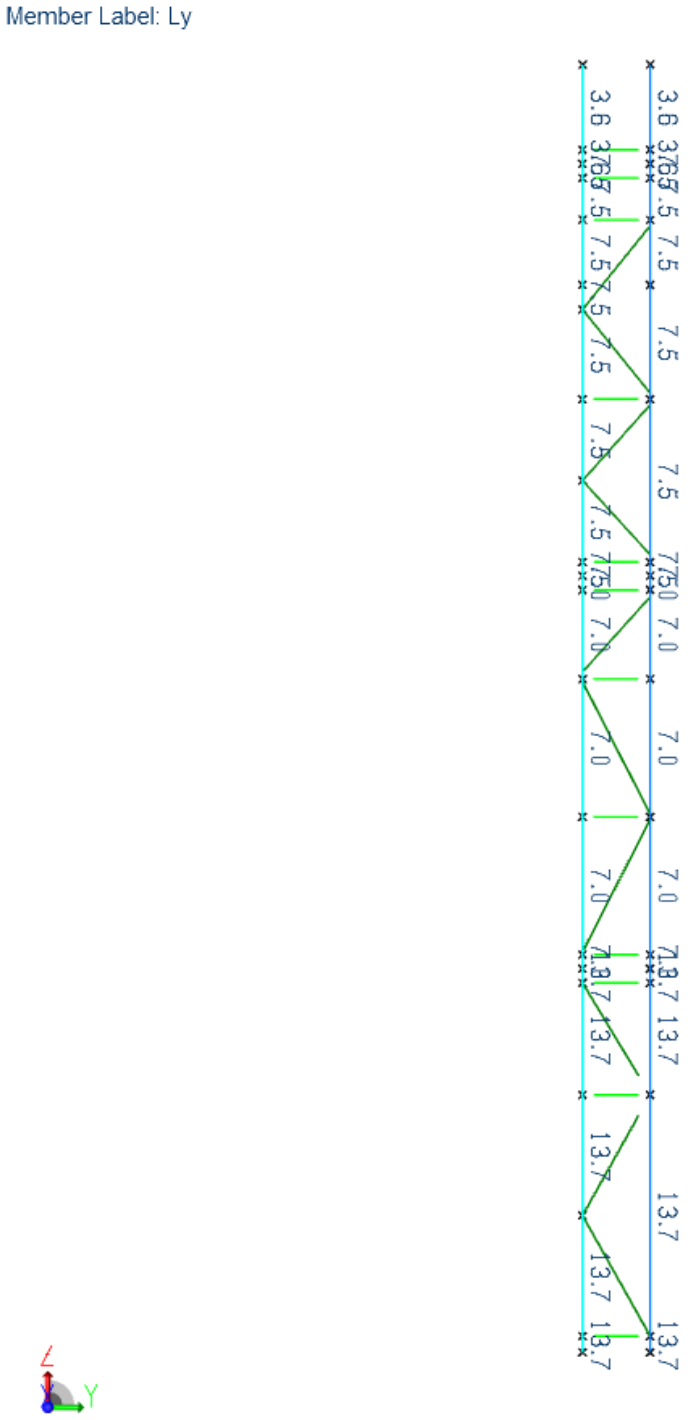
Brine discharge caisson – joints name



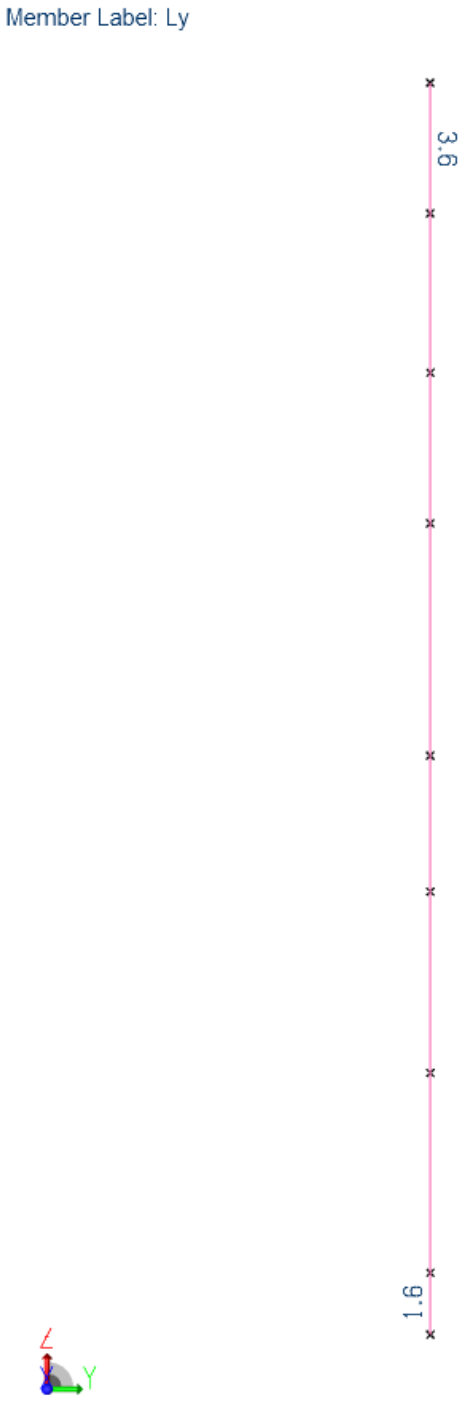
Seawater caissons frame – groups



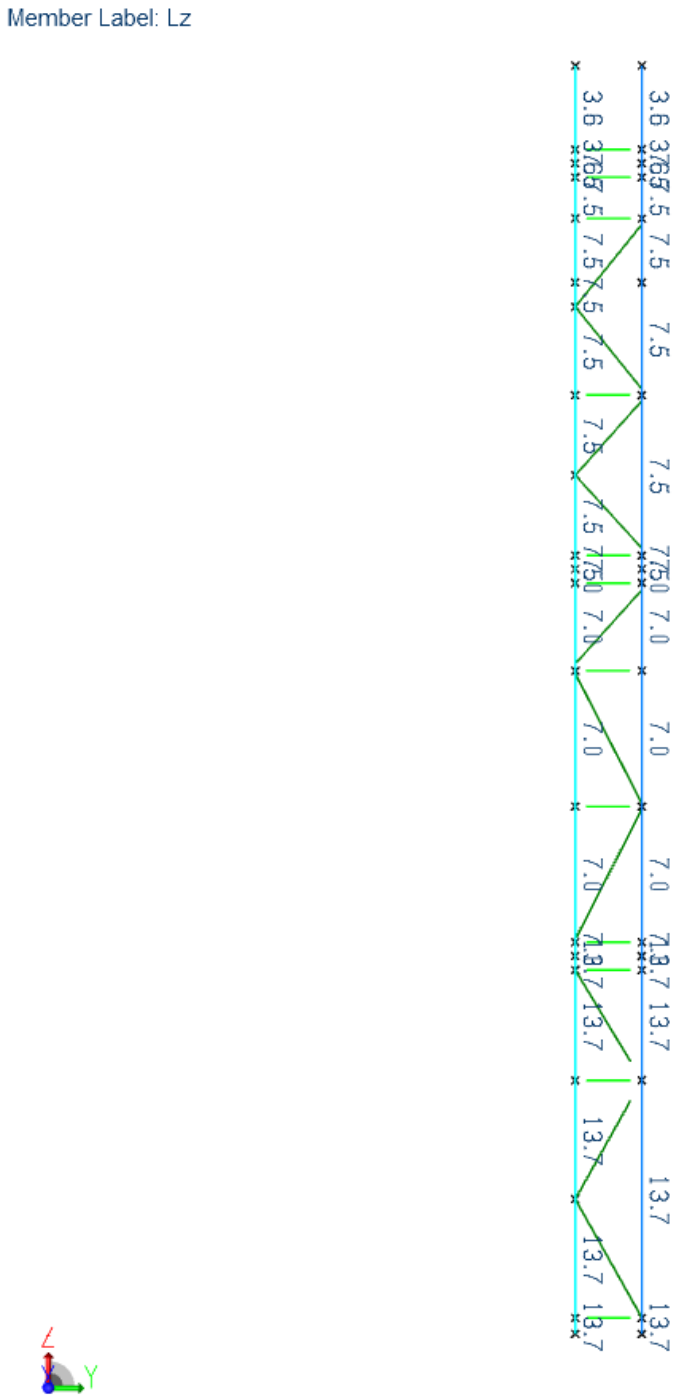
Brine discharge caisson – groups



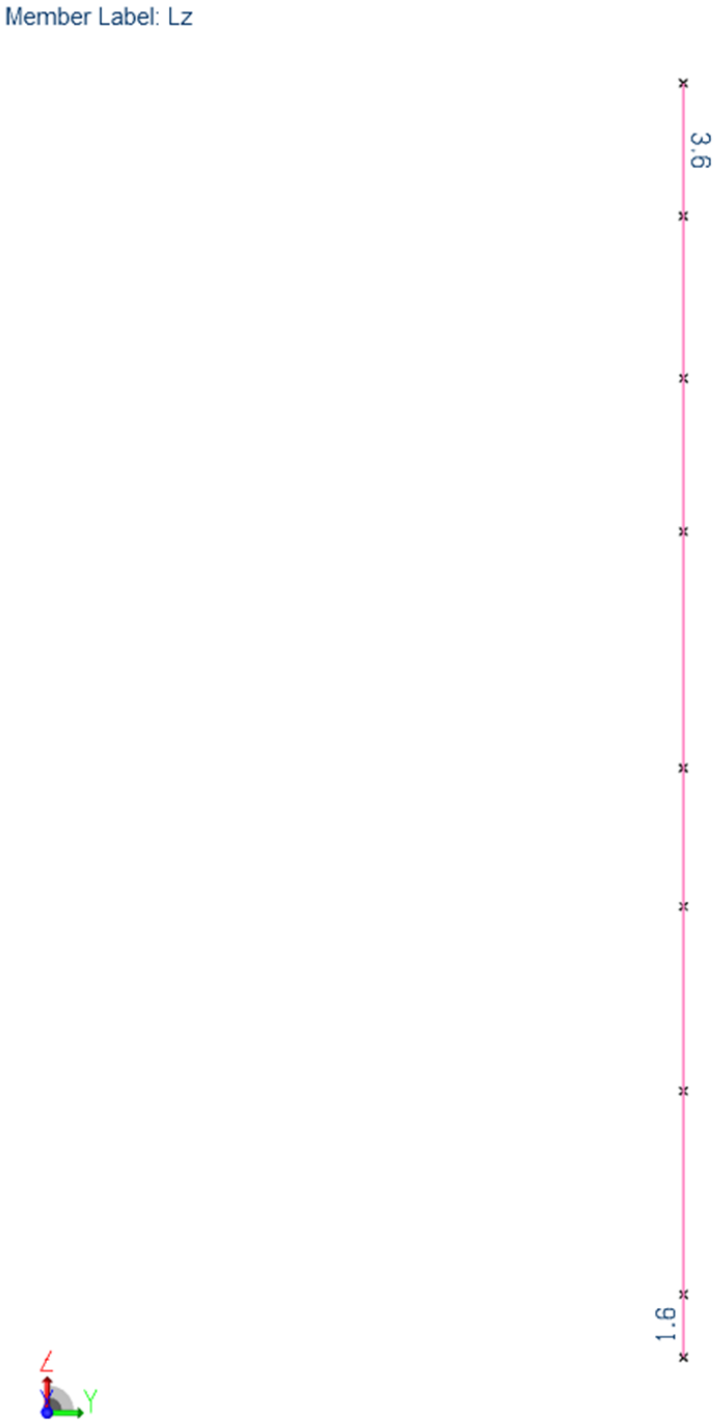
Seawater caissons frame – Ly



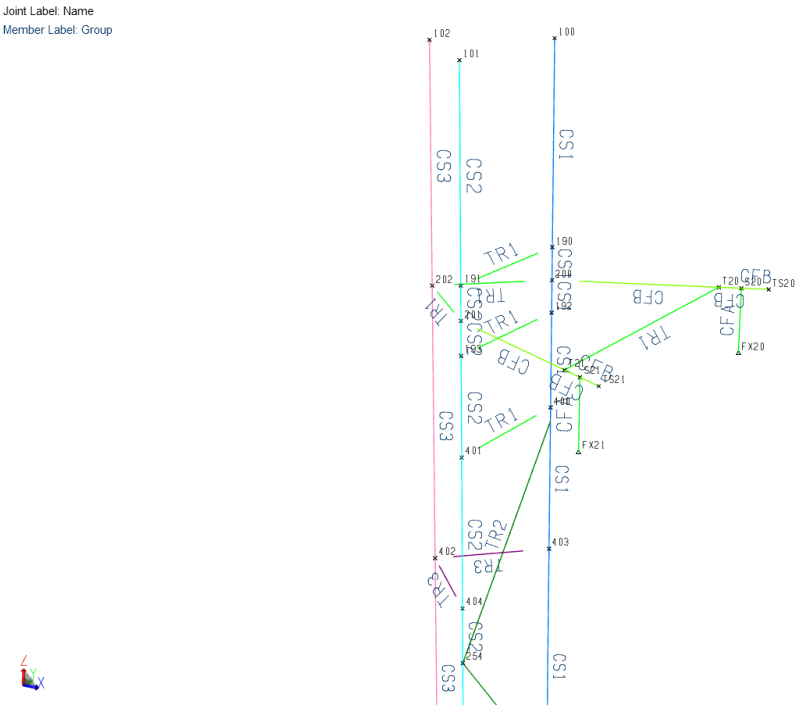
Brine discharge caisson – Ly



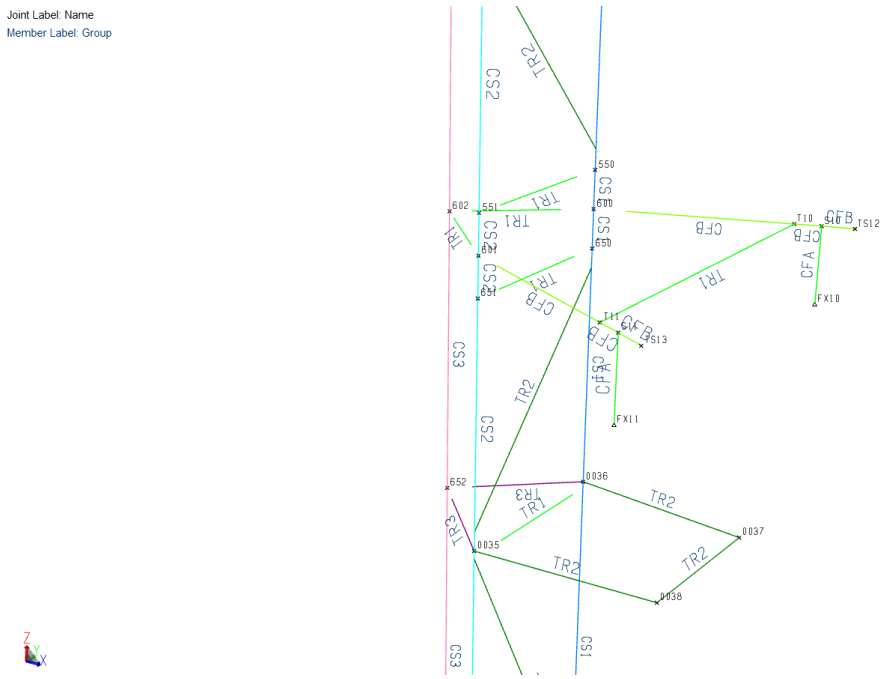
Seawater caissons frame – Lz



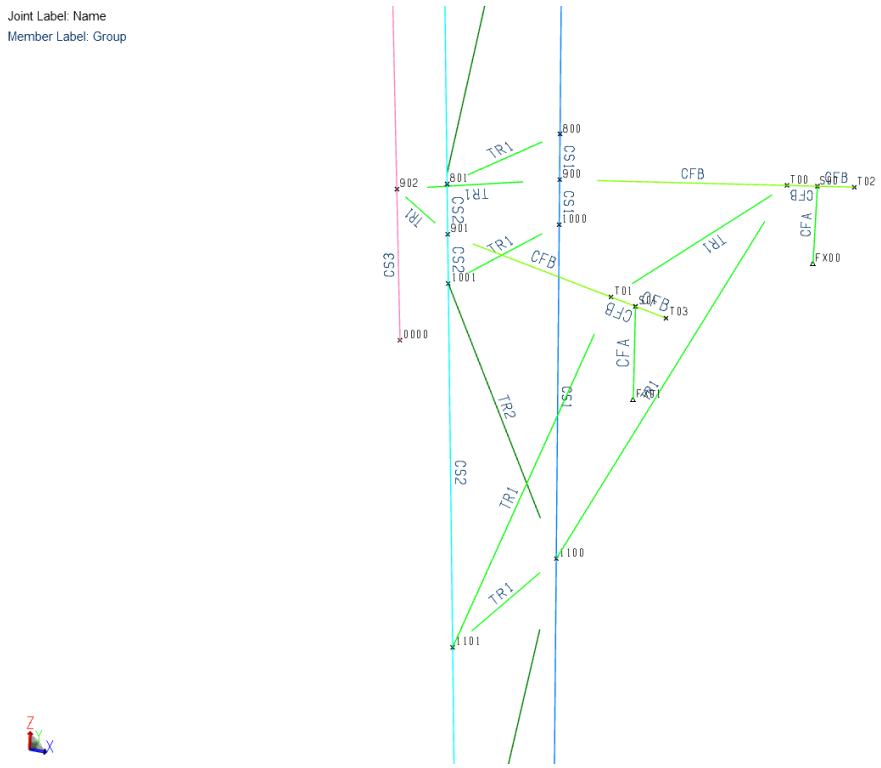
Brine discharge caisson – Lz



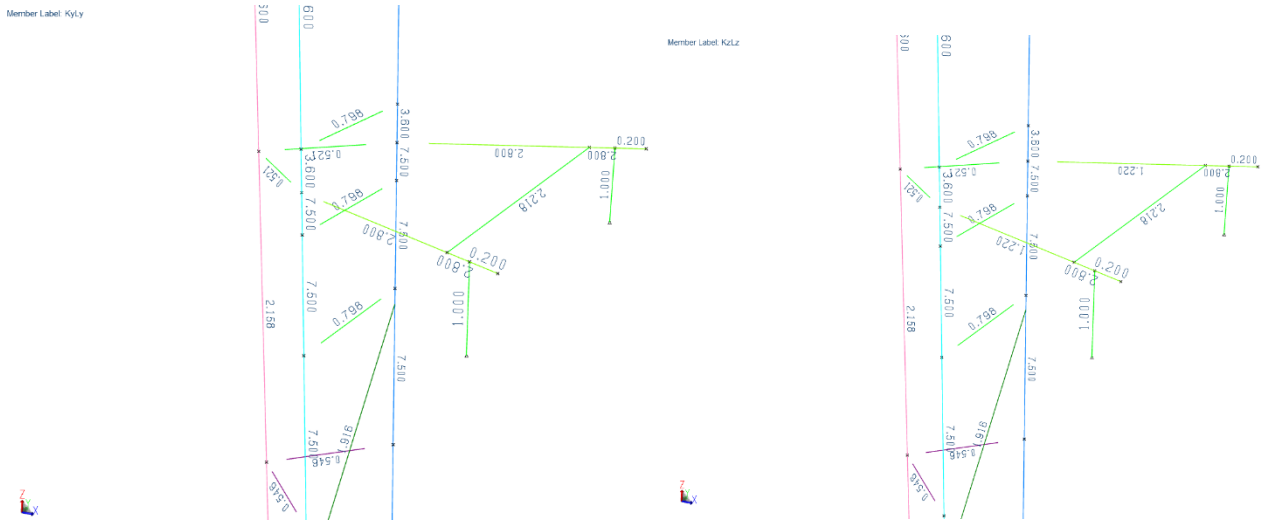
EL + 15.153m LAT – joins name and member groups



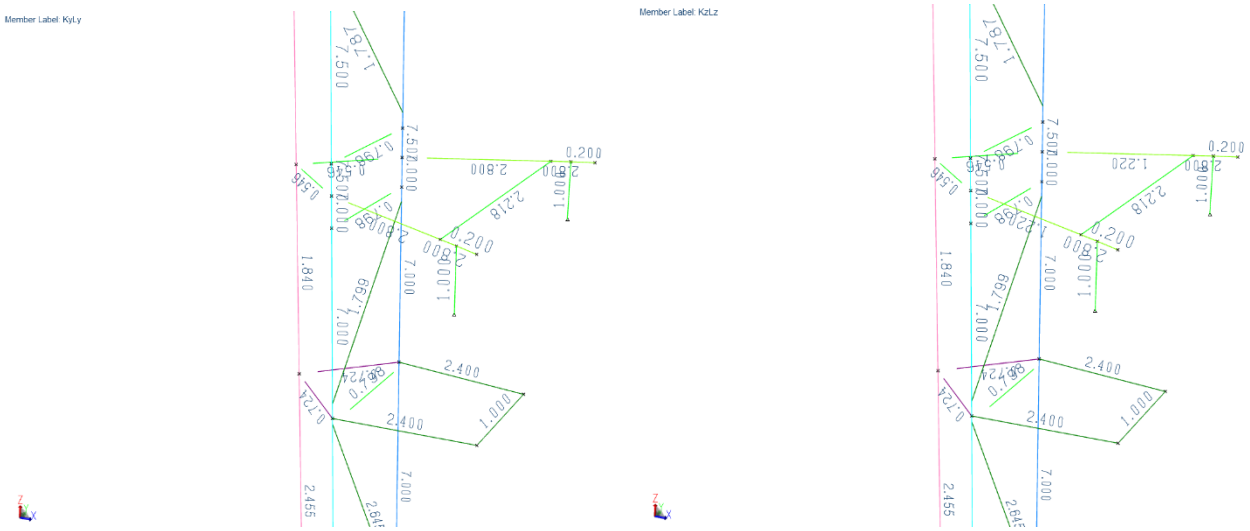
EL + 7.837m LAT – joins name and member groups



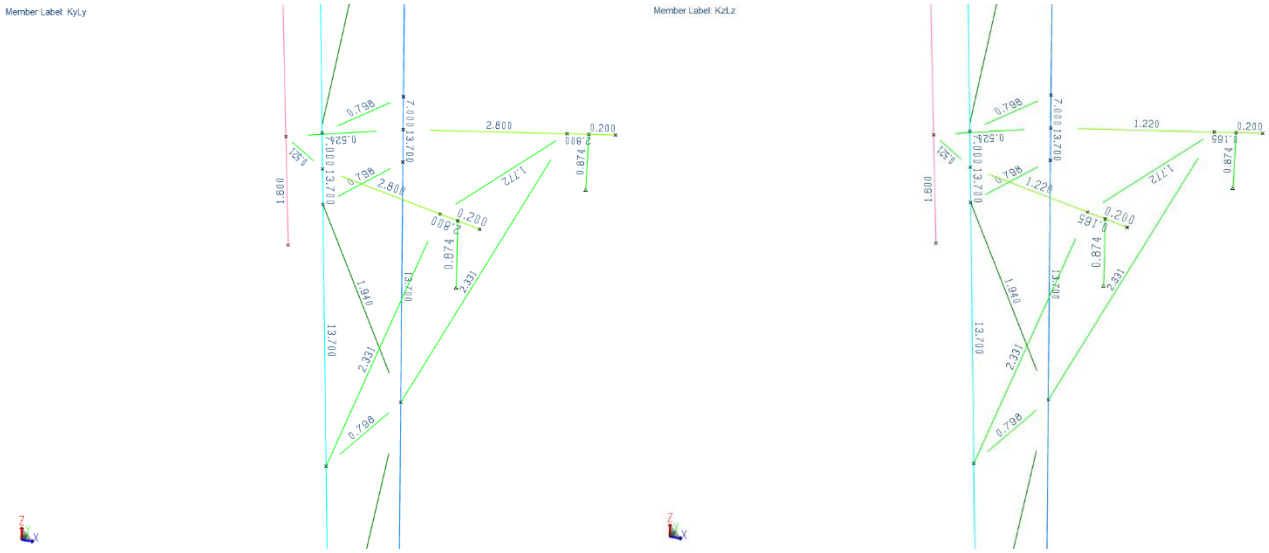
EL + 0.837m LAT – joins name and member groups



EL + 15.153m LAT – Ly & Lz



EL + 7.837m LAT – Ly & Lz



EL + 0.837m LAT – Ly & Lz

APPENDIX C – WAVES VELOCITIES AT MIN WD

```
TECON - BLPH CAISSON FRAME IN-SERVICE    min WD

     **** WAVE DESCRIPTION FOR LOAD CASE EM00 ****

          WAVE THEORY ************ STREAM FUNCTION

          WAVE HEIGHT ************   14.440 M

          WATER DEPTH ************   24.100 M

          WAVE PERIOD ************   13.100 SECS

          WAVE LENGTH ************  230.774 M

          ANGLE FROM X TOWARD Y **    0.000 DEGREES

          MUDLINE ELEVATION ******  -20.000 M

          WAVE CELERITY **********   17.616 M /SEC

          MAX. NO. SEG/MEMBER ****       10

          MIN. NO. SEG/MEMBER ****        5

          STREAM FUNCTION ORDER **        7

          BREAKING WAVE HEIGHT       17.847 M

          CREST POSITION DETERMINED BY MAXIMUM MOMENT

          STARTING CREST POSITION     0.000 M

          NO. STEPS **************       72

          STEP SIZE **************    3.205 M

          CREST WATER DEPTH ******    35.03 M

          TROUGH WATER DEPTH *****    20.59 M
```

TECON - BLPH CAISSON FRAME IN-SERVICE min WD

HORIZONTAL VELOCITY (M /SEC)

THETA	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000
SURFACE	35.028	33.795	31.402	29.062	27.076	25.471	24.208	23.234	22.496	21.946	21.539	21.239
HEIGHT	* * * * *	* * * * ** * * * ** * * *	* * * *	* * * *	* * * * * * * * * *	* * * *	* * * *	* * * *	* * * * * * * * * *
35.03	11.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.72	10.882	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.25	10.666	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33.60	10.376	9.763	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32.78	10.027	9.461	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.79	9.632	9.113	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30.63	9.202	8.735	7.475	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29.30	8.749	8.329	7.193	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.80	8.284	7.911	6.893	5.502	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26.13	7.819	7.491	6.589	5.336	4.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24.29	7.361	7.076	6.279	5.159	3.943	2.812	0.000	0.000	0.000	0.000	0.000	0.000
22.27	6.921	6.673	5.972	4.975	3.872	2.823	1.927	1.223	0.706	0.000	0.000	0.000
20.09	6.504	6.288	5.673	4.787	3.787	2.816	1.966	1.278	0.755	0.376	0.107	-0.083
17.73	6.116	5.928	5.387	4.597	3.691	2.792	1.986	1.314	0.788	0.394	0.105	-0.104
15.20	5.762	5.598	5.119	4.411	3.587	2.752	1.985	1.331	0.804	0.397	0.091	-0.134
12.50	5.447	5.301	4.873	4.232	3.476	2.696	1.964	1.326	0.800	0.383	0.063	-0.178
9.63	5.175	5.042	4.653	4.065	3.362	2.625	1.923	1.299	0.773	0.349	0.017	-0.235
6.59	4.950	4.825	4.463	3.913	3.247	2.543	1.862	1.247	0.722	0.292	-0.048	-0.310
3.38	4.777	4.657	4.309	3.779	3.136	2.449	1.779	1.169	0.644	0.210	-0.136	-0.405
0.00	4.664	4.542	4.194	3.668	3.029	2.345	1.677	1.066	0.538	0.101	-0.249	-0.521

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THETA	120.000	130.000	140.000	150.000	160.000	170.000	180.000
SURFACE	21.021	20.864	20.753	20.678	20.628	20.600	20.590
HEIGHT	*	*	*	*	*	*	*
35.03	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.72	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33.60	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32.78	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.79	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30.63	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29.30	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.80	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26.13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24.29	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.27	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.09	-0.218	-0.312	-0.374	-0.415	-0.443	-0.460	-0.466
17.73	-0.254	-0.361	-0.434	-0.483	-0.515	-0.534	-0.541
15.20	-0.299	-0.418	-0.501	-0.557	-0.594	-0.616	-0.623
12.50	-0.356	-0.485	-0.576	-0.639	-0.680	-0.704	-0.712
9.63	-0.424	-0.563	-0.662	-0.731	-0.776	-0.801	-0.810
6.59	-0.508	-0.654	-0.759	-0.832	-0.880	-0.907	-0.916
3.38	-0.608	-0.759	-0.869	-0.945	-0.995	-1.023	-1.032
0.00	-0.728	-0.881	-0.993	-1.070	-1.121	-1.150	-1.159

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APPENDIX D – WAVES VELOCITIES AT MAX WD

```
**** WAVE DESCRIPTION FOR LOAD CASE EM00 ****

     WAVE THEORY ************ STREAM FUNCTION
     WAVE HEIGHT ************   14.440 M
     WATER DEPTH ************   26.300 M
     WAVE PERIOD ************   13.100 SECS
     WAVE LENGTH ************  235.013 M
     ANGLE FROM X TOWARD Y **    0.000 DEGREES
     MUDLINE ELEVATION ******  -22.200 M
     WAVE CELERITY **********   17.940 M /SEC
     MAX. NO. SEG/MEMBER ****       10
     MIN. NO. SEG/MEMBER ****        5
     STREAM FUNCTION ORDER **        7
     BREAKING WAVE HEIGHT       19.283 M
     CREST POSITION DETERMINED BY MAXIMUM MOMENT
     STARTING CREST POSITION     0.000 M
     NO. STEPS **************       72
     STEP SIZE **************    3.264 M
     CREST WATER DEPTH ******    36.84 M
     TROUGH WATER DEPTH *****    22.40 M

          TECON - BLPH CAISSON FRAME IN-SERVICE     MAX WD

                        HORIZONTAL VELOCITY (M /SEC)

  THETA     0.000   10.000   20.000   30.000   40.000   50.000   60.000   70.000   80.000   90.000  100.000  110.000

SURFACE    36.843   35.950   33.966   31.792   29.813   28.134   26.763   25.669   24.814   24.155   23.653   23.274

 HEIGHT  * * * *  * * * * ** * * * ** * * * ** * * * ** * * *  * * * *  * * * * ** * * * ** * * * ** * * *  * * * *
  36.84   10.117    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  36.54   10.008    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  36.05    9.832    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  35.38    9.594    9.157    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  34.53    9.304    8.900    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  33.50    8.972    8.595    7.558    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  32.29    8.608    8.260    7.306    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  30.90    8.219    7.904    7.034    5.789    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  29.32    7.817    7.534    6.745    5.609    4.335    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  27.56    7.410    7.157    6.448    5.420    4.250    3.109    0.000    0.000    0.000    0.000    0.000    0.000
  25.62    7.006    6.782    6.148    5.220    4.154    3.096    2.153    1.381    0.000    0.000    0.000    0.000
  23.50    6.613    6.415    5.850    5.018    4.048    3.069    2.180    1.436    0.851    0.415    0.099    0.000
  21.20    6.237    6.063    5.561    4.813    3.932    3.029    2.192    1.475    0.896    0.451    0.119   -0.125
  18.72    5.885    5.730    5.283    4.611    3.810    2.975    2.187    1.497    0.925    0.474    0.128   -0.132
  16.05    5.560    5.423    5.023    4.415    3.683    2.910    2.166    1.501    0.937    0.481    0.124   -0.150
  13.20    5.269    5.145    4.783    4.230    3.555    2.833    2.128    1.484    0.929    0.471    0.105   -0.182
  10.18    5.015    4.901    4.569    4.058    3.429    2.748    2.073    1.448    0.901    0.441    0.066   -0.229
   6.97    4.802    4.695    4.384    3.903    3.306    2.655    2.003    1.392    0.849    0.387    0.007   -0.296
   3.57    4.637    4.533    4.233    3.769    3.191    2.556    1.916    1.313    0.772    0.309   -0.075   -0.383
   0.00    4.526    4.422    4.121    3.659    3.085    2.454    1.816    1.212    0.671    0.205   -0.182   -0.494
```

TECON - BLPH CAISSON FRAME IN-SERVICE MAX WD

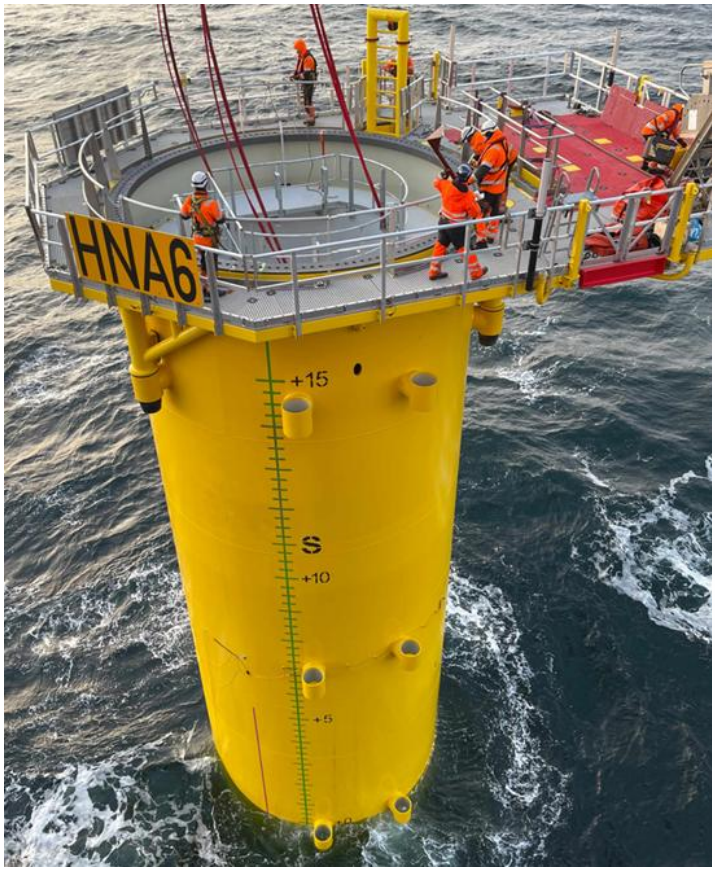
HORIZONTAL VELOCITY (M /SEC)

THETA	120.000	130.000	140.000	150.000	160.000	170.000	180.000
SURFACE	22.991	22.782	22.632	22.526	22.457	22.417	22.404
HEIGHT	*	*	*	*	*	*	*
36.84	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36.54	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35.38	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.53	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33.50	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32.29	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30.90	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29.32	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.56	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.62	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23.50	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21.20	-0.302	-0.429	-0.517	-0.578	-0.617	-0.640	-0.647
18.72	-0.324	-0.464	-0.564	-0.633	-0.678	-0.704	-0.712
16.05	-0.356	-0.508	-0.618	-0.695	-0.746	-0.774	-0.784
13.20	-0.400	-0.563	-0.682	-0.766	-0.821	-0.853	-0.863
10.18	-0.458	-0.630	-0.757	-0.847	-0.906	-0.941	-0.952
6.97	-0.532	-0.712	-0.844	-0.939	-1.002	-1.038	-1.050
3.57	-0.625	-0.809	-0.947	-1.044	-1.110	-1.147	-1.159
0.00	-0.738	-0.925	-1.065	-1.164	-1.231	-1.269	-1.281

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APPENDIX E – MP SLEEVE VERIFICATION

The sleeves welded to MP are shown in the following picture and designed according to structural drawing issued by Van Oord.



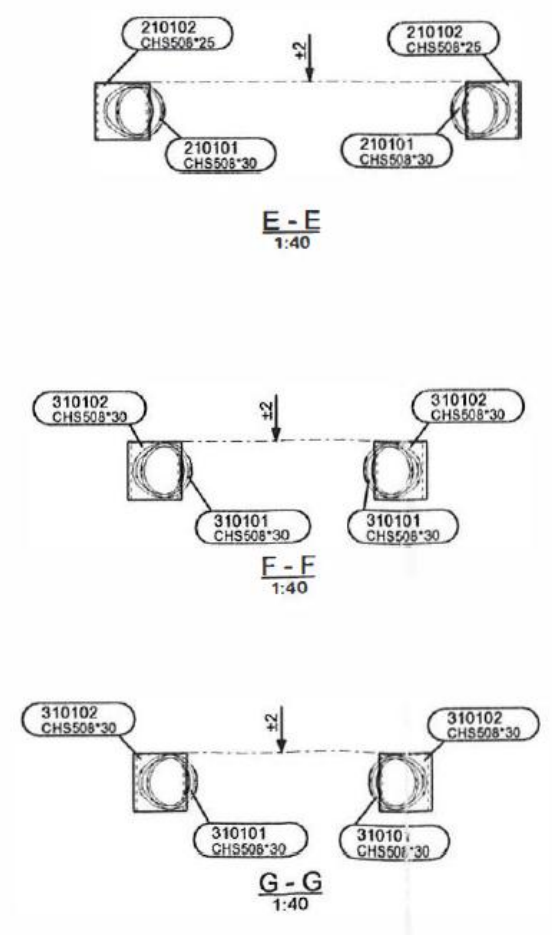


Table 10.14 summarized the actions obtained by in-service analysis.

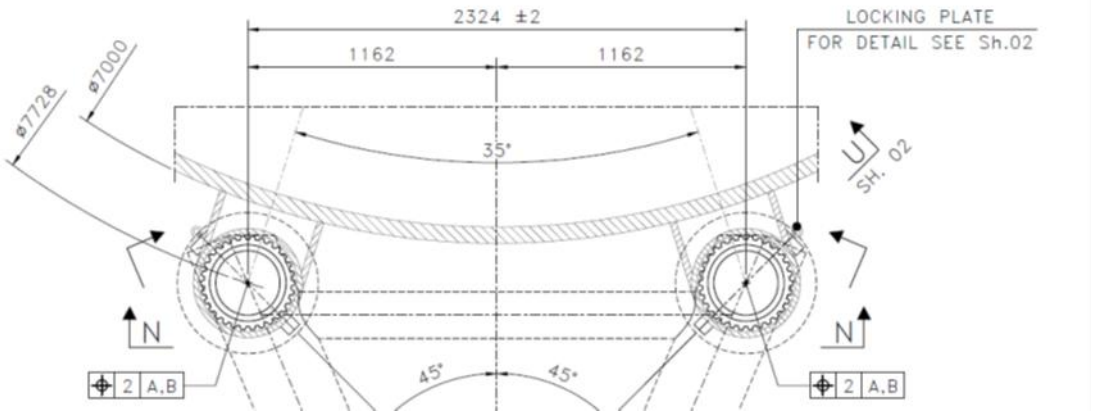
The connection with MP is made by 508x30mm pipe, S355 while the sleeve at upper level is 508x25mm, at the other levels 508x30mm.

Being the sleeves the same present in the MP north side, dedicated to Boat landing structure, their verification has been performed by Van Oord, see ref. /32/, using the max actions from in service and CTV impact, actions that are greater than those calculated here.

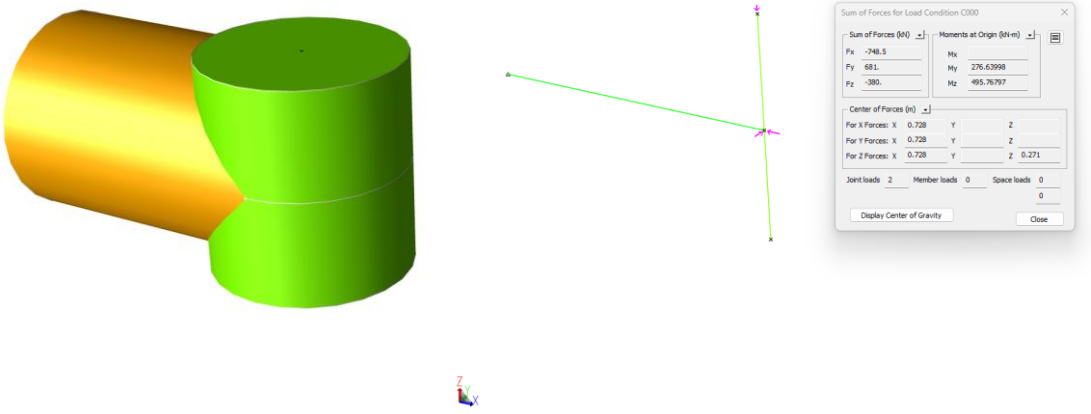
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The calculation here performed is carried out using the maximum actions obtained all applied at the same time.

El. (LAT)	joint	Max Reactions [kN]			description
		X-dir	Y-dir	Z-dir	Load condition / wave direction / WD / period
0.0	FX00	-748.5	-681	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX01	682	-676	-	LC06 / 90deg / min WD / max T
+7.0	FX10	-663	-577	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX11	530	-558	-	LC06 / 90deg / min WD / max T
+14.5	FX20	-327	-364	380	LC05 & LC06 / 45 & 90deg / min WD / max T LC06 / 90deg / min WD / max T
	FX21	422	-226	305	LC06 / 90deg / min WD / max T LC07 / 0deg / max WD / min T



SACS model



Analysis results

TECON - BLPH CAISSON FRAME - EXISTING SLEEVE

********** SEASTATE LOAD CASE CENTER REPORT **********
RELATIVE TO STRUCTURAL ORIGIN

LOAD CASE	LOAD LABEL	********* X - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Y - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)	********* Z - DIRECTION ********* FORCE (KN)	X (M)	Y (M)	Z (M)
1	DEAZ	0.00				0.00				-2.87	0.52	0.00	0.00
2	ACTS	-748.50	0.73	0.00	0.00	681.00	0.73	0.00	0.00	-380.00	0.73	0.00	0.27
3	C000	-748.50	0.73	0.00	0.00	681.00	0.73	0.00	0.00	-382.87	0.73	0.00	0.27

SACS-IV SYSTEM FIXED JOINTS REACTION FORCES AND MOMENTS

JOINT NUMBER	LOAD CASE	********** KN ********** FORCE(X)	FORCE(Y)	FORCE(Z)	********** KN-M ********** MOMENT(X)	MOMENT(Y)	MOMENT(Z)
000	C000	748.500	-681.000	382.875	0.000	-278.132	-495.767

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.70

MEMBER ID	GROUP	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK
000- 100	CFA	0.496	C000	0.0	-25.45	-84.14	149.98	-681.00	382.87	4.4	4.4	-0.000		-0.000
100- 102	CFB	0.046	C000	0.0	-12.94	0.00	0.00	-0.00	0.00	1.6	1.6	-0.000		-0.000
100- 101	CFB	0.000	C000	0.0	0.02	0.00	0.00	0.00	0.00	1.6	1.6	-0.000		-0.000

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.70 AND LESS THAN 0.90

** NO UNITY CHECKS IN THIS GROUP **

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 0.90 AND LESS THAN 999.00

** NO UNITY CHECKS IN THIS GROUP **

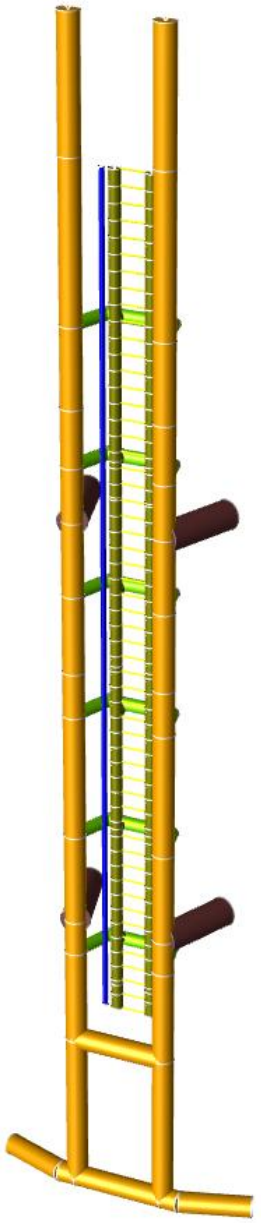
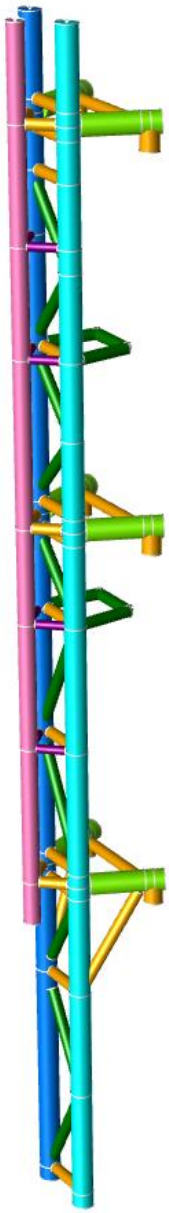
* * * M E M B E R G R O U P S U M M A R Y * * *
ISO 19902:2007 / EC3:2005
(EN 1993-1-1:2005/NA NONE)

GRUP ID	CRITICAL MEMBER	LOAD COND	MAX. UNITY CHECK	DIST FROM END M	* APPLIED STRESSES * AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	*** ALLOWABLE STRESSES *** AXIAL N/MM2	EULER N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	CRIT COND	EFFECTIVE LENGTHS KLY M	KLZ M	CM * VALUES * Y	Z
CFA	000- 100	C000	0.50	0.0	-25.5	-84.1	150.0	.3E+03	.1E+06	.4E+03	.4E+03	ACBI	0.73	0.73	0.85	0.85
CFB	100- 102	C000	0.05	0.0	-12.9	0.0	0.0	.3E+03	.8E+06	.4E+03	.4E+03	ACBI	0.27	0.27	0.85	0.85

* * J O I N T C A N S U M M A R Y * *
(UNITY CHECK ORDER)

	ORIGINAL					LOAD DESIGN					STRENGTH ANALYSIS			
JOINT	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	DIAMETER (CM)	THICKNESS (CM)	YLD STRS (N/MM2)	LOAD UC	STRN UC	BRACE JOINT	LOAD CASE
100	48.800	2.000	335.000	0.458	0.535	48.800	2.000	335.000	0.458	0.535	000	C000

APPENDIX F – MP VERIFICATION

Boatlanding model with extended fenders	Caisson Frame model
	

The load summation of the caisson frame is as follows:

Loads Caisson Frame

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TECON - BLPH CAISSON FRAME IN-SERVICE min WD

***** SEASTATE COMBINED LOAD CASE SUMMARY *****

RELATIVE TO MUDLINE ELEVATION

LOAD CASE	LOAD LABEL	FX (KN)	FY (KN)	FZ (KN)	MX (KN-M)	MY (KN-M)	MZ (KN-M)
8	DEAC	0.00	0.00	-51.00	0.1	-252.8	0.0
9	LC01	2146.60	-0.15	-609.69	2.5	52644.5	1.9
10	LC02	1612.25	1505.34	-581.75	-38704.2	38623.8	-7517.9
11	LC03	1.46	2917.71	-602.78	-75446.5	-2945.2	-14554.4
12	LC04	2198.44	-0.41	-589.75	14.7	53436.4	3.8
13	LC05	1743.92	1623.59	-614.26	-41829.1	41963.2	-8098.8
14	LC06	1.36	3080.36	-595.20	-79324.0	-2910.4	-15345.8

The load summation of the boatlanding element used to represent the caisson frame loads during the monopile design stage is as follows:

Loads representation of caisson frame during monopile design

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***** SEASTATE COMBINED LOAD CASE SUMMARY *****

RELATIVE TO MUDLINE ELEVATION

LOAD CASE	LOAD LABEL	FX (KN)	FY (KN)	FZ (KN)	MX (KN-M)	MY (KN-M)	MZ (KN-M)
8	DEAC	0.00	0.00	-38.28	-10.1	-0.6	0.0

9	LC01	2182.70	-0.30	-431.52	-113.7	56196.9	-715.2
10	LC02	1671.16	1628.65	-429.49	-41794.0	43088.0	-622.6
11	LC03	0.00	3180.04	-435.09	-81392.6	-6.5	-158.6
12	LC04	2278.86	-0.24	-426.89	-113.1	58249.2	-738.9
13	LC05	1743.89	1703.85	-425.60	-43339.6	44629.3	-645.5
14	LC06	0.00	3323.57	-430.84	-84254.2	-6.5	-164.1

The shear loads and overturning moment is larger for the design representation compared to the actual caisson frame structure. The vertical load on the final design is approximately 40% higher, partly due to waves and partly due to a lower weight.

The original boatlanding and it's support have been designed in a single FE model and no reaction were reported, however the design is similar to the main access platform support buckets. The main differences between the MAP supports and the boatlanding supports are listed below:

MAP supports	Boatlanding supports
508x30 horizontal stub	508x30 horizontal stub
508x25 vertical support bucket	508x30 vertical support bucket
Monopile wall 75 thick – S420 (Fy 370)	MP wall 80 thick – S355 (Fy 325) upper supports
	MP wall 85 thick – S355 (Fy 315) lower supports
Ref: 144671-VOOW-TF-ENG-DWG-1113	Ref: 144671-VOOW-TF-ENG-DWG-1112

The support stubs are analyzed in Design Report: 144671-VOOW-TF-ENG-REP-1501 Rev 02, the maximum reaction are listed below:

Support	FXY [kN]	Max FZ [kN]	Min FZ [kN]
Monopile support	1.1 * 775 = 852.5	Not governing	1473.1 [kN]

Table 6-42: Monopile support loads used for verification.

Load condition	FX [N]	FY [N]	FZ [N]	Remark
1	---	---	1473100	Fz only
2	-852500	---	1473100	Fz + FXY pointing away from MP
3	---	852500	1473100	Fz + FXY pointing out of plane from MP
4	852500	---	1473100	Fz + FXY pointing in direction of MP

Table 6-43: Monopile support stub load conditions.

The horizontal load FXY is applied as a bearing load.

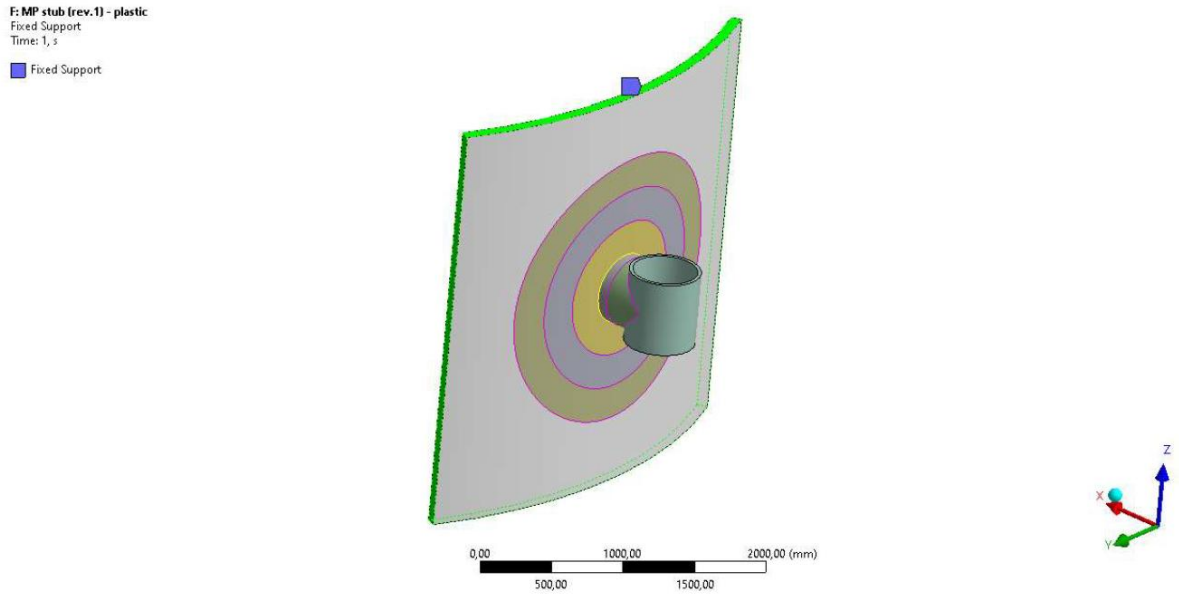


Figure 6-204: Model constraint, isometric view

The maximum support reactions for the caisson frame are given below (see Table 10.14 above):

El. (LAT)	joint	Max Reactions [kN]			description
		X-dir	Y-dir	Z-dir	Load condition / wave direction / WD / period
0.0	FX00	-748.5	-681	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX01	682	-676	-	LC06 / 90deg / min WD / max T
+7.0	FX10	-663	-577	-	LC05 & LC06 / 45 & 90deg / min WD / max T
	FX11	530	-558	-	LC06 / 90deg / min WD / max T
+14.5	FX20	-327	-364	380	LC05 & LC06 / 45 & 90deg / min WD / max T LC06 / 90deg / min WD / max T
	FX21	422	-226	305	LC06 / 90deg / min WD / max T LC07 / 0deg / max WD / min T

Table 10.14 – Summary table of support reactions

The maximum total horizontal reaction occurring at a single time at elevation 0.0m is for joint FX00 LC06 with 960 kN (748 in X & 477 in Y) or 13% higher than the loads reported in the MAP support calculation, however there are no vertical reactions at this location. The maximum Y reaction represents a pull push on the monopile equivalent to Fx in the MAP support stub verification and the maximum X reaction generates a moment on the stub, similar to the vertical load in the support stub verification. Therefore the reactions are within the design envelope for the horizontal stub and the MP interface, overall loads are lower and more than offsets the slight reduction in MP wall strength on the lower supports (increased wall thickness * reduced yield stress is 94% to 96%; vs. approximately 50% bending load {Fx-cf/Fz-map} and 88% push pull load {748/852 Fy-cf/Fx-map}).

For the support bucket it should be noted that the wall thickness of the bucket is 30mm vs 25mm for the MAP bucket and has a 20% increased resistance for local loads (30/25).

The maximum total horizontal reaction at elevation 14.5m is for joint FX10 LC06 with0 858 kN (634 in X & 577 in Y) or 1% higher than the loads reported in the MAP support calculation. This is considered acceptable in line with the results of the supports at elevation 0.0m.

The maximum reaction at elevation +14.5 are all well within design envelope.

The difference in supporting MP wall thickness x design yield stress is very low, the

Main conclusions:

- Global loads are within the design envelope
- Support stubs and the monopile interface have sufficient strength to support the caisson frame.