MICROSOFT WORD/V. MICROSOT 365/I-ET-3010.2Q-1400-140-P4X-001_A.DOCX

INDEX OF REVISION

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	ADJUSTMENTS IN ITEMS 7.3, 7.5, 7.6, 7.7, 9 AND 11

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	APR/03/24	JUN/14/24				
EXECUTION	BGWA	BGWA				
CHECK	B9BO	B9BO				
APPROVAL	CYEL	CYEL				

SUMMARY

1 INTRODUCTION

This document presents BUYER requirements to be adopted by SELLER for the structural analyses and design of the topsides structures of the BASIC DESIGN - REVIT MARLIM LESTE E SUL, as part of engineering design development at the Detailing Phase. Topsides structures comprise, not limited to, topsides modules (including equipment packages and skids structures), outfitting and flare tower. Pull-in structure is not part of topsides SELLER scope of work.

SELLER refers to DESIGN DETAILING COMPANY in this document.

In addition to BUYER requirements, SELLER documents to be delivered to the Classification Society (CS) contracted for the Detailing Phase shall fulfill the additional requirements agreed with this CS rules.

BUYER FPSO Unit may be installed at an area in Campos Basin, southeastern of Brazilian coast.

SELLER shall issue a new “Topsides Structural Requirements” document based on the present one, keeping the same philosophy in general, showing the methodology and computational tools, revising, including additional requirements for assembly and construction, detailing the scope of supply, and submit to BUYER for approval.

SELLER shall fulfill all design requirements specified in this document, but not limited to. Fabrication requirements shall be used by SELLER as information to guide the design.

All structural design reports and drawings, as well as all computer structural analyses models with loadings (input and output), design spreadsheets and computational tools adopted in the structural analysis, such as data importation/exportation tools or data manipulation tools not commercially available shall be attached to calculations notes and submitted to BUYER for approval.

In addition, for equipment weights greater than 50kN, SELLER shall list in the design report the corresponding SELLER reference document number with information about the footprint/foundation type, center of gravity and total weight (dry/operational and test), as well as the equipment list shall also be attached to the design report. All structural drawings and design data shall also be submitted in due time for CS approval. SELLER shall answer CS comments.

This document is complemented by codes, rules and standards presented in Section 2 of this document, subject to approval of the CS of the Unit.

The latest revision of the CS rules shall be used for the design of structures, reinforcements and complementary structures. Additional relevant criteria can be used in the design, based on designer experience and requirements of the CS, since submitted to BUYER and CS for approval.

During the Detailing Phase, any change in the FPSO topsides main structures and details as well as any change of the design philosophy shall be submitted by SELLER to BUYER for approval.

By changes one shall understand, for example:

- Interference with structures;
- Changes of dimensions, cross sections and welds;
- Significant changes on weight and general arrangement;
- Attachments on structures;
- Material changes;
- Main non-conformities during detailing, fabrication, assembly and construction phases;
- Damages during fabrication and found after the inspections;
- Structures out of the specified tolerances, misalignments and deformations above the limits;
- Changes in Painting Schemes.

Besides those mentioned above, SELLER shall follow the same procedure for any other relevant modification or change.

The International System of units (SI) shall be used in the analyses, reports and drawings.

All 2-D drawings shall be provided in system formats compatible with the contractual software and shall be extracted from 3D model. The 3D Model shall be built according to TECHNICAL REQUIREMENTS FOR DIGITAL ENGINEERING [4]. SELLER shall guarantee the consistency for all engineering database.

2 REFERENCES, CODES, STANDARDS AND PROCEDURES

2.1 DESIGN DOCUMENTS

All documents listed in I-LD-3010.2Q-1200-940-P4X-002 shall be used as reference, with emphasis on the following:

[1] I-DE-3010.00-1400-140-P4X-004 – GENERAL NOTES FOR TOPSIDES STRUCTURES;

[2] I-DE-3010.00-1400-140-P4X-006 – TOPSIDES MAIN STRUCTURE – TYPICAL DETAILS;

[3] I-DE-3010.2Q-1200-942-P4X-002 – GENERAL ARRANGEMENT;

[4] I-ET-3000.00-1350-940-P4X-013 - TECHNICAL REQUIREMENTS FOR DIGITAL ENGINEERING;

[5] I-ET-3010.00-1200-251-P4X-001 – REQUIREMENTS FOR BOLTING MATERIALS;

[6] I-ET-3010.00-1200-956-P4X-002 – GENERAL PAINTING;

[7] I-ET-3010.00-1300-140-P4X-001 – GUIDELINES FOR STRUCTURAL DESIGN AGAINST BLAST LOADS;

[8] I-ET-3010.00-1300-140-P4X-003 – FIRE-STRUCTURE ANALYSIS FOR PASSIVE FIRE PROTECTION DESIGN;

[9] I-ET-3010.00-1300-140-P4X-005 - GUIDELINES FOR STRUCTURAL ANALYSES FOR CRYOGENIC PROTECTION DESIGN;

[10] I-ET-3010.00-1350-960-PPC-001 – GUIDELINE FOR FPSO GREEN WATER ANALYSIS;

[11] I-ET-3010.00-1351-140-P4X-001 – HULL GLOBAL DEFLECTION;

[12] I-ET-3010.2Q-1351-140-P4X-001 - HULL STRUCTURAL REQUIREMENTS;

[13] I-ET-3010.00-1400-140-P4X-002 – GUIDELINE FOR DROPPED OBJECT STRUCTURE ANALYSIS;

[14] I-ET-3010.2Q-5266-630-P4X-001 – TOPSIDE'S MECHANICAL HANDLING PROCEDURES;

[15] I-ET-3000.00-1000-941-PPC-001– METOCEAN DATA – CAMPOS BASIN;

[16] I-LI-3010.2Q-1200-940-P4X-002 – EQUIPMENT LIST;

[17] I-RL-3010.2Q-1350-960-P4X-001 – MAXIMUM HEEL AND TRIM ANGLE ANALYSIS;

[18] I-RL-3010.2Q-1350-960-P4X-002 – MOTION ANALYSIS.

2.2 RULES, CODES AND STANDARDS

Rules, codes and standards from the list below shall be used for structural design of the topsides structure and attached structures, subjected to CS approval. Latest edition of each one shall be used, or, otherwise, contractual applicable edition, when specified. Rules, codes and standards other than those shall be submitted to BUYER and CS for approval.

[19] ABS - Floating Production Installations;

[20] ABS – Guide for Load and Resistance Factor Design (LRFD) Criteria for Offshore Structures;

[21] ABS – Rules for Building and Classing Floating Production Installations;

[22] ABS - Rules for Materials and Welding (Part2);

[23] ANSI/AISC 360-16 – Specification for Structural Steel Buildings – Load and Resistance Factor Design - 2016;

[24] API RP 2A – LRFD – Planning, Designing and Constructing Fixed Offshore Structures – Load and Resistance Factor Design - 2019;

[25] API-RP-2FPS – Planning, Designing and Constructing Floating Production Systems – 2011, Reaffirmed 2020;

[26] API RP-2FB – Recommended Practice for the Design of Offshore Facilities Against Fire and Blast Loading;

[27] API RP-2MOP – Marine Operations;

[28] API Standard 537 – Flare Details for General Refinery and Petrochemical Service;

[29] BS 2853 – Specification for the Testing of Steel Overhead Runway Beams for Hoist Blocks;

[30] DNV CG 0129 – Fatigue Assessment of Ship Structures;

[31] DNV OS C101 - Structural Design of Offshore Units – LRFD Method

[32] DNV OS C102 – Structural Design of Offshore Ship-shaped and Cylindrical Units;

[33] DNV RP C201 – Buckling Strength of Plated Structures;

[34] DNV RP C203 – Fatigue Design of Offshore Steel Structures;

[35] DNV RP C205 – Environmental Conditions and Environmental Loads;

[36] DNV ST N001 – Marine Operations and Marine Warranty;

[37] EN 1993-1-2 – Eurocode 3:Design of Steel Structures – Part 1-2: General Rules – Structural Fire Design;

[38] ISO 19901-3 – Petroleum and Natural Gas Industries - Specific Requirements for Offshore Structures Part 3 Topsides - Structure;

[39] ISO 19904-1 – Petroleum and Natural Gas Industries – Floating Offshore Structrure - 2ª Edition;

[40] MODU CODE;

[41] NORSOK N-003 – Actions and Actions Effects;

[42] NORSOK Standard M-101 – Structural Steel Fabrication;

[43] NR13 – Boilers and Pressure Vessels;

[44] Research Council on Structural Connections (RCSC) – Specification for Structural Joints Using High Strength Bolts;

[45] Text of The Resolutions Adopted by the 22nd General Conference on Weights and Measures.

3 DESIGN DATA

3.1 DESIGN LIFE

The Units shall be designed for 25 years minimum operation period without docking.

3.2 ENVIRONMENTAL DATA

Environmental parameters for in-place analyses and for transportation analyses shall be obtained from METOCEAN DATA [15].

3.3 STRUCTURAL CATEGORIZATION

All areas of the structures shall be categorized according to the application and consequence of failure.

Table 3.1 – Structural Categorization

A	**Special Design Area**	Those regions of the Primary Structure that are critical for the load transfer and may be subject to critical stress concentrations. Examples for process plant modules are: module foundations, bottom gusset plate of multi-column supports, lifting padeyes and all structural elements, such as beams, columns, braces and plates, directly connected to lifting padeyes.
B	**Primary Design Area**	Structural elements essential to the overall unit integrity, but less critical than the Special Design Area. This class is represented in process plant modules by main girders, columns and diagonals, major equipment supports (beams which supports equipment with operational weight > 50kN), deck plates and bulkheads that provide global resistance for module.
C	**Secondary Design Area**	Structural elements of minor importance, the failure of which is unlikely to affect the unit integrity. This class is represented in process plant modules by deck plates, stiffeners and bulkheads that are not taking part on global resistance, piping supports (including beams which support them), laydown area bumpers and monorails (including their foundations).
D	**Tertiary Design Area**	Structural elements of minor importance, the failure of with is unlikely to affect the unit integrity. This class is represented in process plant modules by stairs, walkways, handrails, gratings and others.

Further details can be found in GENERAL NOTES FOR TOPSIDES STRUCTURES [1].

3.4 UNITS

International System of units (SI) metric system shall be used throughout the project, including input data and results of structural analyses, and any other numerical information presented in design report, drawings or any other document.

The numerical notation adopted shall be as recommended in the 22nd General Conference on Weights and Measures [45] and presented below:

- The symbol for the decimal marker shall be dot ".";
- Numbers shall be divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups.

The following units shall be used as standard units on the project:

Table 3.2 – Standard Units on the Project

Description or structural characteristic	Unit
Member length, joint coordinates, etc.	m
Tube diameter and wall thickness, section prismatic properties, deflections, etc.	mm or cm
Angles	deg
Forces	kN
Moments	kN.m
Distributed loads	kN/m^2 or kN/m
Masses	kg or metric tons (tonnes)
Member stress	N/mm^2 (MPa)
Time	s (second)
Wind velocities	m/s
Accelerations	m/s^2
Temperature	°C

4 MATERIAL

Material grades shall be in accordance with the requirements of the CS rules of the Unit for topsides structures. Grade selection shall consider the plate thickness, the structural categorization and service temperature. Details on material grades can be found in GENERAL NOTES FOR TOPSIDES STRUCTURES [1].

4.1 STEEL DESIGN PARAMETERS

Steel design properties will be taken as:

- Young's Modulus → E = 206 000 MPa
- Shear Modulus → G = 79 200 MPa
- Poisson's Ratio → ν = 0.3
- Density → ρ = 7 850 kg/m³
- Coefficient of thermal expansion → $\alpha = 12.0 \times 10^{-6}$ / ºC
- Steel design temperature: 0 ºC

If in any phase of the project (e.g.: construction, transport, integration) the environmental temperature is lower than the design temperature 0 °C, SELLER shall proceed all necessary adequation.

Service temperature shall not be taken higher than the design temperature.

Creep curves and heat effects shall be assessed for special application (e.g.: flare tower).

The flare tower structures temperature shall be kept bellow 350 °C, heatshield shall be used to do this.

4.2 MATERIAL THICKNESS

The SELLER shall avoid large amount of different thickness during the selection of the structural elements sections, in order to optimize the material supply and reduce expenditures.

To prevent laminar tearing in plates equal or thicker than 15mm where tensile stresses acting perpendicular to the plane of the plate is greater than 50% of yield stress or when required by CS, "Z" quality (through thickness strength – TTS) material shall be applied.

4.3 BOLT MATERIAL

Structural joints shall be welded. Bolted joints may be used for hook-up parts and removable parts only that do not participate of the primary structure. Bolt material for structural elements shall be specified according to REQUIREMENTS FOR BOLTING MATERIALS [5] and GENERAL NOTES FOR TOPSIDES STRUCTURES [1].

Guidance for definition of joint type, installation requirements, such as possible requirement for specification of a minimum pretension, and other requirements, may be taken from RCSC [44]. Due to the cyclic nature of the loading, only pretensioned bolt shall be used.

5 WELDING

Welds shall be properly dimensioned for all design conditions. In addition, minimum requirements and Welds Non-destructive Testing (NDT) extension shall be in accordance with GENERAL NOTES FOR TOPSIDES STRUCTURES [1].

6 CORROSION CONTROL

The topsides structures shall be adequately corrosion protected by the coating system in accordance with GENERAL PAINTING [6]. No corrosion allowance needs to be considered for topsides structures.

7 STRUCTURAL ANALYSES

This section describes the design analyses to be performed during the Detailing Phase.

The SELLER shall design the topsides structures according to CS Rules and BUYER requirements.

7.1 SOFTWARE

The following software are acceptable for structural analyses.

For modules, flare tower and other frame structures:

- GT STRUDL;
- Sesam GeniE;
- SACS;
- SAP 2000.

For other structures, local and non-linear analysis:

- Sesam GeniE;
- ANSYS;
- FEMAP;
- ABACQUS.

Other structural software shall be submitted to BUYER for approval.

7.2 STRUCTURAL MODELING

A tri-dimensional space frame model shall be elaborated with unidirectional members (bars). The working points of the main elements (columns, beams and braces) shall be at the unique center of a frame joint according to the Figure 7.1, therefore there are no horizontal eccentricities in the structural model.

SELLER shall not change the working point locations of the Basic Design unless submitted and approved by BUYER.

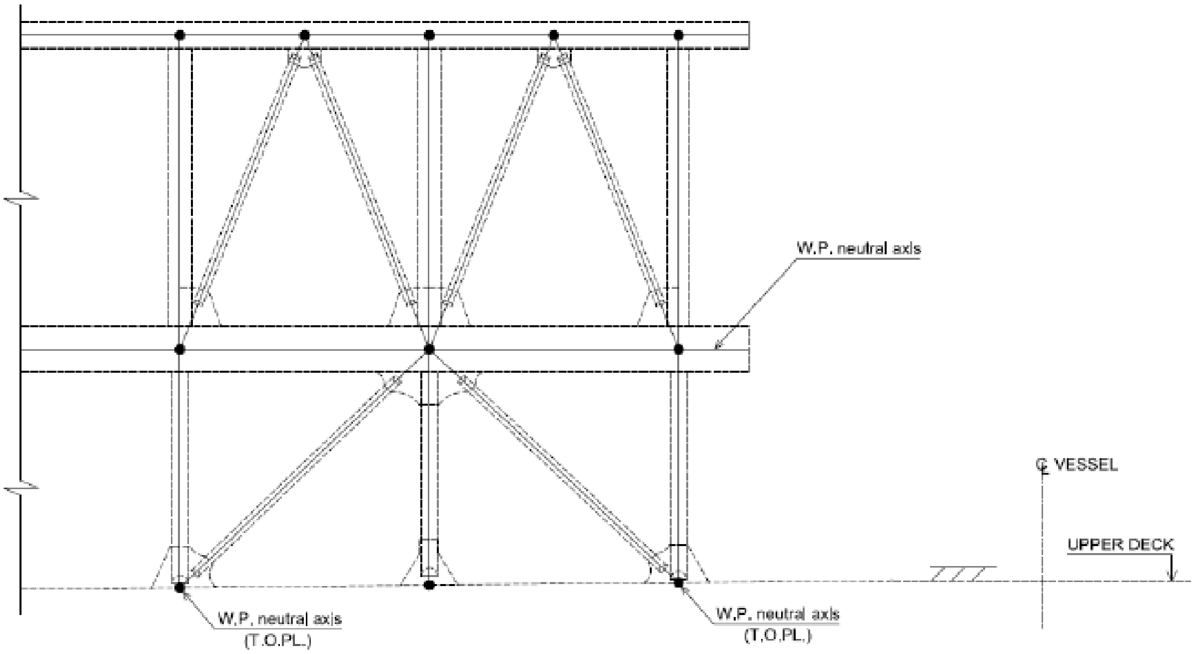


Figure 7.1 – Typical working point position

In general, beams are continuous, the columns and braces are interrupted. When necessary (e.g., avoid overlap, ensure the minimum space for welding etc.) non-competing work points may be adopted.

When the structural shift from the original working point to the new position exceeds 400 mm, it shall be represented in the structural model by adding a new joint, column-beam and brace-beam connections joints shall be defined separately to reflect actual load transfer (e.g., shear load, which is transferred from the brace, might be the controlling factor for beam design) as shown in Figure 7.2.

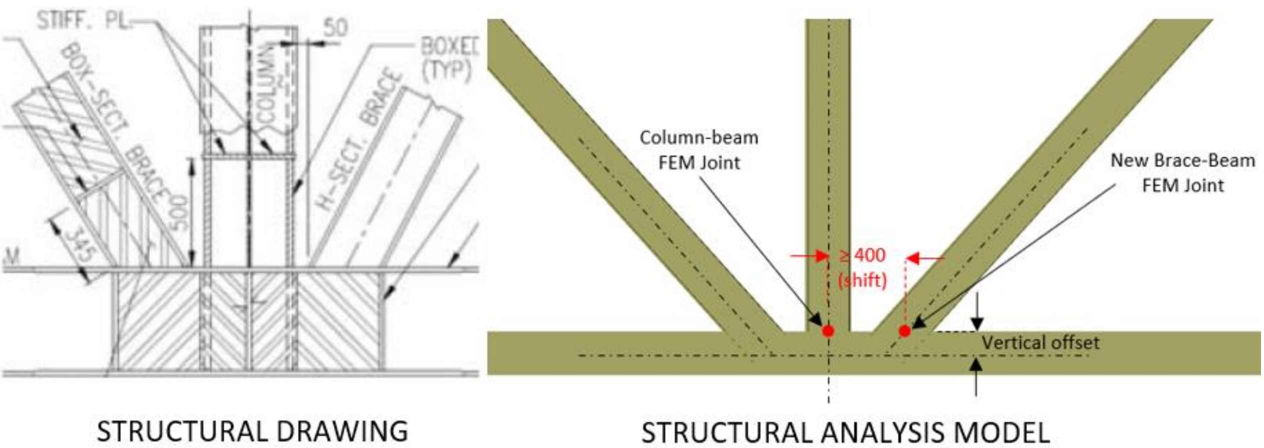


Figure 7.2 – New joint due to structural shift ≥ 400 mm

For shifts lower than 400mm, only the horizontal offset shall be applied as demonstrated in Figure 7.3.

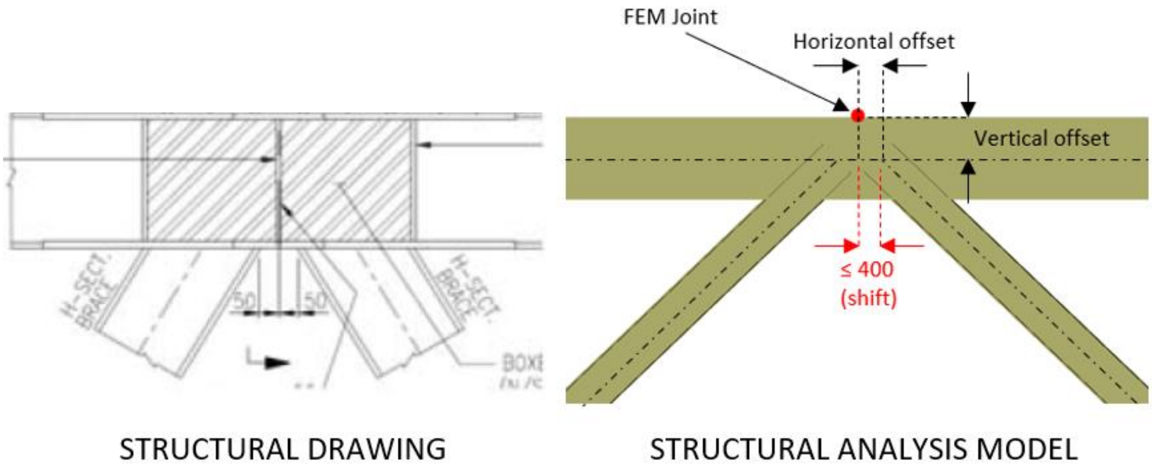


Figure 7.3 – Horizontal offset due to structural shift ≤ 400 mm

Vertical offset of beam members at all deck levels shall be applied in the structural analysis model. The top flanges of beams shall be flushed to the top of steel (refer to Figure 7.4). In the event that bottom flush is required, the requirement shall be clearly stated in the relevant document/drawing.

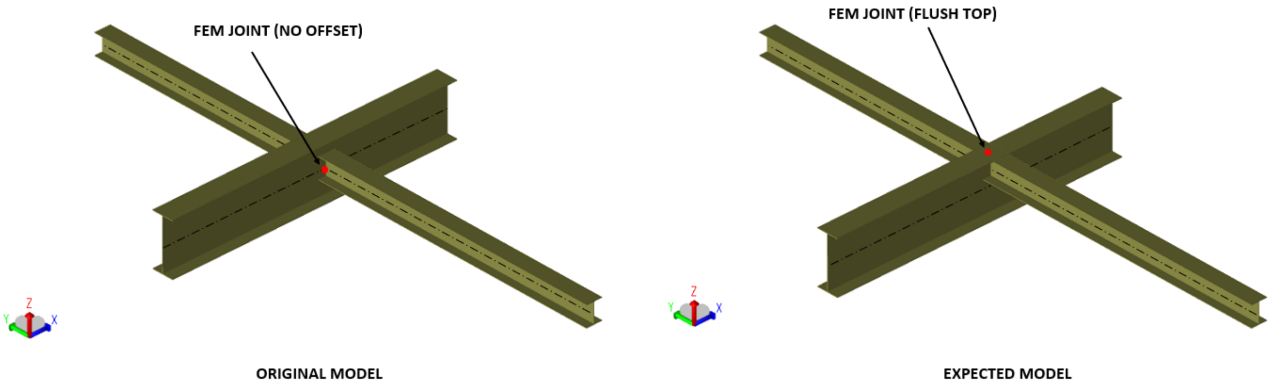


Figure 7.4 – Beam Member Flush in Model

Deck floor shall be modelled with shear only type Finite Element Method (FEM) elements connected at the structural joint in order to give lateral bracing to the whole model. In addition, the secondary structure, such as: stiffeners, brackets e.g., shall not be taken into account in the primary structure FEM model. The secondary structure shall be properly evaluated in the model for secondary structure analysis.

The concept of connections of module structures to hull shall be:

- Module supported on columns attached to the hull main deck by means of gusset plates. These gusset plates are directed in transverse ship direction and are in line with under deck transverse web frame or transverse bulkheads. The function of the transverse gusset plates is to act as hinges, minimizing stress in the module structure due to hull deflections effects under wave loads and loading/unloading of the FPSO, which generates strain in the hull main deck and make the bottom connection of the columns displace in longitudinal direction.

- In longitudinal direction braces are applied between two spans and three columns (two web frame spaces). At these locations, gusset plates are installed at vessel upper deck also in the longitudinal directions and in line with the ship’s longitudinal stiffeners, in order to avoid punching of the upper deck plating.

- Besides bracing in longitudinal direction, braces are also required in transverse direction.

For connections between multi-columns supports and topsides structure, where only a single column is attached at the pancake level, this connection is made by means of a gusset plate for a suitable load transfer of structural details subject to critical stress concentrations. It is recommended that the gusset plate be applied in the transverse ship direction and also have a hinge function to minimize the stress in the topsides structure due to the effects of hull global deflections.

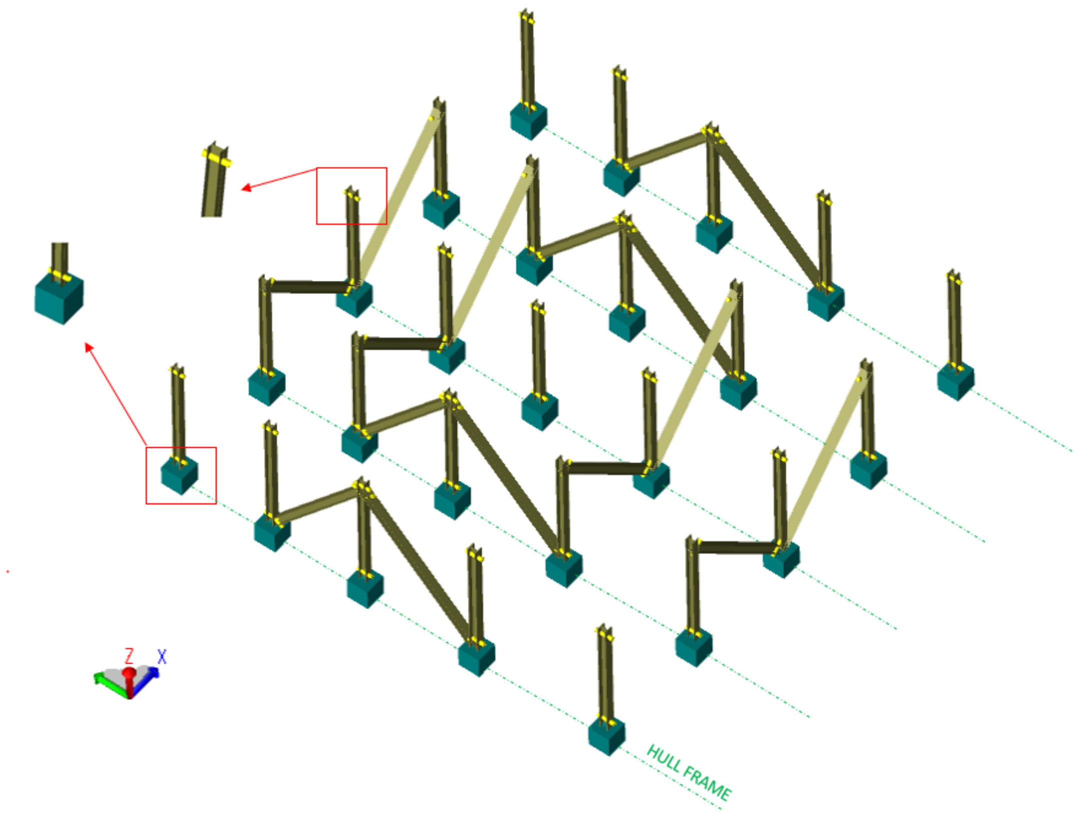


Figure 7.5 – Concept of typical connections of module structures to hull

The brace members located at the planes “xz” and “yz” which are connected to the hull structure shall be oriented as indicated in Figure 7.6 and Figure 7.8 respectively. Brace members at plane “xz” shall meet at common column support on main deck, as well as the brace members at plane “yz” shall meet in the pancake structure. The brace orientations indicated in Figure 7.7 and Figure 7.9 are not recommended due to the frame displacement restrictions, that implies higher stresses in the module structure. Any solution, different than Figure 7.6 and Figure 7.8, shall be submitted to BUYER approval.

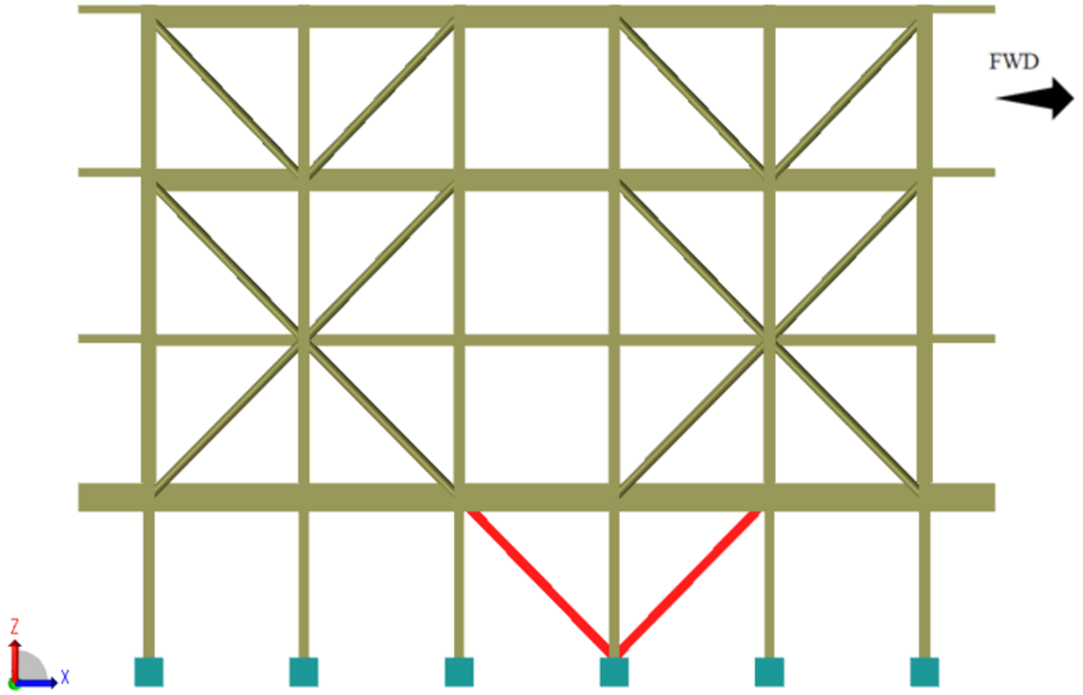


Figure 7.6 – Recommended orientation for the brace in “xz” plane (red marked)

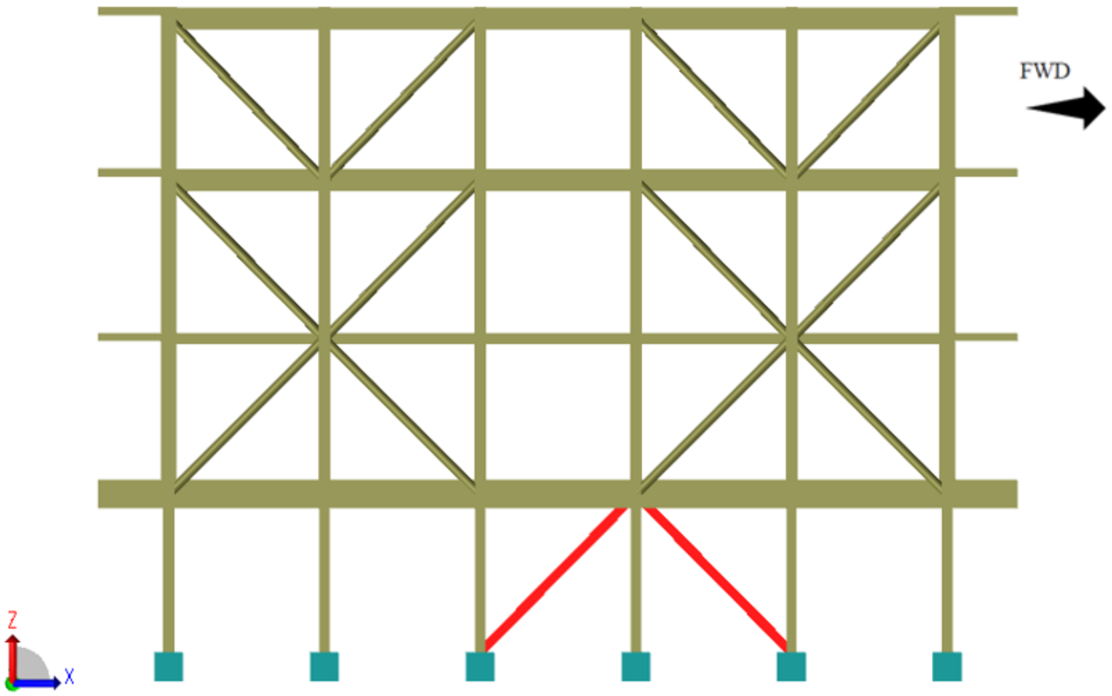


Figure 7.7 – Not recommended orientation for the braces in “xz” plane (red marked)

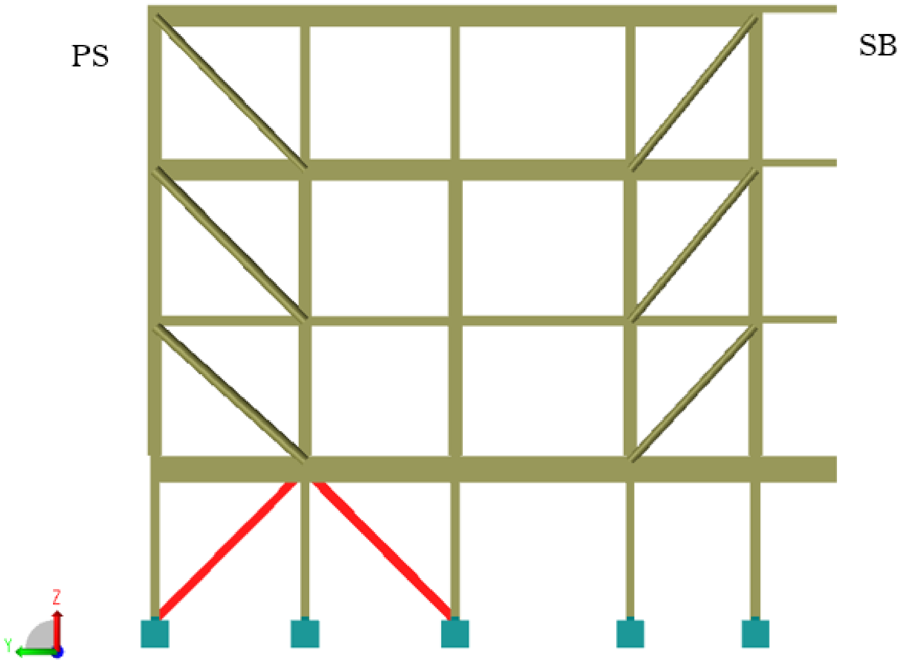


Figure 7.8 – Recommended orientation for the brace in “yz” plane (red marked)

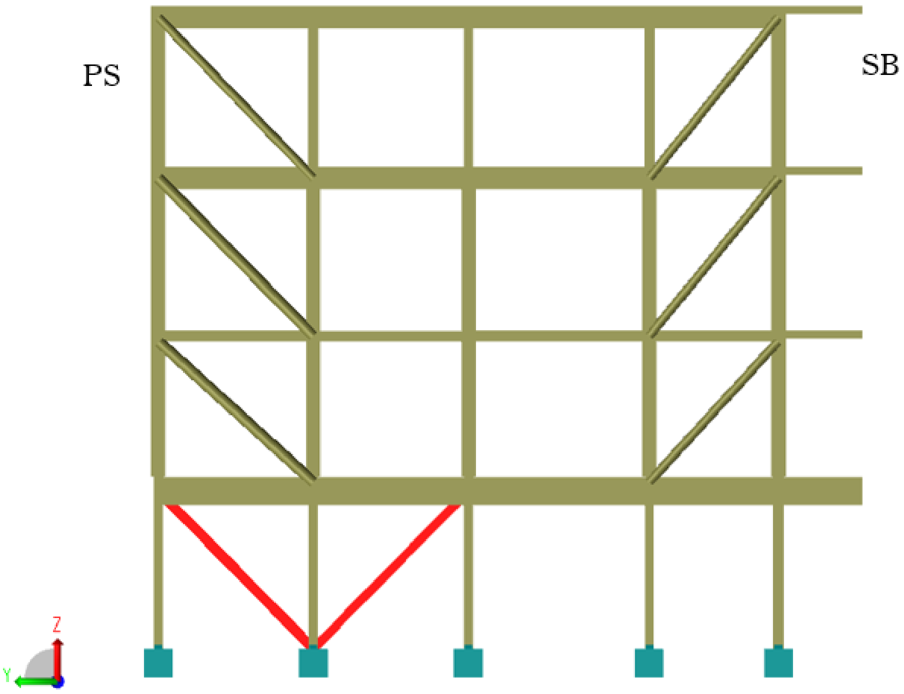


Figure 7.9 – Not recommended orientation for the braces in “yz” plane (red marked)

For module support columns mentioned above, the following boundary conditions shall be applied to the FEM model.

- All supports are restrained for translation and rotations in X, Y and Z direction;
- All elements braced with gusset plates shall have gusset in-plane rotations restrained and gusset out-of-plane rotations released.

If SELLER performs any modification in support columns connection details presented in [2] at detailing phase, or if required by CS, boundary condition used shall be justified considering the effect of out-of-plane stiffness for yielding, buckling and fatigue, and shall be submitted for BUYER approval.

Stress concentration factors and other local effects are evaluated by means of plates and bi-dimensional FEM elements.

The flare tip and the flare headers for gas flow may be modelled as beam elements not for structural verifications but for the correct transference of loads from the piping lines to the flare tower structure.

Relevant equipment package structures shall be included in the modules structural models, including all their loads as dead weight, live loads, equipment weight, inertial loads and wind loads. Structural verification of modules shall be carried out using this complete model.

For analysis of gusset plates between pancake and hull main deck, FEM models with shell type elements, including an appropriate hull region (main deck and foundations) or pancake region, shall be performed. Mesh size shall be of the order of plate thickness at peak stress locations for hot spot stress derivation in fatigue analysis. For yielding and buckling verification, mesh size shall not be greater than 50 mm at these locations, with limiting stresses according to item 7.3.2. The gusset plates shall be verified DOC, DEC and DAMAGE load combinations.

7.3 ACCEPTANCE CRITERIA

7.3.1 GENERAL

The structures are designed such that all the structural members shall comply with the requirements as specified by ANSI/AISC 360-16 [23] and the steel pipes according to API RP 2A [24].

Design criteria adopted in current project is based on Load and Resistance Factor Design (LRFD).

Load factors to be applied in analyses are based on API-RP-2FPS [25] according to limit states and action categories as shown in Table 7.1. Lower values in agreement with CS may be acceptable, provided they are submitted and approved by BUYER.

Table 7.1 – Load Factors for Combinations

LIMIT STATE	LOAD FACTOR			
	Action Category			
	Permanent (G)	Variable (Q)	Environmental (E)	Accidental (A)
ULS-a	1.3	1.3	0.7	-
ULS-b	1.0	1.0	1.3	-
Post-ALS	1.0	1.0	1.0	-
Pre-ALS	1.0	1.0	1.0	1.0
SLS	1.0	1.0	1.0	1.0
FLS	-	-	1.0	-

Where,

ULS-a: Ultimate Limit State where Permanent (G) and Variable (Q) loads are increased (Gravitational action-dominated conditions);

ULS-b: Ultimate Limit State where Environmental (E) loads are increased (Environmental action-dominated conditions);

SLS: Serviceability Limit State;

Post-ALS: Post-Accidental Limit State;

Pre-ALS: Pre-Accidental Limit State;

FLS: Fatigue Limit State.

Material factors are indicated in items 7.5 to 7.7.

7.3.2 LOCAL ANALYSIS

FEM local analysis results shall satisfy the criteria indicated in DNV-OS-C101 [31].

Top/bottom shell stress shall be considered for topsides local analysis.

7.3.3 PLATES, BRACKETS AND STIFFENED PANELS BUCKLING

Plates, brackets and stiffened panels shall be checked for buckling in accordance with DNV-RP-C201 [33].

7.3.4 PADEYES

Padeye checking can be done by both FEM local analysis or by analytical method.

FEM local analysis shall comply with 7.3.2. Pin contact area shall be properly represented.

Analytical method shall satisfy the DNV-ST-N001 [36] requirements.

In addition, analytical method shall include at least the following checks as recommended by ANSI/AISC 360-16 [23].

- Bearing;
- Shear at all critical sections;
- Pull out verification;
- Tensile at all critical sections, including reinforced elements connected to padeye;
- Combined axial and bending stresses at all critical sections, including reinforced elements connected to padeye;
- Weld checking.

7.3.5 STRUCTURE MAXIMUM DEFLECTIONS CRITERIA

7.3.5.1 VERTICAL DEFLECTIONS

Girder deflection limits for primary structure and secondary structure shall be in accordance with ISO 19901-3 [38].

For monorails, the vertical deflection shall be limited to L/500 between its supports and L/250 for cantilever beam, where L is the monorail span, according to BS 2853 [29].

Floor plate deflections shall comply with ISO 19901-3 [38]. For deck plates subjected to trolley loads on material handing routes, the vertical deflections of the deck plates between stiffeners must be evaluated in accordance with VENDOR requirements.

7.3.5.2 HORIZONTAL DEFLECTIONS

Horizontal deflections shall be verified in according with ISO 19901-3 [38].

For module columns, horizontal deflections shall be limited to 0.3% of the height between floors.

For multi-floors modules, the total horizontal deflection shall not exceed 0.2% of the total height of the topsides structure.

OBS: If horizontal deflection criterion is not complied with, structures designer shall verify with other disciplines (e.g.: piping and mechanical) if the deflections are acceptable.

7.3.6 TUBULAR JOINT CHECK

Tubular joint check shall be according to to API RP 2A [24].

Joint can design shall be based on the real acting load. It is not necessary to meet the design requirement of minimum 50% of chord reserve capacity.

7.4 LOAD MODELING

7.4.1 PERMANENT LOADS (P)

Permanent loads are those which variations in magnitude during the Unit’s lifetime are small in relation to the main value.

7.4.1.1 DEAD WEIGHT

The gross dead weight of modelled structure shall be generated directly from the structural analysis software. The gross dead weight of non-modelled secondary and tertiary structures (such as secondary beams, gratings, ladders, stairs, handrails, walkways, maintenance platforms and equipment/piping supports) shall be input as uniformly distributed or concentrated loads.

All equipment shall be represented in the structural model considering the dimensions, Center of Gravity (CoG) positions indicated on the Weight Control Report and most appropriate stiffness and boundary conditions. The footprint indicated by the manufacturer shall be reproduced in the structural model to ensure the correct load transfer.

Piping, EIT (Electrical, Instrumentation and Telecom), safety, architectural and other disciplines loads shall be properly represented along the elevations in-line with their distributions represented in modules arrangement.

Conservatively, equipment and piping content weight may be considered as permanent load.

All input loads shall be shown and described in detail in the calculation notes. In addition, a weight breakdown shall be presented including a comparison between structural model loads and updated weight control information. Differences between the structural model input and Weight Control Report greater than 3% are not acceptable.

7.4.2 VARIABLE LOADS (Q)

Variable loads are originated from normal operation and vary in magnitude, position and direction during the lifetime. Main variable loads, but not limited to, are described below.

7.4.2.1 LIVE LOAD

Live load on deck area shall be applied in accordance with the Table 7.2 or with CS requirements, the most restrictive requirements shall be applied. The Table 7.2 shall be considered as BUYER minimum requirements:

Table 7.2 - Functional Loads on Deck Area

VARIABLE FUNCTIONAL LOADS ON DECK AREAS OF TOPSIDES STRUCTURES (note 7)				
Area	**Local Design (note 1)**		**Primary Design (note 2)**	**Global Design (note 3)**
	Distributed load (kN/m²)	**Point load (kN) (note 4)**	**Distributed load (kN/m²)**	**Distributed load (kN/m²)**
Storage	q = max(γ x H;13)	1.5 x q	q	q
Lay-down	40	40	30	30
Free area between equipment (notes 5 and 8)	5	5	5	may be ignored
Walkways, staircases, platforms and escape routes (note 8)	4.5	4.5	4.5	may be ignored
Storage room and workshop	15	15	15	15
Maintenance areas (note 5)	15	15	15	15
Roofs (note 6)	2.5	2.5	2.5	may be ignored

γ = specific weight of storage material; H= storage height; q = max (γ.H; 13)

(1) Local Design is used in the local analysis of plates, gratings and support beams of secondary structure. Inertial loads shall be disregarded in local analysis.

(2) Primary Design is used in the structural design of the primary structures. Primary structures are defined as the main structural elements of topsides that ensure the structural integrity, such as: beams, columns, braces, structural joints and bulkheads that are considered in modules global resistance;

(3) Global Design is used in the structural design of topsides foundations. Global design condition shall be disregarded for the structural design of the topside foundation with design concept in multi-column supports;

(4) Point loads shall be applied on an area 100 x 100 mm, and at the most severe position, but not added to wheel loads (from cargo handling equipment) or distributed loads. For laydown area with wooden deck, the point loads shall be applied on an area 220 x 220 mm. For floor grating (steel or pultruded material), the point loads shall be applied on an area 200 x 200 mm;

(5) The variable functional loads shall not be applied at free area between equipment and maintenance areas for the DEC, Damage and Fatigue Conditions. For free area definition see Figure 7.10;

(6) For roofs with no access, 2.5kN/m² shall be applied. For roofs with access, the free area value shall be applied;

(7) With the exception of laydown and storage loads, all others live loads shall not be accelerated;

(8) Reduction factor to be applied in live loads along the levels may be considered as it is agreed by CS.

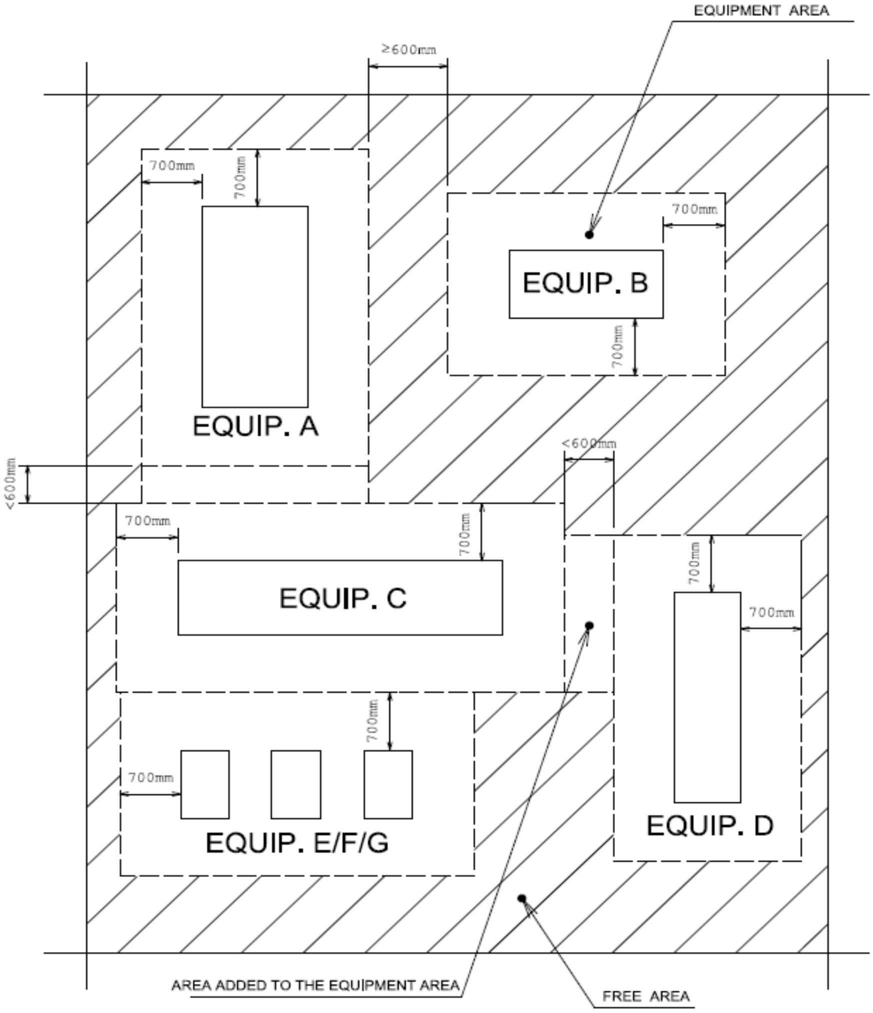


Figure 7.10 – Free Area

7.4.2.1 HULL DEFORMATION

Hull deflections shall be properly considered at structural analyses of modules supported by columns in order to obtain the effect of relative support displacement at columns bases as well as correct relative displacement between support points of piping at adjacent modules or modules/pipe rack. Hull deflections shall be applied as absolute values.

Structural analyses of other structures connected to the hull main deck shall include hull deflections effect according to SELLER Hull Global Deflections Calculations.

7.4.2.2 HANDLING AND CRANE LOAD

For the structural design of trolley handling way, a dynamic amplification factor (DAF) of 10% (trolley capacity or handled load + self weight) shall be applied on structural model in vertical direction. The maximum permissible load pressure due to deck trolley, as well as the deck trolley footprint and the moving load type, shall be obtained in reference TOPSIDE'S MECHANICAL HANDLING PROCEDURES [14]. The values presented in reference [14] already includes the DAF and the load factor due to centre of gravity inaccuracy (CoG), where the CoG load factor for deck trolley of 5 ton and 10 ton capacity is equal to 10%, while 15% for deck trolley of 40 ton.

In case of trolley's VENDOR during the detailing phase confirms that CoG position of the handled load does not affect the wheel pressure due to a hydraulic compensator device, then the CoG load factor may be ignored.

For monorail support structure design, a dynamic amplification factor of 25% of monorail capacity shall be applied on vertical direction. In horizontal (longitudinal and transversal) directions a load of 10% of monorail weight plus lifting capacity shall be applied. These loads (vertical and horizontals) are applied simultaneously.

For reaction load at boom rest structure, the information provided by crane manufacturer shall be considered.

The bumper structure in laydown areas shall be designed for a combined vertical and horizontal impact load equal to 2% and 20% of the maximum crane capacity, respectively.

The primary structure which the bumper is directly attached shall be designed according to the impact loads prescribed in DNV ST N001 [36], considering the bumper horizontal cow-horn type.

7.4.3 ENVIRONMENTAL LOADS (E)

Environmental loads directions shall be combined to produce the most unfavourable stresses and support reactions for those parts of the structures being designed. The structures and equipment areas shall be considered as area of obstruction for the wind loads.

7.4.3.1 WIND

Wind loads shall be applied according to API-RP-2A [24] and METOCEAN DATA [15].

The structures and equipment areas shall be considered as area of obstruction for the wind loads.

7.4.3.2 INERTIAL

The accelerations indicated in the MOTION ANALYSIS [18] is a basic design information and shall be updated during the detailing phase.

All cases obtained from motion analysis shall be separated in sectors (Head, Beam and Quartering) according to directions of wave incidences on FPSO unit and properly reproduced along combinations of topsides modules analysis. See figure below for a better understanding of heading sectors:

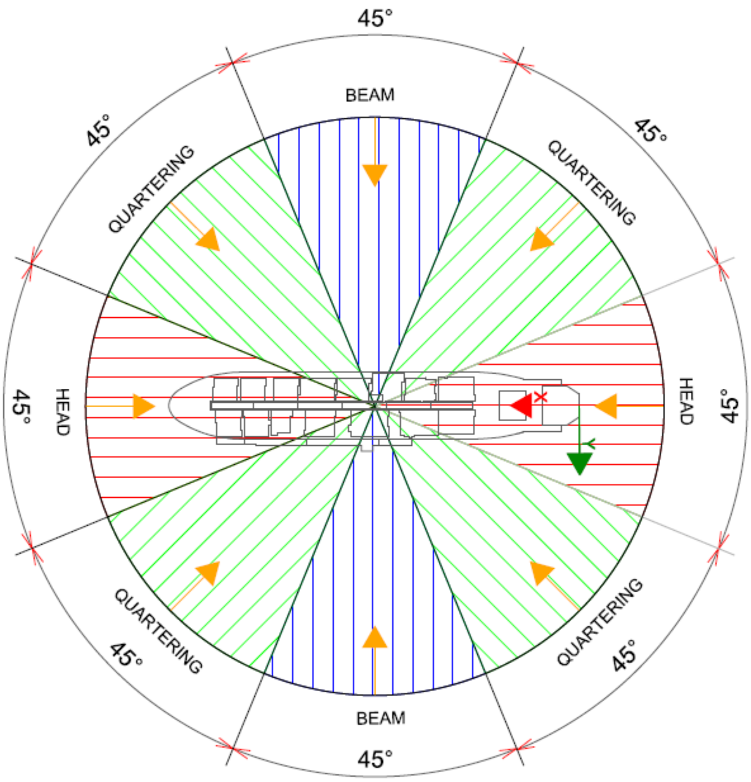


Figure 7.11 – Heading Sectors for Inertial Combinations

Therefore, inertial combinations shall be generated according to the following procedure:

- For head seas conditions (red sector – see figure Figure 7.11): maximum longitudinal accelerations within head sea cases associated with the exact correspondent transversal acceleration.

  Maximum vertical accelerations within head sea cases shall be adopted;

- For beam seas conditions (blue sector – see figure Figure 7.11): maximum transversal accelerations within beam sea cases associated with the exact correspondent longitudinal acceleration.

  Maximum vertical accelerations within beam sea cases shall be adopted;

- For quartering conditions (green sector – see figure Figure 7.11): concomitant transversal and longitudinal accelerations which generate the maximum resultant within quartering sea cases.

  Maximum vertical accelerations within quartering sea cases shall be adopted.

Finally, twelve combinations and 8 directions shall be adopted as indicated in Figure 7.12 and Figure 7.13:

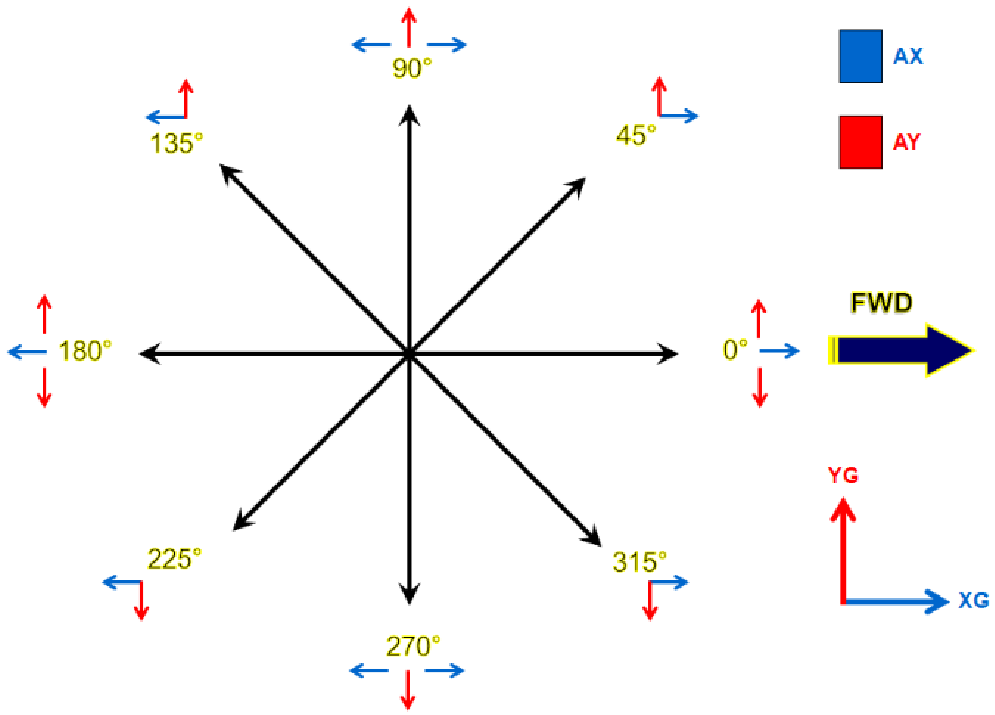


Figure 7.12 – Directions of incidence for Inertial Combinations

0° (head sea case)
(1) $a_{X,maxhead} + a_{y,corresp} + a_{z,maxhead}$
(2) $a_{X,maxhead} - a_{y,corresp} + a_{z,maxhead}$

45° (quartering sea case)
(3) $a_{R,maxquarter} + a_{z,maxquarter} = a_{X,quarter} + a_{y,quarter} + a_{z,maxquarter}$

90° (beam sea case)
(4) $a_{X,corresp} + a_{y,maxbeam} + a_{z,maxbeam}$
(5) $-a_{X,corresp} + a_{y,maxbeam} + a_{z,maxbeam}$

135° (quartering sea case)
(6) $a_{R,maxquarter} + a_{z,maxquarter} = -a_{X,quarter} + a_{y,quarter} + a_{z,maxquarter}$

180° (head sea case)
(7) $-a_{X,maxhead} + a_{y,corresp} + a_{z,maxhead}$
(8) $-a_{X,maxhead} - a_{y,corresp} + a_{z,maxhead}$

225° (quartering sea case)
(9) $a_{R,maxquarter} + a_{z,maxquarter} = -a_{X,quarter} - a_{y,quarter} + a_{z,maxquarter}$

270° (beam sea case)
(10) $a_{X,corresp} - a_{y,maxbeam} + a_{z,maxbeam}$
(11) $-a_{X,corresp} - a_{y,maxbeam} + a_{z,maxbeam}$

315° (quartering sea case)
(12) $a_{R,maxquarter} + a_{z,maxquarter} = +a_{X,quarter} - a_{y,quarter} + a_{z,maxquarter}$

Figure 7.13 – Detailing of Inertial Combinations

Where,

$a_{X,maxhead} = Maximum\ longitudinal\ acceleration\ within\ head\ sea\ cases$

$a_{Z,maxhead} = Maximum\ vertical\ acceleration\ within\ head\ sea\ cases$

$a_{Y,corresp} = Concomitant\ acceleration\ in\ Y\ direction\ for\ a_{X,maxhead}$

$a_{R,maxquarter} = Maximum\ horizontal\ acceleration\ which\ provides\ the\ maximum\ resultant\ within\ quartering\ sea\ cases$

$$a_{R,maxquarter} = \max\left(\sqrt{a_{x1}^2 + a_{y1}^2}, \sqrt{a_{x2}^2 + a_{y2}^2}, \cdots, \sqrt{a_{xn}^2 + a_{yn}^2}\right) = a_{x,quarter} + a_{y,quarter}$$

$a_{X,quarter} = Longitudinal\ acceleration\ associated\ to\ a_{R,max}$

$a_{Y,quarter} = Transversal\ acceleration\ associated\ to\ a_{R,max}$

$a_{Z,maxquarter} = Maximum\ vertical\ acceleration\ within\ quartering\ sea\ cases$

$a_{Y,maxbeam} = Maximum\ tranversal\ acceleration\ within\ beam\ sea\ cases$

$a_{Z,maxbeam} = Maximum\ vertical\ acceleration\ within\ beam\ sea\ cases$

$a_{X,corresp} = Concomitant\ acceleration\ in\ X\ direction\ for\ a_{Y,maxbeam}$

As stated in item 7.3.1, for Ultimate Limit States ULS-a and ULS-b final accelerations factors to be applied along combinations shall be adjusted by LRFD factors.

Conservatively, the gravity effect is always present for the horizontal directions during rotation motions. For these cases, it is assumed that the environment action is a pseudo permanent action multiplied by the environmental factor.

A less conservative approach may be considered provided it is agreed by CS and BUYER as well.

See below how the factors shall be applied:

Table 7.3 – ULS factors

Acceleration for ULS-a	Acceleration for ULS-b
$a_{Rx} = 0.7 \times 1.3 \times a_x$	$a_{Rx} = 1.3 \times 1.0 \times a_x$
$a_{Ry} = 0.7 \times 1.3 \times a_y$	$a_{Ry} = 1.3 \times 1.0 \times a_y$
$a_{Rz} = 0.7 \times a_z + 1.3 \times g$	$a_{Rz} = 1.3 \times a_z + 1.0 \times g$

a_{Rx} = *resulting factored acceleration associated to the direction "x";*

a_{Ry} = *resulting factored acceleration associated to the direction "y";*

a_{Rz} = *resulting factored acceleration associated to the direction "z";*

7.4.3.3 GREEN WATER

In case of green water effect on topsides structures, it shall be applied in accordance with GUIDELINE FOR FPSO GREEN WATER ANALYSIS [10].

7.4.4 ACCIDENTAL LOADS (A)

Actions related to accidental events, abnormal operations or technical failure. In general, are represented, but not limited to, by fire, blast and dropped object events.

Additional information can be found in item 7.7

7.5 IN-PLACE ANALYSIS

The in-place analysis shall include the follows design conditions.

Note: the unity check in any of the multi-columns elements shall be limited to 0.85 for in-place analysis (see item 7.6.4.2).

7.5.1 STATIC OPERATIONAL CONDITION (SOC)

Just dead weights in operation (structural, equipment, piping, electrical, instrumentation, safety and others), live loads and hull deflections (still water) shall be considered. Wind and wave loads shall not be considered.

This condition shall be used for monorails, trolley and others handling loads verification.

ULS-a limit state shall be followed without environmental loads as aforementioned. LRFD load factor applied for handling load (pull-in operation load, monorail etc) only shall be reduced to 1.2.

Material factor Ym = 1.15 shall be considered.

7.5.2 DESIGN OPERATION CONDITION (DOC)

The Design Operation Condition (DOC) refers to the structure under 1-year return period motions accelerations and wind. Operational dead weights (structural, equipment, electrical, instrumentation safety and others), live loads and piping loads, hull deflections, wind pressures and accelerations due to vessel motion shall be considered.

ULS-a and ULS-b limit states shall be followed.

Material factor Ym.= 1.15 shall be considered.

7.5.3 DESIGN EXTREME CONDITION (DEC)

The Design Extreme Condition (DEC) refers to structure under 100-year return period motions accelerations and wind. Operational dead weights (structural, equipment, electrical, instrumentation safety and others), live loads according to item 7.4.2.1 and piping loads, hull deflections, wind pressures and accelerations due to vessel motion shall be considered.

ULS-a and ULS-b limit states shall be followed.

Material factor Ym.= 1.15 shall be considered.

7.5.4 DESIGN SERVICEABILITY CONDITION (DSC)

This condition shall be used to verify the deflections of the structure. Dead weights in operation, live loads, with DOC wind and DOC wave loads shall be considered.

SLS limit state shall be followed.

Material factor Ym.= 1.0 shall be considered.

7.5.5 VORTEX SHEDDING

This analysis aims to verify vortex shedding effects caused by the wind in the structure in all conditions. To avoid resonance due to vortex shedding, the structural tubular of topsides modules and flare tower members shall be verified using the procedures presented in DNV RP C205 [35].

1-year return period wind shall be considered regardless of the condition.

If any reinforcement is required based on simplified VIV checking, a dynamic analysis shall be performed in order to avoid local reinforcements or modifications.

7.5.6 DAMAGE CONDITION (DAC)

This condition refers to the topsides structural verification for the exceptional events where the ship stability is relevantly affected. The structural design for this condition shall be performed for flooding and damage scenarios as indicated in I-RL-3010.2Q-1350-960-P4X-001 – MAXIMUM HEEL AND TRIM ANGLES ANALYSIS [17]. Heel and trim angles indicated below were used during the basic design and shall be updated according to detailing phase analysis.

For both scenarios heel and trim angles shall be applied concomitantly and associated with 1 year environmental loads. Post-ALS limit state shall be followed.

(1) Flooding – a tank is unintended flooded up to its capacity:

- Heel: 14.281°
- Trim: 0.858°

Material factor Ym.= 1.0 shall be considered. This event may be disregarded provided it is agreed with CS and submitted and approved by BUYER.

(2) Damage – one or more tanks are flooded due to a hull collision event:

- Heel: 10.199°
- Trim: 0.642°

Material factor Ym.= 1.25 shall be considered. Lower values in agreement with CS may be acceptable, provided they are submitted and approved by BUYER. This event may be disregarded provided it is agreed with CS and submitted and approved by BUYER.

7.5.7 HYDROTEST CONDITION (HTC)

In accordance with the latest Brazilian Regulation NR13 [43] dealing with Boilers, Pressure Vessels, Piping systems and Tanks, there is no more requirement for hydrotest at final location under qualified professional witness, this requirement is replaced by internal inspection at final location by approved inspector.

In case of future repair on equipment, full radiographic examination (100% RT) can be done instead of new hydrotest.

When full radiographic examination on equipment can be performed on site, no structural analyses are therefore envisaged for hydrotest condition.

Nevertheless, hydrotest condition shall be considered, case by case, where no radiographic examination is possible (there is no way to access all inspectable points needed for radiographic examination) and when test load may generate higher efforts than any other design condition.

7.5.8 GREEN WATER CONDITION

Green water verification shall be done according to the motion analysis report to be issued in the detailing phase and the GUIDELINE FOR FPSO GREEN WATER ANALYSIS [10]. A distributed hydrostatic pressure combined with all loads considered in Operation (DOC) and Extreme Condition (DEC), if during the detailing phase confirm the occurrence on these conditions. Otherwise, this analysis for one or both conditions can be disregarded.

ULS-a and ULS-b limit states shall be followed.

Material factor Ym.= 1.15 to be considered.

7.5.9 FATIGUE CONDITION (FTC)

For the simplified fatigue approach, the maximum double amplitude dynamic loads for fatigue condition are determined with 100-year return period motions and accelerations, to be associated with proper long term response Weibull distribution parameters.

Operational dead weights (structural, equipment, electrical, instrumentation safety and others), live loads according to item 7.4.2, piping loads, hull deflections (only wave hull-girder bending moment) and accelerations due to vessel motion (without the gravity effects in Z direction) shall be considered. The wind action shall be disregarded.

The Weibull shape parameter considered for elements above and at pancake level (first elevation) may be taken equal to 0.70.

The Weibull shape parameter *h* may be obtained from CS rules or based on a specific calibration submitted to BUYER and CS approval.

Average period of wave incidence considered is 10.08s based on DNV-CG-0129 [30]. So that, the total cycles for 25 years design life are 7.82 x 10^7.

Equation 1 – Average period

$$T_{average} = 4\ x\ Log_{10}(L) = 10.08s$$

If another Weibull shape parameter or number of cycles are used in the detailing phase, or if required by CS, this new value shall be justified and submitted to BUYER approval.

- **MODULES STRUCTURES**

For modules and main deck structures, fatigue analysis shall be performed. The simplified approach may be used as presented in DNV RP C203 [34].

A wave distribution based on METOCEAN DATA [15] as detailed in Figure 7.14 shall be considered. In case of METOCEAN DATA [15] is updated, waves distribution shall be adjusted accordingly.

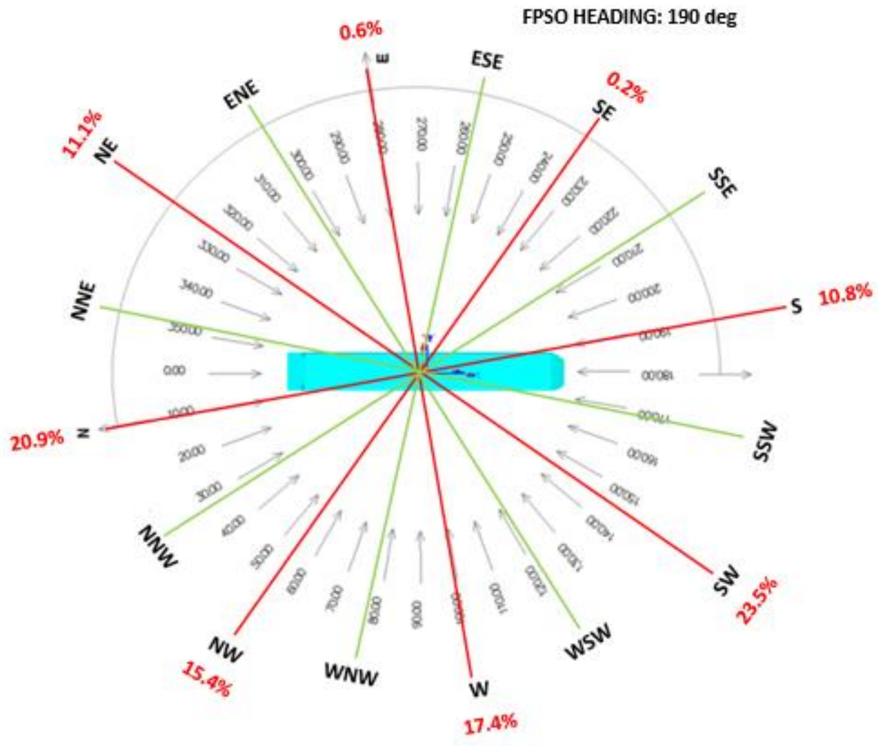


Figure 7.14 – Waves distribution – Campos Basin

If any reinforcement is required based on simplified fatigue analysis, a spectral analysis shall be performed in order to avoid local fatigue reinforcements.

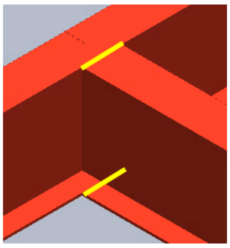
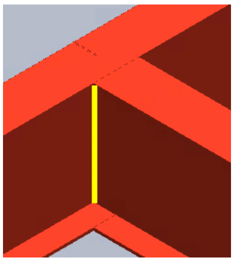
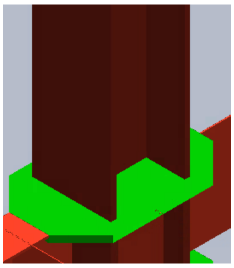
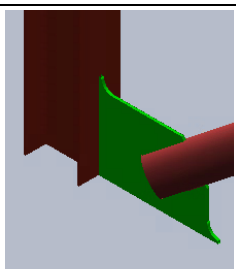
The spectral fatigue analysis may be performed assuming that the operational drafts (FPSO loading condition) have their own probability of occurrence during the operational phase. In the absence of further information, the FPSO load distribution indicated in the document GUIDELINE FOR FPSO GREEN WATER ANALYSIS [10] shall be used.

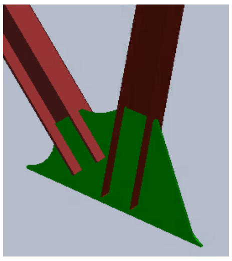
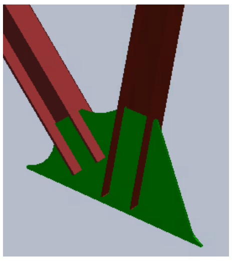
Both unimodal and bimodal sea states shall be taken into account for the spectral fatigue analysis. The data regarding the sea can be found in METOCEAN DATA [15].

In the specific case of PIG Launchers / Receivers and Production & Injection Manifolds module M-09, a spectral fatigue analysis shall be performed regardless of the results.

BUYER suggests the SN-Curves and SCFs shown in Table 7.4 for the fatigue analysis. SELLER is responsible for checking and confirming these parameters during the detailing design phase. These parameters may also be reduced as long as it is demonstrated by finite element analysis results in accordance with the CS methodology.

Table 7.4 – Basic SN-Curves and SCFs

Structural Detail	Description	SN-Curve	SCF
	I/H beams directly connected to others structural items – Flange	W2 (1)	1.0
	I/H beams directly connected to others structural items – Web	W3	1.0
	I/H columns directly connected to others structural items	F1 (1)	1.0
	Tubular braces and columns connected through gusset plate with favourable geometry and located above pancake	D	2.3

Structural Detail	Description	SN-Curve	SCF
	I/H columns connected through gusset plate and located at Multi-columns Supports	D	1.8
	I/H braces connected through gusset plate and located at Multi-columns Supports	D	2.1

(1) SN-Curve may be adapted depending on the section height and width.

Others details not covered by Table 7.4 shall be evaluated case by case and proposed parameters submitted for BUYER approval.

Target fatigue life shall be in accordance with the Table 7.5

Table 7.5 - Target Fatigue Life

Structural Components	Safety Factor	Target Fatigue Life (years)
Secondary Structure Joints	1.0	25
Primary Structure Joints	2.0	50
Module / Hull Connections	2.0	50
Module/ Hull Connections Non-Inspectable Parts	10.0	250

For structural joints where passive fire protection (PFP) is necessary, intumescent paint shall be applied as a PFP coating to avoid module/hull connections non-inspectable parts.

- **FLARE TOWER STRUCTURE**

The fatigue life of flare tower's main structure shall be determined using a spectral fatigue analysis approach.

Flare tower fatigue analysis shall consider the damage due to wind gustiness and the damage due to vessel motions. Total fatigue life shall be determined by their combination according to DNV RP C203 [34].

7.6 INSTALLATION ANALYSIS

This section describes the installation design analyses to be performed during the Detailing Phase.

Installation analysis shall include the following design conditions:

7.6.1 LIFTING CONDITION (LIC)

Lifting analysis shall be according to DNV ST N001 [36].

The structural model CoG and lifting load, including analysis contingencies, shall be monitored and consistent with the project Weight Control Report. Differences between the structural model and Weight Control Report greater than 3% for total lifted gross weight and 0.5 m on both horizontal directions for CoG shall be justified and actions deemed necessary shall be taken.

If the module weight, measured after the weighing, is out of a margin of error (e.g. load cell error range) when compared to the gross weight (dry weight with contingencies) applied on the lifting analysis, the analysis shall be updated in order to check the structural adequacy for new loading scenario. Otherwise, no analysis update shall be done.

The same procedure shall be considered for CoG position (limit of 0.5 m on both horizontal directions).

In any case, the weighing report shall be attached to the lifting design report or a specific document consolidating these reports and evaluations shall be planned and issued prior to the lifting campaigns. The lifting design report will be only considered approved after the module weighing.

The factor of Centre of Gravity Inaccuracy (CoGI) may be taken as 1.10. If SELLER adopt any different factor than 1.10, or if required by CS, this new CoGI factor shall be justified and shall be submitted for BUYER approval.

The modules and flare tower lifting analyses in the Basic Design considered the use of:

i) one hook;

ii) a single crane;

iii) four vertical cables (except flare tower);

iv) spreader bars (except flare tower);

v) inshore condition;

No horizontal and in-plane loads are applied to the referred structures.

If any different condition for the lifting of modules and flare tower is adopted, the SELLER is responsible for all structural adjustments required.

SELLER is fully responsible for the lifting factor definition. Factors such as tilt and yaw shall be confirmed during the detailing phase according to the characteristics of lifting cranes and any other installation condition. All lifting factors shall be confirmed by the CS and MWS.

Design of temporary guides and bumpers, or auxiliary structures to make the lifting procedure feasible for module or flare tower installation, shall be according to DNV ST N001 [36]. Modules columns and other members chosen to support guides and bumpers shall be temporarily braced accordingly.

ULS-a limit state shall be followed.

Material factor Ym.= 1.15 to be considered.

7.6.2 DESIGN TRANSIT CONDITIONS (DTC)

For topsides structures, design transit condition shall be verified for two different phases:

- Transport from the construction site to the shipyard on a transport barge (DTC 1);
- Transit of the FPSO from the shipyard to the installation site, with all structures installed onto (DTC 2).

If it is necessary to include sea fastening elements for (DTC 1) phase, in order to reproduce the real condition, SELLER shall analyse the structure in two steps. The 1st step only with module self-weight and without sea fastening elements. The 2nd step, only with environmental loads (wind pressures and accelerations due to transport barge motion), including the sea fastening elements in this analysis.

ULS-a and ULS-b limit states shall be followed.

Material factor Ym.= 1.15 to be considered.

In the absence of information on the duration of the transit phase, BUYER proposes to add 0.5 years to the on-site fatigue design life.

7.6.3 **LOAD OUT CONDITION (LOC)**

To cover the load out operation, the maximum expected vertical deflection of one support of the module shall be considered combined with the dry dead weights (structural, equipment, piping, electrical, instrumentation, safety and others).

The value defined above is the maximum allowed misalignment between the barge and shore skid ways, and shall be confirmed by SELLER based on the load out procedure to be developed during the Detailing Phase, according to recommendations from CS.

In case of considering SPMT (Self-propelled Modular Transporter) for load-out operation, its configuration and compensation loads distribution shall be properly represented in structural model.

ULS-a limit state shall be followed.

Material factor Ym.= 1.15 to be considered.

7.6.4 SET DOWN (Modules Assembly on Hull)

7.6.4.1 STATIC DRY CONDITION (SDC)

Just dead dry weights (structural, equipment, piping, electrical, instrumentation, safety and others) and hull deflection (still water) shall be considered.

Live loads, wind and wave loads shall not be considered.

This condition shall be used to assess the contact between the pancake beams and the top of the multi-columns, during lifting operation. If a tensile force is observed in a support point, it indicates the possibility of non-contact between the structure and the corresponding multi-column point at the moment of module settlement. In this case, the SELLER shall provide a proper structural solution to this problem.

Boundaries conditions of multi-columns shall be adjusted to simulate the real condition of these elements at module settlement. Columns and braces shall not absorb tension and moments from modules structure.

ULS-a limit state shall be followed.

Material factor Ym.= 1.15 to be considered.

7.6.4.2 PREMISES TO BE ADOPTED DURING THE LIFTING CAMPAIGN

The structural analysis assumes that all support points to main module beams (top of columns and diagonals) are levelled within a level of tolerance such that the main module beams are expected to touch all those points at set down operation. If, during the integration phase, the SELLER verifies that this condition will not be completely reached, additional structural analyses shall be carried out to evaluate the effects of settlement on members of the structure and possible solutions. Static Dry Condition (SDC) premises shall be taken into account on this evaluation.

In order to minimize reinforcements during the integration phase, the unity check in any of the multi-columns elements shall be limited to 0.85 for in-place analysis (see item 7.5).

If a different limit is proposed, it shall be submitted to BUYER approval.

In this respect, in case a non-touching point is observed after the lifting procedure, a re-analysis for Static Dry Condition (SDC) without the non-touching muti-columns element(s) shall be performed and follow guideline shall be complied:

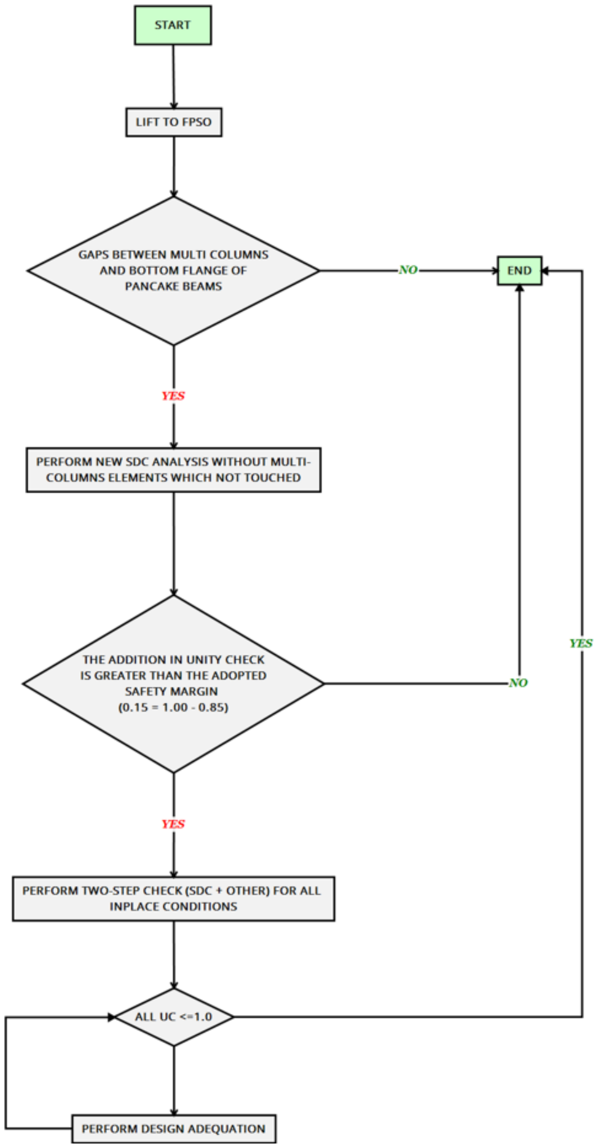


Figure 7.15 – Flowchart for set down

In addition, SELLER shall issue a set down report after the lifting procedure of each module presenting the touching assess between the pancake structure and multi-columns elements.

SELLER shall provide special devices and installation procedures in order to mitigate misalignments and mismatch effects between module structures and multi-columns.

The construction tolerances for the support points of the topsides structures are defined in GENERAL NOTES FOR TOPSIDES STRUCTURES [1].

7.7 ACCIDENTAL ANALYSIS

This section describes the accidental design analyses to be performed during the Detailing Phase.

Accidental analysis shall include the following design conditions:

7.7.1 BLAST ACCIDENTAL CONDITION (BAC)

Based on topside overpressure design results obtained in the Explosion Study, the topside structure shall be assessed according to GUIDELINES FOR STRUCTURAL DESIGN AGAINST BLAST LOADS [7].

Pre-ALS limit state shall be followed.

Material factor Ym.= 1.0 shall be considered. Lower values in agreement with CS may be acceptable, provided they are submitted and approved by BUYER.

7.7.2 DROPPED OBJECT CONDITION

Dropped object verification shall be carried out according to GUIDELINE FOR DROPPED OBJECT STRUCTURE ANALYSIS [13].

Pre-ALS limit state shall be followed.

Material factor Ym.= 1.0 shall be considered. Lower values in agreement with CS may be acceptable, provided they are submitted and approved by BUYER.

7.7.3 FIRE-STRUCTURE ANALYSIS

Based on Fire Propagation and Smoke Dispersion Study results, the need of Passive Fire Protection for the topsides structures shall be assessed according to FIRE-STRUCTURE ANALYSIS FOR PASSIVE FIRE PROTECTION DESIGN [8].

7.7.4 CRYOGENIC PROTECTION

Based on the High Content CO_2 Gas Leakage Embrittlement Study results, the need of Cryogenic Protection for the topsides structures shall be assessed according to GUIDELINES FOR STRUCTURAL ANALYSES FOR CRYOGENIC PROTECTION DESIGN [9].

8 MODULES AND FLARE TOWER FOUNDATIONS AND MULTI-COLUMNS GUSSET PLATES ANALYSES

8.1 MODULES FOUNDATIONS

Topsides modules foundations can be read as the reinforced region of the hull structure up to the upper deck plate (main deck plate) underneath the multiple-columns and flare tower bases (up to EL 40800mm).

On the purpose to send the most appropriate information for their design, SELLER shall attach a table to the respective module design report, containing all the reaction forces at the point P_0 according to Figure 8.2 (in global coordinate system) for all load combinations listed in item 7.5. The presentation of the reaction tables shall follow the guidelines provided in Figure 8.1. Associated internal forces at points P1/P2 shall be provided as well.

These load combinations shall not be calibrated by LRFD factors since the hull structure elements are designed for WSD (Working Stress Design) criteria.

MAXIMUM DEC REACTIONS (1)								
MAXIMUM	SUPPORT	LOAD	F_X [kN]	F_Y [kN]	F_Z [kN]	M_X [kN*m]	M_Y [kN*m]	M_Z [kN*m]
F_X	A	100	- 773	2	1 809	- 10	- 37	0
F_Y	B	101	3	1 475	3 380	- 29	- 6	- 6
$F_{Z,MAX}$	C	102	- 491	15	4 086	- 38	- 27	1
M_X	D	103	- 23	40	661	- 93	0	2
M_Y	E	104	720	- 8	661	18	54	- 1
M_Z	F	105	7	- 731	840	65	- 7	- 9
$F_{Z,MIN}$	G	106	12	- 8	- 977	34	0	2

(1) Load combinations shall not be calibrated by LRFD factors for this purpose

Figure 8.1 - Reactions summary table for each design condition

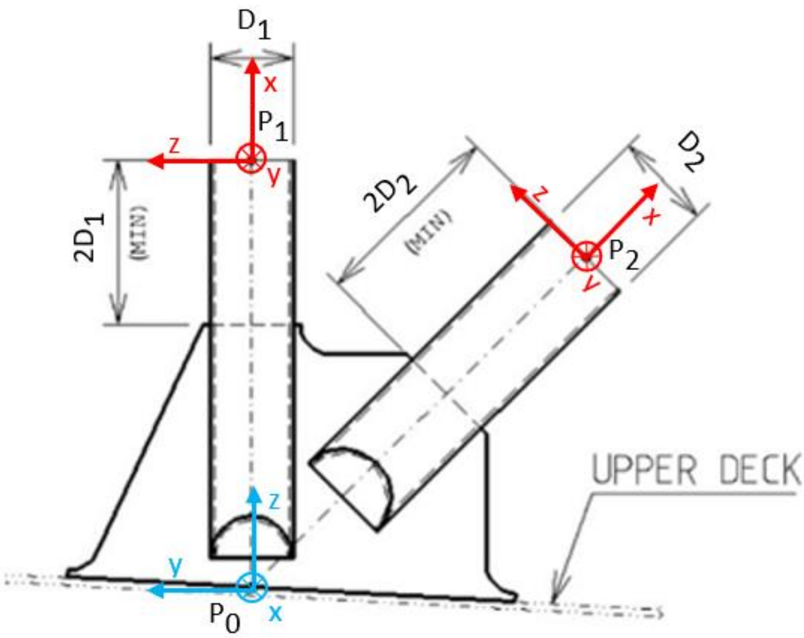


Figure 8.2 – Typical Section

8.2 MULTI-COLUMNS GUSSET PLATES

Stress analyses of topsides modules bottom gusset plates shall cover the follow cases in addition to the ones shown in Figure 8.1. However, all analysed cases shall include the LRFD factors.

1. Maximum axial load of each element connected (both maximum positive and negative shall be considered);

2. Maximum absolute shear load Y (local system) at points P1 / P2 of each element connected;

3. Maximum absolute shear load Z (local system) at points P1 / P2 of each element connected;

4. Maximum absolute bending moment Z (local system) at points P1 / P2 of each element connected;

5. Maximum absolute bending moment Y (local system) at points P1 / P2 of each element connected;

Depending on the structural configuration, some cases may be disregarded. Furthermore, these analyses may be optimized taking into account the combination of the follow variables:

1) Connection types (single column, transversal brace + column, longitudinal brace + column and so on);

2) Structural profiles of the braces and column which compound the connection;

3) Thickness of gusset plates;

4) Incoming angle of the transversal braces.

Buckling and fatigue shall also be analysed for both foundation and gusset plates.

9 EQUIPMENT FOUNDATIONS AND PACKAGES

Besides normal verification, all equipment support shall be verified for the maximum heeling and trim, as well as the extreme loading, according to the motion analysis report to be issued in the detailing phase and the values defined in the CS Rules.

Packages structures as Sulphate Removal Unit (M-11) and Ultrafiltration Unit (M-15) or any other package with two or more elevations shall be treated as primary structure and also designed for fatigue condition in accordance with premises indicated in item 7.5.9.

Functional loads, test loads, equipment vibrations and environmental loads shall be taken into account. SELLER shall provide structural solutions for dynamic equipment foundation which avoid or minimize the possibility of the resonance effect with the surrounded structure.

For compressor and turbo generator skids, it is mandatory to perform a fully equipment/skid FEM dynamic analysis with shell or solid elements, taking into account the correct foundation (Anti-Vibration Mountings – AVM) and piping connections stiffnesses, to ensure that no resonance effects or large deformations occur.

It is SELLER responsibility to supply and install any wedge or plate needed to level the equipment skids that will be installed directly over the hull and modules decks.

For a better understanding of what is defined as equipment support for analysis and structural categorization purposes see Figure 9.1. Exceptions are made to relevant packages structures as aforementioned.

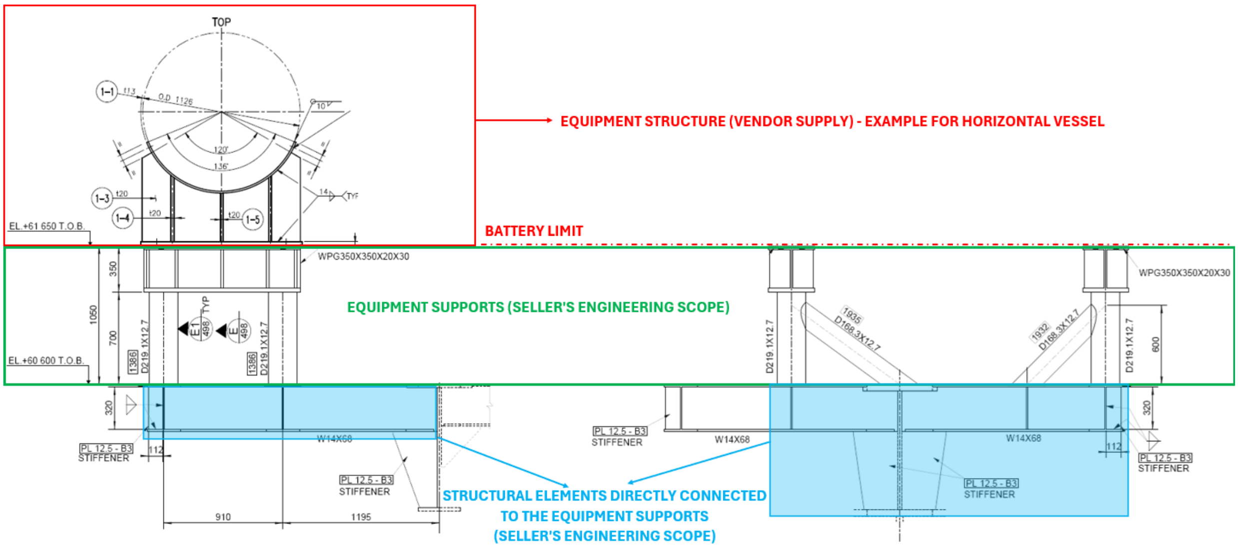


Figure 9.1 – Equipment support definition

10 FLARE TOWER

Flare tower structure, including the necessary supports and hull structural reinforcements, shall be evaluated for all design conditions, including the Unit's transit from the shipyard to installation site.

The structural analysis shall consider the environmental loads as stated in 7.4.3 and thermal loads.

Temperature gradients along flare tower length shall be taken from a Flare Radiation Report, to be issued during the detailing phase, in order to confirm the dimensions of the heat shield

No live loads shall be considered in the flare tower structural analysis.

For flare tower, the horizontal lifting and the upending shall be considered. The entire flare tower, including empty equipment and piping, shall be lifted from the quayside or transport barge and installed onto Units by means of an inshore lift by the top of Flare Tower (lifting padeyes at the top of structure). If SELLER performs any modification in this lifting analysis philosophy, it is SELLER's scope of work to make all necessary adjustments to the structural elements to ensure that the Flare Tower withstands the imposed loads by the new design lifting condition.

SELLER shall provide and supply any additional auxiliary and temporary structure, outfitting and access required for the lifting installation and integration of Flare Tower. After lifting campaign, the additional auxiliary and temporary structure applied only for lifting operation shall be removed.

The natural frequencies of the flare tower shall be evaluated and its dynamic integrated behaviour with the hull structure shall meet the requirements indicated in HULL STRUCTUTAL REQUIREMENTS [12].

11 PIPING SUPPORTS

Piping supports shall be designed according to static and dynamic loads provided by the piping discipline at the Detailing Phase.

In addition, SELLER shall evaluate the modules main structure according to follow two steps and remarks:

Step #1: The structural analysis of primary structure shall be performed with the piping loads (including inertial loads), obtained from Weight Control Report, applied as loads distributed along the topsides module structure levels. Piping supports and flexible piping loading shall be disregarded;

Step #2: Applying the numerical model used in the primary global analysis, piping supports and their structural foundation shall be added, designed and detailed considering the flexible piping loadings (thermal, inertial and static loadings), where the loads from the static loadings (piping stress loadings) shall be deducted from the loads indicated in step #1 (primary global analysis). In this case, after all deduction, the loadings of step #1 shall remain equal to values presented in Weight Control Report.

Follow remarks shall be considered:

1. Only piping supports with loading greater than 50 kN (resultant force in operational condition) shall be take into account in the numerical model;
2. The module primary structure shall also be assessed by the numerical model presented in step #2;
3. In the step #2, only the stiffness of the secondary structure which the piping support is directly attached may be considered in the strength analysis. If any other secondary structure is applied in the numerical model, these structural elements shall be considered as primary structure;
4. Flexible piping loading shall be in accordance with the environment condition and LRFD criteria applied in the structural analysis, e.g. DOC, DEC etc;
5. Flexible piping loads may be disregarded for damage, blast and fatigue conditions;

6. Loading combinations regarding to water hammer effect and friction loads shall be foreseen in the structural design of piping supports only;

7. It is recommended that the piping loads components that rules the design be aligned according to the environmental load condition (head sea, beam sea and quartering) used in the strength analysis.

For a better understanding of what is defined as piping support for analysis and structural categorization purposes see Figure 11.1.

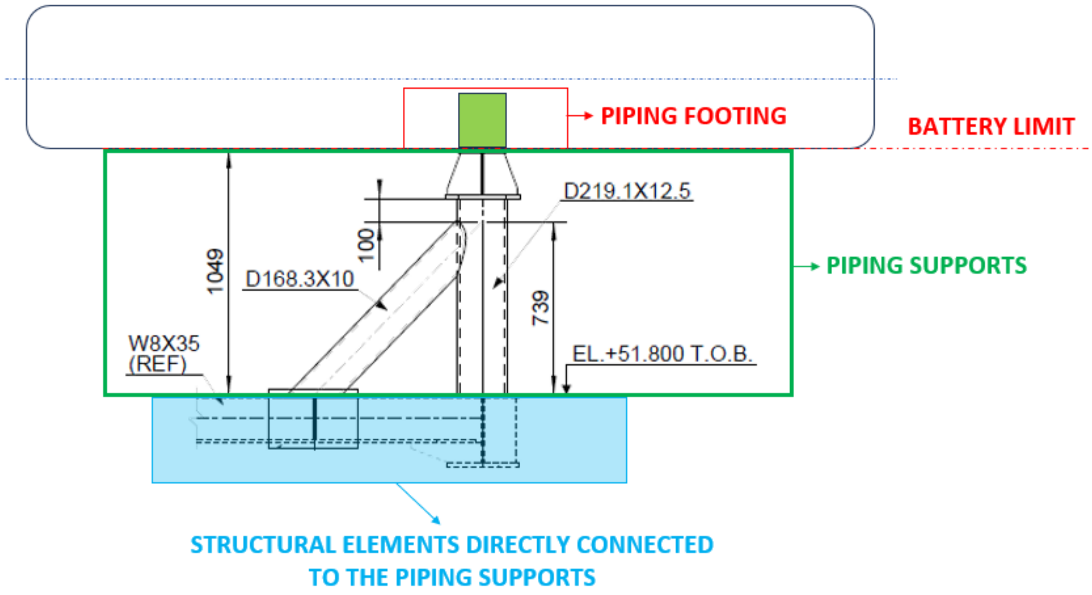


Figure 11.1 – Piping support definition

12 STRUCTURAL WEIGHT

Structural steel weight shall be kept under control by SELLER during the project. Structural, arrangement or any other modification that represent a relevant weight increase shall be properly detailed and justified by SELLER.

13 DOCUMENTATION

Each design report issued by the SELLER shall contain at least the following items, but not restricted to:

- Strength Analysis (In-Place and Transit):
  - Documents used as reference (rules and design documents);
  - Design criteria;
  - Material properties;
  - Boundary conditions and member releases;
  - Geometric properties of elements;
  - Basic load (Description and applied value);
  - Load combination;
  - Load case and load combination summary;
  - Summary of reactions (forces and moments);
  - Maximum and allowable deflection (vertical and horizontal);
  - Members code-check list and pictures;
  - Gussets and main connections design;
  - The complete structural model with loadings and load combinations (electronic file) shall be attached to the design report;
  - Sea-fastening design (only for transportation analysis);
  - Design spreadsheets and computational tools adopted in the structural analysis, such as: data importation/exportation tools or data manipulation tools not commercially available.

- Fatigue Analysis:
  - General description;
  - Fatigue loads and combinations;

- Fatigue curves defined for the analysis;
- SCFs adopted from literature or calculation;
- Stress range and damage calculation;
- Results;
- The complete structural model with loadings and load combinations (electronic file) shall be attached to the design report;
- Design spreadsheets and computational tools adopted in the structural analysis, such as: data importation/exportation tools or data manipulation tools not commercially available.

- Lifting Analysis:
  - Design criteria;
  - Lifting factors;
  - Boundary conditions and member releases;
  - Weighting report;
  - Sling reactions;
  - Members code-check and pictures;
  - Padeye and attachments design;
  - The complete structural model with loadings and load combinations (electronic file) shall be attached to the design report;
  - Design spreadsheets and computational tools adopted in the structural analysis, such as: data importation/exportation tools or data manipulation tools not commercially available.

During the detailing phase, all BUYER comments to the submitted documentation shall be treated and extended to all other documents related to the same subject, whenever applicable.

BUYER can ask for other items that judges necessary.