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Structural Analysis of the Foundation for the Launch and Recovery System (LARS) on Construction Supply Vessel (CSV)

Abstract

Modern marine operations increasingly rely on specialized technical systems that ensure safe and efficient work in demanding sea conditions. Among these systems, a particularly important role is held by Launch and Recovery Systems (LARS) – systems used for deploying and retrieving underwater vehicles and equipment. Although the concept may appear simple, the execution is technically and operationally complex, as the system must function reliably under variable and often unfavorable offshore conditions.

Importance of these systems extends beyond their technical functionality, as they directly influence the design and structural dimensioning of the supporting ship structure.

In this work, the focus is placed on the structural analysis of the LARS foundation, with the aim of determining the capability of the supporting structure to withstand operational and dynamic loads and thus ensure the long-term safe operation of the system.

Keywords: LARS, structural design, FEA

1. Introduction

To establish a clear link between the general concept of the system [1], its actual implementation on the vessel, and its structural integration, the configuration of the LARS system on the CSV vessel, Figure 1 is described below.



Figure 1. Graphical representation of the LARS system

1.1. LARS on CSV vessel

The LARS system's, combined cable (umbilical) is transferred from the winch (1) over the sheaves (2) located below the main deck through protective pipes (3), and then further over the sheave system (4) positioned below the 4th superstructure deck towards the LARS cranes (5), Figure 2.

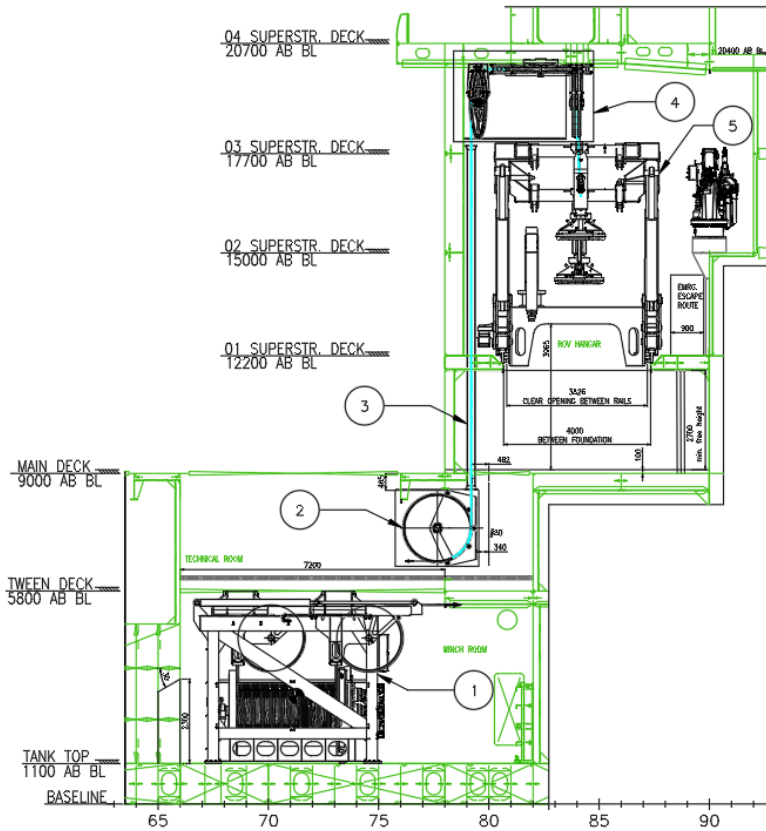


Figure 2. Side view of LARS system

The cranes are positioned inside the ROV hangar, Figure 3, 3000 mm above Main Deck, on transverse rails that allow horizontal movement. This arrangement provides free space beneath them for the storage, preparation, and handling of ROVs. The cranes are arranged symmetrically about the ship's longitudinal axis.

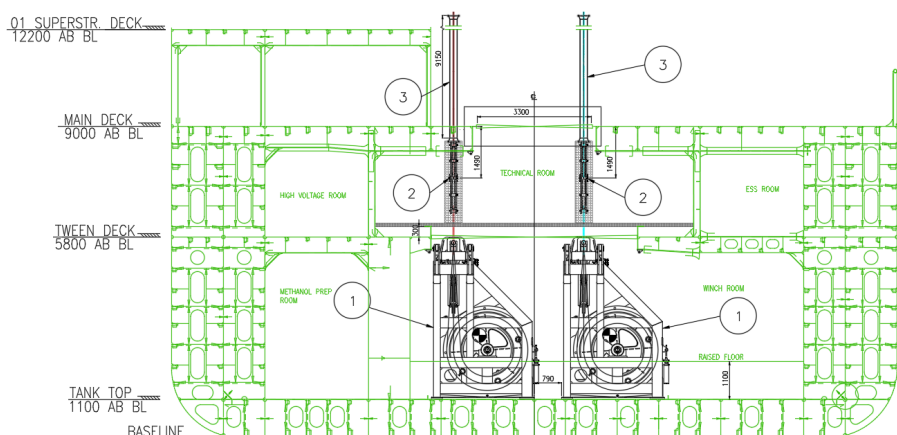


Figure 3. Transverse section of the crane position

The cranes are A-frame type units, Figure 4 with Safe Working Load (SWL) of 25 tonnes. They are equipped with an Active Heave Compensation (AHC) system. Due to their lifting capacity, the cranes transfer significant loads to the supporting structure during operation.

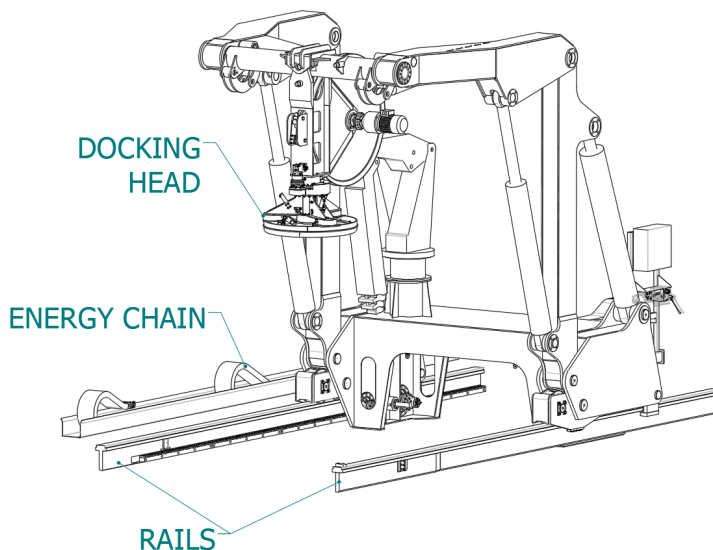


Figure 4. Isometric view of the crane

After their operational position is defined, foundation design and integration are carried out accordingly.

2. Preliminary design

In addition to the previously described layout of the entire system, additional input parameters provided by the vessel owner and equipment manufacturer affected the design and integration of the foundation, namely:

- ◇ Minimum required clear height below the consoles: 2700mm
- ◇ Rail spacing: 4000mm
- ◇ Required opening height for the ROV gate
- ◇ Uninterrupted continuity of the rails

The crane foundation, Figure 5 is configured as two box-type cantilever structures supported on the hangar bulkheads.

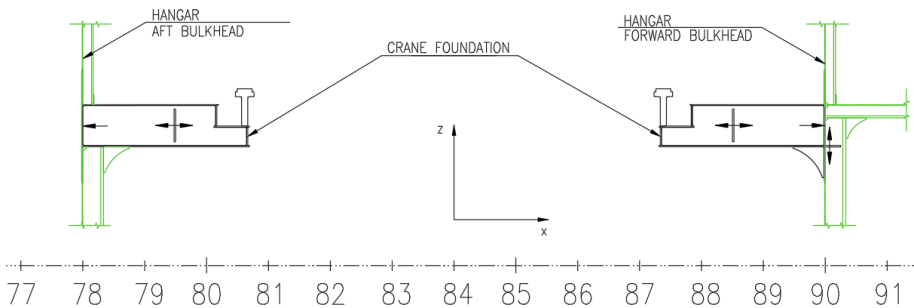


Figure 5. Typical cross section of the foundation

The cantilevers, Figure 6 are 1600 mm wide, with a variable depth: generally, 400 mm, reducing to 200 mm in the rail area where less section height is available given the stated constraints and the installed crane position.

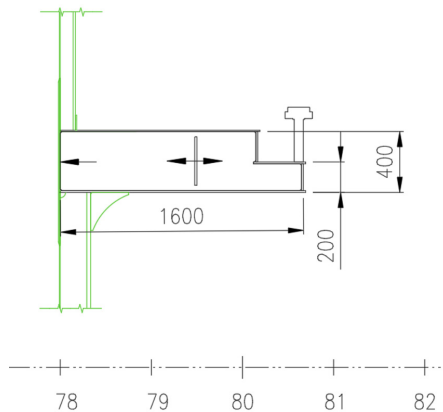


Figure 6. Cantilever dimensions

Integration of the crane foundation into the surrounding ship structure is achieved by:

- ◇ aligning the top plate of the box-type cantilever with the level of the first superstructure deck.
- ◇ Brackets inside the cantilevers are spaced to match the standard longitudinal frame spacing of 600 mm
- ◇ The cantilever geometry is adjusted locally in the area of the ROV doors to suit door frame
- ◇ At the forward cantilever, at frame 90 on the hangar bulkhead, additional stiffeners are inserted between vertical stiffeners to provide supplementary shear transfer into the supporting structure

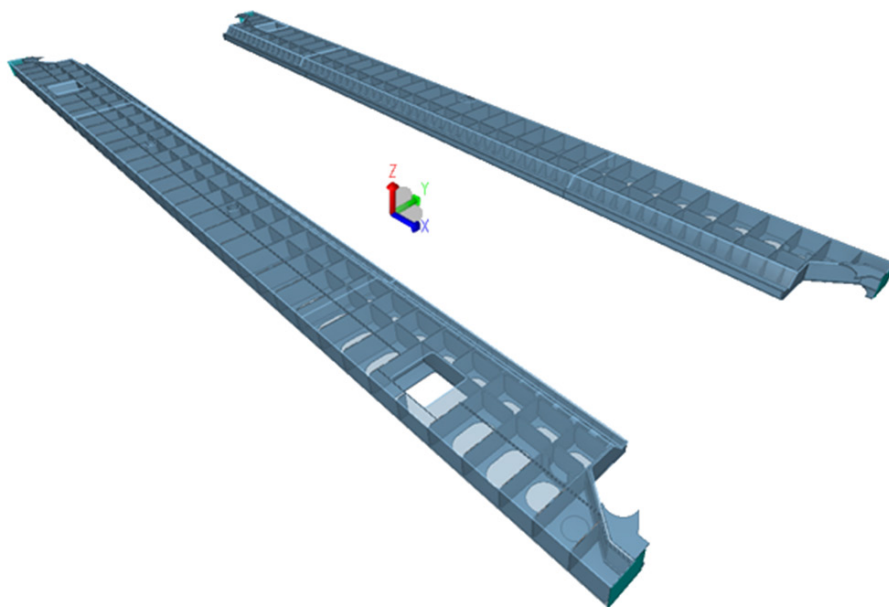


Figure 7. Isometric view of the preliminary crane foundation

With the foundation concept, Figure 7 defined and its constraints identified, the next step is to prepare the computational model and perform its analysis.

3. Structural analyses of LARS foundation

A linear static analysis [2] was performed using the structural finite-element [3] software Sesam GeniE V8.10-01, developed by DNV, [4]. A partial model, Figure 8 was made, extending longitudinally from frame 70 to frame 98, transversely from side to side, and vertically from 5800 AB BL to 23100 AB BL.

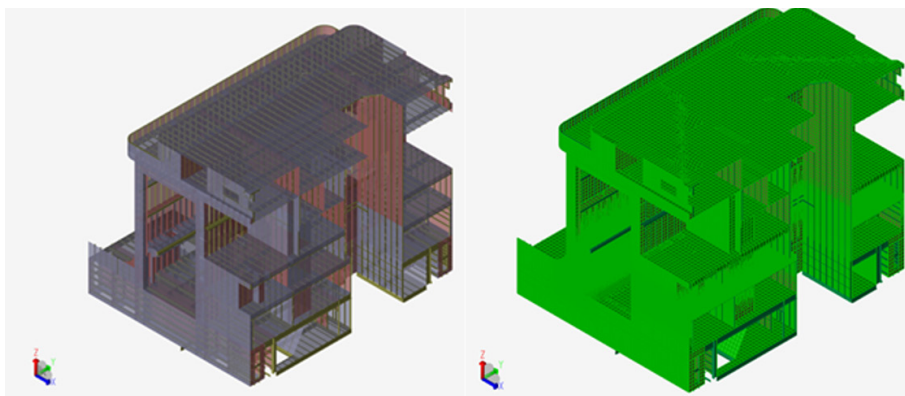


Figure 8. isometric view of partial model

The LARS foundation, Figure 9 was modelled in full, as it constitutes the primary region of interest. Surrounding hull and superstructure elements were included only to the extent required to ensure realistic structural support for the cantilevers.

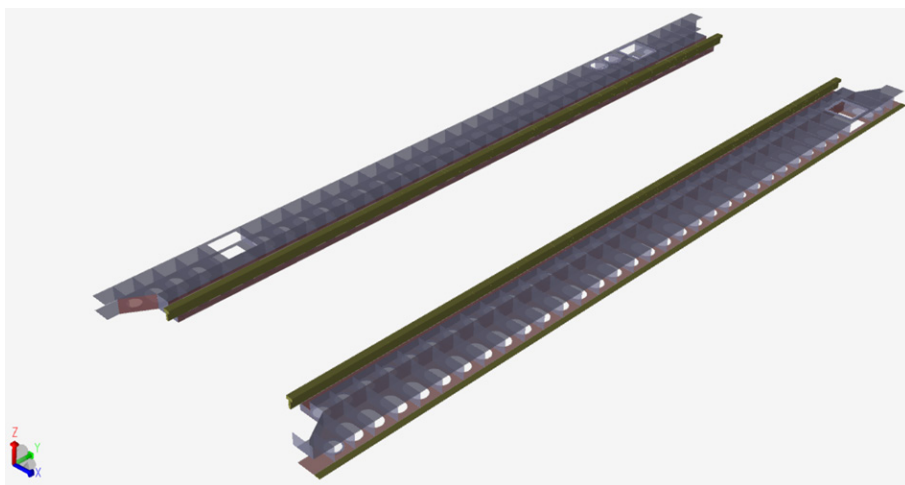


Figure 9. Isometric view of modeled crane foundation

The model utilises 2D shell elements for plating and beam elements where appropriate, while the foundation region itself is modelled exclusively using shell elements with one exception – the rails, which were modelled as beam elements since this was required for load application.

The structural model was analysed using a refined 50x50 mm mesh in the cantilever regions, while the remaining structure was meshed with 300x300 mm elements. Mesh refinement was applied progressively towards critical areas, Figure 10.

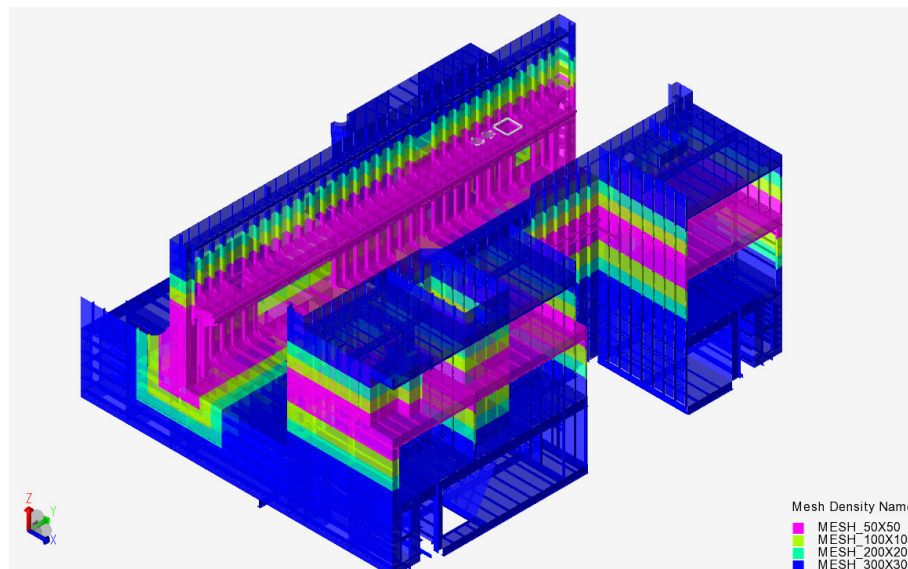


Figure 10. Mesh refinement

Due to the model extent and the distance from the region of interest, boundary nodes at model ends were coupled via rigid links to a master node with prescribed boundary conditions, Figure 11. This approach models end sections as rigid bodies, effectively approximating the stiffness of the remaining ship structure. This means that all structural elements - transverse bulkheads, girders, and deck and platform, longitudinals along the height - at the boundary frames R70 and R98 are fixed against translation and rotation, while the rest of the structure within those modelling boundaries, including decks, platforms, outer shell plating, and other secondary elements, is left free for translations and rotations.

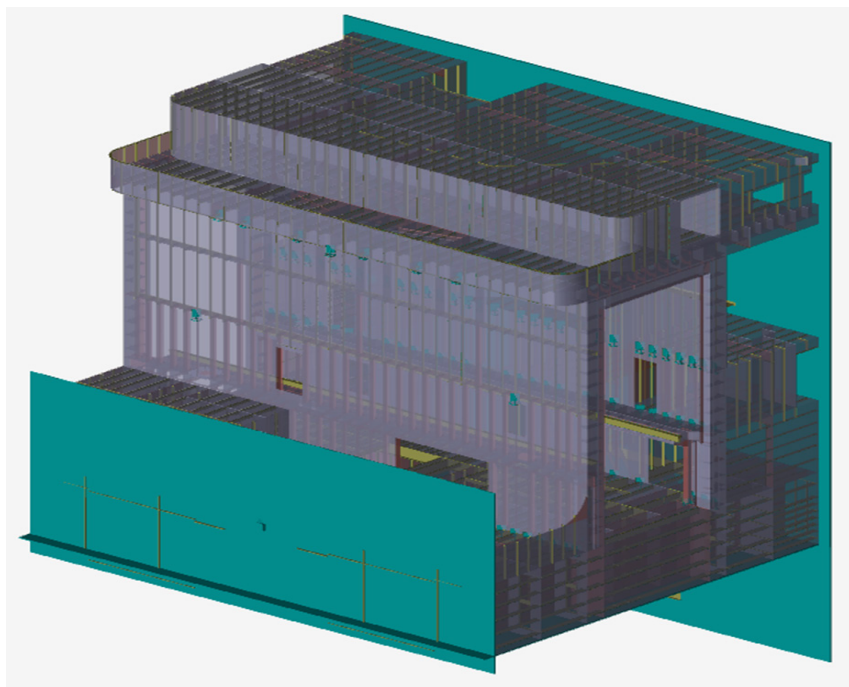


Figure 11. Boundary conditions

3.1. Loads

The structural loads are divided into the following groups:

- ◇ Operational loads – static and dynamic loads resulting from crane operation
- ◇ Inertial loads – the effect of acceleration fields acting on the mass of the cranes and supporting structure due to ship's motion in waves
- ◇ Permanent (static) loads – the self-weight of the structure and the weight of the cranes

In addition to these load groups, the load cases are also defined with respect to the crane positions and their operational states. Four positions/operational cases are defined, Figure 12.

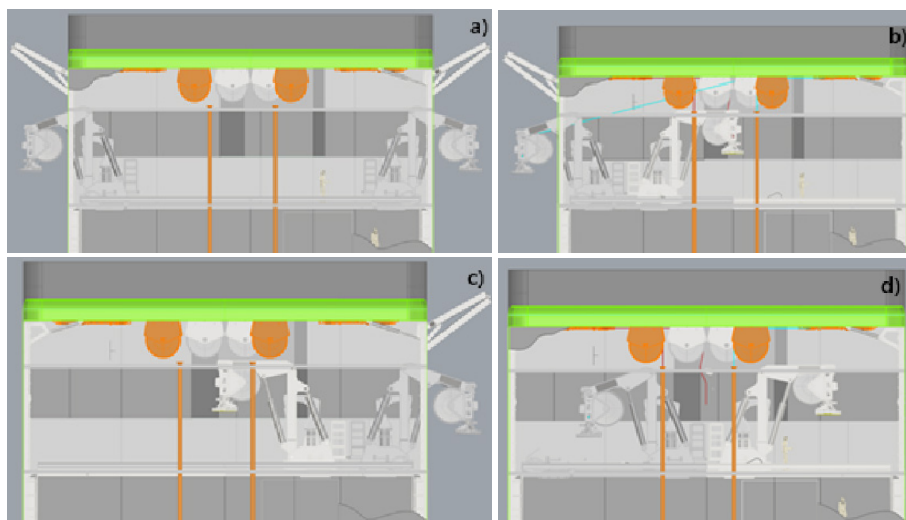


Figure 12. Defined crane positions/load cases, a) both cranes operational b) portside crane operational, starboard crane parked next c) starboard crane operational, portside crane parked next d) both cranes parked in CL

Operational loads [5], provided by the supplier, are defined for six support points, Figure 13. Four supports (AI, AII, BI, BII) transfer vertical and longitudinal loads through sliding pads and wheels, while two locking pins (CI, CII) transfer transverse horizontal loads during ROV handling. Load cases are defined in four tables and vary with the docking head rotation angle.

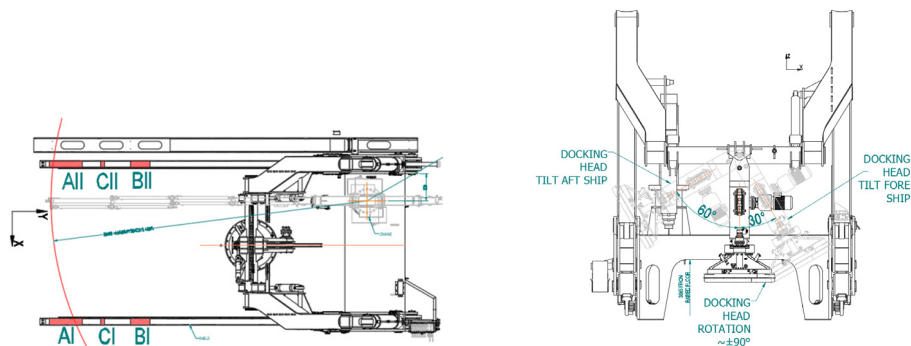


Figure 13. Operational loads

Table 1. Operational loads

Case 1: Acting forces are based on SWL 25 Te and dynamic factor 2. Docking head tilt 60 deg AFT ship. Point A, B – wheels and sliding pads Point C – locking bolts				Case 1a: Acting forces are based on SWL 25 Te and dynamic factor 2. Docking head tilt 30 deg FORE ship. Point A, B – wheels and sliding pads Point C – locking bolts			
Load ID	Fx [kN]	Fy [kN]	Fz [kN]	Load ID	Fx [kN]	Fy [kN]	Fz [kN]
AI	-440	0	-630	AI	0	0	-130
AII	0	0	650	AII	250	0	-800
BI	0	0	615	BI	-20	0	-100
BII	75	0	-630	BII	0	0	700
CI	0	-540	0	CI	0	-680	0
CII	0	1000	0	CII	0	-220	0

Case 2: Acting forces are based on SWL 25 Te and dynamic factor 2. Docking head tilt 0 deg Point A, B – wheels and sliding pads Point C – locking bolts				Case 3: Acting forces are based on weight of A-frame and weight of TMS+ROV+SKID. No dynamic factor added. Point A, B - wheels and sliding pads			
Load ID	Fx [kN]	Fy [kN]	Fz [kN]	Load ID	Fx [kN]	Fy [kN]	Fz [kN]
AI	-20	0	-720	AI	-20	0	-380
AII	20	0	-720	AII	20	0	-380
BI	-20	0	545	BI	-20	0	180
BII	20	0	545	BII	20	0	180
CI	0	240	0				
CII	0	240	0				

According to DNV rules, the crane is classified as heavy equipment. Therefore, the structural assessment must include inertial loads induced by vessel motions. Table 1 defines the load cases based on envelope accelerations.

Table 2. Accelerations for inertial load assessment

	Load combination	a_{x-U}	a_{y-U}	a_{z-U}
1.	Head sea 1	a_{x-env}	0	$a_{z-env-pitch}$
2.	Head sea 2	a_{x-env}	0	$-a_{z-env-pitch}$
3.	Beam sea 1	0	a_{y-env}	$a_{z-env-roll}$
4.	Beam sea 2	0	a_{y-env}	$-a_{z-env-roll}$
5.	Oblique sea 1	$0.6 a_{x-env}$	$0.6 a_{y-env}$	a_{z-env}
6.	Oblique sea 2	$0.6 a_{x-env}$	$0.6 a_{y-env}$	$-a_{z-env}$

The table specifies six loading cases; however, for foundation analysis only the governing combinations relevant to the console supports were considered, i.e. those in which the vertical acceleration component negative.

The crane mass specified by the supplier is 29.506 t. For structural analysis purposes, a mass of 30 t was used. Finally, depending on the crane position, slewing of the crane docking head, and combination of parallel or individual crane operation (load case positions, Figure 12), a total of 80 load cases were obtained. These load combinations couple operational and inertial loads on the structure according to the working position of the crane and the corresponding ship motions that maximise structural response (surge, sway, heave, roll, pitch and yaw).

Table 3. Example of combined load case

1.1. HEAD_SEA_2_AX (+) _AZ (-) - Position 1
1. gravity
2. env_x * (+)
3. env_z * (-)
4. A_FRAME_WEIGHT_EQ_PS
5. A_FRAME_WEIGHT_EQ_SB
6. LARS_CASE_1_PS
7. LARS_CASE_1_SB

3.2. Acceptance criteria

The acceptance criteria follow DNV-RU-SHIP Pt.3 Ch.11 – Hull equipment, supporting structure and appendages; 2 – Supporting structure for equipment, deck fittings and type C fuel tanks; 4 – Lifting appliances, where the acceptance rules for crane foundation structures are prescribed [6].

For the fine mesh (50 mm x 50 mm):

$$\sigma_{vm} < \sigma_d = R_y, \quad (3.1)$$

$$R_y = \frac{235}{k} \quad (3.2)$$

For high-strength steel AH36:- $R_{eH} = 355 \text{ MPa}$, $k = 0.72$, table 1- DNV-RU-SHIP Pt.3 Ch.11

σ_{vM} – von Mises stress

$$\sigma_{vM} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}, \quad (3.3)$$

σ_d – allowable stress

R_y – nominal yield stress

4. Preliminary results

A detailed review of the structural response was carried out based on all 80 load cases and includes deformations and stress. SESAM Xtract [7] was used for the presentation of analysis results. Below are presented preliminary results.

4.1. Deformations

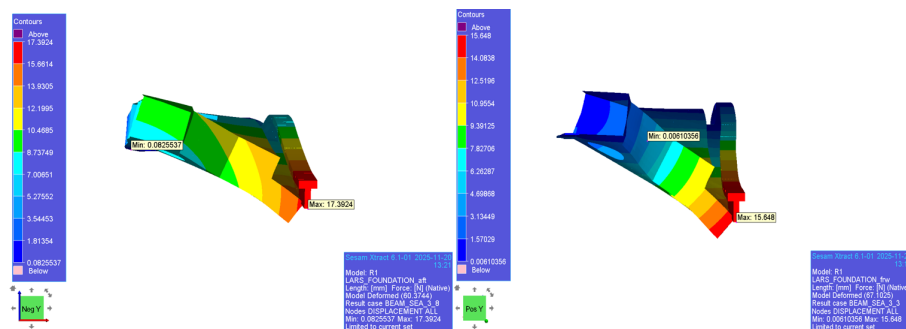


Figure 14. Side view of maximum deflections

The maximum deflection of the forward cantilever is 15.6 mm while the maximum deflection of the aft cantilever is 18.8 mm, Figure 14.

4.2. Stresses

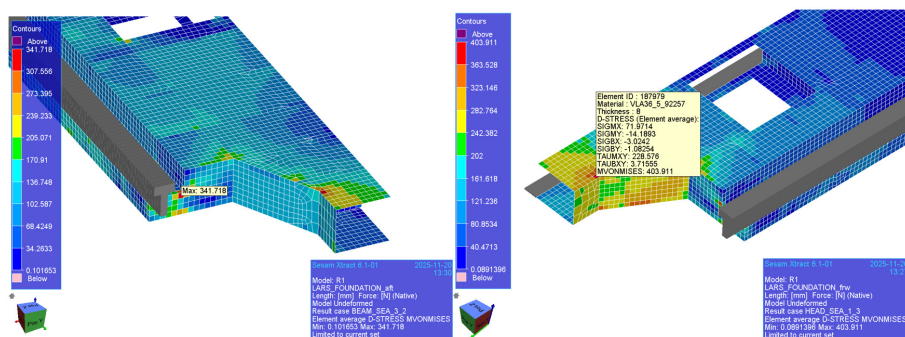


Figure 15. Isometric view of maximum stresses

The maximum stresses for the forward cantilever do not exceed 404.9 MPa while the maximum stresses for the aft cantilever do not exceed 341.7 MPa, Figure 15.

5. Discussion and conclusion

Based on the obtained results, significant deflections were observed on the crane foundation. Excessive deflections may lead to misalignment or jamming of the cranes along its rail system. The most pronounced deflections occurred on the aft cantilever, particularly in the area directly beneath the rails where cantilever height is reduced. In addition to excessive deflections, the stress levels in both cantilevers exceeded the allowable limits, meaning that the original foundation configuration did not satisfy the required acceptance criteria.

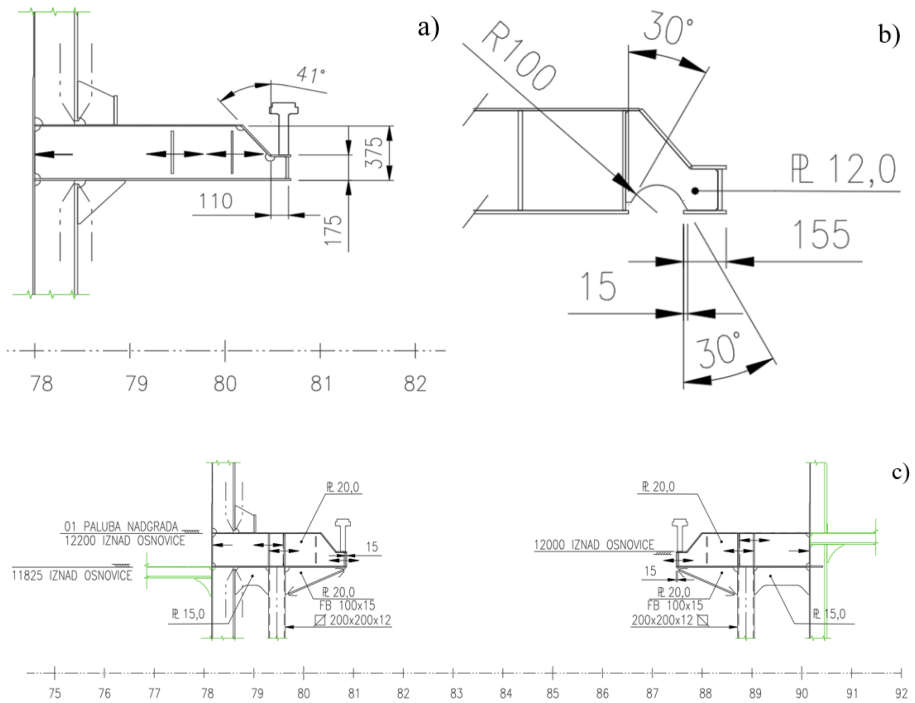


Figure 16. Modifications, a) tapered height transition b) intermediate brackets
c) box pillars

To compensate for the reduced clearance in the rails area, the console geometry was re-profiled by introducing a tapered height transition, Figure 16-a.

Additionally, intermediate brackets were inserted at 300 mm spacing relative to the standard longitudinal stiffener spacing, Figure 16-b.

Furthermore, at the cantilever ends – that is, at the crane working position – box pillars (200x200x12 mm) were added, Figure 16-c.

6. Final results

The modifications were applied to the numerical model, and the analysis for the same load cases was repeated. The final analysis results are presented below.

6.1. Deformations

The maximum deflection of the forward cantilever is 7.9 mm, Figure 17.

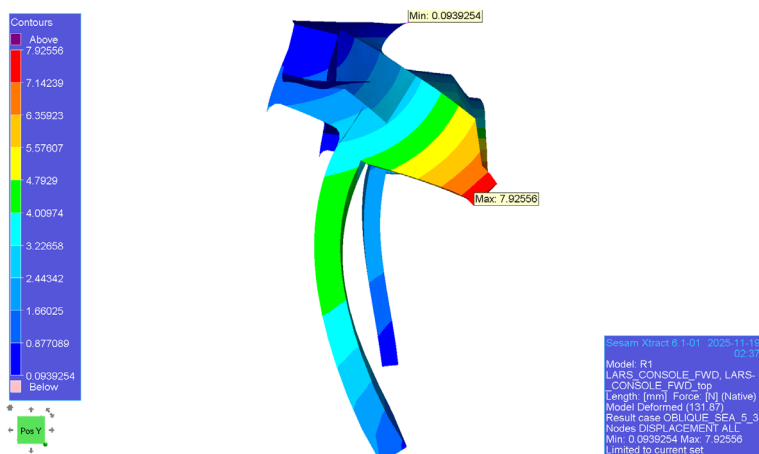


Figure 17. Side view of maximum deflections – forward cantilever

The maximum deflection of the aft cantilever is 6.5 mm, Figure 18.

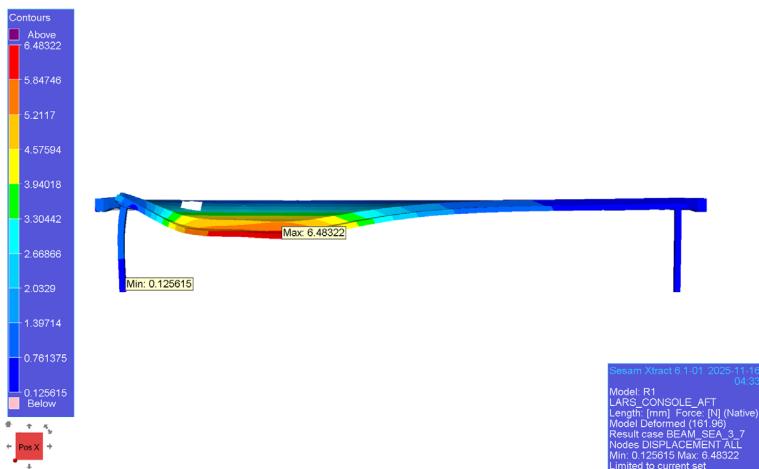


Figure 18. Transverse view of maximum deflections – aft cantilever

Following the applied modifications, the deflection was reduced by 50% on the forward cantilever and by 65% on the aft cantilever.

6.2. Stresses

Peak stress in the forward console does not exceed 321.2 MPa, Figure 19.

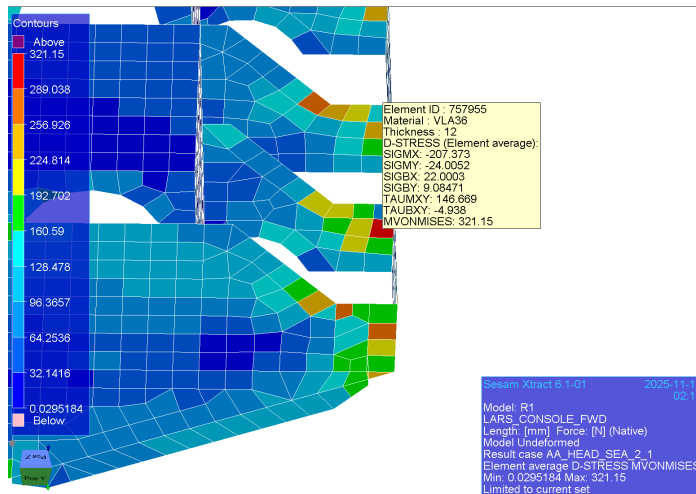


Figure 19. Side view of maximum stress – forward cantilever

Peak stress in the aft console does not exceed 306.7 MPa, Figure 20.

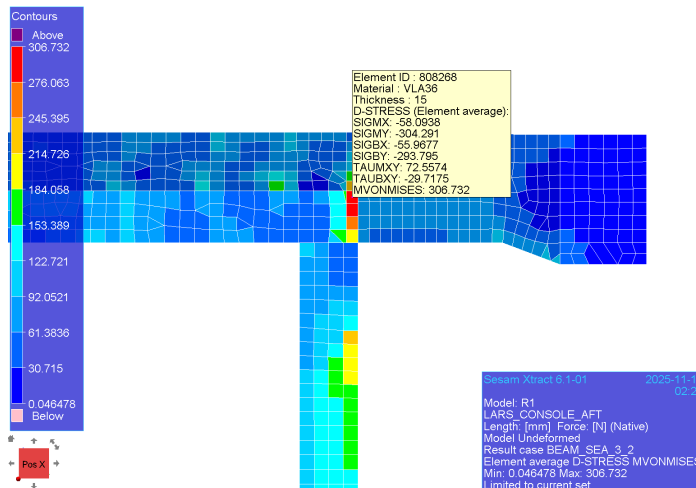


Figure 20. Transverse view of maximum stress – aft cantilever

The obtained stress levels on both the forward and aft cantilever remain within the allowable limits prescribed by DNV. Accordingly, the modified structure satisfies the required capacity criteria for crane operation.

7. Conclusions

The conducted analysis of the LARS foundation has shown that the initial design requires modifications and additional redesign in several specific zones. The most significant challenge was associated with the deformation of the box cantilevers, particularly in the area beneath the crane rails.

Intercostal brackets and pillars were added to reinforce these areas. After modifications, deformations and stresses were reduced within prescribed limits, ensuring stability and functional performance of the system.

This confirms the effectiveness of the applied redesign and highlights the importance of detailed structural assessment when designing foundations for specialised offshore systems.

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