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Finite Element Strength Assessment of a Crane Foundation Deck in a Multi-Cat Fish Farm Support Vessel

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Abstract This study evaluates the structural strength of the forecastle deck in the crane foundation area of a Multi-Cat vessel using the finite element method. A three-dimensional finite element model was established to simulate the deck structure under crane operating loads. The analysis considered the most critical lifting condition and included eight crane rotation angles. Stress results were assessed according to the allowable stress requirements of the ABS Rules for Building and Classing Steel Vessels under 90 Meters. The results show that the maximum Von Mises stress occurs at a rotation angle of 180°, with a value of 160.4 MPa, which is lower than the allowable limit of 165 MPa. Therefore, the deck structure in the crane foundation region satisfies the strength requirement under the examined operating conditions. The study confirms that finite element analysis is an effective tool for verifying the structural safety of crane-supported deck structures.
Keywords FEM; Crane; Forecastle; Deck; ABAQUS; Foundation

1 Introduction

The structural integrity of ship decks subjected to concentrated loads is a key issue in marine structural design, especially in regions supporting crane foundations. During lifting operations, crane loads generate significant local stresses and deformation in the deck plating, stiffeners, girders, and supporting substructure. If these effects are not properly evaluated at the design stage, they may lead to excessive deformation, local yielding, fatigue damage, or even structural failure in service. Therefore, local strength assessment of deck structures under crane loading is an essential part of structural verification for crane-mounted marine vessels.

Recent studies have shown that finite element analysis has become an effective approach for evaluating local reinforcement schemes and structural responses in crane-supported marine structures. For example, Dragatogiannis et al. (2024) analyzed deck reinforcement arrangements for crane installation on a composite yacht and showed that local strengthening has a significant influence on stress distribution and structural safety. Hernández-Ménez et al. (2023) proposed a structural assessment methodology for an FPSO main deck supporting an offshore crane and demonstrated that different crane operating conditions may substantially affect deck behavior. In addition, Abdullah et al. (2023) carried out a finite element strength analysis of a deck crane barge and confirmed that numerical simulation is a practical tool for identifying critical stress locations in crane-bearing deck structures. These studies indicate that finite element-based assessment has become an important method for evaluating the structural adequacy of crane foundation regions in marine applications.

With the development of computational mechanics, the finite element method (FEM) has been widely adopted to simulate complex structural responses under localized marine loading conditions with high accuracy. Compared with simplified analytical approaches, FEM can represent the interaction between deck plating, stiffeners, girders, supporting bulkheads, and pillars more realistically, making it particularly suitable for crane foundation regions where load transfer is highly localized and structurally discontinuous. In practical ship design, classification society rules provide the basis for determining whether the calculated stresses are acceptable. Consequently, combining finite element analysis with rule-based acceptance criteria offers a rational and reliable framework for assessing deck strength in crane installation areas.

This study investigates the structural behavior of the forecastle deck in the crane installation area of a Multi-Cat vessel by means of finite element analysis in accordance with ABS requirements. The analysis focuses on the stress distribution and structural response of the deck and its supporting members under crane loading, with particular attention to the influence of crane slewing position on the critical stress state. The results are intended to support structural verification of the crane foundation region and to provide a practical reference for deck reinforcement design in similar working vessels.

The contribution of this work can be summarized as follows. First, a three-dimensional finite element model is established for the forecastle deck together with its surrounding supporting structure, so that the local load transfer mechanism in the crane foundation region can be evaluated in detail. Second, the crane loading is examined under a series of slewing angles, which makes it possible to identify the most unfavorable operating position rather than relying on a single loading direction. Third, the calculated stresses are assessed against an ABS-based allowable stress criterion, allowing the numerical results to be directly linked to practical structural acceptance in ship design.

2 Research Methods

2.1 Vessel particulars

The vessel analyzed in this study is a Multi-Cat boat classified by ACS and operating under the Iranian flag, with an overall length of 19 m, a moulded breadth of 7.20 m, a moulded depth of 2.20 m, a displacement of 160 tonnes, and a midship draft of 1.70 m (Table 1).

Table 1 Principal particulars of the multi-cat vessel

Ships Name	MULTI CAT BOAT
Classification	ACS
Flag	Iran
GROSS/NET Tonnage	---
Length overall	19 m
Length Between Perpendiculars	18 m
Breadth (moulded)	7.20 m
Depth @ MID (moulded)	2.20 m
DISPLACEMENT	160 tonnes
Draft (mid)	1.70 m
Class Notation	SPECIAL SERVICE, FISH FARM SUPPORT CRAFT
Navigation area	INTERNAL & TERRITORIAL WATERS

2.2 Abaqus software

The software used in this study is SIMULIA Abaqus FEA, which provides comprehensive capabilities for modeling, analysis, and simulation based on the Finite Element Method (FEM).

2.3 System of units

A consistent unit system was adopted throughout the numerical analysis, including millimeters for length, tons for mass, ton/mm^3 for density, newtons for force, and MPa (N/mm^2) for stress and pressure (Table 2).

Table 2 System of units used in the analysis

Unit	Parameter
mm	Length
Ton	Mass
ton/mm3	Density
N	Force
MPa (N/mm2)	Tension (Pressure)

2.4 Analysis type

The deck structure has been analyzed using the linear static analysis method. The fundamental assumptions for employing linear static analysis are as follows:

The material behavior is linear, and stress is directly proportional to strain according to Hooke's law. The applied loads on the structure are static and constant. The relationship between applied loads and structural displacements is linear (Figure 1).

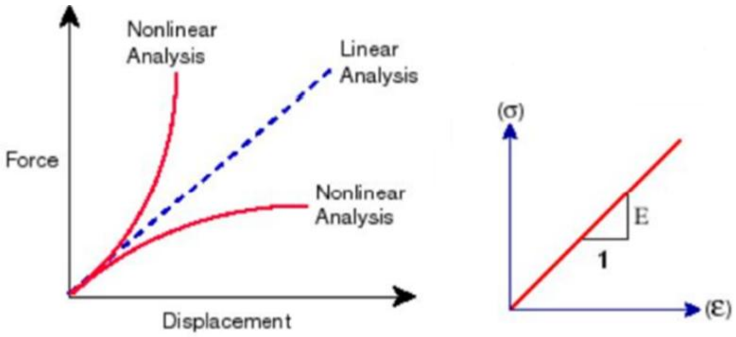

Figure 1 Assumptions of linear static analysis

2.5 Coordinate system

A right-handed Cartesian coordinate system was adopted for structural modeling and analysis. The longitudinal direction was defined as the X-axis and taken as positive toward the bow, the transverse direction was defined as the Y-axis and taken as positive toward port, and the vertical direction was defined as the Z-axis and taken as positive upward toward the deck (Table 3). The origin of the coordinate system was located at the intersection of the ship centerline (CL) and the baseline (BL) (Figure 2).

Table 3 Coordinate system (KR for Steel Ships, Part 3, Annex 3-2, Page 139)

Axis	Direction	Positive orientation
X	Longitudinal	Forward (toward the bow)
Y	Transverse	Port (toward the left)
Z	Vertical	Deck (upwards)

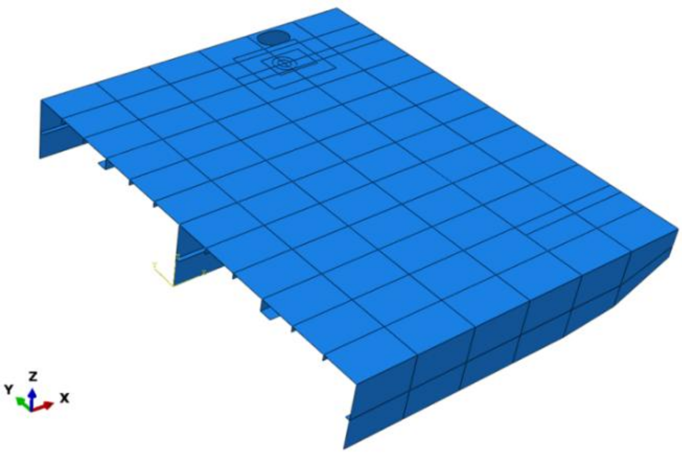

Figure 2 Assumptions of linear static analysis

2.6 Geometric properties of the model

The structural model extends from aft bulkhead 12 to the forecastle region, covering three compartments. The modeled deck region has dimensions of 6 000 mm in the longitudinal direction, 7 200 mm in the transverse direction over the full ship breadth, and 1 100 mm in the vertical direction below the deck (Figure 3).

The hull lines and all structural members in the modeled region were represented using shell elements based on the midship section drawing. The arrangement of frames, bulkheads, and other structural components was defined according to the structural drawings, including the sectional configurations from Frame 13 to Frame 18 and the bulkhead layout in the analyzed region (Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10).

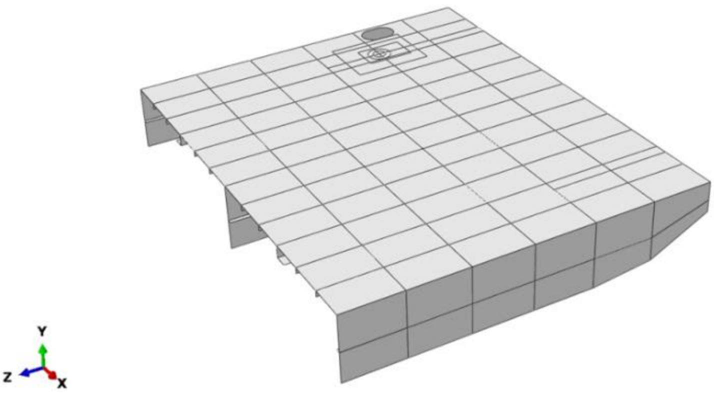

Figure 3 The model represents a length of three compartments in the Abaqus software

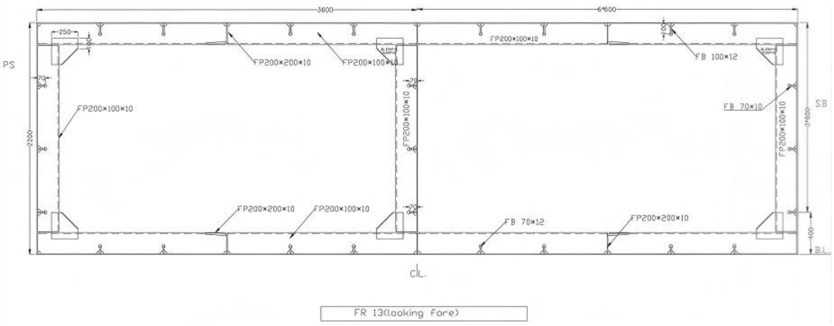

Figure 4 Frame 13 structure

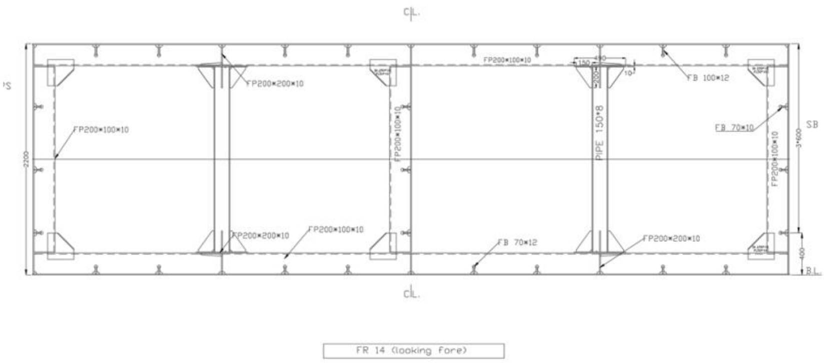

Figure 5 Frame 14 structure

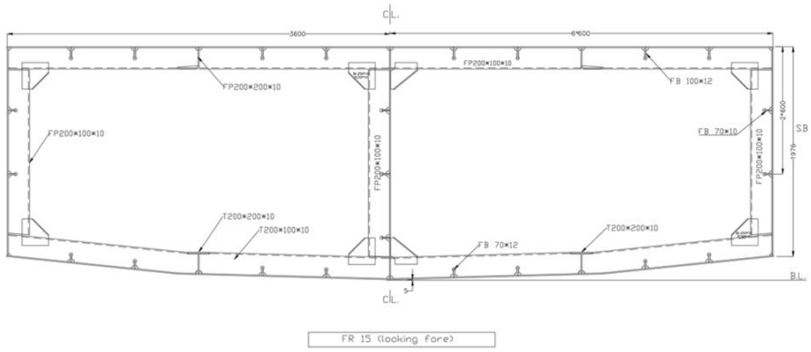

Figure 6 Frame 15 structure

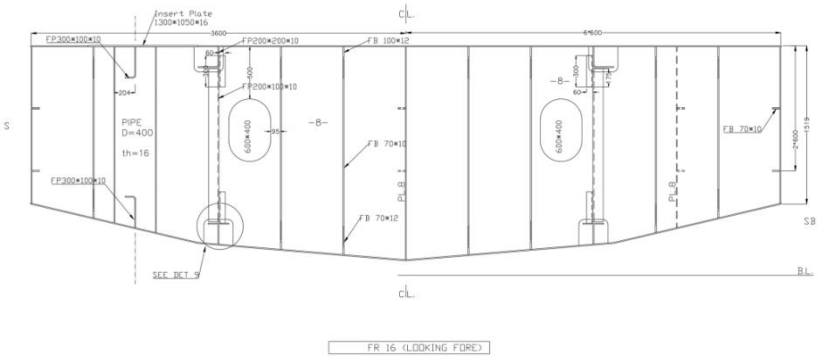

Figure 7 Frame 16 structure

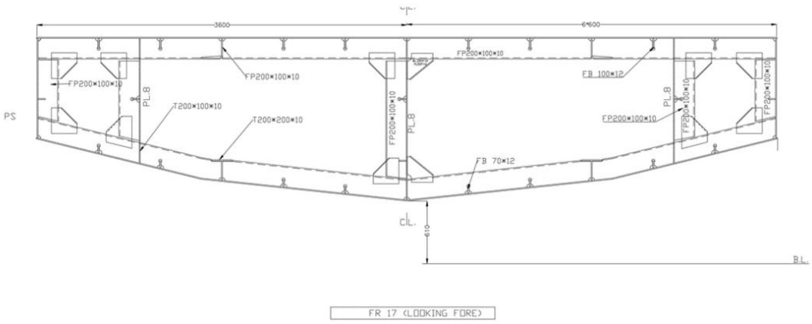

Figure 8 Frame 17 structure

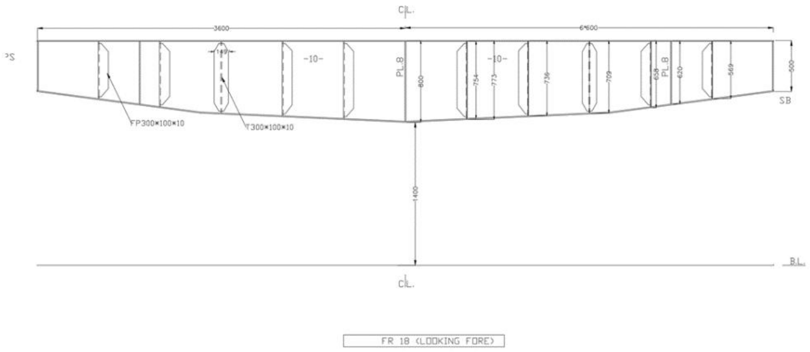

Figure 9 Frame 18 structure

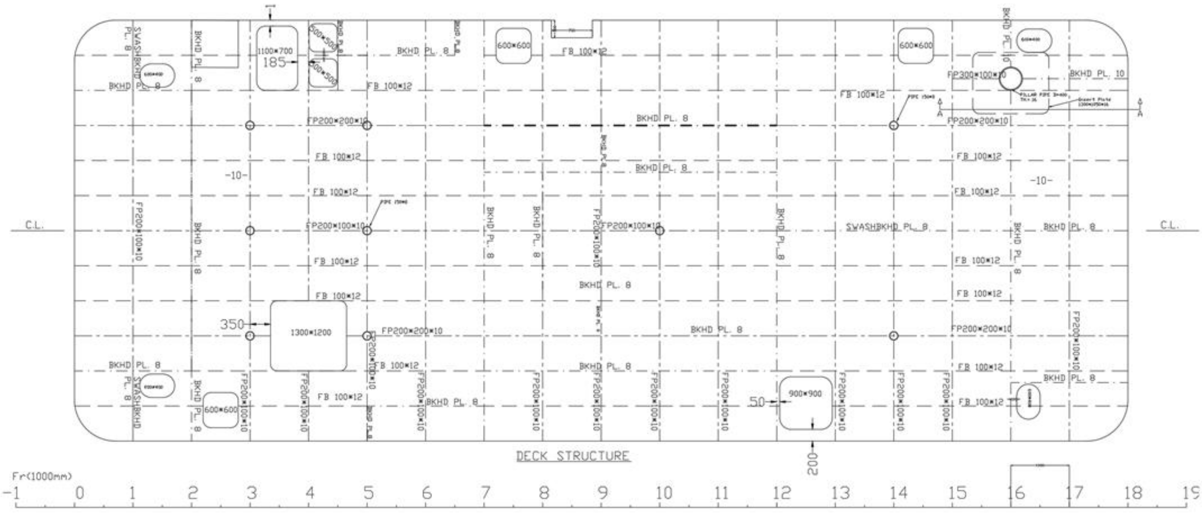

Figure 10 Layout of bulkheads in the modeled region

The dimensions of all structural elements have been modeled as shell elements in Abaqus, as specified in Table 4. The thickness of each element has been defined in the Property Section Manager module.

Table 4 Geometric properties of structural elements in the model

DECK CEN. GIRDER	L200×100×10 mm
DECK SIDE GIRDERS	L200×200×10 mm
DECK TR	L200×100×10 mm
DECK PLATE	10 mm
DECK BEAMs	FB 100×12 mm
SIDE PLATE	10 mm
SIDE TR	L200×100×10 mm
PILLAR	PIPE400×16 & PIPE150×8 mm

To simplify the finite element model, small local features such as cutouts, lugs, scallops, air holes, and snipes were not included in the analysis (Figure 11).

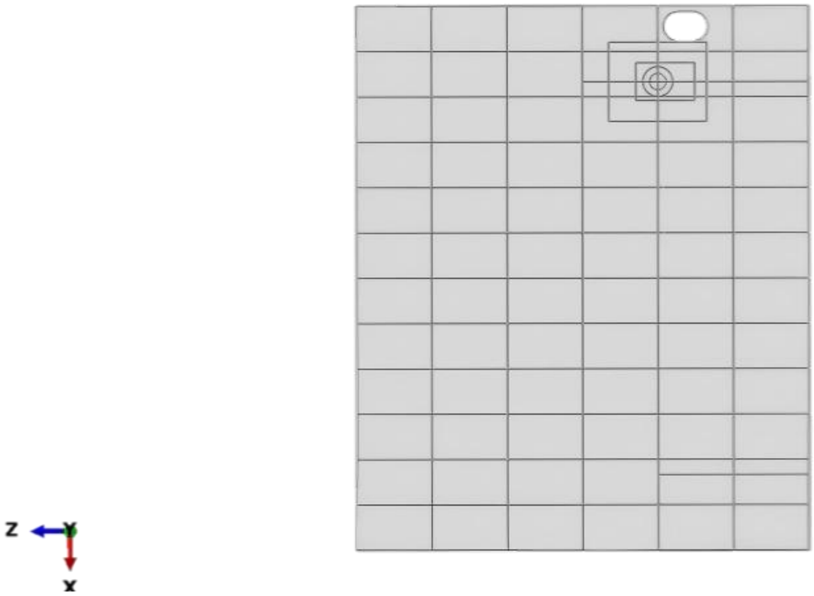

Figure 11 Deck plan showing the layout of longitudinal and transverse reinforcements and columns in Abaqus

2.7 Geometric Properties of the Model

The finite element mesh was generated using free meshing with the medial axis algorithm. The mesh consists of both quadrilateral and triangular shell elements, with a global element size of 40 mm. The final model contains 71 996 nodes and 72 259 elements, including 71 822 quadrilateral elements of type S4R and 437 triangular elements of type S3 (Table 5).

Table 5 Mesh properties of the finite element model

Parameter	Specification
Element Shape	Triangular and Quadrilateral
Meshing Algorithm	Medial Axis
Meshing Technique	Free
Global Element Size (mm)	40
Number of Nodes	71,996
Number of Elements	72,259
Number of Quadrilateral Elements (S4R)	71,822
Number of Triangular Elements (S3)	437

2.8 Material mechanical properties

Marine steel Grade A was selected as the material for the deck structure. The mechanical and physical properties used in the analysis include a Poisson’s ratio of 0.28, a Young’s modulus of 2.10×10^5 N/mm², a density of 7.8×10^{-9} ton/mm³, and a gravitational acceleration of 9.81×10^3 mm/s² (Table 6).

Table 6 Mechanical properties of marine steel grade A

Parameter	Value	Unit
Poisson’s Ratio (ν)	0.28	-
Young’s Modulus (E)	2.10×10^5	N/mm²
Density (ρ)	7.8×10^{-9}	ton/mm³
Gravity (g)	9.81×10^3	mm/s²

2.9 Boundary conditions

A simply supported boundary condition was applied to the modeled deck structure. The displacements at both ends and along the side boundaries of the modeled region were restrained in the X-, Y-, and Z-directions, while rotational degrees of freedom were left unconstrained (Figure 12). In addition, displacement in the Z-direction was constrained along the outer boundary lines at the free ends of the columns and walls in order to represent the structural support conditions more realistically (Figure 13, Figure 14).

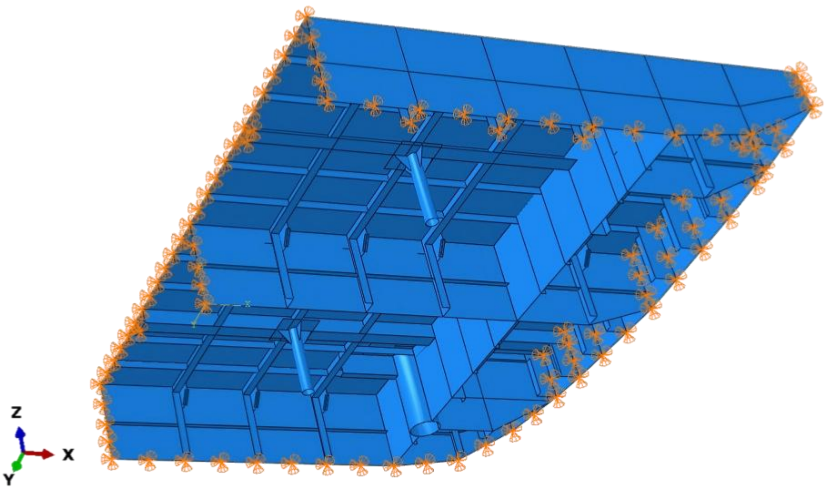

Figure 12 Representation of the simple support boundary condition in the cross-section view

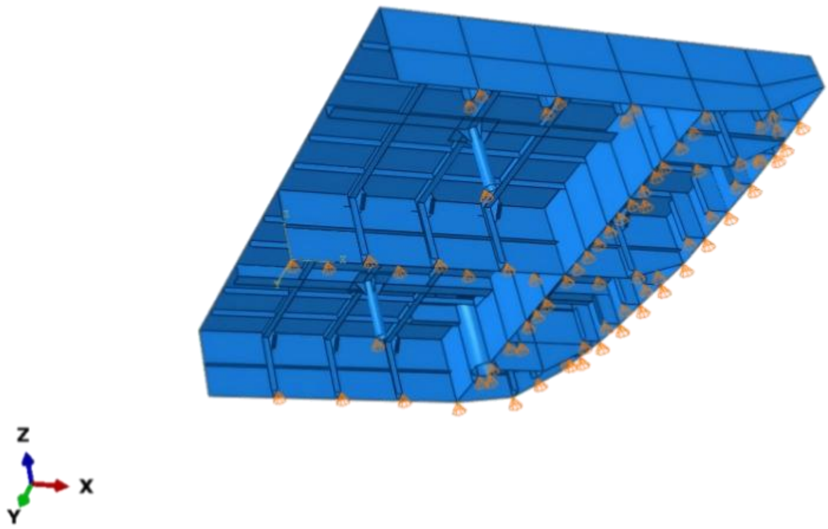

Figure 13 Illustration of Z-direction displacement constraint in 3D view

3 Results and Discussions

3.1 Loading conditions

The deck structure was evaluated under a series of crane loading cases corresponding to different slewing positions. The critical lifting condition considered in this study was defined by a boom length of 2 100 mm and a crane load of 6 300 kg. After applying a safety factor of 1.3, the effective lifting load increased from 61 803 N to 80 344 N. In addition, the boom self-weight of 12 753 N was applied at the boom center of gravity for each slewing position, and a uniformly distributed load of 0.3355 N/mm² representing the crane self-weight was also applied to the deck surface. The crane loading was examined from 0° to 315° at intervals of 45°, with clockwise rotation taken as the positive direction (Figure 14, Figure 15). The loading analysis was conducted under calm sea conditions in order to isolate the local structural response of the crane foundation region from wave-induced global effects.

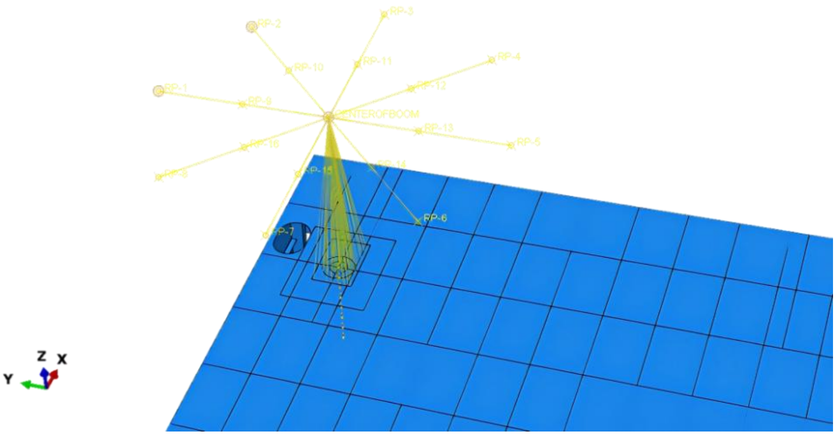

Figure 14 Crane loading cases

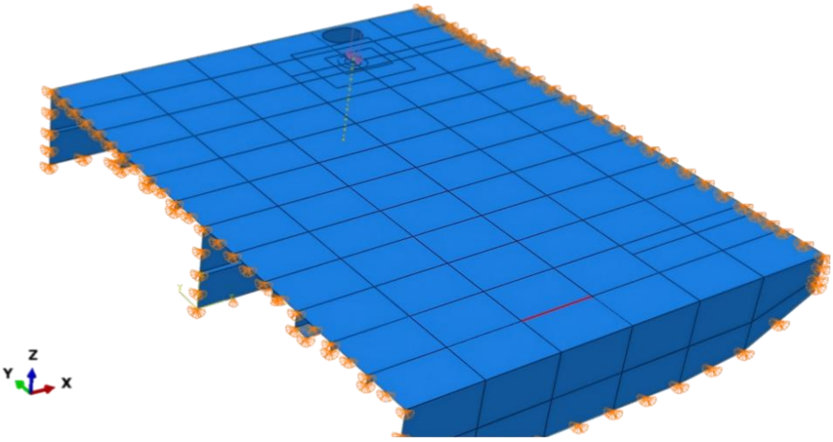

Figure 15 Application of crane self-weight as a static load

3.2 Control criteria

The structural assessment was carried out using the allowable stress criterion specified in the ABS Rules for Building and Classing Steel Vessels under 90 Meters. For conventional steel, the allowable stress is defined as:

$$\sigma_{allow}=0.78\ Sm\ Fy$$

Where Sm=1 for conventional steel and Fy is the stress modification factor, which equals 1 for conventional steel, is the yield strength of the material. Because hull girder strength effects were not included in the present local model, the allowable stress was further reduced by 10% in accordance with the ABS requirement. As a result, the limiting stress adopted for the deck structure was 165 MPa (Figure 16). This criterion was used as the primary basis for evaluating the structural adequacy of the crane foundation region under all investigated loading angles.

Mesh Size	Stress Limit	
	Static + Dynamic	Static
1 × stiffener spacing (*SS*)	0.90 S_mF_y	0.63 S_mF_y
$^1/_2$ × *SS*	0.95 S_mF_y	0.67 S_mF_y
$^1/_3$ × *SS*	1.00 S_mF_y	0.70 S_mF_y
$^1/_4$ × *SS* (1)	1.06 S_mF_y	0.74 S_mF_y
$^1/_5$ × *SS* ~ $^1/_{10}$ × *SS* (1)	1.12 S_mF_y	0.78 S_mF_y

Figure 16 Mesh size and stress limits (American Bureau of Shipping (ABS), 2019)

Since the forces due to hull girder strength were not applied in the model, and in accordance with the aforementioned ABS rules, the allowable stress has been reduced by 10%. Consequently, the maximum permissible stress for the deck structure is considered to be 165 MPa.

4 Conclusion

4.1 Simulation results

The finite element results demonstrate that the forecastle deck structure in the crane foundation region satisfies the ABS allowable stress requirement under all investigated crane loading conditions. Tthe maximum Von Mises stress among the eight slewing cases occurs at a crane rotation angle of 180°, where the stress reaches 160.4 MPa, while the second highest value is obtained at 0° with 154.3 MPa. By contrast, the lowest stress is recorded at 315°, with a value of 105.6 MPa (Table 7). Since all calculated stresses remain below the allowable limit of 165 MPa, the deck structure can be regarded as structurally adequate for the considered static operating conditions. At the same time, the 180° case leaves only a limited safety margin of about 4.6 MPa, indicating that this loading direction governs the strength assessment of the crane foundation region.

Table 7 Maximum von mises stress under different crane loading angles

No.	Angle Relative to Bow (°)	Von Mises Stress (MPa)	Figure No.
1	0	154.3	15
2	45	111.0	16
3	90	139.3	17
4	135	112.8	18
5	180	160.4	19
6	225	117.0	20
7	270	137.6	21
8	315	105.6	22

The stress contour plots shown in Figures 17-24 further clarify the structural behavior behind the values listed in Table 7. In particular, the stress cloud corresponding to the 180° slewing condition (Figure 21) identifies the most critical stress concentration in the crane-supporting region, whereas the contours for 0° (Figure 17) and 270° (Figure 23) also show relatively high stress levels compared with the other loading cases. By comparison, the stress distributions for 45°, 135°, 225°, and 315° (Figure 18, Figure 20, Figure 22, Figure 24) are more moderate, indicating that these slewing directions produce a more favorable load-transfer path through the deck structure. Taken together, Table 7 and Figure 17, Figure 18, Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, Figure 24 show that the structural response is strongly dependent on crane orientation and that a single loading direction would not be sufficient to identify the governing condition.

Similar orientation-dependent stress redistribution has also been reported in crane-supporting marine structures, where different crane positions lead to different load-transfer paths and local reinforcement demands (Hernández-Ménez et al., 2023; Dragatogiannis et al., 2024). From the engineering point of view, these results indicate that the deck plating, girders, stiffeners, and supporting pillars are able to work together to transfer the crane load effectively into the surrounding structure. The highest stresses appear only in specific orientations, which suggests that the local arrangement of supporting members plays a key role in controlling the load path and the resulting stress concentration. Therefore, although the current reinforcement scheme is sufficient for the investigated loading envelope, the regions associated with the 180° and 0° cases should be regarded as critical hot-spot zones for inspection and maintenance (Abdullah et al., 2023; Dragatogiannis et al., 2024).

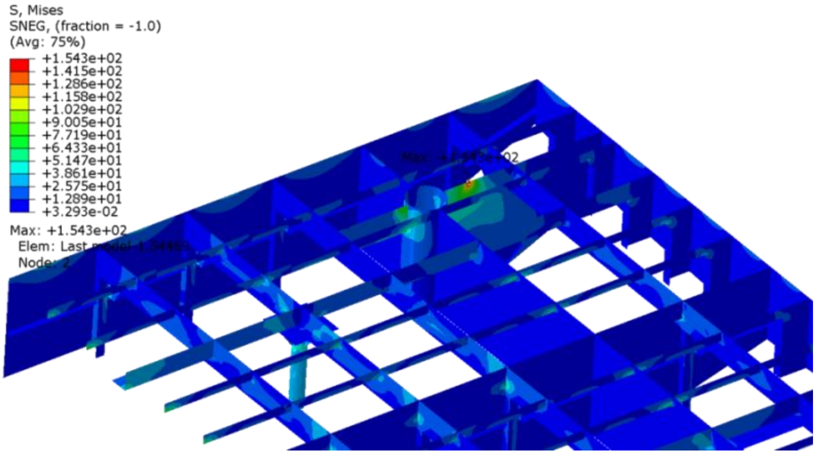

Figure 17 Von mises stress results at 0° crane rotation

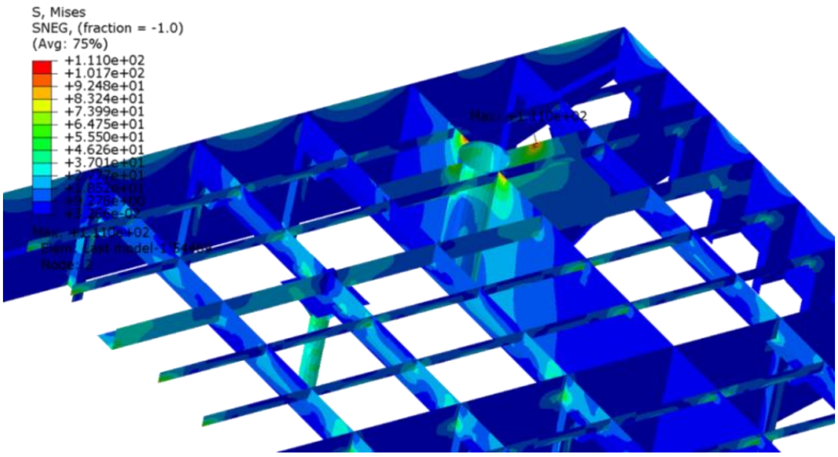

Figure 18 Von mises stress results at 45° crane rotation

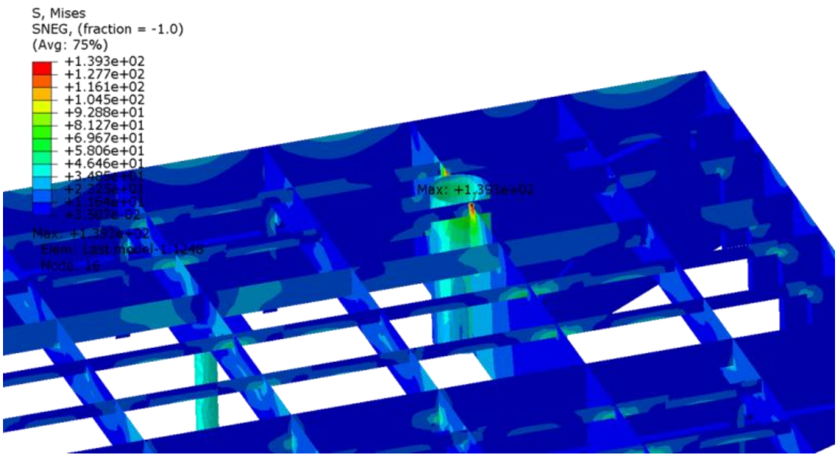

Figure 19 Von mises stress results at 90° crane rotation

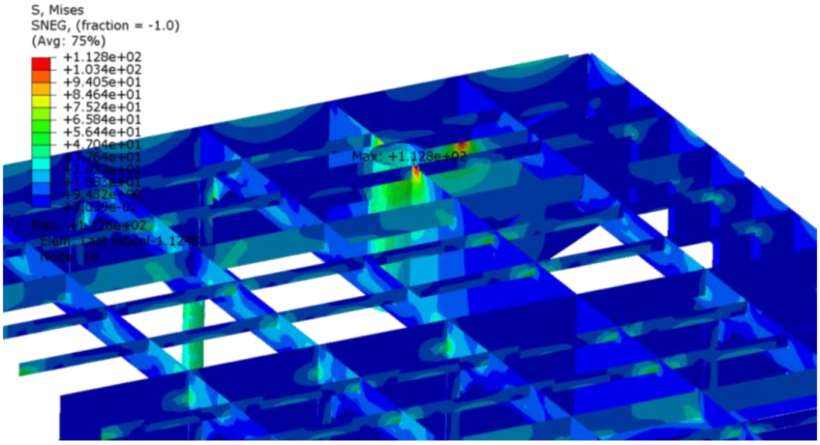

Figure 20 Von mises stress results at 135° crane rotation

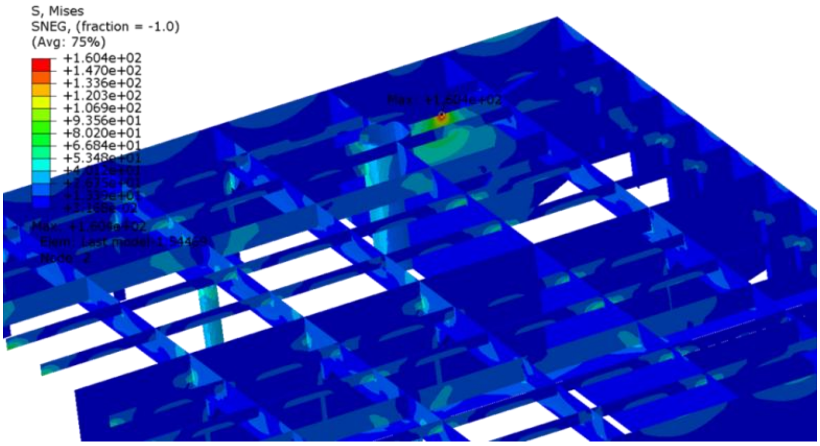

Figure 21 Von mises stress results at 180° crane rotation

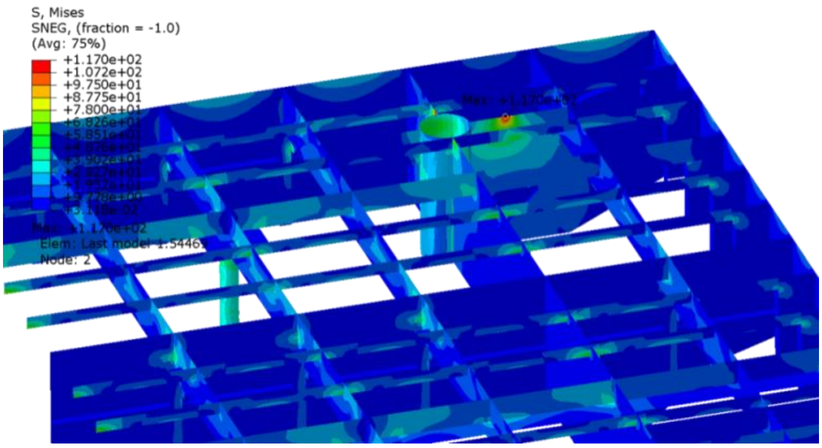

Figure 22 Von mises stress results at 225° Crane Rotation

Repeated crane operation in these unfavorable directions may increase the risk of fatigue damage in welded joints, girder intersections, and pillar-to-deck connections, even if the static stress remains below the allowable limit. This load-sharing mechanism agrees with previous marine structural studies showing that deck plating, longitudinal/transverse stiffeners, and supporting members jointly govern the local stiffness and stress response around crane foundations and similar equipment-support regions. Recent reviews further indicate that repeated loading/unloading, transient operational loading, and welded-detail geometry are among the key factors governing fatigue resistance in ship and offshore structures (Dong et al., 2022).

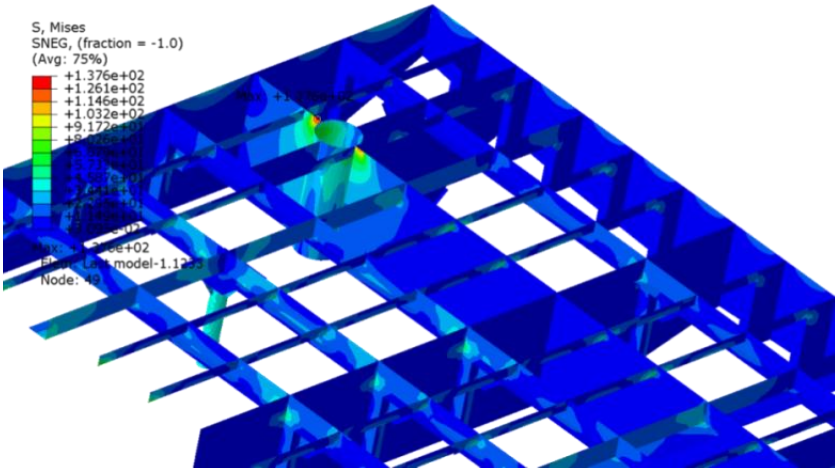

Figure 23 Von mises stress results at 270° crane rotation

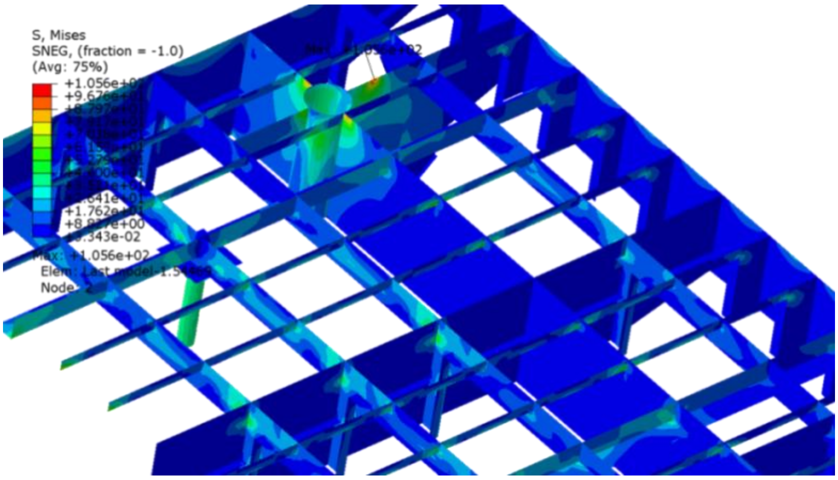

Figure 24 Von mises stress results at 315° crane rotation

Several limitations of the present study should also be acknowledged. First, the analysis was based on a simplified geometric model in which local details such as cutouts, scallops, snipes, and other small discontinuities were not included, although such features may affect local stress concentration in practice. Second, the present assessment was limited to linear static analysis under calm sea conditions, and therefore did not consider dynamic effects associated with vessel motions, impact loading, or oscillation of the lifted load. Third, the study focused on rule-based strength verification and did not include a detailed fatigue assessment of the identified hot-spot regions. For these reasons, the present conclusions are suitable for preliminary structural verification, but they do not fully represent the complete long-term service behavior of the crane foundation structure.

Future work should therefore extend the present analysis in several directions. A fatigue assessment should be performed for the most highly stressed regions identified in Figure 21 and the other critical contour plots. Dynamic loading conditions caused by vessel motion and crane operation in realistic sea states should also be considered in order to provide a more complete structural evaluation. In addition, local sub-modeling of the hot-spot regions would help capture stress concentration more accurately than the current global shell model. If higher lifting loads or more demanding operating conditions are expected in future service, structural optimization measures such as local plate thickening, bracket addition, or improved stiffener continuity may be investigated to increase the available safety margin and improve fatigue resistance. Moreover, refined local stress assessment methods should be considered for welded joints around the crane foundation, since hot-spot stress prediction can vary with the adopted finite element formulation and extraction technique (Li and Choung, 2021). Overall, by combining the numerical comparison in Table 7 with the stress contour interpretation in Figure 17, Figure 18,

Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, this study confirms that the deck structure in the crane foundation area is structurally acceptable under the considered crane loading cases, while also identifying the 180° slewing condition as the governing design case and the most important target for future fatigue assessment, maintenance planning, and possible structural refinement.

Acknowledgement

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contributions

Farzad Tahmasebi (100% of contributions) including: conceived and designed study, collected and analyzed the data and writing conclusions.

References

Abdullah K., Sumardiono S., and Soeroso H., 2023, Strength analysis of the deck crane barge using the finite element method, in Proceedings of the 1st International Conference on Sustainable Engineering Development and Technological Innovation (ICSEDTI 2022), EAI, pp. 11-13.

American Bureau of Shipping (ABS), 2019, Rules for Building and Classing Steel Vessels under 90 Meters (295 Feet) in Length, Part 3 - Hull Construction and Equipment, July 2019.

American Bureau of Shipping (ABS), 2020, Guide for Fatigue Assessment of Offshore Structures.

Dong Y., Garbatov Y., and Guedes Soares C., 2022, Recent developments in fatigue assessment of ships and offshore structures, Journal of Marine Science and Application, 21: 3-25.

Dragatogiannis D.A., Zaverdinos G., and Galanis A., 2024, Structural analysis of deck reinforcement on composite yacht for crane installation, Journal of Marine Science and Engineering, 12(6): 934.

Hernández-Ménez D.F., Félix-González I., Hernández J. H., and Herrera-May A. L., 2023, Methodology for the structural analysis of a main deck of FPSO vessel supporting an offshore crane, Revista UIS Ingenierías, 22(1): 1-16.

Li C.B., and Choung J., 2021, A new method of predicting hotspot stresses for longitudinal attachments with reduced element sensitivities, International Journal of Naval Architecture and Ocean Engineering, 13: 379-395.