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Analysis of potential skidway loadout failures based on the structural strength and Foundation settlement on the fabrication site in the Pre-Fabrication Phase.

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ABSTRACT

The abstract A fabrication company plans to undertake the construction of a topside structure with a weight exceeding 19,000 tons. Based on the Soil Investigation Report, it was found that the foundation in the fabrication area was previously used for the construction of a structure weighing 17,500 tons. Based on the consideration of the weight of the structure, it is necessary to review whether the fabrication area is capable of carrying out the construction of the topside structure until loadout. During the analysis process, it was found that the soil bearing capacity of the fabrication yard was 6108.99 MT at row support A1, while the minimum soil bearing capacity during the fabrication to loadout process at row support A1 was 6776.08 MT. Thus, it is necessary to modify the loadout area. In the process of assessing the strength of the soil foundation against structural loads, a support planning model is also made that will be used to support the topside structure during the fabrication process and also in carrying out loadout. The suitability of the structure and support will affect the process of assessing the strength of the soil foundation in parsing the potential for failure. In the process of analyzing the topside structure and support, under settlement conditions in the fabrication stage, it was found that there was a member that experienced a high enough stress with a UC value of 0.984 in member 2807-2808 on the deck leg above the row support. This occurred because during the settlement condition, there was a shift in the weight point of the structure with a joint reaction value of 4246.72 MT at the row support. During the analysis process on the bearing capacity of the foundation, topside structure, and support structure, the percentage of structural failure before modification of the loadout area is 2.12%, which is included in the failure category because it has a value above 1%.

Keywords: *Failure, Loadout, Foundation*

1. Introduction

Loadout operations are a crucial process in the marine and offshore industry, as they allow for the safe transfer of a structure from its fabrication site to a ship or barge that will then travel across the ocean to be transported to its final destination [4][7].

In its application in the marine/offshore Industry, API RP 2A WSD Classifies the Procedures used to perform Loadout Operations from the Fabrication stage to the Installation stage into three main types, namely Lifting, Skidding/Skidway, and SPMT/Trailer Loadout [4][5].

Skidding was originally used as a foundation or support on the ground on which a structure known as a Skid-Frame would be built, which was then utilized as a way to be able to move a structure that was too large in size and impossible to lift because it avoided too large an impact force on the Barge which could result in a fatality [1][8][15].

Soil inspection for construction in marine operations involves a systematic assessment of the soil and sub-sea floor conditions at a specific marine location where construction activities are planned. The main purpose of these investigations is to provide important geotechnical information that aids in the design and construction of marine structures, such as offshore platforms, jetties, piers, harbors, and other coastal infrastructure [6][13].

Noble Denton developed guidelines that contain loadout schemes. The structure and support under skidding Loadout conditions must bear a Settlement of 25 mm on one of the supports [12]. The scheme is used as a reference in the analysis carried out in this final project and is adjusted to the design basis provided by the company.

2. THEORETICAL BASE

2.1 Definition of Loadout

Loadout in an engineering context often refers to the process of loading and transporting large structures or equipment, particularly in the construction industry, oil and gas, or energy projects. Loadout involves placing and securing the structure or equipment on suitable lifting or moving equipment.

Tabel 1.Weight Control Report

Struktur	Berat (MT)
TEG TOPSIDES	17.000
Installations Aids	65
Temporary Etc.	307
LSF (*Loadout Support* Frame	1.897
weighing beam	111
Sea fastening prior *Loadout*	70
WCR REPORT WEIGHT	19.119

2.2 Loadout procedure

In API RP2A WSD, the Loadout process is classified into 2 conditions. The first condition is Direct Lift, this condition occurs when the load from the structure lifted using the Lifting method produces an impact force / Direct Force on the Barge. The second condition is Horizontal Movement, this condition occurs due to the structure being loaded using the Skidding method and the transporter / trailer in the process, resulting in Longitudinal Force on the Barge [4][5][9].

Table 2. Difference between model design value and WCR

DATA	BERAT (MT)	Batas Memenuhi	Presentase Selisih	Validasi
WCR	19119			
SACS	19418	5%	1,5%	TRUE
Nilai selisih	299			

2.3 *Group pile Bearing Capacity*

Bearing Capacity for group piles is the maximum load that a group of piles can safely support without excessive settlement or failure. It takes into account the individual capacities of the piles in the group and the effects of pile interaction, which can cause a reduction in overall efficiency compared to the sum of the individual pile capacities [6][14]. "Principle of Foundation Engineering" section 9.22.

$$Q_{ult.g} = Q_{ult} \; x \; n \; x \; E_g \tag{1}$$

2.4 *Consolidation settlement*

Geotechnical engineering and soil mechanics use the term consolidation of soil settlement as an important element. This concept refers to the process of decreasing soil volume over time due to the effect of continuous loading, mainly due to the escape of water from soil pores [6][13].

$$Sc \frac{Cc(end\ soil)(1000)}{1+0,7} log \left(\frac{(effective\ stress+Layer\ stress)}{(Layer\ stress)}\right. Q_{ult.g} = Q_{ult} \; x \; n \; x \; E_g \tag{2}$$

2.5 *Inplace Analysis*

Inplace Analysis for fabrication requires careful inspection and assessment of materials, components and assemblies directly at the manufacturing site. This process is critical to ensure that fabrication conforms to precise design specifications, strict quality standards, and stringent safety requirements. The inplace analysis is a static analysis of the structure with consideration of unity check required to be less than 1 as the maximum acceptable limit of the structure under loading conditions [14].

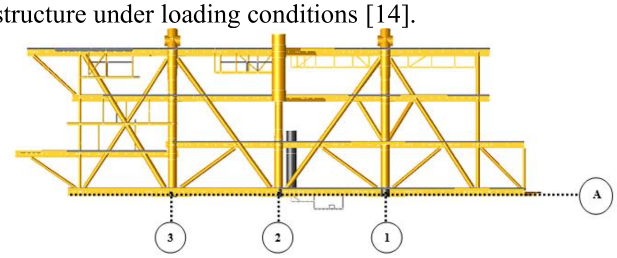

Figure 1. Structrual Analysis Point

2.6 *Von Mises stress*

Von Mises stress is a concept in materials mechanics used to determine when a material will fail or plastically deform. This concept is very important in stress analysis, especially in engineering design and materials engineering. Von Mises stress is calculated using stress components at a point and is a way to combine shear and normal stresses into a single scalar value that can be compared to the strength of the material.

$$\sigma_{VM} = \frac{\sqrt{(\sigma_{xx}-\sigma_{yy})^2+(\sigma_{yy}-\sigma_{zz})^2+(\sigma_{zz}-\sigma_{xx})^2+3(\tau_{xy}+\tau_{xz}+\tau_{yz})^2}}{2} \tag{3}$$

2.7 *Unity Check*

Unity check is a method used in structural analysis to ensure that the stress or deformation in a structural element does not exceed its permissible capacity [3][10]. It is a way to verify the safety and integrity of the structure under the applied load as in equation (4)

$$UC = \frac{\sigma_{actual}}{\sigma_{allowable}} = \frac{\sqrt{\left((\sigma_{xx})-\sigma_{yy}\right)^2+\left(\sigma_{yy}-\sigma_{zz}\right)^2+(\sigma_{zz}-\sigma_{xx})^2+3\left(\tau_{xy}+\tau_{xz}+\tau_{yz}\right)^2}}{2} \tag{4}$$

And to get a safe UC value, in some conditions it is necessary to add a parameter, namely the safety factor so that the following formula is made:

$$UC\ Max = \frac{\sigma_{actual}}{\sigma_{allowable}} x\ SF\ UC = \frac{\sigma_{actual}}{\sigma_{allowable}} = \frac{\sqrt{(\sigma_{xx}-\sigma_{yy})^2+(\sigma_{yy}-\sigma_{zz})^2+(\sigma_{zz}-\sigma_{xx})^2+3(\tau_{xy}+\tau_{xz}+\tau_{yz})^2}}{2} \tag{5}$$

2.8 B*asic concepts Probability of failure*

Probability theory is widely used to model systems in engineering and scientific applications. This note adopts the most widely used probability framework, which is based on Kolmogorov's axioms of probability. Essentially, this theory provides a mathematical framework for measuring uncertainty or chance (probability) in an experiment [2][11].

3. ANALYSIS AND DISCUSSION

Guidelines for table and figure format and arrangement are described in the following sub-sections.

3.1 Bearing capacity of foundation soil

The analysis of the foundation model and structure will focus on the calculation of the bearing capacity of the foundation, the level of ground settlement, and the structural response to changes in the fabricated field foundation [6][16].

Table 3. Foundation data for each support row

Parameters	Value	Units
Pile Diameter (D) Square	0,405	m
Pile Length (L)	14	m
Pile Row	31x6	H x V
Number of Piles (n)	186	sum
Block Length	38	m
Block Wide	8,9	m
Unit Weight Soil (γ)	18,1	kn/ m^3
UCS (qu)	110	kn// m^2
CU (qu/2)	55	Kn/ m^2
Area End Bearing (ap)	0,164025	m^2
Area End Bearing Block (apb)	338,2	m^2
cross section (P)	1,62	m^2
side of block	4	
Factor of Safety (SF)	4	
Alpha (α)	1	
Phi	π	
Nc	9	

to get the value of Group Pile Bearing Capacity using **Equations (1)** with the data used to calculate Group Pile Bearing Capacity which can be seen in **Tables 3** and Result that can be seen in **Tables 4**.

Table 4. Calculation Result Bearing Capacity Existing

Row	Total Load (MT)	Allowable Bearing Capacity (MT)	Validation
A1	6776,08	6108,992	Unacceptable
A2	5956,08	6563,696	Acceptable
A3	6010,16	6108,992	Acceptable
B1	5961,62	6108,992	Acceptable
B2	4859,05	6563,696	Acceptable
B3	5468,71	6108,992	Acceptable

And to get value for consolidation settlement of foundation unsing Equations (2) with the Result which can be seen in Tables 5.

Tabel 5. Settlement Existing Calculation Result

Row Support	Decription	Result (mm)	Result (cm)
A1	Consolidation Settlement on Row 1	59,697	5,970
A2	Consolidation Settlement on Row 2	43,486	4,349
A3	Consolidation Settlement on Row 3	49,666	4,967
B1	Consolidation Settlement on Row 4	36,709	3,671
B2	Consolidation Settlement on Row 5	29,223	2,922
B3	Consolidation Settlement on Row 6	42,395	4,239

3.2 Structural analysis of Existing Condition

With the current foundation data, structural analysis is carried out using SACS and Ansys software. As can be seen in Figure 2.

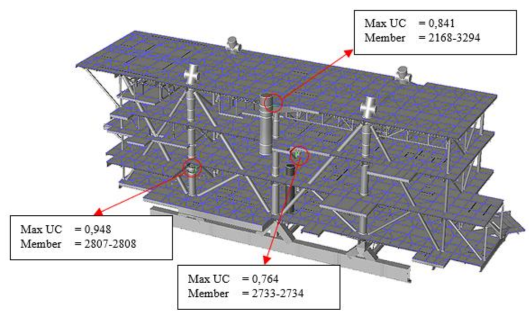

Figure 2. Structure Analysis Results

After analyzing the structure using SACS software, it was found that there were excessive stresses in some members as can be seen in Figure 3 and Table 6.

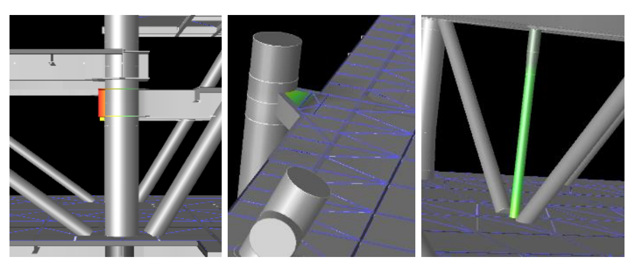

Figure 3. Detail of result in SACS Existing Condition

Table 5. UC Check In Existing Condition

Member	Group ID	Maximum UC
2807-2808	Z30	0.948
2168-3294	D23	0.841
1542-1101	WD1	0.823
2733-2734	Z30	0.764

4188-4373	TCB	0.753

With these results, it is known that the condition of the foundation greatly affects the stress on the structure, so it is very necessary to modify the loadout area.

4. VALIDATION ANALYSIS AND DISCUSSION

4.1Validation of Foundation Capacity after modification

by adding group Pile as many as 10 pieces and pile cap with size 10x5m. obtained the results of bearing capacity and settlement calculations on Modified conditions as can be seen in Tables 7 and 8.

Table 7. Result of Bearing Capacity After modification

Row	Total Load (MT)	Allowable Bearing Capacity (MT)	Validation
A1	6632,44	7,328,827,887	Acceptable
A2	5862,14	7,783,532,093	Acceptable
A3	6117,42	7,328,827,887	Acceptable
B1	6340,37	7,328,827,887	Acceptable
B2	5432,50	7,783,532,093	Acceptable
B3	6086,82	7,328,827,887	Acceptable

Table 8. Result Settlement Foundation After Modification

Row Support	**Decription**	**Result (mm)**	**Result (cm)**
A1	Consolidation settlement on row 1	41,83	4,18
A2	Consolidation settlement on row 2	30,25	3,02
A3	Consolidation settlement on row 3	36,54	3,65
B1	Consolidation settlement on row 4	38,84	3,88
B2	Consolidation settlement on row 5	25,89	2,59
B3	Consolidation settlement on row 6	36,22	3,62

4.2 Structural analysis after Modification

With the current foundation data, structural analysis is carried out using SACS and Ansys software. As can be seen in Figure 4 and Table 9.

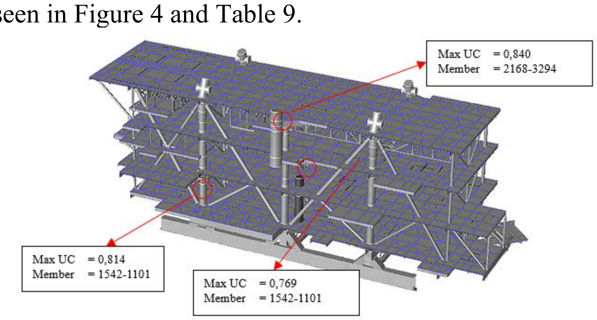

Figure 4. Structure analysis result in Modification Conditions

Table 9. Unity Check on Modified Condition

Member	Group ID	Maximum UC
1542-1101	WD1	0.535
3738-3304	M42	0.496
3304-3737	M42	0.492
4188-4373	TCB	0.488

And for structural analysis in Loadout conditions after modification of the foundation area as can be seen in Figures 5 and 6, with the stress ratio value which can be seen in table 10.

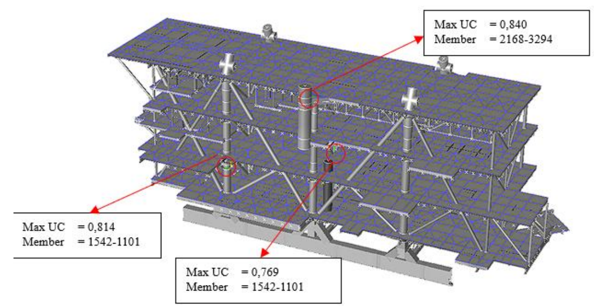

Figure 5 Structure analysis results under loadout conditions

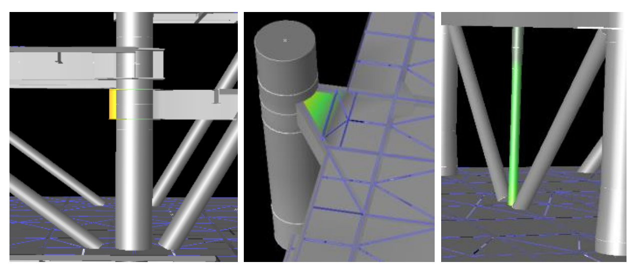

Figure 6 Detail of stress ratio in Loadout condition structure

Table 10. Unity Check on Loadout Condition

Member	***Group*ID**	***Maximum* UC**
2168-3294	D23	0.840
1542-1101	WD1	0.814
2733-2734	Z30	0.769
4188-4373	TCB	0.753
2147-2184	ZDA	0.753

4.3 Local Analysis Using ANSYS Software

After the analysis in SACS, a local analysis was carried out using ANSYS software to determine the effect of the load acting on the support by modeling the support for the fabricated condition as shown in Figure 7.

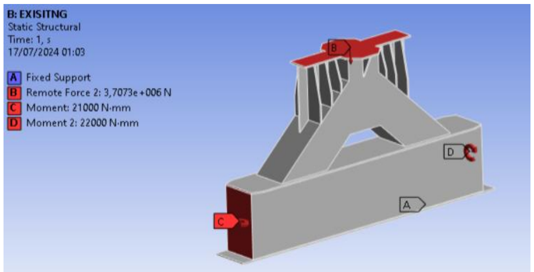

Figure 7. Modeling of Support Structure in ANSYS

By analyzing the ANSYS software and using Equations (4)-(5), the results can be seen in Figure 8 and Tables 11-12.

Table 11. Results of Unity Check Analysis in ANSYS software

Row Support	Force (Kn)	Probe 1 (MPa)	UC	Probe 2 (MPa)	UC	Probe 3 (MPa)	UC
A1	3693193	42,78	0,17	37,23	0,15	42,50	0,17
A2	2385618	27,63	0,11	24,05	0,10	27,45	0,11
A3	1762704	20,42	0,08	17,77	0,07	20,28	0,08
B1	3692330	42,77	0,17	37,22	0,15	42,49	0,17
B2	2763183	32,00	0,13	27,86	0,11	31,79	0,13
B3	1874401	21,71	0,09	18,90	0,08	21,57	0,09

Table 12. Maximum UC Analysis Results in Modification condition

Row Support	*Maximum Stress* (MPa)	*Allowable stress* (MPa)	*Yield* (MPa)	SF	*Maximum* UC
A1	42,78	167,5	250	1,5	0,26
A2	27,63	167,5	250	1,5	0,16
A3	20,42	167,5	250	1,5	0,12
B1	42,77	167,5	250	1,5	0,26
B2	32,00	167,5	250	1,5	0,19
B3	21,71	167,5	250	1,5	0,13

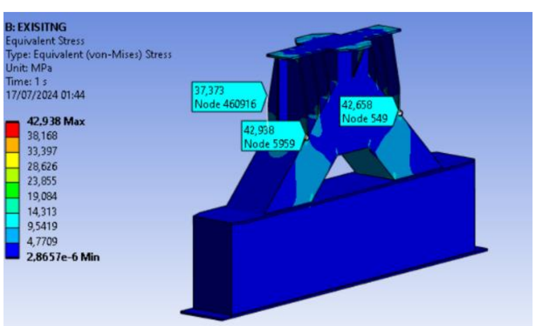

Figure 8 Analysis results in the Modification Condition

After obtaining the results of the analysis in the Fabrication Condition, an analysis was carried out on the Loadout Condition with the results that can be seen in Tables 13-14 and Figure 9.

Table 13. Analysis Results in ANSYS software Loadout condition

Row Support	Force (n)	Probe 1 (MPa)	UC	Probe 2 (MPa)	UC	Probe 3 (MPa)	UC
A1	3693193	42,78	0,17	37,23	0,15	42,50	0,17
A2	2385618	27,63	0,11	24,05	0,10	27,45	0,11
A3	1762704	20,42	0,08	17,77	0,07	20,28	0,08
B1	3692330	42,77	0,17	37,22	0,15	42,49	0,17
B2	2763183	32,00	0,13	27,86	0,11	31,79	0,13
B3	1874401	21,71	0,09	18,90	0,08	21,57	0,09

Table 14. Analysis results on ANSYS software Loadout condition

Row Support	*Maximum Stress* (MPa)	*Allowable stress* (MPa)	*Yield* (MPa)	SF	*Maximum UC*
A1	42,78	167,5	250	1,5	0,26
A2	27,63	167,5	250	1,5	0,16
A3	20,42	167,5	250	1,5	0,12
B1	42,77	167,5	250	1,5	0,26
B2	32,00	167,5	250	1,5	0,19
B3	21,71	167,5	250	1,5	0,13

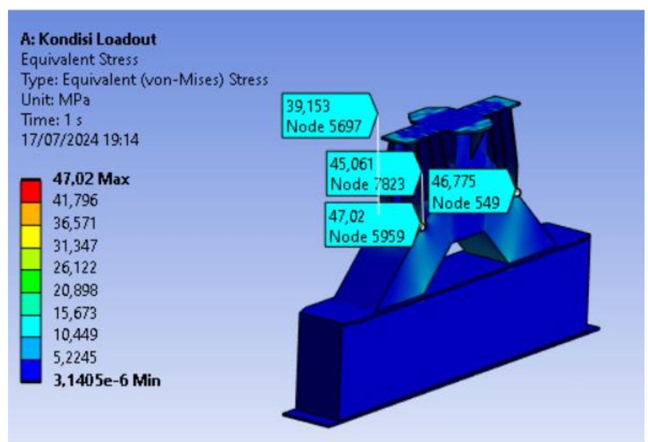

Figure 9 Analysis Results in Loadout Condition

With the results of the analysis that has been obtained, Validation of Failure Criteria in each condition is carried out using Equation (6), with the results as can be seen in Table 15.

Table 15. Failure Probability Value for each Condition

Design criteria	Existing	Modification	Loadout
Bearing capacity	0,167	0,166	0,1656
Settlement foundation	0,111	0,131	0,1311
Structural integrity	0,161	0,160	0,1603
Ansys fabrication	0,6196	0,612	0,613
Total probability	1,058	1,069	1.070

With the Probability of Failure value obtained, it can be calculated for the Percentage of Failure as can be seen in Table 16.

Table 16. Percentage Value of Failure in Each Condition

Design Criteria	Existing	Modification	Loadout
Probability Of Failure	1,058	0,267	0,267
Percentage Probability	1,06%	0,26%	0,27%
Acceptance Criteria	*Unacceptable*	*Acceptable*	*Acceptable*

5. CONCLUSIONS

From the results of the research that has been carried out, it is found that in the Existing Condition, the Fabrication Field foundation has a foundation capacity that is not sufficient to withstand the load of the structure in the fabrication and loadout phase, so it is necessary to modify the fabrication field area by increasing the number of piles and also reassessing the bearing capacity of the foundation to ensure the condition of the fabrication field foundation can be categorized as safe to carry out fabrication and loadout activities of the Topside Structure without experiencing failure with a value of the Percentage of Failure Occurrence below 1 percent in Fabrication and Loadout Conditions and the value of the stress ratio in Unity Check below 1.

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