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Behavior Analysis Conductor Leg From Monopod Platform Effects of Lateral and Axial Loading Using the Finite Element Method

Kunthi Ulfa Diatri* Prabawani, Rudi Walujo Prastianto, Handayanu
Department of Ocean Engineering. Sepuluh Nopember Institute of Technology, Indonesia
*Email: Kunthi.ulfa@gmail.com

Abstract

A minimalist platform is a platform with a smaller and simpler deck and has less equipment. Minimalist platforms are generally designed for fields with lower reservoir reserves and are expected to have low costs in terms of fabrication and installation. One of the studies in developing a minimalist platform is about a conductor pipe that functions as a well and as the leg of the platform. This platform is susceptible to deflection under lateral and axial loads. In this research, an analysis will be carried out on the conductor pipe as a single pile which is subjected to a combination of lateral and axial loads to determine the stress and deflection that occurs in the conductor leg. This study was conducted using the finite element method with ABAQUS software. Inclination variations were carried out to determine the strength of the conductor leg when an inclination occurs. The result of this study was found that the conductor leg with an inclination of up to 1.5 degrees still had a stress below 0.6 yield. The result of this analysis shows that the conductor leg's stress increases with increasing inclination. The maximum stress occurs at 1.5^o of inclination which is 91.41 MPa under operating conditions and 129.43 MPa under extreme conditions. This stress is still below the allowable stress of 213 MPa (0.6 yields).

Keywords: Conductor Leg, Platform Minimalis

1. INTRODUCTION

In order to minimize production costs, the oil and gas industry in Indonesia has begun to conduct studies and research on minimalist platform types. A minimalist platform is a platform with a simpler structural design, smaller deck load and high density cost which is relatively lower at the fabrication and installation stages. This type of platform also minimizes the impact on the environment, and is expected to be reusable. Minimalist platforms are very profitable to apply to marginal fields where the field has limited reservoir reserves. However, a minimalist platform has consequences, including a structure with low redundancy, so that if one structural element fails, it will be very risky to the entire structure, have less reliability, and be susceptible to large deflections.

Research on minimalist platforms is starting to be developed, as was done by Eik H. Lee (2013) who researched one type of minimalist platform, namely tarpon monopod. Tarpon monopod is a platform consisting of caisson The main thing is held by 3 sets of cables which function as anchor piles on the seabed. Structures with single piles are susceptible to deflection, accumulation of deflection on single pile due to long-term cyclic lateral loads, the structure as a whole tilts and can affect operational safety (Leblanc, 2009). Achmus, M (2009) conducted research to estimate the progressive deformation of monopile embedded in a sandy seabed under long-term cyclic lateral loads with a stiffness degradation model concept.

As studies develop regarding minimalist platforms in particular monopile, Now studies are starting to be carried out regarding conductor leg platform namely a platform where the conductor pipe also functions as the platform leg. This type of platform is designed to be operated in shallow water with a short operating life. Conductor leg very susceptible to deflection caused by axial loads from the weight of the structure itself, live loads, and equipment or equipment above the deck and lateral loads from environmental conditions such as wind, waves and currents that impact the structure. Conductor leg platforms can be designed with multi leg or single leg.

In this research, an analysis was carried out on conductor leg who behaves as single pile on monopod platform. The case study used for this research was taken from one of the platforms installed in the shallow waters of Handil, Balikpapan which has a water depth of 6.08 m. The platform is 8 m high seabed this is staked into the ground to a depth of 80.15 m.

2. RESEARCH METHODS

2.1. Platform Modeling Monopod

Conductor Leg in this study taken from the platform monopod which was installed in the shallow waters of Handil, Balikpapan. Platforms monopod modeled with one pile which also functions as a conductor. There is main deck at El (+) 5.0 m which has a size of 2.15 m ´ 3.90 m and utility deck at El (+) 7.5 m. Platform structure weight monopod Of generate as dead load, whereas live load and weight equipment (piping, electrical and intrument) is modeled as a load on the deck. Model validation is carried out by comparing the weight of existing data with the weight of modeling results and results error not more than 5%.

The analysis was carried out in 2 environmental loading conditions, namely during operating conditions (1 year return period data) and storm conditions (10 year return period data). Environmental loads include wave, current and wind loads with 8 loading directions. Tables 3 to 5 are wave, current and wind data for the Handil Balikpapan area. Platform water depth monopod is 6.08 m from seabed with detailed water depth shown in Table 6.

Analysis performed on the platform monopod is a static analysis with interaction pile and land. Interaction pile and soil is carried out using the method P-Y curve.

Table 1. Data Conductor Leg

Conductor-Leg	
Outside Diameter	0.508 m
Wall Thickness	0.016 m
Yield Strength	355 MPa
Material Density	27.472 T/m^3
Penetration Depth	80.15 m

Table 2. Basic Load

Loads	**Fx (kN)**	**Fy (kN)**	**Fz (kN)**
Structure Dead Load	0	0	-83.74
Non Generated Dead Load	0	0	-5.07
Live Load	0	0	-35.40
Equipment Load	0	0	-11.71
Sump tank Load	0	0	-16.60
Piping Load	1.13	-0.64	-40.51

Table 3. Wave Data

Return Period	**1 Year**	**100 Years**
Maximum Wave Height	1.5 m	0
Wave Period	5.5 s	0

Table 4. Flow Data

Return Period	**1 Year**	**100 Years**
Surface Current	1.2 m/s	1.6 m/s
Mid Depth Current	0.9 m/s	1.4 m/s
Seabed Current	0.8 m/s	1.2 m/s

Table 5. Wind Data

Return Period	1 Year	100 Years
Wind Speed	16.1 m/s	26.3 m/s

Table 6. Water Depth

Description	Value
Chart Datum +/- 0.0 (m)	3.00
Highest Astronomical Tide (m)/LAT	2.60
Lowest Astronomical Tide (m)/CD	0.48
Mean Sea Level (m)/LAT	1.10
Max Water Depth (m)	6.08
Min Water Depth (m)	3.48

2.2. Pemodelan Conductor Leg

Geometry modeling conductor leg and soil in this research was carried out with the help of ABAQUS software. Models are divided into 2 part includes domains conductor leg and land domains. Domain conductor leg modeled with a diameter of 0.508 m and in extrude 3 m long above seabed and embedded in the ground along 32.32 m. Conductor leg modeled as elements shell with a thickness of 0.016 m. Material properties of conductor leg presented in Table 1.
The next step is modeling the soil domain with a size of 20 m ´ 20 m and in extrude as the depth of the ground along 43.00 m. The soil domain is modeled as an element solid and divided into 12 layer with each layer having property values presented in Table 7.

Table 7. Soil Data

Soil Layer	Depth (m)	Wet Density (kN/m3)	Dry Density (kN/m3)	Su (kN/m2)	E (kN/m2)
Layer 1	6.40	1590	990	20580	1871800
Layer 2	10.98	1600	960	19600	1783600
Layer 3	17.07	1560	900	23520	2616600
Layer 4	20.12	1700	1150	20580	891800
Layer 5	23.17	1700	1130	21560	1352400
Layer 6	24.70	1670	1090	49000	6125000
Layer 7	27.74	1620	1040	46060	2303000
Layer 8	32.32	1690	1090	43120	2695000
Layer 9	35.37	1840	1380	35280	1538600
Layer 10	36.89	2000	1630	73500	3675000
Layer 11	38.41	1940	1620	119560	5693800
Layer 12	43.00	1690	1130	76440	9555000

2.3. Kondisi Batas

Structural modeling for finite element method analysis only conductor leg without deck with 0 slope variationsthe, 0.5the, 1the, and 1.5the Which represented as a moment load.
The land domain is assumed fixed on the entire ground surface and modeled with a model Mohr Coulomb. Land size 20 m ´ 20 m is considered very large compared to the diameter dimensions conductor leg (20´D), so that boundary conditions in the land domain are considered to no longer influence behavior conductor leg.

3. RESULTS AND DISCUSSION

3.1. Global Platform Analysis Monopod

Platform modeling monopod carried out with SACS software. Modeling was carried out according to existing data and validation of the weight of the structure was carried out by comparing it with the weight in the data. Table 8 is the result of structural weight validation with results error less than 5%.

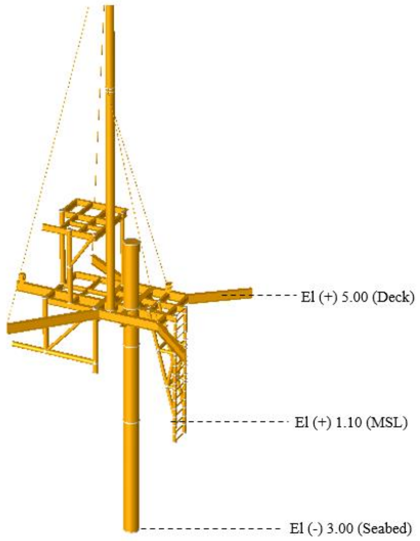


Figure 1. Monopod Platform Model

Global analysis is carried out to determine the suitability of the structure to operate under gravity loads equipment, live loads and environmental loads during operating conditions or storms. Static analysis of the structure will be obtained member unity check namely the ratio of the stress that occurs in the structure to the stress yield on structural materials. A structure is said to be safe when member unity check does not exceed 1 (API RP 2A WSD). Maximum UC member yield on structure conductor leg presented in Table 9.

Table 8. Validation of Structure Weight

Structure Weight (kN)		Error (%)
Data	**Model SACS**	
193.03	199.8	3.51

Table 9. Member Unity Check

Properties	Load Condition	Max. UC
50.9 cm OD x 1.60 cm WT	Operating	0.26
	Storm	0.35

Maximum force and moment acting on conductor leg taken to be used as a load for analysis using the finite element method. Table 9 presents the maximum forces and moments that occur at conductor leg.

Table 10. Maximum Member Force and Moment Conductor Leg

Load Condition	Force			Moment		
	Fx (kN)	**Fy (kN)**	**Fz (kN)**	**Mx (kN.m)**	**My (kN.m)**	**Mz (kN.m)**
Operating	-195.93	7.18	-7.77	-2.56	84.53	-147.62
Storm	-196.06	16.86	-17.47	-1.06	135.58	-196.93

3.2. Analysis Conductor Leg with the Finite Element Method

Finite element analysis is carried out by modeling 2 computational domains, namely soil and conductor leg. Domain conductor leg modeled as elements shell and the soil domain is modeled as an element solid. Conductor leg with materials presented in Table 1. modeled in the middle of the soil domain with a penetration depth of 32.32 m. The land domain is modeled with a size of 20 m x 20 m and in extrude up to 43 m as soil depth. The land domain is divided into 12 layers with each layer having property values presented in Table 7. Soil domain boundary conditions fixed for the entire ground surface. The soil model is simulated with the model Mohr-Coulomb. According to Chen & Mizuno (1990) it can be formulated as follows::

$$|\tau| + \sigma \tan\varphi - c = 0 \qquad (1)$$

Where,

τ shear strength
σ normal stress
φ angle of internal friction
c cohesion

3.3. Sensitivity Meshing

Arrangement mesh carried out in order to obtain good discretization in modeling and obtain optimum simulation results. In obtaining configuration meshing Appropriate simulations need to be carried out several times with varying sizes mesh until a value is obtained output which is convergent. Table 10 and Figure 3 show a graph of the sensitivity results meshing, The total number of soil domain elements is 110752 elements and domains conductor leg 648 elements with shapes hexahedral element. Figure 2 is the result meshing by combining domain models conductor leg and land.

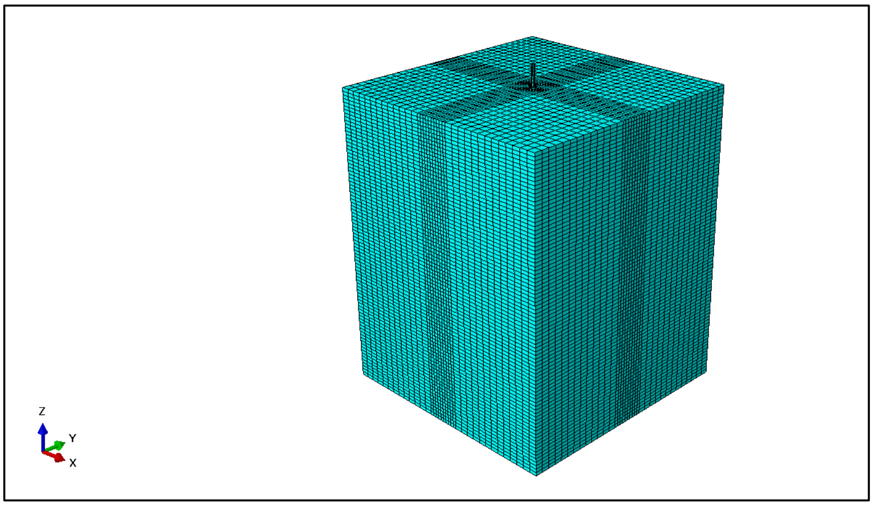


Figure 2. Model Mesh

Table 11. Sensitivity Meshing

Element Size (m)	Element Total	Stress (MPa)	Difference (%)
1.00	22424	47.401	0.000
0.70	45504	47.506	0.220
0.65	68536	47.444	0.131
0.50	111400	47.499	0.115
0.40	137240	47.499	0.000

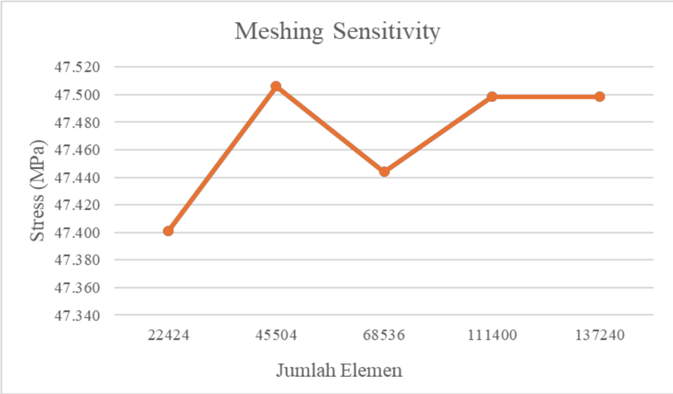


Figure 3. Sensitivity Graph Meshing

3.4. Local Analysis Conductor Leg

Voltage (stress) that happens to members conductor leg analyzed with variations in slope. It is hoped that the voltage will still be within safe limits if there is a slope in the field where the platform is located monopod susceptible to tilt. The slope variation analyzed in this study is 0the, 0.5the, 1.0the and 1.5the.
Validation of the model in this research was carried out by comparing the results von mises stress maximum on conductor leg with results von mises stress during global analysis. Mark error not less than 5% as shown in Table 11.

Table 12. Local Model Validation

Von Misses Stress (Mpa)		**Error (%)**
SACS	**ABAQUS**	
79.13	78.26	1.10

Figures 4 and 5 show the stress graphs von mise maximum occurs at conductor leg during operating environmental and storm/extreme loading conditions. The stress increases as the slope increases. The maximum stress that occurs under operating environmental loading is 91.41 MPa at a slope of 1.5 and 129.43 MPa under storm/extreme environmental loading. The maximum stress is still below the allowable stress, namely 0.6 yields (0.6 x 355 Mpa = 213 Mpa).
Voltage distribution on conductor leg can be seen in Figure 6. The red color indicates that the tension is getting bigger while the blue color shows that the tension is getting smaller. The maximum voltage for operating and storm conditions occurs at elements 144 and 297 located at El. (-) 3.00 m until El. (-) 3.50 m where seabed has El. (-) 3.00.
Figures 7 and 8 show maximum deflection graphs conductor leg with varying slopes. The maximum deflection under operating conditions is 14.09 cm and during storm conditions it is 22.02 cm. This deflection has exceeded the allowable deflection, namely 8 cm (H/100). Therefore, verification is required equipment above the deck is it still safe with a structural deflection of that result?

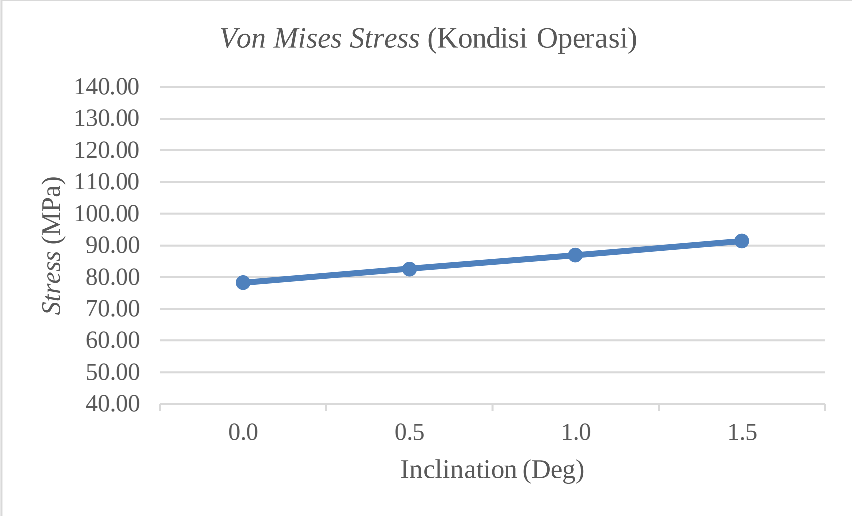


Figure 4. Von Mises stress Operating Conditions

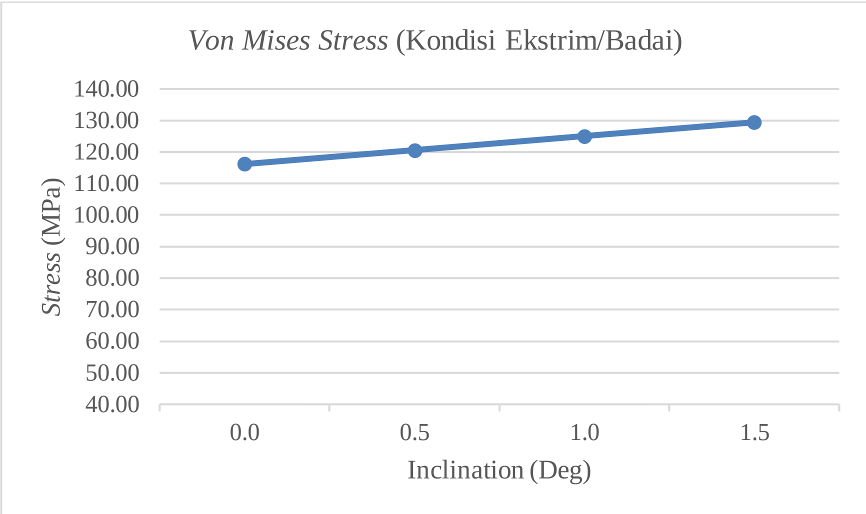
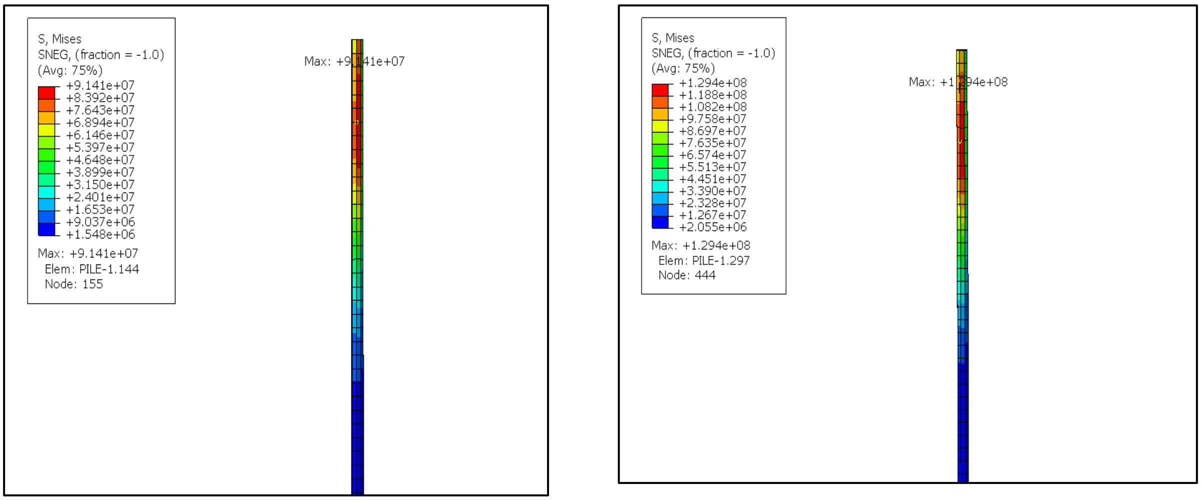


Figure 5. Von Mises stress Stormy/Extreme Conditions



(a) (b)

Gambar 6. (a) Plot Von Mises stress Operating Conditions, (b) Plot Von Mises stress Hurricane Conditions

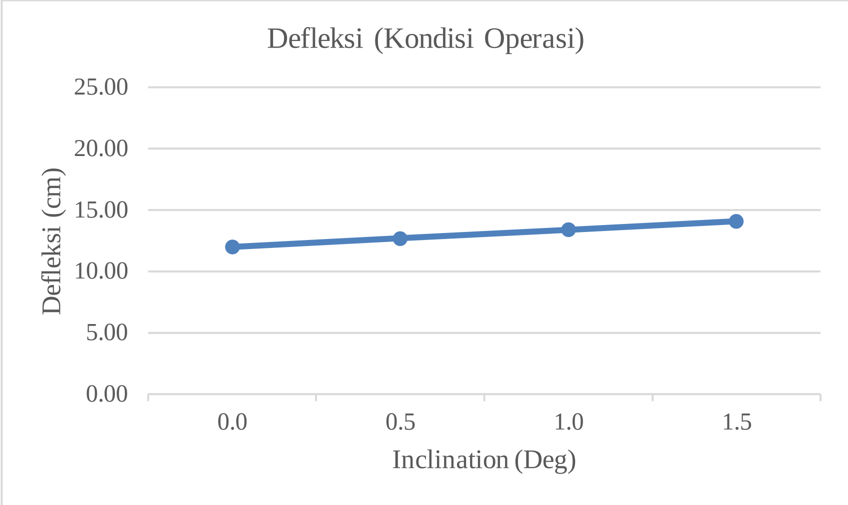


Figure 7. Maximum Deflection Conductor Leg Operating Conditions

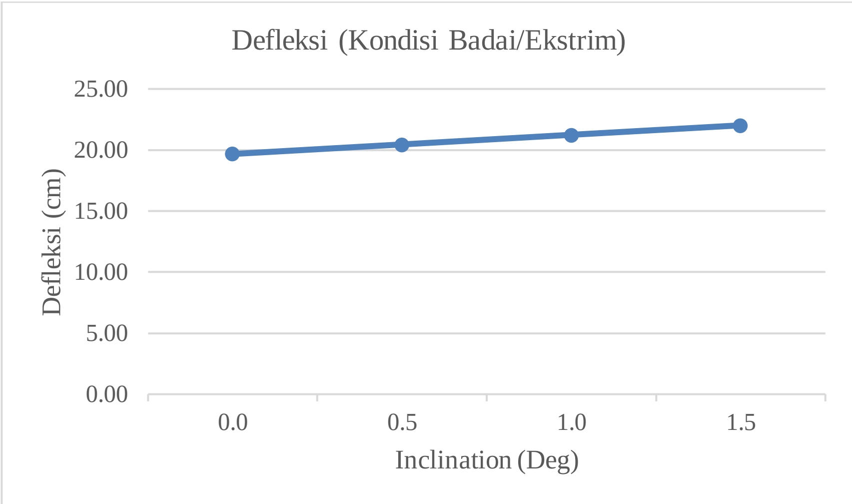


Figure 8. Maximum Deflection Conductor Leg Stormy/Extreme Conditions

4. CONCLUSION

Based on the results of the analysis carried out in this research, namely strength analysis conductor leg with variations in slope it can be concluded that the increase in slope conductor leg can increase the stress on the structure where the maximum stress or most critical stress occurs at the same elevation as seabed. The maximum stress and deflection results are described as follows:

1. Maximum voltage at conductor leg namely 91.41 MPa during operating environment loading and 129.43 MPa during storm/extreme loading conditions, both of which occur when slope conditions are 1.5the. The voltage value is still below voltage allowable that is, 213 MPa (0.6 yields).
2. Maximum deflection occurs at conductor leg is 14.09 cm in operating environmental conditions and 22.02 cm in storm/extreme conditions with a slope of 1.5the. The deflection has exceeded the maximum allowable deflection so verification is required equipment Above the deck, is it still safe if there is a structural deflection of that value?

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