

# Study the Effect of Location and Soil Side Slope on Fixed Offshore Platform

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**Abstract** Fixed offshore structures are designed to resist lateral dynamic loading due to wave, wind, current and ships impact loading. Pile foundations are very important part in fixed offshore structures that is supported these structure, the behaviour of fixed offshore structure is affected by the pile response. The aim of this study is to investigate the effect of location and soil side slope on the response of these structures under wave loading. Three dimension analyses has been performed by using ABAQUS program, structure was represented by three dimension Euler-Bernoulli beam and used twenty node brick element to represented the soil element. Penalty method is used to represent the interface between soil and pile. The calculation of wave loading based on Morison Equation, this equation includes the velocity and acceleration of water particles that is calculated from nonlinear wave theory (Stock's theory). The result show the response is increased at distance about 10 m for the coast and when the side slope angle is  $90^\circ$  due to the effect of turn wave.

**Keywords:** offshore pile, ABAQUS, offshore location, soil side slope

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## 1. Introduction

In the analysis of sensitive and important structure, the response of ground is considered as necessary initial step. In the case of offshore platforms the ability of the geotechnical engineer to evaluation realistically the stress and strain developed on the besetment soil is very success in estimating the distress of their foundation. The dynamic stresses in soil are depended on the field conditions and the excitation characteristics at the base of the soil deposit. Several analytical methods have been established in recent years for study the response of fixed offshore structure under laterally dynamic loads.

Eicher et al. [1], Study the stress deformations in offshore concrete piles subjected to wave and combined structural loading by used finite element methods, also study the effect of change loading on the soil stresses. Chae, et al. [2], performed 3D finite element analysis to represent tests and a prototype test of a pier footing and short rigid offshore piles subjected to lateral load located near slopes and compared between the field tests and model tests. Naggar and Mostafa and [3], has studied the influence of seabed instability on a steel fixed platform structure, the study considering pile-soil interactions, the non-linearity of soil and dynamic soil strength. The factors pile flexibility, soil movement, axial loading at pile head and sliding layer depth are considered in the analysis. Muthukkumaran, K. and Sathyanarayanan, D. [4], performed a parametric study by change the seabed slope to inspect the difference in soil pile interactions, the study

chosen typical offshore steel platform with fixed based, the analysis and modeling are done by FLACK3D finite element package.

## 2. Numerical Modeling

The structure is simulated and analyzed by used finite element package ABAQUS (v.13). The soil continuum is simulated considering a 20-node brick element (C3D20), This element is contained three active translation degree of freedom at each node and have of one integration point at the centroid, the piles is placed along the axial z-direction of the element, the pile and structure were represent by used three dimensional 3-node quadratic beam element (B32), the nodes contain six degree of freedom, three rotation and three displacement in x, y and z direction [5]. Figure 1 show the numerical model geometry for a structure. The soil surface is assumed as stressed boundary with hydrostatic pressure. The boundary condition is used a fixed for all side of soil to reduce the model size. The soil bed considered a fixed.

### 2.1. Structure Description

This paper used a default fixed platform with steel pile jacket. The platform has eight columns stayed on eight steel piles with dimeter 1300 mm and thickness 12.7 mm and length 40 m supported vertically, the superstructure represent I-section (400\*200\*66kg/m<sup>3</sup>) steel deck with square dimensions 20x20 m. the structure frame contain steel beam pipe 750 mm dimeter and 12.7 mm thickness

and steel bracing pipe 500 mm diameter and 12.7 mm thickness, Figure 2 show the structure details and levels. The elastic response of steel structure was defined by Young's modulus, E (200 GPa ) Density (7850 kg/m<sup>3</sup>) and Poisson's ratio, v, (0.3).

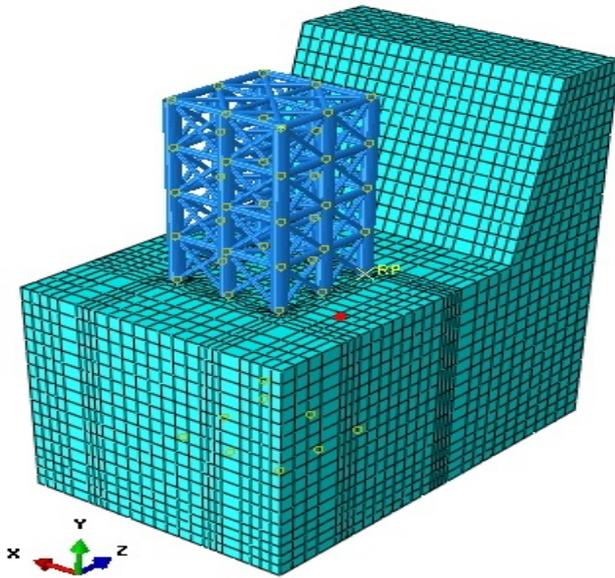


Figure 1. Numerical model geometry for a structure

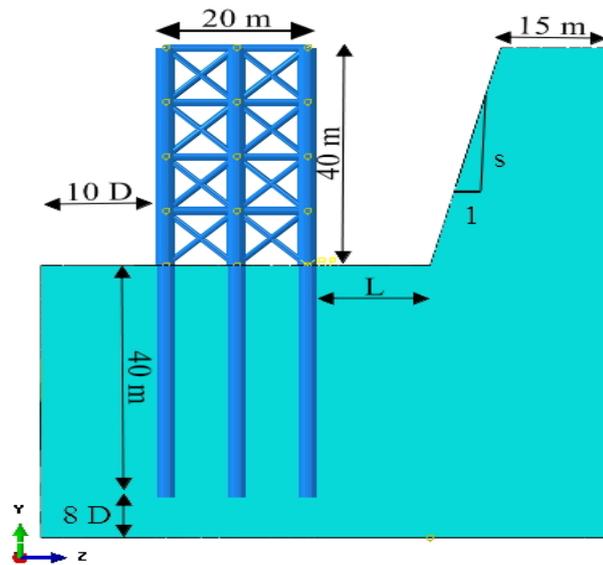


Figure 2. Shows the structure details and levels

## 2.2. Soil and Soil-Pile Interaction

The soil is simulated as an isotropic elastic-plastic continuum with surface failure determinate by the Mohr-Coulomb principle. The elastic properties were considered by Density,  $\gamma$ , (21.4 kg/m<sup>3</sup>),  $\gamma$ , Young's modulus, E, (22.8MPa) and Poisson's ratio, v, (0.49). The plastic response is described by the residual angle of internal friction,  $\phi$  and the dilation angle,  $\psi$ , and material hardening is described by absolute plastic strain,  $\epsilon_{pl}$  and the cohesion yield stress, c (43 kPa). The soil-pile-soil interaction is simulated using the Tangential Behavior Penalty-type Coulomb's frictional model [6,7].

## 2.3. Hydrostatic Data

The environmental data that has been based on the Arabian Golf [8], the wave period 13 sec, maximum wave height 10.7m and wave length 261, Table 1 shows the properties of sea water.

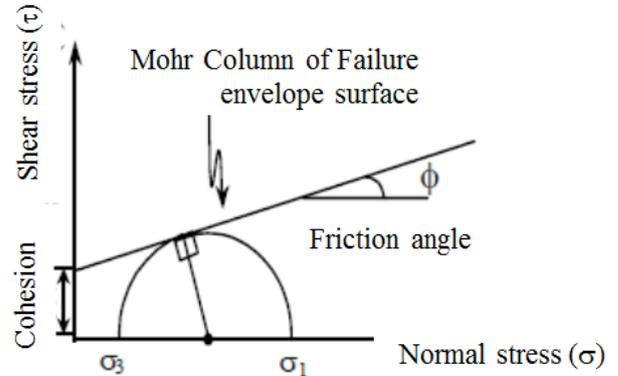


Figure 3. Mohr Coulomb's failure surface [6]

Table 1. Sea Water Characteristics [8]

Item	Value	Unit
Water Depth	21.34	m
Water density	1025	kg/ m <sup>3</sup>
Water Viscosity	1.2 E -6	m <sup>2</sup> /sec
Water Drag Coefficient	0.35	
Inertia Coefficient	1.45	
Gravity Acceleration	9.81	m/sec <sup>2</sup>
Wind velocity	27.2	m/sec
Air density	1.2	kg/ m <sup>3</sup>

## 3. Dynamic of Structures

The dynamic behaviour of structure platform under wave load is calculated by used equation 1

$$[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = \{F\} \quad (1)$$

where [M] is the total mass matrix of the system,  $\{\ddot{U}\}$  is the nodal accelerations, [C] is the damping matrix,  $\{\dot{U}\}$  is the nodal velocities, [K] is the structural stiffness matrix, {U} is the nodal displacements, and {F} is the hydrodynamic force [9].

## 4. Results and Discussion

In this paper, a default fixed platform Figure 2 is taking as a case study under dynamic wave loading with maximum load direction (x-direction) and using Morison equation with physical properties calculated from Stock's theory [10]. Figure 4 show the variation in deck displacement for different structure locations with vertically side slope, the figure show increasing in displacement about 72 % when structure location at 10 m from side because wave reverberation and blockage of water mass behind structure after this location the

response become decrease and become not important at location 25 m and 50 m, when the structure beside the edge (at  $L=0$  m) the response is very low because the edge is increase the support of structure and making additional equilibrium, the response of structure is applies

on the pile response for displacement along pile length [Figure 5](#) and [Figure 6](#) and bending moment along pile length [Figure 7](#) and [Figure 8](#), the pile head displacement is increase about 40 % at location 10 m and bending moment increase about 30 % for same location.

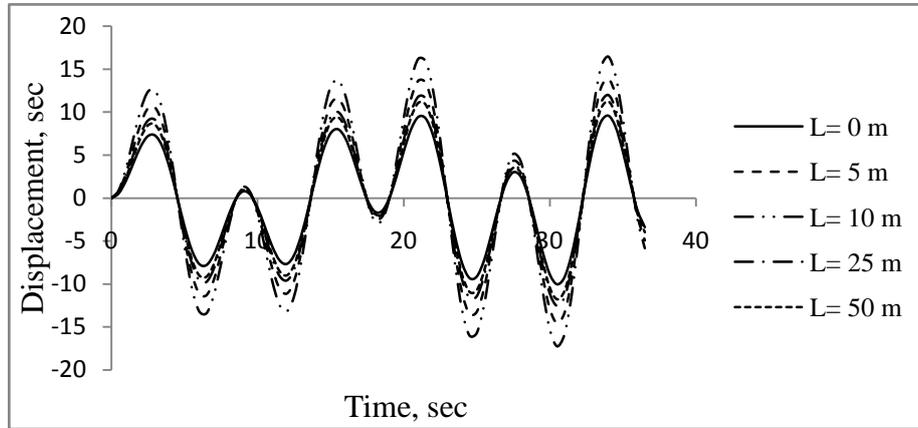


Figure 4. Deck displacements for different structure location

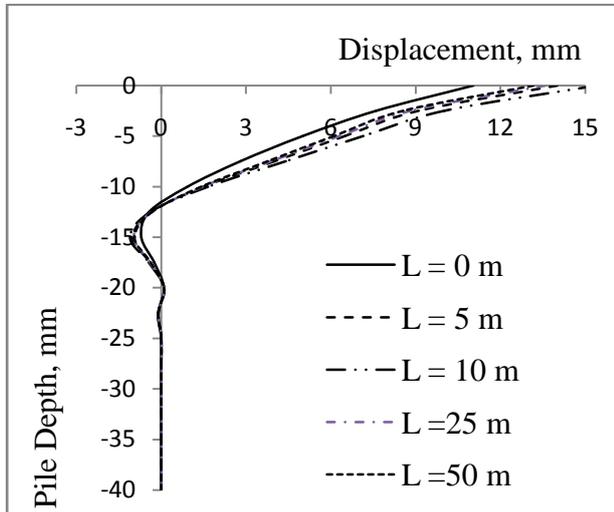


Figure 5. Displacement along pile length

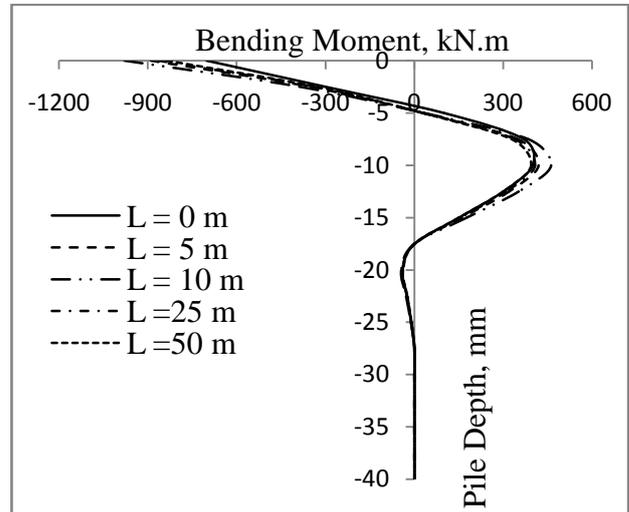


Figure 7. Bending Moment along pile length

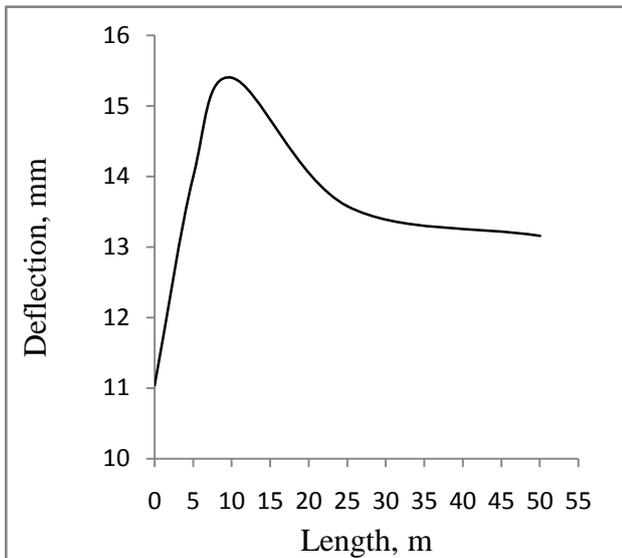


Figure 6. Variation in pile head displacements for different structure location

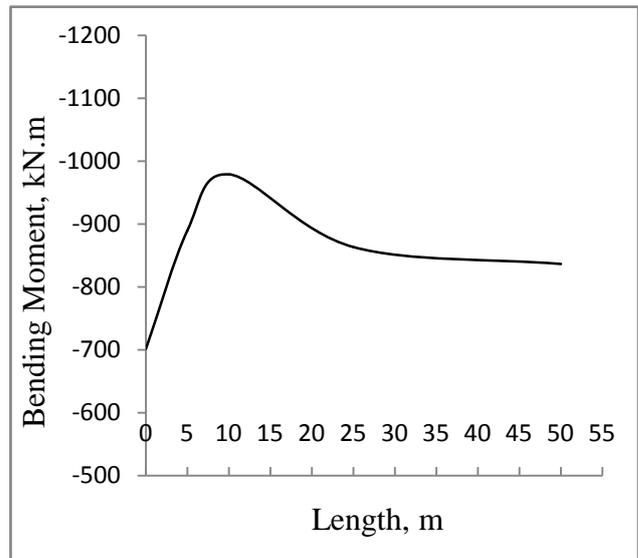


Figure 8. Variation in pile head Bending Moment for different structure location

Figure 9 show the variation in deck displacement for different edge side slope at location 10 m to calculate the maximum structure response, the figure show increasing in displacement about 66 % side slope angle 90° because full wave reverberation, the variation is increasing slowly when side slope 45°, beyond this angle the increasing

become rapidly and this variation is also applies on the pile response for displacement along pile length Figure 10 and bending moment along pile length Figure 12 and Figure 13, the pile head displacement is increase about 90 % and bending moment increase about 35 % when side slope angle 90° behind structure.

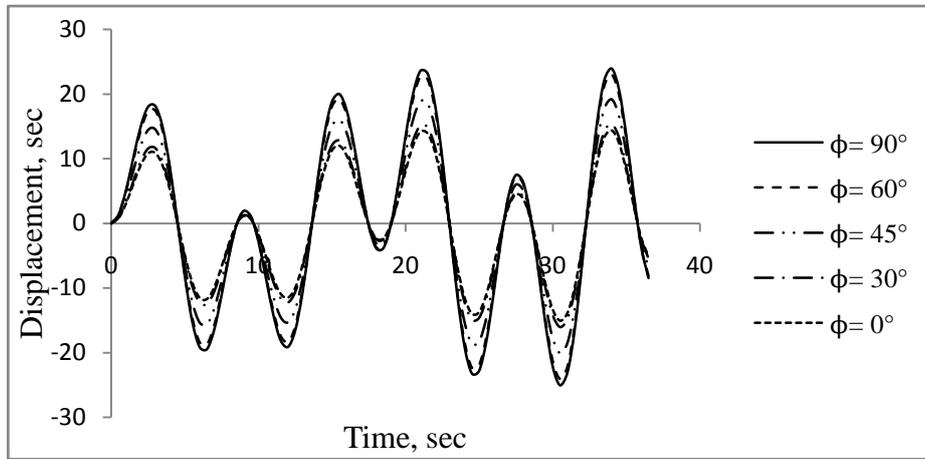


Figure 9. Deck displacements for different offshore side slope

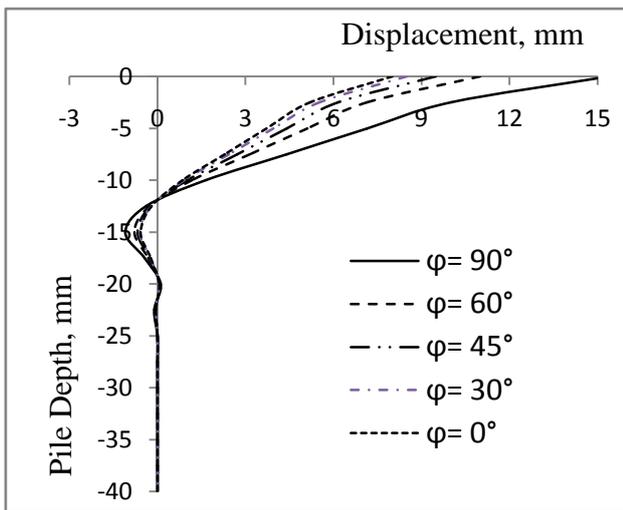


Figure 10. Displacement along pile length

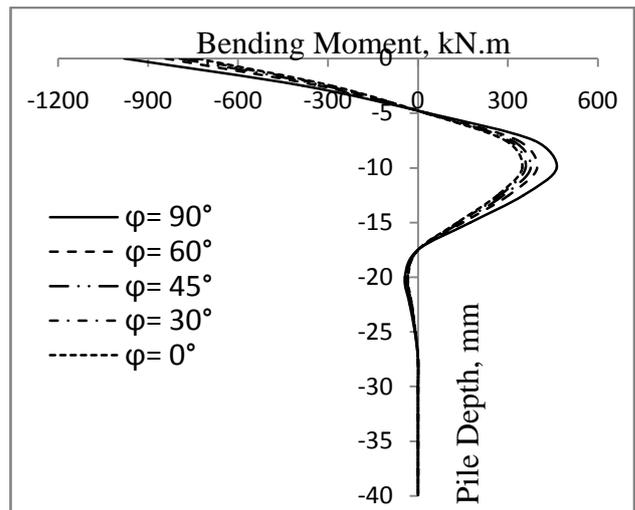


Figure 12. Bending Moment along pile length

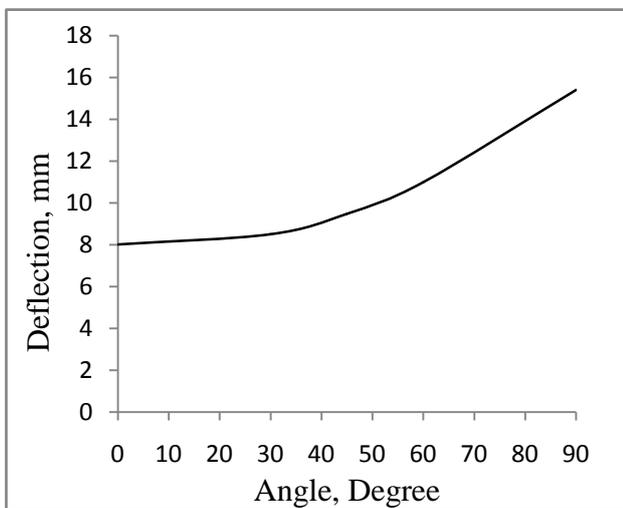


Figure 11. Variation in pile head displacements for different side slope

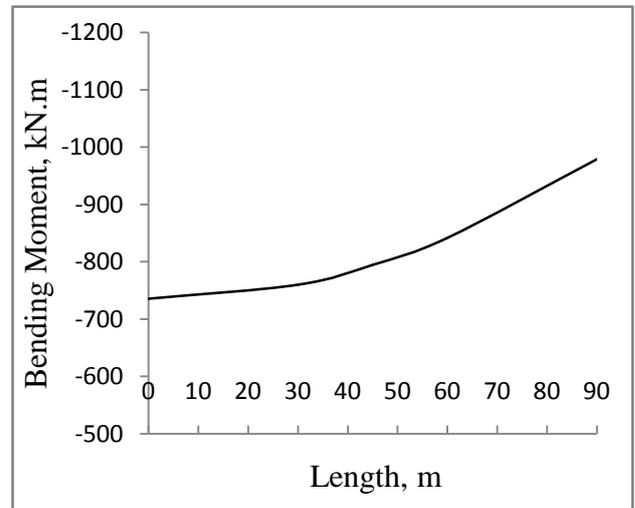


Figure 13. Variation in pile head Bending Moment for different Side Slope

## 5. Conclusions

The main conclusion from this paper shows the dynamic structure response is increase by changing structure location and edge side slope, the deck displacement and the pile head displacement are very sensitive for change structure location and edge side slope other than bending moment, the paper show when the structure location about 10 m and the edge side is vertically is represent critical response of structure.

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