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EFFECTS OF SOIL DOMAIN SIZE ON TORSIONAL RESPONSE OF OFFSHORE PLATFORM

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ABSTRACT

The main target of this work deals with the investigation of the dynamic behavior of offshore platform structure to the torsional load which produces from two ships collision load in opposite direction considering the impact of soil size domain. The ABAQUS software is employed to achieve the structural response considering soil-pile-offshore platform interaction. Two soil models are adopted in this study and these models are elastic model and elastoplastic model, while this study adopted six soil size domains as a function of pile diameter and these sizes are (4D,6D,8D,10D,12D,14D) where D represent pile diameter. The investigation includes pile response and can be described by displacement, twist angle, shear force, bending moment, and shear stress. Also, the displacement of deck slab variation with time is investigated. The investigation illustrates that always the response of piles which comprises displacement, twist angle, shear force, bending moment and shear stress is higher when the pile foundation embedded in elastoplastic soil as compared with elastic soil, also the variation in deck slab response is higher when the pile foundation embedded in elastoplastic soil as compared with elastic soil. It is evident from the result as the soil domain size increases the response of piles and deck slab decrease regardless of the soil model.

Disciplinary: Civil & Geotechnical Engineering.

1. INTRODUCTION

With rapid development in offshore engineering, a large number of the platform are being constructed and installed in the marine environment, the fixed steel jacket platform is the most commonly used. The work [1] studied the response of an offshore platform to the impact load from a ship by adopting the finite element method. The ABAQUS software is used for structural problem

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analysis, their study considered soil-pile-structure interaction, also their study is concerned with lateral displacement of the pile, the twist angle of the pile, shear force and bending moment distribution of the pile respectively, Also displacement of deck slab is investigated. In [2] investigated the Um-Qaser dolphin structure behavior to the lateral impact load. The investigation comprises the impact of pile dimensions and soil properties on the structural response to the ship impact load however the simulation of soil described as an elastic-plastic model.

The studied [3] observed the jacket platform collapse behavior under impact load which applied from the ship by using ANSYS software and compare the result obtained from ANSYS software with a theoretical formula that depends on a rigid plastic mechanism approach. Work [4] investigated the behavior of the dolphin of Khor AL-Amaya berth No.8 to the force of the ship berthing considering the influence of soil-pile interface on dynamic response. In [5], the dynamic behavior of the offshore structure was investigated under combined load, these loads are wave load and ship impact, also soil-pile interaction is considered in this work. The study [6] analyzed the dolphin of Khor AL-Amaya berth No.8 to the impact load from the berthing from an oil tanker of 330000 DWT at 60% cargo. The study [7] focused on the tubes' dynamic behavior to the lateral excitation and obtained that preloading lead to a much more essential altered in a beam-column cylindrical member dynamic properties, in which global buckling is more significant than in member with a low-aspect-ratio. In [8], the steel tube's behavior was investigated under lateral quasistatic loads at their mid-span considering the variation in end conditions types. They found that the axial preload have a substantial influence on the load-bearing capacity for the dissipation of energy was effected dramatically.

This work main target investigates numerically the impact of soil size domain on the structural response of offshore platform considering soil-pile interaction and deck slab response when the offshore platform under torsional load resulting from two ships collision load that is applied in the opposite direction at the platform deck slab. The ABAQUS software is employed to model and simulate this study to observe the structural response considering the soil-pile-structure interaction.

2. PROBLEM FORMULATION

This work studies the response of an offshore platform to the impact load from the ship during berthing. The ABAQUS software is employed to examine the response of the offshore structure to the ship's impact under the effect of changing the soil size domain dimensions. It investigates

1- The influence of soil size domain on pile displacement.
2- The influence of soil size domain on pile rotation.
3- The influence of soil size domain on pile shear force.
4- The influence of soil size domain on pile bending moment.
5- The influence of soil size domain on pile shear stress.
6- The influence of soil size domain on deck displacement.

The soil-pile-structure system can be modeled by using the suiTable required elements.

Beam element B32 (Timoshenko beam): it is a beam has three nodes, this beam is utilized to model piles and structure with linear elastic properties of a material.

Brick element C3D20: it is a brick solid element that has 20 nodes and it is used for soil model with linear and nonlinear properties of soil, the soil nonlinear properties are represented by adopting Mohr-Coulomb.

Two different continua finite elements are used to model the soil. The elastic soil model required soil modulus of elasticity and Poisson's ratio to perform the analysis while the elastoplastic soil model required modulus of elasticity, cohesion, and Poisson ratio to perform the analysis.

The coulomb criteria are given as [9].

$$|\tau| \leq \sigma_n \tan \emptyset + c \quad (1),$$

where τ is shear stress, σ_n is effective normal stress, c is cohesion, and $\emptyset$ is the internal angle of shearing friction. The elasticity modulus of clay soils can be considered as a constant value with soil depth (10), it is also regarded as proportional to the cohesion of soil according to [11, 12].

$$E_s = 500 \times C_u \quad (2),$$

in which C_u is the undrained clay soil shear strength.

The consideration of structure-foundation-soil system interaction altered the real behavior of the structure as compared with considering the structure alone [13]. Three criteria must be satisfied in the design of offshore piles and pile group [14] a-suitable lateral and axial capacities. b-acceptable response in load-deformation. c- feasibility of installation of the piles. The boundary of the soil must be set at a sufficient distance from the edge of the pile, this distance should be sufficiently large but not less than a distance equal to at least five times the diameter of the pile or out of the load area of the envelope [15, 11].

2.1 BOUNDARY CONDITION

It indicates that the entire soil domain is considered fixed while the top of the soil is considered free. Six different soil size domains are considered in this study and express in terms of pile diameter and these distance are 4D, 6D, 8D, 10D, 12D, and 14D. For more clarification, the distance 4D represents the distance measured from pile to soil boundary, also represent the distance measured from the end of the pile to the soil boundary. A full bond is adopted to make the required linkage between piles and soil. The damping ratio is utilized to perform the required analysis of the whole system equal to 0.05.

2.2 LOADING CONDITION

Lateral collision loads from two ships are applied in opposite directions at a platform deck slab to generate the torsion in the platform structure. Overall, it is required to assess the response of the offshore structure platform considering soil- pile-structure interaction.

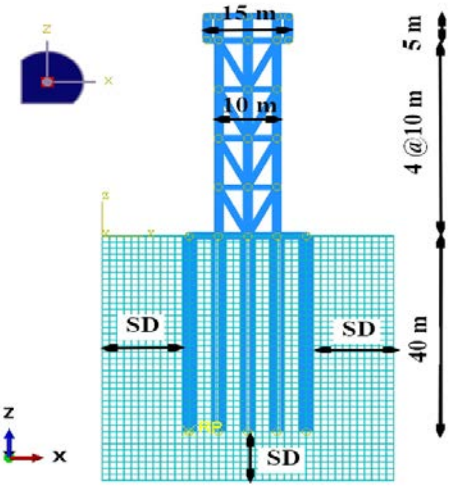

Figure 1: the side view of the whole system

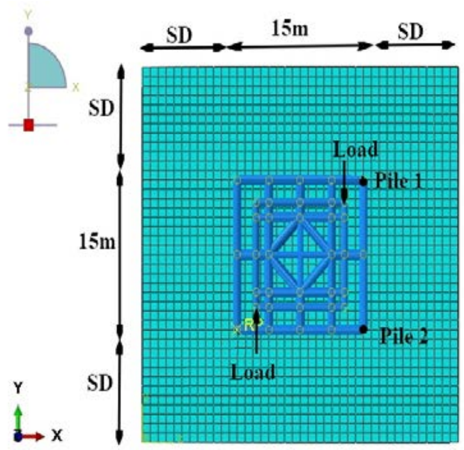

Figure 2: the top view of the whole system

Figure 1 illustrates the side view of the whole system, Figure 2 illustrates the top view of the whole system, Figure 3 illustrates the top view of platform structure and Figure 4 illustrates the whole system.

Table 1 includes all the elements of structure with its dimensions, Table 2 includes the soft clay soil and steel pipe properties that are adopted in the analysis of the current work and Table 3 comprises the applied ship collision load with time.

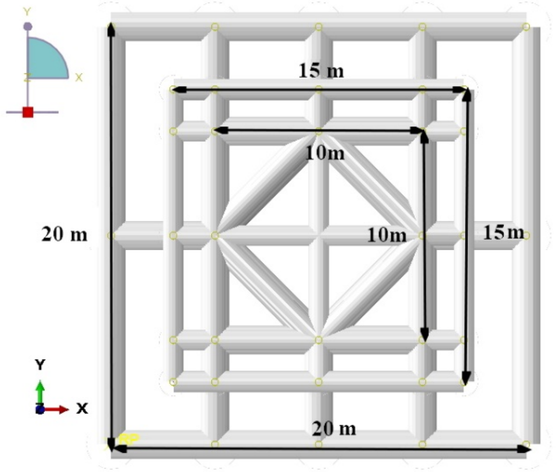

Figure 3: Top view of the platform structure.

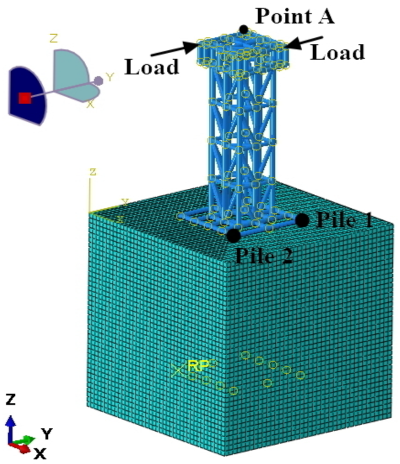

Figure 4: Whole system.

Table 1: the dimensions of the offshore platform elements.

Element	Diameter (mm)	Thickness (mm)
Piles	1000	25
Beams	600	12.7
Piles head beam	700	12.7
Brace	500	12.7
Deck	600	12.7

Table 2: Properties of soft clay soil and steel pipe.

Material	Elastic modulus (MPa)	Poisson s ratio	Cohesion (KPa)	Density (Kg/m^3)
Soft clay soil	12	0.4	24	1800
Steel	200000	0.3		

Table 3: Ship impact force variation with time.

Time (sec)	Load (KN)
0	0
2	2500
13	2300
15	0

3. RESULT AND DISCUSSION

Figure 5 shows the variation in lateral displacement of the pile (P1) which embedded in soft clay soil where the soil has elastic properties, while Figure 6 illustrates the variation in lateral displacement of the pile (P1) which embedded in soft clay soil where the soil has elastoplastic properties. It is clear from figures that the maximum pile head displacement occurs when the pile embedded in elastoplastic soil as compared with elastic soil. Also, Figure 7 shows the variation in lateral displacement of the pile (P2) which embedded in soft clay soil where the soil has elastic properties, while Figure 8 illustrates the variation in lateral displacement of the pile (P2) which embedded in soft clay soil where the soil has elastoplastic properties. It is clear from figures that the maximum pile head displacement occurs when the pile embedded in elastoplastic soil as compared with elastic soil. This happens because of the excess in elastic model stiffness as compared with the elastoplastic model. It is evident from figures as the soil size domain increases the pile response decreases, this is due to an interaction between travel waves and reflected waves and the fluctuation in energy transfer from soil to piles with depth will reflect on the pile's response.

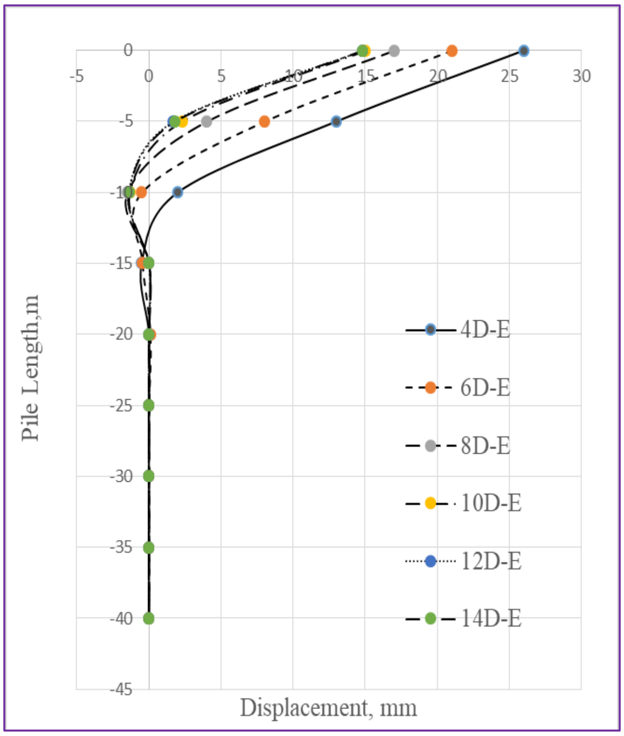

Figure 5: Lateral displacement of P1 pile embedded in soft clay soil with elastic properties

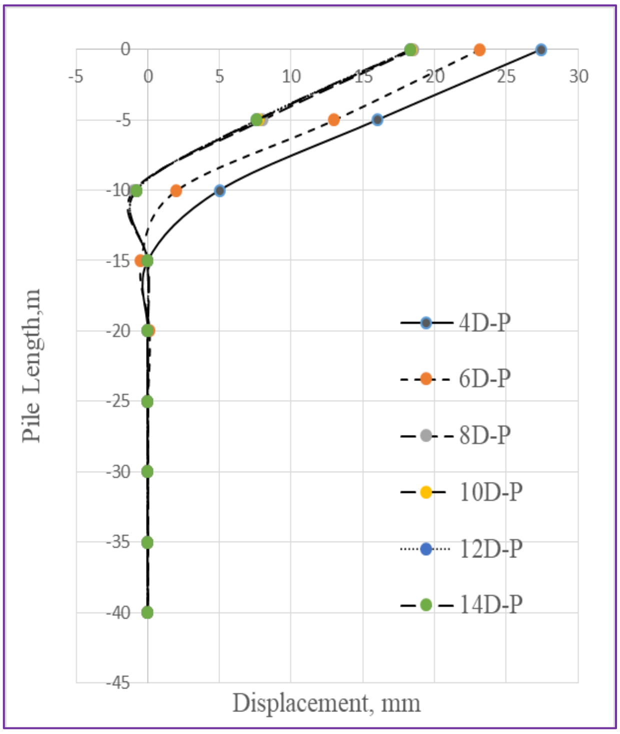

Figure 6: Lateral displacement of P1 pile embedded in soft clay soil with elastoplastic properties

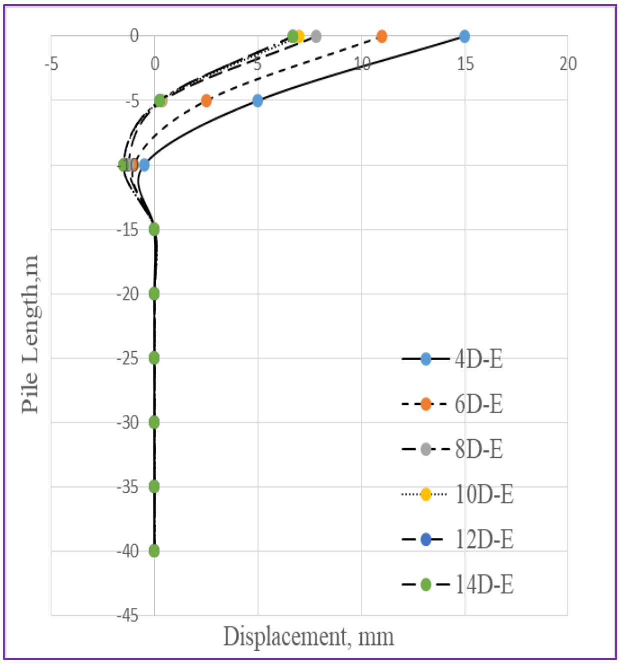

Figure 7: lateral displacement of P2 pile embedded in elastic soft clay soil.

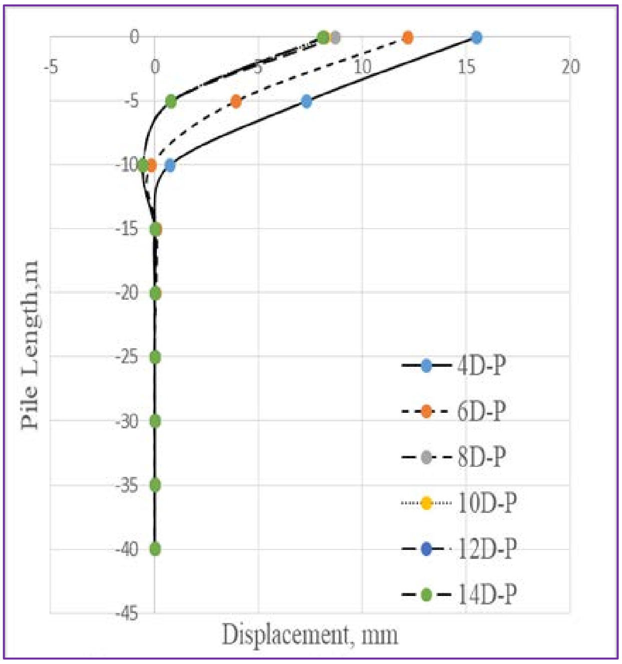

Figure 8: lateral displacement of P2 pile embedded in elastoplastic soft clay soil.

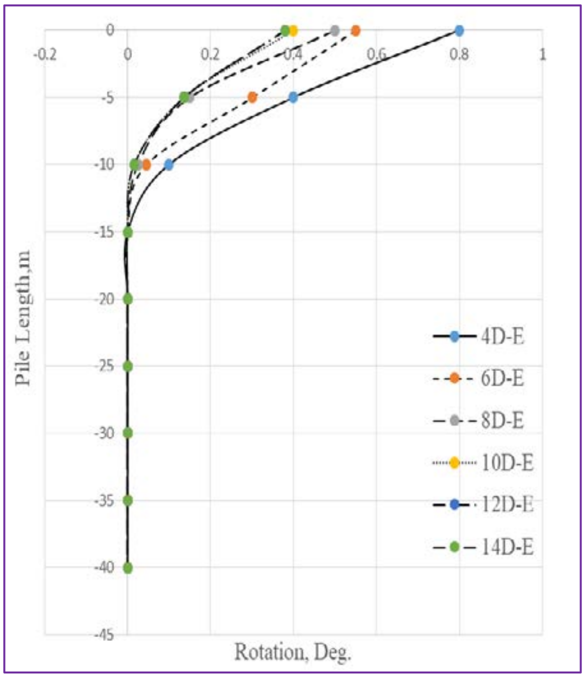

Figure 9: Rotation of the embedded P1 piles embedded in elastic soft clay soil

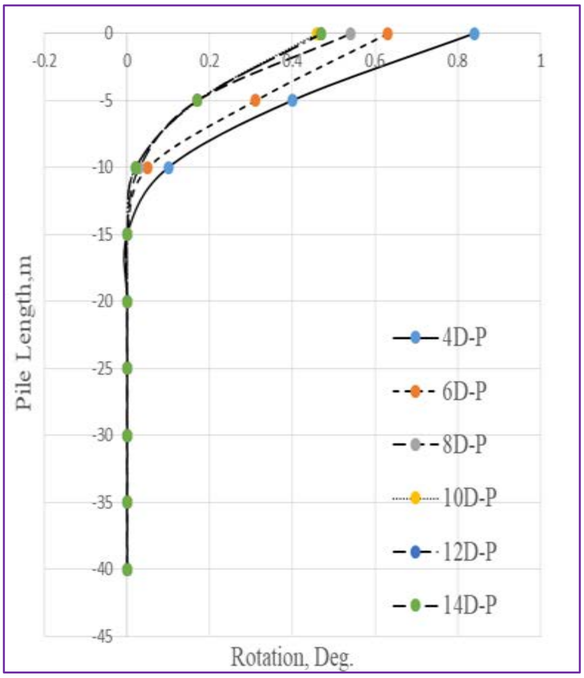

Figure 10: Rotation of the embedded P1 piles embedded in elastoplastic soft clay soil.

Figures 9 and 11 show the rotation of the embedded piles (P1 and P2) in elastic soft clay soil and Figures 10 and 12 show the rotation of the embedded piles (P1 and P2) in elastoplastic soft clay soil. It is obvious from figures that the rotation (twist angle) of piles embedded in the elastoplastic model is higher as compared with a rotation of piles embedded in the elastic model. This happens because of the difference in stiffness between the elastic model and the elastoplastic model. This is clear from figures as the soil size domain increases the pile rotation decreases, this is due to the interaction between travel waves and reflected waves and the fluctuation in the transfer of energy from soil to piles with depth will reflect on the response of the piles.

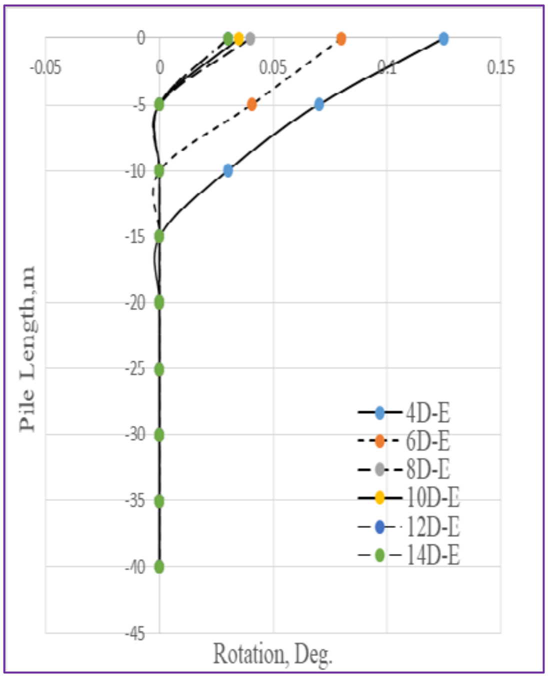

Figure 11: Rotation of the embedded P2 piles embedded in elastic soft clay soil

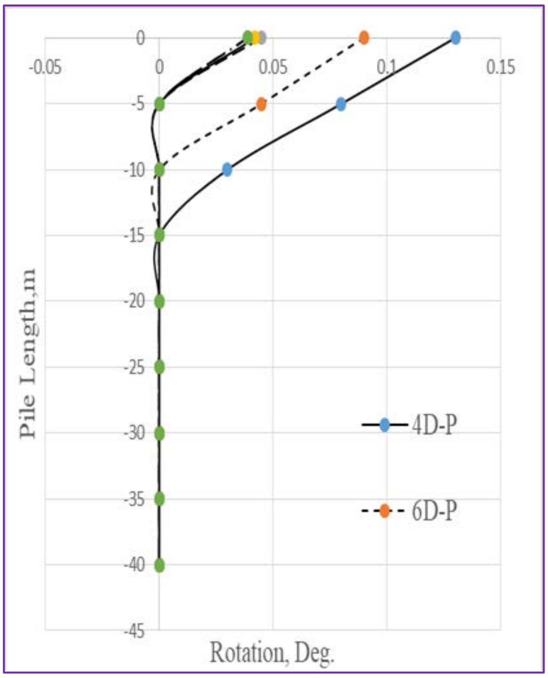

Figure 12: Rotation of the embedded P2 piles embedded in elastoplastic soft clay soil.

Figures 13 and 15 illustrate the shear force along with the piles embedded in elastic soft clay soil while Figures 14 and 16 illustrate the shear force along with the piles embedded in elastoplastic soft clay soil. It appears that the behavior of piles in elastic soil is not the same behavior of piles in elastoplastic soil, also the values of shear force for piles embedded in elastoplastic soil is higher as compare with piles embedded in elastic soil. The variation in behavior depends on soil stiffness and size of the soil domain, these factors which dominate the piles' response.

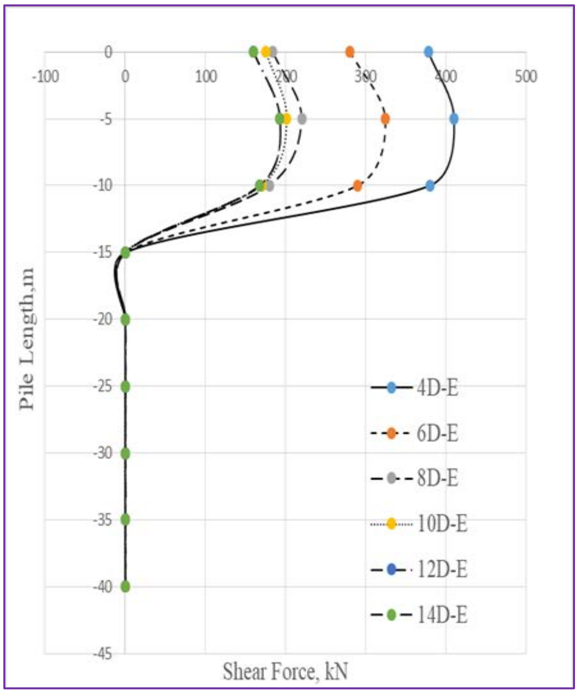

Figure 13: Shear force along with the P1 piles embedded in elastic soft clay soil

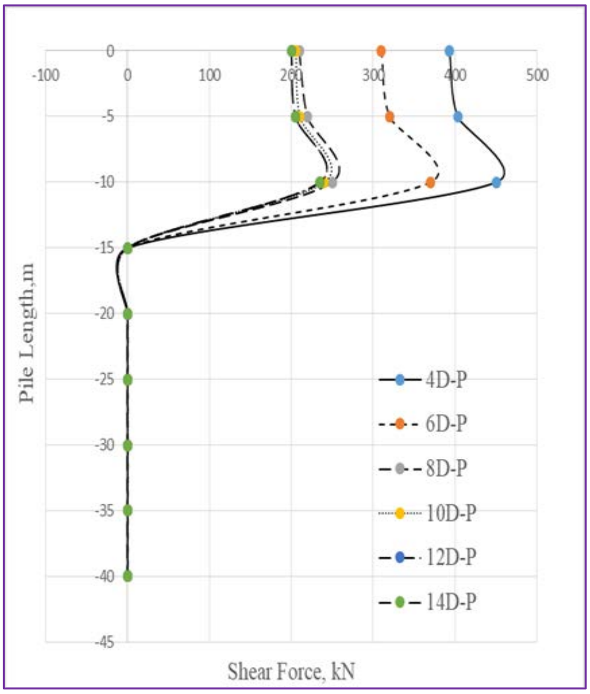

Figure 14: Shear force along with the P1 piles embedded in elastoplastic soft clay soil.

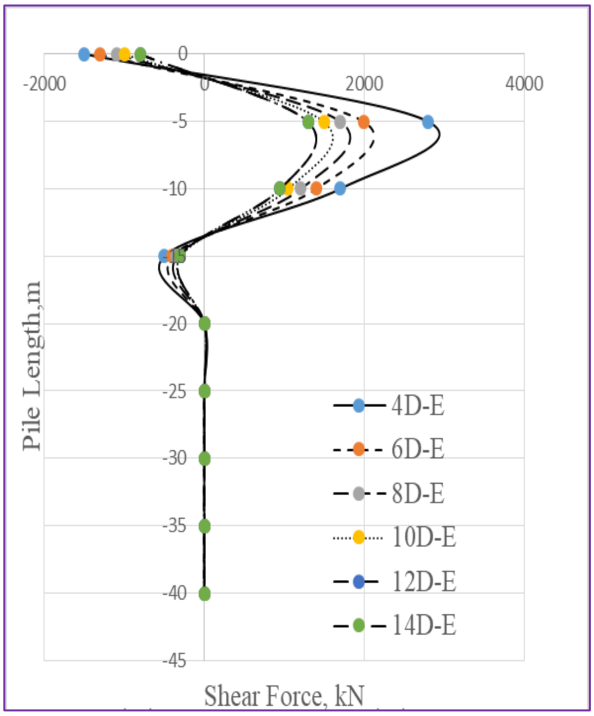

Figure 15: Shear force along with the P2 piles embedded in elastic soft clay soil

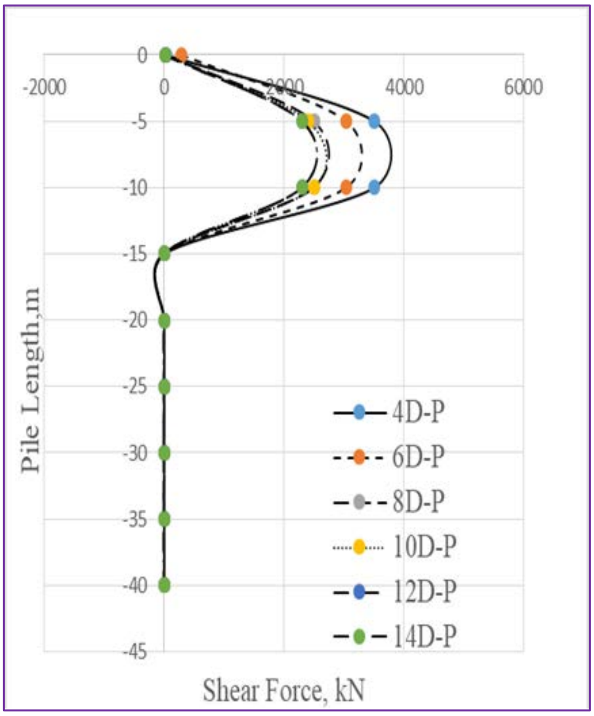

Figure 16: Shear force along with the P2 piles embedded in elastoplastic soft clay soil.

Figures 17 and 19 illustrate the bending moment along with the piles embedded in elastic soft clay soil while Figures 18 and 20 illustrate the bending moment along with the piles embedded in elastoplastic soft clay soil. It appears that the behavior of piles in elastic soil is not the same behavior of piles in elastoplastic soil, also the values of bending moment for piles embedded in elastoplastic soil is higher as compare with piles embedded in elastic soil. The variation in behavior depends on soil stiffness and size of the soil domain, these factors which dominate the piles' response.

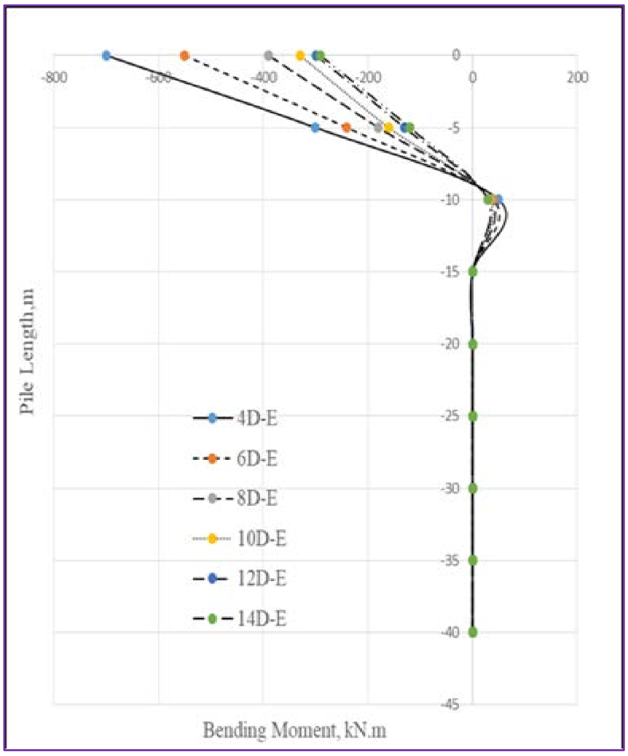

Figure 17: Bending moments in the P1 piles embedded in elastic soft clay soil

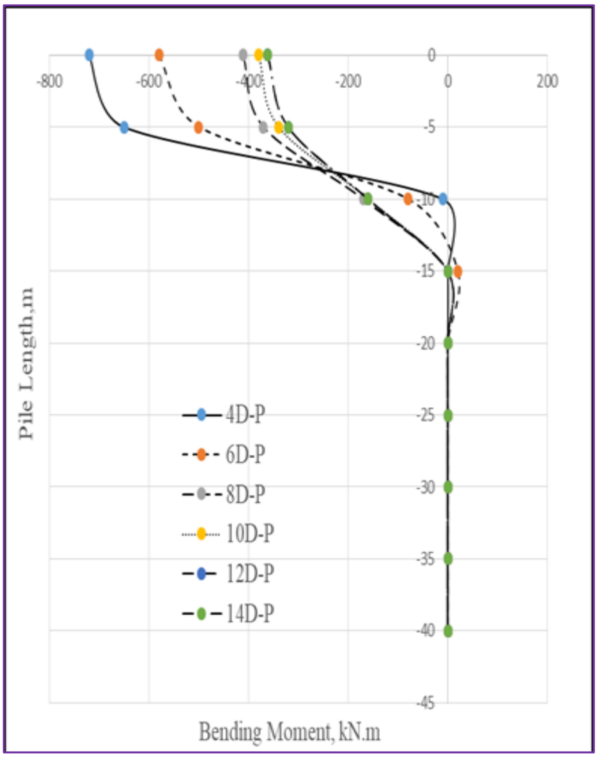

Figure 18: Bending moments in P1 piles embedded in elastoplastic soft clay soil.

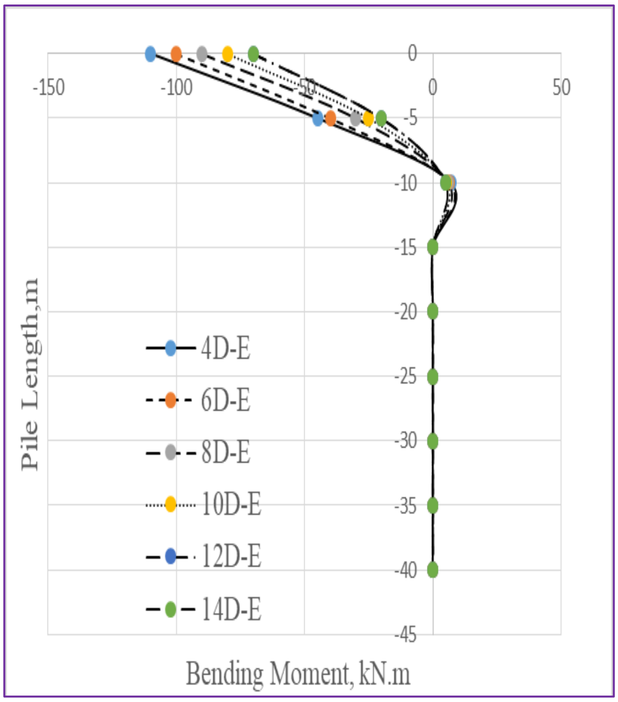

Figure 19: Bending moments in the P1 piles embedded in elastic soft clay soil

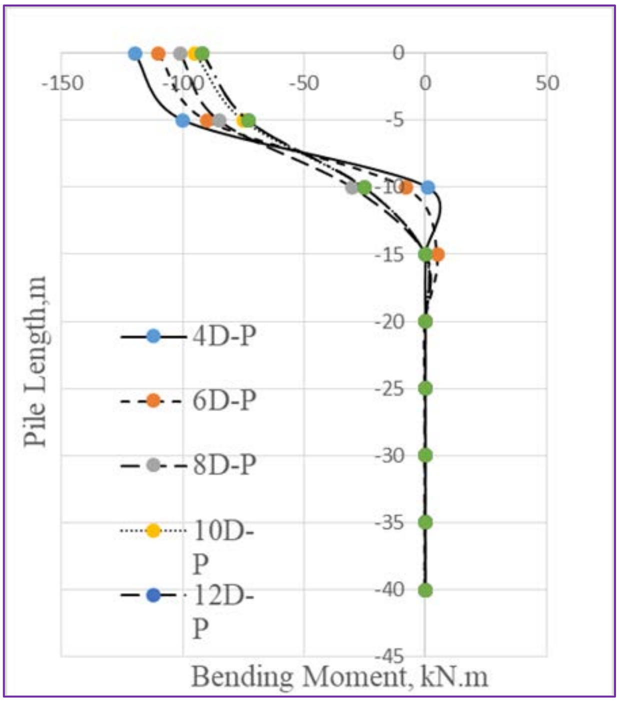

Figure 20: Bending moments in P1 piles embedded in elastoplastic soft clay soil.

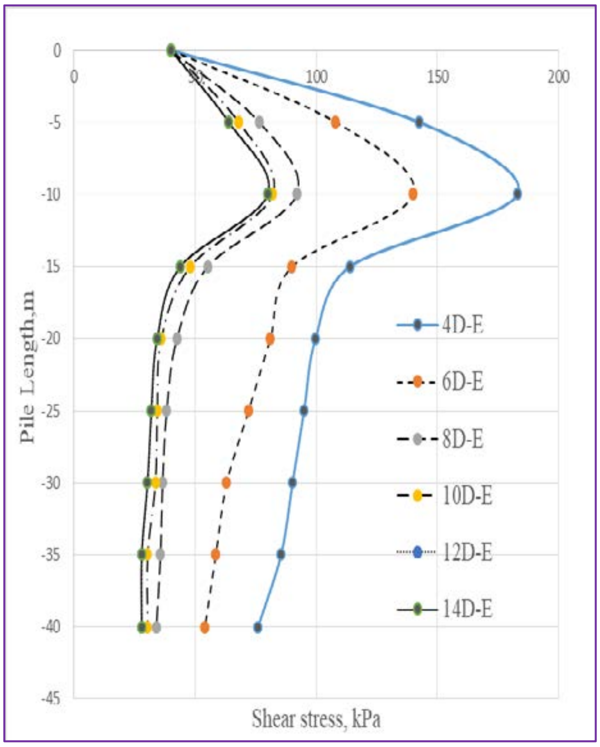

Figure 21: Shear stress in the P1 piles embedded in elastic soft clay soil

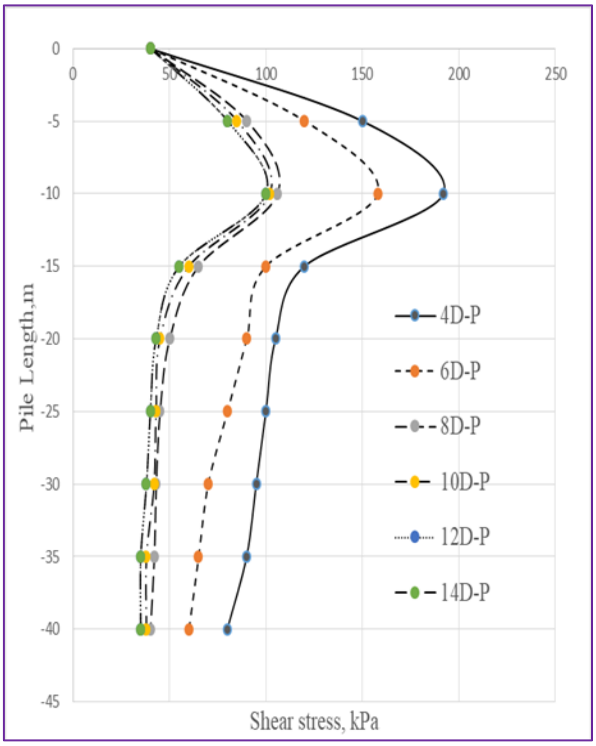

Figure 22: Shear stress in P1 piles embedded in elastoplastic soft clay soil.

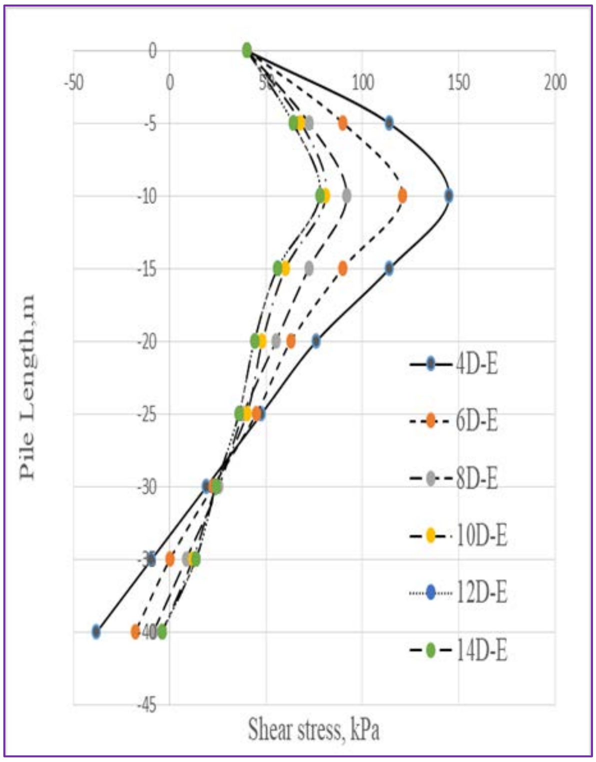

Figure 23: Shear stress in the P2 piles embedded in elastic soft clay soil

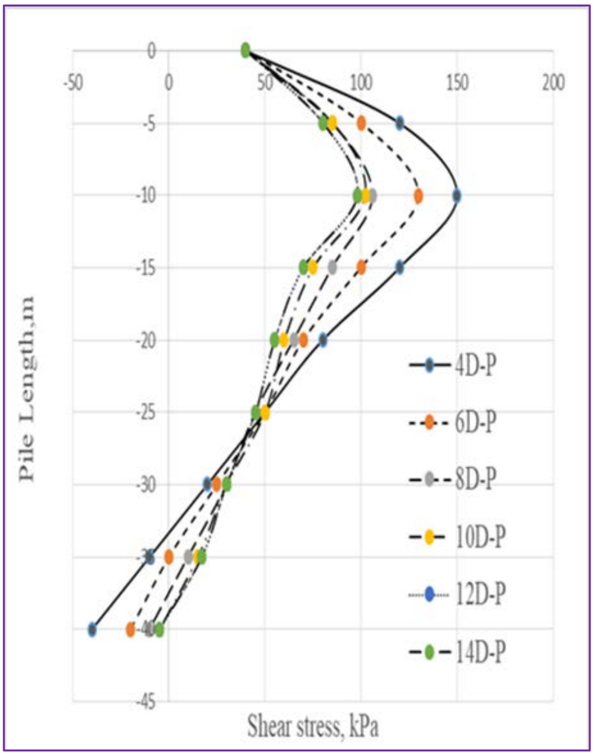

Figure 24: Shear stress in P2 piles embedded in elastoplastic soft clay soil.

Figures 21 and 23 show the shear stress distribution along with the pile depth when the pile embedded in elastic soil, it is obvious that the shear stress starts from the pile head and develop to reach the maximum value and then decreases with depth until it reaches the end of the pile, while. Figures 22 and 24 shows the shear stress distribution along with the pile depth when the pile embedded in elastoplastic soil, it is obvious that the shear stress starts from the pile head and develop to reach the maximum value and then decreases with depth until it reaches the end of the pile. It is evident from figures that the values of pile shear stress are higher when the piles embedded in elastoplastic soil as compare with the values when the piles embedded in elastic soli. Also, it is clear from figures as soil domain increase the response of piles decrease due to interaction between travel waves and reflect waves, also the effect of soil domain boundary condition.

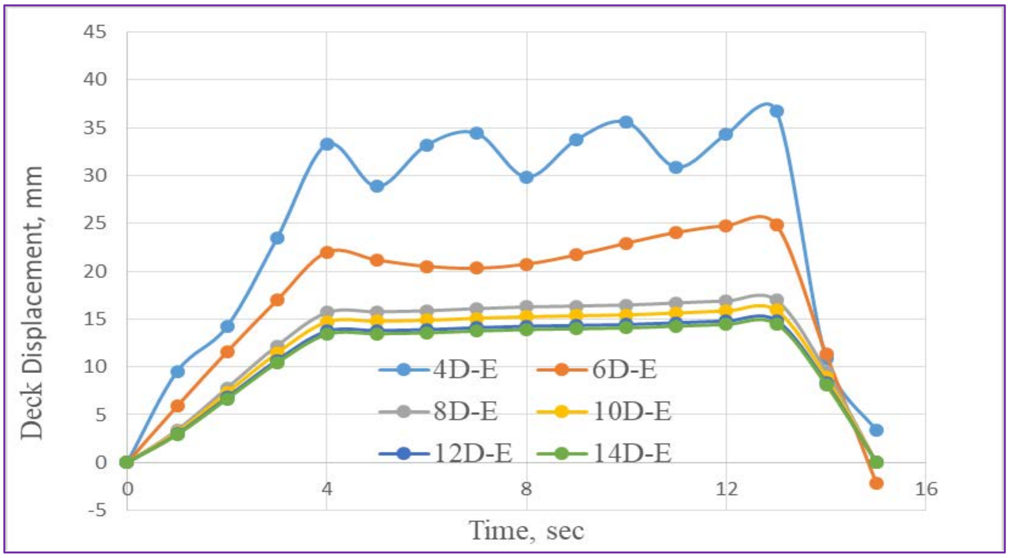

Figure 25: Temporal deck displacement (elastic case)

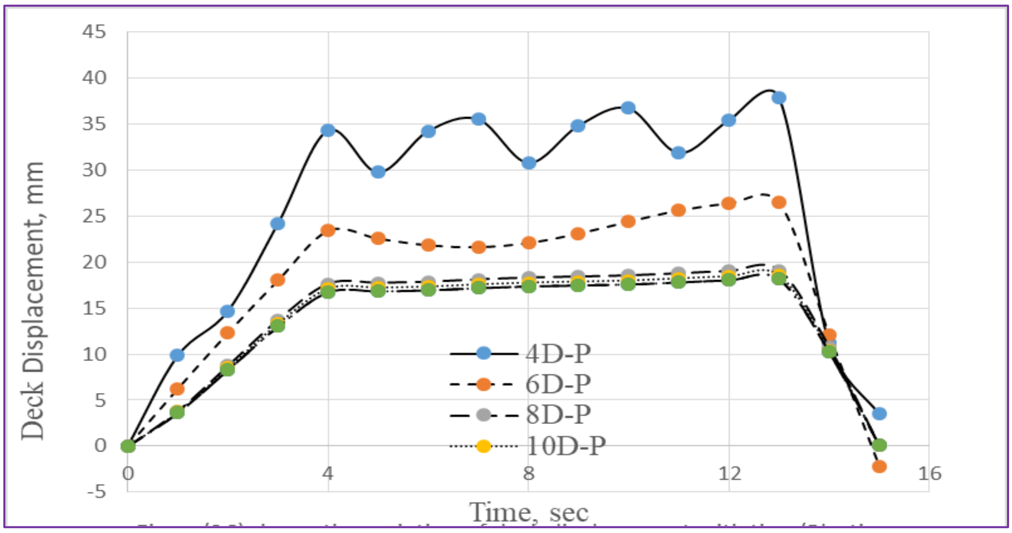

Figure 26: Temporal deck displacement (plastic case)

Figure 25 shows the response of deck slab with time (node A) when the piles of platform structure embedded in elastic soil. Figure 26 shows the response of deck slab with time (node A) when the piles embedded in elastoplastic soil. The response of the deck slab describes by the variation in the displacement of node A with time under torsion load that produces from ship impact in the opposite direction. Apparently, the response of deck when the piles embedded in elastoplastic soil is higher compared with the response of deck when piles embedded in elastic soil, this happened due to the difference in stiffness between elastic soil and elastoplastic soil. It is clear from figures as soil domain increases the response of deck slab decrease due to interaction between travel waves and reflect waves, also the effect of soil domain boundary condition.

4. CONCLUSION

There are main noticeable points from this study. Soil size domain plays a vital role in the response of piles and deck slab regardless of the soil model. The response of piles and deck slab based on and effect by soil model, so the response of piles and deck slab when the supporting soil is described elastoplastic always higher as compare with elastic soil.

The torsional load which results from two ships collision in the opposite direction can be considered a significant problem that must be assessed to prevent the structure ultimate capacity losses due to the damage from the ship's impact lateral load.

The interaction between travel waves and reflect waves into the soil will dominate the response of the whole offshore platform structure. It is essential to investigate the pile displacement, twist angle, shear force, bending moment, and shear stress to assess and modify the required behavior under damage or any accidental load. The investigation of deck slab behavior under the torsional load considered an important matter because of the ship lateral collision applied directly at the deck slab. The size domain of soil has a major influence on the structural behavior of piles and deck slab.

5. DATA AND MATERIAL AVAILABILITY

This study data can be provided upon contacting the corresponding author.

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