INVESTIGATING THE RESPONSE OF SINGLE PILE UNDER PURE TORSION

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Received: 17.06.2021 / Accepted: 05.07.2021 / Revised: 21.03.2022 / Available online: 31.05.2022

DOI: 10.2478/jaes-2022-0006

KEY WORDS: Single pile, Torsion, Soil domain, Plastic soil.

ABSTRACT:

The single pile is a structural element that has an important role in supporting any part of the superstructure. This paper adopted three dimensional finite element modelling by using ANSYS to discover the influence of soil size domain on pile diameter, pile length, load eccentricity and torsion magnitude. One type of soil was used and described by Drucker-Prager model. The numerical analysis has been performed to show how the variation in soil size domain effects on the behaviour of single pile under torsion load. The procedure which is adopted in the investigation depends on fixing all variables and changing one variable to show the impact of this variable on the pile response considering soil domain variation. From the investigation, it is obvious that the pile diameter, eccentricity and torsion load have a major influence on the pile response, while the pile length has a minor influence on the pile response. Here, the increase in pile diameter reduces the load transfer to the soil; also the increase in eccentricity increases the load transfer to the soil while the increase in soil domain reduces the pile response. When the torsion load increases the pile response increases too. The pile response refers to displacement, rotation, shear force and bending moment.

1. INTRODUCTION

The pile foundation is used to support offshore structures, tall buildings and bridges. These structures are often subjected to horizontal loads of noticeable magnitude from ship impact, wave or wind action. Important torsional forces can result from load eccentricity and transport to the pile foundation owing to the eccentricity of these horizontal loads. Hasan and Qasim (2020) investigated the behavior of the offshore structure under the torsional load. Here, the torsion results from two ship impacts in the opposite direction, and two different soil models are adopted in the analysis, these models are elastic and elastoplastic with different soil size domains. The investigation comprises the impact of torsion on the pile rotation, pile displacement, pile shear force, pile bending moment and pile shear stress.

Qasim and Hasan (2020) investigated the response of offshore piles foundation under various loading conditions considering the influence of soil interaction with piles foundation. While Hasan et. al. (2019) were studied the torsion behaviour of a single pile by utilizing the numerical method and experimental method. Also, it reveals that the mass section distribution and soil type have a major effect on the torsional response. Another study by Zou et al. (2019) suggested that an analytical method depended on the shear-displacement method for evaluating the behaviour of a single pile subjected the combined vertical-torsional loads in two-layered nonhomogeneous soil, and investigated the effect of the loading path. Whereas, Basack, et al. (2011) were developed a rigorous analytical method to study the behavior of a single pile under pure torsion. Zahang (2010) used energy principles to develop an analytical solution for torsional loaded piles embedded in two-layered soil where the variation in soil modulus is considered linear. And, Basile (2010) was applied the boundary element method to investigate the behavior of pile groups under the action of torsion. Guo and Randolph (1996) were adopted the influences of soil inhomogeneity and nonlinearity and analyzed the pile's torsional response in the sand with a Gibson profile.

Georgiadis and Saflekou (1990) were predicate numerically the pile response under the action of combined torsional and axial loads. Chow (1985) adopted linear functions for the angles of a twist to calculate the pile response in the soil which consists of two layers by using the finite element method, here the pile under the action of torque. The model of torque transfer is presented by Randolph (1981). He used the theory of elasticity to find the differential equation of the torsion pile-soil interaction. Poulos (1975) obtained the relation between rotation and soil-pile interaction shear stress along with a pile by developing a numerical scheme and solving equilibrium equations. This paper examines the single pile-soil interaction when the pile under the action of torsion loads. Hasan and Qasim, (2021) Studied the behaviour of pile groups under torsional and horizontal Load. The main objective of this paper is to use ANSYS software to evaluate the response of torsional loaded single pile taking into consideration the soil interaction. So, ANSYS finite element program is employed to achieve the requirements of the numerical analysis.

2. PROBLEM AND PROGRAM MODELING

A torsional loaded pile has an important role in transporting a load which is produced from load eccentricity. This paper concerns with the response of a single torsional loaded pile. Also this paper refers to the numerical application to investigate torsion load-single pile-soil interaction. It requires evaluating the following variables on the torsional behaviour of a single pile:

- The behaviour of torsional single pile under the variation in pile diameter. Here, the value range of piles diameter which is adopted in the study are: (0.5, 1, 1.5 and 2) m, while the pile length is equal to 20m, the torsion load is equal to 6000 KN.m, different soil size domain is considered, here the domain changes from (4D) to (12D) and there is no eccentricity.
- The behaviour of torsional single pile under the variation in pile length. Here, the value range of piles length which is adopted in the study are: (20, 40 and 60) m, while the pile diameter is equal to 0.5m, the torsion load is equal to 6000 KN.m, different soil size domain is considered, here the domain changes from (4D) to (12D) and there is no eccentricity.
- The behaviour of torsional single pile under the variation in load eccentricity. Here, the value range of load eccentricity which is adopted in the study are: (0, 2D and 4D) m where D represents the pile diameter, while the pile diameter is equal to 0.5m, the pile length is equal to 20m, the torsion load is equal to 6000 KN.m, and different soil size domain are considered, here the domain changes from (4D) to (12D).
- The behaviour of torsional single pile under the variation in torsion load magnitude. Here, the value range of torsion load which is adopted in the study are: (3000, 6000 and 12000) KN.m. here, the pile diameter is equal to 0.5m, pile length is equal to 20m, different soil size domain is considered, here the domain changes from (4D) to (12D) and there is no eccentricity.

The investigation of the current problem is based on reveal the impact of the previous variables on the response of the single pile. Here, the response comprises the following:

- Pile displacement,
- Pile rotation,
- Pile shear force,
- Pile bending moment.

The three-dimensional analysis is performed by using the finite element program which is achieved by using ANSYS software. The whole problem consists of two parts; these parts are a single pile and soil around the pile. The material properties adopted in the numerical simulation of the model are illustrated in the table 1.

Item	Soil	Pile
Material Model	Drucker-Prager	Linear Elastic
Density (KN/m3)	1800	2400
Modulus of Elasticity (MPa)	22000	23000
Cohesion (KPa)	40	----------
Poisson's ratio	0.35	0.2
Internal angle of friction	0	-------

Table 1. Material Properties

The solid element (solid 45) is used to model both soil and pile. Here, the solid element has 8 nodes. The contact element (Contact 173) and the target element (Target 170, 4- node interface elements) are adopted to model the linkage between the soil and the pile. The fixed boundary conditions are adopted for all sides, except the top of the soil domain which is considered free. The load is applied statically. Here, the Newton Raphson method is used to divide the applied torsion magnitude to get a suitable solution. The present study consists of (130) numerical runs were performed by using ANSYS software. Figure 1 represents a select case to illustrate the modelling of the whole pile-soil system. The select case has the following details; pile diameter 0.5 m, pile length 20 m pile eccentricity = 0 m, torsion load = 6000 KN.m and soil domain = 8D m.

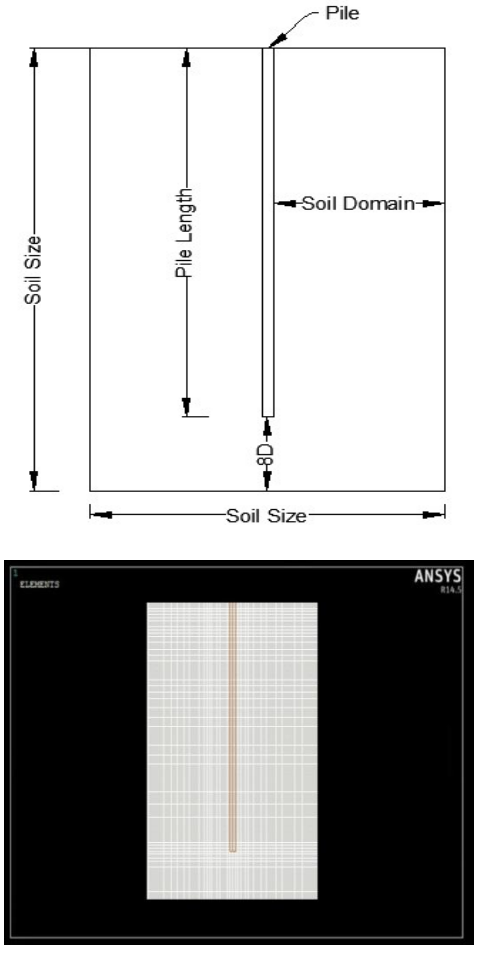


Figure 1. Shows the problem dimensions and modelling in ANSYS program

3. DISCUSSION OF THE RESULTS

Figures 2, 3, 4 and 5 shows the variation in the pile diameter with maximum displacement, rotation, shear force, and bending moment respectively. Here, from the given figures it is clear that when the pile diameter increases, the deformation will be decreased owing to the increase in the pile section moment of

inertia which relies on the pile diameter. So, this will affect pile deformation. This investigation indicates that the remaining variables which are described by torsion load, pile length, and eccentricity are considered constant while the soil size domain changes from (4D) to (12D), here it is clear as the soil size domain increase the deformation will be decreased. This happens owing to the interaction between the travel and the reflected waves respectively, while the variation in the pile response will be influenced by the energy transfer between the pile and soil with the depth of soil domain.

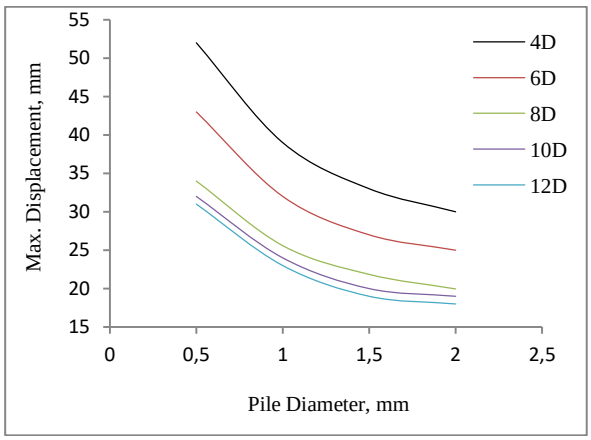


Figure 2. Variation of pile diameter with displacement

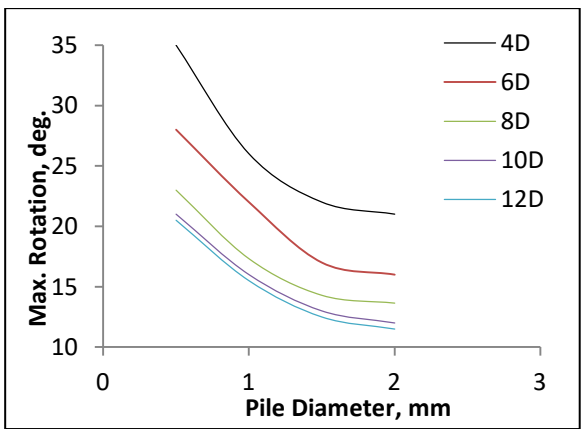


Figure 3. Variation of pile diameter with rotation

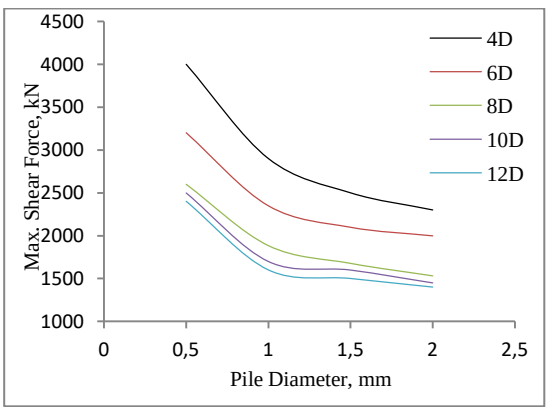


Figure 4. Variation of pile diameter with shear force

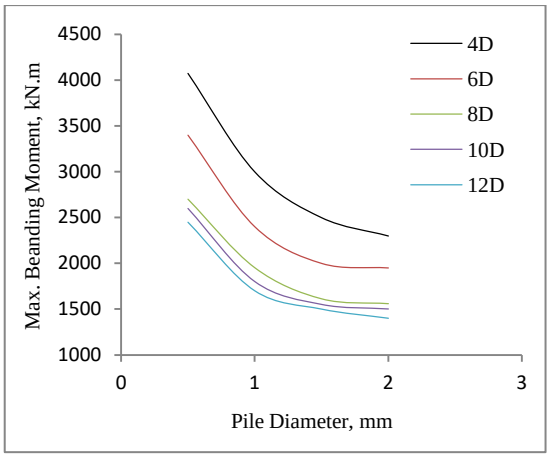


Figure 5. Variation of pile diameter with bending moment

Figures 6, 7, 8, and 9 shows the change in the pile length. Here, it is clear from the figures given that when the pile length increases, the deformation will be decreased but this decrease has no considerable or major impact. So, the pile length has a minor impact on the pile deformation under torsion. This investigation indicates that the remained variables which are described by torsion load, pile diameter, and eccentricity are considered constant. While the soil size domain changes from (4D) to (12D), here it is clear as the soil size domain increase the deformation will be decreased. This happens owing to the interaction between the travel and the reflected waves respectively, while the variation in the pile response will be influenced by the energy transfer between the pile and soil with the depth of soil domain.

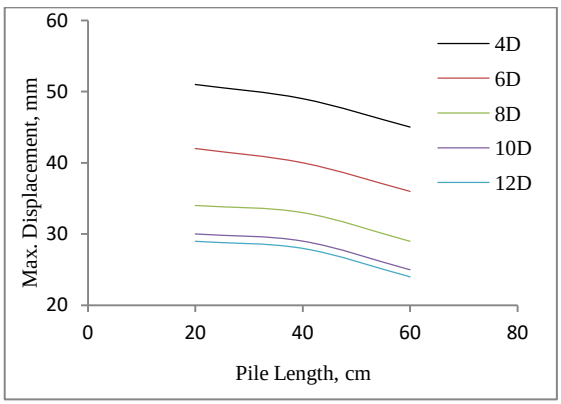


Figure 6. Variation of pile length with displacement

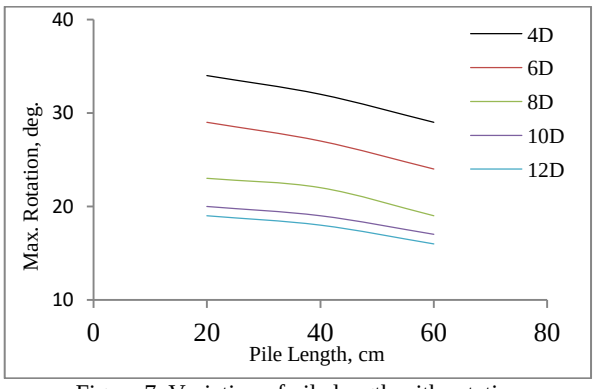


Figure 7. Variation of pile length with rotation

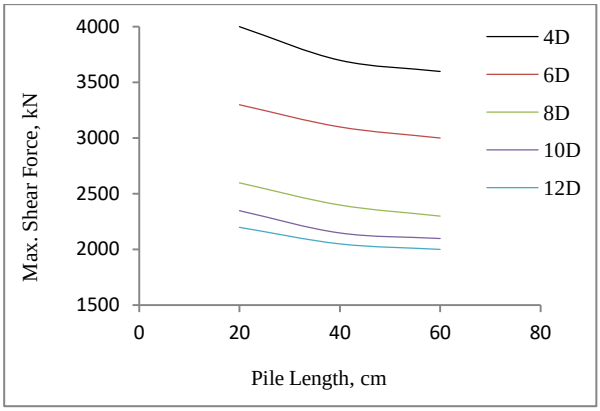


Figure 8. Variation of pile length with shear force

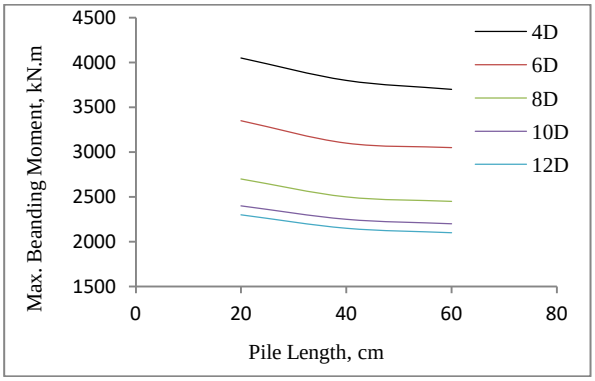


Figure 9. Variation of pile length with bending moment

Figures from 10, 11, 12, and 13 shows the variation in pile eccentricity response. Here, it is clear from the figures given that when the pile eccentricity increases, the deformation will be increased owing to the reduction in pile resistance as the eccentricity increases, the load transfer to the soil increase and this will be reflected on the pile response. The deformation, here, refers to the displacement, rotation, shear force, and bending moment. This investigation indicates that the remained variables which are described by torsion load, pile length, and pile diameter are considered constant, while the soil size domain change from (4D) to (12D), here it is clear from the figure that the increase in the size of soil domain will not reflect on the response of single pile.

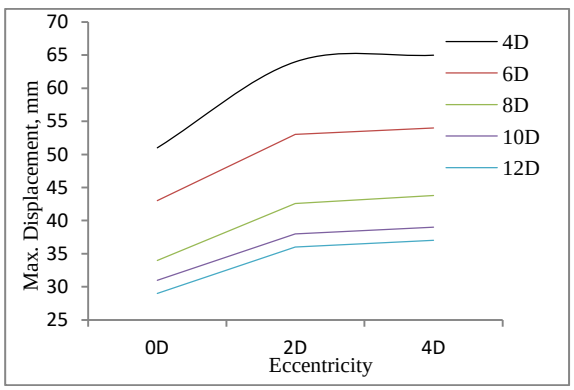


Figure 10. Variation of eccentricity with displacement

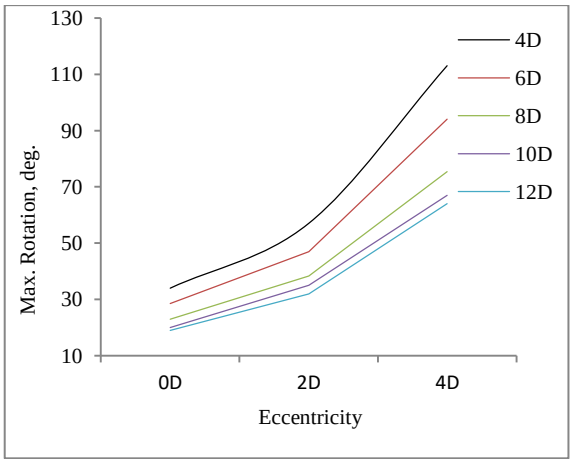


Figure 11. Variation of eccentricity with rotation

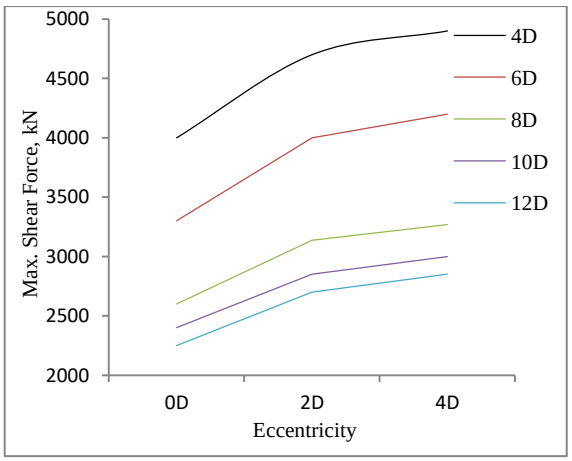


Figure 12. Variation of eccentricity with shear force

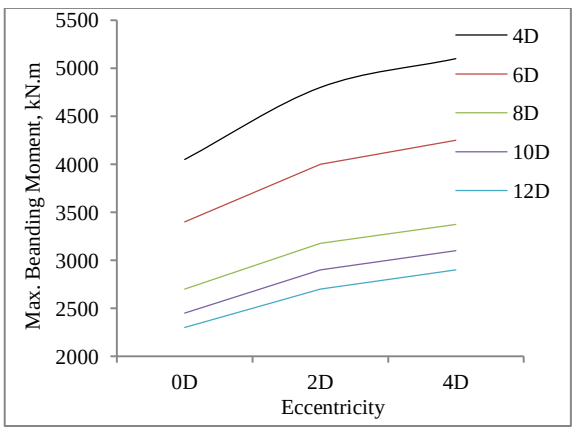


Figure 13. Variation of eccentricity with bending moment

Figures from 14, 15, 16, and 17 illustrate the variation in torsion load magnitude. Here, it is obvious from the figures that given when the torsion magnitude increases, the deformation will be increased gradually due to the increase in the load transfer to the pile regardless of the pile section resistance. The deformation, here, refers to the displacement, rotation, shear force, and bending moment. This investigation indicates that the remaining variables which are described by pile diameter, pile length, and eccentricity are considered constant, while the soil size domain

change from (4D) to (12D), here it is clear from the figure that the increase in the size of soil domain will not reflect on the response of single pile.

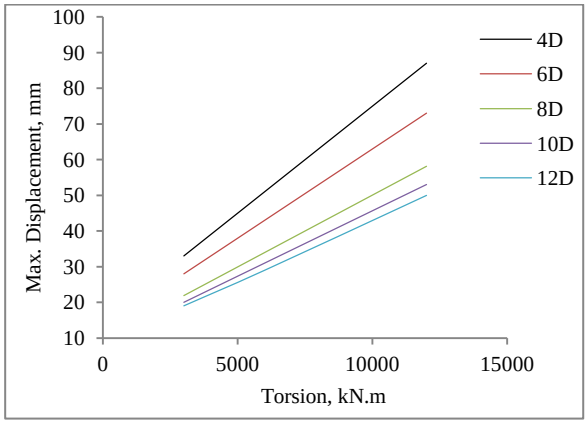


Figure 14. Variation of torsion with displacement

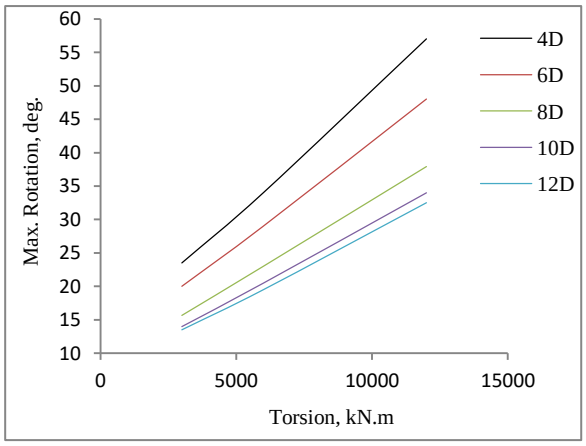


Figure 15. Variation of torsion with rotation

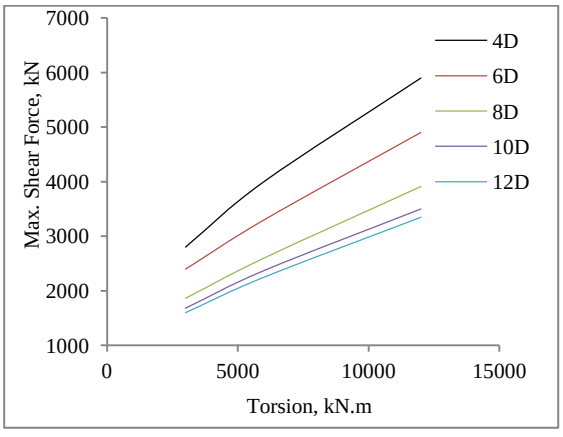


Figure 16. Variation of torsion with shear force

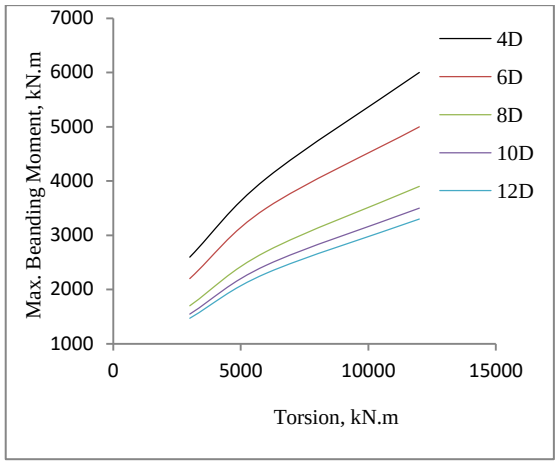


Figure 17. Variation of torsion with bending moment

4. CONCLUSION

This study deals with the investigation of the response of a single pile under the influence of torsion load. Here, the study concentrated on several variables that dominate the response of torsion-pile soil interaction. The main target concentrates on fixing all variables except one variable which will be changed. This procedure is adopted to get a considerable and feasible response taking into account the torsion load. So, the following inferences are obtained from the current investigation:

- The increase in pile diameter leads to a decrease in pile displacement, pile rotation, pile shear force and bending moment. This occurs due to an increase in pile flexural rigidity.
- The increase in pile length has a minor effect on pile displacement, pile rotation, pile shear force and bending moment.
- The increase in torsion load magnitude leads to an increase in pile displacement, pile rotation, pile shear force and bending moment.
- The pile response will be decreased with the increase in the soil size domain. Here the soil domain has a major effect on the pile response because the soil domain dominates the energy transfer between the pile and the soil domain boundary condition.
- The increase in pile eccentricity leads to an increase in pile displacement, pile rotation, pile shear force and bending moment.
- The pile diameter has a major role in controlling the torsion- pile-soil interaction.
- The pile eccentricity has a major effect on the response of the pile under torsion.

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