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ANALYSIS OF PILE FOUNDATION BEHAVIOUR FOR VARIOUS SOIL CONDITION

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ABSTRACT

Pile foundation is used to transfer the ultimate load from the structure to the foundation from soft soil strata to hard soil or rock. FEA model developed to predict the response of pile in static and nonlinear dynamic analysis of pile foundation in layered soil medium based on field data. In the first step static analysis will be performed which were compared and validated with the analytical result. Pile foundation are carried for the various soil condition in order to prove its efficiency in the soil systems.
Numerical analysis has been carried out using FEA (NASTRAN) software, which will be used to give load-displacement, stresses and response at pile. 20 node 3D element used to model the pile, biased meshing will be used toward the pile to produce accurate result in the region of interest. These stresses on the pile will be predicted using the finite element method. FE methodology is more precise in predicting the strength of the piles and foundations.

KEYWORDS: component; FEA; Pile

I. INTRODUCTION

Analysis of pile foundation is performed using the finite element method. The static analysis of pile is performed to determine the stress whereas the dynamic analysis of is performed to determine the Eigen frequencies and Eigen vector Eigen vector is also known as the mode shape of the system which give the modal mass for the corresponding mode.

These stresses on the pile will be predicted using the finite element method. FE methodology is more precise in predicting the strength of the piles and foundations.

Stresses on the pile foundation will be predicted using the static analyses. Based on the result of the analytical method, modification is implemented in the pile joint and dynamic analysis is performed again to evaluate the dynamic performance.
Numerical analysis has been carried out using FEA (ABAQUS) software, which was used to give load-displacement curve for pull out. 8 node axis symmetric element used to model the soil, biased meshing were used toward the pile to produce accurate result in the region of interest. The biggest challenge encounter while modelling the interface between the pile and soil. This modelling strategy is necessary to achieve slip and opening of void, duplicate nodes were created between the soil and pile initially. As there is no attachment between the pile and soil, solution of the numerical analysis will not converge and hence difficulty in achieving the initial equilibrium. No vertical stress will possible across the interface, hence this particular problem is analysed using a boundary element at the base of the pile with reduce axial stiffness of the contact element. Stiffness is considered less for the contact or interface element to allow forces and pore pressure to act across the boundary to simulate resistance between the soil and pile.

Pile and structure both are modelling using 3-D solid element (20 node isoparametric). The circular cross section of pile modelled as square section but assigned equivalent moment of inertia as of circular section. 16 node interface or joint node are provided to simulate the connection between the soil and pile. Pile foundation modelled using 2D plane stress plate element and soil by 8 node plane strain element. The non-linear constitutive model applied to both 3D and 2D element (3)

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II. MATERIALS AND METHODS

In this work designing of the pile which supports the heavy structure is analysed. Pile foundation are generally used for supporting heavy structure under various soil conditions which is used in various type of structures. The pile foundation is designed such that its stress capacity from the analytical calculation validate with the FEA result with the various soil conditions.

This paper focused on the method of analyzing a pile foundation such that the behavior with various soil condition can be studied.

1.Analytical Calculation:
Pile Foundation calculation started with analytical to verify with the FEA method. α method, short term load capacity is considered to the calculation.

This method is based on undrained shear strength of soil and well suited for short term pile load capacity. In this method the skin friction is assumed to be proportional to undrained shear strength Su. Inerface shear stress qs between pile and soil is defined as (1);

A. Static Calculation under vertical load
Pile Foundation calculation started with analytical to verify with the FEA method. α method, short term load capacity is considered to the calculation

B. A-Method, Short-Term Load Capacity For Cohesive Soil Specifications
This method is based on undrained shear strength of soil and well suited for short term pile load capacity. In this method the skin friction is assumed to be proportional to undrained shear strength Su. Inerface shear stress qs between pile and soil is defined as (1);

Qs = α x Su (1)
Su = undrained shear strength
α = adhesion coefficient

NAVFAC DM 7.2 (1984). Proposition for α coefficient depends on type of pile.
To obtain coefficient α based on Su/σv proposed standard DNV-OS-J101-2007 (2)

$$\alpha = \{\frac{1}{2\sqrt{Su/\sigma v}} Su/\sigma v \leq 1$$

$$\alpha = \{\frac{1}{2^4\sqrt{Su/\sigma v}} Su/\sigma v \geq 1$$

(2)

Considering the medium stiff soil condition, for steel piles shear stress qs
qs = 36 x 0.81= 29 MPa
Diameter of pile = D = 400 mm
Considering the area of pile = As = π/4*D2
As = 125663 mm2
Permissible load = 371 tonne is the load capacity of pile.

Table1. Skin friction factor dependent on Su/σv

s_u/σ'_v	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
α	0.95	0.77	0.70	0.65	0.62	0.60	0.56	0.55	0.53	0.52	0.50	0.49	0.48
s_u/σ'_v	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	3.0	4.0
α	0.47	0.42	0.41	0.41	0.42	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39

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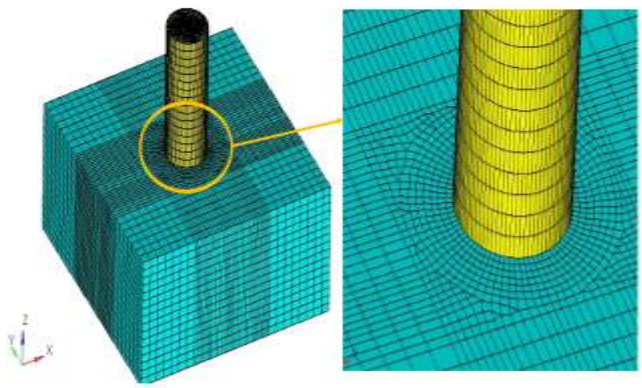
Table2. α vs. undrained shear strength (NAVFAC DM 7.2)

Pile type	Soil consistency	Undrained shear strength s_u [kPa]	α
Timber and concrete piles	Very soft	0–12	1.00
	Soft	12–24	1.00–0.96
	Medium stiff	24–48	0.96–0.75
	Stiff	48–96	0.75–0.48
	Very stiff	96–192	0.48–0.33
Steel piles	Very soft	0–12	1.00
	Soft	12–24	1.00–0.92
	Medium stiff	24–48	0.92–0.70
	Stiff	48–96	0.70–0.36
	Very stiff	96–192	0.36–0.19

2:Modelling strategy and assumption

All components (Pile and soil) are meshed with 3D solid (10 node hexa element) element. Interface between the soil and pile are modelled using contact element. The detail FE model details are shown is Figure 1 and Figure 2**.**

Figure:1



Meshing of pile-foundation assembly

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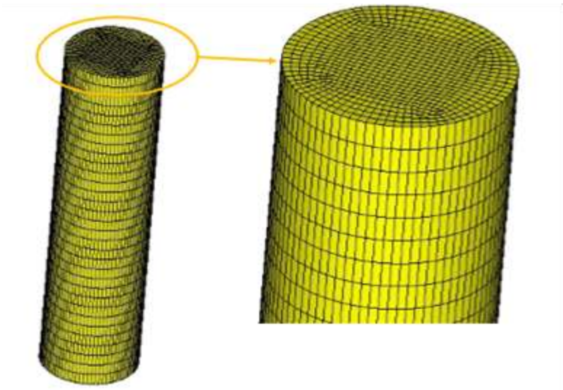
Figure 2:



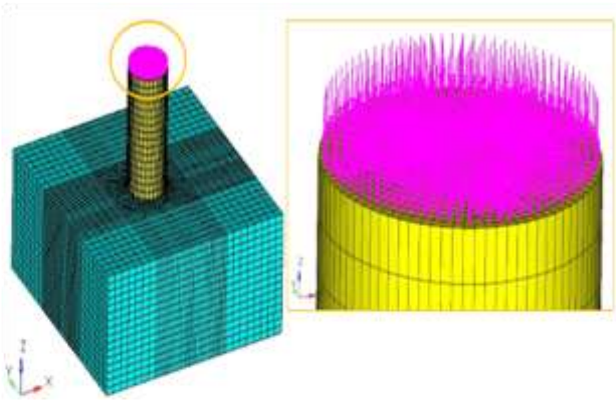
Meshing of pile

3:Loading and boundary condition

3.1Loading
Static analysis:

Vertical force of 271 tonne is applied in vertically downward directions. Summary of the load case for static analysis are shown in Figure 3 and Figure 4. In case of static analysis, for the working case, soil base is constraint in all translation direction as the load is transferred through the base

Figure 3.



Loading on pile

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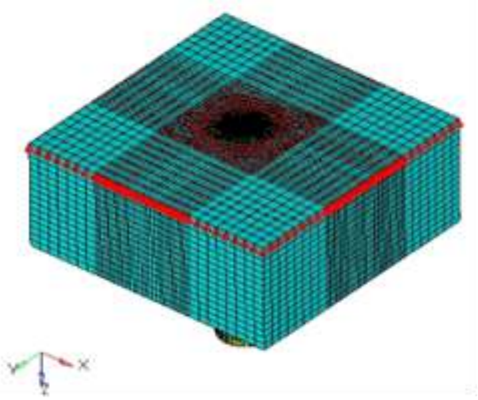
Figure 4.



Boundary condition

III. RESULTS AND DISCUSSION

A.Analytical Calculation:

Pile Foundation calculation started with analytical to verify with the FEA method. α method, short term load capacity is considered to the calculation

A. A-Method, Short-Term Load Capacity For Cohesive Soil Specifications

This method is based on undrained shear strength of soil and well suited for short term pile load capacity. In this method the skin friction is assumed to be proportional to undrained shear strength Su. Inerface shear stress qs between pile and soil is defined as (1);

Qs = α x Su (1)

Su = undrained shear strength

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(2)

Considering the medium stiff soil condition, for steel piles shear stress qs

qs = 36 x 0.81= 29 MPa

Diameter of pile = D = 400 mm

Considering the area of pile = As = π/4*D2

As = 125663 mm2

Permissible load = 371 tonne is the load capacity of pile.

Result are validated with the FEA result as shown in Figure 5. Shear stress of 31 MPa is observed from FEA result, whereas from analytical shear stress of 29 MPa is calculated. Close correlation is observed between the analytical and FEA result.

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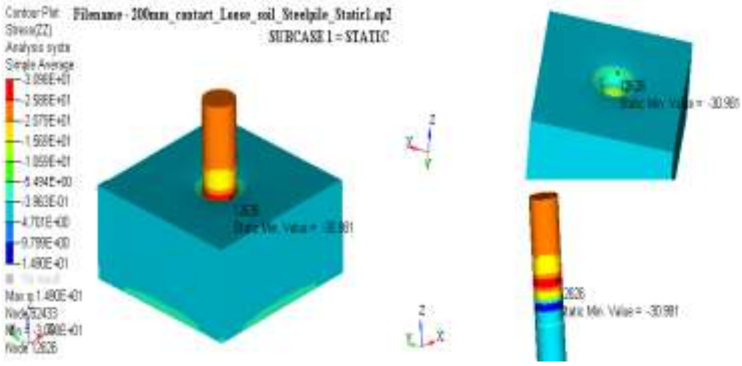
Figure 5.

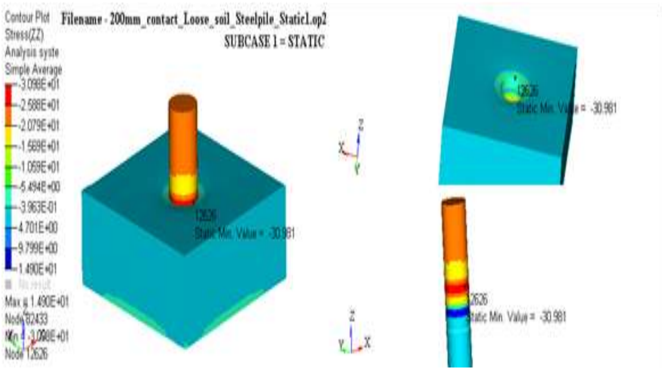


Shear stress at pile for analytical result validation

B.Static analysis: Deformation**:** Maximum deformation of 47mm is observed in vertical direction.. Detail of deformation plot is shown in Figure 7.

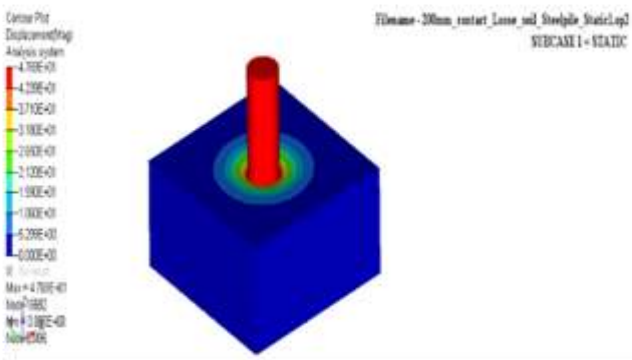
Stress: Maximum Stress of 26.2 MPa is observed as shown in Figure 6. Detail of stresses under different pile soil interaction length and soil condition is tabulated below

Figure 6.



Shear stress at pile for analytical result validation

Figure 7.



Deformation plot

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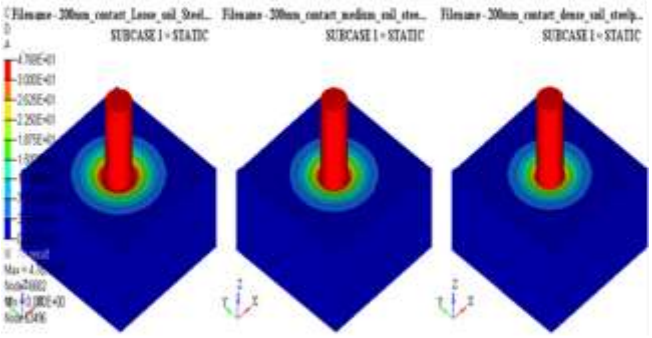
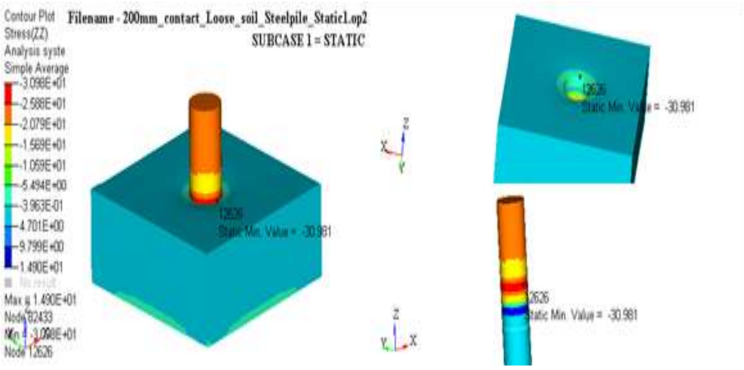
Figure 8.



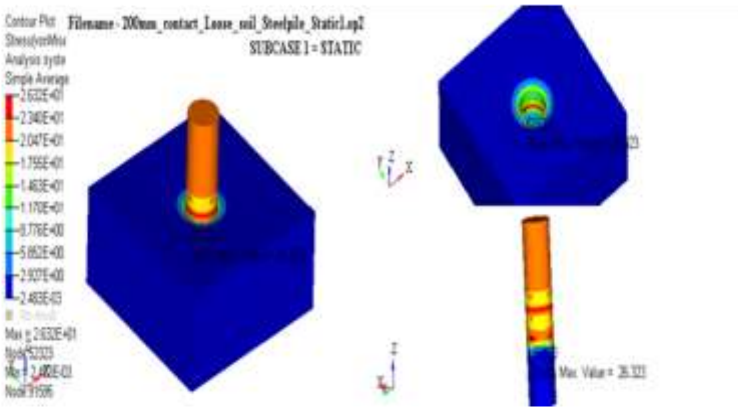
Comparison of deformation for different soil condition

Figure 9.



Shear stress on soil

Figure 10.



Von-mises stress

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For different soil properties displacement,

,von-mises stress ,shear stress are tabulated in table below.

200mm Contact Pile-soil interface					
Loose_soil					
		Displacement (mm)	Von-mises (MPa)	Shear stress (MPa)	
	Pile	47.6	26.3	-30	14.9
	Soil	47.6	25.26	-31	0.5
Medium_soil					
	Pile	38.17	26.3	-30	14.9
	Soil	38.1	25.25	-31	0.5
Dense_soil					
	Pile	31.8	26.3	-30	14.9
	Soil	31.8	25.25	-31	0.5

600mm Contact Pile-soil interface					
Loose_soil					
Static		Displacement	Von-mises	Shear stress	
	Pile	20	22	-24	8.2
	Soil	20	14.5	-13	3
Medium_soil					
	Pile	16	22	-24	8.2
	Soil	16	14.5	-13	3
Dense_soil					
	Pile	13.3	22	-24	8.2
	Soil	13.3	14.5	-13	3

800mm Contact Pile-soil interface					
Loose_soil					
Static		Displacement	Von-mises	Shear stress	
	Pile	12	21.7	-23	0
	Soil	12	18.2	-14	0.14
Medium_soil					
	Pile	9.6	21.7	-23	0
	Soil	9.6	18.2	-14	0.14
Dense_soil					
	Pile	8	21.7	-23	0
	Soil	8	18.2	-14	0.14

IV. CONCLUSION

In the analytical calculation is performed and result are validated with static analysis performed in FEA. The result are in good agreement with the analytical result and error between both are less than 1%.

From the result, it is observed that the stresses induced in pile foundation for various soil condition is less in 600mm contact pile soil interface. Displacement in medium and dense soil for 600mm pile soil interface is low as compared to other soil condition. Hence medium and dense soil condition for 600mm interface is optimum and efficient for the pile foundation. In future accurate soil modelling between the medium dense and high dense can be created and analyzed with more accuracy based on the site conditions

V. ACKNOWLEDGEMENTS

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