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Assessment of Soil Structure Interaction and Vibration Analysis of A Tower Structure

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Abstract—Steel tower structure resting on piles are currentlybecoming popular in any geographical location for electrical transmission,microwave mobile transmission etc. when such structures are used in earthquake prawn areas they have to perform without any problem even during times of disaster due to their importance in communication,power supply etc.Hence it is necessary to have an understudy of the behaviour of such structure and provide an economical design.to understand the performance of such structures is necessary to know their behaviour considering soil structure interaction.In this work a steel tower structure resting on single pile at each leg and group of three piles embedded in soft, medium and stiff soil has been analysed to obtain their stresses and deformations. The modal analysis, static analysis and transient structural analysis considering the kobe earthquake has been considered. The result pointed out that the soil structure interaction is important and need to be accounted to reach a realistic understanding of such structures.

Index Terms—Tower structure, pile group, steel tower foundation, soil pile structure interaction, soil characteristics, seismicresponce

1 Introduction

A structure is an entity consisting of a superstructure and foundation. The function of a structure is to transmit the superimposed and self loads to the supporting soil or the bed rock in such a manner that it does not suffer any distress. When the loads to be transmitted from the superstructure to the ground below are high and when soil at shallow depth is having poor strength, deep foundations such as piles, piers or caissons etc are used. Pile foundations are more commonly adopted for mid to high rise buildings. Piles, being rigid in nature and stiffer compared to shallow foundations, are observed to perform well. Also in earthquake prone areas the performance of piles are comparatively better. The piles which are being designed and used now a day are capable of taking heavy vertical as well as horizontal loads. Their wide spread use makes it necessary to have an understanding of their performance when used even in seismic areas.

Previously the response of structures to earthquake excitation was studied by considering the foundation of a structure to be rigidly fixed to the ground. In that method, the bending moments and shear forces obtained are not realistic because the compressibility of soil mass is neglected. However, this approach makes calculations easier and delivers quick solutions.

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The actual response of a structure to earthquake excitation is highly complex and depends on interaction of the superstructure, foundation and the soil on which it rests. During past and recent earthquakes it was realized that soil structure interaction effect plays an important role in determining the behaviour of structures.

This work is an investigation to evaluate the performance of soil-pile-structure behaviour under earthquake loading. This chapter gives an introduction to pile foundations, soil structure interaction of steel tower structures, objectives and scope of the study.

2 DETAILS OF TOWER AND FOUNDATION

2.1 Pile foundation

Pile foundation is the oldest method of construction for overcoming the difficulties of foundation on soft soils. Pile foundations are used when the upper soil layers are highly compressible and too weak to support the load transmitted from the superstructure. Piles are usually slender having high length to width ratio, and are mainly designed to resist axial loads. They transmit the load to underlying bed rock or stronger soil layer. When the bed rock is not encountered at reasonable depth below the ground surface, friction piles are used to transmit the structural load gradually.

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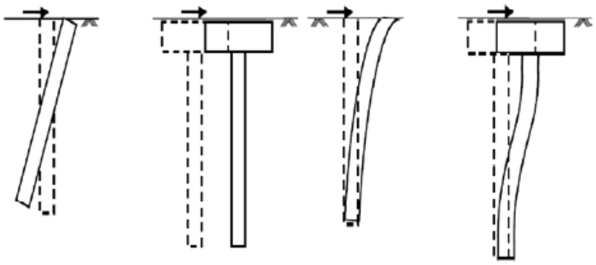
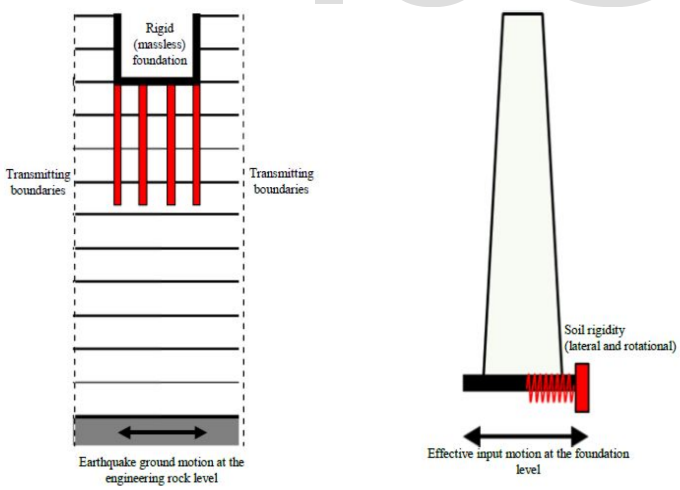


Fig. 1. Response of single pile under lateral load

2.2Soil structure interaction

Many researchers have made contributions to the subject of soil-pile-structure interaction, Different approaches are available to account for dynamic soil-pile interaction but they are usually based on the assumptions that the soil behaviour is governed by the law of linear elasticity or visco-elasticity, and that the soil is perfectly bonded to a pile. In practice, however, the bonding between the soil and the pile is rarely perfect, and slippage or even separation often occurs in the contact area. Furthermore, the soil region immediately adjacent to the pile can undergo a large degree of straining, which would cause the soil-pile system to behave in a nonlinear manner. A lot of efforts have been made to model the soil-pile interaction using the 3D FEM. However, it is too complex, especially for pile groups in nonlinear soil. A rigorous approach to the nonlinearity of a soil-pile system is extremely difficult and time consuming. In general, SSI can be taken into account with two approaches: a) direct method,b) sub-structure method.



a. Kinematic interaction model b. Inertial interaction model

Fig 2 Modeling for substructure method

3 DESCRIPTION OF TOWER AND SOIL

The toweheigt consist bof 33 meters and having 61 nodal points.Structure was modeled with single pile, 3 piles in a group and embedded in loose, medium and stiff soil. The dimension details of 3 pile in sand is shown in Fig. 3. The design was according to IS 456 – 2000, IS 2911- Part I – 1979 and IS SP 16. The seismic response of pile foundation along with the static load was studied. Seismic load corresponding to Kobe earthquake (1995) was applied in the time history analysis.

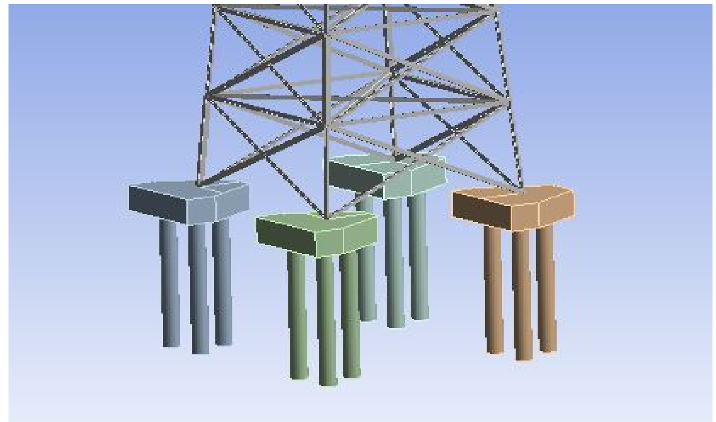


Fig. 3. 3 3pile group in loose sand

length of single pile and group oof pile in soft soils are 10.532m and 4.484m. In case of medium soil it is 10meter and 3.361 meters. In stiff type soil the pile length are 7.503m and 1.677m.

Pile cap dimension for single pile is 1.75*1.75 meters and for group of pile it is 2.8*0.85*1.35 meters

4 FINITE ELEMENT MODELLING

The investigation is conducted using the FEM Software ANSYS WORKBENCH version 15. The soil was modeled in ANSYS and tower is modeled using Stadd Pro.

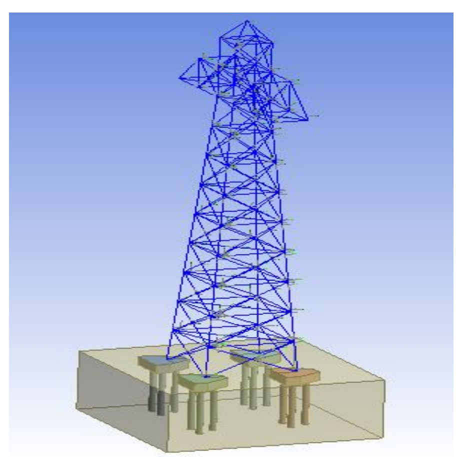


Fig 4. Tower model

Table 1.Properties of soil

Properties	Homogenous soil		
	Soft soil	Medium soil	Stiff soil
Modulus of Elasticity, E_s (kN/m^2)	15 x 10^3	25 x 10^3	60x 10^3
Poisson's ratio	0.3	0.35	0.20
Density (kg/m^3)	1800	2000	2100
Cohesion (kN/m^2)	37.5	50	100
Coefficient of friction	0.95	0.75	0.5

Table 2.Properties of tower

Properties	Value
Modulus of Elasticity, E_c (kN/m^2)	27830
Poisson's ratio	0.3
Density (kg/m^3)	2400
Section(m.m)	L section (150*150*12)
Element length(m.m)	3000
Number of nodes	61
Pile type	Frictional pile

5 RESULTS AND DISCUSSION

Nonlinear static analysis was done for single pile, 3 piles in a group in soft, medium and stiff soil. In this analysis the load on the tower structure coming on the foundation whether it is a single or 3 pile group is the same. The length of single pile has been designed for the load coming from the tower. The length of 3 pile in a group and the layout of the pile group has been designed based on the same load from the tower structure. This analysis has been done statically in order to compare the deformation and other values from the dynamic analysis. The static structural analysis shown that the deformation of the tower structure is varied in soft, medium and stiff soil. Deformation will be more in soft soil and less in stiff soil. The soil deformation which only comes near to the leg of the tower structure and soil deformation is almost negligible

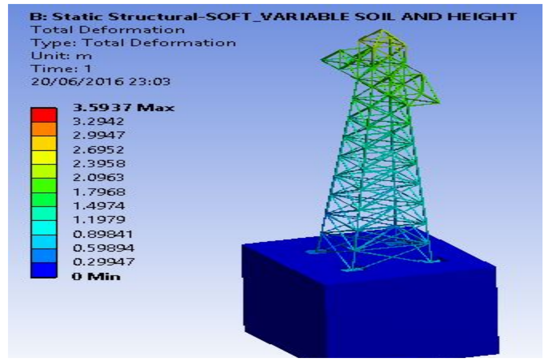


Fig 5.Static structural deformation of soft soil in single pile

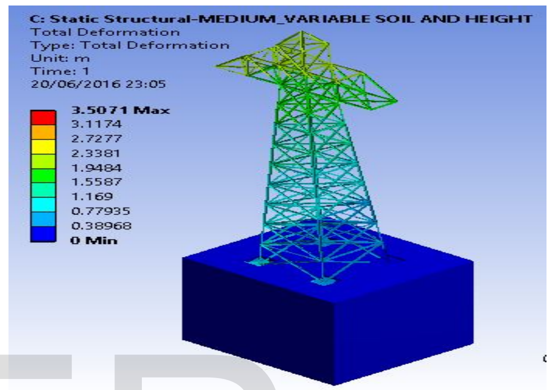


Fig 6.Static structural deformation of medium soil in single pile

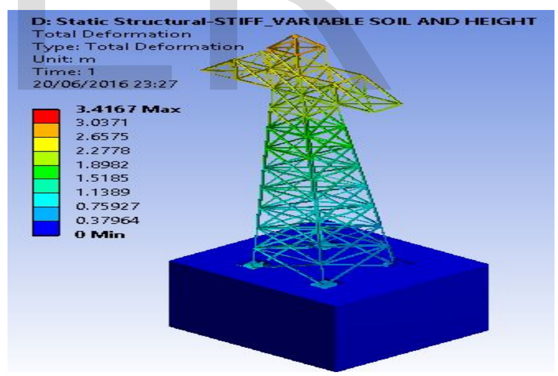


Fig 7.Static structural deformation of stiff soil in single pile

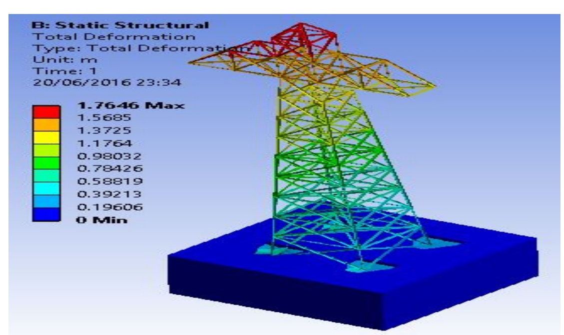


Fig 8. Static structural deformation of soft soil in group of pile

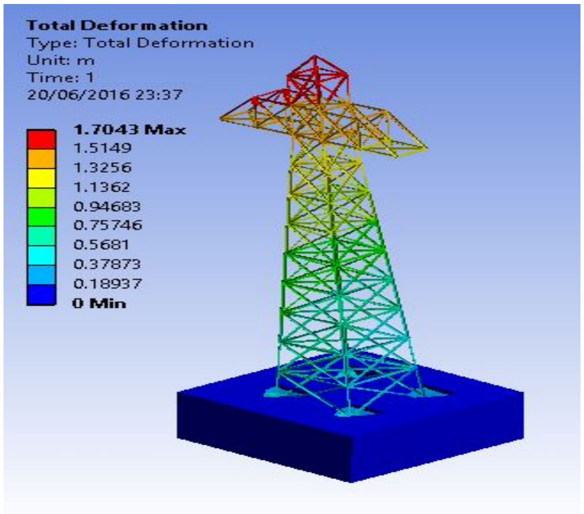


Fig 9.Static structural deformation of medium soil in group of pile

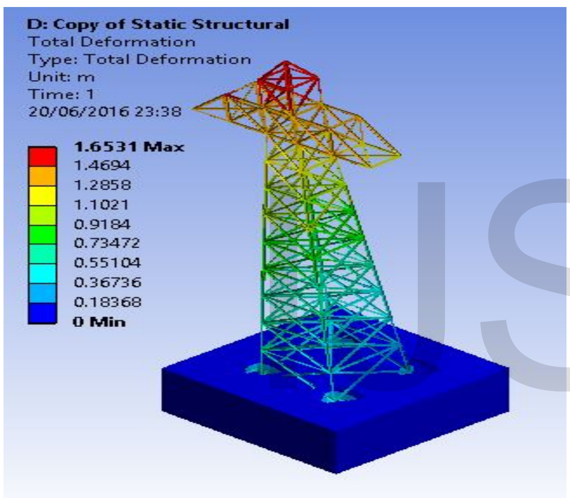


Fig 10.Static structural deformation of stiff soil in group of pile

Table 3 Equivalent stress in tower and soil

Soil type	Single pile		Group of pile	
	Stress in tower (MPa)	Stress in soil (MPa)	Stress in tower (MPa)	Stress in soil (MPa)
Soft	398.41	198.03	275.13	116.75
Medium	409.46	170.93	350.75	131.88
Stiff soil	443.04	168.35	417.97	171.69

6 CONCLUSIONS

The important conclusions formulated from the project work are as follows:-

1. The natural frequency of the soil structure system for soft, medium and stiff soil for frictional soil pile interface were obtained as 0.1368Hz, 0.1318Hz and 0.1278Hz in the case of tower structure supported by one pile at each leg.
2. That is the reduction of 6.49%, 4.60% and 3.66% respectively in the natural frequencies of the soil structure systems investigated for soft, medium and stiff soil when each leg of the tower structure is supported by a group of three piles.
3. Number of pile increases the frequency obtained for soil-structure system increases in both soft, medium and stiff soil
4. The maximum stress in the steel structure obtained for fixed base condition is found to be 198MPa which is lesser than the yield stress by 22.8%.
5. The vertical deformation or settlement decreases by respectively for medium and stiff soil with respect to that of soft soil
6. From the soil pile frictional interface condition, it has been observed that maximum stress in the steel structure is less than the yield stress by 20.8% and it's found to be safe

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