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NUMERICAL STUDY OF A BUILDING FRAME SUPPORTED BY PILE GROUPS EMBEDED IN COHESIONLESS SOIL

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ABSTRACT: This paper addresses the behavior of a simple frame considering soil structure interaction i.e. interaction between substructure of the building and soil. For this purpose a sample of a frame is analyzed in numerical analysis using Finite Element Method by fixed base for various load combinations and determines the parameters displacement, shear force and bending moment. Then a same frame is analyzed in numerical analysis using Finite Element Method with pile foundation by assigning the soil properties to substructure and determines the parameters displacement, shear force and bending moment. According to the analysis results the parameters displacements, shear force and bending moment varies from fixed base to pile foundation.

Keywords: Soil Structure interaction, Numerical Method of Analysis, Displacement, Shear Force, Bending Moment.

1.INTRODUCTION: Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI)

Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil such as low rise buildings and simple rigid retaining walls. The effect of SSI, however, becomes prominent for heavy structures resting on relatively soft soils for example nuclear power plants, high-rise buildings and elevated-highways on soft soil. Investigations of soil structure interaction have shown that the dynamic response of a structure supported on flexible soil may differ significantly from response of the same structure when supported on rigid base. One of the important reasons for this difference is that part of the vibrational energy of flexible mounted structure is dissipated by radiation of stress waves in the supporting medium and by hysteretic action in the medium itself. Analytical methods to calculate the dynamic soil-structure interaction effects are well established. When there is more than one structure in the medium, because of interference of the structural responses through the soil, the soil structure responses through the soil,

soil structure problem evolves to a cross interaction problem between multiple structures.All those discussions have laid a solid theoretical and practical foundation for the subsequent research on Soil Structure Interaction (SSI). However, most of those studies are based on the elastic half space theory, which make analysing the structure with shallow foundation attached to a homogeneous and thick soil layer simple and practical for engineers. Due to the difficulty of the solution for the analysis method and the excessive simplification of the model for soil and structures, it was far from the real solution for problems of SSI. When superstructures, foundations, and topographic and geological conditions become complicated, producing a mathematical solution can be difficult.

Effect of soil structure interaction on structural response: It has conventionally been considered that soil-structure interaction has a beneficial effect on the seismic response of a structure. Many design codes have suggested that the effect of SSI can reasonably be neglected for the seismic analysis of structures. This myth about SSI apparently stems from the false perception that SSI reduces the overall seismic response of a structure, and hence, leads to improved safety margins. Most of the design codes use oversimplified design spectra, which attain constant acceleration up to a certain period, and thereafter decreases monotonically with period. Considering soil-structure interaction makes a structure more flexible and thus, increasing the natural period of the structure compared to the corresponding rigidly supported structure. Moreover, considering the SSI effect increases the effective damping ratio of the system. The smooth idealization of design spectrum suggests smaller seismic response with the increased natural periods and effective damping ratio due to SSI. With this assumption, it was traditionally been considered that SSI can conveniently be neglected for conservative design. In addition, neglecting SSI tremendously reduces the complication in the analysis of the structures which has tempted designers to neglect the effect of SSI in the analysis.In this paper a single frame with fixed ends and with pile foundations is analysed in numerical method of analysis using finite element method with different load combinations and determine the parameters displacements, shear force and bending moment and are compared with base as fixed and with pile foundation

2. LITERATURE REVIEW:

Dr. C Ravi Kumar Reddy (2011) studied a modelled building frame supported by pile groups embedded in cohesion less soil (sand). The effect of soil interaction on displacements and rotation at the column base and also the shears and bending moments in the columns of the building frame were investigated. The experimental results have been compared with those obtained from the finite element analysis and conventional method of analysis. Soil nonlinearity in the lateral direction is characterized by the p-y curves and in the axial direction by nonlinear vertical springs along the length of the piles (τ-z curves) at their tips (Q-z curves). The results reveal

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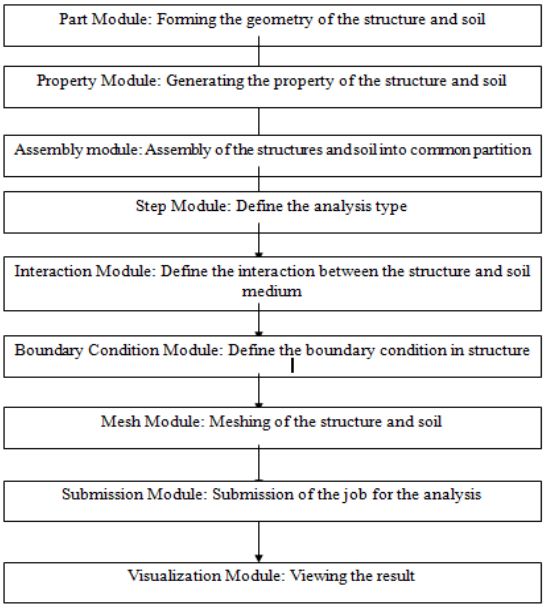
that the conventional method gives the shear force in the column by about 40-60%, the bending moment at the column top about 20-30% and at the column base about 75-100% more than those from the experimental results. The response of the frame from the experimental results is in good agreement with that obtained by the nonlinear finite element analysis.

M.V Gaikwad (2015) analysed a frame with soil structure interaction using FEM. It states the behaviour of bare frame having soil beneath. The results shows bare frame with soil structure interaction shows more displacements than the analysis of structure without soil structure interaction. Also analysis of bare frame with soil structure interaction shows less shear force and bending moment as compared with analysis of bare frame without soil structure interaction.

Step by step procedure for modelling structure in ANSYS:



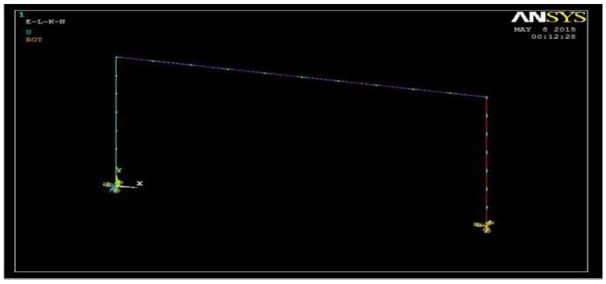


Fig.1 Frame with fixed base

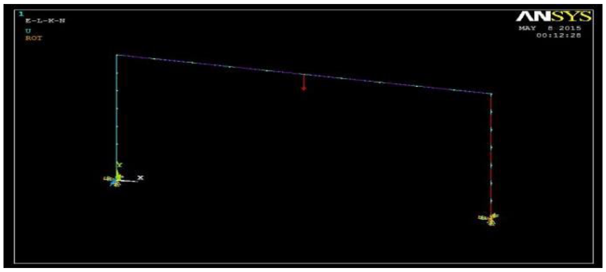


Fig.2 Load applied on a frame with fixed end supports

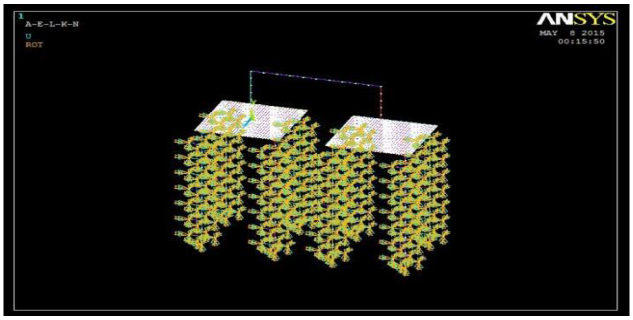


Fig.3 Frame with pile supports

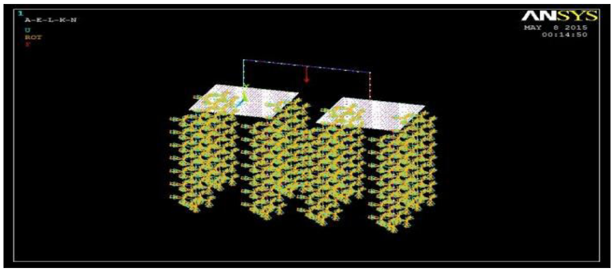


Fig.4 Load applied on a frame with pile supports

4. RESULTS AND DISCUSSIONS:

Maximum Displacements:

The maximum displacements of frame for the cases of loads i.e 10kn,20kn,30kn,40kn,50kn with soil

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structure interaction and without soil structure interaction presented in table below.

Maximum Displacements:

The maximum displacements of frame for the cases of loads i.e 10kn,20kn,30kn,40kn,50kn with soil structure interaction and without soil structure interaction presented in table below.

Maximum displacements in Structure in F_y direction

Maximum Displacements in frame for 10kn in mm

Element	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.13	0.19
ELEMENT 2	0.13	0.19
ELEMENT 3	0.13	0.19

Maximum Displacements in frame for 20kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.21	0.38
ELEMENT 2	0.21	0.38
ELEMENT 3	0.26	0.38

Maximum Displacements in frame for 30kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.23	0.57
ELEMENT 2	0.32	0.57
ELEMENT 3	0.40	0.57

Maximum Displacements in frame for 40kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.26	0.77
ELEMENT 2	0.43	0.77
ELEMENT 3	0.53	0.77

Maximum Displacements in frame for 50kin mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.32	0.96
ELEMENT 2	0.54	0.96
ELEMENT 3	0.67	0.96

Maximum displacements in frame in F_x direction

Maximum Displacements in frame for 10kn in mm

Element	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.37	1.70
ELEMENT 2	0.66	6.3
ELEMENT 3	0.53	6.40

Maximum Displacements in frame for 20kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.53	3.84
ELEMENT 2	0.74	12
ELEMENT 3	0.42	12

Maximum Displacements in frame for 30kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.79	9.18
ELEMENT 2	0.33	18
ELEMENT 3	0.47	19

Maximum Displacements in frame for 40kn in mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.44	16
ELEMENT 2	0.44	25
ELEMENT 3	0.22	25

Maximum Displacements in frame for 50kin mm

Column Number	Displacement without SSI	Displacement with SSI
ELEMENT 1	0.55	20
ELEMENT 2	0.33	31
ELEMENT 3	0.53	32

Maximum Shear Forces:

The maximum shear force of frame for the cases of loads i.e 10kn,20kn,30kn,40kn,50kn with soil structure interaction and without soil structure interaction presented in table below

Maximum Shear Forces in frame in F_y direction

Maximum Shear Forces in frame for 10 kn in KN

Column Number	SF without SSI	SF with SSI
ELEMENT 1	5	5
ELEMENT 2	5	1.2
ELEMENT 3	5	4.9

Maximum Shear Forces in frame for 20kn in KN

Column Number	SF without SSI	SF with SSI
ELEMENT 1	10	10
ELEMENT 2	10	9.9
ELEMENT 3	10	10

Maximum Shear Forces in frame for 30kn in KN

Column Number	SF without SSI	SF with SSI
ELEMENT 1	15	15.01
ELEMENT 2	15	14.9
ELEMENT 3	15	15.01

Maximum Shear Forces in frame for 40kn in KN

Column Number	SF without SSI	SF with SSI
ELEMENT 1	20	20.1
ELEMENT 2	20	19.9
ELEMENT 3	20	20.1

Maximum Shear Forces in frame for 50kn in KN

Column Number	SF without SSI	SF with SSI
ELEMENT 1	25	25.1
ELEMENT 2	25	24.9
ELEMENT 3	25	25.1

Maximum Bending Moments:

The maximum shear force of frame for the cases of loads i.e 10kn,20kn,30kn,40kn,50kn with soil structure interaction and without soil structure interaction presented in table below

Maximum Bending Moment for frame in F_y direction

Maximum Bending Moments in frame for 10kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	4.71	3.0
ELEMENT 2	4.71	3.0
ELEMENT 3	7.78	2.41

Maximum Bending Moments in frame for 20kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	9.43	4.8
ELEMENT 2	9.43	6.0
ELEMENT 3	15.56	3.6

Maximum Bending Moments in frame for 30kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	14.15	9.0
ELEMENT 2	14.15	9.0
ELEMENT 3	23.5	5.4

Maximum Bending Moments in frame for 40kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	18.87	12.0
ELEMENT 2	18.87	12.0
ELEMENT 3	31.12	9.6

Maximum Bending Moments in frame for 50kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	23.59	15.0
ELEMENT 2	23.09	15.0
ELEMENT 3	38.90	15.0

Maximum Bending Moment for frame in F_x direction

Maximum Bending Moments in frame for 10kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	0	0.72
ELEMENT 2	0	0.72
ELEMENT 3	0	0.72

Maximum Bending Moments in frame for 20kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	0	1.4
ELEMENT 2	0	1.4
ELEMENT 3	0	1.4

Maximum Bending Moments in frame for 30kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	0	2.1
ELEMENT 2	0	2.1
ELEMENT 3	0	2.1

Maximum Bending Moments in frame for 40kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	0	2.9
ELEMENT 2	0	2.9
ELEMENT 3	0	2.9

Maximum Bending Moments in frame for 50kn in KN/m

Column Number	BM without SSI	BM with SSI
ELEMENT 1	0	3.6
ELEMENT 2	0	3.6
ELEMENT 3	0	3.6

5. CONCLUSION

The following conclusions have been drawn from above results:

1. Analysis of structure with soil structure interaction shows average 60% increase in displacement than the analysis of structure without soil structure interaction.
2. Analysis of structure with soil structure interaction shows more or less shear forces as compared with analysis of structure without soil structure interaction.

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3. Analysis of structure with soil structure interaction shows average 56% decrease of Bending moments as compared with analysis of structure without soil structure interaction.
4. Hence the analysis performed by keeping frame with fixed base shows highly safe results.

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