Dynamic Analysis of RCC Building Considering Soil Structure Interaction

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Abstract - *In this study, an attempt is made to understand the influence of soil flexibility in soil structure interaction (SSI) on building frames resting on piled raft foundation. Modeling of building frames is carried out in finite element based software ETABS. G+10 storied frames resting on different types of homogenous and stratified soils, with and without interaction are subjected to earthquake. Buildings resting on piled raft foundation are compared with fixed base. Dynamic analysis is carried out using Response Spectra of IS 1893:2002. The soil flexibility is included in the analysis using Winkler approach (spring model). The effect of SSI on various structural parameters i.e. natural time period, lateral displacement, roof displacement etc are studied and discussed. The SSI effect is found to increase time period and displacement. The effect of SSI is observed to be significant for the types of soil and the foundation considered in this study.*

***Key Words*: Soil Structure interaction, Response Spectrum, Piled Raft foundation, ETABS.**

1. INTRODUCTION

Structures founded on the rock are considered as fixed base structures. When a structure founded on solid rock is subjected to an earthquake, the extremely high stiffness of the rock constrain the rock motion to be very close to the free field motion and can be considered as a free field motion and fixed base structures.

Dynamic analysis of SSI can be done using Direct Method and Substructure Method. The direct approach is one in which the soil and structure are modeled together in a single step accounting for both inertial and kinematic interaction. Substructure method is one in which the analysis is broken down into several steps that is the principal of superposition is used to isolate the two primary causes of SSI (Wolf, 1985).

If the structure is supported on soft soil deposit, the lack of ability of the foundation to conform to the deformations of the free field motion would cause the motion of the bottom of the structure to deviate from the free field motion. Additionally, the dynamic response of the structure itself would induce deformation of the supporting soil. This process, in which the response of the soil influences the motion of the structure and the response of the structure influences the motion of the soil, is studied under the interaction effects and popularly known as soil structure interaction. These effects are further significant for stiff and/ or heavy structures supported on comparatively soft soils. For soft and /or light structures found on stiff soil these effects are usually small. It is also significant for closely spaced structure that may subject to pounding, when the relative displacement is large.

Nguyen et al [1] investigated the soil structure interaction phenomena on a 15-story moment-resisting frame sitting on differently sized end-bearing and floating pile foundations. A three-dimensional (3D) numerical model is analyzed for the nonlinear behavior of the soil medium, the piles, and the structural elements. Mathew et al [2] analyzed a nine storey RC building asymmetric in plan, located in seismic zone III using SAP2000. Pushover analysis has been performed to obtain effect of soil-structure interaction on buildings resting on different types of non-cohesive soil, viz., soft and rock. Bagheri et al [3] investigated the effect of soil-pile structure interaction on seismic response of structures. Numerical simulations on two types of superstructures and six types of piled raft foundations were carried using finite element software SAP2000. Parametric study was conducted using time histories of various earthquakes. Maheshwari and Rajib [4] developed a MATLAB to model three-dimensional soil-pile-structure systems. A 2 × 2 pile group in liquefiable soil was considered and a parametric study was conducted to investigate its seismic behavior. Juirnarongrit and Ashord [5] used the p–y method for analysis of single piles and pile groups subjected to lateral spreading. The piles in the groups were modeled as an equivalent single pile with four times the flexural stiffness of a single pile for the four-pile group and nine times the flexural stiffness of a single pile for the nine-pile group.

1.1 Soil structure interaction – Spring Stiffness

In this study Winkler's method is considered, it's idealization represents the soil medium as a system of identical but mutually independent, closely spaced, discrete, linearly elastic springs. The effect of soil flexibility is suggested to be accounted through consideration of springs of specified stiffness. According to this idealization deformation of foundation due to applied load is restricted to loaded regions only. The basic problem with the use of this model is to find out the stiffness of elastic springs used to replace the soil below foundation. For building with isolated footing, below each column three translational springs along two horizontal and one vertical axes respectively together with three rotational springs about those mutually perpendicular axes respectively must be attached to simulate the effect of soil flexibility.

1.2 CODAL PROVISION FOR SSI

IS 1893:2002 gives the statement for considering the effect of SSI in analysis. But the detailed procedure is not mentioned in the code. Clause 9.1.1 of the IS 1893 reads: "The soil-structure interaction refers to the effects of the supporting foundation medium on the motion of the structure. The soil-structure interaction may not be considered in the seismic analysis for structures supported on rock or rock-like material."

2. STRUCTURAL MODELING

For the purpose of analysis, superstructure has been modeled on piled raft foundation. This study consists G+10 storied symmetric building having 4 bays in each principal direction; each bay is having width of 4m. piles of 10m length are provided with spacing of 4m in both directions. Modeling is done using finite element based software ETABS. The earthquake response of the building considering soil structure interaction is examined and the results are compared with the fixed base condition. The analysis was carried out to find the natural period, displacement, torsional moment of the structures.

The detailed properties used in modeling are as follows:

1. Grade of concrete: M30
2. Grade of steel for longitudinal bars: HYSD415
3. Grade of steel for confinement bars (Ties): Fe250
4. Floor to floor height: 3 m
5. Slab thickness: 120mm
6. Size of Column: 400mm×400mm
7. Size of Beam: 230mm×400mm
8. Seismic Zone: IV
9. Importance Factor: 1
10. Building Frame: Special moment resisting frame (SMRF)
11. Density of concrete: 30 kN/m^3

Table 1 presents the soil properties which are used in the modeling.

Table -1: Properties of soil used

No.	Strata	Modulus of Elasticity (E) (kN/m^2)	Poisson's ratio (μ)	Shear Modulus (G) (kN/m^2)
1	Clay	10000	0.4	3570
2	Sand	25000	0.3	9610
3	Silt	15000	0.45	5170

The combinations of soil profiles considered in analysis are as:

1. Clay- 10m
2. Sand- 10m
3. Silt- 10m
4. Sand(5m)- clay(5m)
5. Silt(5m)- clay(5m)

The assignment of soil stiffness produces the effect of the soil strata which supports soil and provides the skin friction so as to support superstructure. 3D modeling of the pile foundation with soil stiffness is as shown in figure 1.

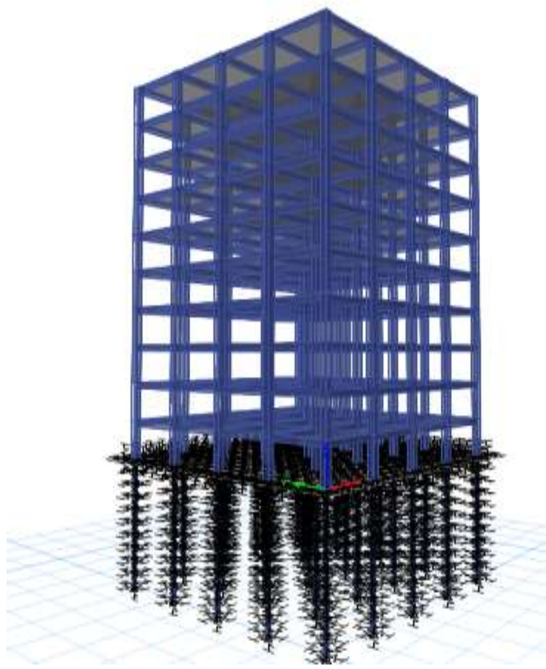

Fig. 1: 3D model in ETABS

For analysis, response spectrum method is used with Zone factor = 0.24 (Zone IV), Importance factor = 1.0 (All Other Buildings), Response reduction factor= 5 for Special moment resting frame (SMRF).

3. RESULTS AND DISCUSSION

In this study, the response of the superstructure considered for the comparison include the time period, horizontal displacement of the frame at the storey level and torsional moment for both fixed base and soil-structure interaction (SSI) cases.

1. Time Period

The study shows that natural period increases with soil flexibility by the inclusion of soil structure interaction when compared to fixed base model. The soil having less stiffness have longer time period. The time period of clayey soil is greater than that of other soils.

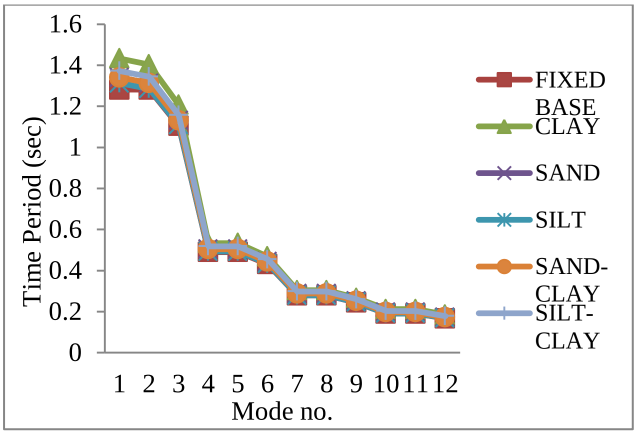

Fig. 2: Time period (sec) Vs. mode no

2. Storey Displacement

The displacements of building are very high in building resting on soil compared to fixed base.The deflection where the soil is stiff is less compared to building on soft soil due to increase in flexibility of soil.

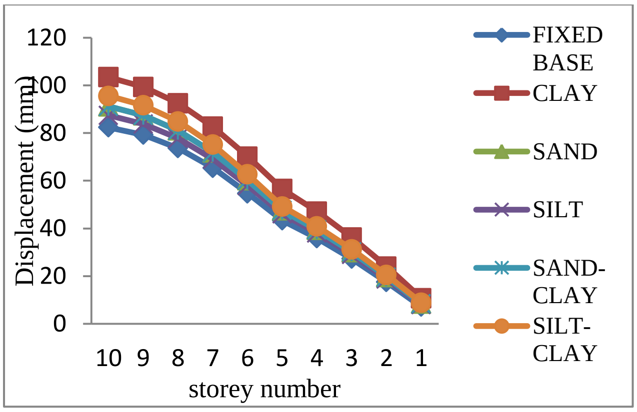

Fig. 3: Displacement (mm) Vs. storey no.

3. Torsional moment

From the result of present study it showed that torsional moment of models with soi- structure interaction is more than that without soil- structure interaction. Torsional moment in different types of soil spring models is increased as soil changes from hard to soft.

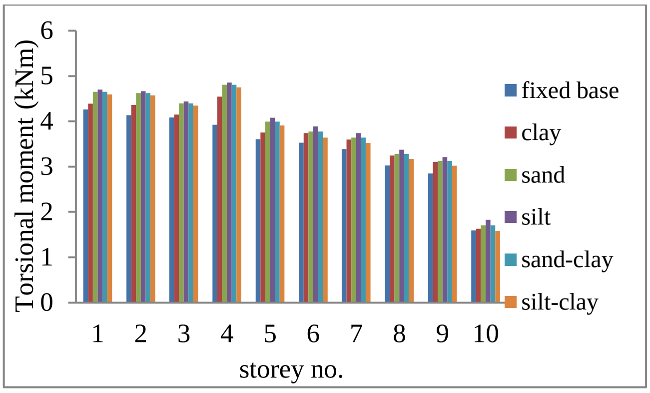

Fig. 4: Torsional Moment vs storey number

4. Bending moment

Maximum bending moments are found in the models with soil- structure interaction compared to the fixed base condition.

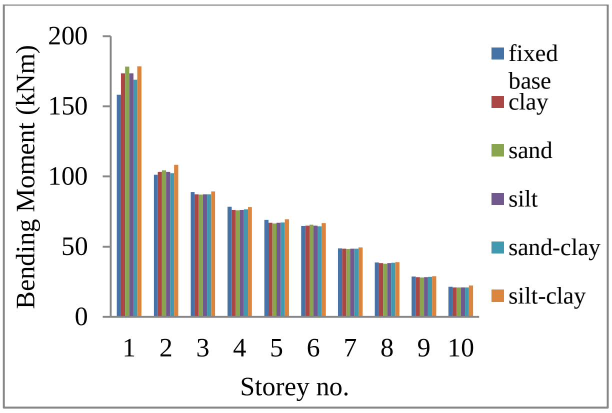

Fig. 5: Bending Moment (kNm) vs storey number

4. CONCLUSIONS

1. Analyses conducted shows that structure models with soil included have much higher values of story displacements, when the soil is modeled using springs.

2. The models with soil included, compared to conventional fixed base models, have higher fundamental periods of vibration. The natural period of structure increases due to SSI effect. For clayey soil the effect is more prominent.

3. As the stiffness of the subsoil decreases, the effects of soil-structure interaction become more dominant to the seismic behaviour of RC building frames.

4. Roof displacement is also observed to be increasing due to incorporation of Soil Structure Interaction. For

clayey soil the roof displacement is higher in Winkler approach (Spring Model).

5. Torsional moments are found to be increased in models with soil- structure interaction compared with that of fixed based models.

5. FUTURE SCOPE

1. Present study uses Response spectrum analysis; it can be extended to pushover analysis. Pushover Analysis is an effective tool in analysis; brief analysis can be easily carried out with this method.

2. In this study simple R.C. Frame with slab is taken, other element like shear wall can be added to check effect. Study also can be done on water tanks, etc.

3. In this study analysis is carried out for reinforced concrete building frame. Steel structures can also be analyzed similarly.

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