Non Linear Time History Analysis of Tall Steel Tower Considering Soil Structure Interaction

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Abstract— **In the conventional method of design of tall structures like towers the flexibility of soil is ignored which is likely to affect the performance of tall towers. In the proposed study an attempt is made to understand the effect of soil structure interaction on the performance of tall towers resting on three different type of soil that is hard soil , medium soil and soft soil .for this purpose soil is modeled as spring at base of foundation and soil is again modeled as solid element in FEM software and the effects of this soil on seismic response is studied.**

Keywords— Soil Structure Interaction; Seismic Response; Time History

I. INTRODUCTION

Over the past years, considerable progress has been made in understanding the nature of earthquakes and how they damage structures, and in improving the seismic performance of the built environment. During past and recent earthquakes, it is realized that the soil-structure interaction (SSI) effects play an important role in determining the behavior of building structures. The interactive response of a structure during an earthquake significantly depends on the characteristics of the ground motion, the surrounding soil medium, its properties and the structure itself. The soil structure interaction refers to the effects of the compression of supporting foundation medium on the motion of the structure. During an earthquake, seismic waves are transmitted through soil from the origin of disturbance to the structure; the wave motion of the soil excites the structure, which in turn modifies the input- motion by its movement relative to the ground. The movements of soil under foundation will interact with the deformations of the structure itself. The interaction phenomenon is generally affected by the mechanism of energy exchange between the soil and the structure, and the primary influence on the building is to modify the natural period of vibration and hence the response in terms of stress and strain.

In the present study 3 towers of 110 meter, 150 meter and 175 meter high are modeled in FEM software SAP 2000. The self weight and dead loads are applied on it, in addition to this antenna loads are also applied on these towers. The soil is modeled as spring at base and FEM model. The acceleration time history of bhuj and Nepal earthquakes are applied at base of the tower and the response of the structure is studied in form of base shear and deflection at the top of the structure

II. FEM MODELING OF TOWER

A. Modelling of Tower

For the present study 3 towers of 110 meter, 150 meter and 175 meter towers are considered; the details of the towers are taken from government of India specifications.

The main leg member of the tower contains the box section of appropriate size and is modeled as continuous member the bracings are of K type in all the towers the appropriate angle sections are assigned to bracing of the tower according to loads acting on it.

The towers are modeled using frame elements and the joints are modeled as fixed in the main leg members and joints are modeled as pinned joints in the bracing systems. so it cannot transfer moments but it can transfer only axial forces in bracing systems.

B. Modeling of Soil As Spring

Various researchers have worked to find the value of equivalent stiffness of soil as a spring and the equations are derived by their experimental works. Some of the researchers are George Gazate, wolf etc. The FEMA has published his recommendations in 2000 known as FEMA 356 entitled "prestandard and commentary for the seismic rehabilitation of buildings" this standard he gives the equation to find stiffness of the soil as equivalent springs to find the stiffness of soil 3 types of soil as shown in table is used. The properties of the soil such as modulus of elasticity, Poission's ratio and shear modulus are considered from Bowles J E book the properties of 3 different types of soil considered are shown in the table1

TABLE-I

Type of soil	*Shear modulus (G)* KN/M2	Elastic modulus (E) KN/M^2	Poission's ratio
Hard	30000	72000	0.2
Medium	20000	50000	0.25
Soft	10000	26000	0.3

From the above properties of 3 types of soil the stiffness of soil is calculated in 6 directions that is displacement along 3 direction and rocking along 3 directions using formulas given in FEMA 356. For calculation of the stiffness of soil the excel sheet are prepared. In addition to this the corrections for depth are also applied to stiffness of spring.

III. MODELING OF SOIL AS FEM

A. Modeling of Foundations

The pad footing of size 2.5 mt X 2.5 mt size is assumed for all types of soil. The depth of footing below foundation is assumed as 0.5 mt. the thickness of the footing assumed is 0.2 mt. the footings are modeled as shell element at foundation level. The meshing of the footing is given so that meshing size of footing matches with meshing size of soil and loads of towers are transferred to the footing and then it are transferred to the soil modeled below the footing..

B. Modeling of Soil

Soil is assumed to be an isotropic, homogeneous, linearly elastic soil medium, the behavior of which can be idealized and represented using solid models for which dynamic shear modulus and Poisson's ratio are entered as inputs. Soil is modeled using solid element having three degrees of freedom of translation and 3 degrees of rotation in the respective co ordinate directions at each node. In order to fix the region of soil below and around the foundation which influence the soil behavior and necessary to be considered in the analysis, pressure isobars based on the Boussinesq equation (Bowles 1988) have been used. Based on this Continuum model for soil is represented by considering breadth equal to twice the width of the foundation along the plan dimension and thrice the width of foundation along the depth of foundation. Trial analyses with few variations with respect to above considerations of size of the soil medium were carried out in order to fix the region of soil below and around the foundation which needs to be considered in the analysis to realistically represent continuum model, and it was found that for thickness of soil medium more than 2.5 times the least width of soil foundation, there was negligible influence on settlement and contact pressure below the footing. Figure 1 shows discretization of foundation-soil system in continuum model for strip footing. Vertical translation is arrested at the bottom boundary.

Another important effect to be considered in soil modeling is soil damping. Numerous studies on this aspect have been made by different investigators. However, critical damping of 5% is considered in each mode of vibration for all cases in the present study as suggested by IS 1893:2002 (Part 1).

To study the effects of earthquake considering soil structure interaction the dynamic analysis of all tall towers are carried out using 2 acceleration time history of recent earthquakes such as bhuj and Nepal earthquake. This 2 time histories are applied in 2 horizontal directions such as X direction and Y direction

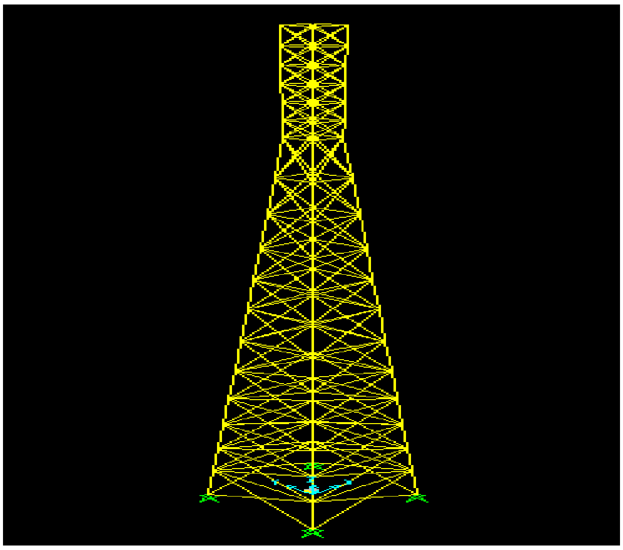

Fig. 1. FEM Model Of Tower

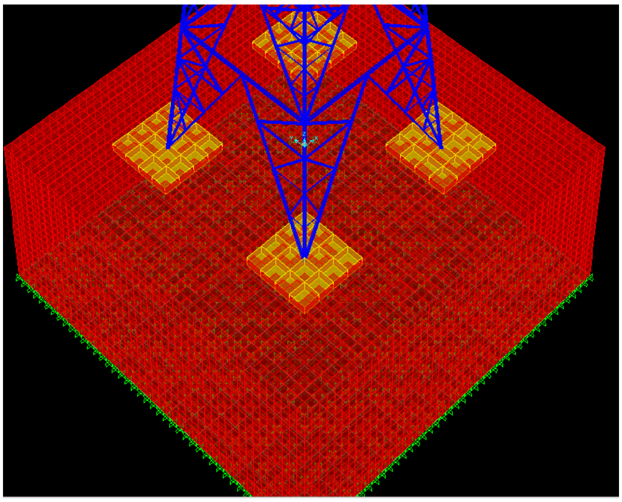

Fig. 2. Modeling Of Soil and Foundation

IV. RESULT AND DISCUSSIONS

A. Results for 110 mt high tower

fig 3 shows the deflection of top joint for 110 meter high tower due to bhuj time history.

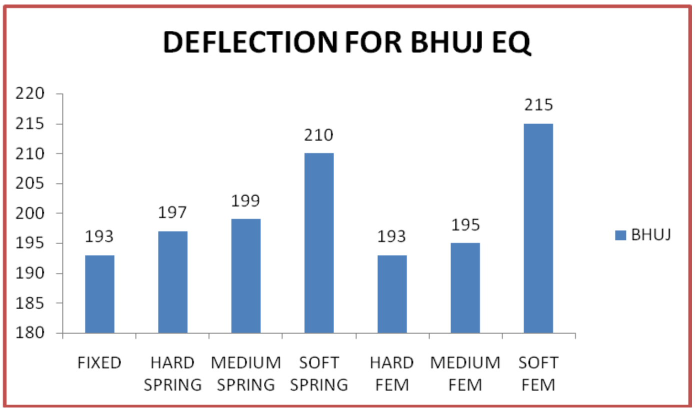

Fig. 3. Deflection At Top For Bhuj EQ in 110 mt tower

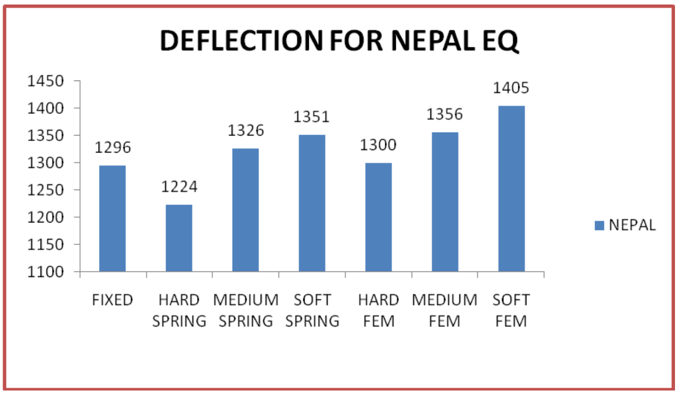

Fig. 4. Deflection at top for Nepal EQ in 110 meter tower

Fig 4 shows the deflection of top joint for 110 meter high tower due to Nepal time history. We can see from the graphs that if we model the soil as FEM we are getting 110 mm more deflection in Nepal time history

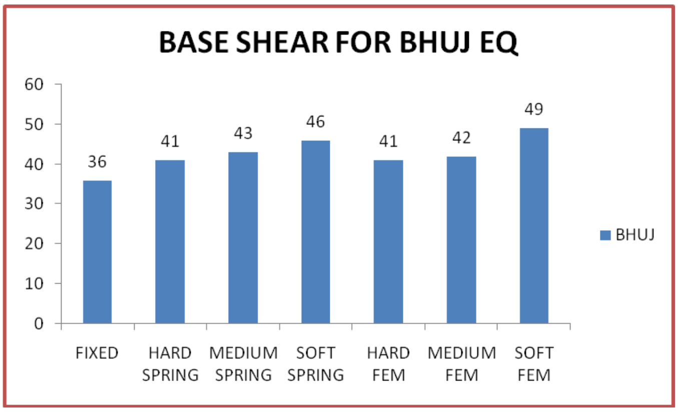

Fig. 5. Base shear for bhuj EQ in 110 meter tower

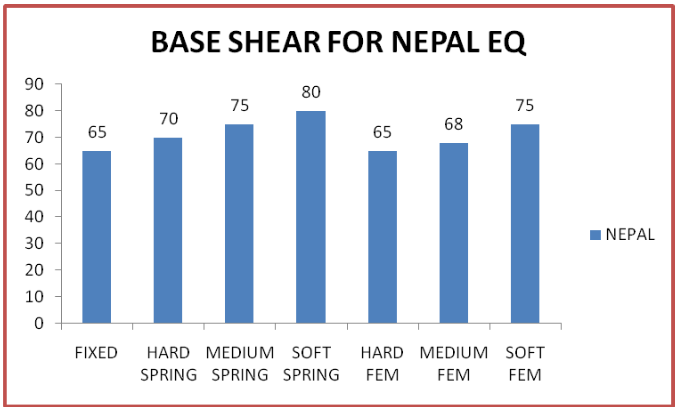

Fig. 6. base shear for nepal EQ in 110 meter tower

Fig 5 and fig 6 shows the base shear for 110 meter high tower due to bhuj and Nepal time history. We can see from the graphs that the base shear of tower by modeling soil as spring is 13 KN higher for bhuj time history and in Nepal time history we are getting 10 KN higher base shears by modeling soil as spring, so we can say that soft soils give rise to the base shear in tall towers.

B. Results for 150 mt high tower

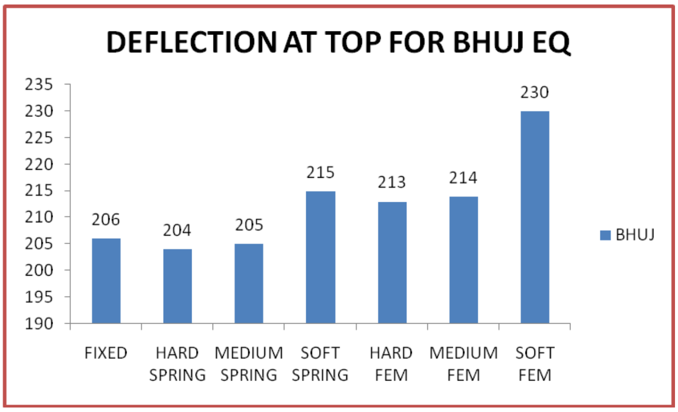

Fig. 7. Deflection At Top For Bhuj EQ in 150 mt tower

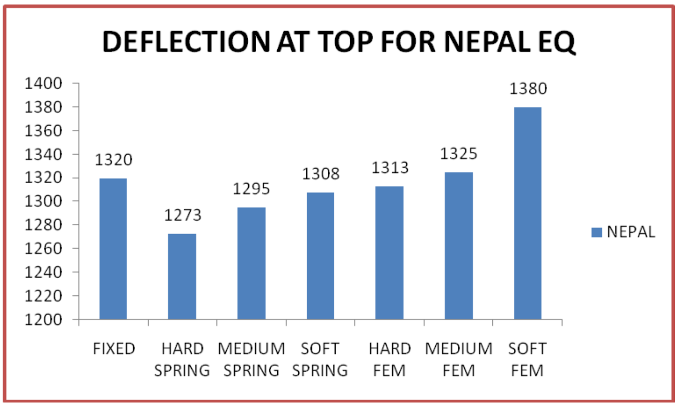

Fig. 8. Deflection at top for Nepal EQ in 150 meter tower

Fig 7 and fig 8 shows the deflection of top joint for 150 meter high tower due to bhuj and Nepal time history. We can see from the graphs that the deflection of tower by modeling soil as FEM is more than the fixed base. In case of Nepal earthquake we are getting 60 mm more deflection in the soft soil modeled as FEM compared to fixed support.

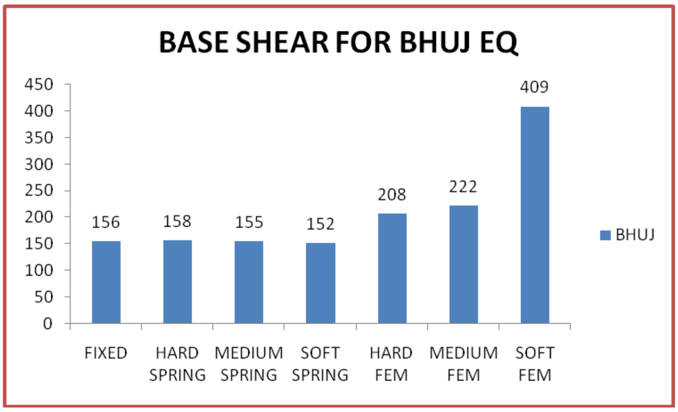

Fig. 9. base shear for bhuj EQ in 150 meter tower

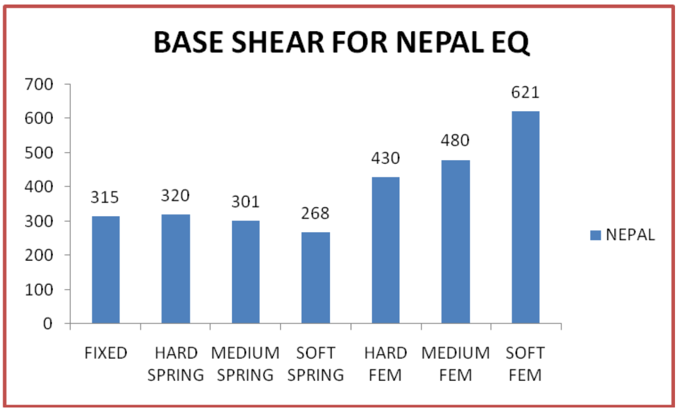

Fig. 10. base shear for nepal EQ in 150 meter tower

Fig 9 and fig 10 shows the base shear for 150 meter high tower due to bhuj and Nepal time history. We can see from the graphs that the base shear is 2.6 times higher for bhuj time history tower by modeling soft soil as FEM compared to the modeling foundation as fixed support In Nepal time history we are getting 2 times higher base shear by modeling soil as FEM in the soft soil compared to fixed support

C. Results for 175 mt high tower

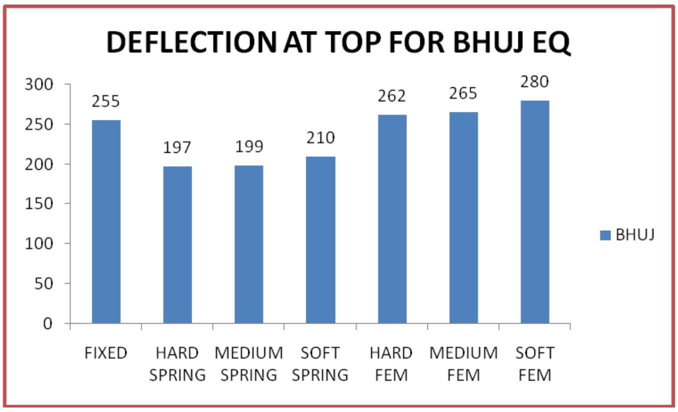

Fig. 11. Deflection At Top For Bhuj EQ in 175 mt tower

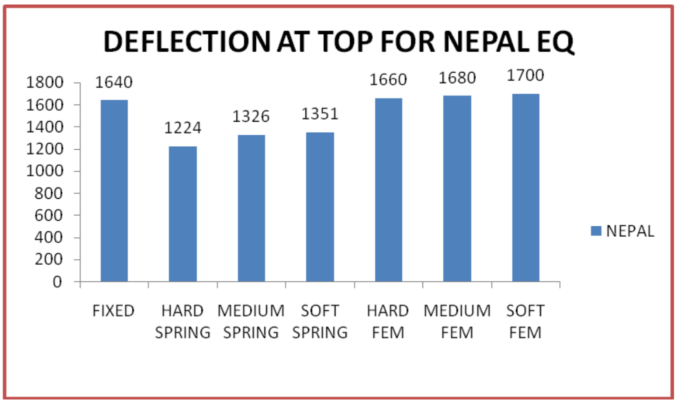

Fig. 12. Deflection at top for Nepal EQ in 175 meter tower

Fig 11 and fig12 shows the deflection of top joint for 175 meter high tower due to bhuj and Nepal time history. We can see from the graphs that the deflection of tower by modeling soft soil as FEM is more than the fixed base. In case of Nepal earthquake we are getting 60 mm more deflection in the soft soil modeled as FEM compared to fixed support at the base.

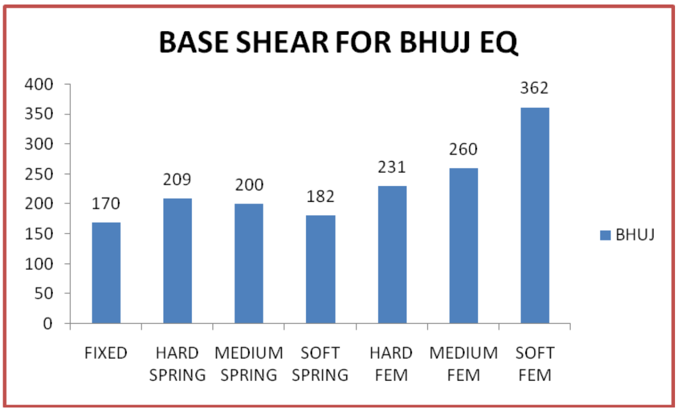

Fig. 13. base shear for bhuj EQ in 175 meter tower

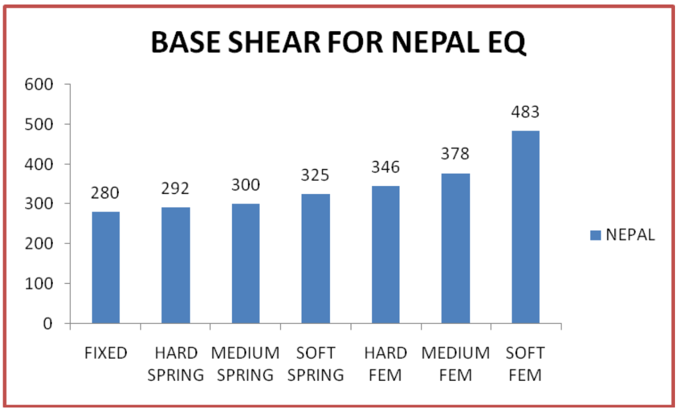

Fig. 14. base shear for nepal EQ in 175 meter tower

Fig 13 and fig14 shows the base shear for 175 meter high tower due to bhuj and Nepal time history. We can see from the graphs that the base shear of is 2.1 times higher for bhuj time history tower by modeling soft soil as FEM compared to the modeling foundation as fixed support In Nepal time history we are getting 1.7 times higher base shear by modeling soft soil as FEM in the soft soil compared to fixed support

V. CONCLUSIONS

From this study following observations are made

- The deflection in case of all the tower are more when we model soft soil as FEM compared to fixed support at the base.
- We are getting variation of 100 mm in deflection in case of 110 metre high tower by modeling soft soil as FEM, while In case of 150 mt and 175 mt high tower we are getting 25 to 60 mm difference in deflection by modeling soft soil as compared to fixed base..

- We are getting higher base shear if we model soil as FEM , from the above result we get 10 to 13 kn higher base shear in the 110 mt high tower
- The base shear is 2 times to 2.6 times higher in case of tower resting on soft soil and modeled as FEM compared to fixed base at base of the tower.
- The base shear is 1.7 to 2.1 times higher in case of tower resting on soft soil modeled as FEM compared to fixed base of tower

From above results we can conclude that we are getting less difference in deflection if we model the soft soil at base but the base shear is 2.6 times higher when we model tall tower considering tower resting on soft soil as compared to tower having fixed supports. So we must include the effects of soil structure interaction in case of tall tower particularly if tall towers are resting on the medium soil to soft soils.

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