# FINITE ELEMENT MODELLING TO STUDY SOIL STRUCTURE INTERACTION OF ASYMMETRICAL TALL BUILDING

by

Pallavi Ravishankar, Dr D Neelima Satyam

in

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# FINITE ELEMENT MODELLING TO STUDY SOIL STRUCTURE INTERACTION OF ASYMMETRICAL TALL BUILDING

B. Pallavi Ravishankar
Research student,GTE, Earthquake Engineering Research Centre, IIIT Hyderabad,INDIA,pallavi.badry@gmail.com

Neelima Satyam D.
Assistant Professor, GTE, Earthquake Engineering Research Centre, IIIT Hyderabad, INDIA, neelima.satyam@iiit.ac.in

ABSTRACT: Tall asymmetric buildings experience more risk during the earthquakes (Ming, 2010). This happens mainly due to attenuation of earthquake waves and local site response which get transferred to the structure and vice versa. This can be well explained by the Dynamic Soil Structure Interaction (DSSI) analysis. In this research paper 150 m tall asymmetrical building with two different foundation systems like raft and pile is considered for analysis and assuming homogeneous sandy soil strata results are studied for input of Bhuj ground motion **(**2001**,** M= 7.7**)**. The response of structure in terms of SSI parameters under dynamic loading for a given foundation systems has been studied and compared to understand the soil structure interaction for the tall structures. It has been clearly identified that the displacement at top is more than that at bottom of the building and stresses are more at immediate soil layer under foundation than the below layers .

## 1.INTRODUCTION:

Most of the civil engineering structures involve some type of structural element which are in direct contact with ground. When the external forces, such as earthquake, 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 explained by the phenomenon Dynamic soil-structure interaction (DSSI). During Earthquake loading the waves travels always with kinetic energy from ground to the surrounding soil mass as well as the structural part in contact with it. A fraction of the kinetic energy released from earthquake waves is transferred into buildings through soil. The exact estimation of transfer of wave energy from soil to structure and again from structure to soil broadly can be divided into two phenomena like a) kinematic interaction and b) inertial i interaction. Soil structure interaction parameters such as stresses and displacements in both structure and support systems (Foundation + Soil mass in contact) are depends up on relative stiffness superstructure, foundation system and supporting soil mass.Type of foundation system is one of the governing parameter n which interaction parameter depends.

In this paper asymmetrical high rise building modelled along with the homogenous sandy soil strata. The building is provided with two different type of foundation systems viz. raft foundation and pile foundation and interaction parameters like displacements and stresses are studied at different points under consideration. It has been observed that displacements and stresses varies with foundation system provided.

## 2. MODELLING :

A Finite element modelling is done for superstructure along with the supporting system using finite element software Ansys-13 (ANSYS Inc). The material models is defined using material library in Ansys for a different linear , nonlinear and contact material for the soil and structure.
In this paper soil and structure modelled integrally with introducing appropriate interface material as per meshing of foundation surface in contact with soil beneath and soil structure interaction parameters like displacements and stresses are studied.

### 2.1.Soil Properties:

A local unbounded homogeneous deep sandy soil volume of 200m x 100m x50 m as shown in Figure1 is considered with the following engineering properties is modelled with Ansys .

Table 1. Parameters of the non-linear soil model

| Soil Type | Sandy soil |
|---|---|
| $E_{ref}$ | 19000 kN/m$^2$ |
| Posson's ratio (η) | 0.3 |
| cohesion (C) | 23kN/ m$^2$ |
| internal friction angle (Ø) | 23$^0$ |
| Mean shear velocity (Vs) | 290 m/s |

The soil structure interaction is modelled with the concept of elastic half space theory. There are two ways to model the soil structure interaction problem viz. Direct method and Substructure method. In direct method superstructure, foundation system and unbounded soil mass is modelled together with a proper interface element. In substructure method superstructure and foundation system is modelled separately with proper consideration of load transfer from superstructure to the foundation system.

In this paper superstructure and support system is modelled by direct method.

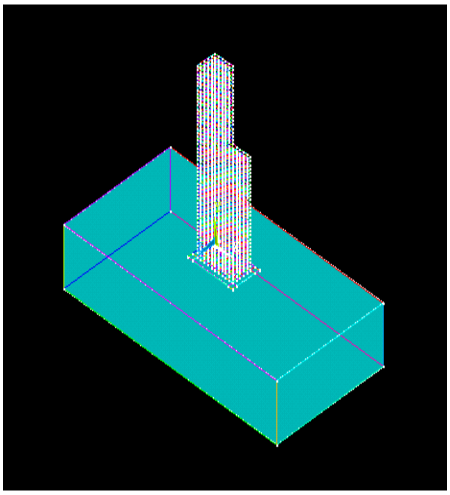

Figure 1. Finite Element non linear soil model.

### 2.2. Description of structure:

A 150 m tall superstructure as shown in Figure 2 of base dimension 40mx20m is considered with a loading asymmetry in such a way, left half portion of building raised to 150 m(50 storeys) and right half raised to 90m (30 storeys). Initial framed structure is modelled in Finite element program Ansys-13.

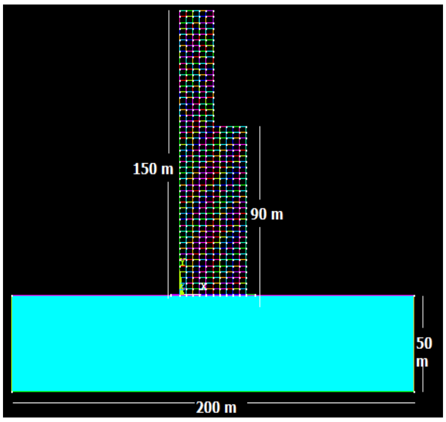


Figure 2. Finite Element model of structure and support system

## 2.3. Foundation System:

Two type foundation system is modelled viz raft and pile foundation.
Raft foundation system (Figure.3) with a dimension 50m x 30m with design uniform thickness 0.5m and a concrete Grade M-20 with rebar material Fe-415 is provided for the modelling.
For pile foundation system (Figure 4) pile cap of 0.2 m thickness is provided with 4m pile spacing in both direction. Pile of diameter 0.25 m and length 10m is modelled.

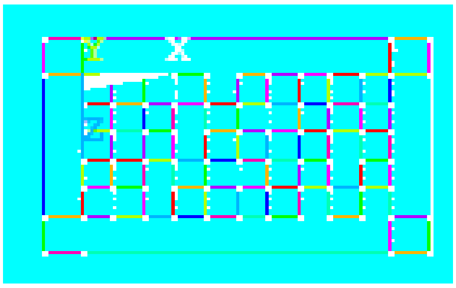

Figure 3. Raft with planer dimension 50m x 30m

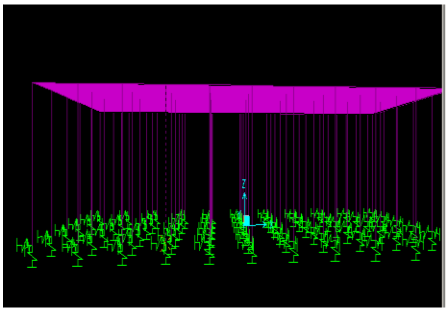

Figure 4. Pile foundation with pile cap dimension 45m x 25m

## 2.4. Elements selection in Ansys-13:

In Ansys framed superstructure is modelled with 2D-Beam element BEAM188 and Piles with SOLID 185, interface element with CONTA175 and TARGE170. Soil is modelled with SOLID 65 and *Drucker–Prager* non linear material model is for soil behaviour.

BEAM188 is suitable for analyzing slender to moderately thick beam structures. The element is based on Timoshenko beam theory which includes shear-deformation effects and element provides options for unrestrained warping and restrained warping of cross-sections.SOLID185 is eight noded 3-D element gives translations in 3-directions used for solid modeling.CONTA175 is ideal to use when there is sliding between two elements in contact (either node to node or line to line). Contact occurs when the element surface penetrates one of the target segment elements, TARGE170 on a specified target surface. Soil is modeled with SOLID 65 which is used for the 3-D modeling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. Material model *Drucker–Prager* for soil describes the non linear plasticity behavior which depends on the engineering soil properties given as a input data of this model.

## 2.5. Dynamic analysis of the soil structure interaction model:

The dynamic analysis carried out by considering Bhuj input ground motions at the bottom of the soil mass and stresses and displacement at different locations like A,B,C.D.E as shown in Figure 5 of the building and the soil are studied.
For the static analysis of structure the self weight, gravity weight is considered and initial stresses are observed which serves as initial stress conditions for dynamic analysis (Figure.6).The ground motion with PGA 0.31g is given to the model to find the displacements and stresses for the soil strata .

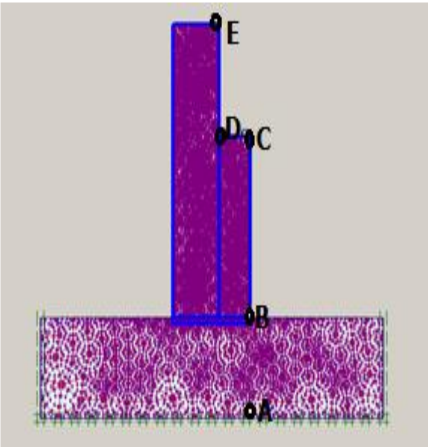


Figure 5. Different points under consideration along elevation of the model

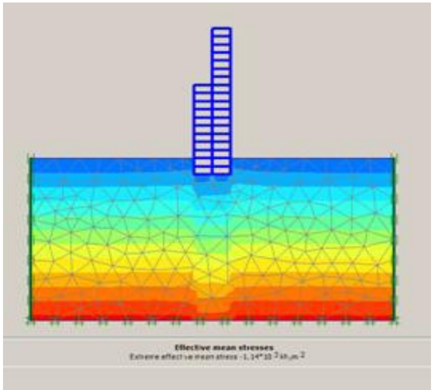


Figure 6. Initial stress contours befor applying dynamic loading with stress 200 kN/m2

## 3. RESULTS :

Displacements in x, y and z direction is calculated for the dynamic loading and at each point from bottom to top of model is been plotted .Figure 7,8 and 9 explains the displacement curves in x , y and z directions supported by raft foundation.

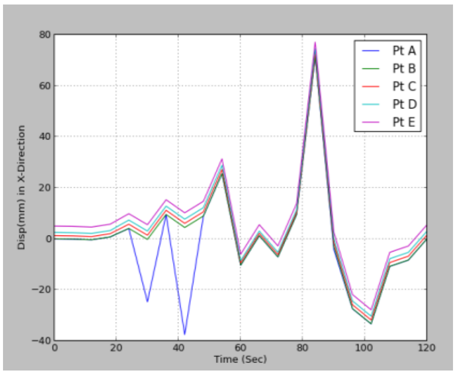


Figure 7. Displacements at different location calculated in X-direction

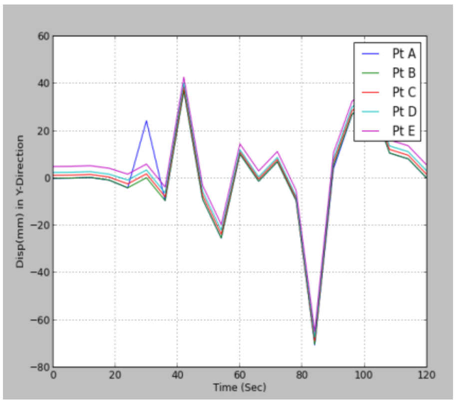


Figure 8. Displacements at different location calculated in Y-direction

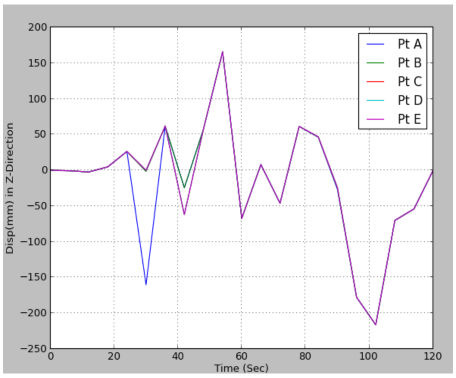


Figure 9. Displacements at different location calculated in Z-direction

Table 2. Maximum displacements under dynamic load conditions for raft foundation system

| Locations | Comparative displacement w.r.t point A ( %) | |
|---|---|---|
| | X-Disp | Y-Disp |
| A | 71.39 mm | 37.10 mm |
| B | 0.42 % | 0.34 % |
| C | 2.51 % | 4.39 % |
| D | 4.61 % | 8.43 % |
| E | 8.12 % | 14.29 % |

When the soil mass and support system is subjected to the dynamic loading it undergoes the deformations which creates the stresses. The stresses in x, y and z direction is calculated for each point mentioned in Table.3. Stress plots at different locations under consideration along the elevation are shown in Figure 10,11 and 12.

Table 3. Maximum Stress value under dynamic load conditions for raft foundation system

| Locations | Comparative stresses w.r.t point A ( %) | |
|---|---|---|
| | X-Stress | Y- Stress |
| A | 428.39 $kN/m^2$ | 222.6 $kN/m^2$ |
| B | 994 % | 990 % |
| C | 20.52 % | 0.44 % |
| D | 14.61 % | 8.43 % |
| E | -8.11 % | 8.29 % |

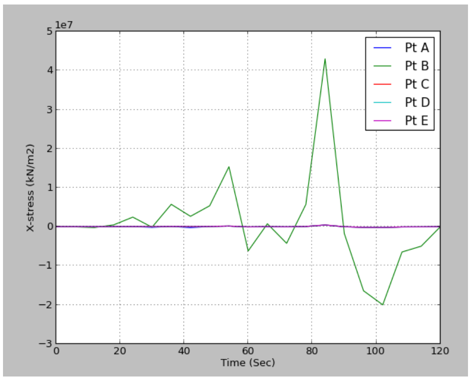


Figure 10. . Stresses at different location calculated in X-direction

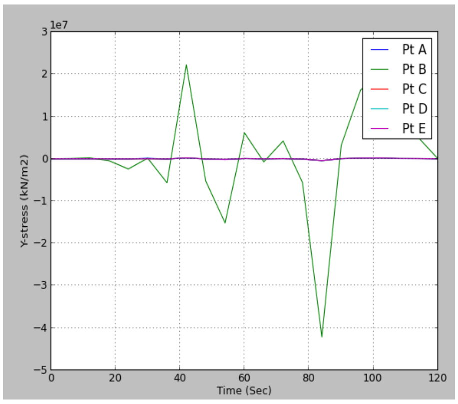


Figure 11. Stresses at different location calculated in Y-direction

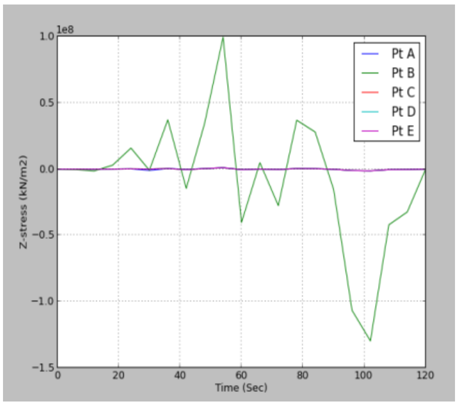


Figure 12. . Stresses at different location calculated in Z-direction

An interactive modelling is done for the same soil properties and same structural configuration and foundation system is altered by a pile type and again results are studied. Table 4, and 5 explains the displacements and stress respectively at different points under consideration for the pile foundation system with initial pile configuration mentioned in foundation system.

Table 4. Maximum Displacements under dynamic load conditions for pile foundation system

| Locations | Comparative displacement w.r.t point A ( %) | |
|---|---|---|
| | X-Disp | Y-Disp |
| B | 0.21 % | 0.20 % |
| C | 2.09 % | 4.07 % |
| D | 4.11 % | 9.22 % |
| E | 7.57 % | 15.27 % |

Table 5. Maximum Stress value under dynamic load conditions for pile foundation system

| Locations | Comparative stresses w.r.t point A ( %) | |
|---|---|---|
| | X-Stress | Y- Stress |
| B | 763 % | 812 % |
| C | 1.18 % | 0.24 % |
| D | 2.52 % | 8.55 % |
| E | 6.61 % | 11.29 % |

## 4. CONCLUSION:

In order to carry out SSI parametric study an asymmetrical building with respect to loading of 150 m height with base dimension 40 m x 20m is analysed for raft and pile foundation systems separately. The soil mass beneath foundation is modelled as per *Drucker–Prager* nonlinear theory in Ansys-13.

The interactive response is studied for the input Bhuj ground motion with PGA 0.31g. The SSI response is studied for both pile and raft foundation systems. The response of building at different key location at different elevation are noted. It has been observed that for a given ground motion the displacements increases as from soil mass to superstructure top in both X and Y direction , but this change is very minute for the Vertical(Z)-direction displacements. Stress concentration is found to be much more in immediate soil layer below the foundation and it decreases evenly in both directions as moving away down and up from foundation. It is noted that for the same soil strata displacements and stresses in case of pile foundation system is comparatively less than raft foundation system.

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