NUMERICAL MODELLING TO STUDY SOIL STRUCTURE INTERACTION FOR TALL ASYMETRICAL BUILDING

by

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EXTENDED 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. Tall Building and unbounded soil is modeled by using the Finite-Element Method, which naturally satisfies the radiation condition for the wave propagation problem. In this research paper 150 m tall superstructure with two different foundation systems like raft and piled raft is considered for analysis. The analysis is done by assuming homogeneous soil strata and the results are studied for input of Bhuj ground motion **(**2001**,** magnitude of 7.7**)**. The response of structure and soil structure interaction parameters for the given dynamic loading for a given foundation systems mentioned above studied and compared to understand the dynamic soil structure interaction for the tall buildings. From the analysis it has been noted that the peak displacement at top is more than that at bottom of the superstructure.

Keywords: Raft, piled raft, Asymmetrical Tall Building, Soil Structure Interaction

INTRODUCTION

Most of the civil engineering structures involve some type of structural element with 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). In Earthquake phenomenon the waves travels always with kinetic energy from ground to the surrounding soil mass as well as the structure part in contact with soil. A fraction of the kinetic energy released from earthquakes waves is transferred into buildings through soils. 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 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 on which interaction parameter depends.

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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

NUMERICAL MODELLING

1.Soil Properties:

A local unbounded homogeneous deep sandy soil area of 200m x 100m x50 m shown in Fig.1 is considered with the engineering properties like drained unsaturated unit weight 17.6 kN/m^3 ,Young's modulus (E_{ref})19000 kN/m^2,Posson's ratio (η) 0.3, cohesion (C) 23kN/m2, internal friction angle (Ø) 23^0 is modelled with Ansys .
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.

2. Description of structure

A tall 50 storied building of base dimension 40mx20m as shown in Fig.1 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.

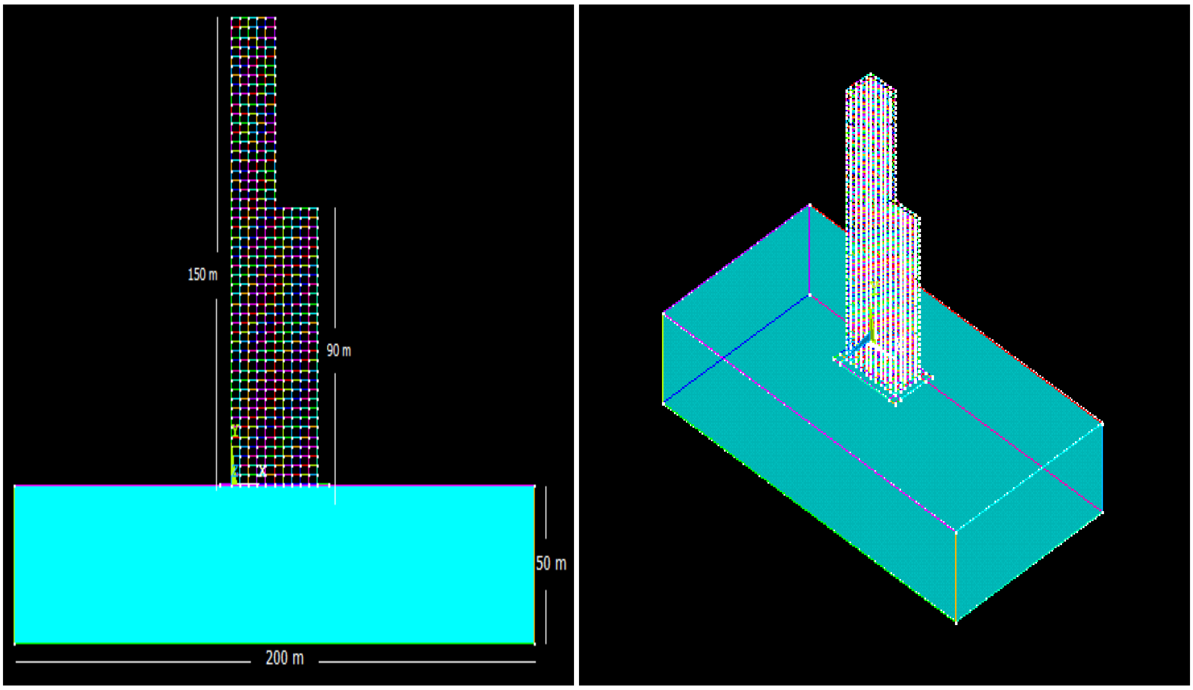


Fig.1 Numerical model of soil , foundation system and building

Raft foundation system (Fig.2) with a dimension 50mx30m 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 (Fig.2) 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.

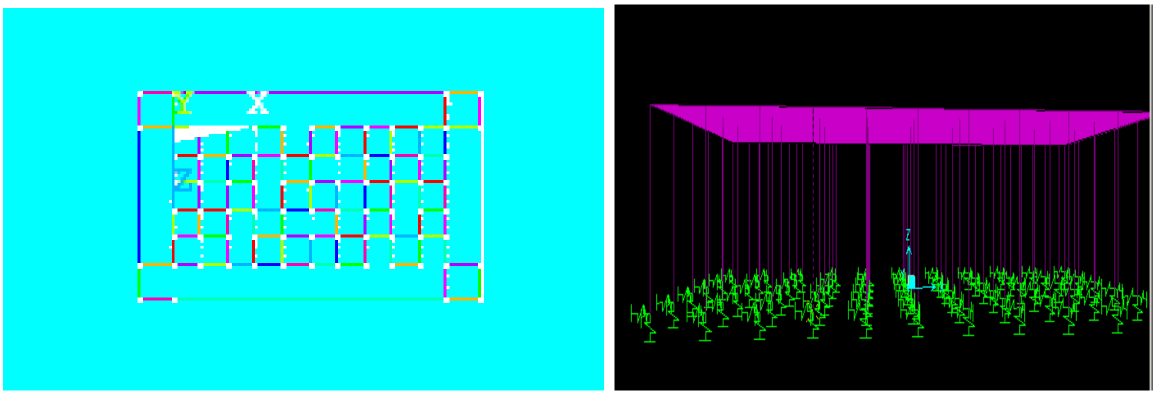


Fig.2 Raft and pile foundation system

3. 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 85 and Drucker–Prager material model is for nonlinear soil behaviour.

4. 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 Fig 3.a 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 (Fig. 3.b). The ground motion with PGA 0.31g (Fig 3.c) is given to the model to find the displacements and stresses for the soil strata .

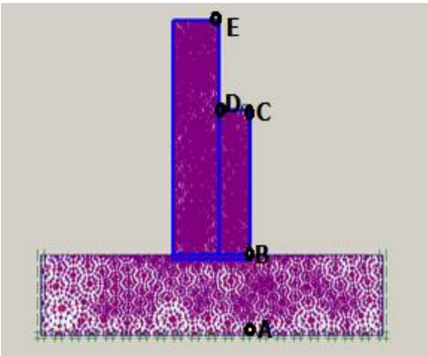


Fig 3.a Different points under considerations

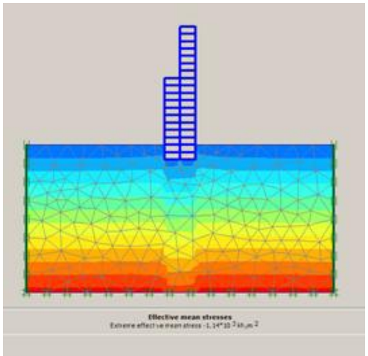


Fig 3.b Initial stress contours under static load (max. 200 kN /m^2)

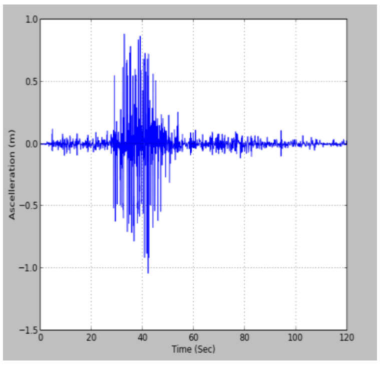
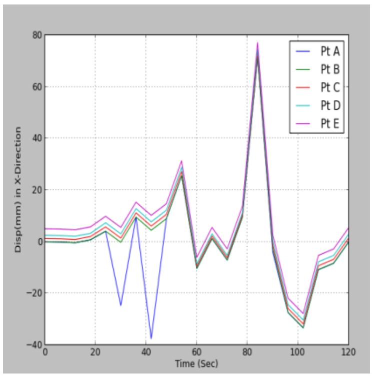
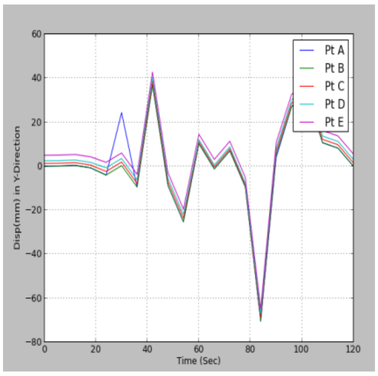


Fig 3.c Bhuj Ground Motion PGA 0.31g

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 .Fig 4 explains the displacement curves in x , y and z directions for raft foundation system.





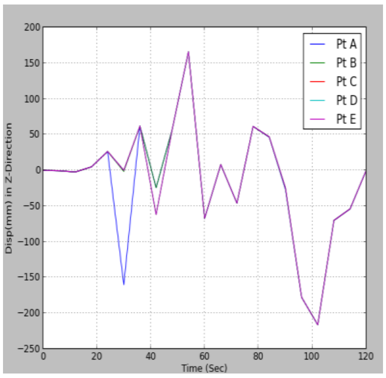


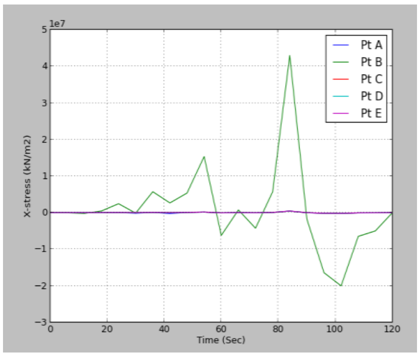
Fig 4.a. Fig 4.b. Fig 4.c.

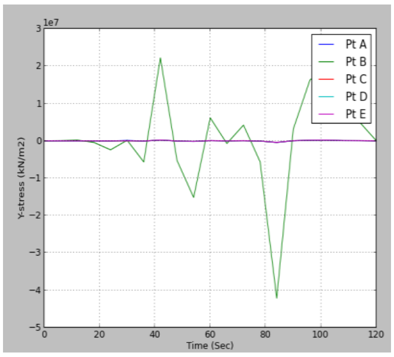
Fig 4. Displacements in x, y and z direction respectively for raft foundation

Table 1. Maximum displacements under dynamic load conditions for raft foundation system

Location Points	Maximum Displacement in mm		
	X-Direction	Y-Direction	Z-Direction
A	71.39833	37.10032956	165.9204
B	71.69894	37.10032956	165.9537
C	73.19575	38.73488956	165.987
D	74.69492	40.36944956	165.987
E	77.19852	42.86944956	165.987

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.2 and stress plots in Fig 5.





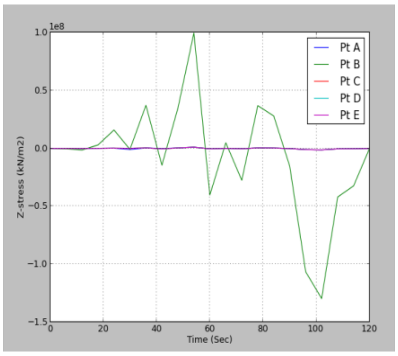


Fig 5.a. Fig 5.b. Fig 5.c.

Fig 5. Stresses in x, y and z direction respectively after giving ground motions to the soil mass .

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

Location Points	Maximum Stresses in kN/m2		
	X-Direction	Y-Direction	Z-Direction
A	428.3935	222.601	995.52
B	43019.30	22260.197	99572.22
C	439.1935	232.4093	995.922
D	448.1935	242.216	995.922
E	463.1935	257.216	995.922

Table 3. Maximum Displacements under dynamic load conditions for pile foundation system

Location Points	Maximum Displacement in mm		
	X-Direction	Y-Direction	Z-Direction
A	69.97036	35.91312	162.1042
B	70.12156	35.98732	161.9708
C	71.43905	37.37917	161.5054
D	73.12633	39.36021	161.3394
E	75.26856	41.92632	162.3353

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

Location Points	Maximum Stresses in kN/m2		
	X-Direction	Y-Direction	Z-Direction
A	427.9651	219.9298	982.5782
B	42933.26	21970.81	98437.1
C	433.0448	228.9232	978.9913
D	438.7814	239.5516	977.9954
E	456.2456	254.1294	983.9709

SUMMARY AND 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 has been observed 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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