COMPARISON OF SYMETRIC BUILDING WITH FIXED BASE AND FLEXIBLE BASE CONTINUUM MODEL IN SAP 2000 V.19.2.1

DEEPA S*, I.R.MITHANTHAYA**, S.V.VENKATESH ***

** Sr.Grade Lecturer, Department of Civil Engineering, Government Polytechnic, Udupi, India.*
***Vice Principal &Dean (Academic), NMAMIT, Nitte Institute of Technology, Udupi, India.*
**** Professor and Chairperson, PES University, Bangalore, Karnataka, India.*

ABSTRACT

Conventional building plan chosen are regular or symmetrical building with fixed base. Practically speaking the building rests on soil. There is negligence in considering flexible soil conditions and also nonlinearity while performing analysis Moreover the building to be analyzed considering soil structure interaction and nonlinear analysis needs appropriate software as the model should be a replica of realistic structure. In the present study a 10 storey, 3D building is modelled using SAP 2000 V19.2.1 software. Two models is selected one with fixed base and other with flexible soil base and both models are subjected to linear static analysis and Non linear pushover analysis. The results obtained are compared for fixed and flexible base for both linear and nonlinear analysis. The variation in displacement, base force and time period are observed and shows that symmetric building or regular building with fixed base analyzed by nonlinear analysis is found to be realistic and hope full to provide economically better design in future.

***Keywords**: Soil structure interaction, Fixed base, Nonlinear Pushover analysis.*

INTRODUCTION

Prior analytical study was performed with fixed base and the results obtained were adopted for design of beams and columns. The model adopted to perform the analysis was unrealistic as it rests on fixed base. As we know that the building rests on 3D soil base and is not considered in most of the analysis. In the present study soil structure interaction is taken into account where the soil is idealized by continuum method. Here the soil is continued below the building to a certain depth and continues along width and length of the building.

“Usually structural systems transfer the load through a series of elements to the ground. Each connection is designed so that it can transfer, or support, a specific type of load or loading condition. In order to analyze a structure, it is first necessary to be clear about the forces that can be resisted, and transferred, at each level of support throughout the structure. The actual behavior of a support or connection can be quite complicated so much, that if all of the various conditions were considered, the design of each support would be a terribly lengthy process. The conditions at each of the supports influence the behavior of the elements which make up each structural system.

No matter the material, the connection must be designed to have a specific rigidity. Rigid, stiff or fixed connections lie at one extreme limit of this spectrum and hinged or pinned connections lie to the other. The stiff connection maintains the relative angle between the connected members while the hinged connection allows a relative rotation.

The type of support connection determines the type of load that the support can resist. The support type also has a great effect on the load bearing capacity of each element, and also the system.

Roller supports are free to rotate and translate along the surface upon which the roller rests. The surface can be horizontal, vertical, or sloped at any angle. A roller support cannot provide resistance to a lateral force. Since most structures are subjected to lateral loads it follows that a building must have other types of support in addition to roller support. A pinned support can resist both vertical and horizontal forces but not moment. They will allow the structural member to rotate, but not to translate in any direction. Many connections are assumed to be pinned connections even though they might resist a small amount of moment in reality. A pinned connection allows rotation in only one direction, providing resistance to rotation in any other direction. A single pinned connection is usually not sufficient to make a structure stable. Another support must be provided at some point to prevent rotation of the structure. The pinned support includes both horizontal and vertical forces. In contrast to roller supports, a designer can often utilize pinned connections in a structural system.

Fixed supports can resist vertical and horizontal forces as well as a moment. Since they restrain both rotation and translation, they are also known as rigid supports. This means that a structure only needs one fixed support in order to be stable. All three equations of equilibrium can be satisfied. Fixed connections demand greater attention during construction and are often the source of building failures."

In the present study we have used pinned and fixed connections for a 3D-elastic half-space discretized model using FE as solid elements. The flexibility of soil is modeled by Continuum method where soil is considered as isotropic, homogenous elastic half space (3D) for which dynamic shear modulus and Poisson's ratio are the inputs. The finite element idealization of continuum model is carried out using eight nodded element (SOLID) having three degrees of freedom of translation 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 it is necessary to consider pressure Isobars based on the Boussinesq equation (Bowles 1988). According to 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 in respect to above considerations of size of soil medium were carried out.The region of soil below and around the foundation were fixed to realistically represent continuum model. Finally region of soil thickness of 2.5 times the least width below and around the foundation was considered to represent the continuum model. During analysis, bottom boundary is fixed while lateral translation is arrested at vertical boundaries of the soil medium.

"The soil region is fixed by Stress Isobar or Pressure bulb or Stress contour. It is a line which connects all points below the ground surface at which the vertical pressure is same. Pressure at points inside the bulb is greater than that at a point on the surface of the bulb and pressures at points outside the bulb are smaller than that value. Any number of stress isobars can be drawn for any applied load. A system of isobars indicates the decrease in stress intensity from the inner to outer ones. Stresses in soil from surface loads displacement solutions from elastic theory can be used at relatively low stress levels. This requires knowledge of the value of Young's modulus (E) and Poisson's ratio (ν) for the soil, either for un-drained conditions or in terms of effective stress. It should be noted that the shear modulus (G), is independent of the drainage conditions, assuming that the soil is isotropic. The volumetric strain of an element of linear elastic material under three principal stresses is given by expression applied to soils over the initial part of the stress strain curve, for un-drained conditions $\Delta V/V = 0$, hence $\nu = 0.5$ ($E = 3G$) for drained or partially drained conditions $\Delta V/V > 0$ and $\nu < 0.5$.

Stresses in soil from surface loads: The stresses within a semi-infinite, homogeneous, isotropic mass, with a linear stress-strain relationship, due to a point load on the surface, were found by Boussinesq in 1885. The stresses due to surface loads distributed over a particular area can be obtained by integration from the point load solutions. The stresses at a point due to more than one surface load are obtained by superposition. In practice, loads are not usually applied directly on the surface but the results for surface loading can be applied conservatively in problems considering loads at a shallow depth.

Foundation stiffness and damping: Inertia developed in a vibrating structure gives rise to base shear, moment, and torsion. These forces generate displacements and rotations at the soil-foundation interface. Displacements and rotations are only possible because of flexibility in the soil-foundation system, which significantly contributes to overall structural flexibility (and increases the building period). Moreover, these displacements give rise to energy dissipation via radiation damping and hysteretic soil damping, which can affect overall system damping. Since these effects are rooted in structural inertia, they are referred to as inertial interaction effects."

METHODOLOGY

Selecting a Model

A 3D model of 25x25m plan and 30m height is selected which satisfies the condition of equilibrium check both manually as well as in SAP 2000. The raft foundation is modeled at the base of the 3D building. The area element is of 27x27m with 0.75m thickness. The footing is divided as finite elements of size 1.0mx1.0m and is linked to the building by providing links at base of building and top of footing. Below the footing a 3D soil layer is modeled as solid element for a depth of 20m width 12.5m on either sides, length as 12.5m on either side (as per bossiniques equation).The entire soil model chosen is 50x50x20m. The solid element for top 5m is divided as finite elements of size 0.5mx0.5m. The bottom 15m is divided as finite element of size 1mx1m. The soil properties such as shear modulus and poisons ratio is assigned to the solid based on the type of soil. In the present case the soil used is soft soil. The 3D soil is connected to the footing by providing a link. The sides of soil is assigned pinned support allowing translation in horizontal and vertical direction and the bottom of the soil is at a depth of 20m at base and is provided with fixed base.

The details f the model is shown below :

Fig.1 shows the Plan of continuum model. Fig.2 and Fig.3 shows Elevation of continuum model whereas Fig.4 shows Elevation of Fixed base model.

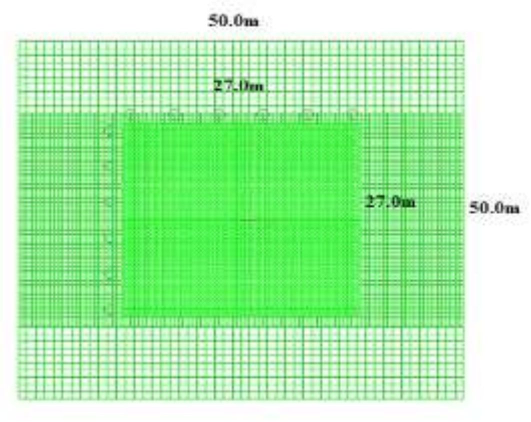

Figure 1: Plan of Continuum model

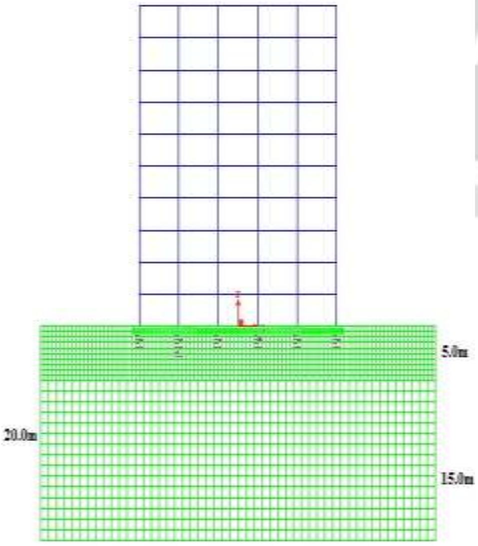

Figure 2: Elevation of Continuum model

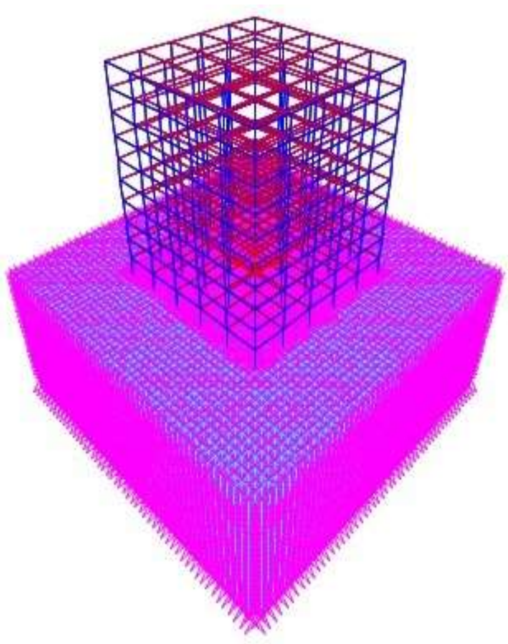

Figure 3: Elevation of 3D Continuum model

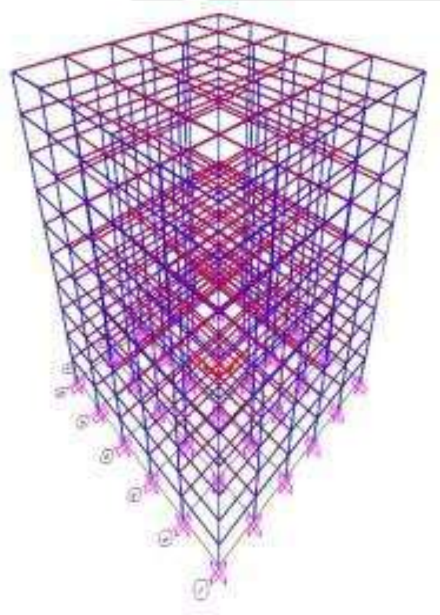

Figure 4: Elevation of 3D Fixed base model

PARAMETERS CHOSEN TO MODEL

Parameters for soil

The parameters selected for modeling the soil is shear modulus and poisons ratio which is calculated as per standards ASCE41-13. The detail of the parameters chosen is given in Table 1.1 and Table 1.2

Table 1:1 Parameters of shear modulus

Description	*Symbol*	*Units*
Site Class (Very dense and soft rock)	C	
Average Shear wave velocity	Vs	m/sec
Density of soil	ɣ	kN/m^3
Specific gravity due to acceleration	g	m/sec^2
Shear Modulus	G	kN/m^2
Effective Shear Modulus(As per Table No:10.4 of	G/Go	
Poisons ratio	µ	
Initial Shear Modulus	Go = (γ x Vs2) /g	kN/m^2
Young's Modulus or Elastic modulus	Es = G*2(1+ µ)	kN/m^2
Density of soil	ɣ	kN/m^3
Specific gravity due to acceleration	g	m/sec^2
Shear Modulus	G	kN/m^2

Table 1:2 Parameters of soil

Soil type	*Effective Shear modulus 'G' kN/m^2*	*Elastic modulus 'Es ' kN/m^2*	*Poisson's ratio 'µ'*
Soft soil	1182.000	3310.000	0.400

ANALYSIS PERFORMED

The analysis is performed on 3D, 10 storey building using SAP200 V 19.2.1 software. The software adopted satisfies the conditions for both soil structure interaction as well as nonlinear analysis.

The two models considered are regular building with fixed base and regular building resting on 3D soil flexible base (continuum model).

Both the models are subjected to linear static analysis and nonlinear static pushover analysis.

The continuum model is modeled based on pressure isobar and bossiniques equation whereas the nonlinear model is modeled by assigning nonlinear parameters to beams and columns as per ASCE 41-13standards. (PM_2M_3 hinges for column and M_3 hinges for beam are assigned.)

RESULTS OBTAINED

The results are obtained for the maximum displacement, maximum base force and Time period which are displayed in Table 1.3.

Table 1:3 Results in case of Soft soil

Analysis type	*Base condition*	*Max. Displacement in 'm'*	*Maximum Base Force in 'k N'*	*Max. Time Period in 'sec'*
Linear static RSM	Fixed	0.122	9183.24	1.516
	CM flexible	0.146	9729.17	1.662
Nonlinear	Fixed	0.187	22251.00	1.369
	CM flexible	0.333	13586.48	1.594

The Linear analysis performed in case of fixed base shows lesser displacement, base force and time period compared to flexible continuum model. This may be because the continuum soil model considers the soil base which is flexible. The soil properties incorporated increases the base force, displacement and time period.

Whereas the nonlinear analysis performed in case of fixed base shows lesser displacement, base force and time period compared to flexible continuum model. This may be because of symmetrical building or regular plan considered without soil base.

CONCLUSION

Observing the results obtained it can be drawn to conclusion as below

- In case of linear analysis, lesser displacement is noticed in case of fixed base compared to flexible base. This may be because flexible soil base increases displacement.
- Max Base force is observed in continuum method compared to fixed base. The reason is because the base of the building is modeled as 3D with soil properties incorporated which increases the load carrying capacity of the building.
- Time period is maximum in continuum method. This is because of flexible soil base which increases the time period.
- In case of nonlinear analysis the results show lesser displacement, greater base force and lesser time period in fixed base compared to flexible base. This may be because pushover analysis considers only the building results irrespective of the soil condition. The symmetrical condition of the building may also be the reason for this.
- Also the continuum method shows greater time period with greater displacement and lesser base force. The increase in displacement and time period is mainly due to soil base.

Overall observation shows that it is necessary to consider 3D soil condition along with nonlinear analysis to check the performance of the building. However, it is noticed that nonlinear analysis in case of regular symmetrical building shows better results with fixed base compared to flexible base. The results also indicate that it is necessary to perform analysis on irregular building with fixed base to study the changes in behavior of the building when subjected to nonlinear analysis.

This study indicates that there is scope for further study on irregular building with flexible soil conditions and nonlinear analysis.

REFERENCES

[1] Halkude S.A, Kalyan shetti M.G and Kadlag V. A, " Pushover Analysis of R.C frames considering soil structure interaction", International Journal of Current Engineering and Technology, E-ISSN 2277- 4106, P-ISSN 2347- 5161, 01 Feb 2015, Vol.5, No.1 (Feb 2015)

[2] Amar.R.Chougule, SS Dyavanal, " Seismic soil structure interaction of buildings with rigid and flexible foundation", International journal of Science and Research , ISSN , Vol.4, Issue 6, June 2015

[3] Nithya Chandran, Abhilash Rajan, Soni Syed, "Seismic Analysis of Building with underground stories considering soil structure interaction", International Journal of Emerging Technology and Advanced Engineering, ISO9001:2008 certified Journal, Vol4, Issue11, and Nov2014

[4] Ayman Ismail, "Effect of Soil Flexibility on Seismic Performance of 3-D Frames", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE Volume 11, Issue 4 Ver. II (Jul- Aug. 2014), PP 135-143

[5] Vimal Chaudhary, K. S. Babu Narayan, "Probabilistic risk evaluation of RC building comparison of modelling approaches", International Journal of Advanced Structures and Geotechnical Engineering, Vol. 03, No. 03, July 2014, PP 272-282

[6] Neena Hede(Panandikar), Dr.K.S.Babu Narayan, "Stochastic analysis for assessment of Sensitivity of pushover curve to design parameters", International Journal of Innovations in Engineering and Technology (IJIET), Vol. 3, Issue 4 ,April 2014, PP 74-83

[7] Ramesh Baragani , Dr.S.S.Dyavanal , "Nonlinear static analysis of multi-storey RC building considering SSI", International journal of advance research in science and engineering, IJARSE, Vol.no.3,Issue No. 7, July 2014