Building with Underground Storey with Variations in Soil Subgrade Modulus

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***Abstract* - This paper studies the seismic behavior of reinforced concrete buildings with multiple underground stories. While current researches mainly aims at understanding the effects of variation in soil subgrade modulus, this study has the ultimate goal of finding appropriate recommendations concerning the inclusion of underground stories in the model for seismic analysis. To achieve this objective, the methodology involves the computer modelling by two alternate approaches, namely, building frame with fixed supports, building frame with supports accounting for soil-flexibility using STAAD.Pro. A comparison of the displacements of the frame and time period of the whole structure is done.**

***Keyword* - Soil subgrade modulus, Winkler Hypothesis, STAAD.Pro, Frame structure with basement floor.**

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1. INTRODUCTION

Today, underground basements are an important component of new urban building construction. Conventionally, it has been considered that basement floors are safe inside the soil and do not oscillate during earthquake. Hence, basement floors are neglected during seismic analysis of building with underground stories. A controversial issue in the seismic analysis and design of buildings with multiple underground stories lies in incorporating the effects of these underground stories on the seismic response of these structures. [1]

A sensitivity analysis is conducted by modelling the structure using the software SAP2000 (CSI, 2007) with the following varying parameters:

- Number of above ground stories [2]
- Number of underground stories [2]
- Subsurface soil conditions [2]

The parameter varied for the study is the modulus of subgrade reaction of the soil. The footings of the space frame are modeled as plate elements and discretized into smaller rectangular plate element. Based on Winkler's hypothesis, the soil beneath the footing is modeled as bed of linear springs having stiffness equal to the modulus of subgrade reaction of the soil. The interactive analyses are carried out for 3 different values of modulus of subgrade reaction. A base-case where the buildings are modeled with a fixed condition at ground level is adopted, and then the number of basements is incrementally increased to investigate changes in performance.

2. SOIL STRUCTURE INTERACTION MODELS

If the structure is supported on soft soil deposit, the inability of the foundation to conform to the deformations of the free field motion would cause the motion of the base of the structure to deviate from the free field motion. Also 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 known as Soil Structure Interaction. [3]

According to the seismic improvement of current structure provision, the members of Structure and foundation must be modelled together in unified model to consider soil structure interaction. In this study two orthogonal springs, a vertical spring and three Rotational springs were used in main direction of structures to simulate soil structure Interaction. [4]

3. FEMA-356 SPRING MODEL

The vertical, horizontal, and rotational elastic stiffness of the footings are calculated using the frequency independent formulas given in the FEMA 356 report. A set of 6 spring constants

Corresponding to the six degrees of freedom are calculated as a function of the footing dimensions and assigned to the model node of the respective footing. [2]

4. CONVENTIONALLY FIXED BASED MODEL

Fixed base analysis has been carried out on a regular multistory frame in the present study as shown in figure 2. Different combinations of dead load, imposed load and seismic load as per the relevant code provisions have been considered and the critical values of stresses and displacements are evaluated. The analytical models of the frame include all components that influence the mass, strength, stiffness and deformability of structure. [1]

5. WINKLER MODEL

Effect of SSI is considered by Winkler model. It is also the oldest and simplest method to model the subgrade. Winkler's idealization represents the soil medium as a system of identical but mutually independent, closely spaced, discrete, linearly elastic springs. The merit of this model is that it uses only one parameter (the modulus of sub-grade reaction, better known as the "k" parameter) to represent the soil. The load deflection equation for this case can be written as:

Load = Modulus of sub grade reaction × displacement [1]

6. METHODOLOGY

Frames with G+8 with 1, 2 and 3 underground storey have been considered in the study. Fundamental period of vibration of the frame with fixed support using codal formula in IS 1893(Part I):2002 and model analysis has been evaluated. In order to understand the effect of soil structure interaction on fundamental period of vibration soil has been modelled as winkler spring and FEMA spring and Fixed model using STAAD.Pro. [5]

7. DESCRIPTION OF THE BUILDING

A 2x2 bays with G+8 with 1, 2 and 3 underground storey R.C. Frame building is considered for the present study to investigate SSI effects on buildings. The plan dimension of the building is 20.0 m by 20.0 m and the height of the building is 33 m, 36 m, and 39 m from the ground level for G+8 with 1, 2 and 3 underground storey building respectively.

Table 1: Building Details

Component	Description	Data
Frame	No. of Storey	G+8 with 1, 2 and 3 UG storey
	No. of bays in X and Z direction	2 x 2 bays
	Storey height	3m
	Bay width in X and Z direction	10m x 10m
	Size of beam	300mm x 450mm
	Size of column	750mm x 750mm
	Thickness of slab	125mm
Foundation	Soil Bearing Capacity	110 kN/m^2
		180 kN/m^2
		250 kN/m^2
	Poissons Ratio of Concrete	0.5

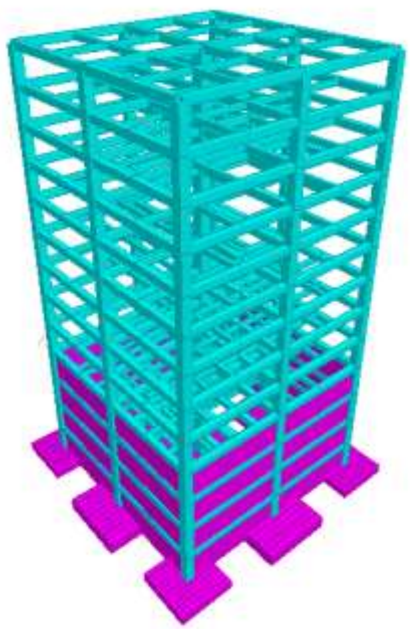

Fig.1 Winkler Model

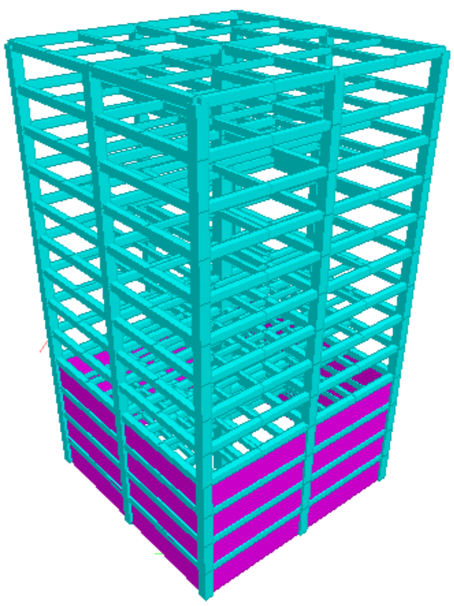

Fig.2 Fixed Based Model

8. RESULTS

Table 2: Result of Maximum Nodal Displacement

Model	SBC (kN/m^2)	Soil Subgrade Modulus (kN/m^3)	FIXED Model mm	FEMA-356 Spring Model mm	WINKLER Spring Model mm
G+8,-1	110	2750	53.927	87.415	107.279
	180	4500	53.927	73.119	80.603
	250	6250	53.927	72.797	77.187

G+8,-2	110	2750	52.707	85.635	106.308
	180	4500	52.707	69.724	78.305
	250	6250	52.707	69.69	74.623
G+8,-3	110	2750	50.591	93.051	112.32
	180	4500	50.591	62.111	69.712
	250	6250	50.591	62.11	65.76

Table 3: Result of Time Period

Model	**SBC (kN/m^2)**	**Soil Subgrade Modulus (kN/m^3)**	**FIXED Model mm**	**FEMA-356 Spring Model mm**	**WINKLER Spring Model mm**
G+8,-1	110	2750	1.924	2.179	2.158
	180	4500	1.924	2.159	2.163
	250	6250	1.924	2.108	2.166
G+8,-2	110	2750	1.935	2.249	2.205
	180	4500	1.935	2.226	2.208
	250	6250	1.935	2.173	2.208
G+8,-3	110	2750	1.954	2.327	2.264
	180	4500	1.954	2.298	2.264
	250	6250	1.954	2.242	2.28

9. CONCLUSIONS

FEMA spring model gives higher time period compared to Fixed based model and Winkler model when soil subgrade modulus is 2750 kN/m^3 and then winkler model gives higher value when soil subgrade modulus is 4500 kN/m^3 and 6250 kN/m^3. Winkler model gives higher value of maximum nodal displacement compared to other to models. Also says that with increasing number of storey variation in soil subgrade modulus effects is reduce. Soil subgrade modulus effects is more on softer soil and plays a significant role in increasing the storey shear and moment demand for relatively low rise building. Soil subgrade modulus effect depend on the stiffness of the foundation and the number of underground storey.

REFERENCES

[1] Nithya Chandran J, Abhilash Rajan, Soni Syed, “Seismic Analysis of Building with Underground Stories Considering Soil Structure Interaction.” International Journal of Emerging Technology and Advanced Engineering Volume 4, Issue 11, November 2014

[2] G. Saad, F. Saddik & S. Najjar, “Impact of Soil Structure Interaction on the Seismic Design of Reinforced Concrete Buildings with Underground Stories.” American University of Beirut, Lebanon 2012

[3] Tuladhar, R., Maki, T., Mutsuyoshi, H. “Cyclic behavior of laterally loaded concrete piles embedded into cohesive soil, Earthquake Engineering & Structural Dynamics” Vol. 37 (1), pp. 43-59,2008

[4] Jinu Mary Mathew, Cinitha A, Umesha P K, Nagesh R Iyer and Eapen Sakaria3, “Seismic Response of Rc Building by Considering Soil Structure Interaction.” ISSN 2319-6009, Vol. 3, IJSCER, 2014

[5] Shiji P.V, Suresh S., Glory Joseph, “Effect of Soil Structure Interaction in Seismic Loads of Framed Structure.” International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013