

Seismic analysis of RC building having underground stories with vertical Irregularities

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Abstract — Now days, population increases day by day and due to that it is necessary to construct multi-storey building. Underground storey (basements) are an important component of urban building construction. To study the behavior of this type of building under seismic loading is main objective of this analysis. When we are considering underground stores it is necessary to consider Soil-Structure Interaction effect. The dynamic interrelationship between the response of the structure is influenced by the motion of the soil and the soil response is influenced by the motion of structure is called a soil structure interaction. Here, we are considering Soil-structure Interaction effect on building with vertical irregularities. G+14 storey building is selected for modeling and analysis. Response spectrum and Time History Analysis is done in SAP2000. Response spectrum analysis and Time History Analysis is carried out according to IS 1893:2002 and acceleration data of past earthquake respectively.

Keywords- Soil Structure Interaction, Underground Stories, Raft foundation, Spring Stiffness, Spring Constant.

I. INTRODUCTION

Today, underground basements are an important component of new urban building construction. 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. Building codes lack recommendations concerning this controversy; thus, the designers are basing their analysis on approximations, engineering judgment and experience.^[15]

II. DEFINITION

Soil structure interaction (SSI): 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 termed as SSI. In this case neither the structural displacements nor the ground displacements are independent from each other.

Raft foundations: It is large concrete slab which can support a number of columns and walls. The slab is spread out under the entire building or at least a large part of it which lowers the contact pressure compared to the traditionally used strip or trench footings.

III. LITERATURE REVIEW

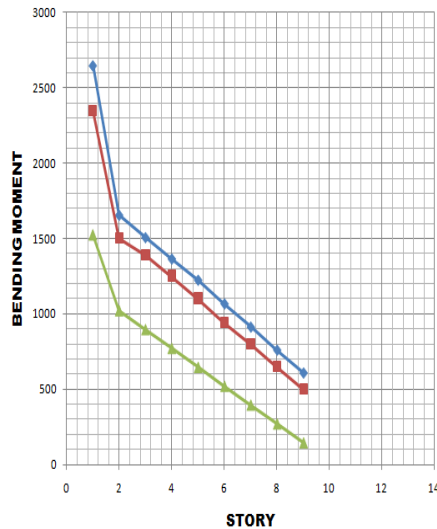
Nithya Chandran J, Abhilash Rajan(2014)^[1] They have studied Seismic Analysis of Building with Underground Stories Considering Soil Structure Interaction. In this building frame were modeled in three ways viz. Fixed base model, Elastic solid model and Winkler model and was idealized as 3D space frames using SAP 2000. The data that used in this research is hypothetical data. The Geometric Properties of Building Frame data is given below

Table: 1 Geometric Properties of Building Frame and Foundation

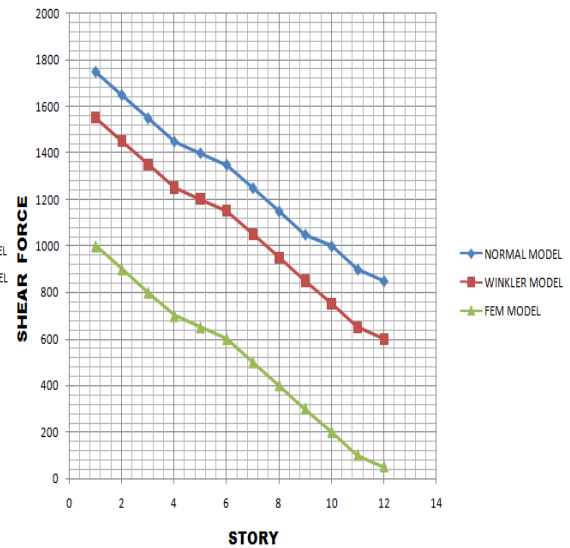
Component	Description	Data
Frames	No: of storeys	12
	No: of bays in X & Y direction	2
	Storey Height	3.2m
	Bay width in X & Y direction	10m
	Size of Beam	0.3mx0.4m
	Size of Column	0.3mx0.45m
	Thickness of Slab	0.125m
Foundation	Raft Footing	14m×14m ;1m depth
	Elastic Modulus of Concrete	2.5 kN /m ²
	Poissons Ratio of Concrete	0.2

The present study is focused on SSI analysis of symmetrical space frame of 2 bay in both x and y direction, 2 storey (2X2X2), 2 bays in both direction, 5 storey (2X2X5) and 2 bay in both direction, 8 storey (2X2X8) resting on raft foundation with fixed base and flexible base. Three types of soil i.e. Hard, Medium Hard and Soft Soil are used for the SSI study.

• Result



**Chart.1: Variation Of Bending Moment
For Different Models**



**Chart 2 : Variation Of Shear Force For
Different Models**

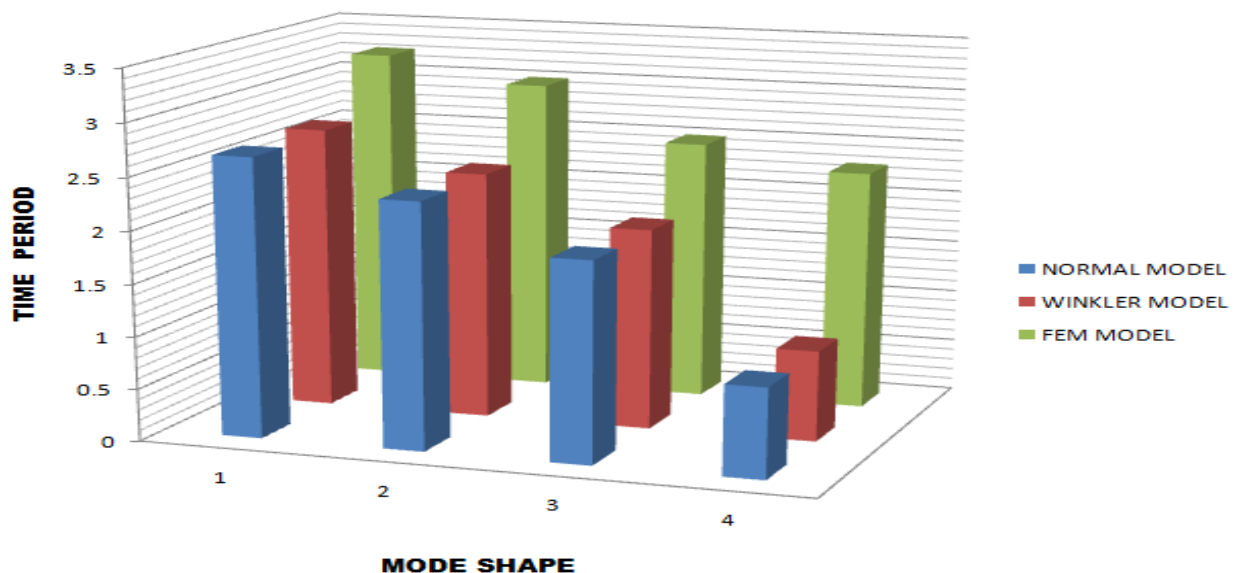


Chart 3: Variation Of Time Period

- CONCLUSION OF LITERATURE:** The effect of basement walls and soil structure interaction on the structural behavior of a building during an earthquake. Variation in dynamic properties such as natural time period, roof displacement, base shear and bending moment are observed. The analysis results shows that, basement walls and soil structure interaction shows significant changes in the response of building during an earthquake which is not addressed by IS1893 explicitly. Elastic continuum approach (FEM model) is found to be more effective than Winkler approach (Spring Model) as it considers elastic continuum below foundation which assists to get realistic behavior of structure.

C. Navarro (1992)^[2] In this paper a large structure of reinforced concrete of box shape and totally embedded in soil, is analyzed. The dynamic pressure acting on roof, wall and floor due to body and surface waves are considered in the analysis. A set of seismic load combination for the different polarization planes of the seismic waves are proposed.

Sang-Hyeok Nam, Ha-Won Song, Keun-JooByun, Koichi Maekawa (2006)^[3] Since underground reinforced concrete (RC) structures interact with the surrounding soil medium, the behavior of the interfacial zone between the RC structure and the surrounding medium of the underground RC structure should be considered for accurate seismic analysis. In this paper, an averaged constitutive model of concrete and reinforcing bars for the RC structure and the path-dependent Ohsaki'' model for the soil are applied, and an elasto-plastic interface model which considers the thickness of the interface is proposed for seismic analysis of underground RC structures. A finite element analysis program is developed and verified by predicting both static and dynamic behaviors of underground RC structures. Then, the effects of the interface on the behavior of underground RC structures are analyzed. The effect of stiffness of the RC structure due to different reinforcement ratios of underground RC box structures to the behavior of the structures is also analyzed. Finally, failure mechanisms of underground RC structure under seismic action are simulated through seismic analysis of an underground RC station structure.

G. Saad, f. Saddik& s. Najjar (2012)^[4] This paper studies the seismic behaviour of reinforced concrete buildings with multiple underground stories. It seeks to provide recommendations on the number or percentage of underground stories to be accounted for in the analysis of reinforced concrete shear wall buildings. A base-case where the buildings are modelled with a fixed condition at ground level is adopted, and then the number of basements is incrementally increased to investigate changes in performance. The beirut local site conditions are used for the analysis. The base shear, inter-story shears and moments are evaluated in order to quantify the effects of soil structure interaction on the design process.

Vasanth Acharya, Akshaya, Shivananda S.M, H L Suresh (2014) The paper evaluates the performance of framed buildings under future expected earthquakes, a non-linear static pushover analysis has been conducted on a typical multi-storey car parking structure. To achieve this objective, a 3D framed multi storey car parking structure (G+3) is modelled in SAP 2000 in which the structure is open in all stories with rigid floors. The effect of strength irregularities in the present multi-storey car parking structure of R/C frames on the seismic performance using nonlinear static push-over analysis based on computational models is done. From output non-linear analysis, we compare the Base shear and Displacement occurs in different strength irregularities for the different load combinations in seismic zone IV..

Chaitanya Patel, Noopur Shah (2016)^[5] This paper studies the seismic behaviour 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.

Halkude S.A, Kalyanshetti M.G. and Barelikar S.M.(2014)^[6] This paper studies to describe and investigate different approaches of considering soil flexibility in the soil structure interaction analysis (SSI) with regard to the response in the superstructure. Three types of soil i.e. Hard, Medium Hard and Soft Soil are used for the SSI study. Dynamic analysis is carried out using the Response Spectra of IS: 1893-2002. Natural Period, Roof Displacement, Base Shear, Beam Moment and Column Moment are observed to be increasing more in case of Elastic continuum approach (FEM model) as comparative to Winkler approach (Spring Model). It is possible to incorporate variation in the soil properties, layered soil and boundary conditions in Elastic continuum approach (FEM model). Elastic continuum approach (FEM model) is more effective than Winkler approach (Spring Model) as it considers elastic continuum below foundation which assists to get realistic behaviour of structure.

H. El Ganainy, M.H. El Naggar(2009)^[7] This paper investigates the seismic performance of moment-resisting frame steel buildings with multiple underground stories resting on shallow foundations. A parametric study that involved evaluating the nonlinear seismic response of five, ten and fifteen story moment-resisting frame steel buildings resting on flexible ground surface, and buildings having one, three and five underground stories was performed. The deformations of the structural components of the buildings have also been affected by thesis. The deformations of buildings with flexible bases have shown a considerable increase that ranged from 50% to about 300%comparedtothefixedbase case for buildings founded on soil classes. This would in turn

increase the lateral deflection of the whole building. Thus, it can have a detrimental effect on the performance of buildings.

Dr. S.S. Patil, Mr. M. G. Kalyanshetti, Ms. Dyawarkonda S. S.(2016)^[8] This paper studies soil structure interaction makes a structure more flexible and thus, increasing the natural time period of the structure compared to the corresponding rigidly supported structure. Interaction effect is ignored to simplify the mathematical model but neglecting the interaction between soils and structures may result in a design that is either unnecessarily costly or unsafe. The SSI analysis is done by the Raft foundation and providing spring of equivalent stiffness (Discrete Support) to the raft foundation. Seismic response buildings considering SSI exhibit variation based on frequency content of motion and stiffness of soil. The Base shear of the structure increases due to SSI effect. Increase in soil flexibility Natural time period is also increase. Natural time period is a primary parameter which regulates the seismic lateral response of the building frames. Thus evaluation of this parameter without considering SSI effect may cause major error in seismic design.

J.H. Wood(2005)^[9] This paper presents work undertaken to extend the present knowledge of the dynamic interaction of box-section structures with the surrounding soil, and a design method for predicting the earthquake loads on underground structures such as basement walls, tanks, subways, utility boxes, highway underpasses, and culverts. Large earthquake-induced forces in the culvert structure it has been indicate that earthquake racking effects need to be considered in the design of rectangular underground structures.

Navya N, Karuna shence (2016)^[10] The study of soil structure interaction on an RC framed building with underground stories under seismic loading. Structure is analyzed using response spectrum method. When the parameter displacement and inter-storey drift is considered, it is observed that the displacement and inter-storey drift is maximum for the soft soil and minimum for the hard soil. Magnitude of base shear is found minimum for the FEM model and maximum for the building resting on soft soil. It is observed that the time period is found to be maximum for the FEM model and maximum for the building which rests in soft soil.

IV CONCLUSION

- Variation of dynamic properties such as natural time period, Seismic coefficient of acceleration, base shear and bending moment are observed. This study does underscore that there is scope for rationalization in the IS code provisions.
- The Base shear of the structure increases due to SSI effect. For soft soil the effect is more as compared to hard soil. The percentage variations are lesser for low rise building and increases with increase in story height. The increase in soil flexibility and story height the Base Shear increase in higher rate.
- As the number of storey increases in the building the base shear and displacement are increases.
- FEM method is useful method for studying the effect of soil structure interaction.
- The stress-strain relationship is observed for the material used in the structural components of variation in strength and failure, strain is observed for confined and unconfined concrete.

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