Seismic Response of RC Frame Having Underground Stories with Vertical Irregularities

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Abstract—Due to increasing in population as well as less availability of land it is necessary to construct multi-storey building. Underground storeys (basements) are an important component of urban building construction for reducing parking problem. To study the behaviour of this type of building under seismic loading is main objective of this analysis. When we are considering underground storeys 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 modelling 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. The effect of SSI on various structural compound like time period ,base shear, roof displacement ,are studied and discussed.

Keyword— Raft footing, Soil-interaction, Sap2000, Response spectrum, Time history.

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]

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.

II. ANALYTICAL WORK

Response spectrum method (RSM) and time history method (THM) (bhuj time history) are used for the analysis of structure in Zone-III. A 17 storey (2 underground and G+14) building with different vertical irregularity is taken for this study. The behaviour of building is studied for different parameters like base shear, maximum displacement.

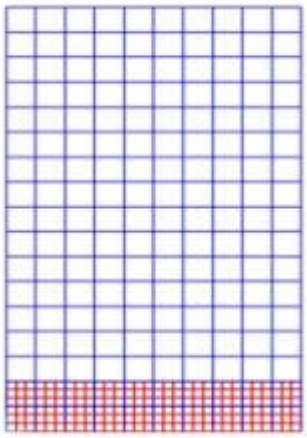
2.1. Structure data

Plan Area	30m X 40m
No of storey	G+14
Typical Storey Height	3 m
Beam Size	For 1st to 5thfloor 300mm X 300mm For 6st to 10th floor 300mmX380mm For 11st to 15th
Column Size	For 1st to 5thfloor 230mmX450mm For 6st to 10th floor 230mmX380mm For 11st to15th
Slab Thickness	150mm

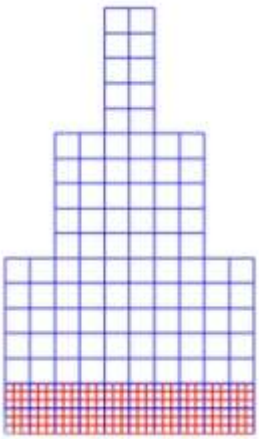
Wall Load	13.8 KN/m^2 (on external Beam)
	6.9 KN/m^2 (on Internal Beam)
Floor Finish	1 KN/m^2
Parapet Load	2.3 kN/m^2
Live Load	3 KN/m^2
Grade of Concrete	M25
Grade of Steel	Fe415
Height of Underground	6m
Depth of Raft Foundation	1m depth
Seismic zone	III
Soil type	Hard soil, Medium soil, Soft soil

2.2. Models

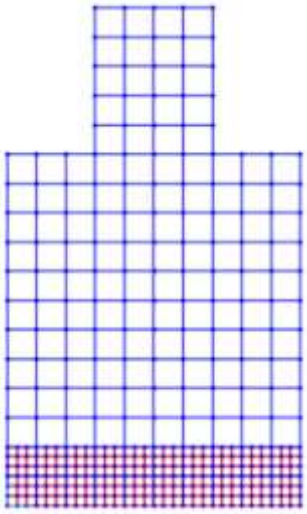
- Model-1



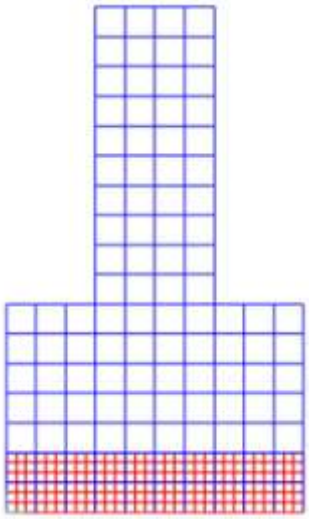
- Model-2



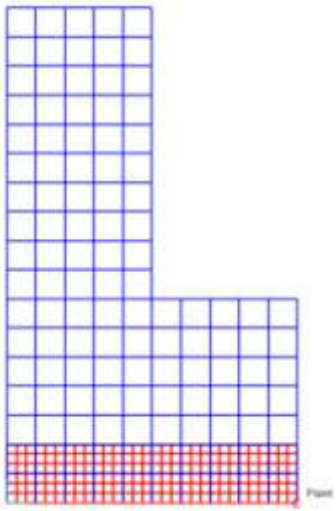
- Model-3



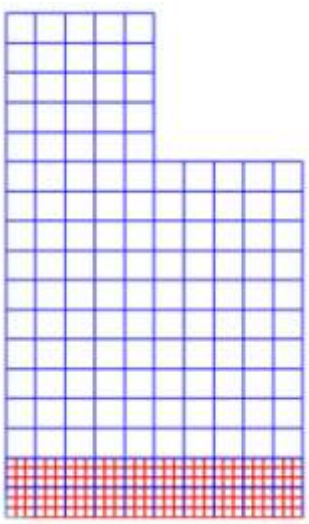
- Model-4



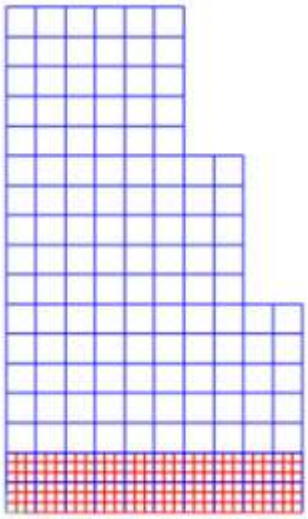
- Model-5



- Model-6



- Model-7



III. RESULT AND DISCUSSION

After completing modelling and analysis work, now it is a time to discuss about the result. Here, result about two different analysis procedures like Static analysis and dynamic analysis (response spectrum analysis and time history analysis) carried out Fix base model and soil structure interaction with vertical irregularity of RC frame structure for zone- III as per Indian Standard Code. In the present work significant change in the seismic parameters such as maximum top story displacement, base shear and modal time period are noticed.

3.1. Response spectrum method

- Base shear

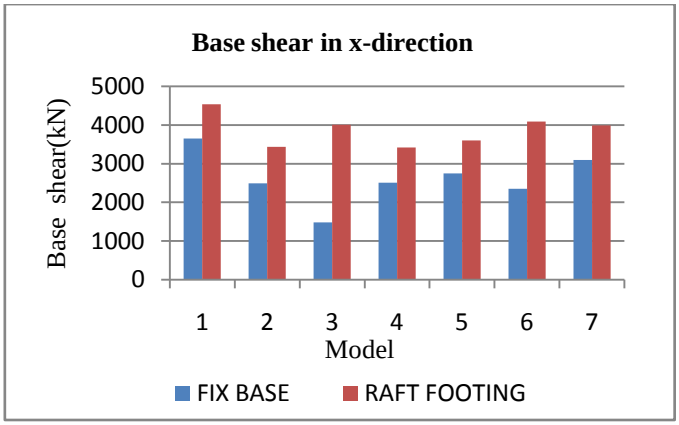


Chart 1: Base shear in x-direction

From above graph:

- In fix base, with respect to model-1 the percentage decrease of base shear are 31.64%, 59.35%, 31.17%, 24.74%, 35.48%, 15.16% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.
- In Raft footing, with respect to model-1 the percentage decrease of base shear are 24.35%, 11.81%, 24.71%, 20.60%, 9.84%, 12.18% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.

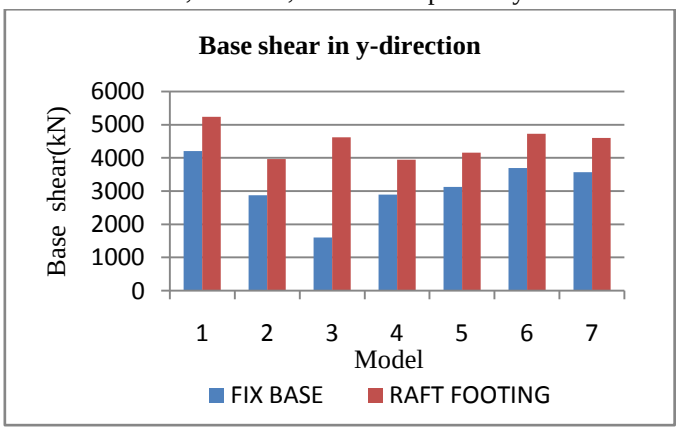


Chart 2: Base shear in y-direction

From above graph:

- In fix base, with respect to model-1 the percentage decrease of base shear are 31.64%, 59.35%, 31.17%, 24.74%, 35.48%, 15.16% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.
- In Raft footing, with respect to model-1 the percentage decrease of base shear are 24.35%, 11.81%, 24.71%, 20.60%, 9.84%, 12.18% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.

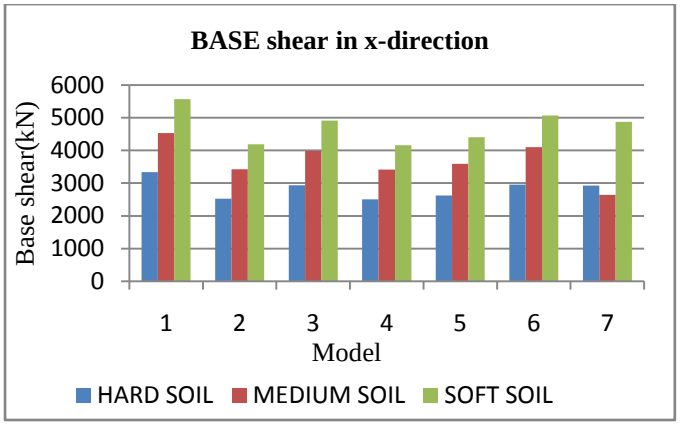


Chart 3: Base shear in x-direction in different soil

From above graph:

- With respect to model-1 the percentage decrease of base shear 24.35%, 11.81%, 24.71%, 20.60%, 9.84%, 12.18% are in model-2, model-3, model-4, model-5, model-6, model-7 in hard, medium and soft soil respectively.

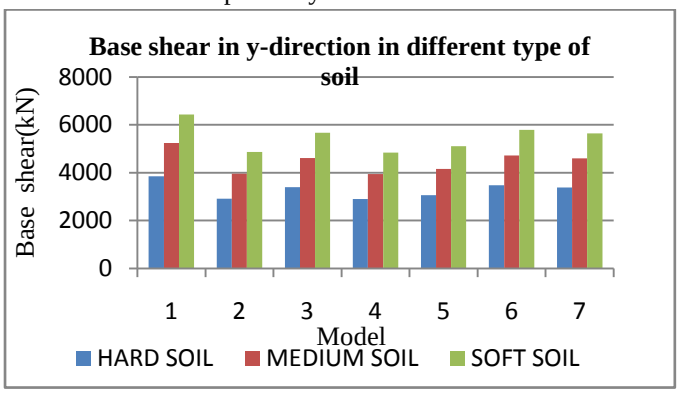


Chart 4: Base shear in y-direction in different soil

From above graph:

- With respect to model-1 the percentage decrease of base shear 24.35%, 11.81%, 24.71%, 20.60%, 9.84%, 12.18% are in model-2, model-3, model-4, model-5, model-6, model-7 in hard, medium and soft soil respectively.

- Roof displacement

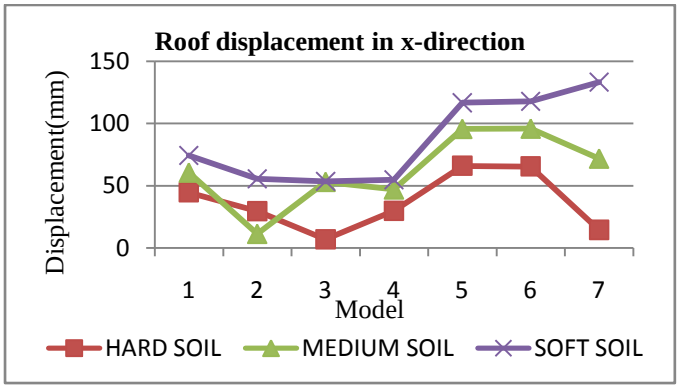


Chart 5: Roof displacement in x-direction

From above graph:

- With respect to hard soil the percentage increase in model-1 are 35.41%, 66.21% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-2 are 61.82%, 87.42% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-3 are 65.48%, 66.10% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-4 are 57.52%, 83.75% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-5 are 44.95%, 76.82% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-6 are 46.43%, 80.04% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increases in model-7 39.19%, 81.23% in medium soil and soft soil respectively.

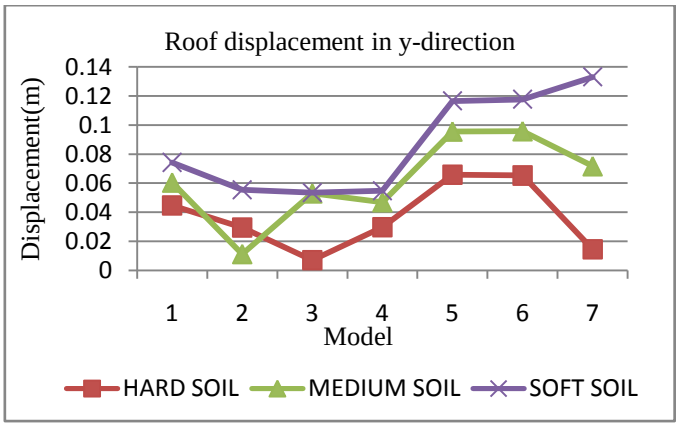


Chart 6: Roof displacement in y-direction

From above graph:

- With respect to hard soil the percentage increase in model-1 are 35.45%, 66.28% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-2 are 61.93%, 87.57% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-3 are 65.94%, 66.57% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-4 are 57.62%, 83.89% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-5 are 44.99%, 76.87% in medium soil and soft soil respectively.

- With respect to hard soil the percentage increase in model-6 are 46.47%, 80.11% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increases in model-7 39.33%, 81.60% in medium soil and soft soil respectively.

3.2. Time history method

- Base shear

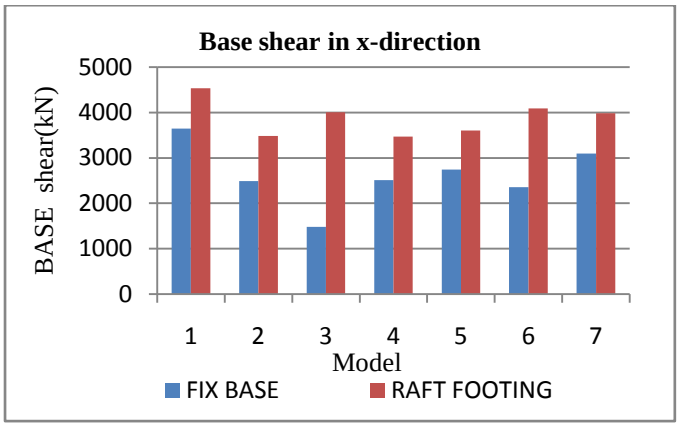


Chart 7: Base shear in x-direction

From above graph:

- In fix base, with respect to model-1 the percentage decrease of base shear are 31.66%, 59.37%, 31.20%, 24.76%, 35.49%, 15.16% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.
- In Raft footing, with respect to model-1 the percentage decrease of base shear are 23.26%, 11.79%, 23.51%, 20.57%, 9.79%, 12.12% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.

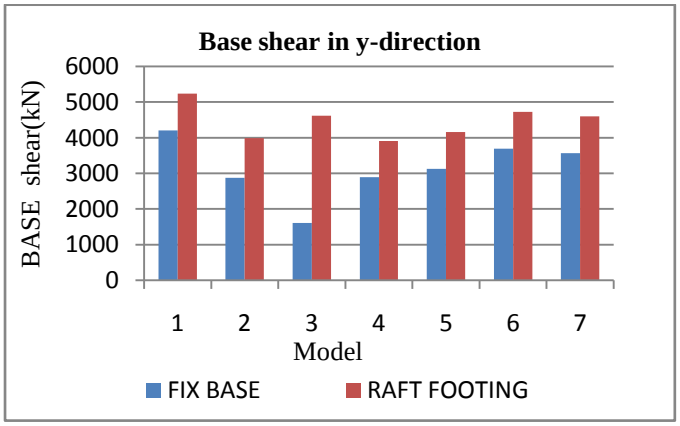


Chart 8: Base shear in y-direction

From above graph:

- In fix base, with respect to model-1 the percentage decrease of base shear are 31.66%, 59.37%, 31.20%, 24.76%, 35.49%, 15.16% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.
- In Raft footing, with respect to model-1 the percentage decrease of base shear are 23.26%, 11.79%, 23.51%, 20.57%, 9.79%, 12.12% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.

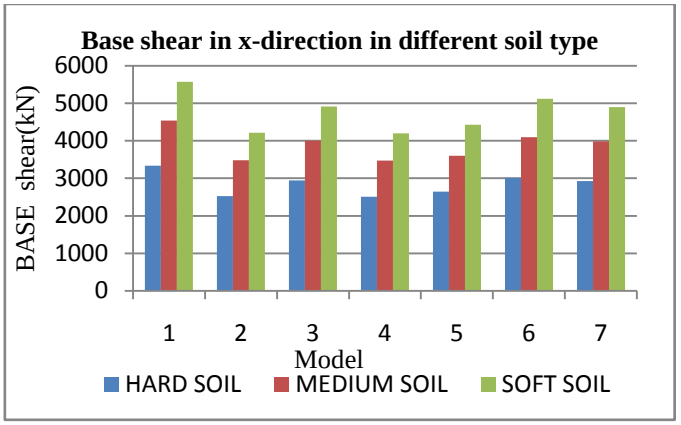


Chart 9: Base shear in x-direction in different soil

From above graph:

- With respect to model-1 the percentage decrease of base shear 24.35%, 11.83%, 24.73%, 20.63%, 9.83%, 12.17% are in model-2, model-3, model-4, model-5, model-6, model-7 in hard, medium and soft soil respectively.

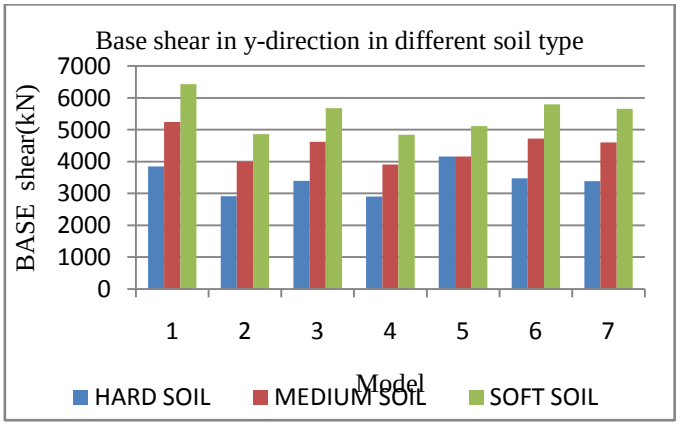


Chart 10: Base shear in y-direction in different soil

From above graph:

- With respect to model-1 the percentage decrease of base shear 24.35%, 11.83%, 24.73%, 20.63%, 9.83%, 12.17% are in model-2, model-3, model-4, model-5, model-6, model-7 in hard, medium and soft soil respectively.

- Roof displacement

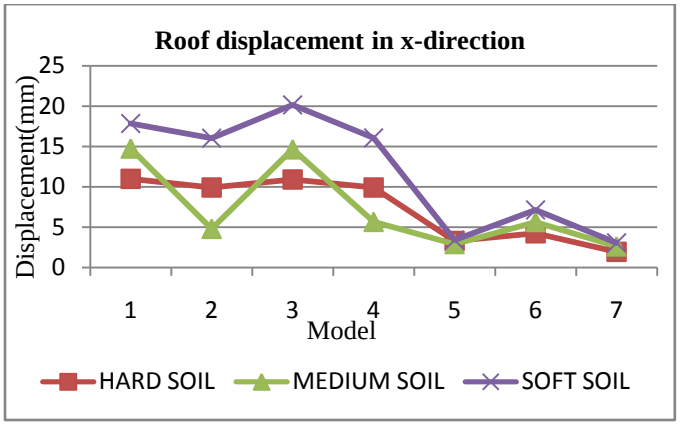


Chart 11: Roof displacement in x-direction

From above graph:

- With respect to hard soil the percentage increase in model-1 are 34.41%, 62.67% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-2 are 51.57%, 61.73% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-3 are 34.41%, 84.73% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-4 are 42.83%, 62.25% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-5 are 11.16%, 23.54% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-6 are 33.72%, 68.79% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-7 are 35.63%, 57.29% in medium soil and soft soil respectively.

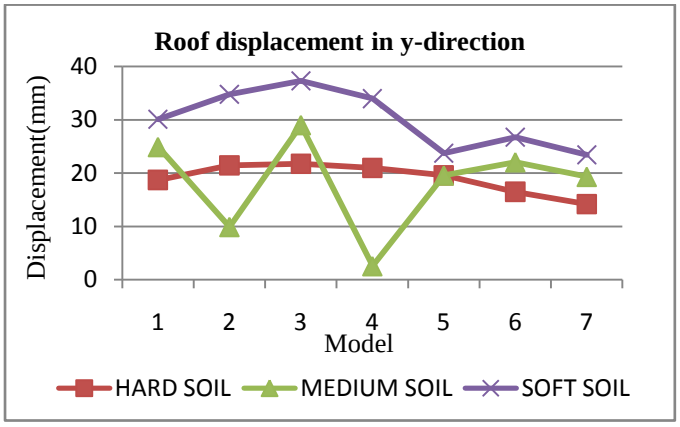


Chart 12: Roof displacement in y-direction

From above graph:

- With respect to hard soil the percentage increase in model-1 are 33.15%, 60.93% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-2 are 53.76%, 62.02% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-3 are 33.56%, 71.53% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-4 are 47.70%, 62.08% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-5 are 32.68%, 70.43% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-6 are 33.72%, 62.09% in medium soil and soft soil respectively.
- With respect to hard soil the percentage increase in model-7 are 36.10%, 65.14% in medium soil and soft soil respectively.

- Time Period

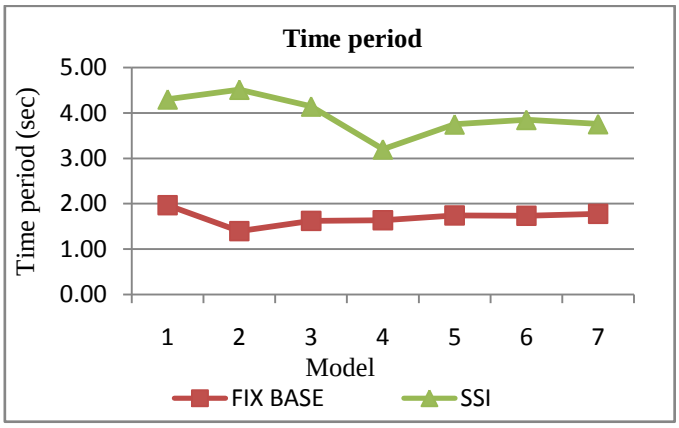


Chart 13: Time period in various model

From above graph:

- In fix base, with respect to model-1 the percentage decrease in time period are 28.93%, 17.77%, 16.75%, 11.68%, 12.18%, 9.64% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.
- In raft footing, with respect to model-1 the percentage decrease in time period are 4.88%, 3.72%, 25.58%, 12.79%, 10.47%, 12.79% in model-2, model-3, model-4, model-5, model-6, model-7 respectively.

IV. CONCLUSION

Analysis of RC Building having Underground Stories with Vertical Irregularities using seismic coefficient method, response spectrum method and time history method. The following conclusions are drawn from the study.

1. It is observed that model-3 gives the minimum result in hard soil, model-2 gives in medium soil, and model-3 gives in soft soil in response spectrum analysis in both directions.
2. It is observed that model-7 gives the minimum displacement in hard, medium, and soft soil type in time history analysis in both directions.
3. Model-4 gives the minimum base shear in both analyses in both directions.
4. In fix base, model-3 gives the minimum base shear while in raft footing model-4 gives minimum base shear in both analyses in both directions.
5. It is observed that in fix base model-2 gives minimum time period while in raft footing model-4 gives the minimum time period.

REFERENCES

[1] Baldev d. Prajapati & d. R. Panchal "Study of seismic and wind effect on multi storey R.C.C., steel and composite building" international journal of advances in engineering & technology, sept. 2013.issn: 22311963.

[2] Bhakti n. Harne1, r. R. Shinde(2015) "Review on seismic performance of multi-storied RC building with soft storeyijret": International journal of research in engineering and technology eissn: 2319-1163 | pissn: 2321-7308 .

[3] C.Navaro(1992) " Seismic analysis of underground structures"Earthquake engineering ,Tenth world conference 1992 Balkema,rottardam,ISBN 9054100605 .

[4] Chaitanya Patel, Noopur Shah,(2016) " Building with underground storey with variations in soil subgrade modulus" international journal of engineering development and research 2016 ijedr | volume 4, issue 2 | issn: 2321-9939.

[5] Chaithra t p, manogna h n(2015) "Dynamic soil structure interaction analysis for piled raft foundation" International journal of engineering and computer science volume 4 issue 7 july 2015|issn:2319-7242.

[6] Dr. S.s. patil, 2mr. M. G. Kalyanshetti(2016) " Parametric study of r.c frames with raft foundation considering soil structure interaction using spring" International journal of scientific development and research april 2016 ijsdr | volume 1, issue 4| issn: 2455-2631.

[7] G. Saad, f. Saddik & s. Najjar(2012) "Impact of soil structure interaction on the seismic design of reinforced concrete buildings with underground stories" american university of beirut, lebanon lisbo.

[8] H.elganainy, m.h.elnaggar(2009) "Seismic performance of three-dimensional frame structures with underground stories" soil dynamics and earthquake engineering 1249–1261.

[9] Halkude S.A., Kalyanshetti M.G. and Barelikar S.M. "Seismic Response of R.C. Frames with Raft Footing Considering Soil Structure Interaction" International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[10] J.H. Wood(2005) "Earthquake design of rectangular underground structures" 2005 NZSEE