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Behavior of Reinforced Concrete Building with Underground Storey's

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Abstract: Today, deep underground basements are an important component of new urban building construction. The integration of underground parking into major, new building projects in urban environments can enhance the aesthetic and economic values of the overall development. The current state-of-practice for seismic design of buildings with multiple underground storeys involves approximate approaches that primarily differ according to the designer's judgment and experience. While current research mainly aims at understanding the effect of soil structure interactions, this study has the ultimate goal of finding appropriate recommendations concerning the inclusion of underground storeys in the modeling and analysis of reinforced concrete buildings and optimizing their design. The underground storeys, basement walls, foundation soil and side soil can be incorporated in the mathematical model of the structure to be able to assess the effect of the underground part of the building adequately on its seismic performance. In relation to objectives, an analysis will be performed for reinforced concrete building with underground storeys using the software. Referring to the international codes an attempt will be made to design a building with underground storeys.
Keywords: Soil-Structure Interaction, Underground Storeys, Earth Pressure, Seismic Design, Equivalent Stiffness.

I. INTRODUCTION

Today, deep underground basements are an essential component of new urban building construction. This is often because parking in most large cities is generally incompetent and often serviced by aging, outdated, and degenerated above-grade parking structures that are not capable the circumferential architecture and engage valuable aboveground space. The assimilation of underground parking into dominant, new building projects in urban environments can upgrade the aesthetic and economic values of the overall development. Most building codes including Indian seismic codes treat low and medium rise regular buildings with multi-level underground stories with the same recommendations used for buildings with surface foundations. Many clauses in the codes (IS:1893 and IS:13920) appear confusing regarding soil-structure interaction and basement floors. But, recent researches show that seismic response of buildings with basement walls is a complicated phenomenon. While current research mainly aims at understanding the effects of soil structure interactions, this study has the ultimate goal of finding appropriate recommendations concerning the incorporation of underground stories in the modeling and analysis of reinforced concrete buildings and optimizing their design. Most of the civil engineering structures involve some type of structural element with direct contact with the ground. When the external forces, such as earthquakes, 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 termed as soil-structure interaction (SSI). It has conventionally been considered that soil-structure interaction has a beneficial effect on the seismic response of a structure. Many design codes have suggested that the effect of SSI can reasonably be neglected for the seismic analysis of structures. Considering soil-structure interaction makes a structure more flexible and thus, increasing the natural period of the structure compared to the corresponding rigidly supported structure. Moreover, considering the SSI effect increases the effective damping ratio of the system. The smooth idealization of design spectrum suggests smaller seismic response with the increased natural periods and effective damping ratio due to SSI. The impact of building substructure on its seismic performance is gauged by explicitly incorporating the underground storeys, basement wall, foundation and side soil in the structural analysis model. The soil types considered in modeling the subsurface conditions are Medium and hard soil. Seismic zone III is adopted for sensitivity analysis of structure. For each case, the base shear, inter-stories shear, and displacements are calculated in order to quantify the effect of soil structure interaction.

II. LITERATURE REVIEW

Current building codes need unrestrained recommendations on how to simulate the seismic performance of high-rise buildings with multiple underground stories. Designers are typically basing their analyses on subjective engineering judgment and experience.

Some model and analyze the buildings cropped at the ground floor level, others include a partial number of basement floors, while a few include all the underground floors. The seismic behavior of reinforced concrete buildings with multiple underground stories is explained by G. Saad, F. Saddik & S. Najjar (1). 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 modeled with a fixed condition at ground level is adopted, and then the number of basements is incrementally increased to investigate changes in performance.

The preliminary designs of the five, ten, fifteen and twenty story buildings are carried out using the structural analysis program ETABS assuming fixed base conditions at the ground surface. The basement walls are designed to resist bearing and lateral earth pressure loads only. The base shear, inter-story shears and moments are evaluated in order to quantify the effects of soil structure interaction on the design process.

H. El Ganainy, M.H. El Naggar (2) investigates the nonlinear seismic response of five, ten and fifteen story moment-resisting frame steel buildings resting on a flexible ground surface, and buildings having one, three and five underground stories. The buildings were assumed to be found on shallow foundations. Two site conditions were considered: soil class C and soil class E, corresponding to firm and soft soil deposits, respectively. Vancouver seismic hazard has been considered for this study. Synthetic earthquake records compatible with Vancouver uniform hazard spectrum (UHS), as specified by the National Building Code of Canada (NBCC) 2005, have been used as input motion. It was found that soil–structure interaction (SSI) can greatly affect the seismic performance of buildings in terms of the seismic storeys shear and moment demand and the deformations of their structural components. The SSI effects generally depend on the stiffness of the foundation and the number of underground stories. SSI effects are significant for soft soil conditions and negligible for stiff soil conditions. It was also found that SSI effects are significant for buildings resting on flexible ground surface with no underground stories, and gradually decrease with the increase of the number of underground stories.

Effect of SSI is considered by Winkler model by Nithya Chandran J, Abhilash Rajan, Soni Syed (3).

Jinu Mary Mathew, Cinitha A, Umesha P K, Nagesh R Iyer and Eapen Sakaria (4) investigates the properties of nonlinear hinges as per FEMA-356 (7) and ATC 40 guidelines for estimation of static stiffness of equivalent soil springs along with various degrees of freedom.

III. MODELLING AND ANALYSIS

A. Details of Soil Parameters Considered

The soil-flexibility effects on frame building resting on different types of soils, viz, hard, the medium is also trying to be studied in the present work.

TABLE I. SOIL PROPERTIES

Property \ Soil Type	Medium soil	Hard Soil
Angle of internal friction(Φ)	30^{o}	35^{o}
Unit wt of soil(γ)	20.42KN/m^{3}	22KN/m^{3}
Wall-soil friction angle(ʒ)	0^{o}	0^{o}
Poisson's ratio	0.3	0.2
Shear modulus (G)	40000KN/m^{2}	80000KN/m^{2}
Shear wave velocity	27.45m/sec	38.92m/sec

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The study is carried out on the foundations at greater depth (embedded foundation). The details related to present work are given below in Table II.

According to the seismic improvement of current structure provision, the members of structure and foundation must be modeled together in the unified model to consider soil-structure interaction. In this study effect of SSI will be considered by Winkler model.

To consider the flexibility effect of soil mass FEMA (Federal Emergency Management Agency) has given the impendence functions for 6 degrees of freedom (6 D.O.F).These stiffness equations are given for surface as well as embedment of the foundation. Stiffness equations are given below in Table no. III.

TABLE II. FOUNDATION DETAILS

Parameters	Medium Soil	Hard Soil
d (Height of effective sidewall contact)	1.2m	1.0m
h (Depth of centroid of effective sidewall contact)	4.4m	4.5m
D (Depth of foundation)	5m	5m
Size of Footing	2.5x2.5m	2.0x2.0m

B. Expressions for Static stiffness of equivalent soil spring along various degrees of freedom

TABLE III. Stiffness Equations for Embedded Foundation

Degree of Freedom	Stiffness of foundation at embedment
Translation along X-axis	$K_x = \{(GB/2-\eta)[3.4(L/B)^{0.65}+1.2]\} x\beta x$
Translation along Y-axis	$K_y = \{(GB/2\eta)[3.4(L/B)^{0.65}+0.4(L/B)+0.8]\} x\beta y$
Translation along Z-axis	$K_z = \{(GB/1-\eta)[1.55(L/B)^{0.75}+0.8]\} x\beta z$
Rocking about X-axis	$K_{rx} = \{(GB^3/1-\eta)[0.4(L/B)+0.1]\} x\beta rx$
Rocking about Y-axis	$K_{ry} = \{(GB^3/1-\eta)[0.47(L/B)^{2.4}+0.034]\} x\beta ry$
Torsion about Z-axis	$K_{rz} = \{(GB^3)[0.53(L/B)^{2.45}+0.51]\} x\beta rz$

Where,

β= Correction Factor for Embedment, d= Height of Effective Sidewall Contact, h= Depth to centroid of Effective Sidewall Contact, D= Depth of Foundation

TABLE IV.STIFFNESS VALUES FOR EMBEDDED FOUNDATION

Soil type	K_x kN\m	K_y kN\m	K_z kN\m	K_{rx} kN-m\deg	K_{ry} kN-m\deg	K_{rz} kN-m\deg
Hard	1750040	1750040	958800	1588000	1931320	2522620
Medium	1041760	1041760	631140	1665170	`1930500	2992000

C. Side Soil

The earth pressure at given depth are typically dependent on the soil type and its properties and on the embedment depth. lateral pressure–lateral defection relation of the side soil is represented into two distinct parts as follows:

(1) Under static loading condition, the side soil acts on the basement walls with a static pressure corresponding to the active earth pressure.

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(2) As the building oscillates, the side soil acts like horizontal nonlinear springs, where their ultimate compression capacities are Pp-Pa.

$$P_a = K_a.\gamma.Z.\cos\partial$$

$$P_p = K_p.\gamma.Z.\cos\partial$$

Where,

$$K_a = \frac{\cos^2\phi}{\cos\partial\left[1+\left(\frac{\sqrt{\sin(\partial+\phi)\sin\phi}}{\cos\partial}\right)\right]^2}$$

$$K_p = \frac{\cos^2\phi}{\cos\partial\left[1-\left(\frac{\sqrt{\sin(\partial+\phi)\sin\phi}}{\cos\partial}\right)\right]^2}$$

γ: unit weight of soil
Z: embedment depth at which the soil pressure is calculated
δ: wall-soil friction angle
ϕ: angle of friction of the soil

TABLE VEARTH PRESSURE VALUES

Embedment Depth (m)	Medium Soil		Hard Soil	
	P_a (kN]m)	P_p (kN]m)	P_a (kN]m)	P_p (kN]m)
3	20.21	183.78	17,82	243.54
6	40.43	367.56	35.64	487.08

D. Description Of Analytical Model

Different building models are analyzed in ETABS. The properties of the building configurations are considered in the present work are summarized below,
Height of each floor: 3m
Plinth height: 1.5m
Plan dimension: 20x10m
Floor thickness: 0.125m
Wall thickness: 230mm
No. of storeys: G+5, G+10, G+15
Max no of underground storeys: 2
Concrete grade:M25
Compressive strength of concrete f_{ck}: 25N\mm^2
The steel used Fe:415
Bending reinforced yield stress f_y: 415N\mm^2
Shear reinforced yield stress f_{ys}: 415N\mm^2
Poisson's Ratio: 0.20
Damping: 0.05
Moderate seismic zone: (III)
External Wall load is: 11.73 kN/m2
Internal Wall load is: 7.30 kN/m2
The parapet wall load is: 5.0 kN/m2
Waterproofing load on terrace floor: 2 kN/m2
The floor finish load is: 1.0 kN/m2
Live load: 4 kN/m2

TABLE VI.SECTIONAL DIMENSION OF FRAMES

Bldg. Frame	Description	Column (m x m)	Beam (m x m)
G+5	5 storeys	0.5x0.5	0.5x0.3
G+10	Top 5 storeys	0.5x0.5	0.5x0.3
G+10	Bottom 5 storeys	0.75x0.75	0.5x0.3
G+15	Top 5 storeys	0.5x0.5	0.5x0.3
	Middle 5 storeys	0.75x0.75	0.5x0.3
	Bottom 5 storeys	1x1	0.5x0.3

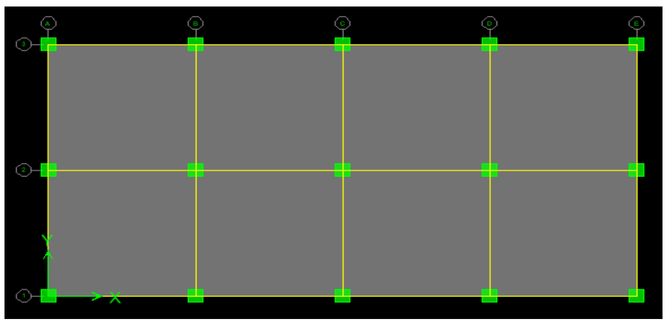

Fig 1. Floor Plan

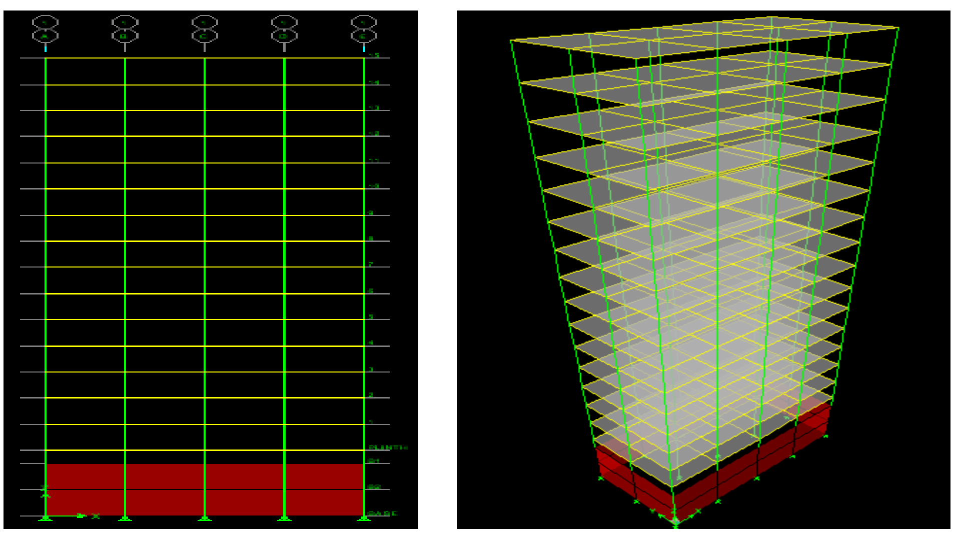

Fig. 2 Elevation

IV. RESULTS AND DISCUSSION

A framed structure of rectangular plan with 5,10 and 15 storeys is analyzed for earthquake load consider in zone-III and zone-V, with the different soil type like hard and medium soil with fixed and flexible base condition considering scenarios shown in table 4.1. Response spectrum analysis is done and the parameters like time period, base shear, and top storeys displacement are measured and are present below.

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TABLE VII
ANALYSIS SCENARIOS

AG FLOOR	5	10	15
UG FLOOR	0	0	0
	1	1	1
	2	2	2

TABLE VIII
BASE SHEAR VALUES FOR G+5 STRUCTURE WITH ZONE III (HARD SOIL)

Underground Storeys	Flexible Base	Fixed Base
0	567.84	578.77
B1	583.79	599.44
B2	630.67	635.49

TABLE IX
BASE SHEAR VALUES FOR G+5 STRUCTURE WITH ZONE III (MEDIUM SOIL)

Underground Storeys	Flexible Base	Fixed Base
0	571.08	589.47
B1	589.44	608.36
B2	637.39	648.78

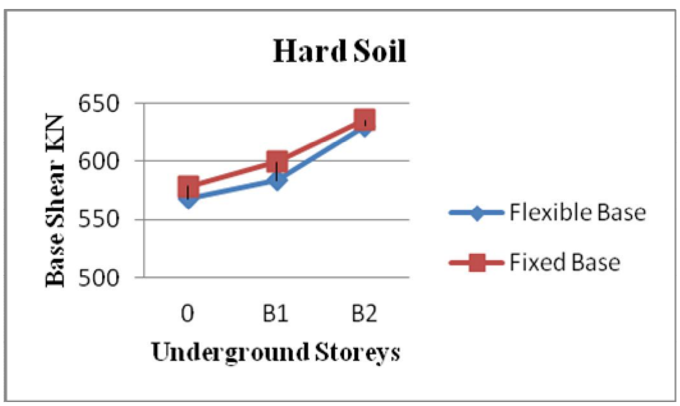


Fig. 3 Base Shear values for Hard Soil condition

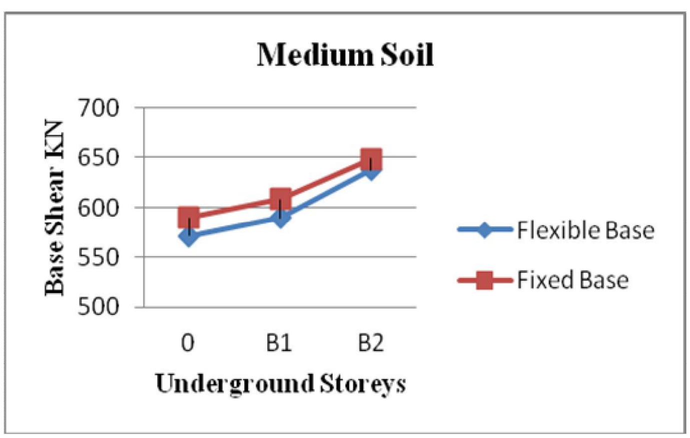


Fig. 4 Base Shear values for Medium Soil condition with zone III

TABLE X
DISPLACEMENT VALUES FOR G+5 STRUCTURE WITH ZONE III (HARD SOIL)

Underground Storeys	Flexible Base	Fixed Base
0	0.0116	0.0109
B1	0.0163	0.0156
B2	0.0291	0.0287

TABLE XI
DISPLACEMENT VALUES FOR G+5 STRUCTURE WITH ZONE III (MEDIUM SOIL)

Underground Storeys	Flexible Base	Fixed Base
0	0.0119	0.0116
B1	0.0167	0.0161
B2	0.0301	0.0291

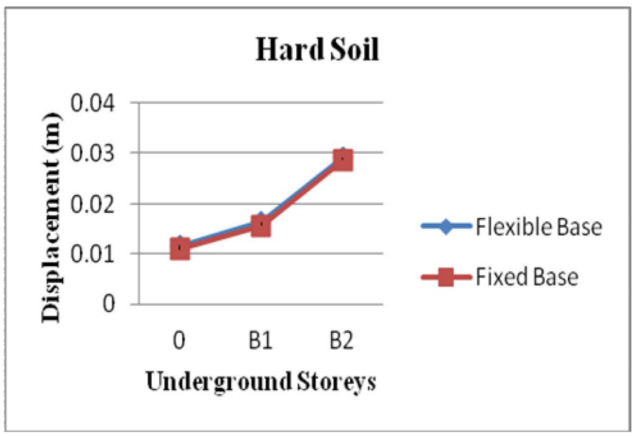


Fig. 5 Displacement values for Hard Soil condition with zone III

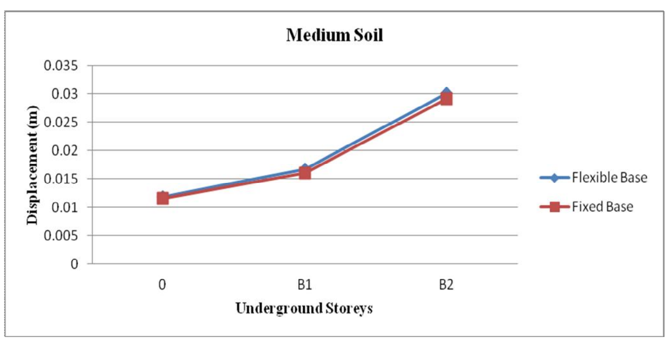


Fig. 6 Displacement values for Medium Soil condition with zone III

TABLE XII
BASE SHEAR VALUES FOR G+5 STRUCTURE WITH ZONE V (MEDIUM SOIL)

Underground storeys	Flexible Base	Fixed Base
0	1302.23	1323.87
B1	1348.75	1374.42
B2	1429.86	1473.98

TABLE XIII
BASE SHEAR VALUES FOR G+5 STRUCTURE WITH ZONE V (HARD SOIL)

Underground storeys	Flexible Base	Fixed Base
0	1284.74	1297.23
B1	1319.64	1347.75
B2	1402.64	1443.86

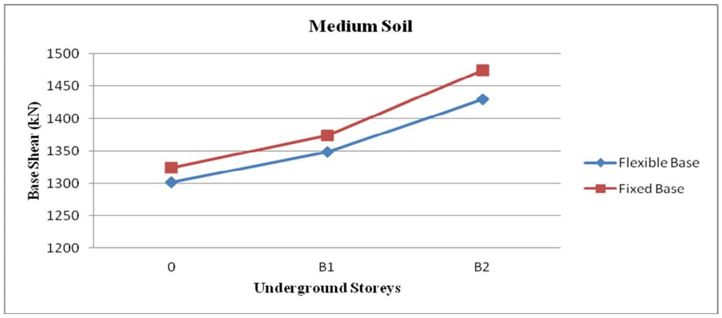


Fig. 7 Base Shear values for G+5 structure with zone V for Medium Soil condition

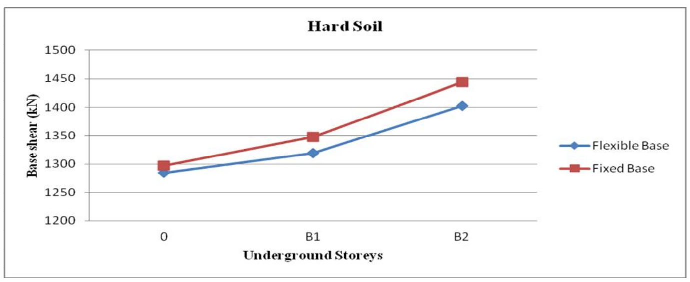


Fig. 8 Base Shear values for G+5 structure with zone V for Hard Soil condition

TABLE XIV
DISPLACEMENT VALUES FOR G+5 WITH ZONE V (MEDIUM SOIL)

Underground storeys	Flexible Base	Fixed Base
0	0.0261	0.0247
B1	0.0388	0.0363
B2	0.0708	0.0646

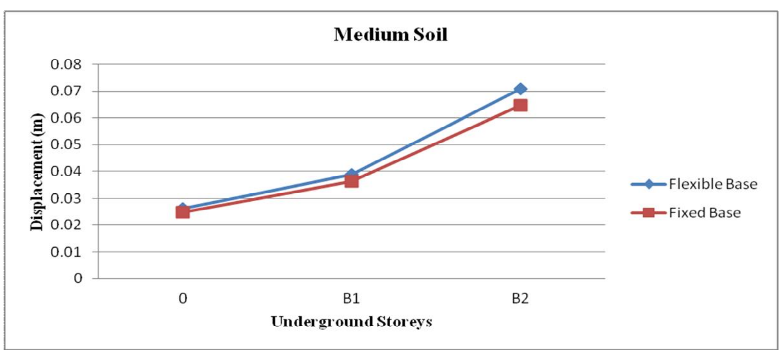


Fig. 9 Displacement values for G+5 structure with zone V for Medium Soil condition

TABLE XV
DISPLACEMENT VALUES FOR G+5 WITH ZONE V (HARD SOIL)

Underground storeys	Flexible Base	Fixed Base
0	0.0241	0.0228
B1	0.0382	0.0363
B2	0.0693	0.0646

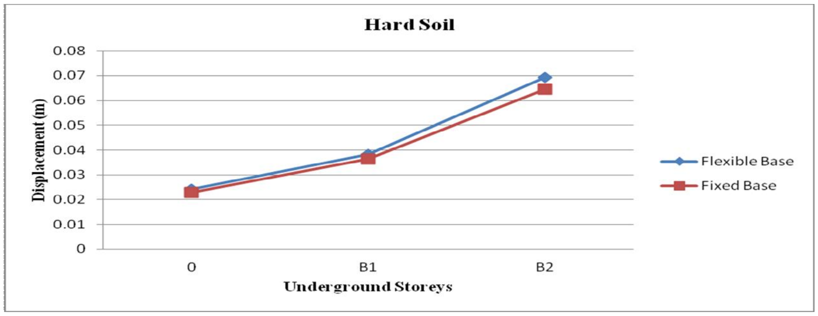


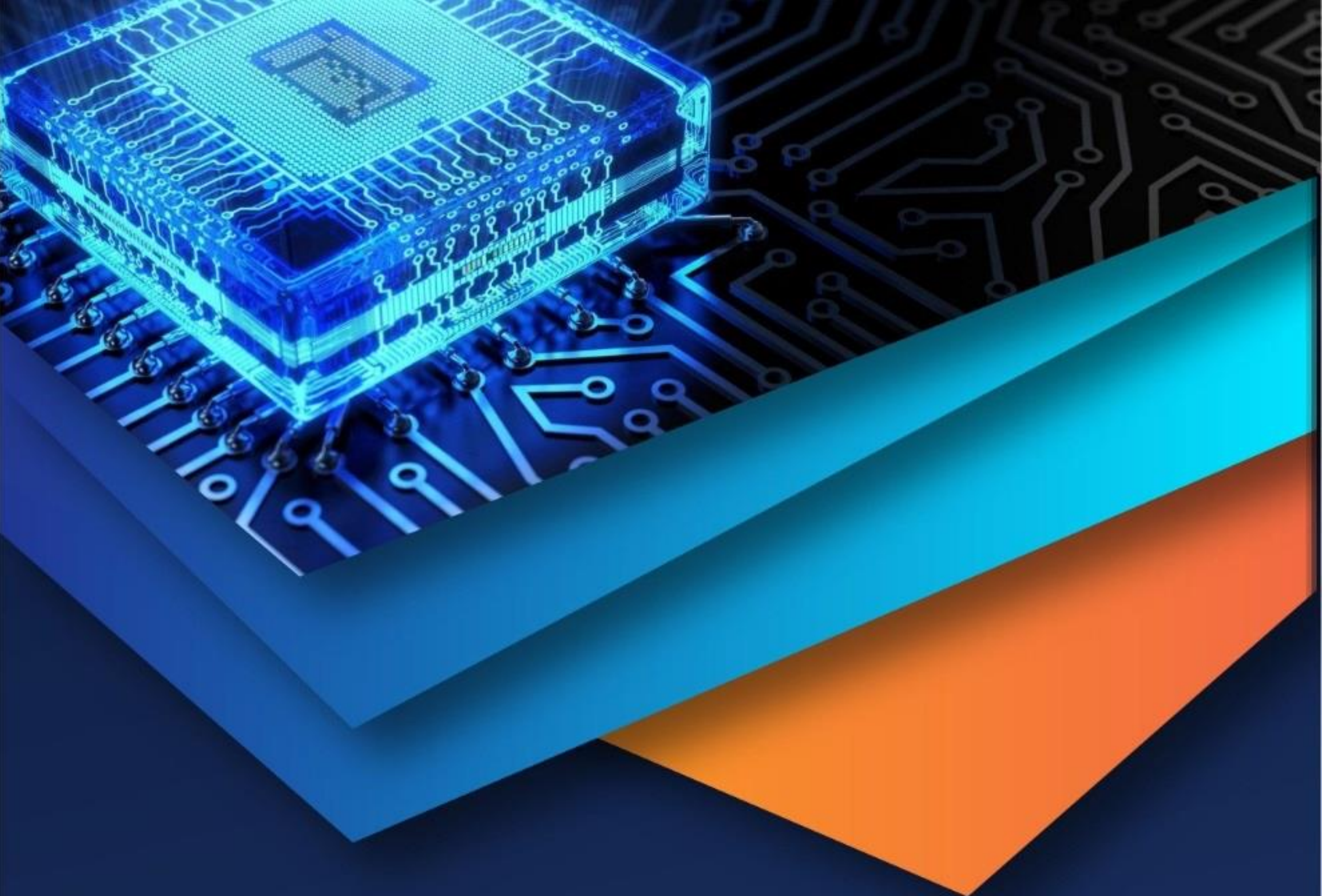
Fig. 10 Displacement values for G+5 structure with zone V for Hard Soil condition

V. CONCLUSIONS

1) Base shear reduces for the flexible base condition in comparison with the fixed base condition by 2.8% for medium soil and 3.65% for hard soil condition with seismic zone III, since the natural period increases for the flexible base condition.
2) For a change of condition from fixed base to flexible base for seismic zone V, base shear reduces by approximately 2.30% for medium soil and 4.07% for hard soil condition.
3) The results obtained for medium soil condition, when compared with hard soil condition, the base shear values were increased for all parametric variations.
4) Base shear and Displacement values of all models increase with an increase in a number of underground storeys by 2.29% and 4% respectively for hard soil with seismic zone V where as for medium soil with seismic zone V, both values increase by 1.68% and 4.07% respectively. Similarly in case of seismic zone III, both the values of base shear and displacement increase by 3% and 3.99% respectively.
5) Top storey displacement values increase from fixed base condition to flexible base condition for all models of seismic zone III, by approximately 3.9%, and for all models of seismic zone V by 4.07%.

REFERENCES

[1] G. Saad, F. Saddik & S. Najjar, “Impact of Soil-Structure Interaction on the Seismic Design of Reinforced Concrete Buildings with Underground Stories” WCEE, Volume 15, pp. 321-242, 2012.
[2] H. El Ganainy, M.H. El Naggar, “Seismic performance of three-dimensional frame structures with underground stories” Soil Dynamics and Earthquake Engineering 29, Volume 4, Issue 11, pp. 1249 –1261,2014.
[3] Nithya Chandran J, Abhilash Rajan, Soni Syed, “Seismic Analysis of Building with Underground Stories Considering SSI” International journal of emerging technology and advanced engineering, Volume 4, Issue 11, 2014.
[4] Jinu Mary Mathew, Cinitha A, Umesha P K, Nagesh R Iyer and Eapen Sakaria, “Seismic response of RC building by considering SSI” International Journal of Structure and Civil engineering research, Vol. 3, No. 1, pp.160-174, 2014.
[5] Seth Pearlman, Michael Walker, Marco Boscardin, Ph.D. P.E, “Deep underground basements for major urban building construction” ASCE Geo-Support, Volume 1, pp.1-16, 2004.
[6] FEMA Guidelines (Federal Emergency Management Agency).
[7] IS 1893 (Part I): 2002 Criteria for Earthquake Resistant Design of Structures-General provisions and Buildings, Bureau of Indian Standards, New Delhi.



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