Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 6, Issue 11, November -2019

Analysis of Reinforced Concrete Building Frame resting on different Support and Soil Condition with Consideration of Soil Structure Interaction

Bhavesh Banjare[1], Gangadhar Ramtekkar[2]

[1] *Bachelor of Technology Student, Department of Civil Engineering, National Institute of Technology-Raipur-492010,Chhattisgarh,India*

[2] *Professor, Department of Civil Engineering, National Institute of Technology-Raipur-492010, Chhattisgarh, India.*

Abstract — *Present Analysis investigates the effect of soil structure interaction on the structural behavior of a building during an earthquake of G+2, G+6 & G+12 Storey Building. The analysis is done by using (Bentley STAAD Pro V8i Version 2007) software. The Analysis carried out for 3x3 bays with G+2, G+6 and G+ 12 storey's R.C.C Frame building with different Support Condition like Fixed, Hinged & Spring. The interactive analyses are carried out for 3 different values of modulus of sub grade reaction. Comparison of both nodal displacements and reactions of the frame is done for different soil and support conditions for all three cases.*

Keywords— *Building Analysis, Soil structure interaction, Support Condition, STAAD Pro V8i, Displacement.*

I. INTRODUCTION

When structure is built on ground some elements of structure are direct contact with soil. When loads are applied on structure internal forces are developed in both the structure as well as in soil. It results in deformation of both the components which are independent to each other. This are called soil structure interaction**.** All problems in Civil Engineering involve interaction of structural elements with ground. When forces are applied externally to the structural element, the physics of the problem dictates the structural Element and ground to deform in a compatible manner. This is because of inherent intendancy of structural-element displacements and ground displacements by the virtue of their intimate physical contact. Therefore, these types of problems are broadly referred to as Soil-structure interaction (SSI) problems. In conventional structural design, SSI effects are not considered. Neglecting SSI effect for a relatively flexible structure founded on hard soil is reasonable. But, for a relatively stiff structure founded on either soft or medium soil neglecting SSI has a great impact on structural response and design. IS 1893(Part I):2002 suggests that SSI may not be considered in the seismic analysis of structure supported on rock or rock like material.

II. LITERATURE REVIEW

Soil structure interactions have been studied by many researches. Musande et al.[1] concluded that Soil Structure Interaction more affected on fixed base. Venkatesh et al.[2] focused on the response spectrum analysis of the soil-structure model considering fixed base and flexible base of modeling the structure. Nirav et al.[3] focused on the effect of Soil-Structure Interaction on a six storey building loaded as per IS 1893.The comparison of various forces, storey drift, storey displacement, has been presented subjected to seismic force and supported on different types of soil condition. Meghna et al.[4] focused on analysis of space frame and considered linear springs having stiffness equal to the modulus of sub grade reaction of the soil. Present Analysis investigates the effect of soil structure interaction on the structural behavior of a building during an earthquake of G+2, G+6 & G+12 Storey Building.

III.OBJECTIVE OF THE RESEARCH WORK

- The objectives of the present investigations are to Study changes in Nodal Displacements and Reactions in case of different Support and Soil Condition.
- Comparison of nodal displacements and reactions of the frame for different soil and support conditions.

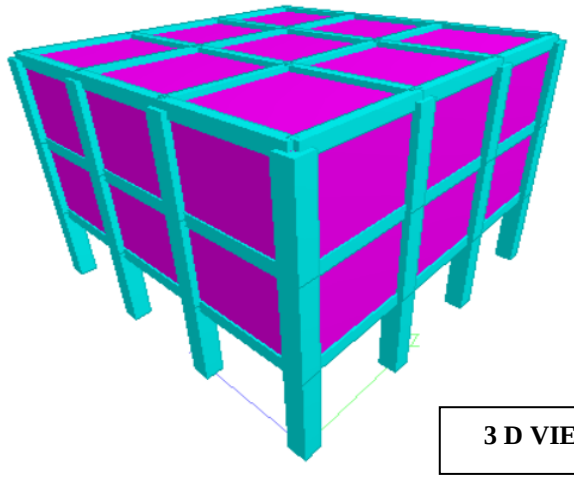
IV. METHODOLOGY

Hard, Medium and Soft Soil are the three types of soil upon which the structural frames are considered to be resting. Fixed, Hinged & Spring Support Conditions are considered in the analysis for G+2, G+6 & G+12 Storey Building. Total 27 structures are analyzed as presented in table 1.

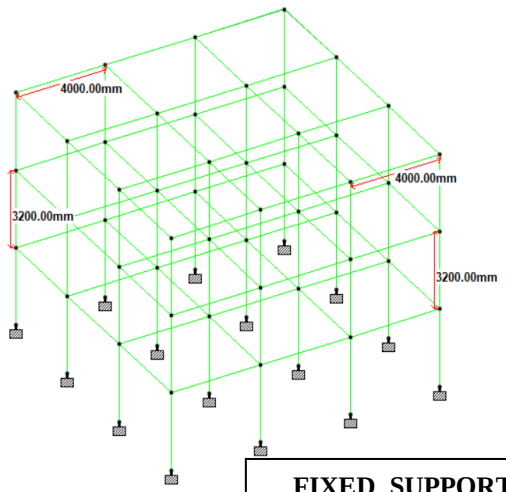
Table 1.Types of Building Considered For Analysis

BUILDING	SOIL TYPE	TYPE OF SUPPORT		
G + 2	SOFT	FIXED	HINGED	SPRING
	MEDIUM	FIXED	HINGED	SPRING
	HARD	FIXED	HINGED	SPRING
G + 6	SOFT	FIXED	HINGED	SPRING
	MEDIUM	FIXED	HINGED	SPRING
	HARD	FIXED	HINGED	SPRING
G + 12	SOFT	FIXED	HINGED	SPRING
	MEDIUM	FIXED	HINGED	SPRING
	HARD	FIXED	HINGED	SPRING

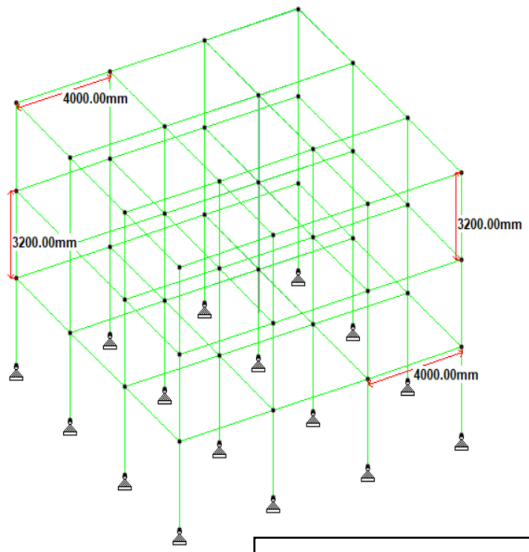
Table 2. G+2 Building Considered for Analysis



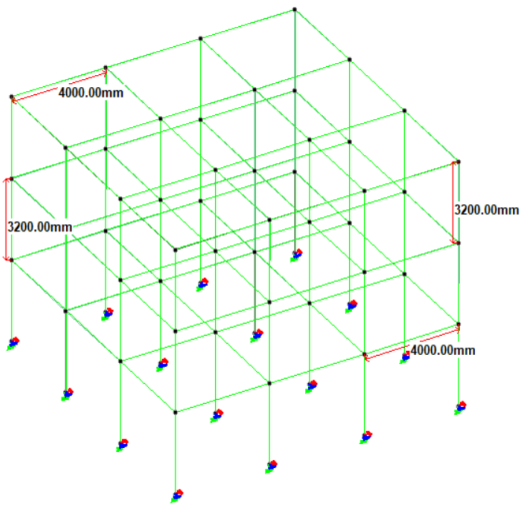
3 D VIEW



FIXED SUPPORT

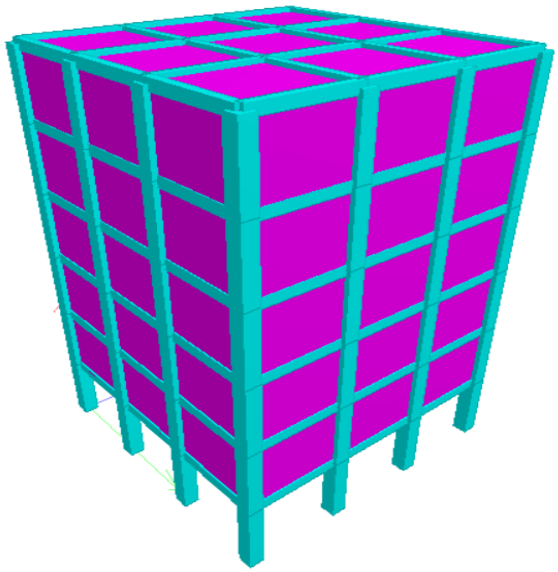


HINGED SUPPORT

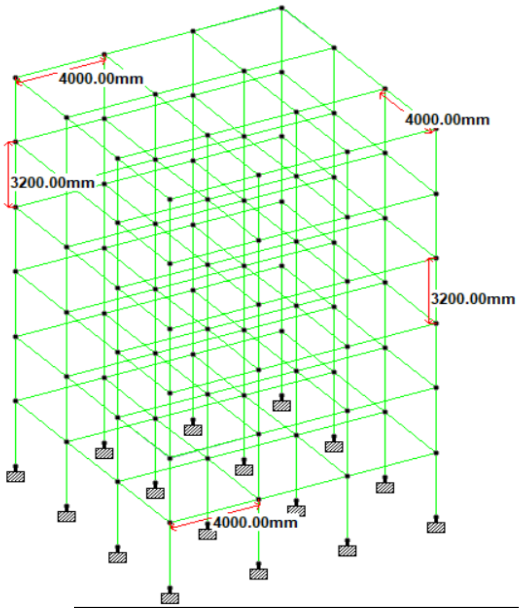


SPRING SUPPORT

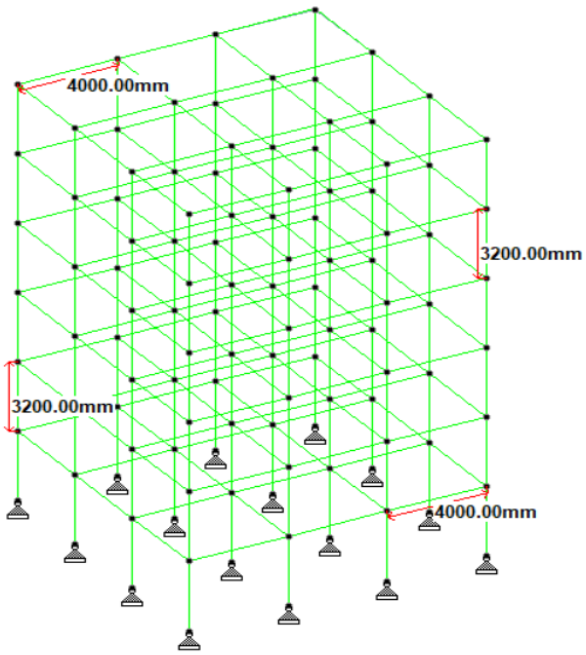
Table 3. G+6 Building Considered for Analysis



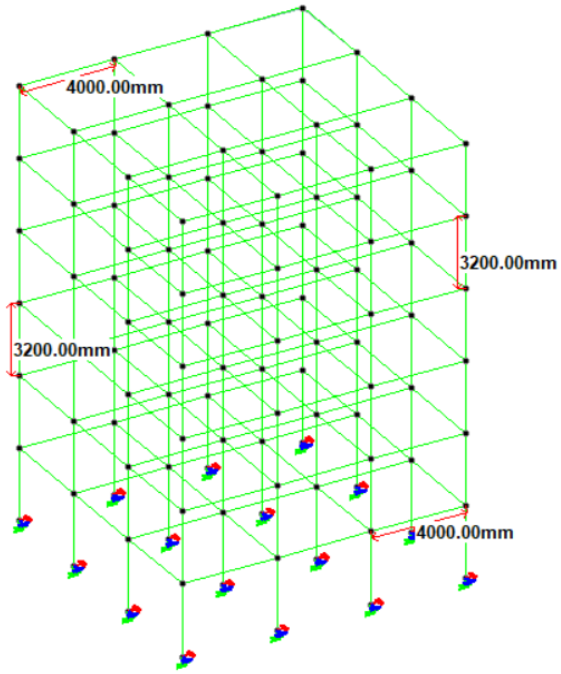
3 D VIEW



FIXED SUPPORT

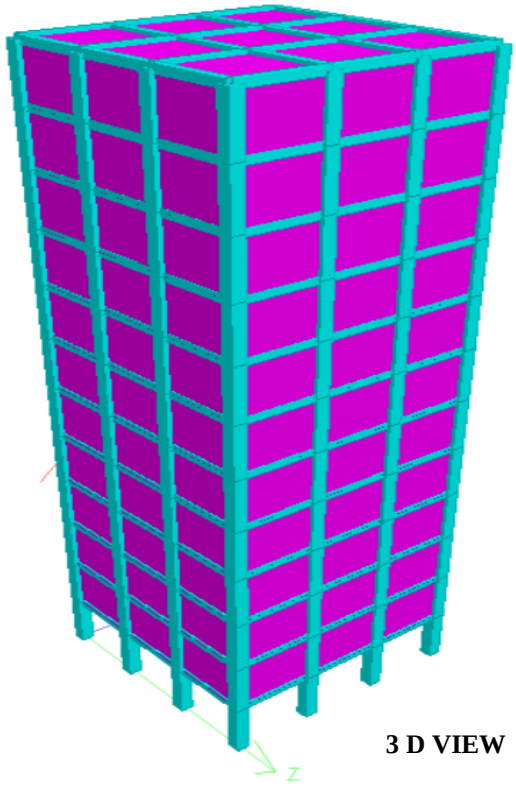


HINGED SUPPORT

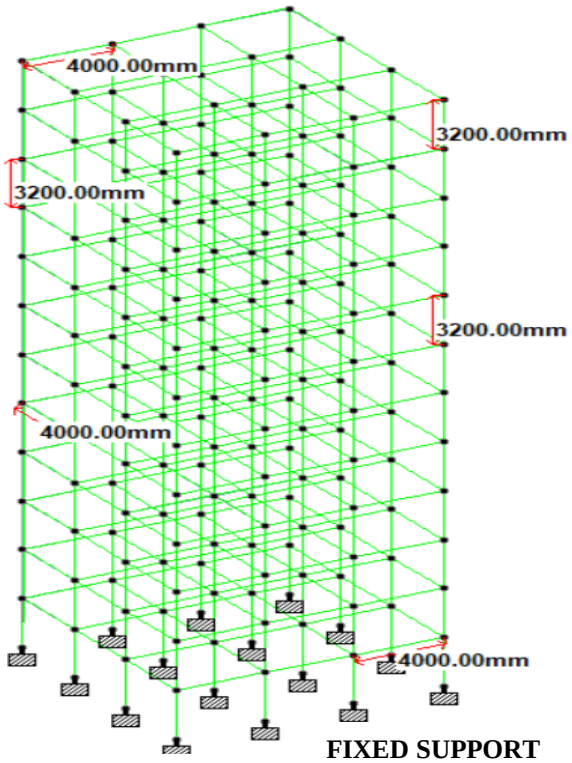


SPRING SUPPORT

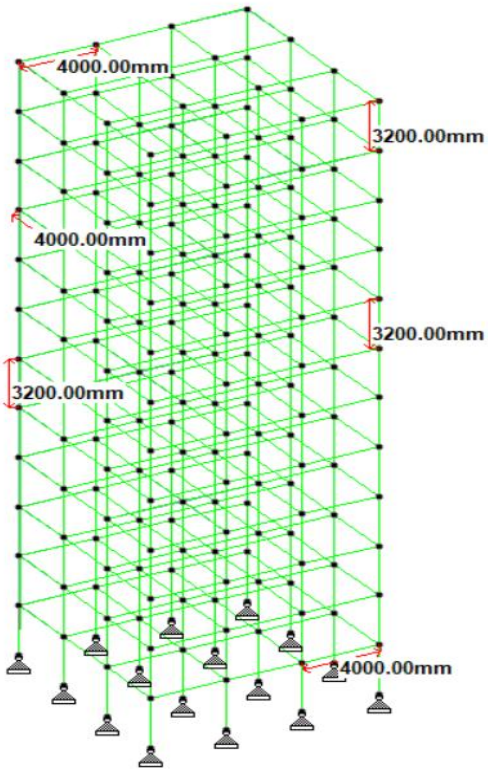
Table 4. G+12 Building Considered for Analysis



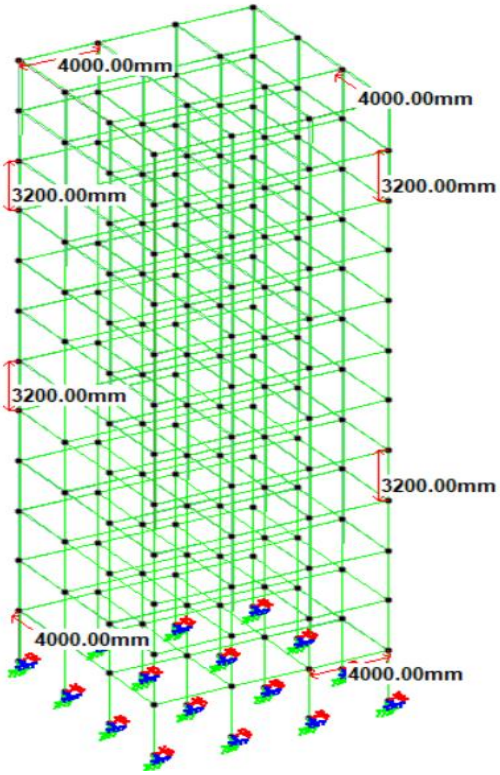
3 D VIEW



FIXED SUPPORT



HINGED SUPPORT



SPRING SUPPORT

V. DESCRIPTION OF THE BUILDING

In the present analysis a 3x3 bays with G+2, G+6 and G+12 storey R.C. Frame building is considered to investigate SSI effects on tall buildings. The plan dimension of the building is 12.0 m x 12.0 m and the height of the building is 9.6 m, 19.2 m, and 38.4m from the ground level for G+2, G+6 and G+ 12 storey building respectively.

Table 5.Discription of Building

Component	Description	Data
Frame	No. of Storey	G+2, G+ 6 and G +12
	No. of bays in X and Z direction	3 x 3 bays
	Storey height	3.2m
	Bay width in X and Z direction	4m x 4m
	Size of beam	300mm x 450mm
	Size of column	300mm x 500mm
	Thickness of slab	125 mm

VI. SEISMIC PARAMETERS

For the SSI analysis using Bureau of Indian Standards in IS 1893 (Part I): 2002 is used for Static and Dynamic analysis. The building is assumed to be situated in Zone IV. Medium, hard and soft are three types of soil upon which structural frames are considered to be resting. The following table is about Seismic Parameters.

Table.6 Seismic Parameters

Sr. No.	**Parameters**	**Values**
1	Zone (IV)	0.24
2	Response Reduction Factor (RF) (SMRF)	5
3	Rock and Soil Site Factor (SS)	1
4	Type of Structure (RC frame building)	1
5	Damping Ratio (DM)	5
6	Period in x Direction (PX)	0.5
7	Period in z direction (PZ)	0.5
8	Importance factor (I) (Important Building)	1.5
9	Depth of Foundation (DT)	3 m

Table 7.Rock and Soil Site Factor (SS)

S.No	Type of Soil	Value
1	Soft	3
2	Medium	2
3	Hard	1

VII. SOIL MODELING AND ANALYSIS

7.1 Soil Modeling

In Reinforced Concrete building with shallow foundation resting on three different soils (soft, medium and hard) , Each Soil has six soil springs, whose stiffness's are calculated From Table 9.These soil springs represent the stiffness of soil in three translational directions and three rotational directions. K_x, K_y, K_z are translational soil stiffness's in kN/m in x,y and z directions respectively. $K_{\Theta x}$, $K_{\Theta y}$, $K_{\Theta z}$ are rotational spring stiffness's in kN-m/rad about x, y and z directions respectively.

Table 8. Characteristic Properties Of Soils

Type of soil	Shear wave velocity Vs (m/s)	Elastic modulus E (kg/cm^2)	Shear modulus G (kg/cm^2)	Density of soil ρ (kN/m^3)	Poisson's ratio of soil μ
Hard	600	16400	6480	17.322	0.28
Medium	320	4945	1808	16.841	0.39
Soft	150	935	335	14.435	0.40

Table 9. Stiffness's of equivalent soil springs along various degrees of freedom

Degrees of freedom	Stiffness of equivalent soil spring
Translation along x – axis (Kx)	KZ -{[(0.2GL)/(0.75-μ)][1-(B/L)}
Translation along y – axis (Ky)	{[(2GL)/(1-μ)][0.73+1.54(B/L)$^{0.75}$]}
Translation along z – axis (Kz)	{[(2GL)/(2-μ)][2+2.5(B/L)$^{0.85}$]}
Rocking about x – axis (Krx)	{[(GI$_X$$^{0.75}$)/(1-μ)](L/B)$^{0.25}$[2.4+0.5(B/L)]}
Torsion along y – axis (Kry)	GJ$_t$$^{0.75}${4+11[1-(B/L)]^{10}}
Rocking about z – axis (Krz)	{[(GI$_Z$$^{0.75}$)/(1-μ)][3(L/B)$^{0.15}$]}

To compute the soil-spring stiffness, the effective shear modulus, Poisson's ratio and dimensions of Foundation are required. The foundations are designed as per code provisions by obtaining the design forces from Staad Pro. In present study to calculate stiffness form above formulae following data is used. L=2m, B=1.5m.

Table 10. Stiffness's Constant Value of different types of soil springs

Direction	**Unit**	**Soft Soil**	**Medium Soil**	**Hard Soil**
Vertical, K_Z	**kN/m**	8,679.07	45,897.75	644,502.27
Horizontal, K_x	**kN/m**	5,786.05	36,936.76	5,80,052.24
Horizontal, K_Y	**kN/m**	5,786.05	36,936.76	5,80,052.24
Rocking, $K_{\Theta x}$	**kN-m/rad**	14,72,678.0	77,87,998.16	10,93,60,086.95
Rocking , $K_{\Theta y}$	**kN-m/rad**	4,25,510.46	22,50,237.11	3,15,98,123.26
Twisting , $K_{\Theta z}$	**kN-m/rad**	9,98,328.62	68,63,330.52	11,12,02,826.79

7.2 Analysis Data:

1) Live Load : 3.0 kN/m² at typical floor
: 1.5 kN/m² on terrace
2) Floor finish : 1.0 kN/m²
3) Earthquake Load : As per IS-1893(Part 1)-2002
Using STAAD Program.
4) Depth of Foundation : 3 m
5) Storey Height : 3.2 m
6) Walls : 230 mm thick brick masonry wall
7) Compressive strength of Concrete (f_{ck}) : 20 N/mm^2
8) Reinforcement (f_y) : 415 N/mm^2
9) Poisson's ratio(μ) : 0.15

VIII. RESULTS AND DISCUSSIONS

The results are presented in the form of tables and graphs considering the effect of different Support and Soil Condition. The variation of Nodal Displacement and Reaction of the building models resting on different types of soil and Support are presented. The properties of the soil used for present study are given in tables 8. The trends observed in the results are also discussed in these sections**.**

8.1 Comparison of Reaction at Node in different Soil – G+2, G+6,G+12 Building

The value of node reactions are presented in the table11, 12 and 13 for G+2, G+6,G+12 buildings respectively. Chart-1 shows the variation of Moment at Z direction of node for fixed and spring support conditions and different Soil conditions. From the chart it is clear that in case of soft soil with spring support its moment value is quit high compared to fixed support.

Table11. Reaction at Node 1 - G+2 Building (EQ X)

SUPPORT	SOIL TYPE			Reaction In KN			Moment In KN-m		
		Node	L/C	V_X	V_Y	V_Z	M_X	M_Y	M_Z
FIXED	SOFT	1	1 EQ X	-32.449	-62.131	-0.674	-0.797	-0.127	56.324
	MEDIUM	1	1 EQ X	-32.449	-62.131	-0.674	-0.797	-0.127	56.324
	HARD	1	1 EQ X	-31.731	-60.758	-0.659	-0.779	-0.125	55.079
HINGED	SOFT	1	1 EQ X	-32.415	-80.121	-0.305	0.000	0.000	0.000
	MEDIUM	1	1 EQ X	-32.415	-80.121	-0.305	0.000	0.000	0.000
	HARD	1	1 EQ X	-31.698	-78.350	-0.298	0.000	0.000	0.000
SPRING	SOFT	1	1 EQ X	-33.388	-39.128	-0.091	0.254	-0.145	134.073
	MEDIUM	1	1 EQ X	-33.112	-56.935	-0.256	-0.078	-0.147	74.825
	HARD	1	1 EQ X	-31.841	-60.419	-0.599	-0.679	-0.133	56.436

Table12. Reaction at Node 1 - G+6 Building (EQ X)

SUPPORT	SOIL TYPE			Reaction In KN			Moment In KN-m		
		Node	L/C	V_X	V_Y	V_Z	M_X	M_Y	M_Z
FIXED	SOFT	1	1 EQ X	-71.406	-274.419	-4.335	-4.892	-0.270	123.689
	MEDIUM	1	1 EQ X	-58.151	-223.479	-3.530	-3.984	-0.220	100.729
	HARD	1	1 EQ X	-42.758	-164.323	-2.596	-2.929	-0.161	74.065
HINGED	SOFT	1	1 EQ X	-70.637	-313.147	-2.178	0.000	0.000	0.000
	MEDIUM	1	1 EQ X	-57.525	-255.018	-1.774	0.000	0.000	0.000
	HARD	1	1 EQ X	-46.159	-205.807	-1.517	0.000	0.000	0.000
SPRING	SOFT	1	1 EQ X	-72.358	-179.114	-0.585	1.854	-0.302	474.536
	MEDIUM	1	1 EQ X	-58.896	-212.198	-1.366	-0.205	-0.265	166.867
	HARD	1	1 EQ X	-42.902	-167.876	-2.400	-2.573	-0.175	77.573

Table13. Reaction at Node 1 - G+12 Building (EQ X)

SUPPORT	SOIL TYPE			Reaction In KN			Moment In KN-m		
		Node	L/C	V_X	V_Y	V_Z	M_X	M_Y	M_Z
FIXED	SOFT	1	1 EQ X	-92.662	-697.292	-13.200	-14.797	-0.369	159.901
	MEDIUM	1	1 EQ X	-75.462	-567.854	-10.750	-12.050	-0.301	130.218
	HARD	1	1 EQ X	-55.486	-417.540	-7.904	-8.860	-0.221	95.749
HINGED	SOFT	1	1 EQ X	-91.916	-761.680	-6.842	0.000	0.000	0.000
	MEDIUM	1	1 EQ X	-73.300	-607.115	-5.535	0.000	0.000	0.000
	HARD	1	1 EQ X	-53.897	-446.408	-4.070	0.000	0.000	0.000
SPRING	SOFT	1	1 EQ X	-91.262	-465.111	-1.785	5.728	-0.416	1064.669
	MEDIUM	1	1 EQ X	-75.399	-550.825	-4.201	-0.548	-0.399	298.592
	HARD	1	1 EQ X	-55.679	-433.504	-7.374	-7.847	-0.252	104.524

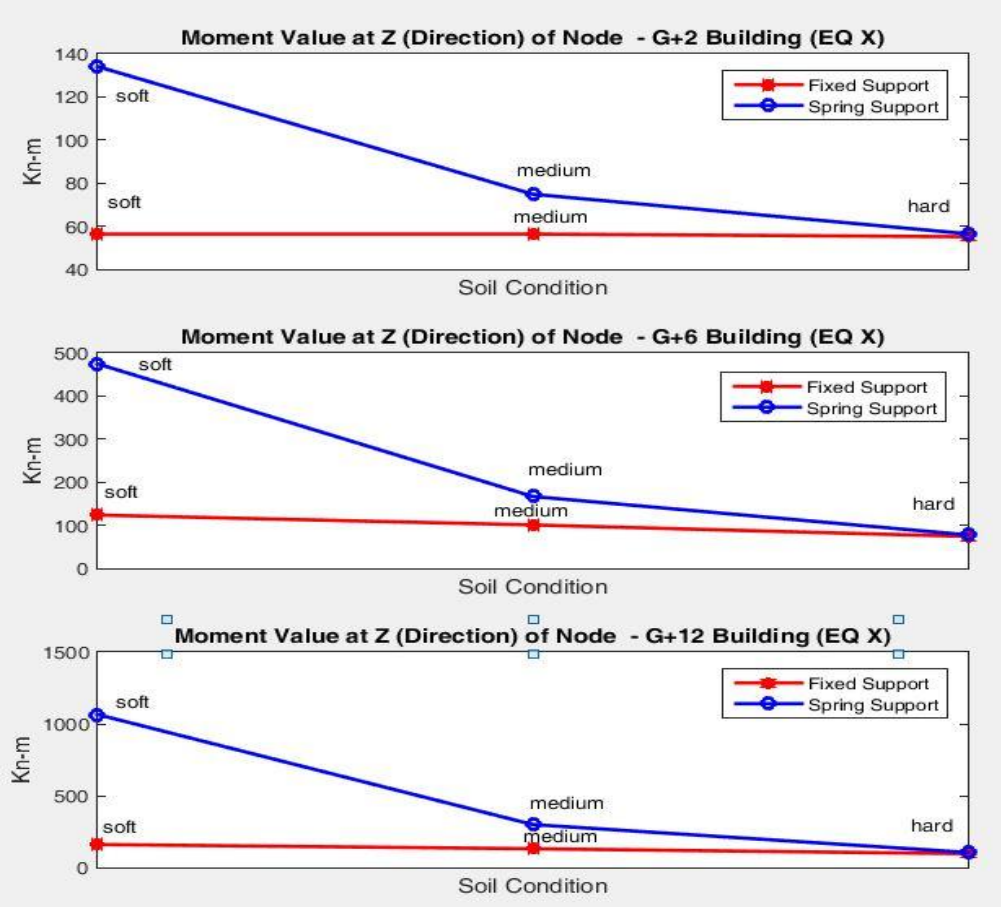


Chart 1. Moment Value at Z (Direction) of different Building

8.2 Comparison of Displacement at Node in different Soil – G+2, G+6,G+12 Building

Table14. Displacement at Node - G+2 Building (EQ X)

SUPPORT	SOIL TYPE			Horizontal	Vertical	Horizontal	Resultant	ROTATIONAL		
		Node	L/C	X In mm	Y In mm	Z In mm	In mm	Θ_X rad	Θ_Y rad	Θ_Z rad
FIXED	SOFT	13	EQ X	0.583	0.032	0.001	0.584	0.000	0.000	-0.000
	MEDIUM	13	EQ X	0.583	0.032	0.001	0.584	0.000	0.000	-0.000
	HARD	13	EQ X	0.570	0.031	0.001	0.571	0.000	0.000	-0.000
HINGED	SOFT	13	EQ X	2.033	0.038	0.001	2.033	0.000	0.000	-0.000
	MEDIUM	13	EQ X	2.033	0.038	0.001	2.033	0.000	0.000	-0.000
	HARD	13	EQ X	1.988	0.037	0.001	1.988	0.000	0.000	-0.000
SPRING	SOFT	13	EQ X	15.228	6.787	0.001	16.672	0.000	-0.000	-0.001
	MEDIUM	13	EQ X	3.334	1.571	0.001	3.686	0.000	-0.000	-0.000
	HARD	13	EQ X	0.758	0.135	0.001	0.770	0.000	0.000	-0.000

The Displacement Value at Node is presented in the table 14, 15 and 16 for G+2, G+6, G+12 buildings respectively.

Table15. Displacement at Node - G+6 Building (EQ X)

SUPPORT	SOIL TYPE			Horizontal	Vertical	Horizontal	Resultant	ROTATIONAL		
		Node	L/C	X In mm	Y In mm	Z In mm	In mm	Θ_X rad	Θ_Y rad	Θ_Z rad
FIXED	SOFT	13	EQ X	1.736	0.183	0.002	1.746	0.000	-0.000	-0.000
	MEDIUM	13	EQ X	1.414	0.149	0.002	1.422	0.000	-0.000	-0.000
	HARD	13	EQ X	1.040	0.110	0.001	1.046	0.000	-0.000	-0.000
HINGED	SOFT	13	EQ X	4.893	0.197	0.002	4.897	0.000	-0.000	-0.000
	MEDIUM	13	EQ X	3.985	0.161	0.002	3.988	0.000	-0.000	-0.000
	HARD	13	EQ X	3.172	0.130	0.001	3.175	0.000	-0.000	-0.000
SPRING	SOFT	13	EQ X	104.314	31.113	0.002	108.855	0.000	-0.000	-0.005
	MEDIUM	13	EQ X	19.432	5.894	0.002	20.306	0.000	-0.000	-0.001
	HARD	13	EQ X	1.959	0.402	0.001	1.999	0.000	-0.000	-0.000

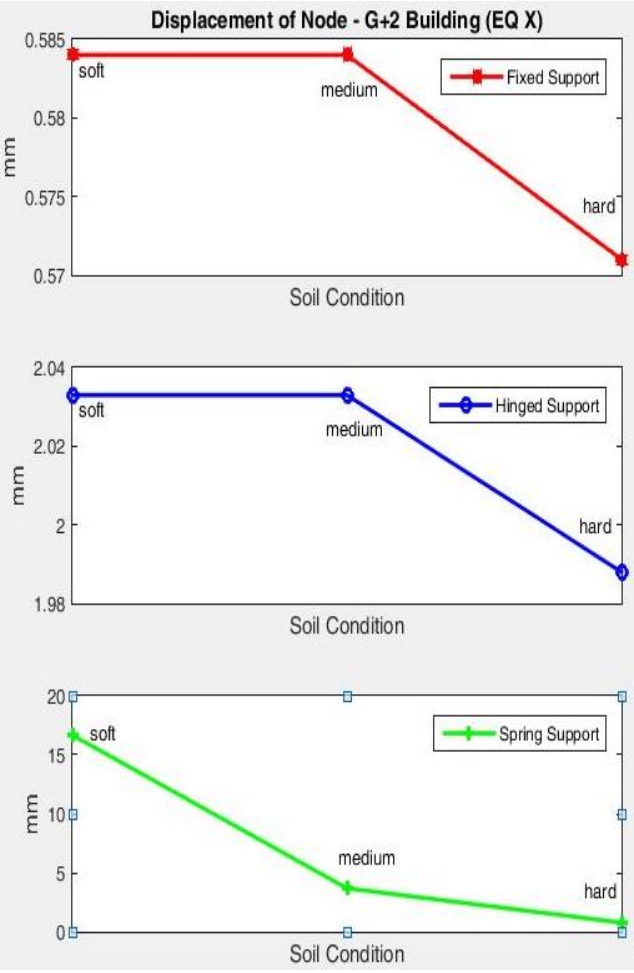


Chart 2.Displacement of Node- G+2 Building(EQ X)

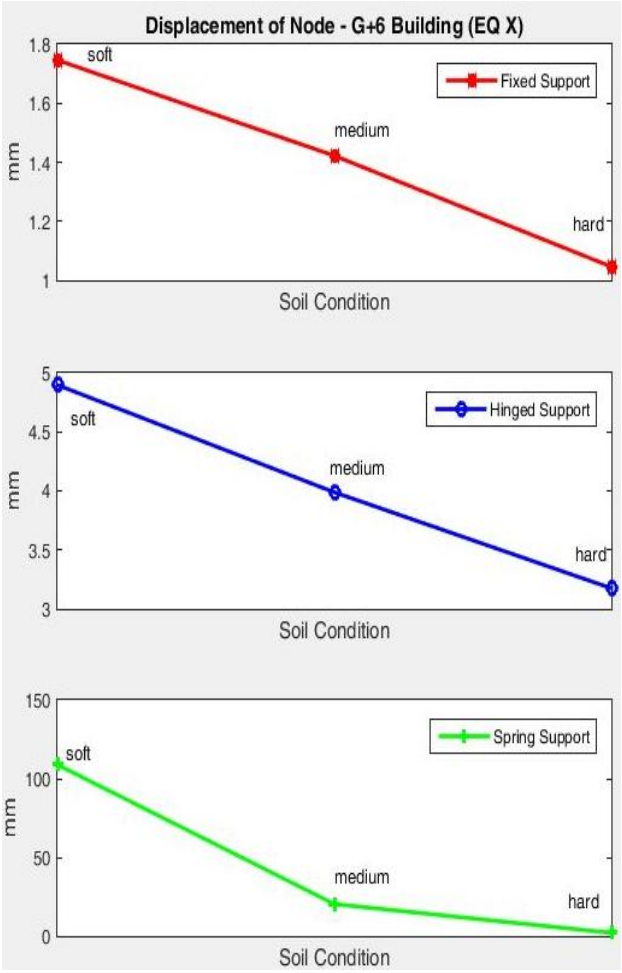


Chart 3.Displacement of Node- G+6 Building(EQ X)

Displacement of Node is represented graphically in chart 2 and 3 for G+2 and G+6 Building respectively. From the chart it is clear that in case of soft soil with spring support its displacement value is quit high compared to fixed support .

Table16. Displacement at Node - G+12 Building (EQ X)

SUPPORT	SOIL TYPE			Horizontal	Vertical	Horizontal	Resultant	ROTATIONAL		
		Node	L/C	X In mm	Y In mm	Z In mm	In mm	Θ_X rad	Θ_Y rad	Θ_Z rad
FIXED	SOFT	13	EQ X	5.279	0.677	0.002	5.322	0	0	-0.000
	MEDIUM	13	EQ X	4.299	0.552	0.002	4.334	0	0	-0.000
	HARD	13	EQ X	3.161	0.406	0.001	3.187	0	0	-0.000
HINGED	SOFT	13	EQ X	9.499	0.711	0.002	9.525	0	0	-0.000
	MEDIUM	13	EQ X	7.590	0.567	0.002	7.611	0	0	-0.000
	HARD	13	EQ X	5.581	0.417	0.001	5.597	0	0	-0.000
SPRING	SOFT	13	EQ X	511.960	81.005	0.002	518.329	0	0	-0.014
	MEDIUM	13	EQ X	97.125	15.473	0.002	98.350	0	0	-0.003
	HARD	13	EQ X	7.889	1.165	0.001	7.974	0	0	-0.000

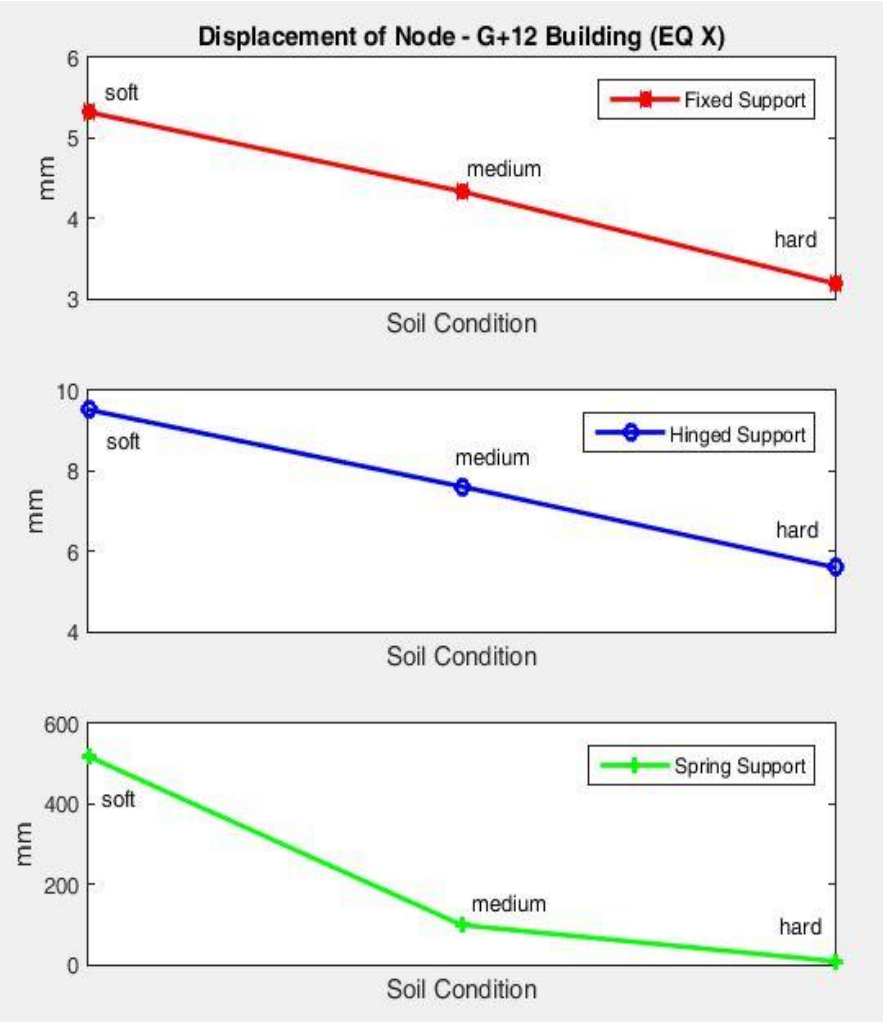


Chart 4. Displacement of Node- G+12 Building (EQ X)

Displacement at Node is presented in table 16 for G+12 Building. Displacement variation is plotted in Chart 4 for different support and soil condition. From the chart it is clear that in case of soft soil with spring support its displacement value is quit high compared to fixed support.

IX. CONCLUSION

Present Analysis investigates the effect of soil structure interaction on the structural behavior of a building during an earthquake of G+2, G+6 and G+12 Storey Building. Following observations were made during the analysis.

1. Moment value's along Z direction was high as compared with Fixed and Spring Support, Soil Type – Soft and Medium.
2. Displacement at Node Increases exponentially as the Storey Height increases in case of Medium and soft soil – Spring Support.
3. For high rise building resting on soft, medium Soil. Soil Structure Interaction has to be considered in the analysis for safe design.
4. Structure built in location's which belongs to earthquake zone - 3, 4 and 5. Soil Structure Interaction Should be considered in the analysis for safe design.

REFERENCES

[1.] Mr S.K. Musande, Prof. V.P. Kumbhar, Prof. A.H. Kumbhar -" Soil Structure Interaction (Pump house) for Bending Moment" [Vol-2, Issue-5 May- 2016].
[2.] Venkatesh M. B., R. D. Deshpande -" Analysis of R.C. building frame with raft foundation considering soil structure interaction"- [Volume: 04 Issue: 05 | May -2017].
[3] Nirav K Parmar, Prof. Paresh kumar G Patel-" Parametric Study Of Soil-Structure Interaction On G+6 Storey Building For Different Soil Condition" [Volume 5, Issue 05, May -2018]
[4] Meghna Modi, Noopur Shah-" Raft Foundation with SSI and without SSI Effects on Different Storey" [Volume 4, Issue 2 2016 IJEDR].
[5] S.R.K.Reddy, et al, "Terrain evaluation and influence of soil-structure interaction on seismic response of structures in urban environs" proc of 3rd International conference (2006)Venice, Italy, pp235-242.
[6] Whiteman. R.V, Richart.F.E, "Design procedure for dynamically loaded foundations" journal of soil mechanics and foundation engg., Division, ASCE 93, 1967, pp167-191.

