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SEISMIC BEHAVIOUR OF BUILDINGS ON DIFFERENT TYPES OF SOIL

Ketan Bajaj* PG Student, S.V. National Institute of Technology,16ketan1990@gmail.com
Jitesh T Chavda PG Student, S.V. National Institute of Technology, jiteshchavda03@yahoo.in
Bhavik M Vyas PG Student, S.V. National Institute of Technology, bhavik_vyas05@yahoo.in

Abstract: - Buildings are subjected to different earthquake loading and behaves differently with diversification in the types of soil condition, such as dense soil, medium and soft soil. Different soil properties can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts with the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure. As the seismic waves transfer from the ground which consist of alteration in soil properties and performs differently according to soil's respective properties. In this study, different soil strata are taken and corresponding base shear and lateral displacement is determined with variation in floors as G+4, G+5 and G+6 and zone as 3, 4 and 5. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft. A building is modeled in SAP-2000 having different Winkler's springs as its foundation corresponding to different soil properties. This research has immense benefits in the Geotechnical Earthquake engineering field.

INTRODUCTION

Vibrations which disturb the earth's surface caused by waves generated inside the earth are termed as earthquakes. It is said that earthquakes will not kill the life of human but structures which are not constructed in considering the earthquake forces do. At present a major importance has given to earthquake resistant structures in India for human safety. India is a sub-continent which is having more than 60% area in earthquake prone zone. A majority of buildings constructed in India are designed based on consideration of permanent, semi-permanent, movable loads. But earthquake is an occasional load which leads to loss of human life but also disturbs social conditions of India. The extent to which the structural response changes the characteristics of earthquake motions observed at the foundation level depends on the relative mass and stiffness properties of the soil and the structure. Thus the physical property of the foundation medium is an important factor in the earthquake response of structures supported on it.

The estimation of earthquake motions at the site of structure is most important phase of design of the structure. It is assumed that the motion in foundation level of equal structure is to ground free field motion. This assumption is correct only for the structures constructed on rock or very stiff soil. For the structures constructed on soft soil, foundation motion is usually different from the free field motion and a rocking component caused by the support flexibility on horizontal motion of foundation is added.

Anand et al [1] studied the seismic behaviour of RCC buildings with and without shear wall under different soil conditions. Lateral displacement, Base shear, axial force and Moment in the column value increases when the type of soil changes from hard to medium and medium to soft for all the building frames. It was concluded that the soil structure interaction must be suitably considered while designing frames for seismic forces. Pandey et al [2] studied the seismic soil-structure interaction of buildings on hill slopes. It was found that response reduction factor decreases with increasing time period, but it was expected to be constant beyond a certain value of time period.

Jenifer Priyanka et al [3] studied the effect of lateral force on tall buildings with different type of irregularities. It was found that building with soft soil gives more deflection as compared to medium and hard soil for all types of building. Building with stiffness irregularity gives more deflection as compared to other type of buildings with different irregularity. Constantinou and Kneifati [4] proposed an energy method to estimate the damping of seismically isolated structure, taking into account the energy dissipation of the bearing and the radiation damping in the soil. Novak and Henderson [5] investigated the modal properties of base-isolated structures and concluded that, when the flexibility of soil and isolators are comparable, the contribution of SSI should not be ignored. Kelly [6, 7] carried out an experimental study concerning base-isolated nuclear facilities founded on soft-sites, led to the conclusion that the isolator design should be taken into the account for significant displacement demands. Spyrakos and Vlassis [8] assessed the effects of SSI on the response of base-isolated bridges by a parametric study. They derived analytical expressions to demonstrate the significance of SSI phenomena in influencing the response of the isolated system. Tsai et al. [9] developed a time-domain procedure to investigate the efficiency of isolators to reduce the energy imported in an FPS-isolated building for earthquake motion. Both radiation damping and foundation flexibility were found to be essential in the accuracy of response prediction and safety of the isolated structure. Spyrakos and Maniatakis [10] studied on effects of soil-structure interaction on the response of base-isolated 4-DOF located on an elastic soil layer overlying rigid bedrock and subjected to a harmonic ground motion. Initially, a four degree of freedom system was developed and the equations of motion were formulated in the frequency domain. Frequency independent expressions were used to determine the stiffness and damping coefficients for the rigid surface foundation on the soil stratum underlined by bedrock at shallow depth.

India having different soil conditions and different earthquake intensity places with more than 60% area is prone to earthquakes, should develop earthquake resistant structures in consideration to IS:1893(part: I):2002. India classified into 4 seismic zones namely zone II, III, IV, V, having different types of soils which increases the importance of understanding of effect of base shear in consideration to various types of soils in same zone also. Response of structures to earth's surface vibrations is a function of type of soil available at site conditions. Response acceleration coefficient (S/g) for 5% damping is calculated for rock, medium, soft soils. Zone factor value indicates expected intensity of earthquake in different seismic zones.

When a structure is subjected to an earthquake excitation, it with interacts the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure. As the seismic waves transfer from the ground which consist of alteration in soil properties and performs differently according to soil's respective properties. In this study, different soil strata are taken and corresponding base shear and lateral displacement is determined with variation in floors as G+4, G+5 and G+6 and zone as 3, 4 and 5. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft. A building is modelled in SAP-2000 having different Winkler's springs as its foundation corresponding to different soil properties. This research has immense benefits in the Geotechnical Earthquake engineering field.

METHODOLOGY

Analysis of building is done using SAP2000, which is general-purpose civil-engineering software ideal for the analysis and design of any type of structural system. Basic and advanced systems, ranging from 2D to 3D, of simple geometry to complex, may be modeled, analyzed, designed, and optimized using a practical and intuitive object-based modeling environment that simplifies and streamlines the engineering process.

Table1 Buildings specifications for analysis

Building Name	No. of stories	Type of soil	Seismic zone
B11	4	Hard	III
B12		Medium	
B13		Soft	
B14	4	Hard	IV
B15		Medium	
B16		Soft	
B17	4	Hard	V
B18		Medium	
B19		Soft	
B21	5	Hard	III
B22		Medium	
B23		Soft	
B24	5	Hard	IV
B25		Medium	
B26		Soft	
B27	5	Hard	V
B28		Medium	
B29		Soft	
B31	6	Hard	III
B32		Medium	
B33		Soft	
B34	6	Hard	IV
B35		Medium	
B36		Soft	
B37	6	Hard	V
B38		Medium	
B39		Soft	
Common Configuration			
Height of each floor			3.5 m
Imposed Load			2 KN/m^2
Response spectra, Damping factor, Importance factor, Response Reduction factor			As per IS 1893 (Part 1)-2002

Multi storied building with fixed and flexible base subjected to seismic forces were analyzed under different soil condition like hard, medium and soft. The buildings were analyzed using Response spectrum method using software SAP-2000. Seismic analysis was carried out by following IS1893:2002-PartI. Different response results were found for fixed and flexible base buildings as shown in table 1

Table 2 and 3 shows the value of Elastic properties of foundation soil and soil stiffness in lateral (x & z) and vertical (y) direction

Table 2 Elastic Properties of Foundation Soil

Type of Soil	Shear Modulus G (KN/m^2)	Elastic Modulus E (KN/m^2)	Poisson's Ratio ν
Hard	2700	6750	0.25
Medium	451.1	1200	0.33
Soft	84.5	250	0.48

Table 3 Soil Stiffness values for buildings with Flexible base

Type of Soil	Soil Stiffness (kN/m)		
	K_x	K_y	K_z
Hard	8000	100000	8000
Medium	4000	50000	4000
Soft	1500	25000	1500

RESULT AND DISCUSSION

G+4, G+5 and G+6 building frames with fixed and flexible base analyzed in SAP-2000 shown in figure 1 to understand the behavior under seismic forces with different soil conditions and different zones. Various seismic responses were compared for all types of building frames.

All the 54 buildings are analyzed in the software SAP-2000 with the configuration as shown in table 1 and the result of all the them are disused below with respect to the base shear and lateral deflection and with bending moment and axial force. It has been seen from figure two that for G+6 building on hard soil the flexible foundation is having 46.44 increments in the lateral deflection of the roof.

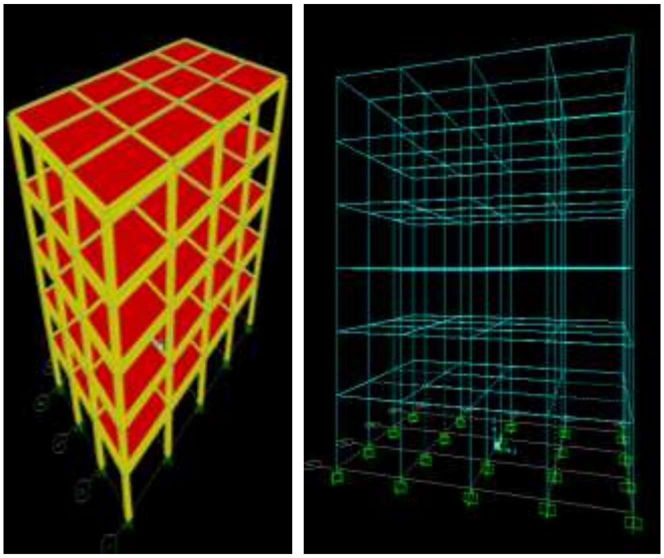

Fig. 1 Frame of G+4 and G+5 building

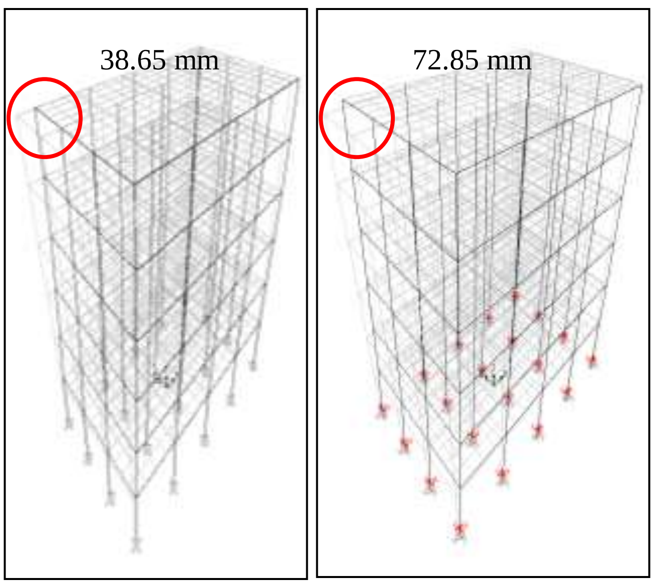

Fig. 2 Lateral deflection of G+6 building on hard soil with fixed and flexible base

Table 4 Lateral Deflection of building on fixed and flexible foundation

Building Name	Lateral Deflection (mm)	
	Fixed base	Flexible base
B11	21.04	75.85
B12	28.26	89.58
B13	37.85	160.26
B14	23.58	82.52
B15	32.58	95.28
B16	40.87	174.58
B17	26.45	61.07
B18	36.09	102.84
B19	43.47	182.58
B21	28.98	61.25
B22	41.87	91.47
B23	55.36	168.25
B24	30.25	62.35
B25	44.58	100.58
B26	58.85	180.25
B27	33.56	68.58
B28	48.69	111.28
B29	60.25	192.58
B31	33.58	58.25
B32	51.25	85.25
B33	65.28	165.28
B34	35.28	65.28
B35	55.25	102.58
B36	68.25	188.25
B37	38.65	72.85
B38	58.47	120.58
B39	72.85	205.25

It has been seen from the table 2 with the change in zone and soil the lateral load varies extensively. As seen from B11, B12 and B13 with the change in soil property from hard to medium and from hard to soft the lateral deflection has increased by 53.33 and 60.25% respectively for flexible base, similar pattern has seemed in the building B21, B22 and B23 and B31, B32 and B33. In case of flexible foundation, on comparing B31, B34 and B37 i.e. change in zone from III too IV and from III to V with same hard soil the deflection has increased by 12.07% and 24.72% respectively for the same type of symmetric building.

It has been seen from the figure 3 that with the change in zone and soil the base shear varies extensively. As seen from B24, B25 and B26 with the change in soil property from hard to medium and from hard to soft the base shear has increased by 26.85% and 43.25% respectively for flexible base, similar pattern has seemed in the building B14, B15 and B6 and B34, B35 and B36. But as if we compared the same for zone V and zone 3, the base shear has increased approximately same. In case of flexible foundation, on comparing B21, B24 and B27 i.e. change in zone from III too IV and from III to V with same hard soil the deflection has increased by 10.68% and 21.53% respectively for the same type of symmetric building. Similar change is seemed in case of soft and medium soil for different story of building.

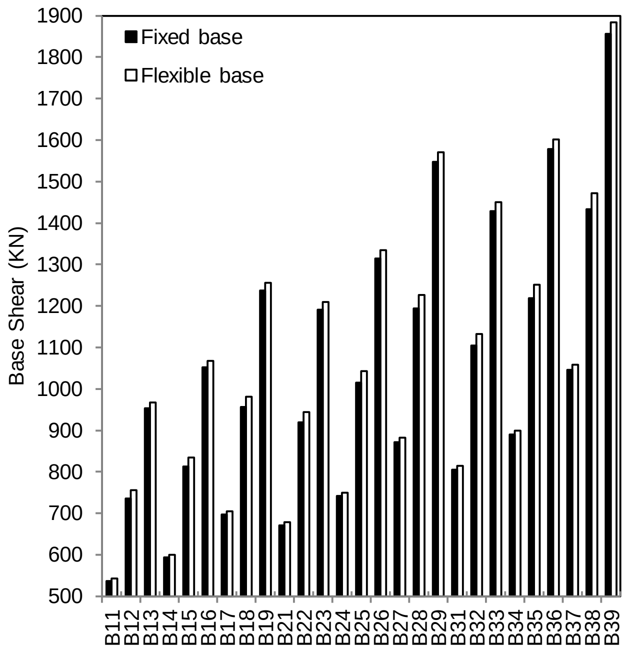

Fig. 3 Change in base shear of buildings

It has been seen from the figure 4 and 5 that with the change in zone and soil the story drift varies extensively. As seen from B37, B38 and B39 with the change in soil property from hard to medium and from hard to soft the base shear has increased by 18.25% and 25.36% respectively for flexible base, similar pattern has seemed in the building B17, B18 and B9 and B27, B28 and B29. But as if we compared the same for zone V and zone 3, the base shear has increased approximately same. In case of flexible foundation, on comparing B21, B24 and B27 i.e. change in zone from III too IV and from III to V with same hard soil the deflection has increased by 10.68% and 21.53% respectively for the same type of symmetric building. Similar change is seemed in case of soft and medium soil for different story of building.

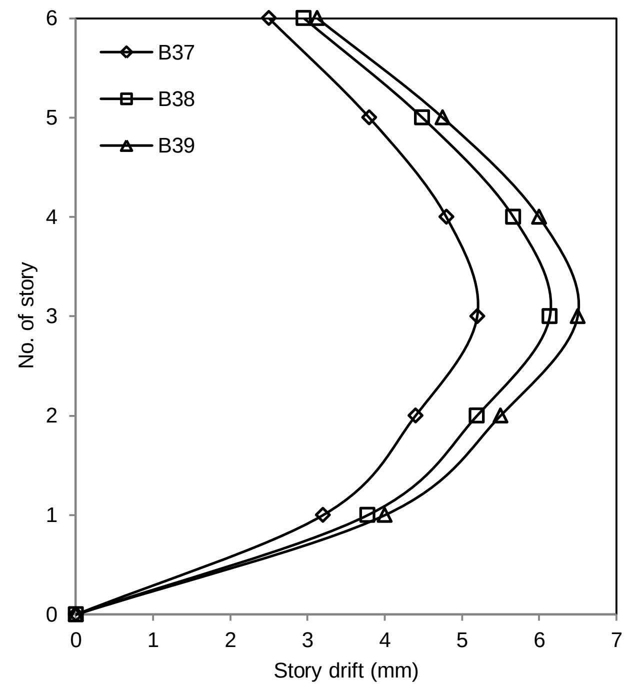

Fig. 4 Story drifts for building B37, B38 and B39

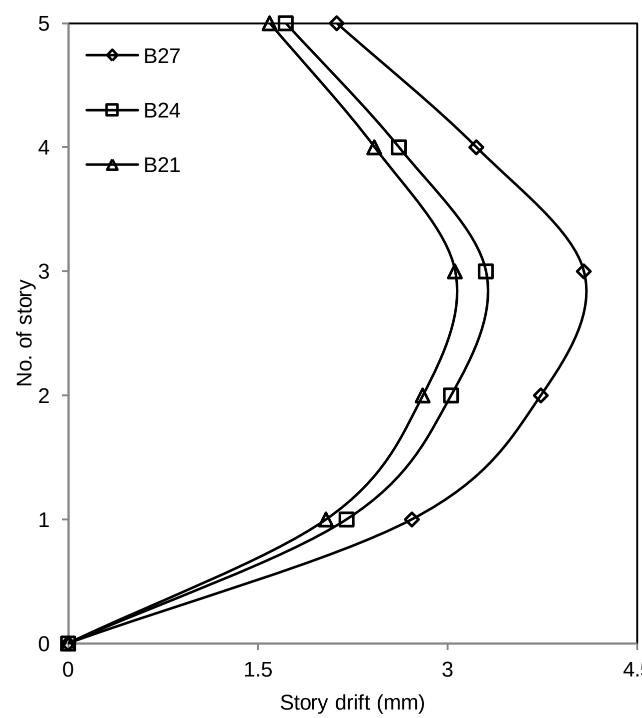

Fig. 5 Story drifts for building B37, B38 and B39

CONCLUSION

The following conclusion has been found from the present study are:-

All the 54 buildings are analyzed in the software SAP-2000 with the configuration as shown in table 1 and the result of all them are with respect to the base shear, story drift and lateral deflection. It has been seen that with the change in zone and soil the lateral load varies extensively. With the change in soil property from hard to medium and from hard to soft the lateral deflection has increased by 53.33 and 60.25% respectively for flexible base. In case of flexible foundation with change in zone from III too IV and from III to V with same hard soil the deflection has increased by 12.07% and 24.72% respectively for the same type of symmetric building.

It has been seen with the change in soil property from hard to medium and from hard to soft the base shear has increased by 26.85% and 43.25% respectively for flexible base. But as if we compared the same for zone V and zone III, the base shear has increased approximately same. In case of flexible foundation, with the change in zone from III too IV and from III to V with same hard soil the deflection has increased by 10.68% and 21.53% respectively for the same type of symmetric building. Similar change is seemed in case of soft and medium soil for different story of building. It has been found that with the change in soil property from hard to medium and from hard to soft the base shear has increased by 18.25% and 25.36% respectively for flexible base; similar pattern has seemed in the building. It has also concluded that change in zone from III too IV and from III to V with same hard soil the deflection has increased by 10.68% and 21.53% respectively for the same type of symmetric building. Similar change is seemed in case of soft and medium soil for different story of building.

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