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Studies on Soil Structure Interaction of Multi Storeyed Buildings with Rigid and Flexible Foundation

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***Abstract*— Though the structures are supported on soil, most of the designers do not consider the soil structure interaction and its subsequent effect on structure during an earthquake. 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 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. Tall buildings are supposed to be of engineered construction in sense that they might have been analyzed and designed to meet the provision of relevant codes of practice and building bye-laws. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft. An attempt has been made in this paper to study the effect of Soil-structure interaction on multi storeyed buildings with various foundation systems. Also to study the response of buildings subjected to seismic forces with Rigid and Flexible foundations. Multi storeyed buildings with fixed and flexible support subjected to seismic forces were analyzed under different soil conditions like hard, medium and soft. The buildings were analyzed by Response spectrum method using software STAAD Pro. The response of building frames such as Lateral deflection, Storey drift, Base shear, Axial force and Column moment values for all building frames were presented in this paper.**

***Keywords*— Base shear, Fixed base, Flexible base, Soil stiffness, Storey drift**

I. Introduction

As waves from an earthquake reach a structure, they produce motions in the structure. These motions depend on the structure's vibrational characteristics and the layout of structure. For the structure to react to the motion, it needs to overcome its own inertia force, which results in an interaction between the structure and the soil. 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 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).

II. Review Of Literature

Anand et al (2010) studied the seismic behaviour of RCC buildings with and without shear wall under different soil conditions. One to fifteen storeyed space frames with and without shear wall were analyzed using ETABS software for different soil conditions (hard, medium, soft). The values of Base shear, Axial force and Lateral displacement were compared between two frames. 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 (2011) studied the seismic soil-structure interaction of buildings on hill slopes. Static pushover analysis and response spectrum analysis (RSA) was conducted on five buildings i.e. three step back buildings and two step back-set back buildings with varying support conditions. These buildings had been analyzed for different soil conditions (hard, medium and soft soils) using SAP2000 software idealized by equivalent springs. The response parameters, i.e. total base shear (V), displacement from pushover analysis (δ performance point), displacement from RSA (δ elastic) and response correction factor (R) had been studied with respect to fixed base analysis to compare the effect of soil springs. In general 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.

Amin et al (2011) studied the effect of soft storey on multi storeyed reinforced concrete building frame. Four building models (3, 6, 9 and 12 storey) with identical building plan were considered to investigate the effect of soft storey for multistoried reinforced concrete building frame.

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Equivalent diagonal struts were provided in place of masonry to generate infill effect. Earthquake load was provided at each diaphragm's mass centre as a source of lateral load. Soft storey level was altered from ground floor to top floor for each model and equivalent static analysis was carried out using ETABS software. Inter-storey drift ratio was found increasing below the mid storey level and maximum ratio was obtained where the soft storey was located. The rate of increase in drift ratio at any particular floor (kept soft) for different building height increases linearly from bottom to top floor. Results showed a general changing pattern in lateral drift irrespective to building height and location of soft storey.

Jenifer Priyanka et al (2012) studied the effect of lateral force on tall buildings with different type of irregularities**.** An attempt made in this study to understand the behavior of tall buildings subjected to lateral forces for different soil conditions. Ten Storied building with various spacing of columns such as 2.5m, 4m and 5m of buildings with different irregularities like Vertically irregular, Mass irregular and Stiffness irregular, were analyzed using the software STAAD Pro. The top storey lateral deflection due to seismic load of these buildings was compared with regular building configuration for different soil conditions. 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.

III. METHODOLOGY

Multi storeyed 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 STAAD Pro.

Seismic analysis was carried out by following IS1893:2002-PartI. Different response results were found for fixed and flexible base buildings.

A. Input- data

Size of the building 30m X 30m, Type of structure : RCC Multi storey frames, Seismic zone V , Response reduction factor - 3, Importance factor – 1 , Height of the building- 40m, No of storey–10, Height of floor – 4m, Imposed load – 4 kN/m^2, Materials – M25(beam), M30(column), Fe415, Depth of the slab – 150mm, Unit weight of RCC – 25kN/m^3, Type of soil – Hard , Medium and Soft, Response spectra – IS 1893(Part I) 2002 , Damping 5% , Depth of foundation - 1.5m, Wall thickness-230mm.

Table I shows the value of Soil stiffness in lateral (x & z) and vertical (y) direction

TABLE I
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

IV. ANALYSIS OF RESULTS

Ten storeyed building frames with fixed and flexible base analyzed and designed to understand the behavior were under seismic forces. Various seismic responses were compared for both the type of building frames.

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Fig.1 shows the lateral deflection of building frames subjected to seismic forces

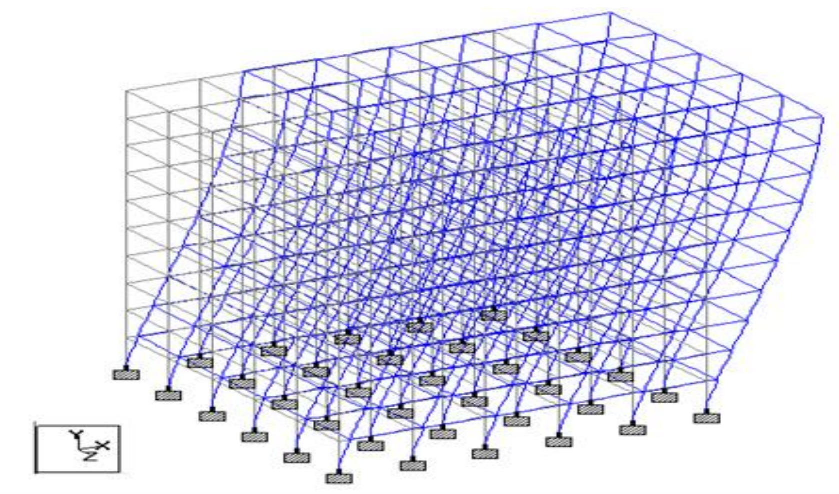

Fig 1 Lateral Deflection of a Building Frame with Fixed Base

Fig.2 shows the distribution of seismic forces throughout the height of the building frame

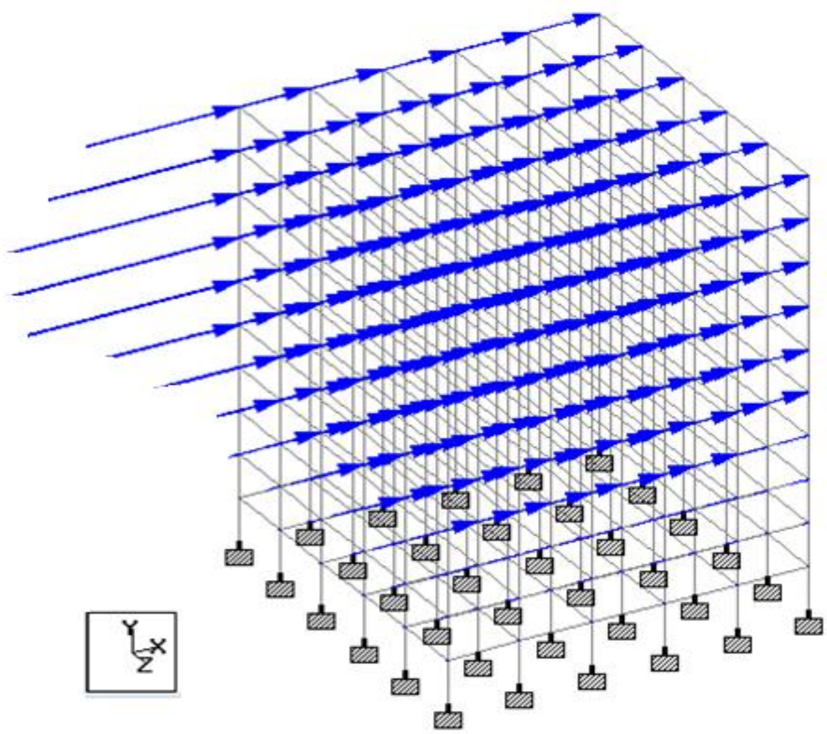

Fig 2 Seismic Loading of a Building Frame with Fixed Base

Table II shows the values of Lateral deflection of building frames with fixed base for different soil condition.

TABLE II
LATERAL DEFLECTION VALUES OF BUILDING WITH FIXED BASE

Storey	Lateral Deflection (mm)		
	Hard soil	Medium soil	Soft soil
Tenth	58.93	79.19	96.72
Ninth	56.60	76.12	93.05
Eighth	52.92	71.17	87.01
Seventh	48.01	64.55	78.89
Sixth	42.15	56.61	69.15
Fifth	35.56	47.69	58.22
Fourth	28.45	38.09	46.47
Third	21.03	28.09	34.23
Second	13.46	17.90	21.78
First	5.98	7.88	9.54

Table III shows the values of Storey drift of building frames with fixed base for different soil condition.

TABLE III
STOREY DRIFT VALUES OF BUILDING WITH FIXED BASE

Storey	Storey Drift (mm)		
	Hard soil	Medium soil	Soft soil
Base	0	0	0
First	5.10	6.94	8.52
Second	7.38	10	12.33
Third	7.60	10.34	12.69
Fourth	7.48	10.18	12.49
Fifth	7.19	9.77	12
Sixth	6.69	9.11	11.18
Seventh	5.98	8.13	9.99
Eighth	5	6.80	8.35
Ninth	3.72	5.06	6.22
Tenth	2.18	2.97	3.65

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Table IV shows the values of Lateral deflection of building frames with flexible base for different soil condition

TABLE IV
LATERAL DEFLECTION VALUES OF BUILDING WITH FLEXIBLE BASE

Storey	Lateral Deflection (mm)		
	Hard soil	Medium soil	Soft soil
Tenth	92.27	131.38	218.76
Ninth	89.97	128.62	214.63
Eighth	86.48	124.31	208.56
Seventh	81.88	118.88	201.14
Sixth	76.45	112.64	192.79
Fifth	70.44	105.91	183.87
Fourth	64.07	98.95	174.76
Third	57.50	92.01	165.70
Second	50.85	85.19	156.82
First	43.88	78.46	147.92

Table V shows the values of Storey drift of building frames with flexible base for different soil condition.

TABLE V
STOREY DRIFT VALUES OF BUILDING WITH FLEXIBLE BASE

Storey	Storey Drift (mm)		
	Hard soil	Medium soil	Soft soil
Base	0	0	0
First	16.25	18.77	26.47
Second	8.54	11.13	15.45
Third	7.47	9.75	13.62
Fourth	7.19	9.33	13.12
Fifth	6.89	8.94	12.62
Sixth	6.43	8.36	11.89
Seventh	5.77	7.55	10.83
Eighth	4.87	6.44	9.40
Ninth	3.71	5.02	7.56
Tenth	2.35	3.41	5.43

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Table VI shows different responses of buildings with fixed and flexible base for various soil condition

TABLE VI
COMPARISON OF RESPONSES OF BUILDING FRAME WITH FIXED AND FLEXIBLE BASE UNDER DIFFERENT SOIL CONDITION

	Fixed base			Flexible base		
	Hard soil	**Medium soil**	**Soft soil**	**Hard soil**	**Medium soil**	**Soft soil**
Lateral deflection (mm)	58.93	79.19	96.72	92.27	131.38	218.76
Storey drift (mm)	7.38	10	12.33	16.25	18.77	26.47
Base shear (kN)	1744.16	2391.97	3093.24	1763.33	2452.24	3140.66
Axial force (kN)	5640	5770	5810	5520	5330	5120
Column moment (kNm)	103.54	133.59	151.95	218.23	316.86	393.99
Seismic weight (kN)	71190.54	71831.44	75629.53	71972.79	73640.94	76788.80

Fig.3 shows the variation in Lateral deflection of buildings with fixed and flexible base for different soil conditions

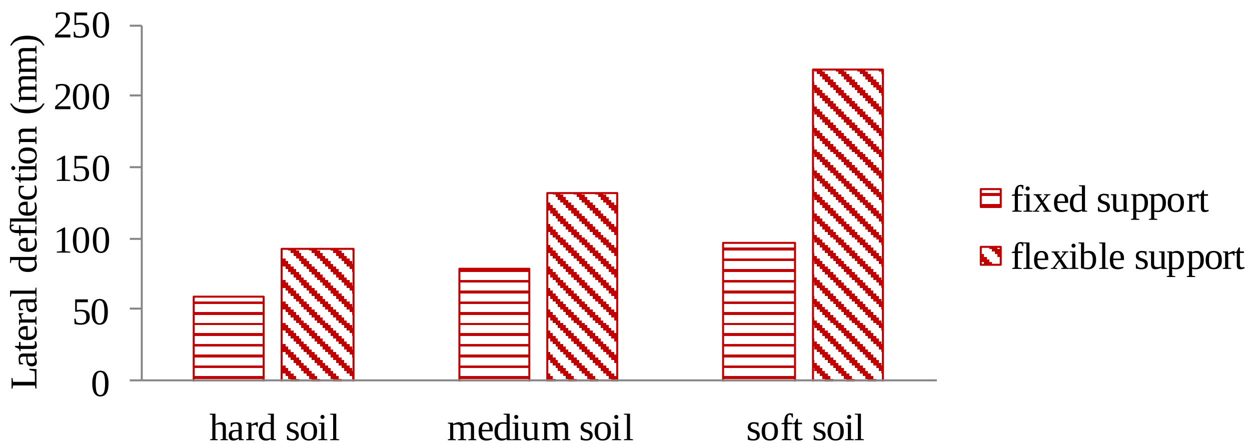

Fig.3 Comparison of Lateral Deflection of Buildings with Fixed and Flexible Base for Different Soil Condition

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Fig.4 shows the variation in Storey drift of buildings with fixed and flexible base for different soil conditions

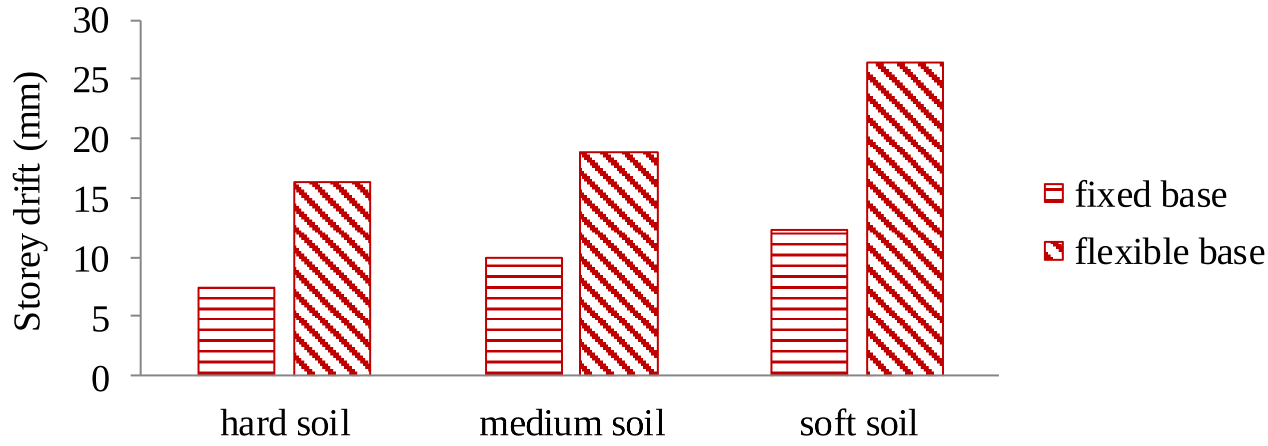

Fig.4 Comparison of Storey Drift of Buildings with Fixed and Flexible Base for Different Soil Condition

Fig.5 shows the variation in Base shear of buildings with fixed and flexible base for different soil conditions

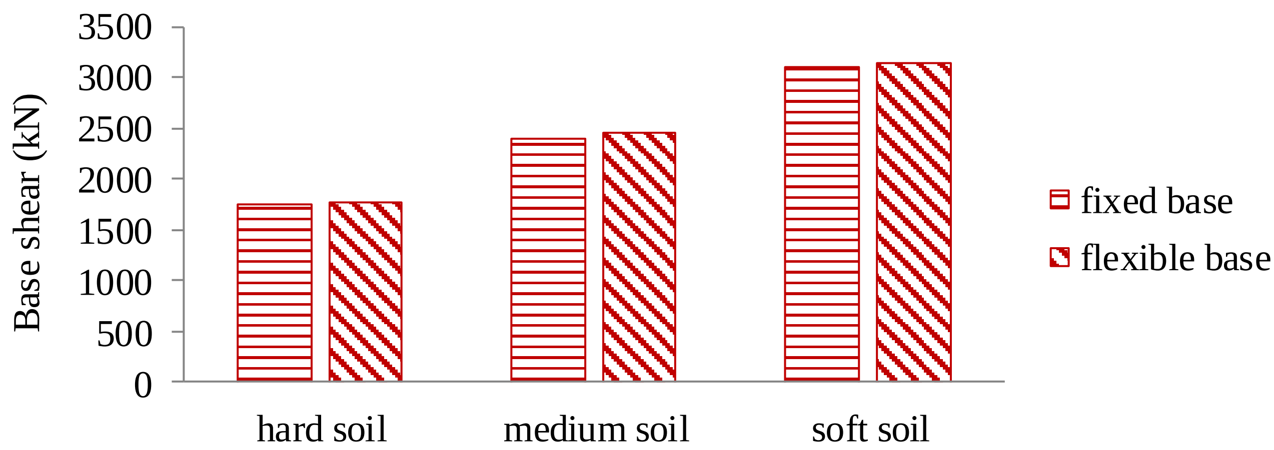

Fig.5 Comparison of Base Shear of Buildings with Fixed and Flexible Base for Different Soil Condition

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Fig.6 shows the variation in Column moment of buildings with fixed and flexible base for different soil conditions

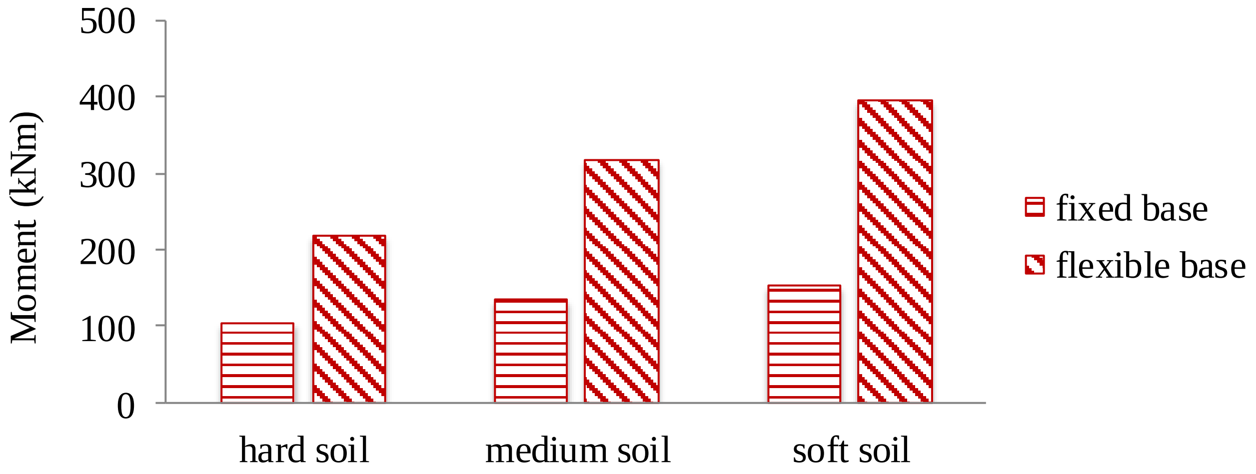

Fig.6. Comparison of Column Moment of Building Frames with Fixed and Flexible Base under Different Soil Condition

It can be seen from the figures (Fig.3, Fig.4, Fig.5 and Fig.6) that the Lateral deflection, Storey drift, Base shear and Column moment values found to be higher for building with soft soil. These response values are higher for building with flexible base.

V. CONCLUSION

Multi storeyed building frames with fixed and flexible base subjected to seismic forces were analyzed and designed for different soil conditions. The seismic response of the building frames such as Lateral deflection, Storey drift, Base shear and Moment values were compared for both type of building frames. Lateral deflection, Storey drift, Base shear and Moment values increases when the type of soil changes from hard to medium and medium to soft for fixed and flexible base buildings. Lateral deflection, Storey drift, Base shear and Moment values of fixed base building was found to be lower as compared to flexible base building. Hence suitable foundation system considering the effect of Soil stiffness has to be adopted while designing building frames for seismic forces.

REFERENCES

[1] Wolf, J.P, Prentice Hall, Englewood Cliffs, N.J., 1985. Soil-Structure Interaction

[2] Anand, N. and Mightraj, C. 2010. Seismic behavior of rcc shear wall under different soil conditions. In Proceedings of the Indian Geotechnical Conference on GEOtrendz

[3] A.D. Pandey, Prabhat Kumar and Sharad Sharma "Seismic soil-structure interaction of buildings on hill slopes", Journal of Civil and Structural Engineering, 2011.

[4] Amin, M.R. and Hasan, P. 2011. Effect of storey on multistoried reinforced concrete building frame. In Proceedings of 4th Annual Paper Meet and 1st Civil Engineering Congress

[5] Jenifer Priyanka, R.M. and Anand, N. 2012. Effect of lateral force on tall buildings with different type of irregularities. In Proceedings of the INCACMA Conference on Advances in Construction, Manufacturing and Automation Research

[6] IS 1893 (Part 1)-2002: Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1–General Provisions and Buildings (Fifth Revision), Bureau of Indian Standards, New Delhi.

[7] IS 456 – 2000: Indian standard Criteria for Plain and Reinforce Structure, New Delhi.