Evaluation of soil-structure interaction for structures subjected to earthquake loading with different types of foundation

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Abstract. However 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 SAP2000. The response of building frames such as Lateral deflection, Story drift, Base shear, Axial force and Column moment values for all building frames were presented in this paper.

1 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) [1].

2 Literature review

Anand and Mightraj [2] studied the seismic behavior of RCC buildings with and without shear wall under different soil conditions. One to fifteen storied 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. [3] 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 and Hasan [4] studied the effect of soft soils on multi-storey reinforced concrete building frame. Four

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building models (3, 6, 9 and 12 storey) with identical building plan were considered to investigate the effect of soft soil for multistoried reinforced concrete building frame.

3 Procedure

Multi storeyed building with fixed and flexible base subjected to seismic forces were analysed under different soil conditions like hard, medium and soft. The buildings were analysed using response spectrum method by the software SAP2000 Expert. Seismic dissection might have been conveyed crazy eventually Tom's perusing accompanying IS1893:2002-PartI [6]. Diverse reaction outcomes were found.

3.1 Input- information

Measure of the building 30m X 30m, sort from claiming structure : RCC Multi story frames, seismic zone v , reaction decrease variable - 3, essentialness component – 1 , tallness of the building- 40m, no about storey–10, tallness from claiming floor – 4m, forced load – 4 kN/m², Materials – M25(beam), M30(column), Fe415, profundity of the piece – 150mm, unit weight for RCC – 25kN/m³, kind of soil – difficult , medium and soft, reaction spectra – may be 1893(Part I) 2002 , damping 5% , profundity of establishment - 1. 5m, divider thickness-230mm. Table 1 indicates the quality from claiming soil firmness in parallel (x, z and y) headings.

Table 1. 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

4 Analysis of results

Ten storeyed building frames with fixed and flexible base analysed and designed to understand the behaviour were under seismic forces. Various seismic responses were compared for both the type of building frames. Fig. 1 indicates the parallel redirection of fabricating frames subjected will seismic powers. Fig 1 parallel redirection of a building outline with settled Fig. 2 indicates the conveyance from claiming seismic powers all around those stature of the building frame.

Fig. 1. Parallel redirection of a building outline with altered base.

Fig. 2. Seismic stacking of a building outline with altered base.

Table 2 shows the values of Lateral deflection of building frames with fixed base for different soil condition.

Table 2. Lateral deflection of building frames 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 3 indicates the values for story float about fabricating frames with settled build to diverse dirt condition.

Table 3. Storey float qualities for fabricating with settled base.

Story	Story 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

Table 4 shows the values of Lateral deflection of building frames with flexible base for different soil condition

Table 4. 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 5 indicates the values for story float about fabricating frames with settled build to diverse dirt condition.

Table 5. Story float values about building with adaptable base.

Story	Story 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

Table 6 indicates diverse reactions from claiming edifices with altered Furthermore adaptable base to Different soil state.

Table 6. Examination of reactions about fabricating span for altered Furthermore adaptable base under diverse soil Condition for adaptable build.

Parameter	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

5 Conclusions

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.

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