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Seismic Analysis of R.C Building with Fixed and Flexible Base under Different Soil Conditions

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Abstract – Earthquakes have the potential to cause the greatest damages, among the other natural hazards. Earthquakes are maybe the most flighty and highly destructive of all the natural disasters. Structures are subjected to different earthquake loading, behaves differently with diversification in dense, medium and soft soil. Soil properties get affected drastically as seismic waves 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. In this study, different soil strata, with rigid and flexible base foundations types are illustrates and corresponding base shear and lateral displacement are determined with variation in floors as G+7, G+8 and G+9 for Earthquake Zones 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 using ETABS -2015 having different Winkler's springs as its foundation corresponding to different soil properties. To find out seismic performance of rigid and flexible to RCC building, parameters as Lateral displacement, Storey shear and Storey drift should be studied. It was found that by comparing the flexible base results with fixed base results, flexible base structure shows better seismic performance in all soil conditions.

Index Terms – Seismic Performance, Fixed Base, FlexibleBase, StoreyDrift, Storey Displacement.

1. INTRODUCTION

1.1 General

Earthquake is a form of energy of wave motion, which originates in a limited region and then spreads out in all directions from the source of disturbance. Seismic waves generated by an earthquake source are commonly classified into two main types. First, the P and S waves are propagated within the earth crust, while the secondary waves consisting of Love and Rayleigh waves, arepropagated along its surface. P waves are the first to reach any point on the earth's surface. 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. 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.

Many researchers have studied on different soil conditions. Anand [1] studied the seismic behaviour 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. Ketanbajaj [2] studied the 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 are determined with variation in floors as G+4, G+5 and G+6 for earthquake zones 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. Abuilding is modeled in SAP-2000 having different Winkler's springs as its foundation corresponding to different soil propertiesJenifer Priyanka[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.

1.2 Objective of the Project

The main objective of this project is

- 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 strata.
- To compare seismic performance of Fixed and Flexiblebase foundations in different seismic zones.
- To identify the resistance of seismic loads either fixed or flexible base

2. STRUCTURAL MODELLING AND ANALYSIS

For this study8-storey, 9-storey and 10-storey buildings with a 3.5-meters height for each storey, regular in plan is modeled. Building with fixed and flexible base subjected to seismic forces were analyzed under different soil condition like hard, medium and soft soil strata. The buildings were analyzed using Response spectrum method using software ETABS. These buildings were designed in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings

Description of the Building

The data of modelled buildings is given below

Plan dimension – 15 x 9 m

Structure - OMRF

No. of storeys- G + 7, G+8, G+9

Floor to floor height - 3.5 m

Type of building - Residential

Soil strata – hard, medium, soft

Material Properties

Grade of concrete - M25

Grade of steel - Fe 415

Density of concrete – 25kN/m^3

Density of brick - 19.20 kN/m^3

Modulus of elasticity of concrete –25KN/mm^2

Modulus of elasticity of steel - 2×10^5 N/mm^2

Geometric Properties of Components:

Beam section	:	300 mm X 450 mm
Column section	:	230 mm X 230 mm
Slab thickness	:	150 mm
External wall thickness	:	230 mm
Internal wall		110mm
Height of parapet wall	:	1.5m

Load Intensities

Dead load

Dead Weight of wall=14.72kN/m^2

Dead Weight of Internal wall =7.36kN/m^2 Dead Weight of parapet wall =4.6kN/m^2

Floor finish =1kN/m^2

Live load – 2kN/m^2

Load Combinations: Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.

1. 1.5(DL+LL)
2. 1.2(DL+LL±EQ-
3. 1.5(DL+LL)
4. 1.2(DL+LL±EQ-X)
5. 1.5(DL±EQ-Y)
6. 0.9DL±1.5EQ-X
7. 0.9DL±1.5EQ-Y

Response spectra – IS 1893(part 1) 2002

Seismic zone – III, IV, V

Depth of foundation - 1.5m

Type of soil -Hard, Medium and Soft.

Damping ratio - 5%

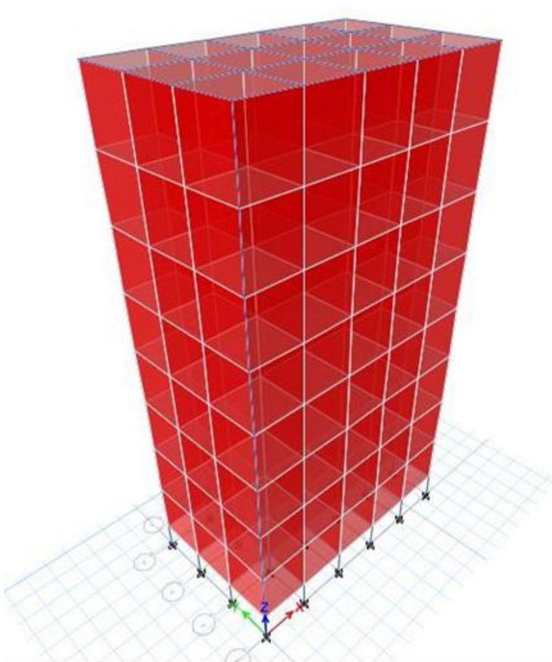
Multi storied building with fixed and flexible base subjected to seismic forces were analyzed under different soil condition viz hard, medium and soft soil strata. The buildings were analyzed using Response spectrum method using software ETABS software. Seismic analysis was carried out according to IS1893 (Part1.):2002. Different response results were found for fixed and flexible base buildings as shown in Table1 and Table2 shows the value of soil stiffness in lateral (x & z) and vertical (y) direction

Table1: Buildings specifications for analysis

Building name	No. of stories	Type of soil	Seismic zone
B11	8	Hard	III
B12		medium	
B13		Soft	
B14	8	Hard	IV
B15		medium	
B16		Soft	
B17	8	Hard	V
B18		medium	
B19		Soft	
B21	9	Hard	III
B22		medium	
B23		Soft	
B24	9	Hard	IV
B25		medium	
B26		Soft	
B27	9	Hard	V
B28		medium	
B29		Soft	
B31	10	Hard	III
B32		medium	
B33		Soft	
B34	10	Hard	IV
B35		medium	
B36		Soft	
B37	10	Hard	v
B38		Medium	
B39		soft	

Table 2: Soil Stiffness values for buildings with Flexible base

Type of Soil strata	Soil Stiffness (kN/m)		
	kx	ky	kz
Hard	8000	100000	8000
Medium	4000	50000	4000
Soft	1500	25000	1500



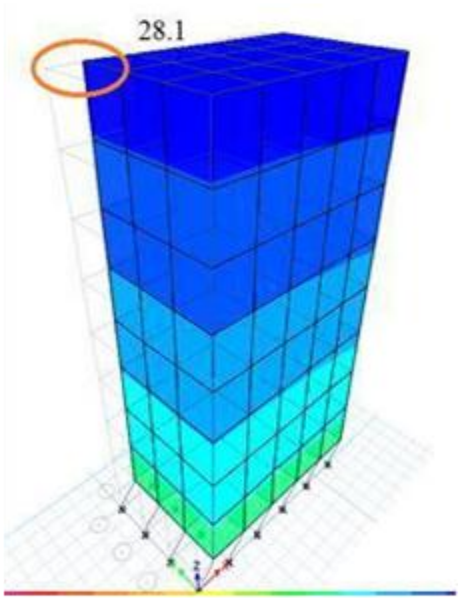


Fig.2A Lateral Deflection of G+7Storey Building on soft soil with fixed foundation

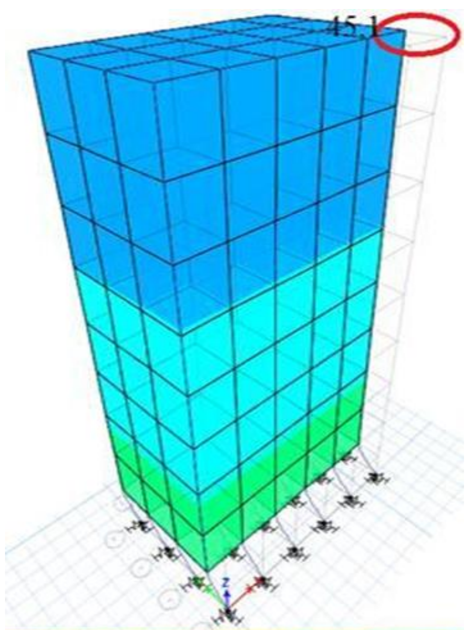


Fig.2B Lateral Deflection of G+7Storey Building on soft soil with flexible foundation

3. RESULTS AND DISCUSSION

8-storey 9-storey and 10-storeybuilding frames with fixed and flexible base analyzed in ETABs 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 ETABS with the configuration as shown in table 1 and the resultof all them are disused below with respect to the base shear, lateral deflection and storey drift.

3.1.1Storey Displacement

Table 3 LATERAL DEFLECTION OF BUILDING ON FIXED AND FLEXIBLE FOUNDATION

Buliding Name	Fixed base	Flexible base
B11	8.3	13.3
B12	11.3	16
B13	12.5	20
B14	12.5	18
B15	17	24.5
B16	18.7	30
B17	18.7	27
B18	25.4	36.7
B19	28.1	45.1
B21	9.5	13.2
B22	13	17.9
B23	15.7	22
B24	14.3	19.8
B25	19.5	26.9
B26	23.3	33
B27	21.5	29.7
B28	29.2	40.4
B29	35	49.6
B31	10.2	14.7
B32	14	19
B33	16.5	24.1
B34	15	21.7
B35	16.3	29.5

B36	27	36.2
B37	28.5	32.5
B38	32.5	44.2
B39	39.7	54.3

Table 4 LATERAL DEFLECTION IN MM OF BUILDING WITH FIXED BASE ZONE III (B11, B12, ANDB13)

Elevation (m)	Hard	Medium	Soft
29.8	8.3	11.3	12.5
26.3	7.8	10.7	11.8
22.8	7.4	10	11.1
19.3	6.9	9.4	10.3
15.8	6.4	8.7	9.6
12.3	5.9	8.1	8.9
8.8	5.5	7.4	8.2
5.3	5	6.8	7.5
1.8	4.5	6.2	6.8
0	0	0	0

Table 5 LATERAL DEFLECTION VALUES OF BUILDING WITH FLEXIBLE BASE ZONE III (B11, B12, and B13)

Elevation(m)	Hard	Medium	Soft
29.8	13.3	16	20
26.3	12.9	15.6	19.6
22.8	**12.5**	**15.2**	**19.1**
19.3	12.1	14.9	18.6
15.8	11.7	14.5	18.2
12.3	11.3	14.1	17.7
8.8	10.9	13.8	17.2
5.3	10.5	13.4	16.8
1.8	10.2	13	16.3
0	0	0	0

Table 6 LATERALDEFLECTION INMM OF BUILDING WITH FIXED BASE IN ZONE IV (B14, B15, B16)

Elevation(m)	Hard	Medium	Soft
29.8	12.5	17	18.7
26.3	11.8	16	17.6
22.8	11	15	16.6
19.3	10.3	14.1	15.5
15.8	9.6	13.1	14.4
12.3	8.9	12.1	13.4
8.8	8.2	11.2	12.3
5.3	7.5	10.2	11.3
1.8	6.8	9.2	10.2
0	0	0	0

Table7 LATERAL DEFLECTION VALUES OFBUILDING WITH FLEXIBLE BASE ZONEIV (B14, B15, B16)

Elevation(m)	Hard	medium	Soft
29.8	18	24.5	30
26.3	17.6	23.9	29.3
22.8	17.2	23.3	28.6
19.3	16.7	22.8	27.9
15.8	16.3	22.2	27.3
12.3	15.9	21.6	26.6
8.8	15.5	21.1	25.9
5.3	15.1	20.5	25.2
1.8	14.7	19.9	24.5
0	0	0	0

Table8LATERAL DEFLECTION VALUES OFBUILDING WITH FIXED BASE ZONE5 (B17, B18, B19)

Elevation(m)	Hard	Medium	Soft
29.8	18.7	25.4	28.1
26.3	17.6	24	26.5
22.8	16.6	22.5	24.9
19.3	15.5	21.1	23.3
15.8	14.5	19.7	21.7
12.3	13.4	18.2	20.1
8.8	12.3	16.8	18.5
5.3	11.3	15.3	16.9
1.8	10.2	13.9	15.3
0	0	0	0

Table9 LATERAL DEFLECTION VALUES OFBUILDING WITH FLEXIBLEBASE ZONE5 (B17, B18, B19)

Elevation(m)	hard	medium	soft
29.8	27	36.7	45.1
26.3	26.4	35.9	44
22.8	25.7	35	43
19.3	25.1	34.1	41.9
15.8	24.5	33.3	40.9
12.3	23.9	32.4	39.8
8.8	23.2	31.6	38.8
5.3	22.6	30.7	37.7
1.8	22	29.9	36.7
0	0	0	0

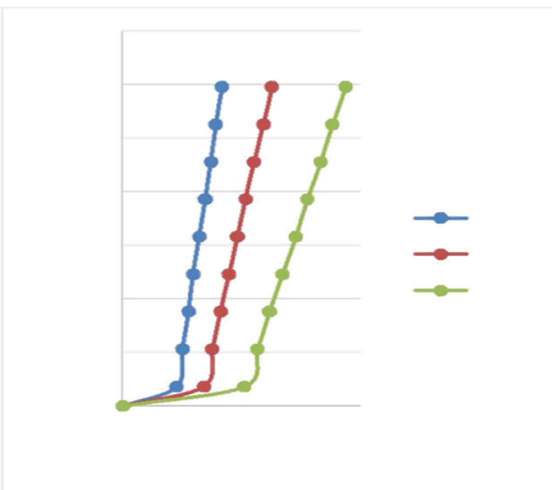


Fig 3: Lateral Deflection of Buildings with Fixed base for Different zones and hard soil

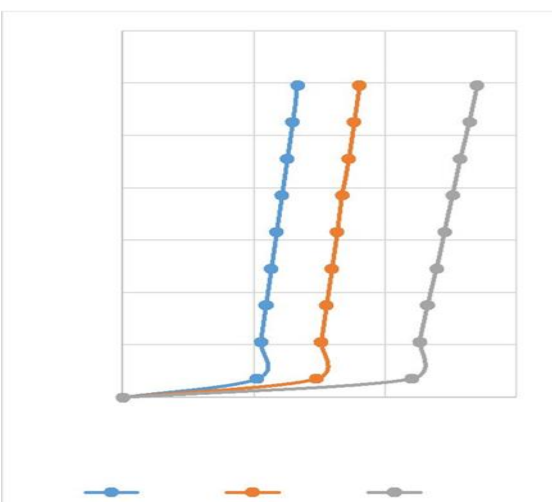


Fig4: Lateral Deflection of Buildings with Flexible base

From the table2, it was found that with, the change in zone and soil the lateral load varies extensively. As observed from B11, B12 and B13 (table4, 5) with the change in soil property from hard to medium and from hard to soft the lateral deflection value has increased by 26.7% and 34.4% respectively for flexible base and fixed base, similar pattern has seemed in the building B21, B22 and B23 (table6, 7) and B31, B32 and B33 (table8,9)respectively.

On comparing B11, B14 and B17 i.e. change in zone from III to IV and from III to V with same hard soil, the deflection has increased by 33.4% and 55% respectively for the same type of symmetric building, on comparing the both the fixed and flexible base configuration and the lateral deflection value it is found to be more in flexible base configuration.

3.1.2Storey Shear

From the table 2, it was found that with, the changein zone and soil the base shear varies. As observed from B11, B12 and B13 with the change in soil property from hard to medium and from hard to soft the base shear has increased by 26.7% and 30% respectively for flexible base and fixed base, similar pattern has seemed in the building B21, B22 and B23 and B31, B32 and B33respectively.

On comparing B11, B14 and B17 i.e. change in zone from III to IV and from III to V with same hard soil the base shear has increased by 33.4% and 55% respectively for the same type of symmetric building, on comparing the both the fixed and flexible base configuration and the base shear value, it is found to be more in flexible base configuration

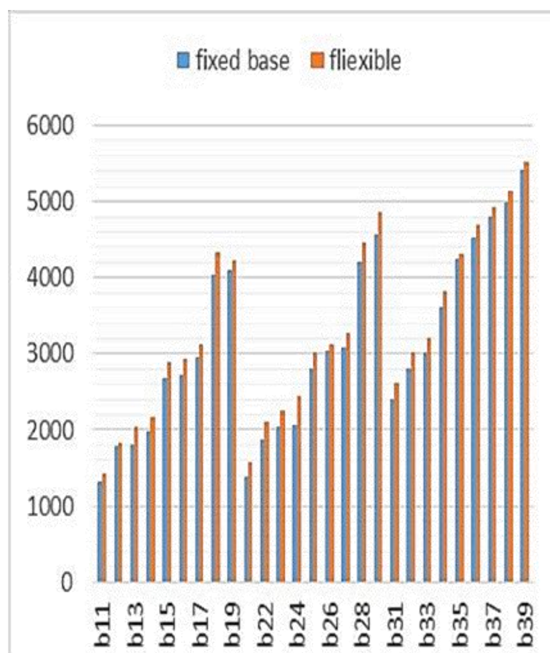
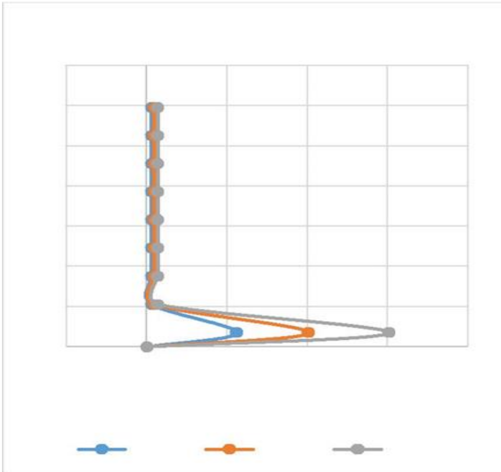


Fig Change in Base Shear of Building



Storey Drift for soft soil strata on fixed base

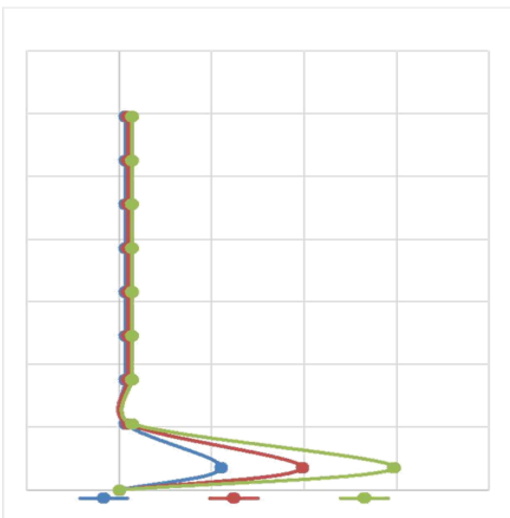
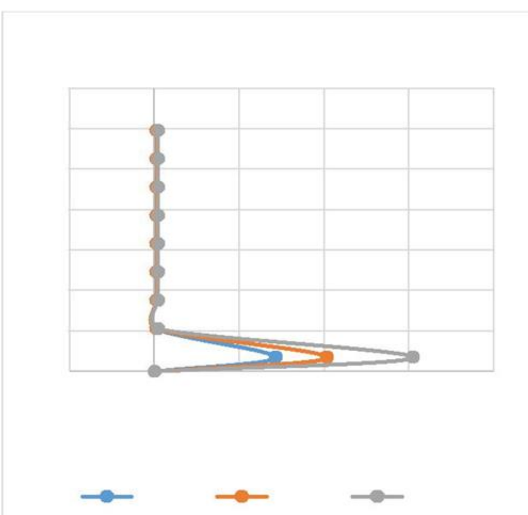


Fig Shows storey Drift with fixed Base for hard strata



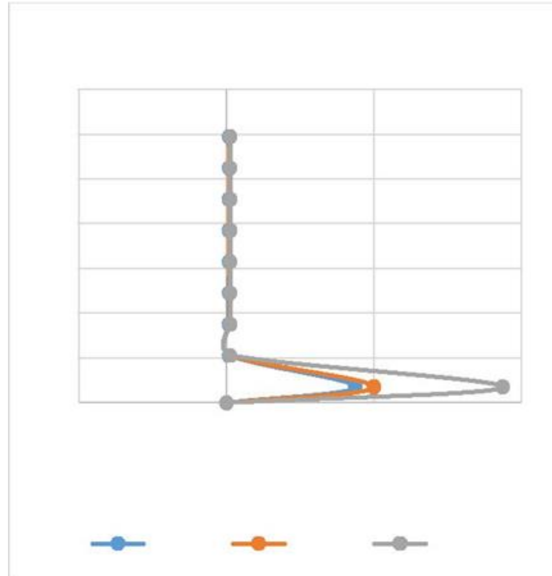
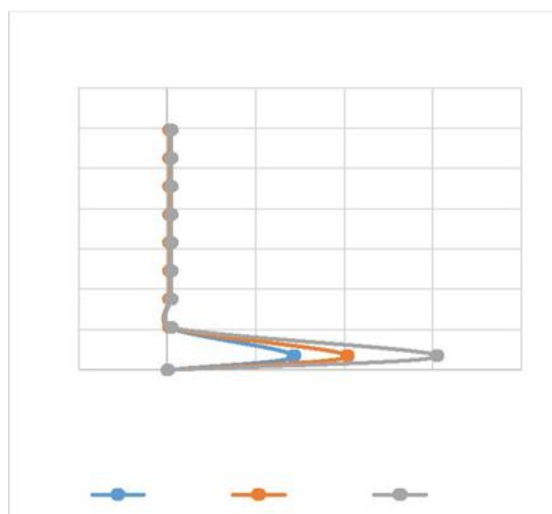


Fig11Storey Drift for soft soil strata on flexible base

From the table 2, it was found that with the change in zone and soil the storey drift varies. As observed from B11, B12 and B13 with the change in soil property from hard to medium and from hard to soft the storey drift value has increased by 26.7% and 30% respectively for flexible base and fixed base, similar pattern has seemed in the building B21, B22 and B23 and B31, B32 and B33repectevely.

On comparing B11, B14 and B17 i.e. change in zone from III to IV and from III to V with same hard soil, the base shear has increased by 33.4% and 55% respectively for the same type of symmetric building, on comparing

From the table 2, it was found that with the change in zone and soil the storey drift varies. As observed from B11, B12 and B13 with the change in soil property



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On comparing B11, B14 and B17 i.e. change in zone from III to IV and from III to V with same hard soil, the base shear has increased by 33.4% and 55% respectively for the same type of symmetric building, on comparing the both the fixed and flexible base configuration and the storey drift value, it is found to be more in flexible base configuration

4. CONCLUSION

In the present project report seismic design analysis of an asymmetrical plan building is carried out. Multi storied building frames with fixed and flexible base subjected to seismic forces were analyzed and designed for different soil conditions.54 buildings are analyzed in the software ETABS with the configuration as shown in table 1

1. Lateral deflection values increases when the type of soil changes from hard to medium and medium to soft for fixed and flexible base buildings.(Ref:able4 to able9)
2. Lateral deflection values of fixed base building were found to be lower as compared to flexible base building.(Ref:table3).
3. Lateral deflection values increases when the type of zone changes from zone3 to zone4 and zone3 to zone5 (Ref:able4 to able9)
4. Base shear values increases when the type of soil changes from hard to medium and medium to soft for fixed and flexible base buildings. (Ref:Fig5)
5. Base shear values of fixed base building was found to be lower as compared to flexible base building. (Ref:Fig5)
6. Base shear values increases when the type of zone changes from zone3 to zone4 and zone3 to zone5(Ref:Fig5)
7. Storey drift values increases when the type of soil changes from hard to medium and medium to soft for fixed and flexible base buildings. (Ref:Fig6 to Fig11)
8. Storey drift values of fixed base building were found to be lower as compared to flexible base building. (Ref:Fig6toFig11)
9. Hence suitable soil condition has to be adopted along with the type of foundation while designing building for Earthquake resistant.
10. Storey drift values increases when the type of zone changes from zone3 to zone4 and zone3 to zone5 (Ref:Fig6 toFig11)

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