Seismic Performance of RC Frame Building on Different Slopes

Gaurav D. Zinjade[1], Prof. A. B. Pujari[2]
[1]Dept of Civil Engineering
[2]Assistant professor, Dept of Civil Engineering
[1, 2] K.J.College of Engineering and Management Research, Pune, India

Abstract- *In our country, after every earthquake, we come across the reality that the earthquake doesn't kill people; it is due to unsafe buildings which causes damage to property and life. In India, about 60% area is susceptible to damaging levels of seismic hazards. In the present work, an attempt is made to study seismic behavior of buildings situated on sloping ground for various types of building configurations such a set-back, step back-setback buildings with and without soil structure interaction is considered. Different slopes of ground such as 0°, 5°, 10°, 15°, 20° etc are considered. To study various static and dynamic properties due to variation in slope, (G +18) building model with and without setbacks are analysed firstly by equivalent static analysis. Various forces like axial force, shear force, bending moment for various groups are compared for both types of buildings. Dynamic analysis is then carried out by response spectrum method and dynamic parameters like base shear, frequency are compared for both types. From the results obtained it is observed that, the buildings on sloping ground having setback configurations can be used for better seismic performance rather than without set back configurations.*

Keywords- Building with setback, buildimg without setback, Bending moment, axial force, base shear, mode shapes.

I. INTRODUCTION

India has track record of catastrophic earthquakes, at various regions, which left behind loss of many lives and heavy destruction to property and economy. Analysis of buildings in hill region is somewhat different than the buildings on levelled ground, since the column of the hill building rests at different levels on the slope. Such buildings have mass and stiffness varying along the vertical and horizontal planes resulting the centre of mass and centre of rigidity do not coincide on various floors, hence they demand torsion analysis, in addition to lateral forces under the action of earthquakes. The unsymmetrical buildings require great attention in the analysis and design under the action of seismic excitation. Past earthquakes in which, buildings located near the edge of a stretch of hills or on sloping ground suffered serious damages. The shorter column attracts more forces and undergoes damage, when subjected to earthquakes. The other problems associated with hill buildings are, additional lateral earth pressure at various levels, slope instability, different soil profile yielding unequal settlement of foundation

1.1 **Seismic Behaviour of Buildings on Slopes in India**

North and north-eastern parts of India have large scales of hilly region, which are categorized under seismic zone IV and V. In this region the construction of multi-storey RC framed buildings on hill slopes has a popular and pressing demand, due to its economic growth and rapid urbanization. This growth in construction activity is adding increase in population density. Since there is scarcity of plain ground in hilly areas, it obligates the construction of buildings on slopes. During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey. Poor behavior of short columns is due to the fact that in an earthquake, a tall columns and a short column of same cross section move horizontally by same amount which can be seen in the Figure 1.1 below. However, the short column is stiffer as compared to the tall column, and it attracts larger earthquake force. Stiffness of a column means resistance to deformation, the larger is the stiffness, larger is the force required to deform it. Also due to the varied configurations of buildings in hilly areas, these buildings become highly irregular and asymmetric, due to variation in mass and stiffness distributions on different vertical axis at each floor. Such construction in seismically prone areas makes them exposed to greater shear and torsion as compared to conventional construction.

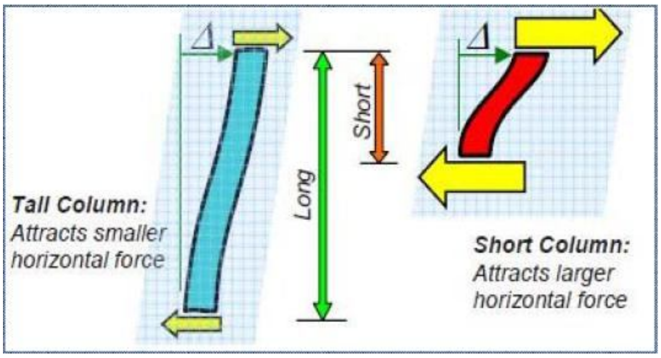


Figure- 1.1 Structural behaviour of short column under lateral loads

1.2 Soil Structure-Interaction Effect

Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. 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. METHODOLOGY

2.1 Building Considered for the Analytical Study

For present work seismic analysis is carried out for reinforced concrete moment resisting building frame having (G+18) storey situated in zone III for varying ground slopes. The analysis is carried out using ETABS.

Two types of buildings considered in the study, which are

1) Buildings without Setbacks.
2) Buildings with Setbacks.

Various models have been prepared by varying ground slopes from 0 degree, 5, 10, 15, 20 degree for both with and without set back configuration as shown with beams tying them at various levels.

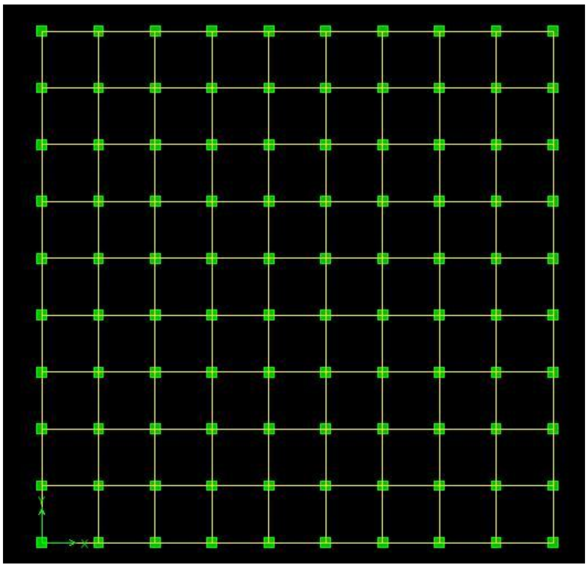
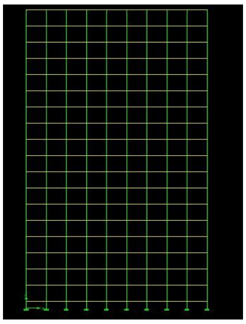


Fig 2.1: Plan of the Building at Plinth Level in ETABS

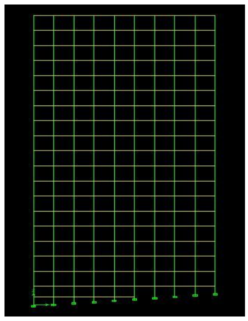
2.2 Modeling of the Buildings

The building is modeled using the finite element software ETABS. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, slab, walls, and foundation. The non-structural elements that do not significantly influence the building behavior are not modeled. Slopes of building have been varied from 0 to 20 degrees.

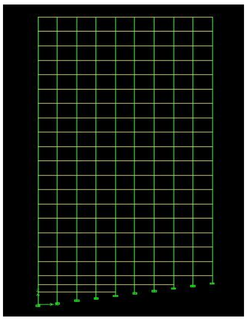
A) Buildings without Setbacks



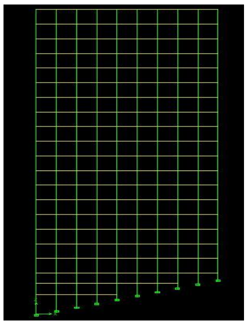
Model 1 Slope=0°



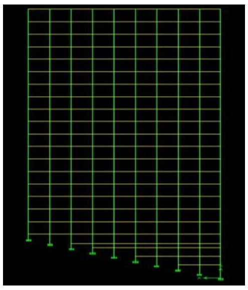
Model 2 Slope=5°



Model 3 Slope=10°



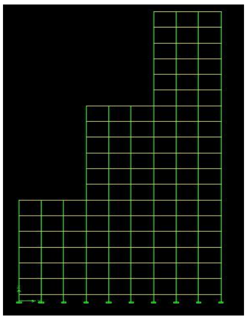
Model 4 Slope=15°



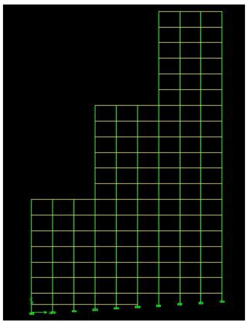
Model 5 Slope=20°

Figure 3.2: Different models of building without Setbacks in ETABS

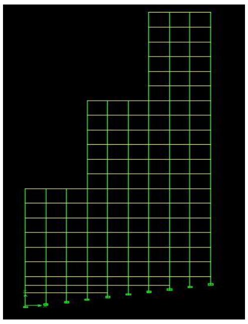
B) Buildings with Setbacks



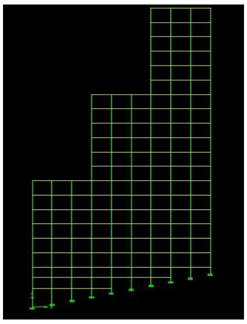
Model 1 Slope=0°



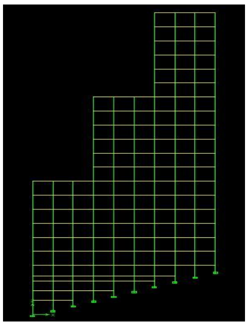
Model 2 Slope=5°



Model 3 Slope=10°



Model 4 Slope=15°



Model 4 Slope=20°

2.3 Seismic Analysis of Buildings Using IS 1893(Part 1) - 2002

At present there are three accepted methods by which the magnitude and the distribution of the earthquake induced lateral forces are estimated on the structures. These methods of analysis enable the designer to estimate design forces due to earthquake in multi storied building.

A) Equivalent static method of analysis.
B) Dynamic analysis

The dynamic analysis is of two types

a) Response spectrum method.
b) Time history analysis.

Seismic codes are unique to a particular region or country. In India, IS 1893 is the main code that provide outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests and its ductility. Part I of IS 1893: 2002 deals with assessment of seismic loads on various structures and buildings. Whole code centers on the calculation of base shear and its distribution over height. Depending on the height of the structure and zone to which it belongs, type of analysis i.e. static and dynamic analysis is performed.

2.3.1 Equivalent Static Analysis

The total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure.

Following procedure is generally used for the equivalent static analysis:

i) Calculation of lumped weight.
ii) Calculation of fundamental natural period.

The fundamental natural period of vibration (T_a) in seconds of a moment resisting frame building,

$T_a = 0.075\, h^{0.75}$ (without brick infill panels)
$T_a = 0.09\, h/\sqrt{d}$ (with brick infill panels)

where
h = Height of the building
d = Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

iii) Determination of base shear (V_B) of the building.

$$V_B = A_h \times W$$

where

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficient (S_a/g). S_a/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

iv) Lateral distribution of design base shear

The design base shear V_B thus obtained is then distributed along the height of the building using a parabolic distribution expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

where Q_i is the design lateral force, W_i is the seismic weight, h_i is the height of the i^{th} floor measured from base and n is the number of stories in the building.

2.3.2 Dynamic Analysis of Buildings

Dynamic analysis shall be performed to obtain design seismic forces, and its distribution to different levels along the height of the building and to the various lateral load resisting elements under any of the following conditions

- For regular buildings, if the height is greater than 40m in zones IV and V or greater than 90m in zone II and III
- For irregular buildings, if the height is more than 12m in zone IV and V and more than 40m in zone II and III.

Dynamic analysis can be performed either by time history method or response spectrum method.

2.3.2.1 response Spectrum Method

In response spectrum method the peak response of the structure is calculated from model combination, where the following two methods can be used.

a) Square Root of Sum of Square (SRSS) Method

$$\lambda = \sqrt{\sum_{k=1} (\lambda K)2}$$

where, λk = Absolute value of quantity in mode k
r = Number of modes being considered.

b) Complete Quadratic Combination Method

$$\lambda = \sqrt{\sum_{i=1}^{r}\sum_{j=1}^{r} \lambda_i \rho_{ij} \lambda_j}$$

where, λi = Response quantity in mode
Pij = Cross modal coefficient
λj = Response quantity in mode j

ρ_{ij} = cross-modal coefficient

$$\frac{8\zeta^2(1+\beta)\beta^{1.5}}{(1+\beta^2)^2 + 4\zeta^2\beta(1+\beta)^2}$$

where, ξ = Modal damping ratio in fraction
β = Frequency ratio = ωj/ωi
ωi = Circular frequency in i^{th} mode
ωj = Circular frequency in j^{th} mode

III. STRUCTURAL MODELS

3.1 General

Seismic performance evaluation is a complex phenomenon as there are several factors affecting the behavior of the building. The models given in chapter 3 are firstly analysed for various slopes *i.e* 0°, 5°, 10°, 15°, 20° respectively by equivalent static analysis, then the effect of soil structure interaction is taken into consideration for these models for various soil conditions as mentioned in the previous chapter. The dynamic analysis is carried out for Stepback and Setback building models for various slopes considering the effect of soil-structure interaction. The main parameters considered in this study to compare the seismic performance of different models having varied slope considered are base shear, bending moment, shear force, and axial force.

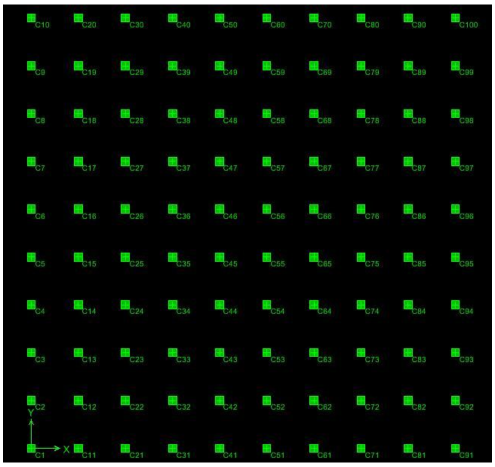


Figure 3.1Column layout of the building

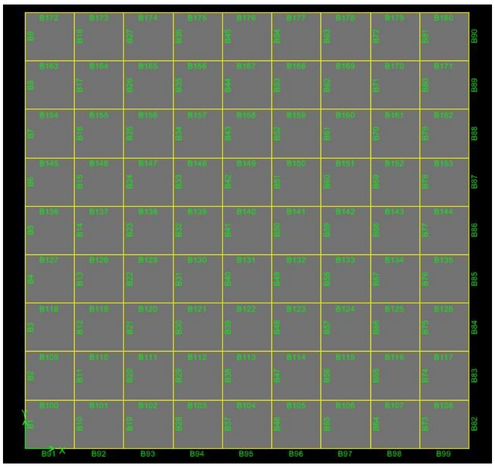


Figure 3.2 Floor beam layout of the building

Following are the load combinations considered in this analysis

1)1.5(DL+LL)
2)1.2(DL+LL+EQX)
3)1.2(DL+LL-EQX)
4)1.2(DL+LL+EQY)
5)1.2(DL+LL-EQY)
6) DL+1.5EQX
7) DL-1.5EQX
8) DL+1.5EQY
9) DL-1.5EQY]

IV. RESULTS AND DISCUSSIONS

A) Equivalent static method of analysis

The results are shown graphically which are listed below

i) Buildings without Setbacks

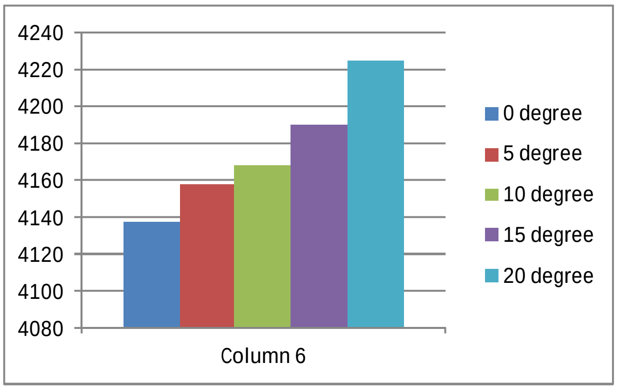
Table-4.1 shows the values of maximum axial force in column C6, C56, C96 and Graph 4.1 (a), (b) and (c) shows the variation of axial force in column C6, C56, C96
Table-4.2 shows the values of maximum B.M. in column C6, C56, C96 and Graph 4.2 (a), (b) and (c) shows the variation of B.M. in column C6, C56, C96
Table-4.3 shows the values of maximum S.F. in floor beam B1, B140, B90 and Graph 4.3 (a), (b) and (c) shows the variation of S.F. in floor beam B1, B140, B90
Table-4.4 shows the values of maximum B.M. in floor beam B1, B140, B90 and Graph 4.4 (a), (b) and (c) shows the variation of B.M. in floor beam B1, B140, B90

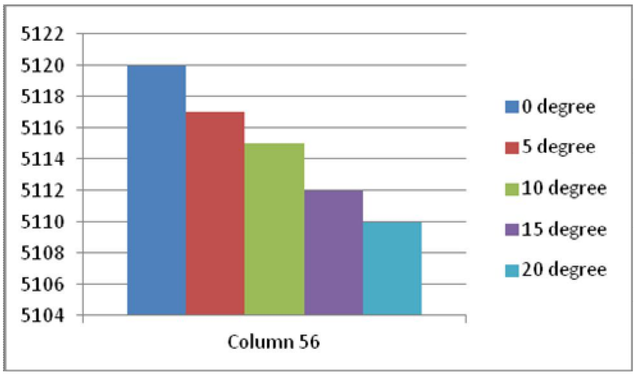
ii) Buildings with Setbacks

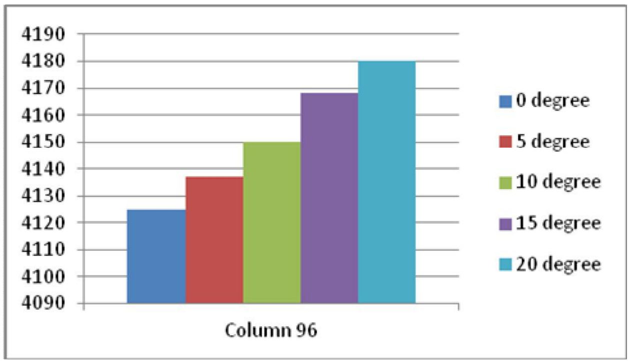
Table-4.5 shows the values of maximum axial force in column C6, C56, C96 and Graph 4.5 (a), (b) and (c) shows the variation of axial force in column C6, C56, C96
Table-4.6 shows the values of maximum B.M. in column C6, C56, C96 and Graph 4.6 (a), (b) and (c) shows the variation of B.M. in column C6, C56, C96
Table-4.7 shows the values of maximum S.F. in floor beam B1, B140, B90 and Graph 4.7 (a), (b) and (c) shows the variation of S.F. in floor beam B1, B140, B90
Table-4.8 shows the values of maximum B.M. in floor beam B1, B140, B90 and Graph 4.8 (a), (b) and (c) shows the variation of B.M. in floor beam B1, B140, B90

Table-4.1 Values of maximum axial force in column C6, C56, C96 for without set back building

	Maximum Axial Force (KN)				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
Column 6	4137	4157	4168	4190	4225
Column 56	5120	5117	5115	5112	5110
Column 96	4125	4137	4150	4168	4180



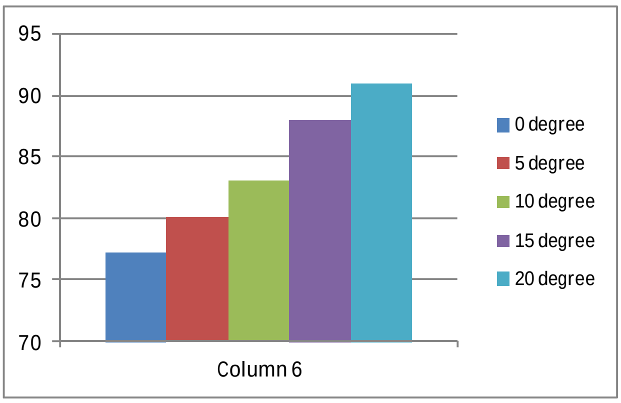


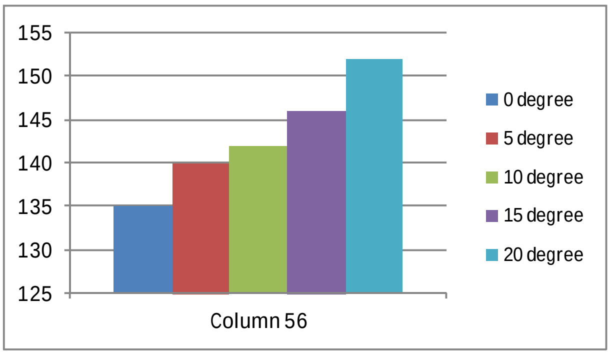


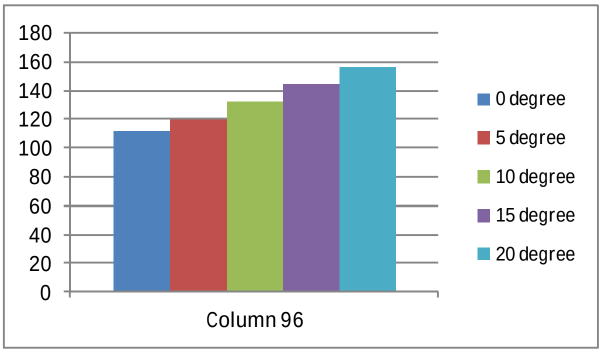
Graph 4.1(a), (b) &(c): Variation of A.F. in kN Vs Slope in degree in Columns C6, C56 & C96 for without set back building

Table-4.2 Values of maximum B.M. in column C6, C56, C96 for without set back building

	Maximum Bending moment in KN -m				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
Column 6	77.2	80	83	88	91
Column 56	135	140	142	146	152
Column 96	112	120	132	144	156



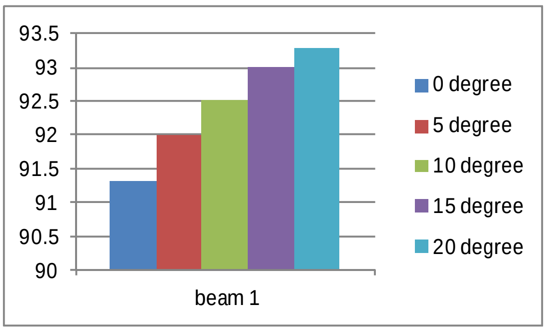


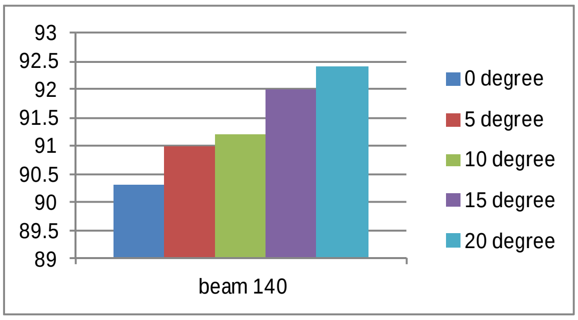


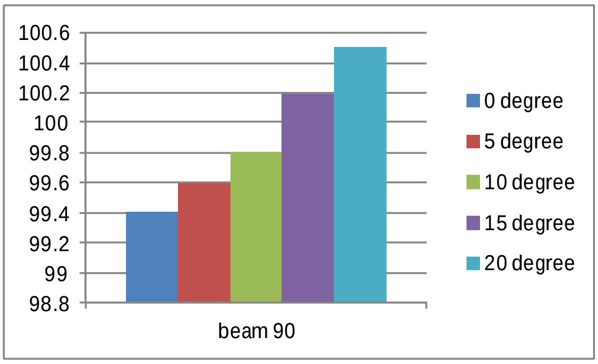
Graph 4.2(a), (b) &(c): Variation of B.M. in kN Vs Slope in degree in Columns C6, C56 & C96 for without set back building

Table-4.3 Values of maximum S.F. in floor Beams 1, 140 & 90 for without set back building

	Maximum S.F. in KN				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
beam 1	91.3	92	92.5	93	93.3
beam 140	90.3	91	91.2	92	92.4
beam 90	99.4	99.6	99.8	100.2	100.5



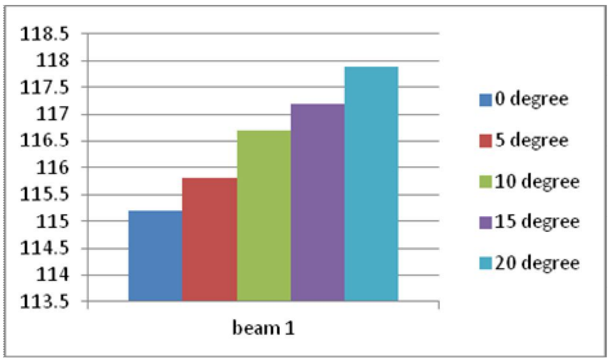


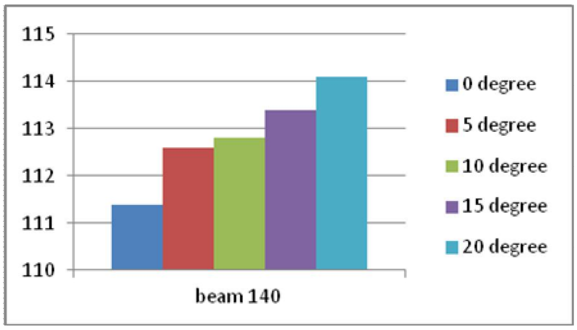


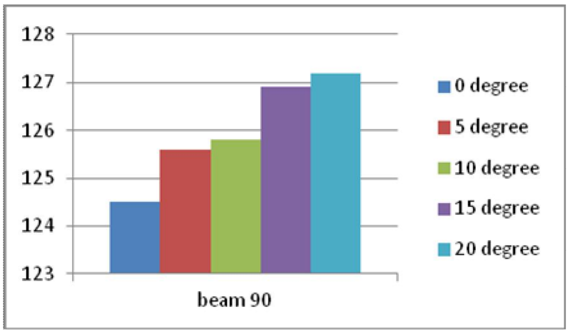
Graph 4.3 (a), (b) and (c) shows the variation of S.F. in floor beam B1, B140, B90 for without set back building

Table-4.4 Values of maximum B.M. in floor Beams 1, 140 & 90 for without set back building

	Maximum B.M. in KN -m				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
beam 1	115.2	115.8	116.7	117.2	117.9
beam 140	111.4	112.6	112.8	113.4	114.1
beam 90	124.5	125.6	125.8	126.9	127.2



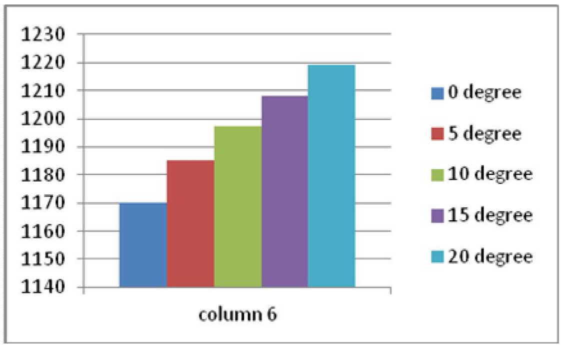


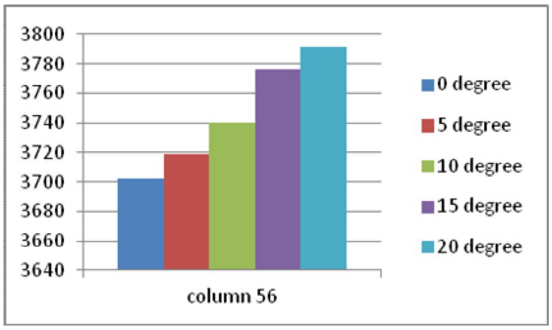


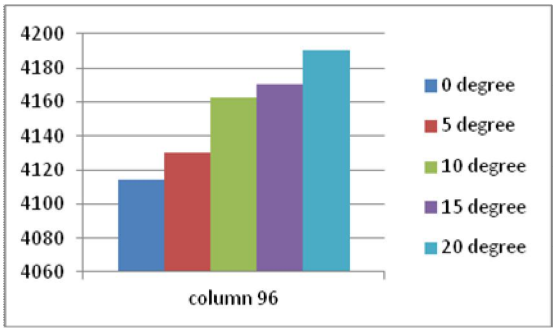
Graph 4.4 (a), (b) and (c) the variation of B.M. in floor beam B1, B140, B90 for without set back building

Table-4.5 Values of maximum axial force in column C6, C56, C96 for with set back building

	Maximum Axial Force (KN)				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
column 6	1170	1185.4	1197.3	1208.2	1219.4
column 56	3702.6	3719.2	3740.3	3776.3	3791.3
column 96	4114	4130	4162.6	4170.8	4190.4



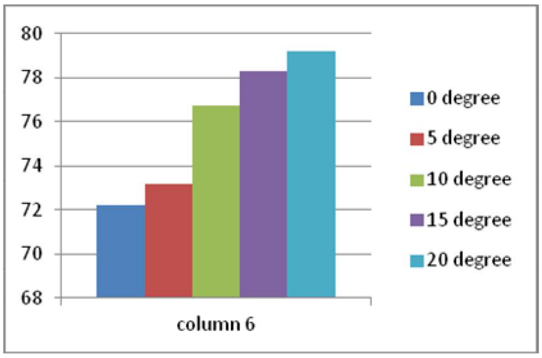


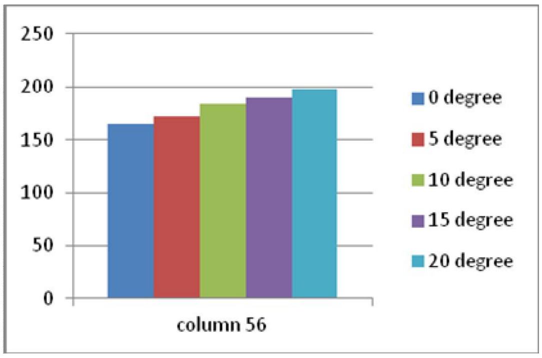


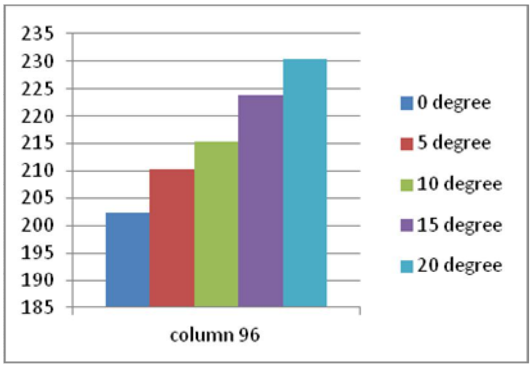
Graph 4.5(a), (b) &(c): Variation of A.F. in kN Vs Slope in degree in Columns C6, C56 & C96 for with set-back building

Table-4.6 Values of maximum B.M. in column C6, C56, C96 for with set-back building

	Maximum Bending moment in KN -m				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
column 6	72.2	73.2	76.7	78.3	79.2
column 56	165.2	172.4	184.2	190.3	198.3
column 96	202.4	210.3	215.4	223.7	230.4



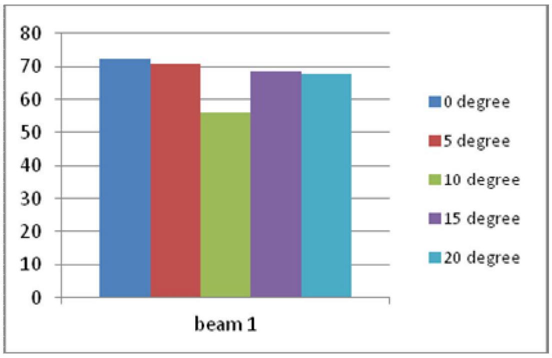


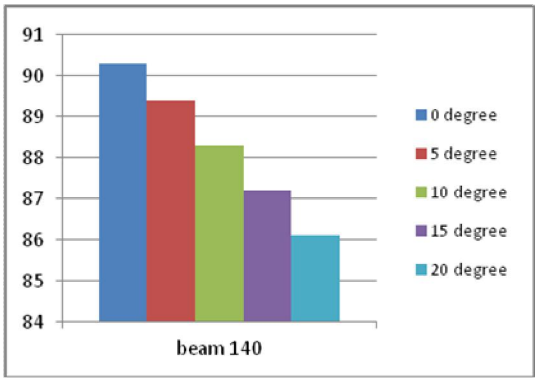


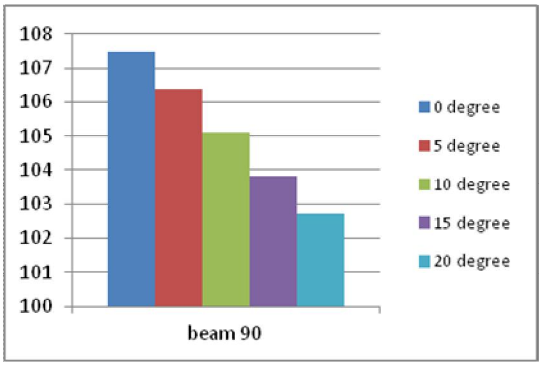
Graph 4.6(a), (b) &(c): Variation of B.M. in kN Vs Slope in degree in Columns C6, C56 & C96 for with set-back building

Table-4.7 Values of maximum S.F. in floor Beam 1, 140 & 90 for with set-back building

	Maximum shear force in kN -m				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
beam 1	72.3	70.8	69.2	68.4	67.8
beam 140	90.3	89.4	88.3	87.2	86.1
beam 90	107.5	106.4	105.1	103.8	102.7



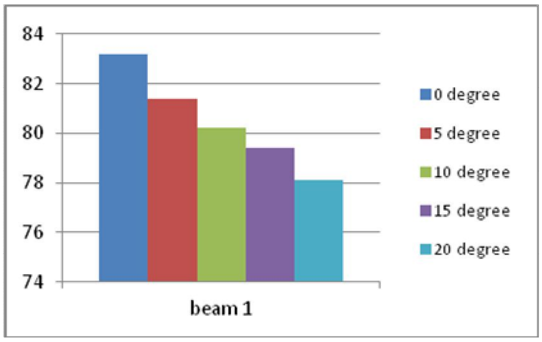


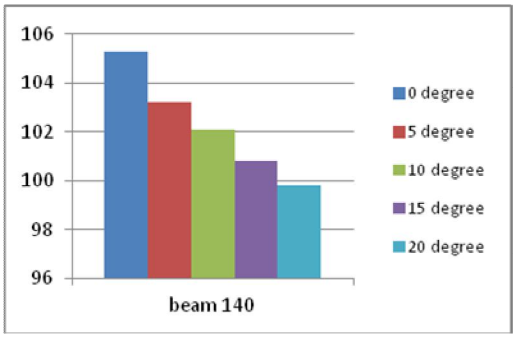


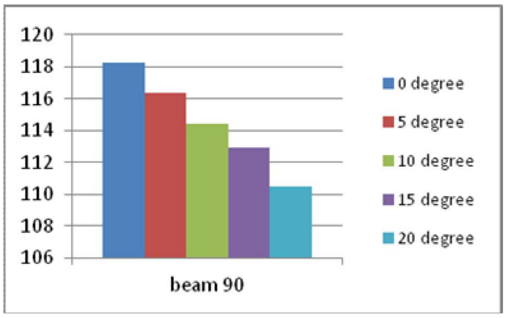
Graph 4.7 (a), (b) and (c) shows the variation of S.F. in floor beam B1, B140, B90 for with set-back building

Table-4.8 Values of maximum B.M. in floor Beam 1, 140 & 90 for with set-back building

	Maximum Bending moment in kN -m				
Slope angle	0 degree	5 degree	10 degree	15 degree	20 degree
beam 1	83.2	81.4	80.2	79.4	78.1
beam 140	105.3	103.2	102.1	100.8	99.8
beam 90	118.3	116.4	114.4	112.9	110.5







Graph 4.8 (a), (b) and (c) shows the variation of B.M. in floor beam B1, B140, B90 for with-set back building

B) Dynamic Analysis

The dynamic analysis is also carried out by using Response spectrum analysis for both types of building *i.e* buildings with and without setbacks. Also the effect of soil structure interaction is taken into consideration. Results are shown graphically from graph 4.9 to 4.12.

The results are shown graphically which are listed below Table-4.9 & Table-4.10 shows the values of lateral displacement with floor level for both buildings with and without setbacks. Graph -4.9 & 4.10 shows the variation of lateral displacement with floor level for both buildings with and without setbacks.

Table-4.11 (a), (b), (c), (d) & (e) shows the values of time period of building with mode shape no for 0°, 5°, 10°, 15° and 20° slope for buildings without setbacks and Graph 4.11 (a), (b), (c), (d) & (e) shows the variation of time period of building with mode shape no for 0°, 5°, 10°, 15° and 20° slope for buildings without setbacks.

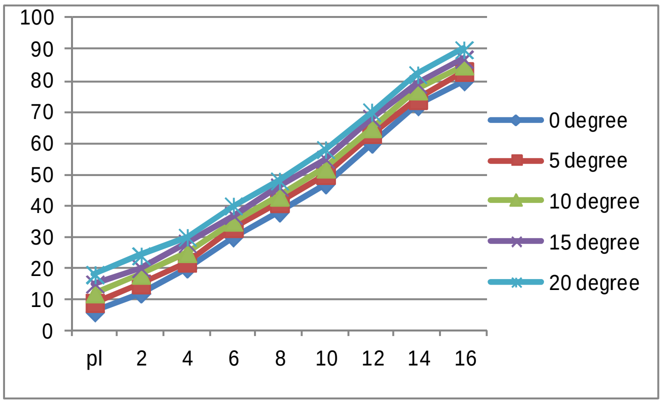
Table-4.12 (a), (b), (c), (d) & (e) shows the values of time period of building with mode shape no for 0°, 5°, 10°, 15° and 20° slope for buildings without setbacks and Graph 4.12 (a), (b), (c), (d) & (e) shows the variation of time period of building with mode shape no for 0°, 5°, 10°, 15° and 20° slope for buildings with setbacks.

Lateral Displacement Vs Floor Level

Building without set back

Table-4.9 Values of lateral displacement for without set-back building

FLOOR	0 degree	5 degree	10 degree	15 degree	20 degree
PL	1.8	4	7	9	12
2	6	9	12	15	18
4	12	15	18	20	24
6	20	22	25	28	30
8	30	33	35	37	40
10	38	41	43	46	48
12	47	50	52	55	58
14	60	63	65	68	70
16	72	74	77	79	82
18	80	83	85	87	90

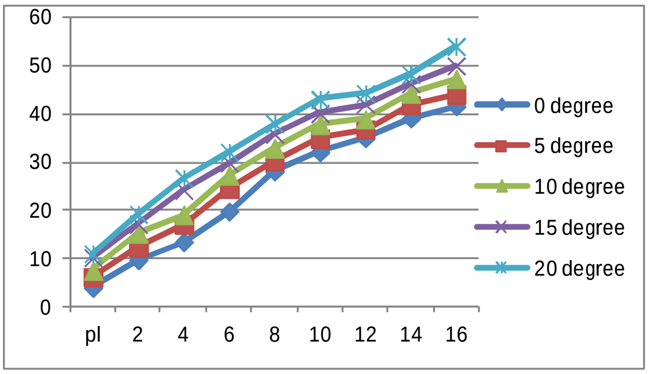


Graph 4.9 shows the variation of lateral displacement for without set-back building

Building with set back

Table-4.10 Values of lateral displacement for with set-back building

	0 degree	5 degree	10 degree	15 degree	20 degree
pl	1.5	3	5.8	7.2	10
2	4	6.2	7.5	10.2	11
4	9.8	12.3	15.2	17.2	19.2
6	13.5	17.1	19.1	24.2	26.7
8	19.8	24.5	27.3	29.9	32.1
10	28.1	30.2	32.9	35.8	38
12	32.1	34.9	37.8	40.1	43
14	35	36.8	38.9	42	44.3
16	39.1	41.8	44.3	46.3	48.2
18	41.6	44	47.3	50	54



Graph 4.10 shows the variation of lateral displacement for with set-back building

Time period Vs Mode Shape

Buildings without Setbacks

Table-4.11 (a) Values of time period in sec with respect to mode number for slope 0° for without set-back building

	FB	HS	MS	SS
1	2.10	2.10	2.10	2.22
3	1.90	1.90	1.90	1.95
5	0.70	0.70	0.70	0.78
7	0.40	0.40	0.40	0.48
9	0.39	0.39	0.39	0.45
11	0.29	0.29	0.29	0.36
13	0.23	0.23	0.23	0.31
15	0.22	0.22	0.22	0.3
17	0.19	0.19	0.19	0.24
19	0.16	0.16	0.16	0.21

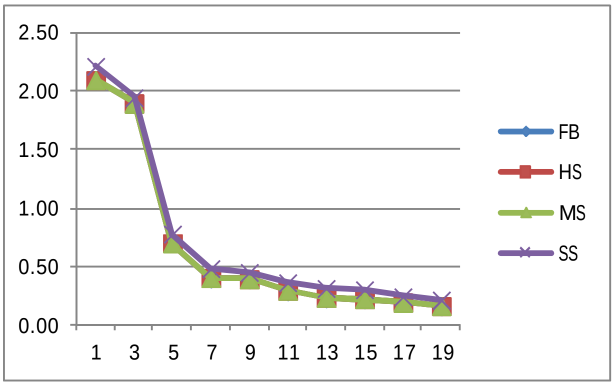


Table-4.11 (b) Values of time period in sec with respect to mode number for slope 5° for without set-back building

	FB	HS	MS	SS
1	2.12	2.12	2.12	2.24
3	1.91	1.91	1.91	1.96
5	0.72	0.72	0.72	0.79
7	0.42	0.42	0.42	0.5
9	0.40	0.40	0.40	0.46
11	0.31	0.31	0.31	0.37
13	0.24	0.24	0.24	0.33
15	0.23	0.23	0.23	0.31
17	0.20	0.20	0.20	0.26
19	0.17	0.17	0.17	0.22

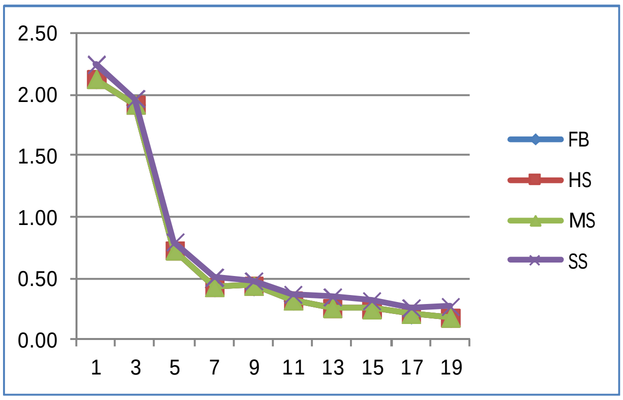


Table-4.11 (c) Values of time period in sec with respect to mode number for slope 10° for without set-back building

	FB	HS	MS	SS
1	2.13	2.13	2.13	2.25
3	1.92	1.92	1.92	1.97
5	0.73	0.73	0.73	0.8
7	0.43	0.43	0.43	0.51
9	0.44	0.44	0.44	0.48
11	0.32	0.32	0.32	0.37
13	0.26	0.26	0.26	0.35
15	0.25	0.25	0.25	0.32
17	0.21	0.21	0.21	0.26
19	0.18	0.18	0.18	0.27

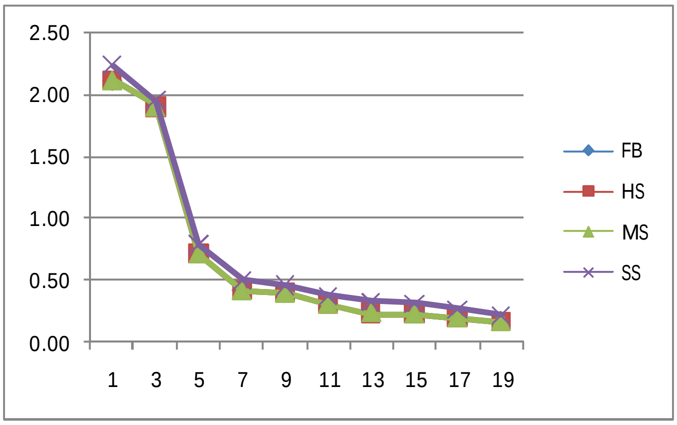
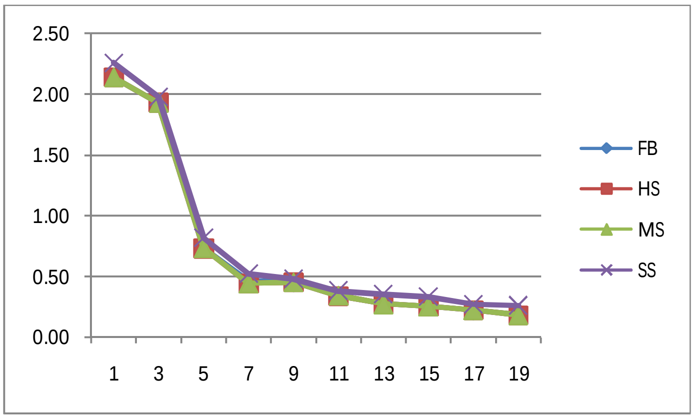


Table-4.11 (d) Values of time period in sec with respect to mode number for slope 15° for without set-back building

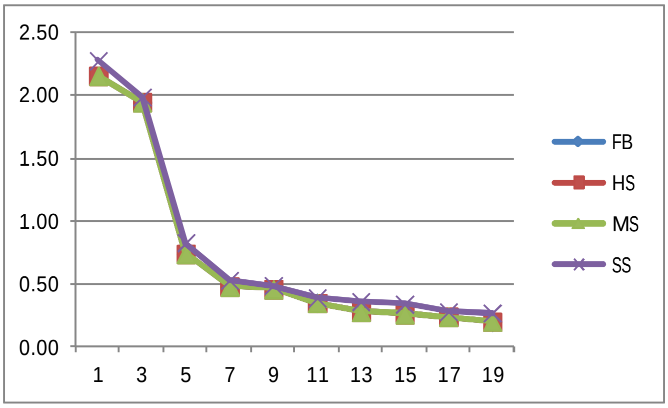
	FB	HS	MS	SS
1	2.14	2.14	2.14	2.26
3	1.93	1.93	1.93	1.98
5	0.73	0.73	0.73	0.82
7	0.46	0.46	0.46	0.52
9	0.45	0.45	0.45	0.48
11	0.34	0.34	0.34	0.38
13	0.27	0.27	0.27	0.35
15	0.25	0.25	0.25	0.33
17	0.22	0.22	0.22	0.27
19	0.18	0.18	0.18	0.26



ISSN **[ONLINE]: 2395-1052**

Table-4.11 (e) Values of time period in sec with respect to mode number for slope 20° for without set-back building

	FB	HS	MS	SS
1	2.16	2.16	2.16	2.28
3	1.95	1.95	1.95	1.99
5	0.74	0.74	0.74	0.83
7	0.48	0.48	0.48	0.53
9	0.46	0.46	0.46	0.49
11	0.35	0.35	0.35	0.39
13	0.28	0.28	0.28	0.36
15	0.26	0.26	0.26	0.34
17	0.24	0.24	0.24	0.28
19	0.20	0.20	0.20	0.27



Graph 4.11 (a), (b), (c), (d) & (e) shows the variation of time period with mode numbers for without set-back building

Time Period Vs Mode Shape

Buildings with Setbacks

Table-4.12 (a) Values of time period in sec with respect to mode number for slope 0° for with set-back building

	FB	HS	MS	SS
1	1.75	1.75	1.75	1.85
3	1.18	1.18	1.18	1.22
5	0.65	0.65	0.65	0.67
7	0.43	0.43	0.43	0.44
9	0.38	0.38	0.38	0.42
11	0.26	0.26	0.26	0.29
13	0.21	0.21	0.21	0.24
15	0.2	0.2	0.2	0.22
17	0.14	0.14	0.14	0.16
19	0.13	0.13	0.13	0.15

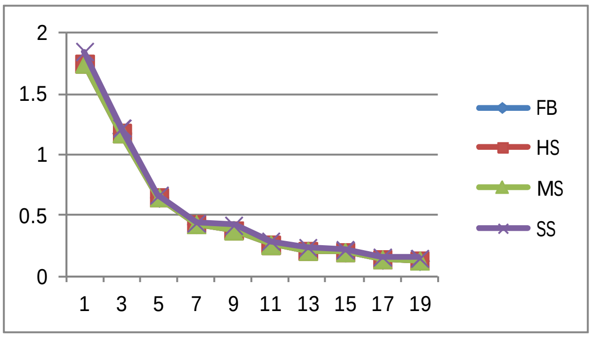


Table-4.12 (b) Values of time period in sec with respect to mode number for slope 5° for with set-back building

	FB	HS	MS	SS
1	1.76	1.76	1.76	1.89
3	1.21	1.21	1.21	1.26
5	0.66	0.66	0.66	0.7
7	0.43	0.43	0.43	0.46
9	0.38	0.38	0.38	0.42
11	0.26	0.26	0.26	0.31
13	0.23	0.23	0.23	0.29
15	0.22	0.22	0.22	0.28
17	0.19	0.19	0.19	0.23
19	0.15	0.15	0.15	0.2

Time Period vs Mode Number for slope 5

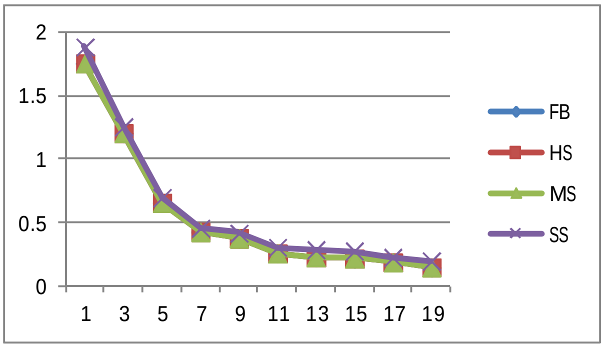


Table-4.12 (c) Values of time period in sec with respect to mode number for slope 10° for with set-back building

	FB	HS	MS	SS
1	1.77	1.77	1.77	1.9
3	1.23	1.23	1.23	1.27
5	0.66	0.66	0.66	0.71
7	0.44	0.44	0.44	0.47
9	0.38	0.38	0.38	0.43
11	0.26	0.26	0.26	0.32
13	0.24	0.24	0.24	0.3
15	0.23	0.23	0.23	0.29
17	0.18	0.18	0.18	0.24
19	0.16	0.16	0.16	0.21

Time Period vs Mode Number for slope 10

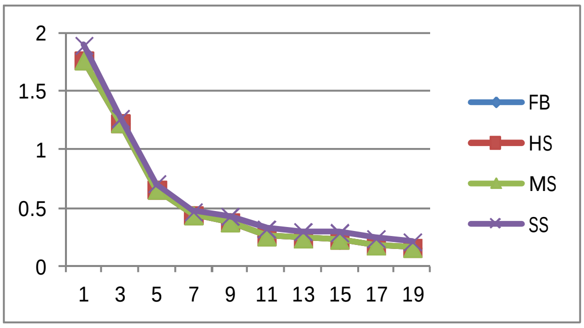


Table-4.12 (d) Values of time period in sec with respect to mode number for slope 15° for with set-back building

	FB	HS	MS	SS
1	1.78	1.78	1.78	1.91
3	1.26	1.26	1.26	1.28
5	0.68	0.68	0.68	0.72
7	0.44	0.44	0.44	0.47
9	0.38	0.38	0.38	0.43
11	0.28	0.28	0.28	0.34
13	0.25	0.25	0.25	0.31
15	0.24	0.24	0.24	0.3
17	0.19	0.19	0.19	0.24
19	0.17	0.17	0.17	0.22

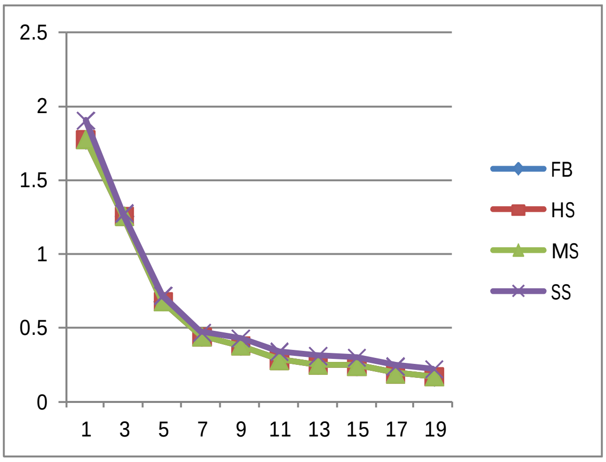
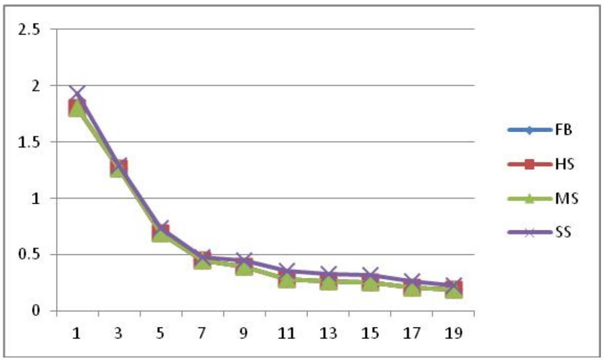


Table-4.12 (e) Values of time period in sec with respect to mode number for slope 20° for with set-back building

	FB	HS	MS	SS
1	1.8	1.8	1.8	1.93
3	1.27	1.27	1.27	1.29
5	0.69	0.69	0.69	0.74
7	0.45	0.45	0.45	0.48
9	0.39	0.39	0.39	0.45
11	0.28	0.28	0.28	0.36
13	0.26	0.26	0.26	0.33
15	0.25	0.25	0.25	0.32
17	0.21	0.21	0.21	0.26
19	0.19	0.19	0.19	0.23



Graph 4.12 (a), (b), (c), (d) & (e) shows the variation of time period with mode numbers for with set-back building

V. CONCLUSION

5.1 Conclusions

This chapter presents a summary of the present study, for the buildings with varied sloping angle without set-back and with set-back. On the basis of the results and discussions obtained in this investigation, the following conclusions have been drawn.

1. Step back Set back combination is better than without set back.
2. From results it is found out that, the value of axial force is increases with increase in slope. For set-back building the column towards slope angle axial force decreases as compared to with-out set back building and for other two columns axial force increased.
3. From results, it is found out that, the value of bending moment is increased between15 % to 25% due to increase in slope for all beams groups.
4. Also in set-back building there is a little increase in bending moment and shear force value as compared to with-out set back building.
5. Also there is increase in lateral displacement of building with increase in slope.
6. In step-back building, lateral displacement of the building is less as compared to with set-back building.
7. There is an increase in base shear with increase in slope.
8. Time period of the structure increase with increase in slope, also in case of soil structure interaction time period increase for soft soil as compared to other cases.

REFERENCES

[1] S. M. Nagargoje and K. S. Sable, “Seismic performance of multi-storeyed building on sloping ground”

[2] P. P. Chandurkar and Dr. P. S. Pajgade "Seismic Analysis of RCC Building with and without Shear Wall"
[3] Jaswant N. Arlekar, Sudhir K. Jain and C.V.R "Effect of infill patterns and soft storey"
[4] I.S.1893, "Criteria for Earthquake Resistant Design of Structures (part1) General Provisions and Buildings (Fifth Revision)", Bureau of Indian Standards, 2002.
[5] I.S.456, "Plain and Reinforced Concrete-Code of Practice", Bureau of Indian Standards, 2000.
[6] I.S13920, "Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces-Code of Practice", Bureau of Indian Standards, 1993.
[7] SP16, "Design Aids for Reinforced Concrete", Bureau of Indian Standards, 1980.
[8] Agarwal Pankaj and Shrikhande Manish, "Earthquake resistant design of structures", Prentice Hall of India Private Limited.