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Study of Earthquake Forces by Changing the Location of Lift Core

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Abstract **- Lift core is an important element for strengthening of structure in earthquake prone area (*M_w*=6.5 or more). This paper deals with use of lift cores to resist the seismic forces and its effect by changing the lift core location. The study for G+5 and G+10 type frame buildings are taken under consideration. These buildings are further subdivided as per soil strata i.e. hard, medium, and soft. Two locations of lift core considered for studies i.e. centre core and corner core. Zone V is considered for all buildings which will cause maximum base shear to the structure. Study is focused on comparative static and dynamic analysis which will show graphical representation of G+5 and G+10 building along with soil type. Economy is studied in analysis.**

Keywords: Lift core location, story drift, modal analysis, base shear, DBE.

I. INTRODUCTION

Earthquake is natural phenomena of movement of underground tectonic plates which releases tremendous amount of energy that leads earth surface to vibrate. According to the theory of Plate Tectonics, the entire surface of the earth can be considered to be constantly on the move. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Earthquakes became frequent after the construction of Koyna Dam and this is regarded as a classic case of man-made seismicity. It was considered that earthquake may not occur on hard rock ground but after the earthquake that occur in Latur city (1993) which is considered to be the most stable land in Maharashtra hence it can be considered that Earthquakes are one of the unpredictable natural calamity that can occur anywhere in the world. Hence it is must to design all structures as per earthquake standard. One of the important observations has been done regarding multistory building that; core shear wall can be used as an earthquake resisting element.

Lift core plays vital role as a strengthening element in structure and it is observed that architectural planning for many buildings avoiding this concept of study. Ideal location for lift core will be important for safety and economy purpose in structure as the study gives analysis of earthquake forces by changing the location of lift core with various cases included. In this report there will be static and dynamic analysis to be taken in to consideration. There are many methodologies to spot the location for lift core and it has to be done on the basis of static and dynamic analysis which gives comparison of base shear and time period of structure.

II. DESIGN

A. Design criteria:

The study will focus all in behaviour of frames as per soil strata hence according to the lift locations there will be selected frames of structures considered. Details of frame behaviour are studied with the help of the section considered from the structure.

For more elaborated differentiation there are total six numbers of cases, as follows (Fig. 1)

1. North edge members for X direction. (X1)
2. South edge members for X direction.(X2)
3. West edge member for Z direction. (Z1)
4. East edge member for Z direction.(Z2)
5. Mid Members for X direction. (MX1)
6. Mid members for Y direction. (MZ1)

Fig. 2.1 Cases for building of lift core at centre

In this study we will compare analysis results between G+5 and G+10 with Soil strata Soft, Medium, Hard & R= 3.This will be done for all following parameters.

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B. Assumptions:

For the purpose of transparency in results the study considered some important assumptions that are as follows,

i) Study is limited to Rectangular Shaped building only i.e. 50X25m.
ii) The depth of foundation for all types of strata is 2m.
iii) Zone V, R=3, I=1, Damping=0.05
iv) Structure is OMRF type.(Ordinary moment resistant frame)
v) IS code 1893-2002 considered, limit state.

In all cases only single lift core is provided which is placed either in corner or in centre of the structures. Hence with the consideration of strata there will be total number 12 models to be taken in to consideration for static and dynamic study.

C. Parameters used for study:

1. Maximum considered earthquake (MCE)
2. Zone Factor: (*Z*) = V
3. Response Reduction: (*R*) = 3
4. Importance Factor (*I*) = 1
5. Damping: 0.05
   (*As per IS 1893-2002 Part I)*
6. Design Basis Earthquake (DBE)
7. Design Horizontal Seismic Coefficient (A_h)
8. Ductility.
9. Richer Scale Magnitude (M_w)
10. Structural response factor (*Sa/g)*
11. Design seismic base shear (V_B)
12. Story drift
13. Response Spectrum
14. Modal Participation Factors(P_k)
15. Fundamental natural period *(T)*
16. Seismic weight of building *(W)*

D. Steps of Methodology:

Step 1:
Based on area of focus of the study certain assumptions of building and study certain assumptions of building of building and seismic parameters should be done.

Step 2:
Prepare STAAD model, apply loading and seismic factor for analysis.

Step 3:
Static analysis and response spectrum analysis is carried out.

Step 4:
Comparative study is established with help of graphs for

i) Storey Drifts
ii) Column Forces
iii) Mode Shapes
iv) Mass Participation Factors
v) Base Shear
vi) Column Design & Economics
vii) Response Spectrum

III. STATIC ANALYSIS

A. Story Drift:

Methodology:

In static analysis column forces and story drift will be analyzed. Earthquake design parameter is applied as explained earlier. In analysis most important aspect are given below.

1. Design Horizontal Seismic Coefficient of a structure ***(A$_h$)* :**

$$A_h = \frac{ZIS_a}{2Rg}$$

(Abbreviations in II-C)

Values of Sa/g will vary as per soil type and time period; value of A_h will change according to soil strata.

2. Total design lateral force or design seismic base shear **(V_B):**

Along any principle direction is determined by the following expression:

$$V_B = A_h W$$

(Abbreviations explained in II-C)

3. The approximate fundamental natural period of vibration (***T***)***: (In Sec)***

For buildings of moment-resisting frame and with brick infill panels is estimated by the empirical expression:

$$T_a = \frac{0.09\,h}{\sqrt{d}}$$

Where,
h = Height of the building
d= Base dimension of the building at plinth level in m.

4. Distribution of design force:

The design base shear computed in further distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i\, h_i^2}{\sum_{j=i}^{n} W_i\, h_i^2}$$

Where,

Q_i = Design lateral force at floor i,

W_i = Seismic weight force at floor i

h_i = Height of floor i measured from base

n = number of stories in the building

(As per IS 1893-2002 Part 1)

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Result Analysis:

Results of story drift are shown in graphical format and it is observed that all types of structures giving symmetrical results for deflection. Total twelve graphs extracted from results from which two of them are shown above. Graphs prove that drifting in both G+5 and G+10 type building will be more for lift core at corner. Here is Graph of G+10 type building which is showing Story drift of all the six cases i.e. Corner lift core building for hard, medium, soft strata and Centre lift core for hard, medium, soft strata. The graphs shows deflection rate of building increases at increasing story height, graph shows that centre lift core for hard strata gives minimum deflection and corner lift core for soft strata gives maximum deflection. All graphs of centre lift core are showing comparatively lesser amount of deflection.

As per IS code 1893-2002 -Part 1(7.11.1) above are some valid graphs for study. It is observed that the Storey drift is more in case of building with lift core at Corner as the Building goes into Torsion Mode. For the study, total 12 number of model bought under observation, and it is observed that all models are giving same results as it is given in above graphs. Hence building at centre core will have the minimum deflection with hard strata of the soil.

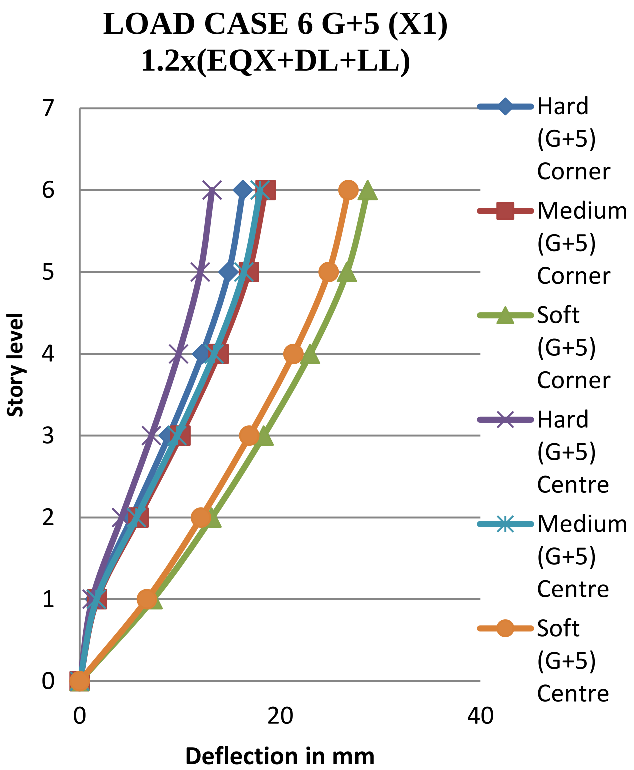

Fig. 3.1 Story drifts of G+5 Type building

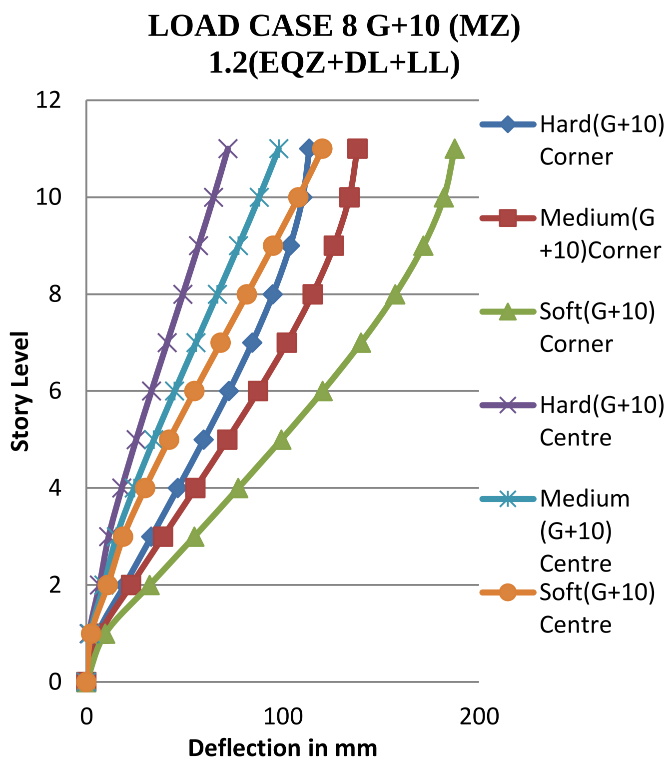

Fig. 3.2 Story drifts of G+10 Type buildi

Results of story drift are shown in graphical format and it is observed that all types of structures giving symmetrical results for deflection. Total twelve graphs extracted from results from which two of them are shown above. Graphs prove that drifting in both G+5 and G+10 type building will be more for lift core at corner. Here is Graph of G+10 type building which is showing Story drift of all the six cases i.e. Corner lift core building for hard, medium, soft strata and Centre lift core for hard, medium, soft strata. The graphs shows deflection rate of building increases at increasing story height, graph shows that centre lift core for hard strata gives minimum deflection and corner lift core for soft strata gives maximum deflection. All graphs of centre lift core are showing comparatively lesser amount of deflection.

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IV. DYNAMIC ANALYSIS

A. Responce Spectrum Analysis:

Response spectrum is peak or steady response of a series of oscillators of varying natural frequency, which are forced into motion by the same base shear. The resulting plot can be used to pick the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes.

In dynamic study this will be the basic parameter which will come under analysis. As per IS code response spectrum will be computed. Dynamic analysis is performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements. The basic calculation of response spectra i.e. Design Horizontal Seismic Coefficient (A_h) can be calculated by Static Method. For Dynamic analysis, response spectrum command has to place with modal analysis command; this will give the specified demonstration.

Some of the important parameters to be used in methodology are as follows,

i) Base shear analysis
ii) Time period analysis
iii) Frequency and Mass Participation

1. *Modal Mass: M_k*

$$M_k = \frac{[\sum_{i=1}^{n} \boldsymbol{W_i \emptyset_{ik}}]^2}{\boldsymbol{g} \sum_{i=1}^{n} \boldsymbol{W_i} (\boldsymbol{\emptyset_{ik}})^2}$$

Where,
g = Acceleration due to gravity,
$\emptyset_{ik}$ = mode Shape coefficient at floor i in mode k
W_i = Seismic weight of floor i

2. *Modal Participation Factor: (P_k)*

Modal participation factor of mode ***k*** of vibration is the amount by which mode ***k*** contributes to the overall vibration of the structure under horizontal and vertical earthquake ground motions.

$$P_k = \frac{\sum_{i=1}^{n} W_i \emptyset_{ik}}{\sum_{i=1}^{n} W_i (\emptyset_{ik})^2}$$

3. Peak lateral force (Q_{ik}):

$$Q_{ik} = A_k \emptyset_{ik} P_k W_i$$

Where,
A_k = Design horizontal acceleration spectrum values
k = mode

4. Peak shear force: (V_{ik})

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

(IS 1893-2002-Part 1)

These are the equations used for Dynamic analysis.

V. RESULT ANALYSIS:

i) *Base shear Result:*

Normalizes base shear values are presented in graphs below.

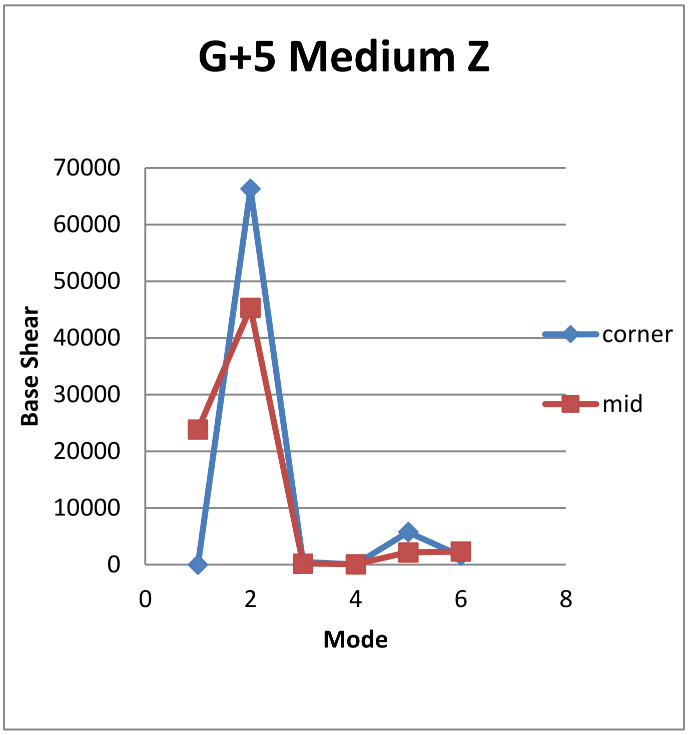


Fig 5.1 Base Shear of G+5 Medium strata in Z direction

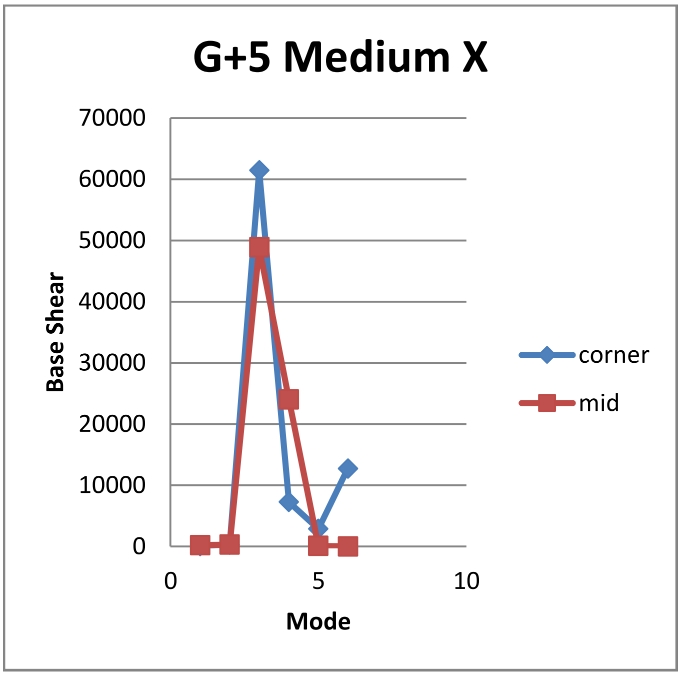


Fig 5.2 Base Shear of G+5 Medium strata in X direction

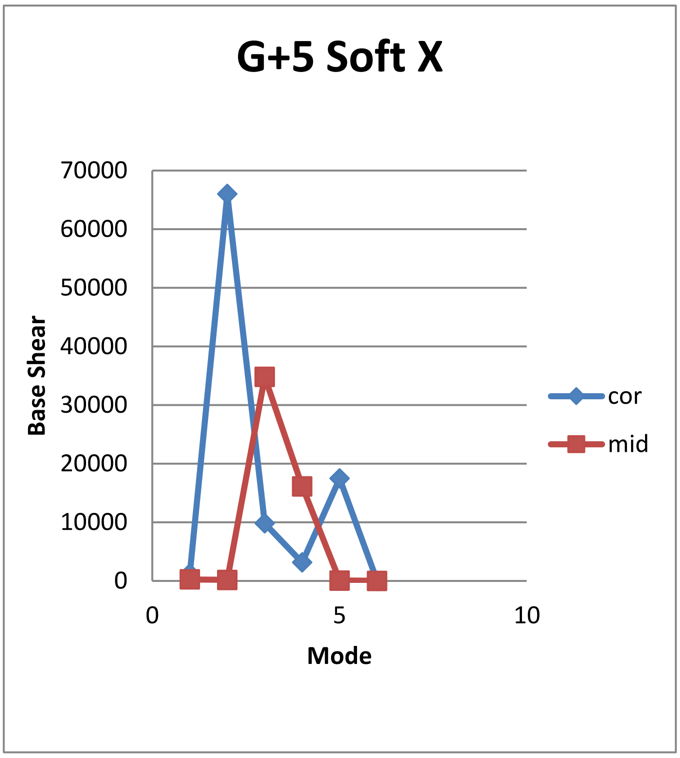


Fig 5.2 Base Shear of G+5 Medium strata in X direction

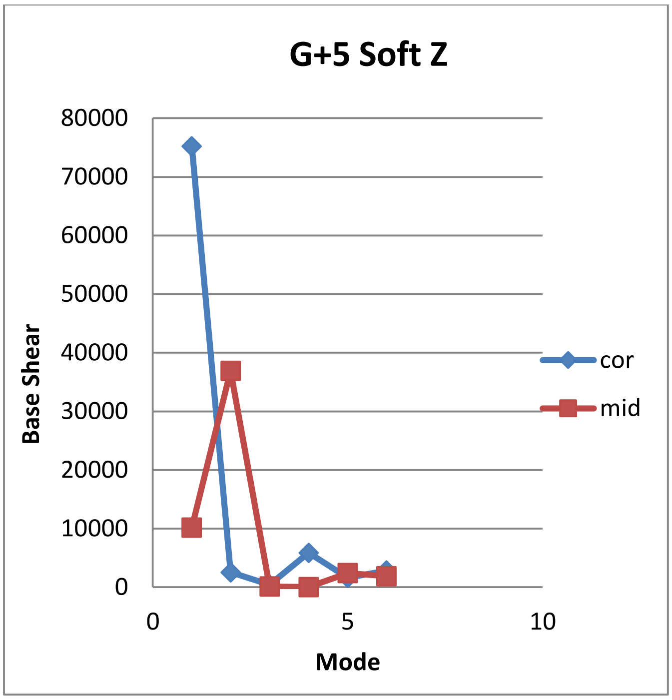


Fig 5.4 Base Shear of G+10 Medium strata in Z direction

Above are few graphs, shown in linear format which proves that base shear for building at centre/mid lift core is lesser than that of corner lift core. As per proven study it is required to have lesser Base shear for building to achieve economy in structures. Here G+5 type and G+10 type building shows similar results as it shown in Static analysis. Hence this concludes that in dynamics analysis base shear will be lesser in centre lift core as compared to corner lift core building. Here study models are shown maximum base shear as there are assumption have be considered to get transparency in results.

1. *Time Period: (TP)*

i) Time period for G+5 hard strata (Centre and Corner core):

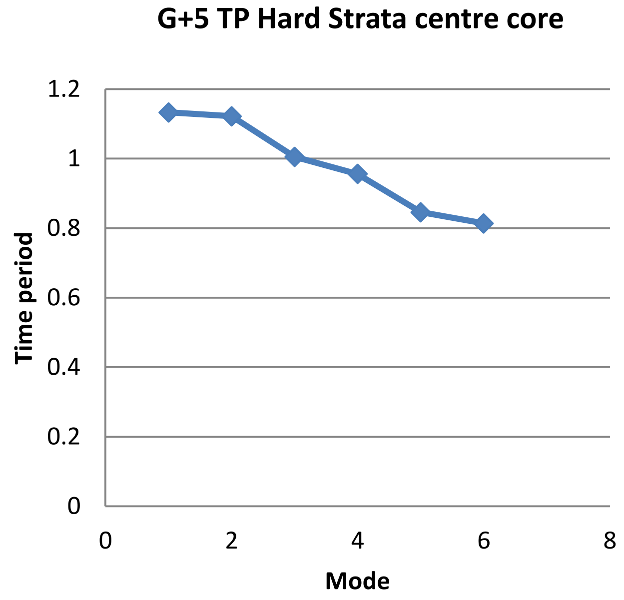
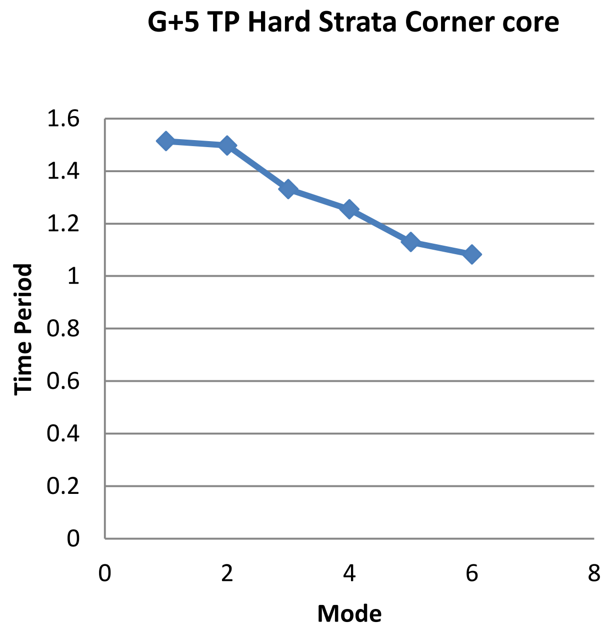


Fig.5.5 Time period of G+5 at hard strata



ii) *Time period for G+5 Soft soil centre :*

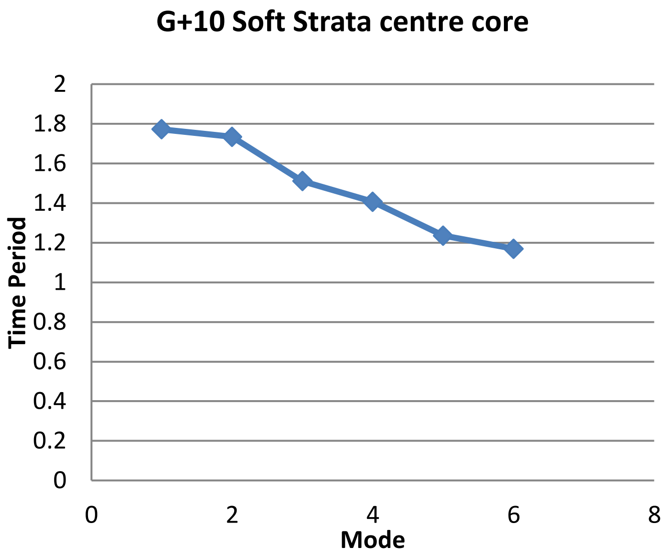


Fig.5.7 Time Period of G+10 at Centre Core (Soft strata)

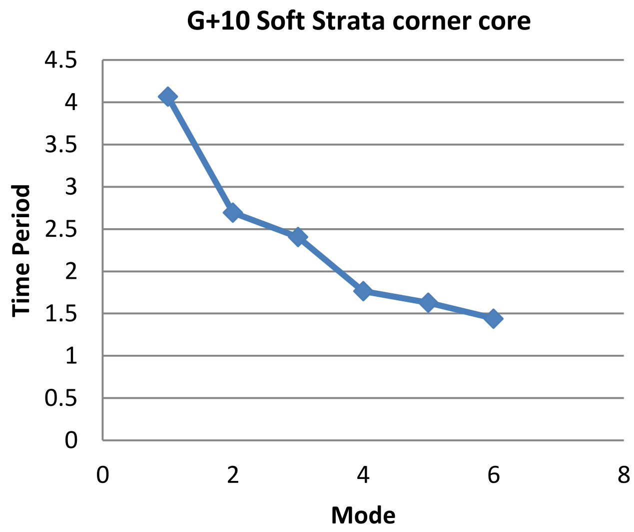


Fig.5.8 Time Period of G+10 at Corner core (Soft strata)

From all above results it is computed that time period for corner core is much lesser than the time period at centre core building. As the TP for lift core at corner is more it is clear that the building is in torsion. Torsion mode invites more destruction of elements as columns are not designed for turning or torsion behavior.

2. *Modal analysis and Mass Participation:*

Mass participation behavior of one of the structure which shows clearly that the frame which is extremely near to the lift core is giving less amount of mass participation than frame which is placed away from lift core. The other frame considered to be a corner lift core which gives maximum deflection in one direction only. The torsion is an additional force that acts because if the location core at corner hence mass participation can be optimized if core be placed at centre. Some of the images of test results from STAAD Pro showing mode shapes of particular case are as follows.

i) G+5 Hard strata-Centre lift core:

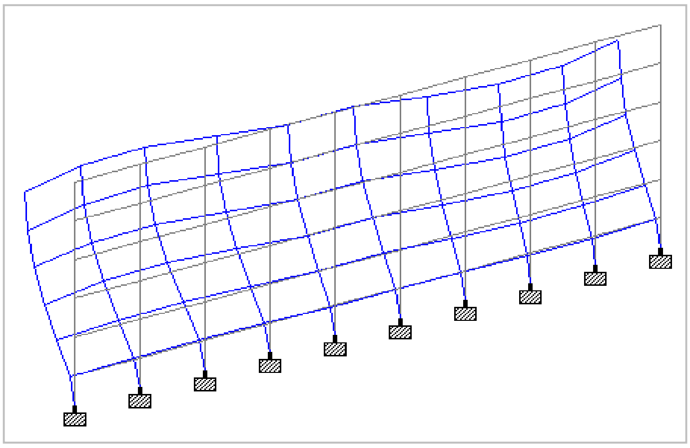


Fig. 5.9 Modal analysis for G+5 (Centre core) Frame at Section MX (Front view)

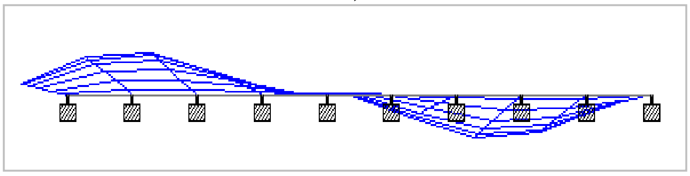


Fig. 5.10 Modal analysis for G+5 (centre core) Frame at Section MX (Top view)

G+5 centre lift _Hard - Frequencies & Mass Participations

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	0.883	1.133	0.286	0.000	14.598
2	0.891	1.122	0.069	0.000	55.215
3	0.995	1.005	45.418	0.000	0.000
4	1.046	0.956	23.535	0.000	0.001
5	1.182	0.846	0.005	0.000	3.368
6	1.229	0.814	0.051	0.000	0.084

Fig 5.11 Table for Frequencies and mass participation for G+5

ii) G+10 Soft strata- Corner lift core:

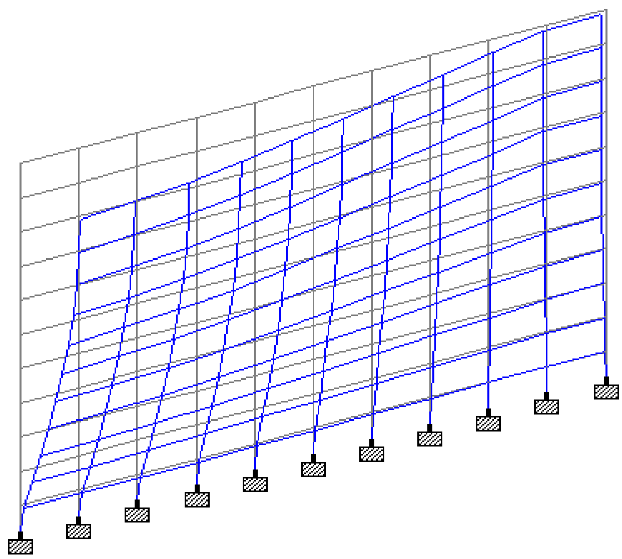


Fig. 5.12 Modal analysis for G+10 (Corner core) Frame at Section MX (Front view)

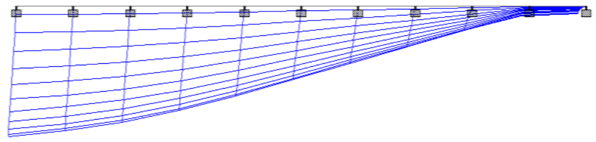


Fig. 5.13 Modal analysis for G+10 Frame at Section MX (Top view)

G+10_Soft (25X50) - Frequencies & Mass Participations

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	0.263	3.800	0.675	0.000	58.687
2	0.400	2.501	37.230	0.000	10.135
3	0.448	2.231	33.798	0.000	4.501
4	0.615	1.625	0.916	0.000	2.926
5	0.666	1.501	7.190	0.000	1.163
6	0.741	1.350	0.000	0.000	6.901

Fig. 5.14 Table for Frequencies and mass participation for G+10(Corner core) Soft strata.

VI. CONCLUSION:

i) It was observed that the Storey drift is more in building with corner lift core as the Building goes into Torsion Mode.

ii) The base shear is higher in Corner Core as compared with the base shear of building with Centre Core.

iii) Time periods of the structure is inversely proportional with soil stiffness hence it is conclude that the hard soil strata gives best safety for earthquake resistant structures

iv) The Buildings with Lift Core at Corner tend to go in Torsion Mode which develops extra forces in the frames.

v) Greater Economy can be achieved by keeping the Lift Cores at Centre of the Buildings.

vi) Building at centre lift core will gives economical design as well as sufficient amount of safety

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