Comparative Study on G+15 RCC Building with Plan Irregularity Using Response Spectrum Analysis and Time History Analysis

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Abstract: Earthquakes are one of the major natural disasters that mostly tend to damage/destroy not only a structural building but also the individuals dwelling in the disaster prone areas. An irregular building with irregularities in the structure is the most vulnerable type of building prone to destruction. Therefore, it is essential to analyse such structures priorly. In this present study, a G+15 RCC building with plan irregularity is analysed using ETABS software. Re-entrant corner irregularity is considered in this study. This study has carried out the comparison between response spectrum analysis and time history analysis on a G+15 story RC framed structure with irregularities in seismic zone III. The main objective of this study is to study the behaviour of the structure by determining different parameters such as story displacements, story drifts, story shears etc. The analysis is carried out in JB Institute of Engineering and Technology on ETABS software at CAD laboratory, Moinabad, Hyderabad.

Keywords: Earthquakes; Response Spectrum Analysis; Time History Analysis; Re-entrant corners; Seismic Zone III

1. Introduction

A structural building has two major components, one of the two take the loads and transfer those loads from the superstructure and the other will transfer these loads coming from superstructure to substructure to the ground surface. These loads are of different types and the structural behaviour is depends on this loading action in a building. The structure has its self-weight and some additional forces may act on the structure due to various factors. One of which is earthquake, this impacts the structure in the lateral direction and the impact may be greater if the building is a tall structure. For an Indian tectonic plate, there are four seismic zones across the country. They are seismic zone 2, 3, 4 and 5 based on the history of seismic occurrences and the ground motions. Out of the four zones, seismic zone V is most vulnerable and highly prone to earthquakes frequently whereas seismic zone II is less vulnerable compared to all other zones. The seismic performance is dependent on the re-entrant corners in the structure as it causes concentration of stresses and load variation resulting in torsion during earthquake events. Therefore, during the construction practices in the seismic zones, dynamic analysis has to be performed for a building of height greater than 15meters for regular buildings and for all irregular buildings in seismic zones 3,4 and 5 as disclosed in IS-1893:2016. Here, in this study, an irregular building of G+15 is built in seismic zone III. This building is analysed using linear static analysis, response spectrum analysis method and time history analysis method and the results of both methods are analysed.

Regular structure: A regular structure is that which have no significant discontinuity in the plan layout or the lateral force resisting system.

Irregular structure: An irregular structure that have significant physical discontinuities in the configuration of the building or in the lateral force resisting members. On a broader classification, irregularities in a structure are of two categories. They are Plan irregularity and Vertical irregularity.

I. Plan irregularity~
   a. Torsion irregularity
   b. Re-entrant corners
   c. Diaphragm discontinuity
   d. Non-parallel systems
   e. Out of plane offsets
II. Vertical irregularity~
   a. Mass irregularity
   b. Stiffness irregularity
   c. Vertical geometric irregularity
   d. In-plane discontinuity in vertical lateral force resisting element
   e. Discontinuity in capacity (weak story)

~ As Provided in IS:1893-2016

Anis S. Shatnawi, Mazen Musmar, Laith I. Gharaibeh(2018), This study analysed a re-entrant building structure using Equivalent Lateral Force(ELF) method and found that ELF method overestimates maximum displacements and drift ratio. It can be safely used for upto 12 storey buildings. It is also observed that the column at re-entrant corner is not affected until a re-entrant corner of 25% exists in the building.

S. R. Kangle, D. S. Yerudkar(2020), This study analysed a regular G+12 multi-storied building using Response spectrum analysis in seismic zone III on STAAD pro and ETABS software. This study concluded that the multi-storied buildings are stiff for seismic performances because the modal participation factor is observed to be >75% and the base reactions have little differences in between the used software's.

P. Sanketh, B. D. V Chandra Mohan Rao(2015), This study analysed the behaviour of asymmetric re-entrant structures of H shape and + shape are analysed with various configurations in seismic zone 5 using Response spectrum analysis on EssssTABS and studied the storey response plot data. It is found that there is considerable decrease in base shear as compared to regular buildings and observed that H shaped buildings are prone to seismic activity than +shaped structures.

Dr. K. Chandrasekhar Reddy & G. Lalith Kumar (2019), This study analyses a high rise building of 30 floors(G+30) considering seismic zones 2,3,4 and 5. This study concludes that the lateral displacements and drifts are comparatively more in zone 5 rather than other three zones. It also suggests that ETABS software provides more accuracy for analysis of the structures.

2. Methodology

In this present study, analysis of G+15 story RCC framed irregular building in seismic zones III is carried out. A 3D rendered model is developed for G+15 story building using ETABS software.

There are different types for the method of analysis.

- Linear Static Analysis Method
- Response Spectrum Analysis
- Time History Analysis

- Push over Analysis
- Sequential Yield Analysis

2.1 Modelling of structure

Irregular structure of G+15 in seismic zone III is modelled for linear static analysis method, response spectrum analysis method and time history analysis method using ETABS software.

Applied loads

1. Dead Load
2. Live Load
3. Seismic Loads as per IS 1893:2016 in X and Y direction without eccentricity

Building specification

PARAMETERS	VALUE
Type of Building	RC Residential Building
Number of Stories	G+15
Height	Ground: 3.5m
	Remaining: 3m
Grade of Concrete	M20
Rebar	HYSD415
Beam 1	150*200mm
Beam 2	200*250mm
Column 1	150*200mm
Column 2	200*250mm
Slab	120mm
Zone Factor	0.16
Importance factor I	1.2
Reduction factor R	5.0

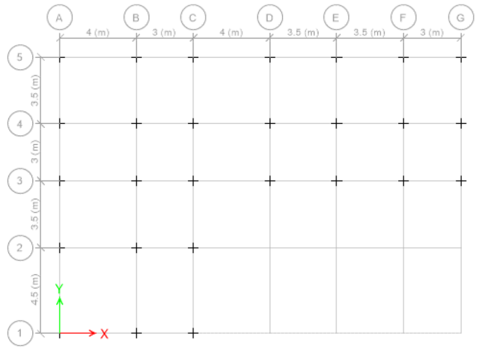


Figure 2.1: PLAN

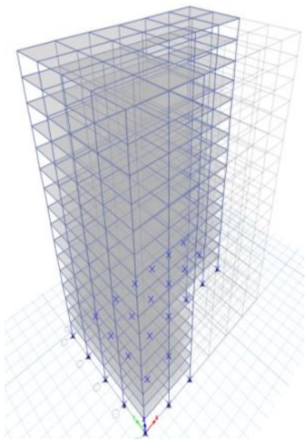


Figure 2.2: 3D ELEVATION

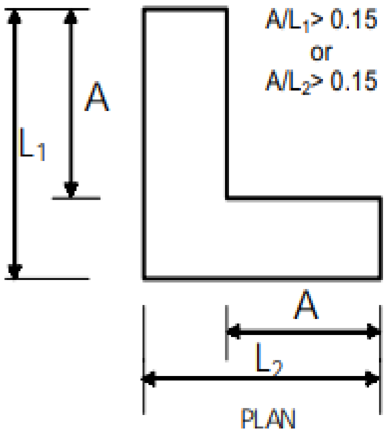
Name	Height mm	Elevation mm
F15	3000	48500
F14	3000	45500
F13	3000	42500
F12	3000	39500
F11	3000	36500
F10	3000	33500
F09	3000	30500
F08	3000	27500
F07	3000	24500
F06	3000	21500
F05	3000	18500
F04	3000	15500
F03	3000	12500
F02	3000	9500
F01	3000	6500
GF	3500	3500
Base	0	0

Figure 2.3: Elevation data

3. Results and discussion

3.1 Re-entrant corner

If the structure is said to have re-entrant corner irregularity, then both the plan projections of the structural building at the re-entrant corner should be greater than 15 percent of the overall plan dimension in the building.



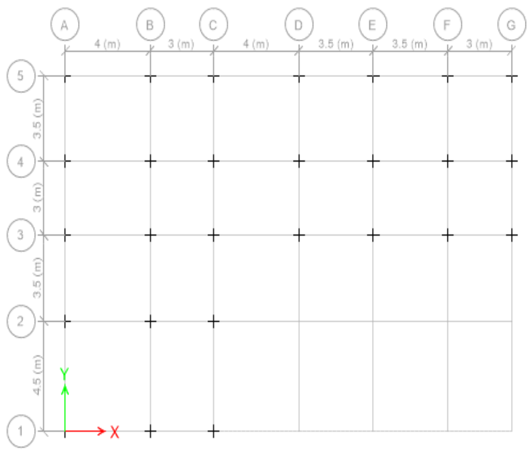


Figure 2.4: Rentrant corner

Comparing both the figures, we find that in X direction A/L_1=0.66>0.15 and in Y direction A/L_2=0.55>0.15.

3.2 MODEL 1

For linear static analysis in zone III

Table 1: Story displacement

Storey	X direction	Y direction
Storey 15	0.006	0.044
Storey 14	0.006	0.044
Storey 13	0.006	0.043
Storey 12	0.006	0.041
Storey 11	0.005	0.04
Storey 10	0.005	0.038
Storey 9	0.005	0.035
Storey 8	0.005	0.033
Storey 7	0.004	0.03
Storey 6	0.004	0.026
Storey 5	0.003	0.023
Storey 4	0.003	0.02
Storey 3	0.002	0.016
Storey 2	0.002	0.0012
Storey 1	0.001	0.008
Ground	0.001	0.004
Base	0	0

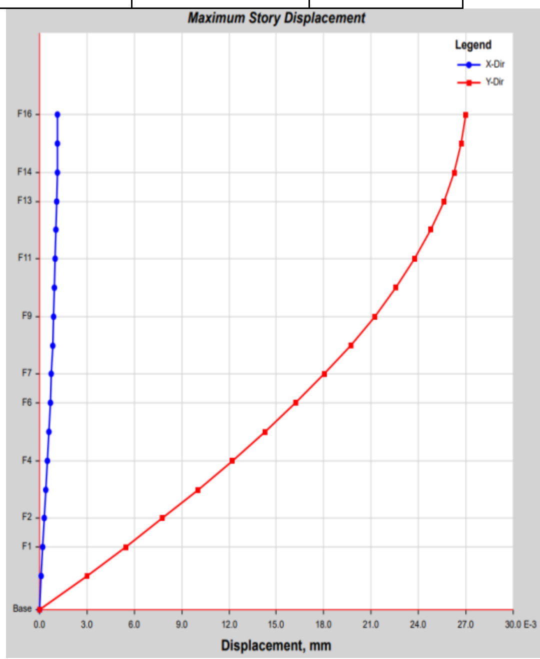


Figure 3.1: Story Displacement of modal

From Table 1, the Maximum and Minimum story displacement in X-direction are found as 0.006 and 0.001 at storey 15 and Ground stories. Maximum and Minimum displacements in Y-direction are found as 0.044 and 0.004 at storey 15 and Ground stories.

Table 2: Story drift

Storey	X direction	Y direction
Storey 15	1.729E-08	2.323E-07
Storey 14	1.996E-08	3.293E-07
Storey 13	3.908E-08	4.508E-07
Storey 12	5.766E-08	0.000001
Storey 11	7.57E-08	0.000001
Storey 10	9.305E-08	0.000001
Storey 9	1.096E-07	0.000001
Storey 8	1.252E-07	0.000001
Storey 7	1.391E-07	0.000001
Storey 6	1.531E-07	0.000001
Storey 5	1.652E-07	0.000001
Storey 4	1.76E-07	0.000001
Storey 3	1.854E-07	0.000001
Storey 2	1.932E-07	0.000001
Storey 1	2.015E-07	0.000001
Ground	1.841E-07	0.000001
Base	0	0

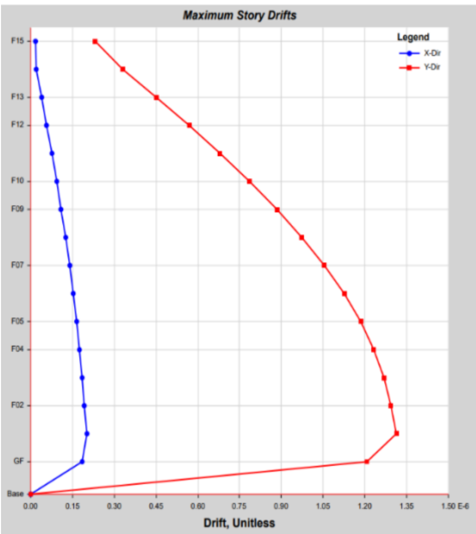


Figure 3.2: Story drift

From Table 2, the Maximum and Minimum story drifts in X-direction are found as 2.015E-07 at storey 1 and 1.729E-08 at storey 15. Maximum and Minimum story drifts in Y-direction are found as 0.000001 from Ground to storey 12 and 2.323E-07 at storey 15.

Table 3: Story shear

Storey	X direction	Y direction
Storey 15	0.0001	-0.0067
Storey 14	0.0002	-0.0137
Storey 13	0.0003	-0.0205
Storey 12	0.0004	-0.0271
Storey 11	0.0004	-0.0334
Storey 10	0.0005	-0.0394
Storey 9	0.0006	-0.045
Storey 8	0.0006	-0.0502
Storey 7	0.0007	-0.0549
Storey 6	0.0007	-0.059
Storey 5	0.0007	-0.0627
Storey 4	0.0008	-0.0657
Storey 3	0.0008	-0.0682
Storey 2	0.0008	-0.0701
Storey 1	0.0008	-0.0714
Ground	0.0008	-0.072
Base	0	0

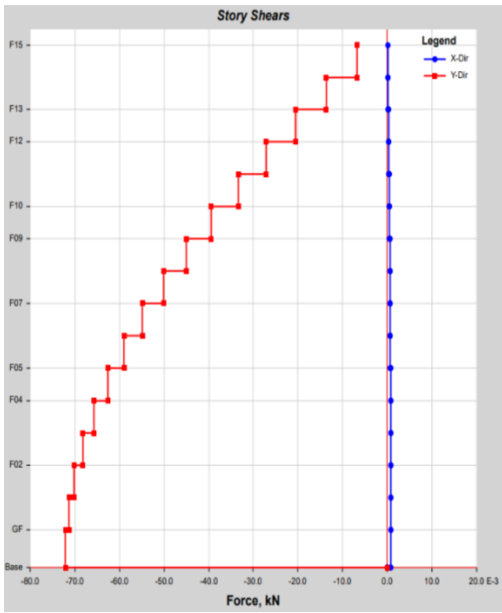


Figure 3.3: Story shear/ Base shear

From Table 3, the Maximum and Minimum values of story shears in X direction are found as 0.0008(1KN) at Ground and 0.0001(0KN) at storey 16.

Maximum and Minimum story shears in Y direction are found as -0.0067(-7KN) at storey 16 and -0.072(-72KN) at Ground. Base shear is maximum at base.

3.3 MODEL II

For Response Spectrum Analysis in Zone III

Table 4: Story displacement

Storey	X direction	Y direction
Storey 15	6.217E-09	1.227E-07
Storey 14	1.082E-08	1.858E-07
Storey 13	2.016E-08	2.584E-07
Storey 12	2.951E-08	3.309E-07
Storey 11	3.886E-08	4.025E-07
Storey 10	4.82E-08	4.731E-07
Storey 9	5.749E-08	0.000001
Storey 8	6.673E-08	0.000001
Storey 7	7.589E-08	0.000001
Storey 6	8.497E-08	0.000001
Storey 5	9.399E-08	0.000001
Storey 4	1.03E-07	0.000001
Storey 3	1.122E-07	0.000001
Storey 2	1.233E-07	0.000001
Storey 1	1.611E-07	0.000001
Ground	4.731E-07	0.000004
Base	0	0

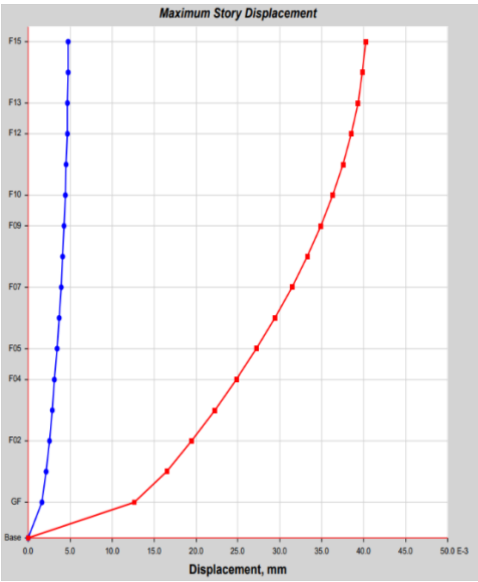


Figure 3.4: Storey displacement

From Table 4, the Maximum and Minimum values of Story displacement in X direction are found as 0.005 from storey 11 to storey 15 and 0.002 at Ground and storey 1. Maximum and Minimum values of Story displacement in Y direction are found as 0.04 at storey 15 and 0.013 at Ground.

Table 5: Story drift

Storey	X direction	Y direction
Storey 15	0.005	0.04
Storey 14	0.005	0.04
Storey 13	0.005	0.039
Storey 12	0.005	0.039
Storey 11	0.005	0.038
Storey 10	0.004	0.036
Storey 9	0.004	0.035
Storey 8	0.004	0.033
Storey 7	0.004	0.031
Storey 6	0.004	0.029
Storey 5	0.003	0.027
Storey 4	0.003	0.025
Storey 3	0.003	0.022
Storey 2	0.003	0.019
Storey 1	0.002	0.016
Ground	0.002	0.013
Base	0	0

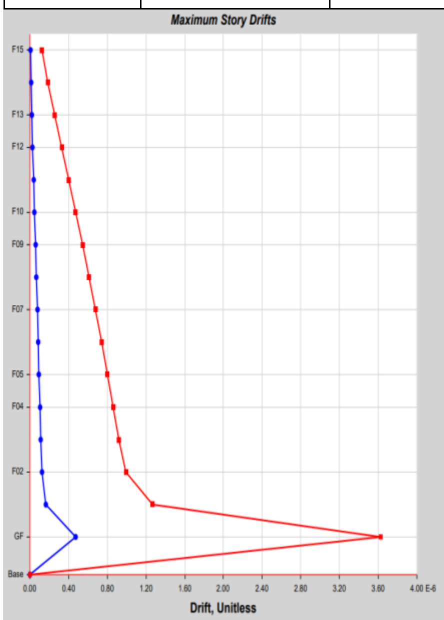


Figure 3.5: Story drift

From Table 5, the Maximum and Minimum values of Story drift in X direction are found as 4.731E-07 at Ground and 6.217E-09 at storey 15. Maximum and Minimum values of Story displacement in Y direction are found as 0.000001 from storey1 to storey 9 and 1.227E-07 at storey 15.

Table 6: Story shear/ Base shear

Storey	X direction	Y direction
Storey 15	-1.363E-05	-0.0028
Storey 14	-2.957E-05	-0.0059
Storey 13	-4.684E-05	-0.0089
Storey 12	-0.0001	-0.0119
Storey 11	-0.0001	-0.0148
Storey 10	-0.0001	-0.0178
Storey 9	-0.0001	-0.0207
Storey 8	-0.0001	-0.0235
Storey 7	-0.0002	-0.0263
Storey 6	-0.0002	-0.029
Storey 5	-0.0002	-0.0316
Storey 4	-0.0002	-0.0342
Storey 3	-0.0003	-0.0367
Storey 2	-0.0003	-0.0393
Storey 1	-0.0003	-0.042
Ground	-0.0003	-0.0453
Base	0	0

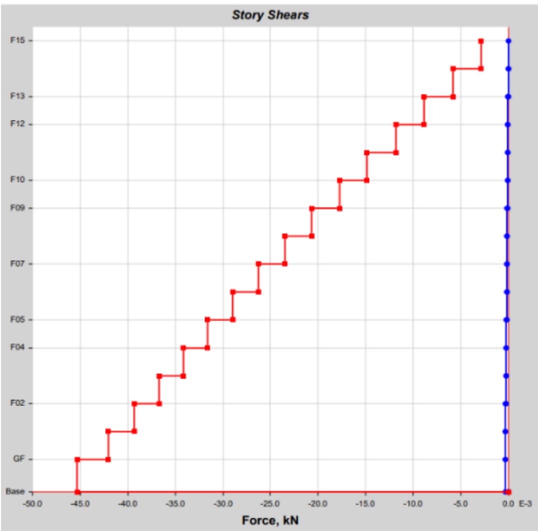


Figure 3.6: Story shear /Base shear

From Table 6, the Maximum and Minimum values of Story shear in X direction are found as –1.363E-05(-6KN) at storey 15 and -0.0003(-45.5KN) at Ground. Maximum and Minimum values of Story shear in Y direction are found as -0.0028(0KN) at storey 15 and -0.0453(-0.5KN) at Ground. Base shear is maximum at ground.

3.4 MODEL III

For Time History Analysis in zone III using ELCENTRO Time History Function.

Table 7: Story displacement

Storey	X direction	Y direction
Storey 15	0.006	0.044
Storey 14	0.006	0.044
Storey 13	0.006	0.043
Storey 12	0.006	0.041
Storey 11	0.005	0.04
Storey 10	0.005	0.038
Storey 9	0.005	0.035
Storey 8	0.005	0.033
Storey 7	0.004	0.03
Storey 6	0.004	0.026
Storey 5	0.003	0.023
Storey 4	0.003	0.02
Storey 3	0.002	0.016
Storey 2	0.002	0.012
Storey 1	0.001	0.008
Ground	0.001	0.004
Base	0	0

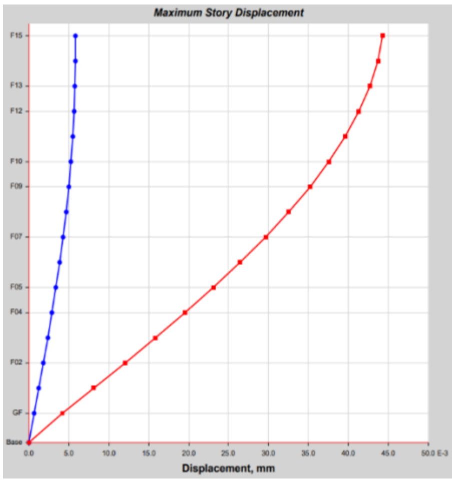


Figure 3.7: Story displacement

From Table 7, the Maximum and Minimum values of Story displacement in X direction are found as 0.006 from storey 12 to 165 and 0.001 at Ground. Maximum and Minimum values of Story displacement in Y direction are found as 0.044 at storey 15 and 0.004 at Ground.

Table 8: Story drift

Storey	X direction	Y direction
Storey 15	1.729E-08	2.323E-07
Storey 14	1.996E-08	3.293E-07
Storey 13	3.908E-08	4.508E-07
Storey 12	5.766E-08	0.000001
Storey 11	7.57E-08	0.000001
Storey 10	9.305E-08	0.000001
Storey 9	1.096E-07	0.000001
Storey 8	1.252E-07	0.000001
Storey 7	1.397E-07	0.000001
Storey 6	1.531E-07	0.000001
Storey 5	1.652E-07	0.000001
Storey 4	1.76E-07	0.000001
Storey 3	1.854E-07	0.000001
Storey 2	1.932E-07	0.000001
Storey 1	2.015E-07	0.000001
Ground	1.841E-07	0.000001
Base	0	0

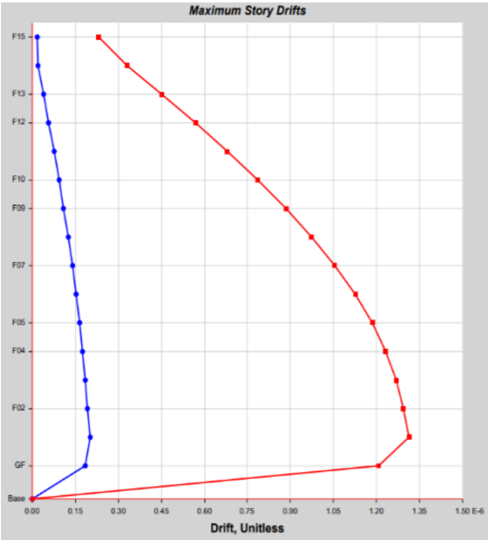


Figure 3.8: Story drift

From Table 8, the Maximum and Minimum values of Story drift in X direction are found as 2.015E-07 at storey 1 and 1.729E-08 at storey 15. Maximum and Minimum values of Story drift in Y direction are found as 0.000001 from Ground to storey 12 and 2.323E-07 at storey 15.

Table 9: Story shear/ Base shear

Storey	X direction	Y direction
Storey 15	0.0001	-0.0067
Storey 14	0.0002	-0.0137
Storey 13	0.0003	-0.0205
Storey 12	0.0004	-0.0271
Storey 11	0.0004	-0.0334
Storey 10	0.0005	-0.0394
Storey 9	0.0006	-0.045
Storey 8	0.0006	-0.0502
Storey 7	0.0007	-0.549
Storey 6	0.0007	-0.059
Storey 5	0.0007	-0.0627
Storey 4	0.0008	-0.0657
Storey 3	0.0008	-0.0682
Storey 2	0.0008	-0.0701
Storey 1	0.0008	-0.0714
Ground	0.0008	-0.072
Base	0	0

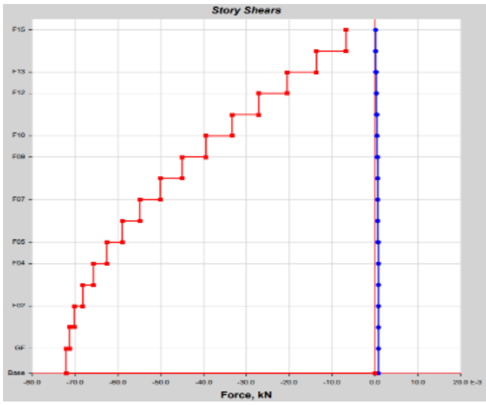


Figure 3.9: Story shear

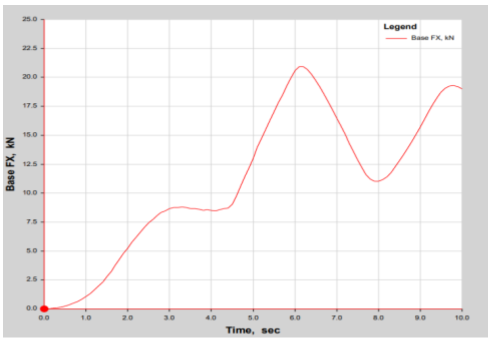


Figure 3.10: Time History Plot

From Table 9, the Maximum and Minimum values of Story shear in X direction are found as 0.0008(1KN) at Ground and 0.0001(0KN) at storey 15. Maximum and

Minimum values of Story shear in Y direction are found as -0.0067(-7KN) at storey 15 and -0.072 at Ground(-72KN). As for Table 10, the time history plot is obtained by considering base shear component.

4. Conclusions

An irregular building with re-entrant corner irregularity is considered for the analysis. The building that which is assumed for analysis had plan asymmetry. For all the models, linear static analysis is carried out for Dead and Live loads and in case of MODEL II and MODEL III response spectrum analysis and time history analysis is done for seismic load in x and y direction and the corresponding story response plots were compared.

Summary of the results:

i. The analysis is carried out considering the combination of load cases on the building (100% of Dead,50% of Live and 0.25% of Seismic loads).
ii. It is observed that the action of torsion is greater along the Y direction.
iii. According to time history graph, the maximum base shear has occurred at 6.1seconds.
iv. The base shear values have slight deviations in response spectrum analysis and time history analysis. The linear static analysis and time history analysis show similar values of base shear. Therefore, from this study the author assumes that the response spectrum analysis values are close to practical application.
v. The story drift values of response spectrum and time history analysis have comparatively different maximum story drifts.
vi. Considering base reactions, the seismic moment along the Y direction is maximum but is compensated by the self-weight of the structure.

It is important to consider plan asymmetry for analysis for the structural safety of an irregular building.

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