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Comparison of Seismic Performance of Multi-Storied RCC Buildings with Plan Irregularity

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Abstract: **Earthquake is one of the most devastating natural disaster that not only causes loss of life but also causes loss of economy. The buildings which have plan irregularity in forms of torsion irregularity, reentrant corner, diaphragm discontinuity, non-parallel lateral load resisting system etc. are subjected to more severe damages during earthquake excitation in comparison to regular building. In this study a regular square shape and three irregular building shape as 'L' shape, 'C' shape, 'T' shape are chosen for the study of seismic behavior. All the four models are modelled, conforming to IS code 1893:2002 part1 and analyzed by using Etabs software. The parameters such as time period, base shear, story stiffness are studied for four models. The main objective of this study isthat, after analysis using Linear Time history method, comparison of seismic performance of different models was performed and most vulnerable building shape against earthquake forces was located in this study.**

KEY WORDS: Natural disaster, plan irregularity, reentrant corner, seismic excitation, seismic vulnerable etc.

INTRODUCTION

Earthquakes pose inevitable risks to everyone who lives in a seismically active region. Even though hazard is well recognized, no one knows when an earthquake will strike and how severe it will be. There is considerable effort over the years to develop the capability to predict earthquakes, it is unclear whether it will be achieved. By doing effective planning, design , construction and response measures, it will be possible to reduce injuries, loss of life, property damage, interruption of economy and social activity. We cannot prevent earthquake but can mitigate the loss caused by earthquake.

IS Code 1893:2002 (Part 1) has explained building configuration system for better performance of RC buildings during earthquake response. A building is said to be regular when building configuration are almost symmetrical about the axis and it is said to be irregular when it lacks of symmetry and discontinuity in geometry, mass or load resisting elements. The damages of the building is directly proportional to the amount of energy released during seismic excitation.

During seismic excitation, the behaviour of regular and irregular shape buildings is totally different. When earthquake hits the building, the damages in building which have lack of symmetry are more severe than regular shape building. The lack of symmetry in a building acts as the weakness point during earthquake excitation, so in building damages starts at that point.

In this research paper four different plan configuration shape building models are chosen, in which one is regular square shape and three is irregular 'L' shape, 'C' shape, 'T' shape models. The parameters like as time period, base shear and story stiffness are chosen for the study. The method chosen for analysis is linear time history method which gives best results for high rise irregular shape building.By comparing above parameters the best model which performs well during seismic excitation was located.

STRUCTURAL MODELING

Four building shapes representing regular square shape and irregular 'L' shape, 'C' shape, 'T' shaped building are modelled using EATBS.For this study, structures of G+14 (15) story are chosen. These structures are modelled according to the Indian Standard Code IS 1893:2002(part 1). The details of structure which are used in analysis are as follows

Table 1: Geometric and Material Data

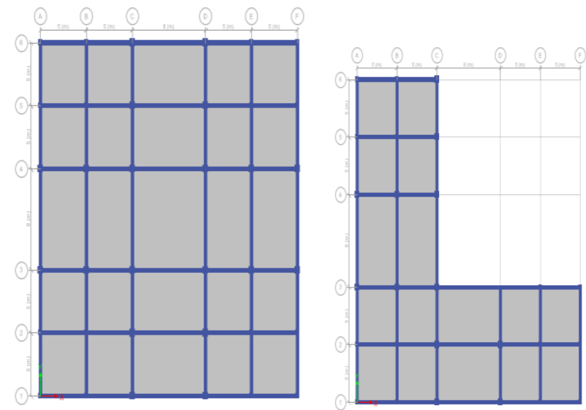
Building Type	Office Purpose Building
Area of plot	28m X 28m
Number of bays in X direction	2 No@ 5m, 1 No@ 8m, 2 No@ 5m

Number of bays in Y direction	2 No@ 5m, 1 No@ 8m, 2 No@ 5m
Number of Story	15 (G+14)
Floor to floor height	3m
Bottom Story height	3.5m
Total height of building	45.5m
Slab thickness	180mm
Size of Beam	300x550 mm 300x450 mm
Size of Column	600x600 mm 450x450 mm
Grade of concrete (Beam, Slab)	M30
Grade of concrete (Column)	M30
Unit wt. of concrete	25KN/m^3
Live Load	4.0 KN/m^2
Grade of Steel	HYSD 415

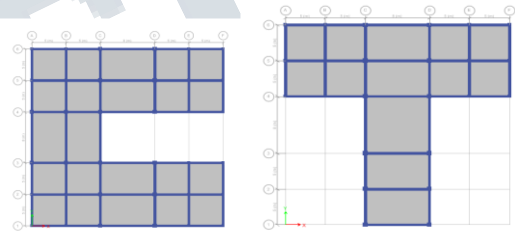
Table 2: Seismic Data

Zone Factor (z)	IV(0.24)
Importance factor (I)	1.5
Response reduction factor (R)	5
Soil type	II
Damping	5%
Code used for analysis	IS 1893-2002
Time history data used	Delhi University, New Delhi (DLU).

2.1 Plan Detail of buildings shapes



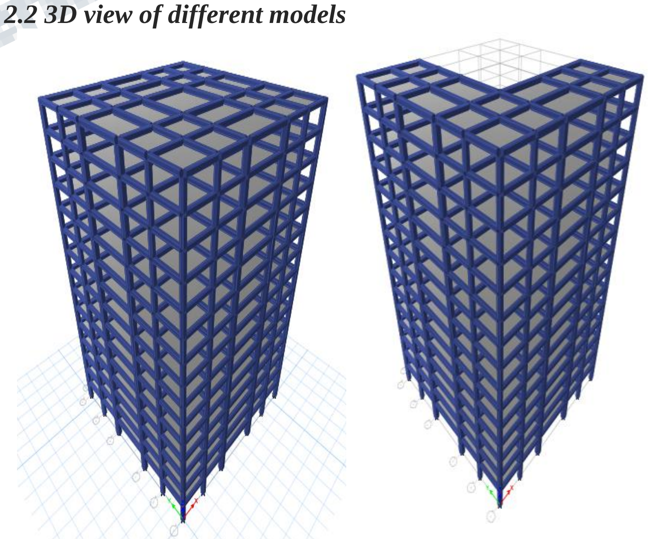
Square Shape *'L' Shape*



'C' Shape 'T' Shape

Fig 1: Plan details of different shape building models.

2.2 3D view of different models



'Square' Shape 'L' Shape

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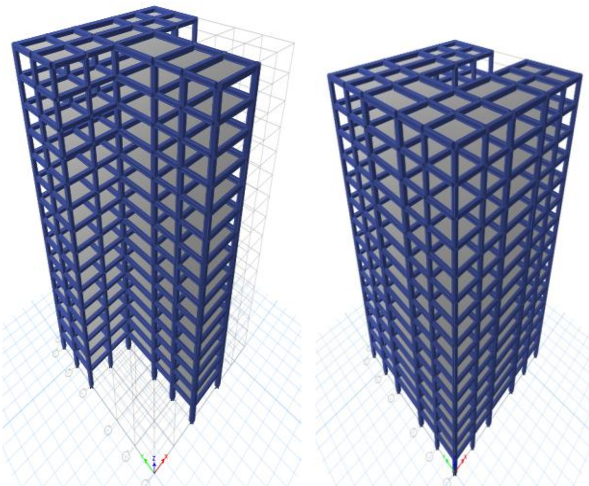

'T' Shape *'C' Shape*

Fig 2: 3D View of different shape building models.

ANALYSIS OF THE STRUCTURES

In this study, linear time history method is used since the structure is of irregular type therefore torsional irregularity is the major parameter to be considered for the study, also time history method gives better result in case of irregular and high rise building. In time history analysis actual ground acceleration data in both X and Y direction is used during earthquake analysis which leads to a more better and quick assessment of the structure. The building site chosen for construction is Delhi University, Delhi in zone IV. Necessary time history data is provided by IMD. In seismic analysis, the behaviour of building is studied for natural time period, base shear and story stiffness.

3.1. Time Period

Natural time period 'T' of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

its mass 'm' and stiffness 'k'. These three quantities are related by Unit of the natural time period is 'second'. Buildings that are heavy (with larger mass m) and flexible (with smaller stiffness k) have larger natural period than light and stiff buildings. The reciprocal (1/ T) of natural period of a building is called the Natural Frequency 'f'. Its unit is Hertz (Hz). The building offers least resistance against seismic forces when shaken at its natural frequency (or natural period). Table, whichshows the values of natural period in different modes of vibration in regular square shape, 'L' shape and 'C' shape and 'T' shape building is as follows.

Table:3 Natural Time Period

Mode No	Square Shape Time Period (Sec.)	'L' Shape Time Period (Sec)	'C' Shape Time Period (Sec)	'T' Shape Time Period (Sec)
1	2.227	2.188	1.727	2.217
2	2.227	2.16	1.684	2.203
3	1.957	1.926	1.583	1.976
4	0.727	0.71	0.558	0.719
5	0.727	0.703	0.55	0.716
6	0.642	0.631	0.522	0.645
7	0.417	0.402	0.311	0.408
8	0.417	0.4	0.309	0.406
9	0.374	0.364	0.301	0.369
10	0.286	0.275	0.218	0.277
11	0.286	0.274	0.217	0.277
12	0.257	0.25	0.212	0.252

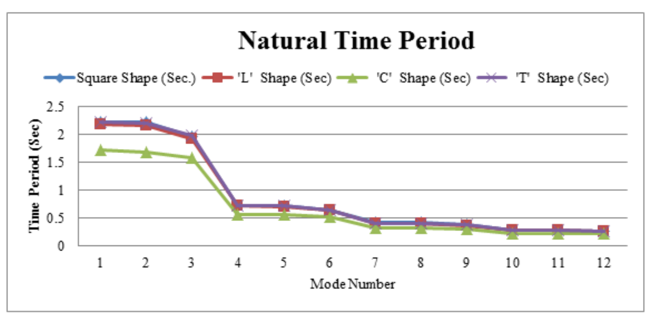

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Fig:3 Natural time period of different shape building models.

3.2. Base Shear:

Base shear is an estimate of maximum expected lateral force that will occurs due to seismic ground motion at the base of a structure. Calculations of base shear (VB) depends on

- Soil conditions at the site.
- Proximity to potential sources of seismic activity (such as geological faults)
- Probability of significant seismic ground motion
- The fundamental (natural) period of vibration of the structure when subjected to dynamic loading.

$$V_B = A_h W$$

Where Ah = Design horizontal seismic coefficient
W = Seismic weight of the building.

Table:4Calculated base shear in X and Y-Direction:

Direction	Model	Period Used (Sec.)	Base Shear V_B (KN)
X + Ecc. Y	Square Shape	2.227	**2272.349**
Y + Ecc. X	Square Shape	2.227	**2272.349**
X + Ecc. Y	'L' Shape	2.188	**1424.0576**
Y + Ecc. X	'L' Shape	2.188	**1442.1086**
X + Ecc. Y	'C' Shape	1.727	**3214.1623**
Y + Ecc. X	'C' Shape	1.727	**3134.4928**
X + Ecc. Y	'T' Shape	2.217	**1289.2521**
Y + Ecc. X	'T' Shape	2.217	**1297.4166**

Table:5 Story shear in 'X' and 'Y' direction

Story	Elevation (m)	Story shear in 'X' direction: Square Shape (kN)	'L' Shape (kN)	'C' Shape (kN)	'T' Shape (kN)	Story shear in 'Y' direction: Square Shape (kN)	'L' Shape (kN)	'C' Shape (kN)	'T' Shape (kN)
Story15	45.5	389.41	242.45	554.20	219.15	389.41	245.52	540.47	220.54
Story14	42.5	359.76	225.76	508.22	204.45	359.76	228.62	495.62	205.75
Story13	39.5	310.76	195.01	439.00	176.61	310.76	197.48	428.12	177.72
Story12	36.5	265.35	166.51	374.85	150.80	265.35	168.62	365.56	151.75
Story11	33.5	223.52	140.26	315.76	127.03	223.52	142.04	307.94	127.83
Story10	30.5	185.28	116.27	261.74	105.29	185.28	117.74	255.25	105.96
Story9	27.5	150.62	94.52	212.78	85.60	150.62	95.72	207.51	86.14
Story8	24.5	119.55	75.02	168.89	67.94	119.55	75.97	164.70	68.37
Story7	21.5	92.06	57.77	130.06	52.32	92.06	58.50	126.83	52.65
Story6	18.5	68.16	42.77	96.29	38.74	68.16	43.31	93.91	38.98
Story5	15.5	47.85	30.02	67.59	27.19	47.85	30.40	65.92	27.36
Story4	12.5	31.12	19.52	43.96	17.68	31.12	19.77	42.87	17.79
Story3	9.5	17.97	11.28	25.39	10.21	17.97	11.42	24.76	10.28
Story2	6.5	8.41	5.28	11.88	4.78	8.41	5.34	11.59	4.81
Story1	3.5	2.46	1.54	3.47	1.40	2.46	1.56	3.38	1.41
Base	0	0	0	0	0	0	0	0	0

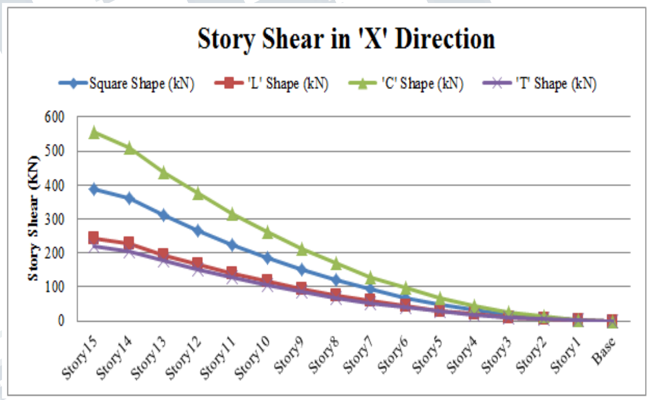

Fig:4. Story Shear vs story height in X-Direction.

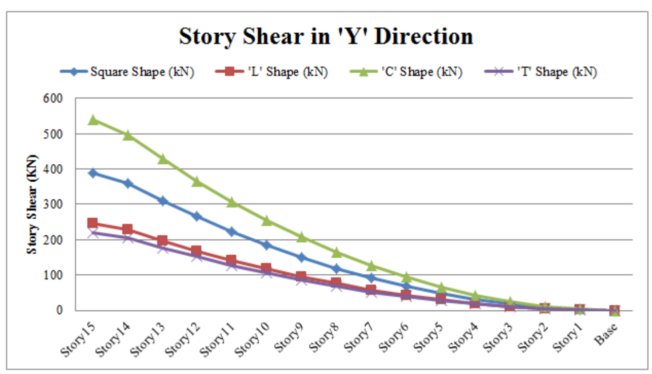

Fig:5 Story shear vs story height in Y Direction

3.3. Story Stiffness

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As per IS Code 1893-2016, Soft story is a story whose lateral stiffness is less than that of story above.
As perIS 1893-2002, soft story is one in which the lateral stiffness is less than 70 percent of
that in the story above or less than 80 percent of average lateral stiffness of the three story
above.

Table:6 Story stiffness in 'X' and 'Y' direction

Story	Story Stiffness in 'X' direction				Story stiffness in 'Y' direc			
	Square Shape (kN/m)	'L' Shape (kN/m)	'C' Shape (kN/m)	'T' Shape (kN/m)	Square Shape (kN/m)	'L' Shape (kN/m)	'C' Shape (kN/m)	Sh (k
Story15	347759.79	179374.73	447081.534	190503.8	347759.79	182834.62	349997.598	17
Story14	444603.75	247371.28	644922.275	254182.29	444603.75	250359.33	537172.746	23
Story13	472983.82	272948.52	749432.348	274719.68	472983.82	275882.32	646305.102	25
Story12	485538.62	285996.41	814414.053	283981.75	485538.62	289027.73	718568.611	26
Story11	492870.03	294163.04	859616.93	289364.83	492870.03	297309.79	771015.03	27
Story10	497969.13	300034.1	894015.525	293088.16	497969.13	303278.83	812209.409	28
Story9	501968.4	304714.44	922453.63	296004.31	501968.4	308040.39	847096.301	28
Story8	505425.51	308788.79	947894.831	298530.28	505425.51	312184.8	878884.43	28
Story7	508679.33	312624.41	972386.461	300924.34	508679.33	316083.07	909918.369	29
Story6	512005.61	316509.2	997528.539	303416.39	512005.61	320020.26	942139.35	29
Story5	515810.28	320798.96	1024740.13	306375.9	515810.28	324328.67	977377.189	29
Story4	521237.57	326319.51	1055365.06	310794.71	521237.57	329751.41	1017495.86	30
Story3	532959.89	336211.18	1091161.83	320220.08	532959.89	339152.24	1064934.24	31
Story2	572298	364277.89	1125993.29	349484.7	572298	365575.17	1115636.23	33
Story1	774259.2	500152.05	1131565.33	489794.07	774259.2	493566.81	1122149.51	47

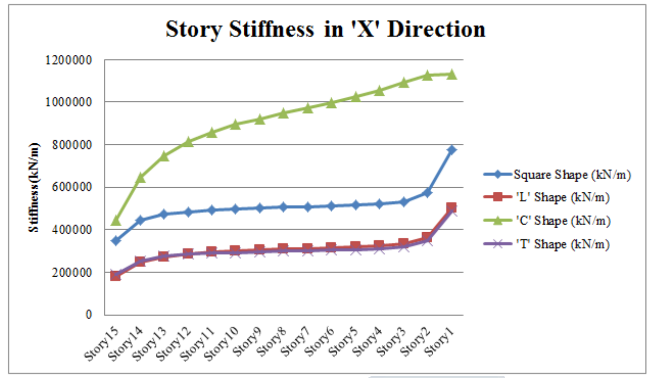

Fig:6 Story Stiffness vs Story height in 'X' Direction

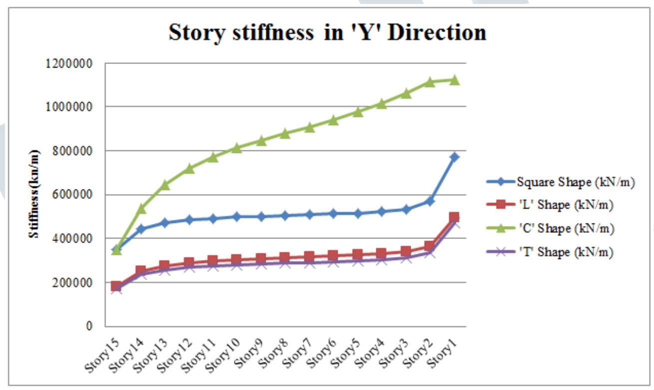

Fig:7 Story Stiffness vs Story height in 'Y' Direction

RESULT AND CONCLUSION:

A linear time history analysis was performed and results were found in terms of natural time period, base shear and story stiffness. From the results of analysis of the models following conclusions can be drawn
Time period of building depends upon mass and stiffness of building. When mass is heavy and stiffness is less than time period will be large. When mass is light and stiffness is high than time period will be small.
The maximum value of natural time period is observed in square shape building and minimum value of time period is observed in 'C' shape building. Time period of square shape building is 28.95% more than 'C' shape building. It means that square shape building is more flexible building (less stiffer) and 'C' shape building is less flexible (more stiffer) building. The observation of natural time period shows that 'C' shape building is most stiffer building among four different shape building models.

Base shear is an estimate of maximum lateral force that will occurs due to seismic ground motion at the base of a structure. Base shear increases with the increase in mass and stiffness of building. In this study maximum value of base shear is observed in ‘C’ shape building and minimum value is observed in both ‘L’ Shape and ‘T’ shape. The value of base shear in ‘C’ shape building is 12-15% more than ‘L’ and ‘T’ shape building.

It is observed that base shear is maximum for ‘C’ shape building, it means that during earthquake excitation ‘C’ shape building is subjected to large lateral force at base compare to other models, so extra attention is taken at the time of design of seismic strengthen building.

The maximum value of story stiffness is observed in ‘C’ shape building which is 46% more than square shape, 126% more than ‘L’ shape, 131% more than ‘T’ shape building. It means that ‘C’ shape building is most stiffer building among all four different building models.

From the above study, we can conclude that irregular shaped buildings are more vulnerable to damages during earthquake in compare to regular shape buildings.

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