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EFFECT OF STIFFNESS ON DIFFERENT SHAPES OF BUILDING TO SEISMIC ZONES

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Abstract:

The objective is to conduct a literature review to provide importance to develop a computational model on which linear/non-linear, static/ dynamic analysis is performed. The first part of this chapter presents a summary of various parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study.Analysis of any structure for resisting earthquake is the basic need of this study. In this project analysis of a seismic resistant structure is a need of concern, and thereby establishing a comparison between structures with different plan geometry. Here the study is carried out for the behaviour of G + 5 H shaped buildings. The proposed H shaped building size is 29 x 35 m and also properties are defined for the building structure. The model of the building is created in STAAD Pro software . The properties are defined as per IS 1893: 2002 part1. The seismic zone considered for the model of building are in IV zone and soil type is medium. The modelling of building is done for Indian seismic zone IV IS1893 -2002.For given structure loading with applied loads includes live load, earthquake zone and dead load accordingly .Load consumptions are also provided according to the IS1893(part 1):2002.The analysis is carried out to determine max node, displacement and base shear ,stiffness. After analysis results are obtained in the form of graphs which are in turn observed to form conclusions.

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Introduction

Buildings are the complex system and multiple items have to be considered. Hence at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and good building configuration is chosen. If we have a poor configuration to start with, all that engineers can do is to provide a Band-Aid i.e. improve a basically poor solution as best as he can. Conversely, if we start off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much. But constructions can suffer diverse damages when they put under seismic excitations, although for same structural configuration, region, EQ damages in the systems are neither uneven nor homogenous. A desire to create an aesthetic and functionally efficient structure drives architects to conceive wonderful and imaginative structures. Sometimes the shape of building catches the eye of visitor, sometimes the structural system appeals, and in other occasions both shape and structural system work together to make the structure a Marvel. However, each of these choices of shapes and structure has significant bearing on the performance of building during strong earthquake. So the symmetry and regularity are usually recommended.

The behaviour of building during earthquake depends critically on its overall shape, size and geometry. Buildings with irregular geometry respond differently against seismic action. Plan geometry is the parameter which decides its performance against different loading conditions. The effects of irregularity (plan and shape) on structure have been carried out by using structural analysis software STAAD Pro. V8i. Earthquakes, caused by movements on the earth surface, result in different levels of ground shaking leading to damage and collapse of buildings and civil infra-structures. The structure should withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. This limit state may correspond to earthquake intensity equal to the strongest either experienced or forecast at the site. The results are studied for response spectrum method.

Literature Review

Milind.V.Mohod (2015) In this paper, the seismic response of different shape and plan configuration on of structure in 3rd zones is studied with the help of STAAD.Pro software. Equivalent static analysis as per IS 1893-2002 method was adopted in order to design buildings and overcome effect of earthquake on it.

Dileshwar Rana ,Prof Juned Raheem,"Seismic Analysis of regular and vertical geometric irregular RCC framed building", International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 04 | July-2015

t is observed in the structure are irregular structure configuration either in plan or in elevation were often cause major causes of collapse during earthquake .It is concluded that the critical bending moment of irregular frames is more than the regular frame for all building heights .This is due to decrease in stiffness of building frames .Thus there is need for providing more reinforcement for irregular frames. Akhil R.Awasthy ,S.Kumar."Seismic Analysis of Regular and Irregular Buildings with Vertical Irregularity using STAAD Pro" International Research Journal of Engineering and Technology (IRJET) (June2017). This study includes the modelling of regular and H-shape plan G+10 storey .

The performance of this framed building during study earthquake motions depends on the distribution of stiffness, strength, and mass in both the horizontal and vertical planes of the building.

The main aim of this work is comparative study of the stiffness of the structure by considering the three models in Regular Structure and three models in Plan irregular structure with different Vertical irregular structure. All models are analysed with dynamic earthquake loading for the Zones V .Result found from the response spectrum analysis that in irregular shaped building displacements are more than that of regular shaped building. All building frames are modeled & analysed in software Staad .Pro V8i. Various seismic responses like base shear, frequency, node displacement, etc. are obtained. The overall performance of regular building is found better than irregular building. The seismic performance of multistory regular building is determined by Response Spectrum analysis in STAAD Pro. Software.

Methodology

Building Description

A RC framed building plan (Seismic Zone IV) is selected for the present study. The building is fairly assymmetric in plan. This building is a G+5 storey building (18m high) and is made of Reinforced Concrete (RC) Ordinary Moment Resisting Frames (OMRF). The concrete slab is 120mm thick at each floor level. The brick wall thicknesses are 230 mm for external and internal walls. Imposed load is taken as 2.5 kN/ m^2 for all floors and 3.0 kN/ m^2 for stair case slabs. Roof live load is taken as 1.5 kN/ m^2 for roof. Following Figure presents typical floor plans showing different column and beam locations. The cross sections of the structural members are equal in all frames and all stories.

Modeling

Details of models

A RC framed building plan (Seismic Zone IV) is selected for the present study. The building is fairly assymmetric in plan. This building is a G+5 storey building (18m high) and is made of Reinforced Concrete (RC) Ordinary Moment Resisting Frames (OMRF). The concrete slab is 120mm thick at each floor level. The brick wall thicknesses are 230 mm for external and internal walls. Imposed load is taken as 2.5 kN/ m^2 for all floors and 3.0 kN/ m^2 for stair case slabs. Roof live load is taken as 1.5 kN/ m^2 for roof. The cross sections of the structural members are equal in all frames and all stories. Rectangular, H shape, L shape and T shape plan geometry is considered in modeling. Column shape of square, rectangle and T shape are used in analysis. Finally column with changed orientation is done in modeling.

So, total twenty models have been considered for the purpose of the study.

- ***Model 1- Five storey (G+5) building as rectangular in plan geometry.***
- ***Model 2- Five storey (G+5) building as H shape in plan geometry.***
- ***Model 3- Five storey (G+5) building as L shape in plan geometry.***
- ***Model 4- Five storey (G+5) building as T shape in plan geometry.***

Defining the material properties, structural components and modeling the structure:

Beam, column and slab specifications are as follows:
Square Column 550mm x 550mm
Rectangular Column 800mm x 400mm
T shape Column with flange of 600mm x 300mm and web of 550mm x 300mm
Beam 500mm x 300mm
Slab thickness 120mm
Stair case slab thickness 150mm

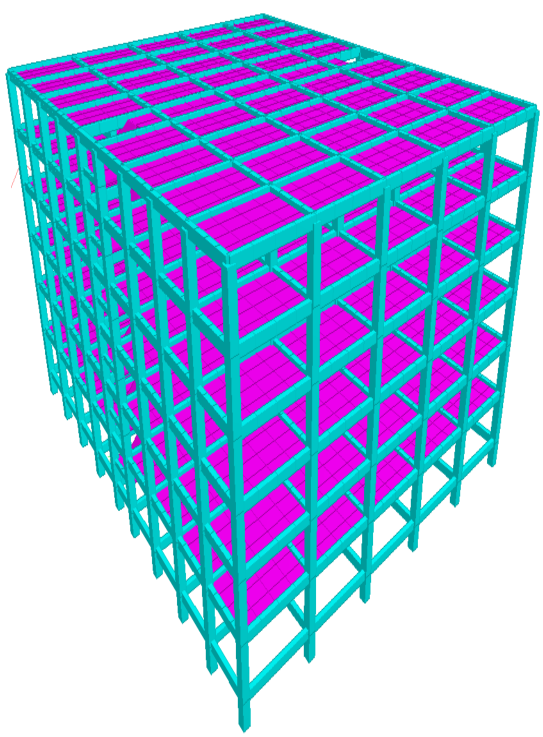
The required material properties like mass, weight density, modulus of elasticity, shear modulus and design values of the material used can be modified as per requirements or default values can be accepted.
Beams and column members have been defined as 'frame elements' with the appropriate dimensions and reinforcement.
Soil structure interaction has not been considered and the columns have been restrained in all six degrees of freedom at the base.
Slabs are defined as area elements having the properties of shell elements with the required thickness. Slabs have been modeled as rigid diaphragms.

Assigning loads.

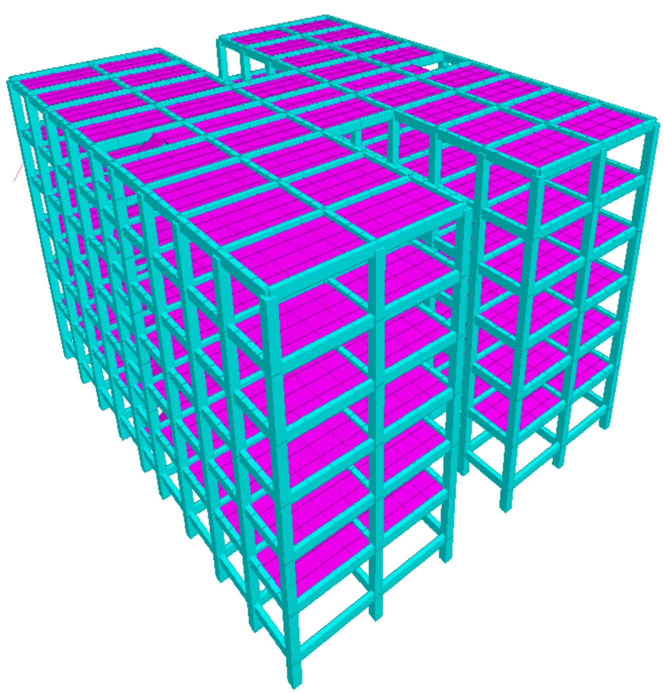
After having modeled the structural components, all possible load cases are assigned. These are as follows:

Gravity loads

Gravity loads on the structure include the self weight of beams, columns, slabs, and other permanent members. The self weight of beams and columns (frame members) and slabs (area sections) is automatically considered by the program itself. The wall loads have been calculated and assigned as uniformly distributed loads on the beams.
Wall load = unit weight of brickwork x thickness of wall x height of wall.
Unit weight of brickwork = 20KN/m3
Thickness of wall = 0.23m
Wall load on all other levels = 20 x 0.23 x 3 = 13.8KN/m (wall height = 3m)
Live loads have been assigned as uniform area loads on the slab elements as per IS 1893 (Part 1) 2016
Live load on roof 1.5 KN/m^2
Live load on all other floors 2.5 KN/m^2
Live load on stair case slab 3.0 KN/m^2
As per Table 10, **Percentage of Imposed load to be considered in Seismic weight calculation**, IS 1893 (Part 1) 2016, since the live load class is up to 3 KN/m2 , 25% of the imposed load has been considered.
Quake loads have been defined considering the time history method for medium soil as per IS 1893 (Part 1) 2016.



3D view elevation of Model 1



3D view elevation of Model 2

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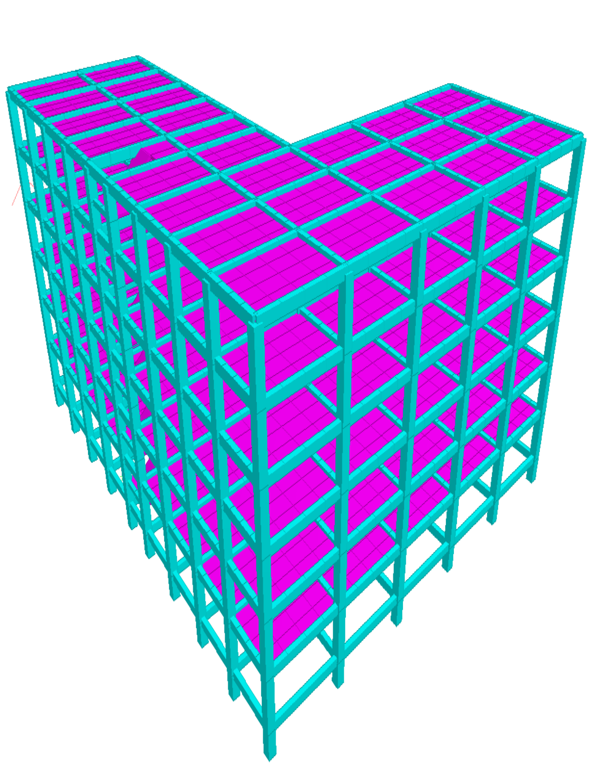
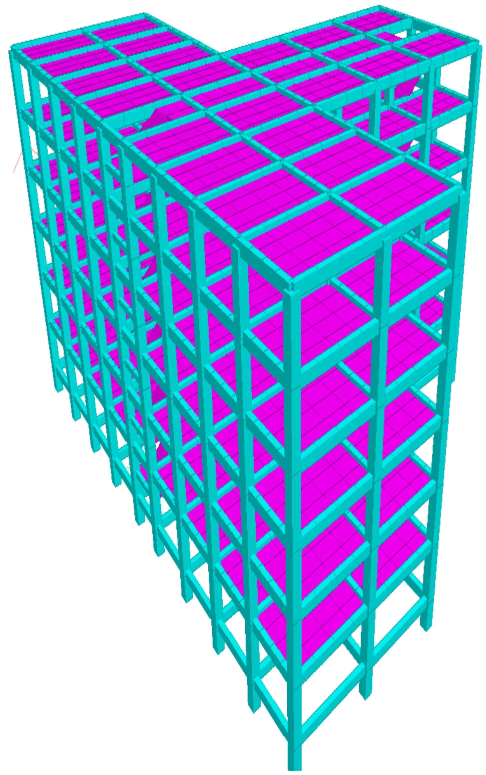


3D view elevation of Model 3



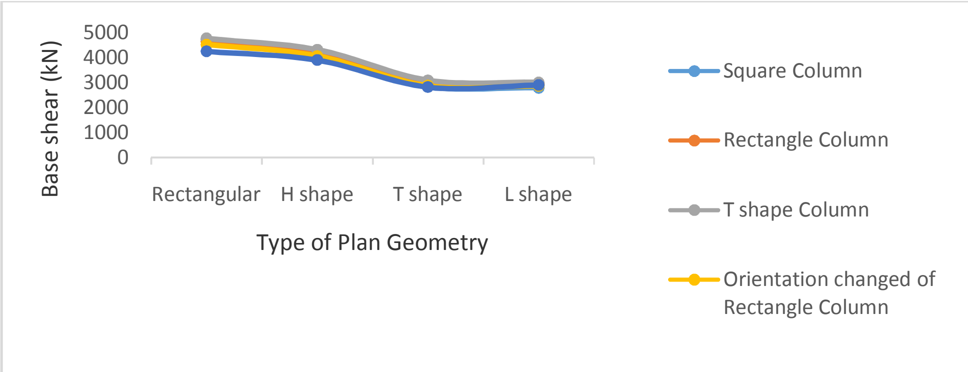
3D view elevation of Model 4

Result and discussion

In this area I have compared Base shear in X and Z direction, Maximum Lateral Displacement in X and Z direction, Modal time periods, Axial forces, shear forces and moments in columns of all 20 models with respect to each other in STAAD-PRO V8i software. By comparing the result one can easily observe the performance of structure and can predict the good shape among all shape structure which performs well against earthquake forces. Detailed study of each graph is shown below,

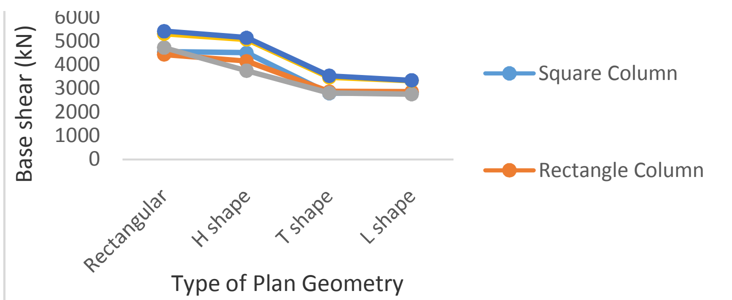
Base shear in X dirc (KN)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	4717.61	4631.3	4760.37	4518.06	4248.75
H shape	4025.45	4235.52	4309.04	4061.33	3898.52
T shape	2836.48	3039.19	3087.87	2872.74	2817.92
L shape	2791.69	2960.18	3005.04	2867.25	2901.79



Base shear in Z dic(KN)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	4538.12	4432.14	4728.24	5308.04	5416.04
H shape	4495.1	4145.07	3744.45	5062.3	5142.56
T shape	2793.18	2859.82	2808.26	3457.01	3528.98
L shape	2831.37	2848.76	2754.2	3321.54	3339.66



Maximum lateral displacement in Z dir(mm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	38.049	30.31	28.947	37.643	33.268
H shape	33.155	31.453	33.04	37.113	33.086
T shape	37.673	31.85	31.334	35.352	31.597
L shape	37.178	34.777	41.116	39.577	36.335

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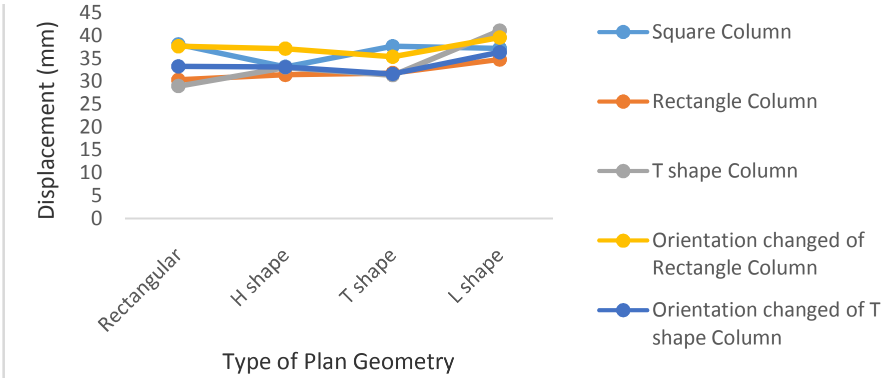
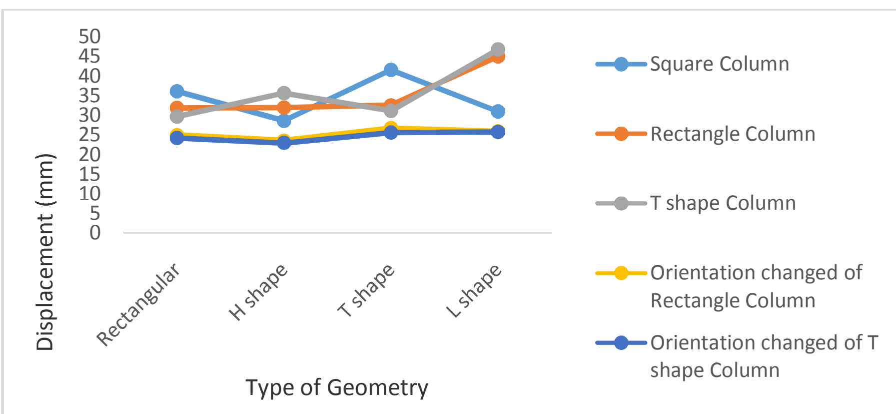


Maximum lateral displacement in Zdirc(mm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	36.082	31.822	29.589	24.898	24.135
H shape	28.541	31.918	35.559	23.507	22.889
T shape	41.502	32.478	31.078	26.716	25.532
L shape	30.897	44.966	46.695	25.875	25.671



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SUMMARY RESULTS

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	1741.11	1709.74	1743.76	1734.09	1678.25
H shape	1740.33	1750.1	1812.56	1721.08	1671.86
T shape	1790.84	1960.75	2037.8	1753.69	1716.67
L shape	1990.94	1757.37	1743.64	1830.09	1759.34

Comparison of Axial force for Column C1 (kN)

It states that, rectangular, H shape, T shape buildings has highest axial force in T shape columns. Also L shape building has highest axial force in square column.

Comparison of Axial force for Column C2 (kN)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	2671.04	2307.29	2344.1	2358.82	2366.27
H shape	2305.83	2313.61	2388.16	2332.58	2339.88
T shape	2306.56	2447.17	2543.51	2033.9	2356.25
L shape	2513.37	2307.7	2329.02	2423.99	1759.34

It states that, rectangular, L shape buildings has highest axial force in square columns. Also H shape and T shape building has highest axial force in T column.

Comparison of Axial force for Column C3 (kN)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	2959.73	2798.45	2810.52	2822.24	2838.03
H shape	2822.09	2778.74	2885.64	2801.5	2809.6
T shape	2780.13	2628.61	2686.18	2771.39	2799.83
L shape	2995.8	2773.87	2810.51	2810.79	2827.73

It states that, rectangular, L shape buildings has highest axial force in square columns. Also H shape building has highest axial force in T column and T shape building has highest axial force in changed orientation of T column.

Comparison of Axial force for Column C4 (kN)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	2512.47	2502.75	2515.2	2522.05	2524.5
H shape	2494.82	2498.2	2520.46	2518.51	2520.72
T shape	2484.67	2482.95	2498.91	2518.07	2519.77
L shape	2479.42	2498.42	2513.06	2508.47	2511.49

It states that, rectangular, H shape, T buildings has highest axial force in changed orientation of T columns. Also L shape building has highest axial force in T column.

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Comparison of Moment Y for Column C1 (kNm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	304.582	202.72	245.578	222.681	183.706
H shape	243.53	200.663	323.983	216.137	283.773
T shape	286.859	259.624	393.184	235.495	211.205
L shape	313.656	204.6	291.053	207.918	181.073

It states that, rectangular, L shape buildings has highest moment y in square columns. Also H shape and T shape building has highest moment y in T shape column.

Comparison of Moment Y for Column C2 (kNm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	362.497	255.345	286.657	252.174	267.274
H shape	283.33	253.948	332.479	245.851	261.538
T shape	327.606	333.399	411.533	269.554	293.266
L shape	271.066	259.694	296.761	234.629	181.073

It states that, rectangular buildings has highest moment y in square columns. Also H shape, T shape and L shape building has highest moment y in T shape column.

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Comparison of Moment Y for Column C3 (kNm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	348.607	272.756	305.813	427.358	462.473
H shape	307.29	269.734	355.026	416.854	452.596
T shape	346.439	256.273	275.058	454.506	497.804
L shape	383.622	275.682	318.44	386.088	422.209

It states that, rectangular, H shape, T shape and L shape buildings has highest moment y in changed orientation of T column.

Comparison of Moment Y for Column C4 (kNm)

Geometry	Square Column	Rectangle Column	T shape Column	Orientation changed of Rectangle Column	Orientation changed of T shape Column
Rectangular	309.064	245.71	273.068	251.921	266.699
H shape	262.861	237.529	288.445	246.463	260.542
T shape	276.709	298.801	348.733	270.38	291.552
L shape	231.857	233.2	260.704	233.526	248.172

It states that, H shape, T shape and L shape buildings has highest moment y in T column. Also rectangular building has highest moment y in square column.

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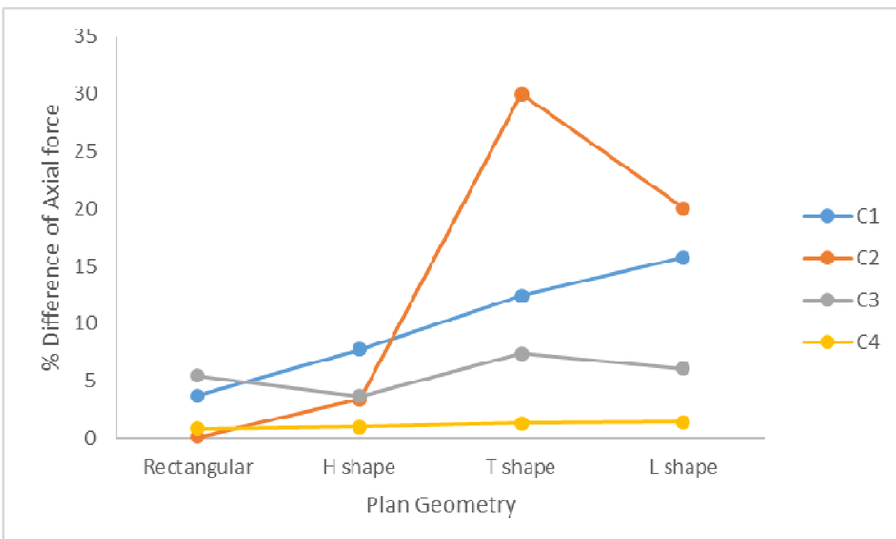
CONCLUSIONS

The main conclusions obtained from the analysis are summarized below:

1. For models considering different plan geometry and different column shapes, effect of stiffness in % is tabulated as below

Effect of stiffness in % difference of axial force in columns

Column No.	Rectangular	H shape	T shape	L shape
C1	3.75666	7.76293	12.4213	15.7586
C2	0.13618	3.44739	30.0009	20.0358
C3	5.44927	3.70472	7.40807	6.11506
C4	0.86144	1.0276	1.33825	1.46129



Above graph shows that % difference of axial force in column C2 is maximum for T shape plan geometry and it is minimum for column C2 for rectangular plan geometry. Also in T shape plan geometry, C2 with square column has maximum axial force while C2 with changed orientation of T shape column has minimum axial force in columns. So it can be concluded that complex plan geometry and column shapes shows more variations in stiffness of building.

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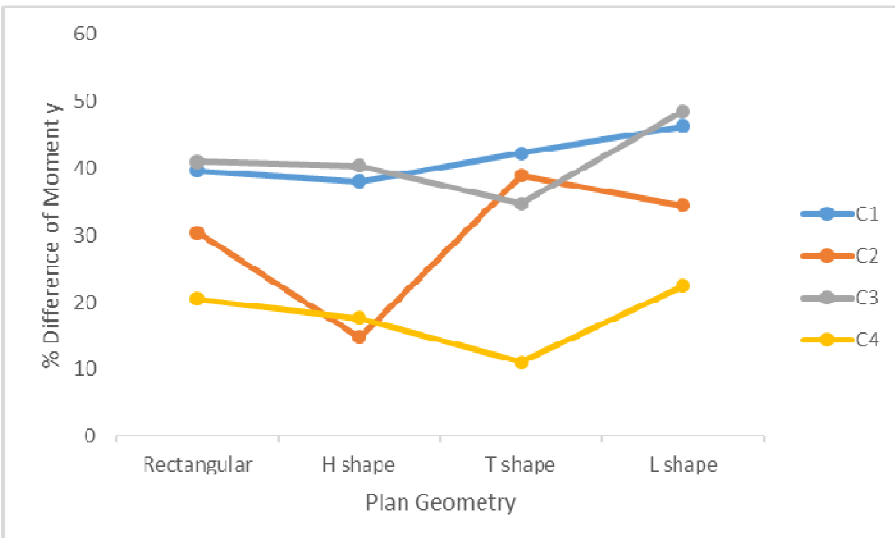
Effect of stiffness in % difference of Moment y in columns

Column No.	Rectangular	H shape	T shape	L shape
C1	39.6859	38.0637	42.2702	46.2834
C2	30.4342	14.7826	38.9836	34.5
C3	41.0223	40.4029	34.7048	48.5193
C4	20.4987	17.6519	11.065	22.4679



Effect of stiffness in % difference of Moment y in columns

Above graph shows that % difference of moment in column C3 is maximum for L shape plan geometry and it is minimum for column C4 for T shape plan geometry. Also in L shape plan geometry, C3 with changed orientation of T shape column has maximum moment while C3 with rectangular column has minimum moment in columns. So it can be concluded that complex plan geometry and column shapes shows more variations in stiffness of building.

2. The base shear were highest for rectangular plan geometry with square column and lowest for L shape model with square column in X direction.
3. The base shear were highest for rectangular shape plan geometry with changed orientation of T shape column and lowest for L shape model with T shape column in Z direction.
4. The lateral displacement were highest for rectangular plan geometry with T shape column and lowest for rectangular shape model with T shape column in X direction.
5. The lateral displacement were highest for L shape plan geometry with T shape column and lowest for H shape model with changed orientation of T shape column in Z direction.

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6. Considering the effect of lateral displacement on different shapes of the building of the structure. It has been observed that, L-shape building have displaced more in both direction (X and Y) in comparison to other remaining simple shaped building.
7. Axial force in columns is increased to maximum 20% in H shape, T shape and L shape building than rectangular building.
8. Moment in columns is increased to maximum 25% in H shape, T shape and L shape building than rectangular building.
9. Considering all these above conclusions made on analysis, we may finally say that simple geometry attracts less force and perform well during the effect of earthquake.

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