Seismic Analysis of Multistorey RCC Buildings using IBC-2012 and IS-1893-2002 Codes

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Abstract— Earthquake is a very important aspect to be considered while designing structures. Lots of work has been reported by many researchers who have worked to study the effect of structures with irregular plan and shape. In recent years, there has been a significant rise in usages of irregular structures in plan. Irregular buildings constitute a large portion of the modern urban infrastructures. Such irregular structures needs to be taken care by structural engineers especially in a high seismic zones. Unexpected effects can be observed on irregular structures under various load patterns and it causes extra shear, torsion etc. Asymmetry in the plan increases stresses of certain structural elements. Hence it is necessary to choose good building configuration. This paper presents a comparison of the seismic provisions of the two seismic codes, namely IBC-2012 (International building code 2012) and IS-1893-2002 (Indian Standard-Criteria for Earthquake Resistant Design of Structures, Part-1, General Provisions and Buildings). For this study, two plans of G+7 storey reinforced concrete framed buildings have been selected. The first one is a regular in plan which has rectangular-shape and second one is irregular in plan which has T-shape. For analysis, both selected shapes of building are analyzed by STAAD. Pro V8i SS6 software and the analysis is done by Linear Static Method. The aim of this study is to compare provisions of IBC-2012 and IS-1893-2002 codes and study the response of irregular buildings. Conclusions are made on the basis of comparisons of various structural parameters of building.

Key words: Response of Regular and Irregular RCC Buildings, Comparison of Seismic Provisions, Seismic Analysis

I. INTRODUCTION

In the design of multi-storey buildings in seismically active areas, the effects of earthquakes become a predominant consideration. The severity ground shaking during earthquake may be minor, moderate and strong. The building should be designed such way to resist the minor earthquake without any structural and negligible non-structural damage; resist the moderate earthquake with repairable structural and heavy non-structural damage and resist the major earthquake with severe structural and non-structural damage but not collapse. That minor shaking occurs frequently, moderate shaking occasionally and strong shaking rarely. For example, on average annually about 800 earthquakes of magnitude 5.0-5.9 occur in the world while the number is only about 18 for magnitude range 7.0-7.9. So, the building should be design for resisting the rare earthquake which may come in 500 years or even in 2000 year for the selected project site, even though the life of the building itself may be only 50 or 100 years. If the building design for strong earthquake that building will be too robust and expensive, but if the effect of earthquake is not considered for design of building there will be major disaster. So the buildings should be earthquake resistant; such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Consequently, safety of people and contents is assured in earthquake-resistant buildings, and thereby a disaster is avoided. This is a major objective of seismic design codes throughout the world.

In this paper the IS-1893-2002(15) and IBC-2012(12) codes are considered to compare the results of these seismic codes for analysis and design of regular and irregular multi storey buildings.

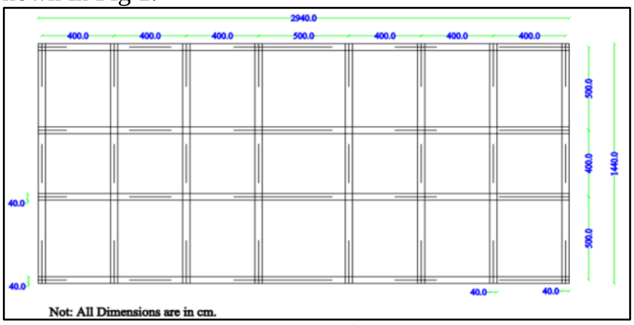
The Uniform Building Code (UBC), published by the International Conference of Building Officials, Whittier, California and was used in the western half of the United States. The seismic design provisions of the Uniform Building Code, since its 1962 edition, have been based on the "Recommended Lateral Force Requirements and Commentary" developed by the Seismology Committee of the Structural Engineers Association of California (SEAOC)(21). The legal building codes of most jurisdictions within the United States have in the recent past been based on one of three model building codes; the BOCA National Building Code (BOCA/NBC)(5), the Standard Building Code (SBC) (20) and Uniform Building Code (UBC)(13). The BOCA/NBC is typically adopted in the northeastern quarter, the SBC in the southeastern quarter, and the UBC in the western half of the United States. This division is obviously imprecise, and is meant solely to convey an overall picture; there are exceptions to the normal patterns. In the mid-1990s, there was a concerted attempt at developing a single unifying model building code for the entire country, to replace the three regional model building codes mentioned above. This resulted in the International Building Code (IBC) (12) developed by the three model code groups under the auspices of the International Code Council which they had together formed.

The IS-1893-2002(15), which is Indian Standard-Criteria for Earthquake Resistant Design of Structures (Part-1, General Provisions and Buildings). The earthquake resistant design of structures taking into account seismic data from studies of Indian earthquakes has become very essential, particularly in view of the intense construction activity all over the country. It is to serve this purpose that IS 1893 : 1962 'Recommendations for earthquake resistant design of structures' was published and revised first time in 1966 and the fourth revision, brought out in 1984.

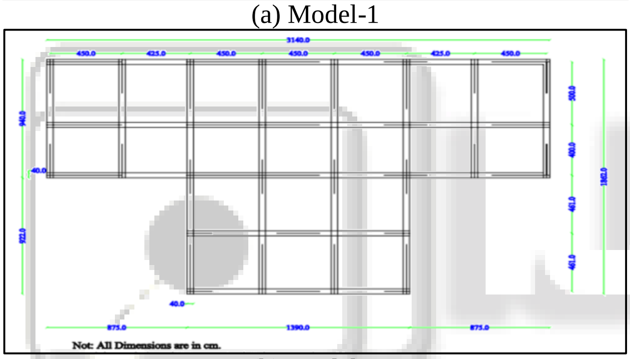
Irregular buildings constitute a large portion of the modern urban infrastructures. Such irregular structures needs to be taken care by structural engineers especially in a high seismic zones. Unexpected effects can be observed on irregular structures under various load patterns and it causes extra shear, torsion etc. Asymmetry in the plan increases stresses of certain structural elements. So in this study, two plans of G+7 storey reinforced concrete framed buildings have been selected. The first one is a regular in plan which has rectangular-shape and the second one is irregular in plans which have T-shape.

II. DETAILS OF RCC BUILDINGS SELECTED FOR THE STUDY

For this study, two plans of G+7 storey reinforced concrete framed buildings have been selected. In these two models, the first one is a regular plan which has rectangular-shape and second one is an irregular plan which has T-shape as shown in Fig 1.



(a) Model-1



(b) Model-2

Fig. 1: Plans of Selected Reinforced Concrete Framed Buildings

Both models of G+7 storey of reinforced concrete framed building are modeled in STAAD. Pro V8i SS6. Both models have the same floor area. The number of columns is equal in both models (32 columns), so the lateral stiffness of both models have equal value. The data for design of the selected building is given in the Table 1.

Live load	4.0 kN/m^2 at typical floor 1.5 kN/ m^2 on terrace
Floor finish	1.0 kN/ m^2
Water proofing	2.0 kN/ m^2
Terrace finish	1.0 kN/ m^2
Seismic zone	313
Important factor	1
Type of soil	Medium
Storey height	Typical floor: 3m, GF: 3m, and height of column from base to Ground floor level: 2m
Floors	G.F. + 7 upper floors
Column size	400mm*400mm
Beam size	400mm*500mm
No. of Columns	32
Slab thickness	100mm
Thickness of all masonry Walls	230mm
Parapet wall height	1.2m
Grade of concrete	M35 for plinth columns and ground floor columns, M30 from first floor to the 7th floor columns, M30 for all other components
Grade of steel	Fe 415 HYSD
Floor Area	423.3 sqm

Table 1: Data for the Building

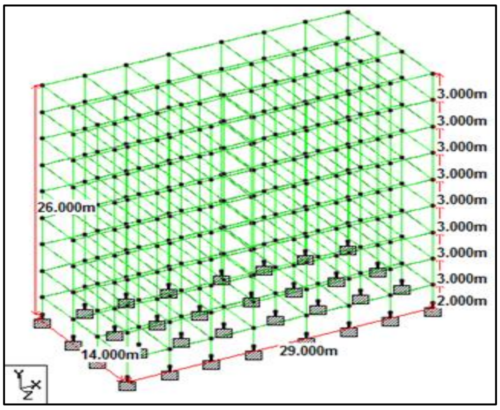
The numbers are assigned to the different portion of the building between two successive grids of beams and different levels are defined as follows:

Portion of the building	Assigned numbers to different Levels of the building to study stresses / forces / displacements
Foundation top to ground floor	1
Ground floor to first floor	2
First floor to second floor	3
Second floor to third floor	4
Third floor to fourth floor	5
Fourth floor to fifth floor	6
Fifth floor to sixth floor	7
Sixth floor to seventh floor	8
Seventh floor to roof	9

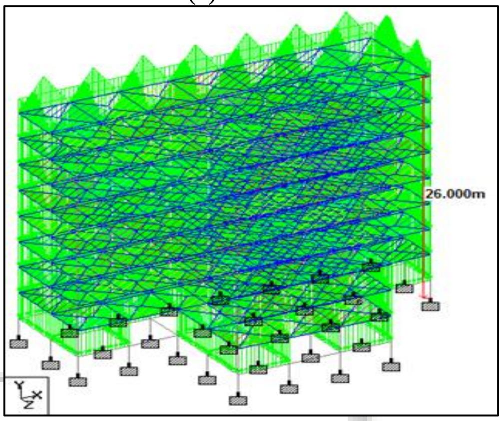
Table 2: Data for the Building

A. *Analysis of Models*

For analysis, both selected G+7 reinforced concrete framed buildings are first modeled in STAAD. Pro V8i SS6 according to the given data and after modeling each model has been analyzed using IS-1893-2002 and IBC-2012 codes. The analysis is done by Linear Static Method. Both models are considered with infill masonry wall reinforced concrete framed and at ground storey have tie beams which do not have slab at ground floor level. In this study, plan irregularities (re-entrant corners) are considered, but no vertical irregularities are considered like mass irregularity, soft story, weak story etc. The dead load and live load data is shown in Table 1 and the seismic load is defined according to these two codes for each models. The load combinations are considered that are defined in these codes for reinforced concrete structure design.



(a) Model-1



(b) Model-2

Fig. 2: 3D Models STAAD. Pro

III. Result and Discussion

After analysis and design, the results come from models using IS-1893-2002 and IBC-2012 codes are compared. In this part the seismic weight, base shear, storey displacement, storey drift, torsional moment, moments and shear forces in beams, axial forces and moments in columns are compared.

A. *Total seismic weight, base shear and lateral loads*

The total seismic weight of each model is shown in Table 2 below.

Models	Shape	Seismic Weight (kN)	
		using IS-1893-2002 code	Using IBC-2012 code
Model-1	Rectangular	35173.30	32331.29
Model-2	T	35000.80	32176.52

Table 2: Total Seismic Weight of Buildings

In case of using IBC-2012 code, the total seismic weight of building decrease about 8%, but the base shear a little increase when it is compared to the IS-1893-2002 code for both models (see Fig. 3). The rectangular shape exhibits lower base shear and lateral load in Z-direction than T-shape in case of IS-1893-2002 code.

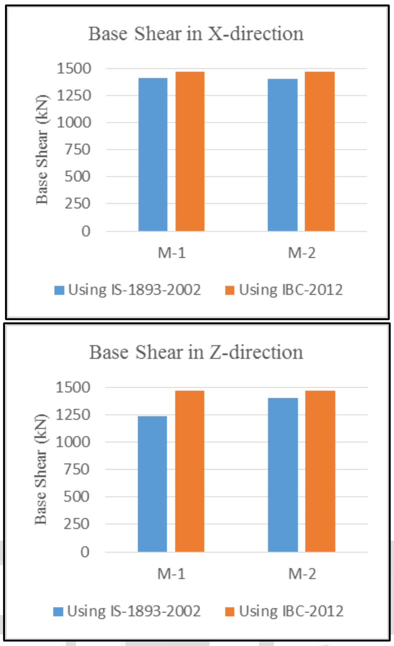


Fig. 3: Base Shear

B. *Torsional Moment*

The torsional moments of both shapes are shown on Table 3.

Height (m)	Torsional Moment (kNm)							
	Using IS-1893-2002 Code				Using IBC-2012 Code			
	Rectangular-Shape		T-Shape		Rectangular-Shape		T-Shape	
	X-Dir.	Z-Dir.	X-Dir.	Z-Dir.	X-Dir.	Z-Dir.	X-Dir.	Z-Dir.
2	0.81	1.46	1.04	1.76	5.58	11.57	7.18	12.22
5	11.17	20.31	14.45	24.58	33.16	68.70	42.90	73.0
8	28.61	51.99	36.99	62.94	57.88	119.90	74.88	127.4
11	54.08	98.30	69.94	118.99	84.42	174.86	109.21	185.81
14	87.61	159.2	113.28	192.74	112.34	232.71	145.33	247.27
17	129.2	234.7	167.04	284.2	141.40	292.91	182.93	311.24
20	178.8	324.9	231.19	393.36	171.44	355.12	221.78	377.34
23	236.5	429.8	305.75	520.21	202.32	419.08	261.73	445.31
26	258.2	469.2	335.75	571.26	221.16	458.11	287.73	489.55

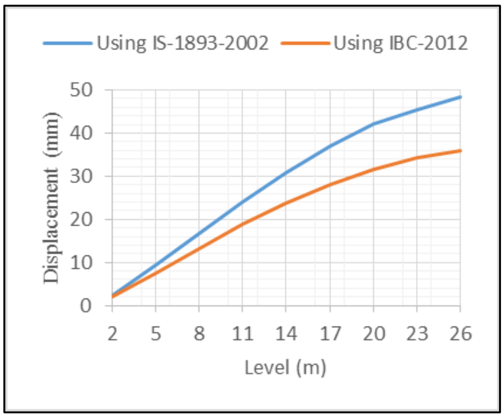
Table 3: Torsional Moment at Different Height

From the above Table 3, it is observed that torsional moment is increased by 81% & 107% in Z-direction as compared to torsional moment in X-direction as per IS-1893-2002 & IBC-2012 respectively in case of rectangular-shape (model-1).

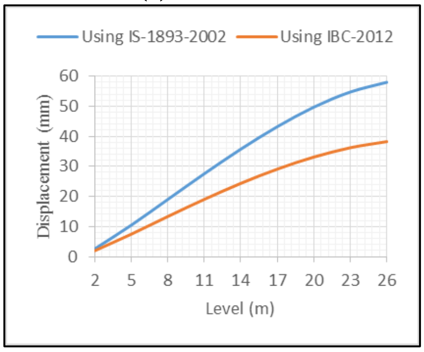
The results show that T-shape building (model-2) have the higher values of torsional moments as compared to Rectangular-shape in both codes. The torsional moment in Z-direction is increased by 70.1% than the torsional moment in X-direction in both codes in case of T-shaped building.

C. *Storey displacement and storey drifts*

Storey displacement and storey drift for the analyzed buildings is shown in Fig.4 & Fig.5 below.

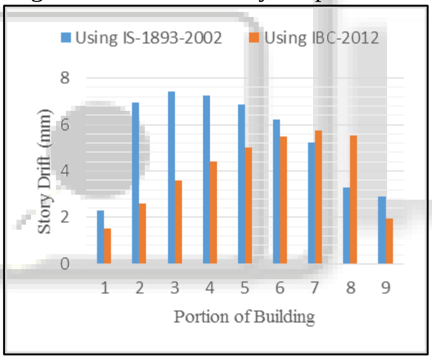


(a) Model – 1

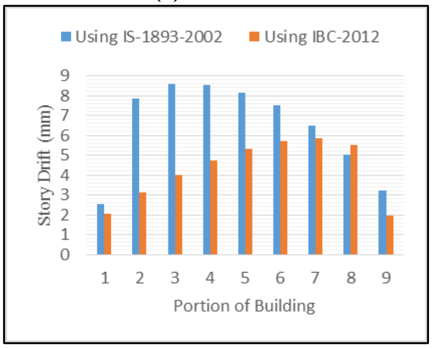


(b) Model-2

Fig. 4: Maximum Storey Displacement



(a) Model-1



(b) Model-2

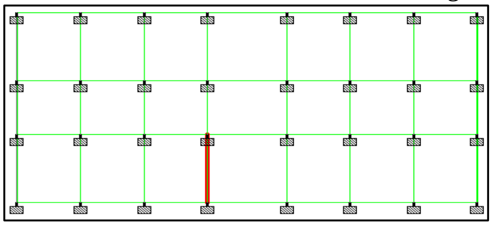
Fig. 5: Maximum Storey Drift

In Fig.4, the results show that maximum storey displacement for both models in result of IS-1893-2002 code is more than result IBC-2012 code. The rectangular-shape exhibits lower displacement than T-shape in both codes results.

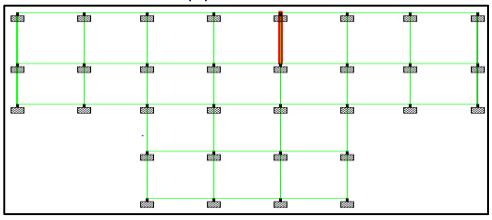
From Fig. 5, it is cleared, when comparing storey drift, it is more as per IS-1893-2002 as compared to IBC-2012. In the result of IS-1893-2002 the highest storey drift is in the 2nd storey, but in IBC-2012 the highest storey drift is in 5th storey. The rectangular-shape exhibits lower storey drift than T-shape.

D. Maximum Moment and Shear Force in Beams

The center to center span length of selected beam is 5 m for both models. The selected beams are shown in Fig. 6.

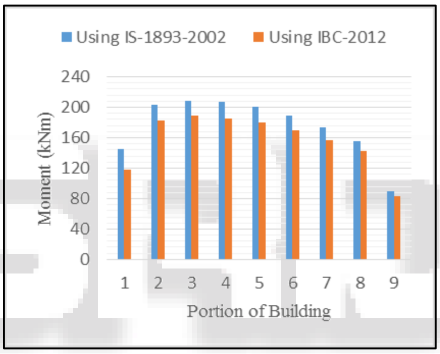


(a) Model-1

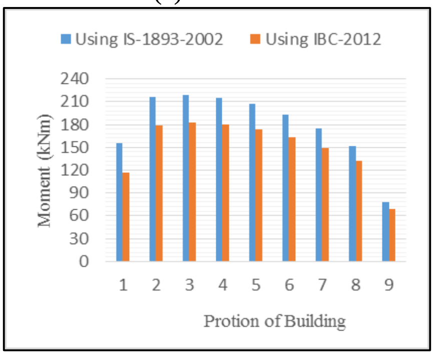


(b) Model-2

Fig. 6: Selected Beams for Comparing Maximum Moment and Shear Force

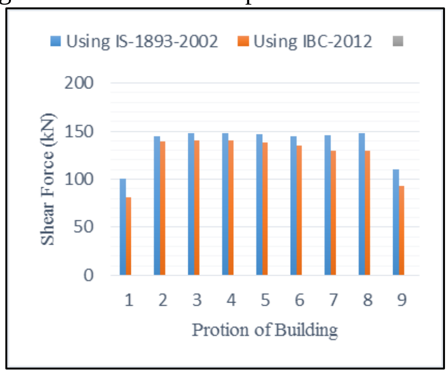


(a) Model-1

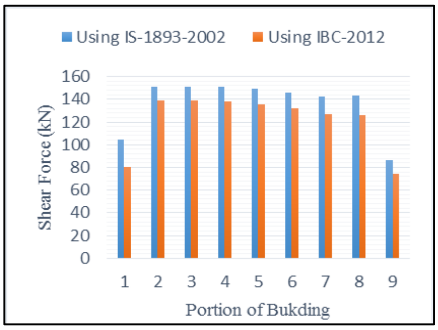


(b) Model-2

Fig. 7: Maximum Envelope Moment in Beams



(a) Model-1



(b) Model-2

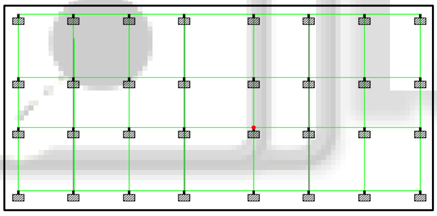
Fig. 8: Maximum Envelope Shear Force in Beams

It is observed in both models, moments in the same beams are higher as per IS-1893-2002 as compared to IBC-2012. From storey 2 to storey 8, the dead load and live load on floor area are equal, but beam moments of lower storeys are higher than the upper storeys in results of both codes (see Fig. 7).

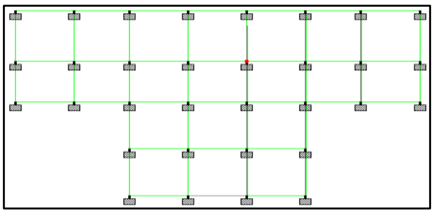
As shown in Fig. 8, it is observed that shear forces in the same beams are higher in IS-1893-2002 as compared to IBC-2012 in both models.

E. Maximum Axial Force and Moment at Columns

For each model one interior column in each floor which has maximum loading area is selected and the selected columns are shown in Fig. 9 for each model. The height of each column from Protion-2 to Portion-9 is 3 m, but the height of Portion-1 of building is 2m, which is the base column from top of foundation up to ground floor plinth level. The size of columns from base to the top floor same (400 mm × 400 mm).



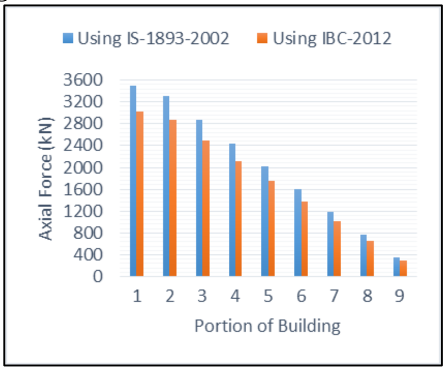
(a) Model-1



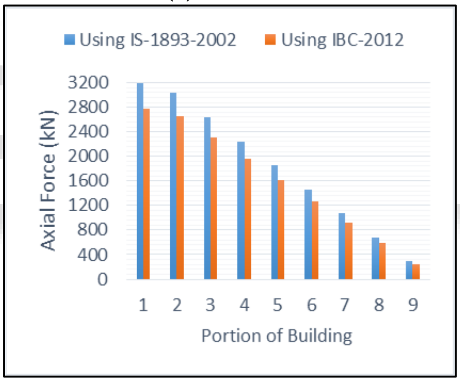
(b) Model-2

Fig. 9: Selected Columns for Comparing Maximum Axial Forces & Moments

Generally the axial force of the same column decreases (about 13%) as per IBC-2012 as compared to IS-1893-2002 in both models. The moments (M_z and M_y) of columns have much higher values when using IS-1893-2002 than using IBC-2012 code.



(a) Model-1



(b) Model-2

Fig. 10: Maximum Envelope Axial Forces in Columns

Portion of Building	Moment (kNm)							
	Using IS-1893-2002 Code				Using IBC-2012 Code			
	Rectangular-Shape		T-Shape		Rectangular-Shape		T-Shape	
	Mz	My	Mz	My	Mz	My	Mz	My
1	89	94.53	91.60	105.76	62.39	74.41	64.16	73.28
2	117.18	130.96	120.91	144.87	83.46	103.93	84.77	102.25
3	119.61	134.60	119.81	147.28	87.39	107.83	82.73	105.26
4	118.84	129.12	118.77	141.47	84.95	99.74	79.78	97.37
5	115.13	122.90	114.64	134.38	80.42	91.60	74.65	89.10
6	107.55	112.75	106.63	123.05	73.57	81.06	67.30	78.50
7	95.36	98.13	93.79	106.58	64.46	68.20	57.56	65.71
8	76.76	76.38	75.95	83.41	52.52	52.23	46.07	50.70
9	58.61	52.62	45.38	52.23	42.51	34.15	27.12	30.26

Table 4: Maximum Envelope Moments in Columns

IV. Conclusion

In this paper, two plans of G+7 storey reinforced concrete framed buildings have been selected. In these two models the first one is a regular in plan which has rectangular-shape and second one is irregular in plans which has T-shape. Both models of G+7 storey of reinforced concrete framed building are modeled in STAAD. Pro V8i SS6 and analyzed using IS-1893-2002 and IBC-2012 codes. In summary, the main conclusion is the following:

- Total seismic weight of building decrease about 8% in case of IBC-2012 as compared to IS 1893 - 2002, but the base shear is increased a little as compared to the IS-1893-2002 code in both models.
- Maximum displacement, storey drift, moments and shear forces in beams and axial forces and moments in columns have lager values as per IS-1893-2002 as compared to results of IBC-2012.
- The rectangular shape exhibits lower base shear and lateral load in Z-direction than T-shape in case of IS-1893-2002 code.
- The T-shape has the higher values of torsional moments than Rectangular-shape in both codes.
- T-shape has lager displacement and storey drift than Rectangular-shape in both codes results.

The result shows that T-shaped building is not appropriate in seismic area as compared to rectangular-shaped building. Performance of regular structures is better than irregular structure. Therefore structures with symmetry are recommended for the building having higher seismic risk.

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