Assessment on Torsional Effect of Unsymmetrical Buildings

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Abstract - *The building with torsion is not performing well; it is observed in the past earthquake and is more damages. So, it is become essential to identify the torsional effect on building and irregularity of building which create torsion. The main objective of this present work is to minimize torsion ratio up to IS 1893:2016 (part1) limit by changing vertical element stiffness in plan configuration. For this purpose, IS code 1893:2016 (part1) give guidelines, according to that L Shape G+15 storey models are done in ETABs 2017 with beam-column and slab and beam-shear wall and slab method. Response reduction method is used for analysis. Results are obtained based on max. storey drift, mode vs. frequency and torsional irregularity.*

Key Words: Frequency, IS code 1893:2016 (part1), Storey drift, mode, Response Reduction Method, torsional irregularity.

1. INTRODUCTION

In the past earthquake, it is observed that building with the torsional effect is more damaged as compared with other normal or ordinary-buildings, which may lead to a collapse of the structure. As the population increase demand of the structure increase but the availability of land or plot size is not fulfilled that criterion. So, it is necessary or become essential that use maximum plot size and FSI for constructing structures. And the available plot doesn't need to be always rectangular, square or in regular shape. Which leads to the planning of irregular shape structure and this irregular shape of the structure becomes a reason for generating torsion in it. So, the structural engineer has to challenge to find out the reasons of torsion and try to minimize it.

IS code 1893:2016 specifies the various reasons which introduce torsion effect which is generally irregular mass, strength and stiffness distribution. These projects dealing with G+15 storey L shape model analysed for earthquake load and its torsional ratio is minimized to the permissible limit as noted in IS code 1893:2016 by arranging beams, columns and shear walls.

IS code 1893:2016 classifying irregularity into two types:

- Plan Irregularities: -It is generally irregularity in a plan or it is horizontal irregularity. It includes Torsion Irregularity, Re-entrant Corners, Diaphragm Discontinuity, Out-of-Plane Offsets and Non-Parallel Systems.
- Vertical Irregularities: - It is an irregularity in the vertical direction of the building. It includes Stiffness Irregularity – Soft Storey & Extreme Soft Storey, Mass Irregularity, Vertical Geometric Irregularity and In-plane Discontinuity.

2. OBJECTIVES OF THE STUDY

- To find out the effect of torsion on the building.
- To find the cause of torsion generated in the building.
- To study the different methodologies for torsion reduction.
- To compare different torsion reduction method using the vertical element stiffness plan configuration.
- To study the parameter of all models during the earthquake.

3. PROBLEM STATEMENT

Analyse G+ 15 storeys L shape structure situated in Pune by IS 1893:2016.

4. METHODOLOGY

The present study is carried out on the analysis of G+15 storey L shape models using ETABS 2017 software. The models in the present work are analyzed for Response reduction method according to IS 1893:2016. Following is a procedure for model making:

- Firstly, gravity load i.e. Dead Load (DL), Super Dead Load (SDL) and Live Load (LL) is defined.
- After that, the seismic load is defined i.e. static (EQX and EQY in X and Y direction respectively) as well as dynamic load (RSX and RSY in X and Y direction respectively).

- All load combination is defined. i.e.
  0.9(DL+SDL) ±1.5EQX, 0.9(DL+SDL) ±1.5EQY,
  0.9(DL+SDL) +1.5RSX, 0.9(DL+SDL) +1.5RSY,
  0.9DL±1.5EQX, 0.9DL±1.5EQY,
  0.9DL±1.5RSX, 0.9DL±1.5RSY,
  1.2(DL+SDL+LL) ±1.2EQX, 1.2(DL+SDL+LL) ±1.2EQY,
  1.2(DL+SDL+LL) ±1.2RSX, 1.2(DL+SDL+LL) ±1.2RSY,
  1.5(DL+SDL),
  1.5(DL+SDL) ±1.5EQX, 1.5(DL+SDL) ±1.5EQY,
  1.5(DL+SDL) ±1.5RSX, 1.5(DL+SDL) ±1.5RSY,
  1.5(DL+SDL+LL),
  1.5(DL+SDL+LL) ±1.5EQX, 1.5(DL+SDL+LL) ±1.5EQY,
  1.5(DL+SDL+LL) ±1.5RSX & 1.5(DL+SDL+LL) ±1.5RSY.
- Then the model is analyzed for all defined load combination.
- Then torsion of a structure is calculating as, taking a ratio of max joint displacement to min joint displacement for EQX, EQY, RSX and RSY.
- Checking torsion ratio if it is less than 1.5 then it is okay.
- If not then deleting shear wall/column/beam and adding column/shear wall/beam or changing the orientation of column/shear wall.
- Again, follows *step6* and *step7.*

5. DESCRIPTION OF MODELS

Five models are made, out of the model 1, 2 and 3 are Beam-column and slab model and model 4 and 5are Beam- shear wall and slab model. Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Fig. 5 shows models plan view.

Details of structure:

The structure is G+15 storey L shape RCC building with a storey height 3.2 meters and that for a foundation is 3.5 meters and having plan area as 34.77 meters * 51.38 meters. Remaining necessary data of models are in Table I

Table- 1: Data of the Structures

Parameters		Values
Grade of Concrete		M35
Grade of Steel		Fe 500
Slab Thickness		150 mm
Beam Size		200*500 mm
Column Size		300*700 mm
Shear Wall Thickness		200 mm (For model 1,2,3) 230mm (For model 4,5)
Live Load	Each Slabs	2 (kN/m²)
	Roof Slab	1.5 (kN/m²)
	Staircase	3 (kN/m²)
Super Dead Load	Each Slabs	1.5 (kN/m²)
	Roof Slab	4 (kN/m²)
	Staircase	2.5 (kN/m²)
	Each Storey Beams	4.968 (kN/m)
	Roof Outer Beams	2.208 (kN/m)
Seismic Zone		III
Zone Factor		0.16
Importance Factor		1.2
Soil Type		I
Response Reduction Factor		5 (For model 1,2,3) 4 (For model 4,5)

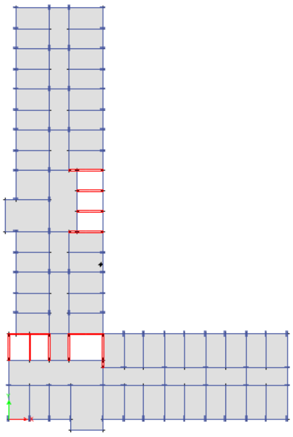


Fig. 1: Model 1

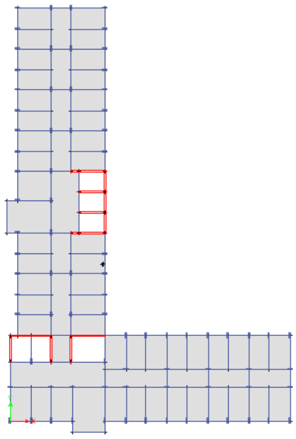


Fig. 2: Model 2

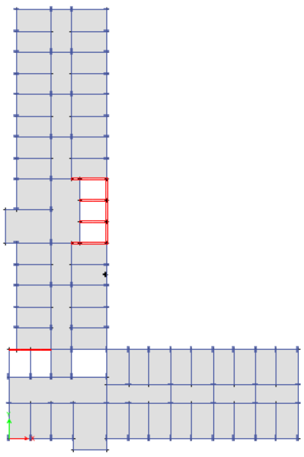


Fig. 3: Model 3

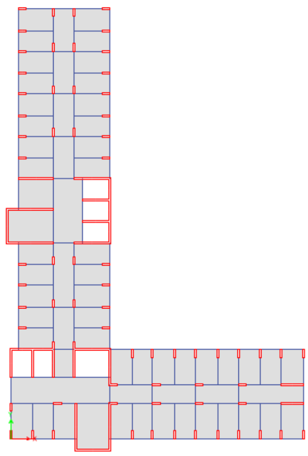


Fig. 4: Model 4

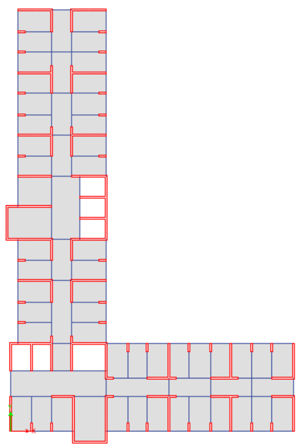


Fig. 5: Model 5

6. RESULTS AND DISCUSSION

The results are obtained based on Storey Drifts, Mode vs. Frequency, and Torsional Irregularity. Table 2 and Table 3 show Storey Drifts in X and Y direction respectively and Graph 1 and Graph 2 are respective graphs. The12 mode vs. frequency (Frequencies are obtained by taking reciprocal of period) results show in Table 4 and its graphical representation in Graph 3. Table 5 shows Torsional Irregularity results in X and Y direction and Graph 4 and Graph 5 is its graphical representation in X and Y direction respectively. In Graph 4 horizontal red line indicates IS 1893:2016 limit of Torsion ration which should be limited to 1.5 as per IS 1893:2016 (part 1) Table 5.

Table-2: Storey drifts in X direction

Storey	Model 1	Model 2	Model 3	Model 4	Model 5
Base	0	0	0	0	0
Story1	0.000563	0.000405	0.000671	0.00027	0.00015
Story2	0.001223	0.000908	0.001095	0.000697	0.000321
Story3	0.00178	0.001347	0.001473	0.00101	0.000448
Story4	0.002136	0.001669	0.001703	0.001272	0.000577
Story5	0.002375	0.001909	0.001918	0.001479	0.000686
Story6	0.00253	0.002082	0.002137	0.001641	0.000777
Story7	0.002617	0.002199	0.002289	0.001762	0.000851
Story8	0.00265	0.002267	0.002383	0.001847	0.00091
Story9	0.002635	0.002293	0.002427	0.001899	0.000954
Story10	0.00258	0.002282	0.002429	0.001923	0.000984
Story11	0.002489	0.00224	0.002396	0.001922	0.001003
Story12	0.002368	0.002173	0.002336	0.0019	0.001012
Story13	0.002222	0.002085	0.002259	0.001861	0.001012
Story14	0.00206	0.001986	0.002174	0.001812	0.001006
Story15	0.001894	0.001884	0.002091	0.001756	0.000996
Story16	0.001743	0.001794	0.002023	0.001704	0.000984
Story17	0.00163	0.00172	0.001967	0.001657	0.000973

Table- 3: Storey drifts in Y direction

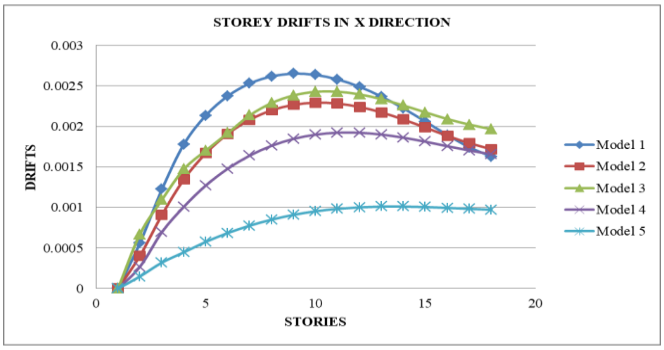
Storey	Model 1	Model 2	Model 3	Model 4	Model 5
Base	0	0	0	0	0
Story1	0.000854	0.000425	0.000572	0.000261	0.000167
Story2	0.001754	0.000777	0.000941	0.000614	0.000339
Story3	0.00235	0.000974	0.001159	0.000813	0.000455
Story4	0.00272	0.001169	0.00135	0.000983	0.000567
Story5	0.002951	0.001321	0.001499	0.001123	0.000659
Story6	0.003082	0.001437	0.001611	0.001232	0.000732
Story7	0.003136	0.001525	0.001689	0.001315	0.000789
Story8	0.003128	0.001596	0.001738	0.001374	0.000831
Story9	0.003067	0.001643	0.001759	0.001411	0.00086
Story10	0.00296	0.001667	0.001756	0.001428	0.000876
Story11	0.002811	0.00167	0.001729	0.001427	0.000881
Story12	0.002626	0.001655	0.001683	0.00141	0.000877
Story13	0.002411	0.001624	0.001646	0.00138	0.000865
Story14	0.002176	0.00158	0.001609	0.001341	0.000848
Story15	0.001933	0.001527	0.001562	0.001294	0.000827
Story16	0.001707	0.001468	0.00151	0.001248	0.000806
Story17	0.001517	0.001391	0.001428	0.001197	0.000787

Table- 4: Mode vs. Frequency

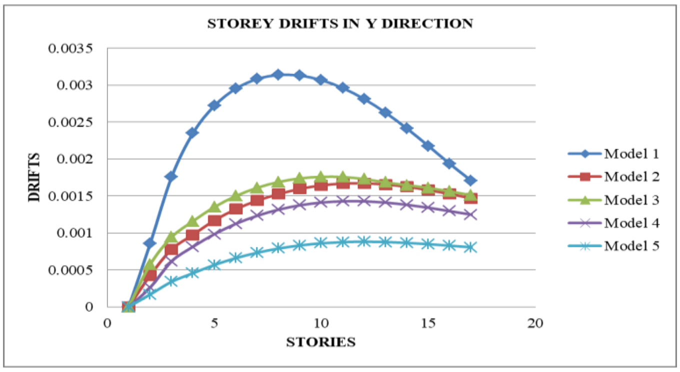
Mode	Model 1	Model 2	Model 3	Model 4	Model 5
1	0.29	0.32	0.31	0.42	0.62
2	0.37	0.43	0.36	0.57	0.66
3	0.45	0.46	0.44	0.60	0.73
4	0.97	1.08	0.99	1.67	2.75
5	1.30	1.61	1.31	2.35	2.87
6	1.67	1.76	1.64	2.51	3.05
7	1.89	2.17	1.86	3.72	6.33
8	2.72	3.48	2.86	5.35	6.90
9	3.06	3.57	2.92	5.68	7.14
10	3.61	3.80	3.41	6.25	10.64
11	4.50	5.15	4.18	8.93	11.76
12	4.67	5.92	5.00	9.26	12.35

Table- 5: Torsional Irregularity

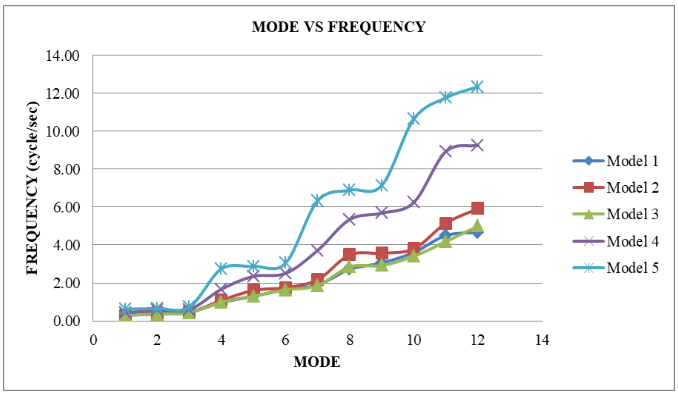
MODEL NAME	TORSION RATIO	
	EQX IN X DIRECTION	EQY IN Y DIRECTION
Model 1	2.44	1.33
Model 2	1.79	1.04
Model 3	1.22	1.05
Model 4	2.18	1.18
Model 5	1.19	1.05



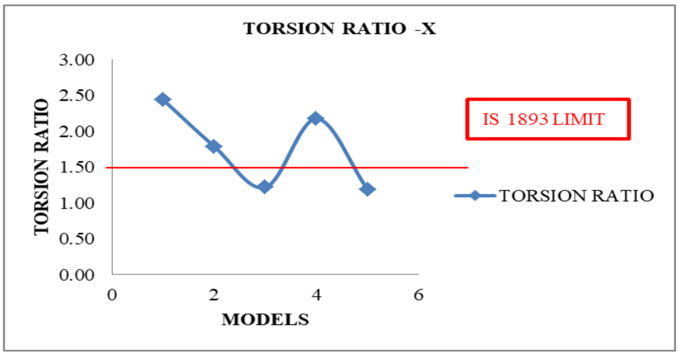
Graph-1: Storey drifts in X direction



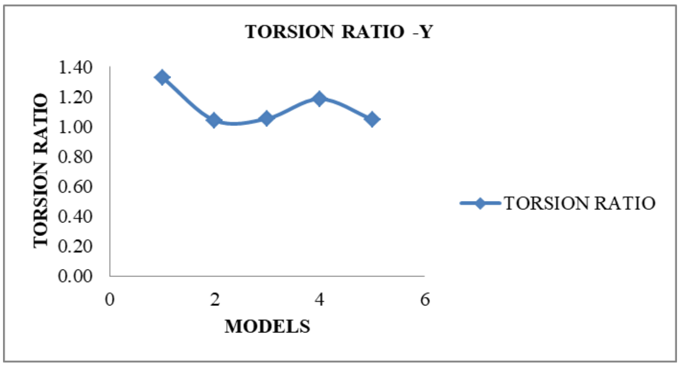
Graph-2: Storey drifts in Y direction



Graph-3: Mode vs. Frequency



Graph-4: Torsional Irregularity in X direction



Graph-5: Torsional Irregularity in Y direction

7. CONCLUSIONS

[1] Total five models of L shaped building models are analysed using linear dynamic (RSA) method. Table 2 and Table 3 show storey drift results of all models. Based on storey drift investigations following conclusions are drawn:

- Storey drift values of X and Y direction for all models are within the permissible limit as per IS 1893:2016 Cl.no 7.11.1.1. This is 0.4% of storey height calculated as 0.0128.
- Model-1 shows the highest value from storey 4 to 12. It shows max value 0.003136 in 7th storey in Y direction which is well within the permissible limit as per IS code provision.
- All models have shown its maximum value of storey drift between 7th to 13th storeys level in X and Y direction from which it can be concluded that as eccentricity decreases i.e. torsion reduces at the same time storey drift shifted towards the top.
- Storey drift values observed very less in model -4 and 5 at all storey which may due to higher stiffness and reduction in torsional irregularity.

[2] Table 4shows the mode vs. frequency results of all models. Based on mode vs. frequency investigations following conclusions are drawn:

- From graph -3 has been proved that the frequency of model-4 and model-5 is higher than other models this may due to higher stiffness and lower value of RR.
- The frequency of building model increases with the increase of no modes. Model-2 performed well when compared the first three models with the same value of RR this is happened due to uniform distribution of stiffness in the plan area.

[3] Table 5 shows Torsional irregularity results of all models. Based on torsion ratio investigations following conclusions are drawn:

- From graph 4 and graph 5, it has been observed that all L shaped models (i.e. Model-1 to model-3 with RR-5 and model 4to model 5 with RR-4) are performed well in the Y direction and the torsional ratio is well within the limit.
- In X and Y direction model -1 performance is worst due to eccentricity between the centre of mass and centre of rigidity is observed to be maximum.
- In X-direction model-3 and model-5 are performed well and shows minimum torsion ratio due to uniformly distribution of stiffness over plan area and less eccentricity of CM and CR.

SCOPE FOR FUTURE WORK

[1] Non-linear static (Push over-analysis) or Non-linear dynamics (Time history analysis) analysis can be done.
[2] The above study can be done by varying storey height and torsion ratio in check.
[3] The torsional effect can be studied by implementing a flat slab for the same structures.
[4] This study can be implemented on real structures and soil interaction can also be studied.

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