

Study on Performance of Seismically Induced Torsion in Irregular RC Structures

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ABSTRACT: No structure is perfectly regular. Because it is impossible to avoid irregularity in a structure, it is important for designers to be aware of their effects and to consider them appropriately in design. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure and mechanical properties of the structural materials. Buildings should be designed so that they can resist earthquake induced deflections and internal forces. Structural irregularities are important factors which decrease the seismic performance of the structures. Buildings which have structural irregularities may experience different drifts of adjacent stories, excessive torsion, etc. according to irregularity type and fail during an earthquake. This paper is highlighting the effects of torsional irregularity on seismic behaviour of structures. Different buildings which have different number of floors and floor areas with different column size which cause torsional irregularities in building are modelled by ETABS and calculations are made. Results are compared and precautions are given to prevent torsional failure during earthquakes. We are also going to study the effect of infill walls in structure to study the effect of infill walls in performance of building.

KEYWORDS: ETABS, Irregularity, Pushover Analysis, Response Spectrum Method, Seismic Performance, Torsional Effect

I. INTRODUCTION

Irregular buildings constitute a large part of the modern urban infrastructure. The group of people involved in constructing the building facilities, including owner, architect, structural engineer, contractor and local authorities, contribute to the overall planning, selection of structural system, and to its configuration. This may lead to building structures with irregular distributions in their strength, stiffness and mass along the height of building. When such buildings are located in a high seismic zone, the structural engineer's role becomes more challenging. Therefore, the structural engineer needs to have a complete understanding of the seismic response of irregular structures. In recent past, several studies have been carried out to evaluate the response of irregular buildings work that has been already done pertaining to the seismic response of vertically irregular building frames. Torsion responses in structures arise from two sources: Eccentricity in the mass and stiffness distributions, causing a torsion response coupled with translation response; and torsion arising from accidental causes, including uncertainties in the masses and stiffness, the differences in coupling of the structural foundation with the supporting earth or rock beneath and wave propagation effects in the earthquake motions that give a torsion input to the ground, also torsion motions in the earth during the earthquake. Torsional irregularity is not an unfamiliar concept, having been expressed in codes in various forms for decades. Extreme torsional irregularity, however, is a somewhat newer concept and subset within the larger issue of torsional behavior. It is something that can greatly limit and restrict flexibility in choosing seismic force-resisting systems and configurations.

II. MODEL DESCRIPTION

The symmetric plan layout of the reinforced concrete special moment resisting frame building of six storied building considering and neglecting the stiffness of walls with open ground storey and unreinforced masonry infill walls in the

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upper storeys are chosen. The bottom storey height is kept 4.2m and a height of 3.2m is kept for all the other storeys, there are total 6 bays of 4m span are considered in both the directions. All models are modeled and analyzed in ETAB software. End condition is assumed as fix end for column. Grade of concrete and steel is M25, Fe500 respectively.

III. DESIGN DATA

Total eight numbers of models are created in ETAB having columns with different size along one edge of the building. Four models are modelled considering stiffness of infill walls and four models are modelled neglecting the stiffness of infill wall. Other basic parameters required for design are as mentioned in table below.

Table No. 1: Loads and Earthquake parameters

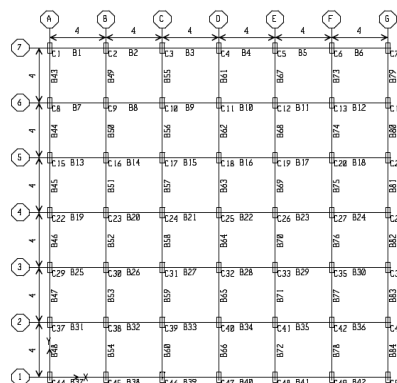
Dead load (floors)	- 1 KN/m ²
Live load (floors)	- 2 KN/m ²
Diaphragm	- Rigid
Soil Type	- Type II
Seismic Zone	- III
Importance Factor	- 1
Type of Structure	- OMRF
Response Reduction Factor	- 3

Table No. 2: Member details

Beam	- 300mm X 450mm
Column	- 300mm x 750mm
Slab thickness	- 150mm
Wall thickness	- 300mm

Table No. 3: Detail of cases consider in study

Case No.	Column Size (mm)	Corner Column Size (mm)
1	300 x 750	300 x 750
2	300 x 750	300 x 900
3	300 x 750	300 x 1050
4	300 x 750	300 x 1200



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Fig.1. Plan of G+5 Storey building used for study

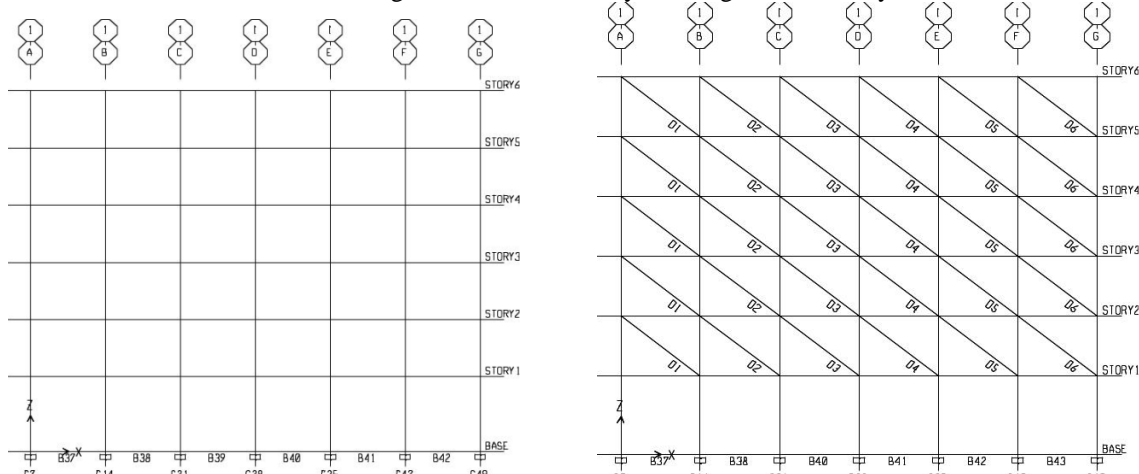


Fig.2.Elevation of models neglecting stiffness of wall

Fig.3.Elevation of models considering stiffness of wall

IV. ANALYSIS RESULTS

4.1 Change in Time Period:

Table No.4: Change in Analytical Fundamental Natural Periods for Different Models

Type of Structure	Fundamental Natural Periods T (sec)					
	Neglecting the stiffness of walls			Considering the stiffness of walls		
	Code	Analysis	Vb (kN)	Code	Analysis	Vb (kN)
Symmetric	0.751	1.458	2910.23	0.371	0.98	3827.13
Asymmetric I	0.751	1.452	2917.49	0.371	0.976	3853.94
Asymmetric II	0.751	1.446	2924.72	0.371	0.975	3863.49
Asymmetric III	0.751	1.442	2931.95	0.371	0.97	3878.04

4.2 Change in Base shear:

Lateral forces applied on building due to seismic activity or wind at base is known as base shear. Base shear of all models considering stiffness of infill wall and neglecting the stiffness of infill wall are as follows –

Table 4.2: Storey shear (kN) borne by columns of symmetric models neglecting and considering stiffness of infill walls

Storey	Neglecting the Stiffness of Walls		Considering the Stiffness of Walls	
	ESA	RSA	ESA	RSA
Storey 6	806.87	583.951	1221.04	496.08
Storey 5	1751.93	1345.219	2692.39	1336.08
Storey 4	2374.82	1892.32	3663.99	2173.02
Storey 3	2742.32	2309.30	4237.48	3006.02
Storey 2	2921.43	2673.57	4517.25	3834.90
Storey 1	2979.89	2979.13	4601.33	4601.25

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Table 4.3: Storey shear (kN) borne by columns of Asymmetric I models neglecting and considering stiffness of infill walls

Storey	Neglecting the Stiffness of Walls		Considering the Stiffness of Walls	
	ESA	RSA	ESA	RSA
Storey 6	808.02	586.24	1222.933	495.82
Storey 5	1755.4251	1349.22	2696.977	1336.38
Storey 4	2379.7283	1897.62	3670.44	2174.46
Storey 3	2748.068	2315.89	4245.035	3009.14
Storey 2	22927.584	2681.06	4525.329	3840.26
Storey 1	2986.192	2986.15	4609.616	4609.59

Table 4.4: Storey shear (kN) borne by columns of Asymmetric II models neglecting and considering stiffness of infill walls

Storey	Neglecting the Stiffness of Walls		Considering the Stiffness of Walls	
	ESA	RSA	ESA	RSA
Storey 6	809.3653	588.66	1224.700	495.37
Storey 5	1758.917	1353.27	2701.568	1338.04
Storey 4	2384.636	1902.75	3676.891	2177.53
Storey 3	2753.812	2322.05	4252.5848	3013.77
Storey 2	2953.734	2622.00	4533.414	3846.61
Storey 1	2992.497	2992.63	4617.909	4617.99

Table 4.5: Storey shear (kN) borne by columns of Asymmetric III models neglecting and considering stiffness of infill walls

Storey	Neglecting the Stiffness of Walls		Considering the Stiffness of Walls	
	ESA	RSA	ESA	RSA
Storey 6	810.709	591.16	1224.3445	495.79
Storey 5	1762.4102	1357.36	2706.159	1339.72
Storey 4	2389.545	1907.77	3683.343	2180.61
Storey 3	2759.556	2377.95	4260.134	3018.39
Storey 2	2939.885	2654.61	4551.499	3852.89
Storey 1	2998.800	2998.78	4626.186	4626.28

It can be seen that for both types of models, neglecting and considering stiffness of infill walls, the storey shear distribution to the higher storeys is less in case of RSA than ESA. But the design base shear V_b at ground storey columns is same for both ESA and RSA.

4.3 Change in storey displacement:

Horizontal displacement of building at top with respect to base is called as storey displacement.

Table 6.18: Lateral Displacements (m) at collapse along X for Equivalent Static Analysis (Pushover Analysis in X, EQ in X) for Different Models Neglecting the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.1895	0.1535	0.1628	0.1898
5	0.1838	0.1521	0.1598	0.1852
4	0.1709	0.1470	0.1516	0.1738
3	0.1521	0.1319	0.1343	0.1493
2	0.1175	0.1022	0.1022	0.1095
1	0.0678	0.0584	0.0565	0.0582

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Table 6.19: Lateral Displacements (m) at collapse along X for Response Spectrum
Method (Pushover Analysis in X, EQ in X) for Different Models Neglecting the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.1805	0.1261	0.1585	0.1890
5	0.1781	0.1287	0.1575	0.1831
4	0.1701	0.1215	0.1506	0.1666
3	0.1456	0.1085	0.1311	0.1389
2	0.1095	0.0838	0.0991	0.1002
1	0.0618	0.0472	0.0555	0.0532

Table 6.20: Lateral Displacements (m) at collapse along Y for Equivalent Static
Analysis (Pushover Analysis in Y, EQ in Y) for Different Models Neglecting the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.1714	0.1145	0.1224	0.1342
5	0.1624	0.1105	0.1198	0.1235
4	0.1495	0.1066	0.1101	0.1155
3	0.1382	0.1018	0.1075	0.102
2	0.98	0.905	0.995	0.921
1	0.0479	0.0427	0.0429	0.0305

Table 6.21: Lateral Displacements (m) at collapse along Y for Response Spectrum
Method (Pushover Analysis in Y, EQ in Y) for Different Models Neglecting the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.1171	0.921	0.0597	0.0285
5	0.0618	0.0678	0.0196	0.0251
4	0.0115	0.0275	0.0228	0.0195
3	0.0112	0.0070	0.018	0.0124
2	0.098	0.0021	0.0109	0.0055
1	0.065	0.0015	0.0056	0.0006

Table 6.22: Lateral Displacements (m) at collapse along X for Equivalent Static
Analysis (Pushover Analysis in X, EQ in X) for Different Models Considering the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.0462	0.0485	0.0482	0.0481
5	0.0461	0.0483	0.0481	0.0478
4	0.0460	0.0478	0.0477	0.0475
3	0.0458	0.0473	0.0473	0.0473
2	0.0454	0.0468	0.0470	0.0457
1	0.0453	0.0461	0.0464	0.0461

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Table 6.23: Lateral Displacements (m) at collapse along X for Response Spectrum Method (Pushover Analysis in X, EQ in X) for Different Models Considering the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.0462	0.0464	0.0463	0.0465
5	0.0461	0.0461	0.0460	0.0462
4	0.0458	0.0460	0.0458	0.0460
3	0.0459	0.0459	0.0457	0.0458
2	0.0458	0.0456	0.0455	0.0457
1	0.048	0.0453	0.0452	0.0455

Table 6.24: Lateral Displacements (m) at collapse along Y for Equivalent Static Analysis (Pushover Analysis in Y, EQ in Y) for Different Models Considering the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.0570	0.0260	0.0609	0.0357
5	0.0561	0.0256	0.0148	0.0355
4	0.0552	0.0253	0.0157	0.0353
3	0.0537	0.0250	0.0155	0.0350
2	0.0523	0.0247	0.0153	0.0347
1	0.0500	0.0236	0.0140	0.0341

Table 6.25: Lateral Displacements (m) at collapse along Y for Response Spectrum Method (Pushover Analysis in Y, EQ in Y) for Different Models Considering the Stiffness of walls

Storey	Symmetric	Asymmetric I	Asymmetric II	Asymmetric III
6	0.0448	0.0395	0.0295	0.0289
5	0.0445	0.0376	0.0294	0.0286
4	0.0444	0.0348	0.0293	0.0285
3	0.0441	0.0318	0.0290	0.0284
2	0.0436	0.0288	0.0288	0.0282
1	0.0430	0.0218	0.0286	0.0271

From above tables, it can be observed that for models considering the stiffness of infill walls, the roof displacement is very low as compared with corresponding models neglecting stiffness of infill walls for both ESA and RSA. It can be observed that for the models considering the stiffness of walls, the roof displacement is higher in X-direction as compared to Y-direction.

6.5 Axial Force and Bending Moments of Some Selected Columns:

In practice, medium rise buildings are designed only for gravity loads, but these buildings are likely to experience earthquakes during their lifetime. Since they are designed only for gravity loads, they are vulnerable when subjected to seismic loads. We can estimate the vulnerability of such buildings by comparing the amount of reinforcement required when designed only for gravity loads with that required when designed for gravity and seismic loads.

Table 6.26: Design forces (ESA) and reinforcement of columns for ground storey Symmetric structure neglecting stiffness of walls

Storey	Column	Load	P (kN)	M2 (kN-m)	M3 (kN-m)	Ast (mm ²)	% Change
Storey 1	C1	1.5GRAV	-885.76	6.930	-5.120	1200	38.23
	C1	1.5(DL+EQY)	-1010.52	150.70	-4.196	1950	
	C5	1.5GRAV	-885.76	6.930	5.120	1200	38.23

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	C5	1.5(DL+EQY)	-1010.52	150.70	4.196	1950	
	C10	1.5GRAV	-1365.42	0	7.25	1200	55.25
	C10	1.5(DL+EQX)	-1220.08	162.62	5.492	2700	
	C14	1.5GRAV	-1365.42	0	7.25	1200	55.25
	C14	1.5(DL+EQY)	-1220.08	162.62	5.492	2700	
	C20	1.5GRAV	-882.76	-6.927	5.127	1200	0
	C20	1.5(DL+EQY)	-607.75	138.26	4.252	1200	
	C24	1.5GRAV	-882.76	-6.927	-5.127	1200	0
	C24	1.5(DL+EQY)	-607.75	138.26	-4.252	1200	

Table 6.27: Design forces (ESA) and reinforcement of columns for ground storey
Symmetric structure considering stiffness of walls

Storey	Column	Load	P (kN)	M2 (kN-m)	M3 (kN-m)	Ast (mm ²)	% Change
Storey 1	C1	1.5GRAV	-9.723.25	5.211	-5.264	1200	69.12
	C1	1.5(DL+EQY)	-1175.82	221.35	-4.365	3900	
	C5	1.5GRAV	-958.12	5.790	5.021	1200	60.00
	C5	1.5(DL+EQY)	-843.75	2.765	209.048	3000	
	C10	1.5GRAV	-1389.06	-1.652	6.851	1200	72.32
	C10	1.5(DL+EQX)	-1565.41	-1.488	211.845	4350	
	C14	1.5GRAV	-2039.02	-1.538	-0.465	3000	44.44
	C14	1.5(DL+EQY)	-1763.22	233.622	-0.352	5400	
	C20	1.5GRAV	-1398.93	-1.423	-7.322	1200	71.38
	C20	1.5(DL+EQY)	-1235.04	230.521	-5.597	4200	
	C24	1.5GRAV	-990.01	-7.428	-5.231	1200	55.51
	C24	1.5(DL+EQY)	-583	-6.125	201.154	2700	

Table 6.28: Design forces (ESA) and reinforcement of columns for ground storey
Asymmetric 3 structure neglecting stiffness of walls

Storey	Column	Load	P (kN)	M2 (kN-m)	M3 (kN-m)	Ast (mm ²)	% Change
Storey 1	C1	1.5GRAV	-1062.02	7.21	-4.9	3000	0.00
	C1	1.5(DL+EQY)	-1222.85	538.85	-52.1	3000	
	C5	1.5GRAV	-897.23	6.82	-6.25	1200	38.42
	C5	1.5(DL+EQY)	-1027.21	5.63	112.12	1950	
	C10	1.5GRAV	-1278.65	0	8.65	1200	55.52
	C10	1.5(DL+EQX)	-1468.82	0	118.23	2700	
	C14	1.5GRAV	-1562.04	0	-7.98	3000	0.00
	C14	1.5(DL+EQY)	-1412.25	552.10	-6.25	3000	
	C20	1.5GRAV	-895.56	-6.86	6.64	1200	0.00
	C20	1.5(DL+EQY)	-1027.82	-5.21	112.25	1200	
	C24	1.5GRAV	-1061.54	-7.52	-4.98	3000	0.00
	C24	1.5(DL+EQY)	-745.89	532.35	42.85	3000	

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Table 5.29: Design forces (ESA) and reinforcement of columns for ground storey
Asymmetric 3 structure considering stiffness of walls

Storey	Column	Load	P (kN)	M2 (kN-m)	M3 (kN-m)	Ast (mm ²)	% Change
Storey 1	C1	1.5GRAV	-1182.65	-10.95	-5.23	3000	0.00
	C1	1.5(DL+EQY)	-1362.72	670.14	-88.85	3000	
	C5	1.5GRAV	-1015.21	5.85	5.75	1200	71.38
	C5	1.5(DL+EQY)	-1208.16	242.60	-31.01	4200	
	C10	1.5GRAV	-1462.35	-1.25	7.98	1200	61.85
	C10	1.5(DL+EQX)	-1590.85	-1.21	175.25	3150	
	C14	1.5GRAV	-1721.74	-17.25	-8.12	3000	0.00
	C14	1.5(DL+EQY)	-1539.38	680.01	-6.18	3000	
	C20	1.5GRAV	-1022.58	-7.38	5.85	1200	0.00
	C20	1.5(DL+EQY)	-1208.95	-5.95	175.05	1200	
	C24	1.5GRAV	-1234.45	-24.25	-4.12	3000	0.00
	C24	1.5(DL+EQY)	-762.85	658.18	80.45	3000	

V. CONCLUSION

Basic purpose of this study is to know the performance of seismically induced torsion in irregular RC building. From all above results and discussion, conclusion made as follows -

1. It is observed that time period of structures considering stiffness is less than structures neglecting the stiffness of infill wall.
2. In Symmetric, Asymmetric I, Asymmetric II and Asymmetric III models, the base shear is higher for models considering stiffness of walls than the model neglecting the stiffness of walls.
3. In Symmetric, Asymmetric I, Asymmetric II and Asymmetric III models, the lateral displacement is higher for models neglecting the stiffness of infill walls than the models considering the stiffness of walls.
4. The required area of reinforcement in selected columns is greater when designed for gravity and earthquake loads as compared to corresponding models designed only for gravity loads. In the case of models where stiffness of infill walls is neglected, this increase is between 30% to 60%, whereas for models where stiffness of infill walls is considered, it varies between 50% to 70%. It is therefore important to consider the seismic loads in the design of medium rise buildings.

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