

Analysis and Design of Regular and Irregular Buildings

Srishti Bhomaj¹, Parikshit Ghodake², J.P.Patankar³

¹B.Tech, Civil Engineering, Government College of Engineering, Karad, India.

²B.Tech, Civil Engineering, Government College of Engineering, Karad, India.

³Professor, Applied Mechanics Department, Government College of Engineering Karad, Maharashtra, India.

Abstract - In structural engineering, the analysis and design of the reinforced cement concrete (RCC) building is carried out manually as well as by using software. In this project, we have analyzed and designed RCC (G+3) building, regular as well as irregular, manually and by using Structural Engineering software ETABS and StaadPro.v8i.

The problem in the design of the irregular building is introduced due to discontinuity in stiffness or due to geometry of structure. The design had been carried out on ETABS and StaadPro.v8i for 13 load combinations as per IS 1893-2016.

The center of mass, center of stiffness, torsion and base shear developed have been calculated for comparison between the regular and irregular buildings.

In recent days, due to requirement of unique architectural appearance of building, the regularity in plan, mass and stiffness may get disturbed and may lead to development of torsion in the structure.

The project deals with the comparative study of regular and irregular building of same area and same mass, the irregularity being caused by shifting of center of stiffness. The results derived in this project are location of center of mass and center of stiffness, torsion induced in the building, forces acting on column and changes observed in column design.

Key Words: Regular building, Irregular Building, Stiffness, Torsion, Base Shear

1. INTRODUCTION

Regularity of the structure deals with the a symmetrical and compact shape of the structure. The importance of regularity of the building is for avoiding unpredictable stress concentration that can cause local collapses and modification of the dynamic behaviour.

Irregular structures, like structures having a L-shaped plan, that can be defined "irregular" according to both perceptible criteria and irregularity rules provided by guidelines, show that, if the diaphragms are rigid and the columns are distributed according to the shape, the irregularity is "apparent". The disturbance to the response, induced by the irregularity consists of torsional effects, that can be accounted for, at design stage.

An extensive study of literature is carried out to understand the concept of regularities and irregularities in building. In addition to this, literature related to shear walls, Irregularities in building, torsion in building is also reviewed and behaviour of structure is understood.

1.1 IRREGULAR BUILDINGS

When a building is subjected to seismic excitation, horizontal inertia forces are generated in the building. The resultant of these forces is assumed to act through the center of mass (C.M) of the structure. The vertical members in the structure resist these forces and the total resultant of these systems of forces act through a point called as center of stiffness (C.S). When the center of mass and center of stiffness does not coincide, eccentricities are developed in the buildings which further generate torsion. When the buildings are subjected to lateral loads, then phenomenon of torsional coupling occurs due to interaction between lateral loads and resistant forces. Torsional coupling generates greater damage in the buildings. Eccentricity may occur due to presence of structural irregularities. These irregularities may be broadly classified as Plan (Horizontal) and Vertical irregularity.

Plan irregularity is further subdivided into Torsional irregularity, Re-entrant corners, Floor Slabs having Excessive Cut-Outs or Openings, Out-of-Plane Offsets in Vertical Elements, Non-Parallel Lateral Force System etc. And Non-Parallel Lateral Force System etc. And Vertical irregularities is further classified into Stiffness Irregularity, Mass Irregularity, Vertical Geometric Irregularity, In-Plane Discontinuity in Vertical Elements Resisting Lateral Force, Strength Irregularity etc.

1.2 TORSION IN BUILDING

Due to dynamic loads such as earthquake load or wind load the high rise structure subjected to unbalanced couple and it rotate about the axis of centre of stiffness of building this phenomenon is known as torsion in building. These effects occur due to different reasons, such as no uniform distribution of the mass, stiffness and strength, torsional components of the ground movement, etc. In ductile structures, the main consequence of floor twist is an unequal demand of lateral displacements in the elements of the structure. Design codes incorporate especial requirements to take into account the torsional effects, which usually imply de-amplification of eccentricity and the consideration of an accidental eccentricity. The seismic response of buildings

subjected to ground motions may be significantly modified due to the occurrence of torsional effects. As a result, the floors of the building not only translate laterally but also rotate along a vertical axis. Centre of mass is a position defined relative to an object or system of objects. It is the average position of all the parts of the system, weighted according to their masses. For simple rigid objects with uniform density, the centre of mass is located at the centroid. Centre of rigidity is the where the entire stiffness of the building acts. Stiffness is contributed by the column and shear walls of the building.

2. STRUCTURAL DESIGN

The Civil Engineering structures are analyzed and designed by following the Indian Standard Code 456-2000. And for ductile detailing of reinforcement the Indian Standard Code 139202002 is followed.

The key plan of regular and irregular building, schedule and details of reinforcement of all structural elements that are Slab, Beam, Column and Footing, which are concluded from manual calculation are shown below.

2.1 GENERAL DESCRIPTION OF BUILDING

Both the buildings i.e., regular and irregular in plan, have plan dimensions of 12m x 15m. Both the buildings are G+3 RCC buildings, having floor to floor height of 3.6m. Regular building is kept symmetrical in both the principal directions in plan. And irregular building is kept unsymmetrical in one of the principal direction (x-direction).

Plan Dimensions	12m X 15m
Story height	3.6m
Slab thickness	100mm
Plinth height	600mm
Characteristic strength of concrete	20 MPa
Characteristic strength of steel	415 MPa
Density of reinforced concrete	25 kN/m ³
Floor finish for floor slab	1kN/m
Floor finish for roof slab	2.5kN/m
Live load for floor slab	3kN/m
Live load for roof slab	1.5kN/m

The above mentioned data is common for both the models. Figure 1 shows key plan for regular building and fig 2 shows the key plan for irregular building.

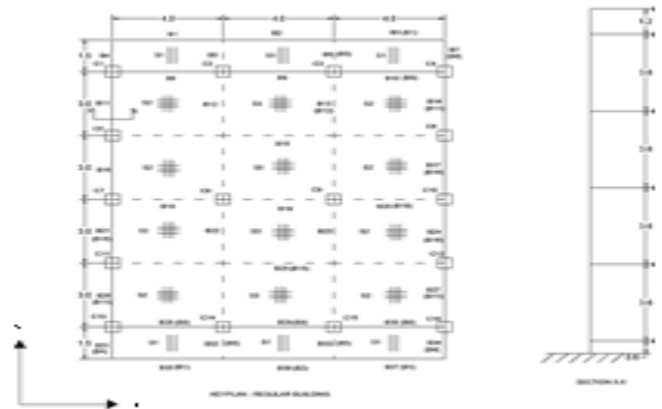


Fig -1: Key Plan for Regular Building

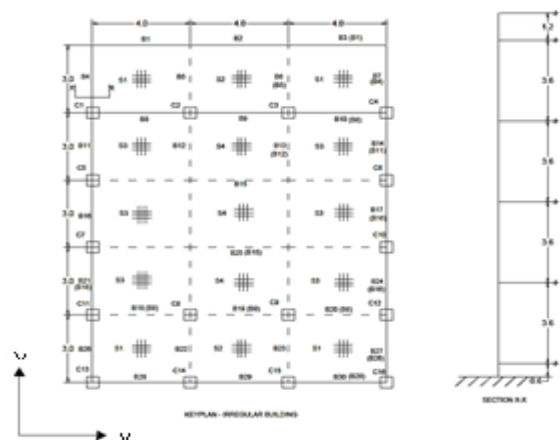


Fig -2: Key Plan for Irregular Building

3. RESULTS

The irregularity dealt with in this project was torsional irregularity (Table5- Clause 7.1- IS 1893 (part1):2016) as the displacement between two ends of the floor is greater than 1.5 times the displacement at the other end (9mm and 66mm resp. at two ends). The result obtained after comparing the two models are as follows.

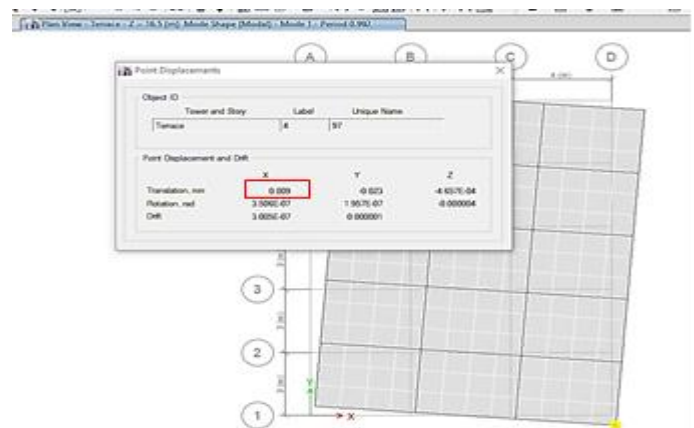


Fig 3: Horizontal Displacement in Regular Building

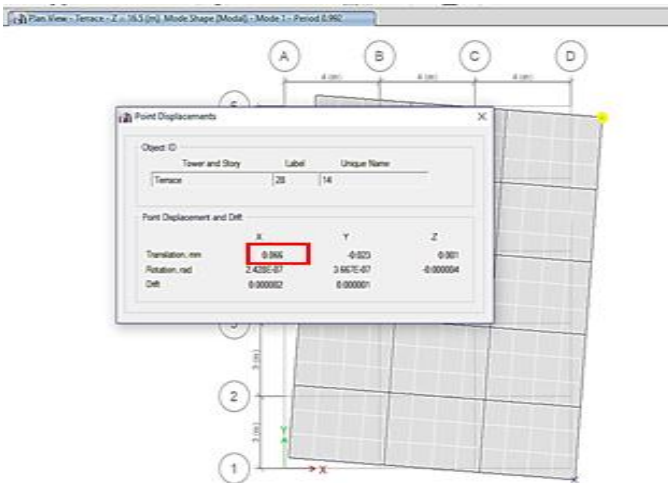


Fig 4: Horizontal Displacement in Irregular Building

- Max. Base Shear in X Direction = 840kN (for load case .9DL-1.5EX)
- Max. Base Shear in Y Direction = 890kN (for load case .9DL-1.5EY)

Story	Diaphragm	Mass X	Mass Y	XCM	YCM	XCR	YCR
		kg	kg	m	m	m	m
Terrace	D1	182414.78	182414.78	6	7.4017	6	6.0875
Story3	D1	244560.97	244560.97	6	7.0811	6	6.0660
Story2	D1	244560.97	244560.97	6	7.0811	6	6.0305
Story1	D1	244560.97	244560.97	6	7.0811	6	5.9414

Table 2: Centre of Mass & Centre of Rigidity of Irregular Building.

Torsion induced = 840 x (7.4017-6.0875) = 1103.928 kNm

3.1 CENTRE OF MASS (CM) AND CENTRE OF RIGIDITY (CR)

3.1.1 Centre of mass and center of rigidity of regular building.

The table 1 shows the software results for center of mass and center of rigidity of the regular building. The base shear as found using ETABS are as below:

- Max. Base Shear in X Direction = 870kN (for load case .9DL-1.5EX)
- Max. Base Shear in Y Direction = 772kN (for load case .9DL-1.5EY)

Story	Diaphragm	Mass X	Mass Y	XCM	YCM	XCR	YCR
		kg	kg	m	m	m	m
Terrace	D1	179662.4	179662.4	6	7.5	6	7.5
Story3	D1	269489.3	269489.3	6	7.5	6	7.5
Story2	D1	269489.3	269489.3	6	7.5	6	7.5
Story1	D1	269489.3	269489.3	6	7.5	6	7.5

Table 1: Centre of Mass & Centre of Rigidity of Regular Building.

Torsion Induced = Base Shear x (Center of Mass- Center of Rigidity) = 0 kNm

3.1.2 Centre of mass and center of rigidity of irregular building.

The table 2 shows the software results for center of mass and center of rigidity of the irregular building. The base shear as found using ETABS are as below:

3.2 COLUMN FORCES

The table 3 and 4 shows the different forces acting on the columns of regular and irregular building.

TABLE: Column Forces- Regular Building							
Story	Column	P	Fx	Fy	T	(Mx)	(My)
		kN	kN	kN	kN-m	kN-m	kN-m
Terrace	C-1	151.076	33.277	18.801	0.001	38.678	54.548
Terrace	C-2	273.219	26.542	13.040	0.001	29.638	40.971
Terrace	C-3	273.388	26.547	13.010	0.001	29.693	40.978
Terrace	C-4	151.149	33.260	18.745	0.001	38.587	54.519
Terrace	C-5	147.357	67.856	30.315	0.001	48.033	123.587
Terrace	C-6	147.059	67.784	30.323	0.001	48.046	123.467
Terrace	C-7	138.460	27.298	27.800	0.001	47.293	48.516
Terrace	C-8	330.358	26.539	19.299	0.001	42.211	41.246
Terrace	C-9	330.542	26.540	19.331	0.001	42.253	41.247
Terrace	C-10	138.446	27.281	27.884	0.001	47.420	48.489
Terrace	C-11	147.399	67.853	30.337	0.001	48.071	123.575
Terrace	C-12	147.507	67.896	30.281	0.001	47.974	123.650
Terrace	C-13	151.071	33.282	18.812	0.001	38.696	54.556
Terrace	C-14	273.218	26.547	13.056	0.001	29.614	40.979
Terrace	C-15	273.211	26.582	13.054	0.001	29.616	41.028
Terrace	C-16	151.083	33.303	18.808	0.001	38.689	54.590

Table 3: Forces acting on the columns of regular building.

TABLE: Column Forces- Irregular Building							
Story	Column	P	F _x	F _y	T	(M _x)	(M _y)
		kN	kN	kN	kN-m	kN-m	kN-m
Terrace	C-1	200.938	33.113	42.294	0.743	69.350	50.624
Terrace	C-2	430.226	35.883	48.444	1.814	71.168	55.905
Terrace	C-3	430.226	35.883	48.444	1.814	71.168	55.905
Terrace	C-4	200.938	33.113	42.294	0.743	69.350	50.624
Terrace	C-5	153.642	64.159	44.403	0.743	70.445	106.211
Terrace	C-6	153.642	64.159	44.403	0.743	70.445	106.211
Terrace	C-7	176.023	65.153	36.856	0.743	60.213	107.412
Terrace	C-8	260.336	26.083	52.817	0.743	85.630	40.761
Terrace	C-9	260.336	26.083	52.817	0.743	85.630	40.761
Terrace	C-10	176.023	65.153	36.856	0.743	60.213	107.412
Terrace	C-11	123.277	24.208	31.923	0.743	51.107	45.154
Terrace	C-12	123.277	24.208	31.923	0.743	51.107	45.154
Terrace	C-13	85.483	20.945	11.673	0.743	23.881	36.554
Terrace	C-14	109.437	18.353	12.630	0.743	24.666	31.501
Terrace	C-15	109.437	18.353	12.630	0.743	24.666	31.501
Terrace	C-16	85.483	20.945	11.673	0.743	23.881	36.554

Table 4: Forces acting on the columns of irregular building.

3.3 COLUMN DESIGN

Table 5 shows the difference in column design due to irregularity in the structure.

Regular column			Irregular column		
Column no.	size	Main reinforcement	Column no.	size	Main reinforcement
C1	400x400	12 # 16	C1	400x400	12 # 20
C2	400x400	10 # 20	C2	500x500	16 # 20
C3	400x400	10 # 20	C3	500x500	16 # 20
C4	400x400	12 # 16	C4	400x400	12 # 20
C5	400x400	12 # 20	C5	400x400	16 # 20
C6	400x400	12 # 20	C6	400x400	16 # 20
C7	400x400	12 # 16	C7	400x400	16 # 20
C8	400x400	10 # 20	C8	400x400	12 # 20
C9	400x400	10 # 20	C9	400x400	12 # 20
C10	400x400	12 # 16	C10	400x400	16 # 20
C11	400x400	12 # 20	C11	400x400	8 # 20
C12	400x400	12 # 20	C12	400x400	8 # 20
C13	400x400	12 # 16	C13	400x400	8 # 20
C14	400x400	10 # 20	C14	400x400	8 # 20
C15	400x400	10 # 20	C15	400x400	8 # 20
C16	400x400	12 # 16	C16	400x400	8 # 20

Table 5: Difference in column design due to irregularity

4. CONCLUSIONS

In this project, analysis and design of regular building and irregular building were carried out and the conclusions drawn from the results have been discussed below.

- Center of mass and center of stiffness coincides in regular building whereas in irregular building some eccentricity is observed.
- The torsion in regular building due to earthquake in both directions along X- direction and along Y- direction was found out to be zero kNm. Whereas the torsion was developed in irregular building due to earthquake along the X- direction.
- In regular building no torsion was observed in columns whereas in irregular building every column was subjected to torsion.
- The sectional requirements of an irregular building are relatively higher than that of regular buildings.
- Change in value of base shear in both direction was observed in regular and irregular model.

5. FUTURE SCOPE

In this project the torsional irregularity has been studied and similarly on the same basis other irregularities can also be studied. The effects of irregularity have been shown in this project and it will help the designers to design the buildings in a more efficient way possible.

ACKNOWLEDGEMENT

The success of this project has come through many efforts put in by the group members and our project guide Prof. J. P. Patankar. Applied Mechanics Department, GCE Karad, India.

We are very grateful to Dr. Y. M. Ghugal, Head, Applied Mechanics Department, GCE Karad, India. For giving us this invaluable opportunity to carry out this project work.

We also extend our sincere thanks to Dr. A.T. Pise, Principal, GCE, Karad, India for providing institutional facilities and extending all kinds of co-operation.

Last but not the least; we thank all those who directly and indirectly contributed in completion of this project.

REFERENCES

[1] C. V. R. Murty, Indian Institute of Technology Kanpur, India, "Why are Buildings with Shear Walls preferred in Seismic Regions", IITK-BMTPC Earthquake Tips.

[2] Naveen. G.M., Chaya. S, "Study on regular and irregular building structures during an earthquake" International Journal of Latest Engineering Research and Applications

(IJLERA) ISSN: 2455-7137 Volume - 01, Issue - 08, November - 2016, PP - 42-48.

- [3] Francisco Crisafulli, Agustín Reboledo and Gonzalo Torrisi, "Consideration of torsional effects in the displacement control of ductile buildings", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 1111.
- [4] Elena Mola¹, Paolo Negro, Arthur V. Pinto, "Evaluation of current approaches for the analysis and design of multi-storey torsionally unbalanced frames", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 3304.
- [5] Shaik Muneer Hussain, Dr. Sunil Kumar Tengli, "Study on Torsional Effects of Irregular Buildings Under Seismic Loads", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 55-60.
- [6] Subodh. S. Patil, Ajim G Mujawar, Pritam. A. Mali and Murugesh. R. Katti, "A Study of Torsional Effect On Multi-Storied Building with Plan-Irregularity", January 2017, Int. J. Adv. Res. 5(1), 1625-1632.
- [7] Himanshu Bansal, Gagandeep, "Seismic Analysis and Design of Vertically Irregular RC Building Frames", August 2014, International Journal of Science and Research (IJSR), Volume 3 Issue 8, Pg. 207- 215.
- [8] Vikram Singh Kushwah, Ravi Dwivedi, "Seismic Analysis of RC Frame with the Variation of Position of Soft Storey", International Journal of Science and Research (IJSR), Volume 5 Issue 10, October 2016, Pg. No. 1073-1080.
- [9] IS 1893 (Part1):20016 "Criteria for earthquake resistant design of structure"
- [10] IS 13920:1993, "Ductile detailing of reinforced concrete structure subjected to seismic forces".
- [11] IS 456:2000 "Plain and Reinforced Concrete - Code of Practice".
- [12] Dr. V. L. Shah, Dr. S. R. Karve (2016), "Limit State Theory and Design of Reinforced Concrete", 8th Edition.