Torsional Irregularities in Multi-storeyed Structures

Adarsh A[1], Rajeeva S V [2]

[1] M.Tech. (CAD Structure), S J B Institute of Technology, Karnataka, India
[2]Professor of Civil Engineering, S J B Institute of Technology, Karnataka, India

Abstract - **Damage reports on recent earthquakes have indicated that torsional motions often cause significant damage to buildings, at times leading to their collapse. The objective of this work aimed a better understanding of the torsional behaviour of building systems. In this analysis both symmetric and asymmetric structures with plan irregularity are compared. Symmetric structures have centre of mass coinciding with the centre of rigidity and the torsion effect in such structures occurs out of accidental eccentricity whereas in asymmetric structures have irregular distribution of mass and stiffness and its centre of mass and centre of rigidity do not coincide and hence causes the torsional effect on the structures which is one of the most important factor influencing the seismic damage of the structure. To assess the torsional effect on the structures in the present study 5 types of structures having same different perimeter area are considered and strengthened by introduction of shear wall cores. A simple linear comparison based on eccentricity is also carried out for the structures. Structures with asymmetric distribution of mass and stiffness undergoes torsional motions during earthquake. The performance of the structures is assessed as per the procedure prescribe in IS 1893:2002. Equivalent loads and wind loads are considered for the analysis of the structure. The analysis of the structural models is carried out using ETABS 2015 software.**

Keywords - **Displacement, drift, Equivalent static load, wind load analysis**

I. INTRODUCTION

During earthquake ground motions, structures much of the time will encounter torsional vibration in addition to lateral oscillations. A significant torsional reaction hotspot is due to asymmetrical distribution of mass or horizontal load opposing components in the plan of the structure which is usually refers to eccentricity of mass or rigidity. Distinctive sorts of torsional reaction can take place in regular structures if there should arise an occurrence of irregular ground movement along the base of the structure or or inelastic performance of opposing component or loss of strength of such a component. This research focuses mainly on the latter case that can also occur during moderate earthquake movement. In the event of extreme or moderate earthquakes, most of the structures work inelastically. In view of this inelastic performance, horizontal coupled torsional shakings of the structure may be altogether superior than anticipated by linear-elastic analysis. When one of the horizontal opposing components yields, the position of the focal point of rigidity will change and this can cause a critical change in eccentricity of the whole structure.

The torsional irregularity is an imperative parameter which measures the stretch out of torsion impact on the structures. It can be interpreted as the proportion of highest drift to the mean drift of the individual story. Torsional irregularity should be considered when maximum story drift at one side of the structure transverse to a axis is more than 1.2 times the mean of the story drift at the two closures of the structure. $\Delta 1$ and $\Delta 2$ are the story drift (or inter-story drifts) at the two closures of the structure. Relative eccentricity is generally considered the main factor influencing the torsional effects.

II. LITERATURE REVIEW

Rahila Thaskeen, Shinu Shajee (2016) [1] The objective of their work aimed at enhanced understanding of the torsional behaviour of building systems. In the analysis both symmetric and asymmetric structures with plan irregularity were compared. To assess the torsional effect on the structures they modelled 4 types of structures having same outer perimeter area and strengthened by introduction of shear wall cores. A simple linear comparison based on eccentricity is also carried out for G+12 and G+17 structures. The analysis of the structural models is carried out using ETABS software. From their investigation on reviews they concluded that the eccentricity shows the tendency of a structure for torsional effects. Model IV (C- shaped structure) had the maximum tendency for torsional effects with higher value of eccentricity. The highest torsional irregularity ratio was found maximum for model IV which was the C shape structure and it is seen that the rigidity centre of model IV is intense at outside the structure. The drift and displacement values yielded values, indicating the dependence of the stiffness and mass concentration on the structure. Strengthened model yielded shorter-period which permitted smaller drift limits and longer-period structures that is the ideal symmetric structure allowed larger drift limits.

P.S Pajgade, Vipin Guptha (2015) [2] explains that the torsion is the most basic element prompting significant harm or completes collapse of building; therefore it is necessary that symmetric buildings should also be analyzed for torsion. As result the buildings should be designed by considering the design eccentricity and accidental eccentricity. They observed that the irregular profile buildings got larger forces and displacement as compared to regular one. Structures are never consummately consistent and thus the architects routinely need to assess the feasible level of irregularity and the impact of this irregularity on a structure during an earthquake.

Arvindreddy and R.J.Fernandes (2015) [3] presented a review about the Seismic analysis of RC regular and irregular frame structures. They considered 2 types of reinforced concrete structures with regular and irregular 15 story structures and analysed for static and dynamic methods. For time history examination past seismic earth ground movement record is taken to think about reaction of the considerable number of structures. Directly they taken six models. One is of general structure and remaining are unpredictable structural models. From their investigation on reviews they concluded that, the static analysis strategy demonstrate lesser story displacements when compared with response spectrum analysis. This variation may be because of nonlinear distribution of force. In diaphragm irregularity, story displacement and story drift observed to be less when compared with normal structures in both static and response spectrum analysis.

O. A. Mohamed and O. A. Abbass (2015) [4] explains review about the Consideration of torsional irregularity in Modal Response Spectrum Analysis. The motivation behind their work is to determine the impacts of torsional irregularity on seismic reaction as per ASCE 7–10, when MRSA is utilized for count of seismic forces and drifts. They discussed about why torsional irregularity must be represented, notwithstanding when MRSA is utilized. From their investigation on reviews they concluded that the torsional irregularity of building diaphragm or floor frameworks prompts increased structural reactions including bending moments and drift and should be represented in the computational model to maintain a strategic distance from structural failures and building pounding effects.

Turgut Ozturk , Zubeyde Ozturk and Onur Ozturk (2015) [5] presented a review about the seismic behavior analysis of multi-story reinforced concrete buildings having torsional irregularity. The purpose of their work is to understanding of the characteristics of an earthquake and correct determination of the behavior of buildings under earthquake excitation turn out to be the most important requirement to build earthquake resistant buildings. In their study torsional effects that occur during earthquake excitations are analyzed in multi-story reinforced concrete buildings. In that manner the behavior of reinforced concrete structures under earthquake loads are examined and by the way the behaviors of structures having torsional irregularities are enlightened and clarified. From the results they explains that the torsional irregularity can occur in the buildings that have regular geometrical shape and regular rigidity distribution. The reason of this irregularity which is called hidden torsional irregularity, is due to lack of rigidity along the extern axes. In certain cases, torsional irregularity can be lowered or totally removed as a result of decrease shear wall rigidity at central zone. torsional irregularity is more related to the rigidity distribution than the geometrical plan of the building. For this reason, determination of the load carrying system of a structure is the most important issue at the planning stage of the project. It is essential that shear wall locations and cross-sectional areas must be properly selected, and the shear walls must be symmetrical in the plan in order to prevent torsional irregularity

III OBJECTIVES

(i) To determine optimum position of shear walls by taking irregular building plan.
(ii) To determine the structural response under wind and seismic loading using shear walls with the same cross sectional area in different models
(iii) To find parameters like storey displacements, base shear, and relative storey drifts.
(iv) To study the structural response for torsional irregularities.
(v) To understand the behavior of irregular building subjected to lateral loading with the help of time period, frequency ,modal mass participating ratio and the magnitudes of stress resultants.

IV MODELLING

The analysis of 15 storey building is carried out using ETABS 15.2.2 software situated in zone IV. Lateral displacement, storey drift, storey shear and torsional irregularity is compared for all models.

A. Details of models

TABLE I
DETAILS OF BUILDING MODEL

Depth of foundation	3m
Floor to floor height	3m
Building dimension	22.76m x 34.15m
Type of steel	Fe-500
Grade of concrete	M-30
Column size	200mmx750mm
Beam size	200mmx450mm
Thickness of masonry wall	200mm
Slab thickness	150mm
Live load	3 kN/m²
Floor finishes	1.5kN/m²
Wall load	11kN/m
Seismic zone, Z	IV
Importance factor, I	1
Response reduction factor, R	5
Soil type	Medium

Building height	33.5m
Wind speed, Vb	50 m/s
Terrain category	1
Structure class	B
Risk coefficient (k1 factor)	1
Topography (k3 factor)	1

B. Model type

TABLE II
TYPE OF MODELS

Model	Type
1	RC frame without shear and core wall
2	RC frame with only core walls
3	RC frame with shear walls and core walls
4	RC frame with shear walls and core walls of different positions.
5	RC frame with shear walls and core walls of different positions.

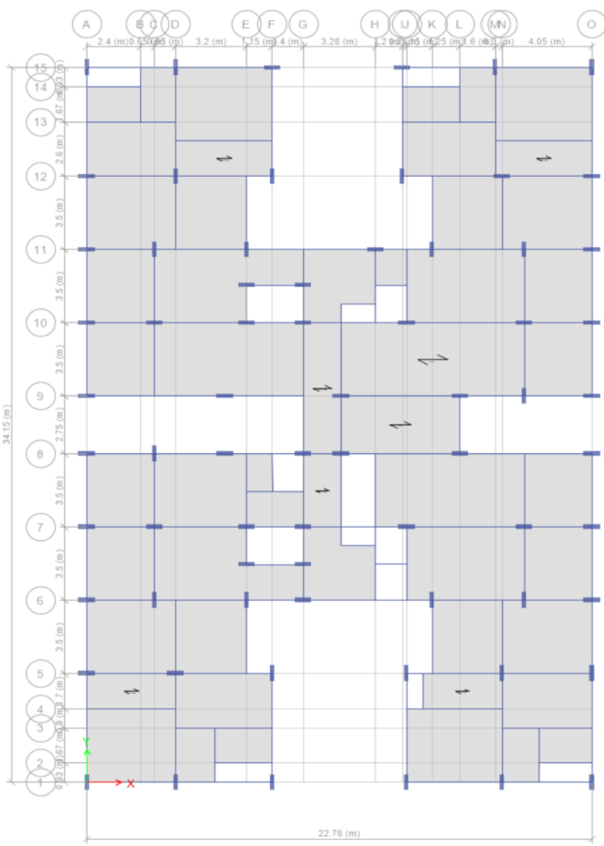

Fig.1. Plan view of model 1

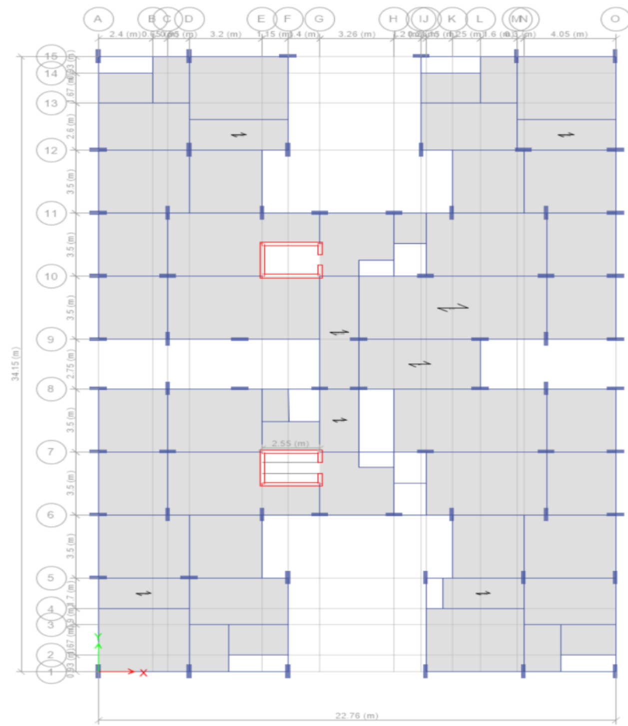

Fig.2. Plan view of model 2

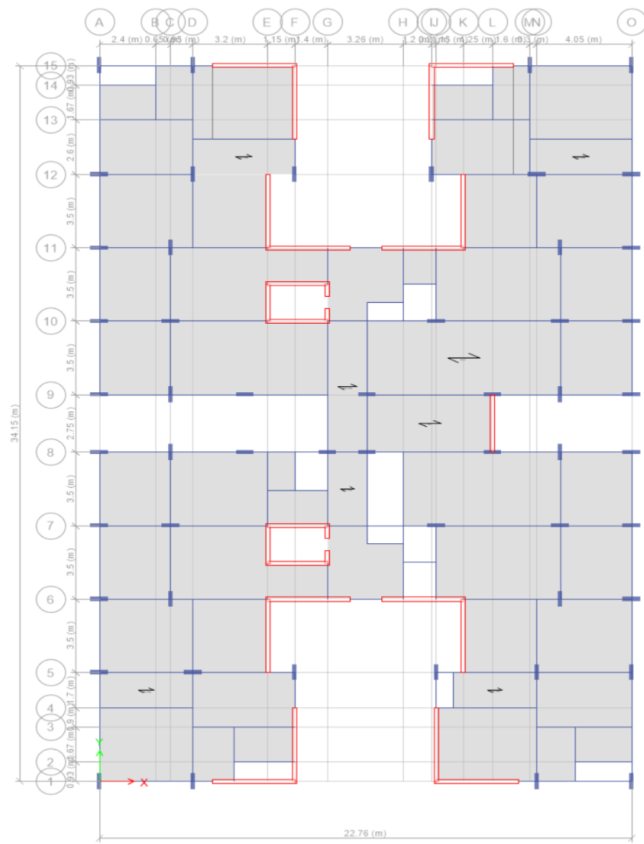

Fig.3. Plan view of model 3

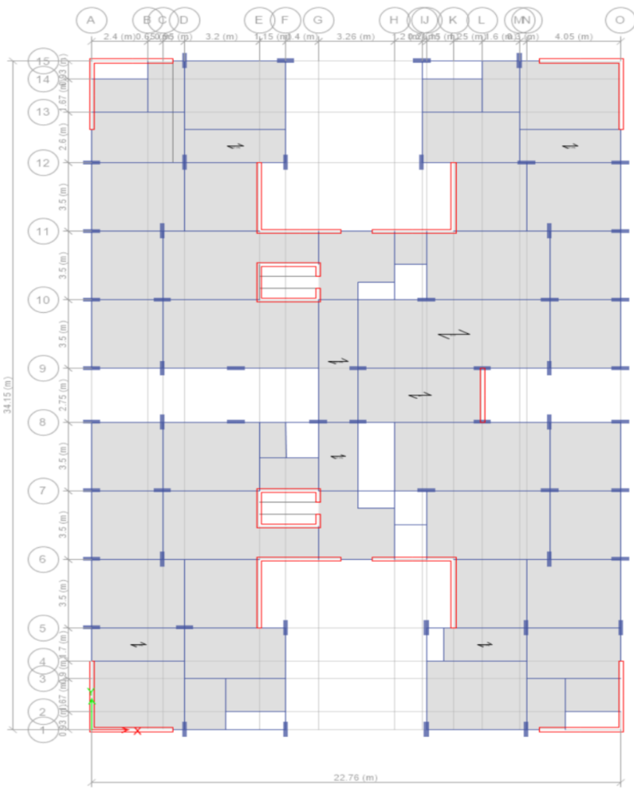

Fig.4. Plan view of model 4

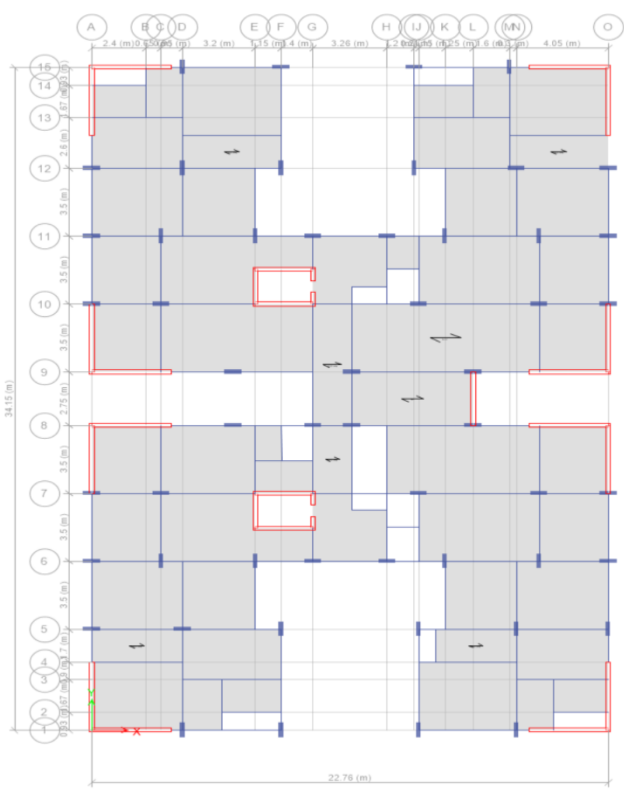

Fig.5. Plan view of model 5

V. Results and Discussions

Storey displacement, storey drifts, and torsional irregularity values are taken from the software. The comparison between the models with and without shear walls and core walls for the parameters mentioned above presented in tables and figures below.

A. Maximum storey displacements

The maximum lateral displacement values for all the models in zone IV for both equivalent static analysis and response spectrum analysis along X and Y direction tabulated in table III and graphical representation in Fig.6.

TABLE III
MAXIMUM DISPLACEMENT IN X AND Y DIRECTION

Model	ESA Ux	ESA Uy	Wx	Wy
1	125.22	175.34	24.04	20.283
2	89.37	141.08	15.865	13.36
3	30.88	38.85	4.775	4.775
4	30.55	46.59	4.757	4.006
5	40.00	50.48	6.766	5.698

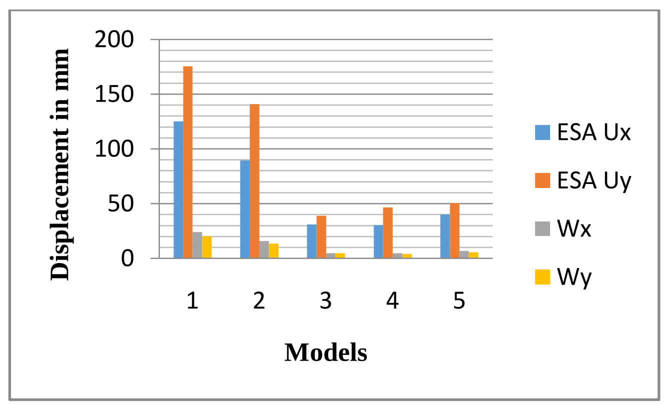

Fig.6. Maximum displacement in X and Y direction

From table III and Fig.6, it is observed that the lateral displacement is reduced to large extent for model 3 and model 4, while the displacement is maximum for model 1.

B. Maximum storey drifts

The maximum storey drift values for all the models in zone IV for both equivalent static analysis and response spectrum analysis along X and Y direction tabulated in table IV and graphical representation in Fig.7.

TABLE IV
MAXIMUM DRIFT RATIO IN X AND Y DIRECTION

Model	ESA DriftX	ESA DriftY	Wx DriftX	Wy DriftY
1	0.0045	0.0063	0.000814	0.000686
2	0.0033	0.0052	0.00059	0.000496
3	0.0011	0.0014	0.000173	0.000146
4	0.0011	0.0016	0.000172	0.000145
5	0.0015	0.0018	0.000243	0.000205

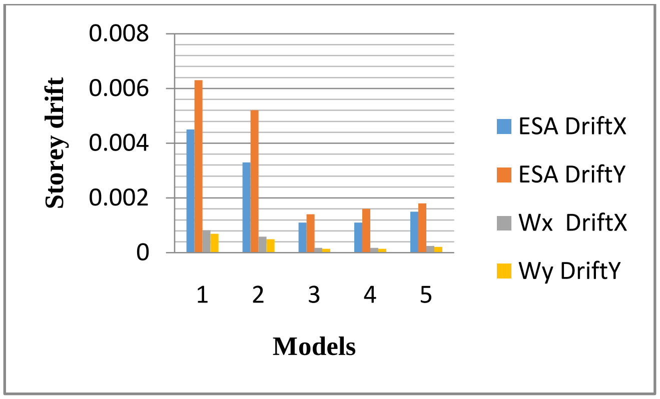

Fig. 7. Maximum storey drift ratios along X and Y direction

From table IV and Fig 7, it is observed that the storey drift reduced to large extent for model 3 and model 4, while the drift is maximum for model 1.

D. Torsional irregularity

The table and Fig below shows the time period for the different models.

TABLE VI

TORSIONAL IRREGULARITY OF ALL MODELS

Model	ESA X	ESA Y	WX	WY
1	1.226	1.072	1.083	1.083
2	1.014	1.22	1.03	1.03
3	1.009	1.021	1.003	1.003
4	1.006	1.001	1.001	1.001
5	1.008	1.006	1.0	1.0

Torsional irregularity should be considered when maximum story drift at one end of the structure transverse to an axis is more than 1.2 times the average of the story drift (or inter-story drifts) at the two ends of the structure. Table VI shows Torsional irregularity for different types of model. It is observed that the torsional irregularity of model 1 and model 2 has exceeded the specified limit for equivalent static analysis and for remaining models the torsional irregularity value has been reduced due to introduction of core walls and shear walls.

VI. CONCLUSIONS

- The displacement is more in model 1 compare to other models, the model 1 is building without shear wall and the other models are building with shear walls.
- Positions of shear walls in building influenced the displacement due to seismic actions.
- Keeping shear walls at proper places significantly minimize the displacement caused by earth quake and wind forces
- In this study it is found that model 3 building shows less displacement compare to other models for both earth quake and wind forces.
- The permissible limit of $\Delta Max / \Delta Avg < 1.2$ as per IS 1893(part-1):2002.
- Hence it can be said that the proper location of shear walls results in good, useful and efficient performance of building subjected to lateral forces i.e earth quake and wind load.

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BIOGRAPHIES

Dr. Rajeeva S V, presently working as an Engineering, SJBIT, Bengaluru. He has total teaching experience of 34 years. He obtained M. Tech from NITK, Surathkal and Ph.D. from IIT, Madras with a specialization in Structural Engineering. He has guided 48 M. Tech and 2 Ph.D. thesis. He is a member of ACCE, IIBE, ICI, IE, ISET, ISTE.

Mr. Adarsh A, PG Student, M. Tech, CADS, at SJB Institute of Technology, Bengaluru.