Torsional Behaviour of Asymmetrical Buildings

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Abstract: *Torsional behaviour of asymmetric building is one of the most frequent source of structural damage and failure during strong ground motions. In this work a study on the influence of the torsion effects on the behaviour of structure is done. In building two cases are considered, case one is without considering torsion and case two is considering torsion. The Indian standard code of practice IS-1893 (Part I: 2002) guidelines and methodology are used to analyzed and designed building. Results are compared in terms of % Ast in columns.*

Keywords: *Asymmetric plan, Earthquake, Eccentricity, Torsion.*

I. Introduction

Seismic damage surveys and analyses conducted on modes of failure of building structures during past severe earthquakes concluded that most vulnerable building structures are those, which are asymmetric in nature. Asymmetric-plan buildings, namely buildings with in-plan asymmetric mass and strength distributions, are systems characterized by a coupled torsional-translational seismic response. Asymmetric building structures are almost unavoidable in modern construction due to various types of functional and architectural requirements. Torsion in buildings during earthquake shaking may be caused from a variety of reasons, the most common of which are non-symmetric distributions of mass and stiffness. Modern codes deal with torsion by placing restrictions on the design of buildings with irregular layouts and also through the introduction of an accidental eccentricity that must be considered in design. The lateral-torsional coupling due to eccentricity between centre of mass (CM) and centre of rigidity (CR) in asymmetric building structures generates torsional vibration even under purely translational ground shaking. During seismic shaking of the structural systems, inertia force acts through the centre of mass while the resistive force acts through the centre of rigidity as shown in Fig. 1.

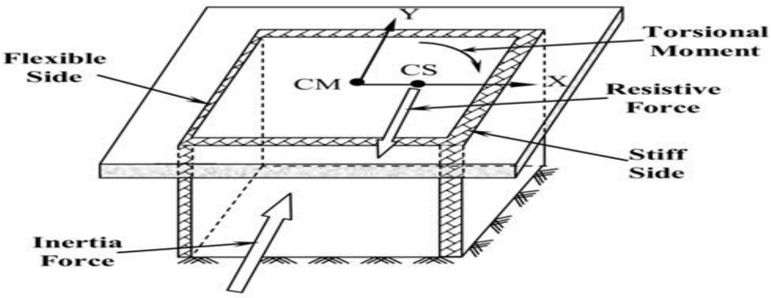


Fig1- Generation of torsional moment in asymmetric structures during seismic excitation.

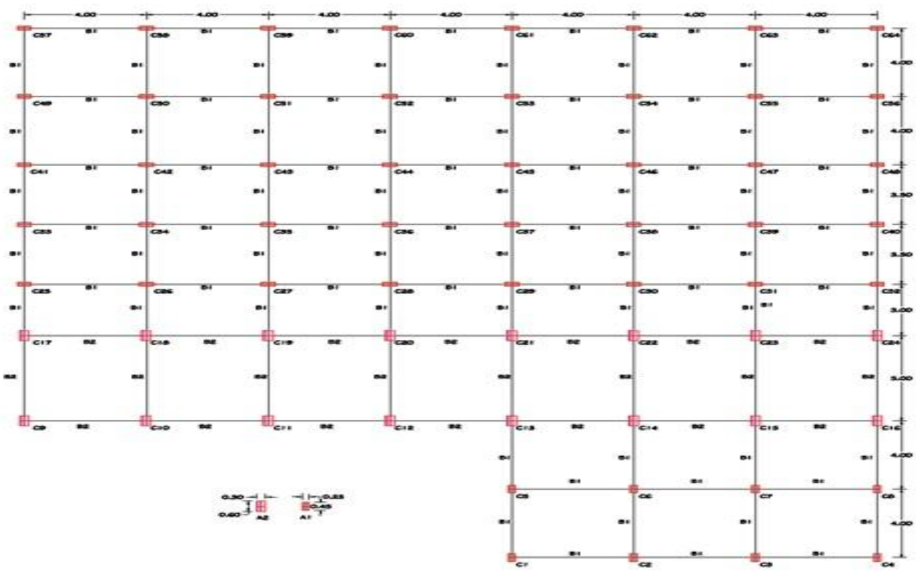


Fig 2- Building plan

II. Building Details

The structural analysis and design of four storey reinforced concrete asymmetrical frame building has been done with the help of Etab software. The building is assumed as commercial complex. Linear static analysis has been done. Regular grid plan of the structure is shown in fig 2. The structure is assumed to be located in seismic zone IV on a site with medium soil. Building contains different irregularity like plan irregularity and Re- Entrant corner irregularity. Building is studied for two cases as mentioned below:

Case 1: seismic analysis of building is done without considering design eccentricity.

Case 2: seismic analysis of building is done considering torsion. Centre of mass, Centre of rigidity, static eccentricity and design eccentricity is calculated for seismic forces at each floor level.

Structural data:

Table1: Structural data

No of storey	=	4
Ground storey height	=	3.5m
Intermediate storey height	=	3.2m
Total no of columns	=	64
Slab thickness	=	125mm
Outer wall	=	230mm
Inner wall	=	150mm
Parapet (1m height)	=	230mm
Beam size	=	B_1= 230 x 450 mm
	=	B_2= 300 x 600 mm
Column size	=	A_1 = 230 x 450 mm
	=	A_2= 300 x 600 mm
Grade of concrete	=	M_{20}
Grade of steel	=	Fe415
Density of concrete	=	25kN/m^3
Density of brick	=	20 kN /m^3
Live load	=	4 kN /m^2
Roof Live load	=	2 kN /m^2
Floor finish	=	1 kN /m^2

Earthquake data:

Seismic Zone	=	IV
Importance factor	=	1.5
Response reduction factor	=	5 (SMRF)
Type of soil	=	TYPE II (Medium)
Damping	=	5%

III. Analysis And Design

The asymmetric building is analysed by modelling two models

Case 1- asymmetric building without considering design eccentricity (edi)

Case 2- asymmetric building considering design eccentricity (edi)

Case 1 building is modelled in Etab; a rigid diaphragm is assigned at different storey level. Supports are assigned as fixed supports neglecting soil structure interaction. A linear static analysis was performed for two earthquake cases, earthquake in X-direction (Eqx) and in Y-direction (Eqy) by defining auto seismic lateral loading in Etab. Case 1 is design for 13 load combinations.

Case 2 building is same as case1, from output data from Etab the design eccentricity is calculated as the difference between centre of mass and centre of rigidity.

Table 2- Design eccentricity in X- direction

Story	XCCM	XCR	esi=XCR - XCCM	0.05 x bi	edi=1.5(esi) + 0.05(bi)	edi=(esi) - 0.05(bi)
STORY5	15.014	15.549	0.535	1.4	2.2025	-0.865
STORY 4	15.036	15.49	0.454	1.4	2.081	-0.946
STORY3	15.036	15.438	0.402	1.4	2.003	-0.998
STORY2	15.035	15.313	0.278	1.4	1.817	-1.122

Table3 - Design eccentricity in Y- direction

Story	YCCM	YCR	esi=YCR - YCCM	0.05 x bi	edi=1.5(esi) + 0.05(bi)	edi=(esi) - 0.05(bi)
STORY5	17.225	18.634	1.409	1.55	3.6635	-0.141
STORY 4	17.329	18.671	1.342	1.55	3.563	-0.208
STORY3	17.349	18.738	1.389	1.55	3.6335	-0.161
STORY2	17.357	18.893	1.536	1.55	3.854	-0.014

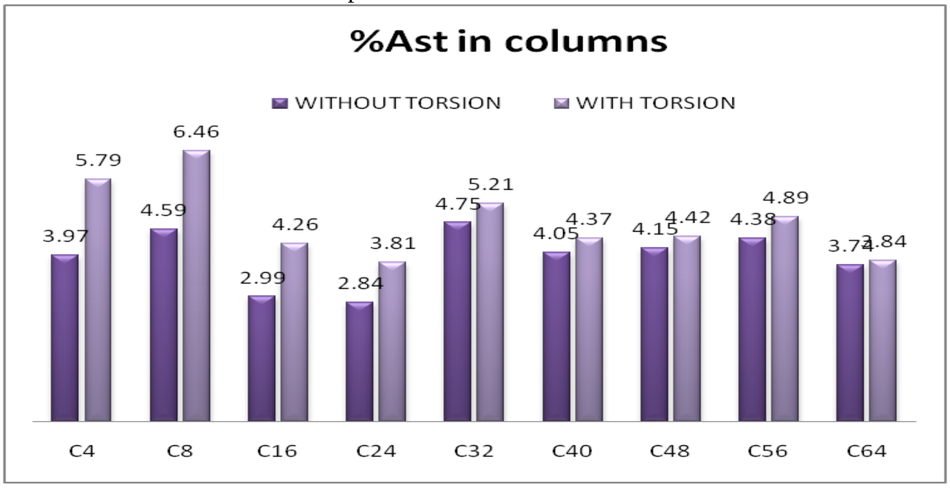
XCCM = Centre of mass in X -direction
YCCM = Centre of mass in Y -direction
XCR = Centre of rigidity in X -direction
YCR = Centre of rigidity in Y -direction
edi = Design eccentricity at ith floor
esi = Static eccentricity at ith floor
bi = Floor plan dimension of floor i^{th} perpendicular to the direction of force.

The value of design eccentricity is calculated from table 2 and 3 is assigned to auto seismic lateral loading cases by overriding diaphragm eccentricity.

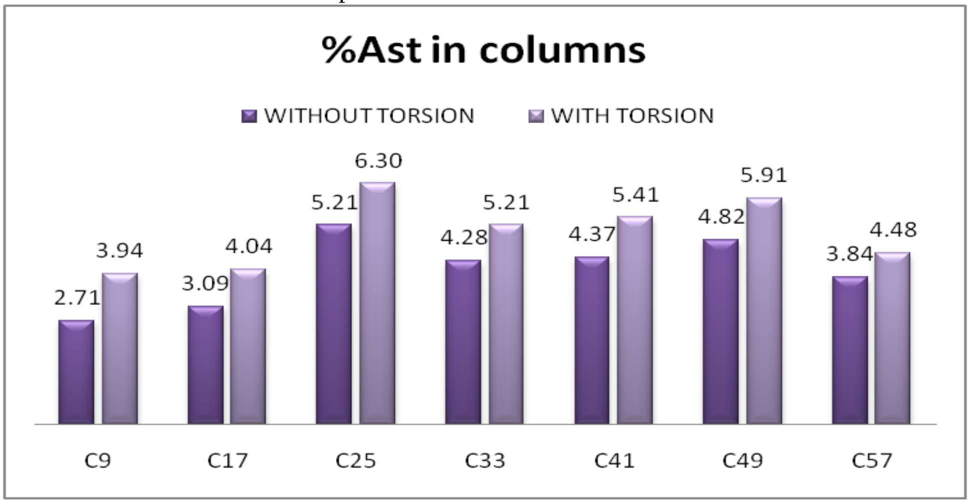
Earthquake cases
EXTP = Earthquake in X- direction torsion positive.
EXTN = Earthquake in X- direction torsion negative.
EYTP = Earthquake in Y- direction torsion positive.
EYTN = Earthquake in Y- direction torsion negative.
Case 2 building is design for 25 loading combination.

Results: Comparison of Ast for various columns.

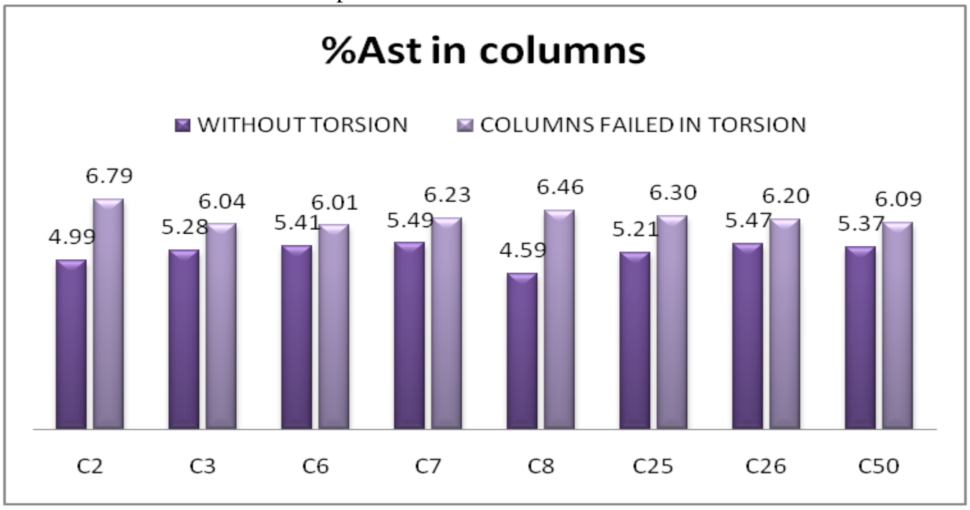
- Graph 1- % Ast in columns on stiff side



- Graph 2- % Ast in columns on flexible side



- Graph 3- % Ast in columns failed in torsion



IV. Conclusion

In the asymmetric building case 2, it was observed that the forces in the columns located in the stiff side of the plan are much smaller than those obtained in the elements of the flexible side of the plan. There is no significant change in column forces around centre of rigidity.

It is observed that column no C2, C3, C6, C7 and C8 in case 2(columns which are farthest from centre of rigidity) while designing it considering design eccentricity are failed. Column no C25, C26 and C50 (columns on flexible side) are failed in case 2. (Reinforcement required exceeds maximum allowed).

Most of the designer adopts approximate methods for the torsional analysis of building. However this may be an inaccurate assessment. Several studies of structural damage during the past earthquake reveal that torsion is the most critical factor leading to major damage or complete collapse of building. It is, therefore, necessary that irregular buildings should be analyzed for torsion. A three dimensional analysis using Etab is able to calculate the center of rigidity; by getting these values we can perform torsional analysis.

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