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EFFECT OF DIAPHRAGM DISCONTINUITY ON MULTISTORY BUILDING FOR IRREGULAR SHAPES USING ETABS-18

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Abstract: Earthquakes are natural hazards under which disasters are mainly caused by damage or collapse of buildings. In the present scenario, most of the buildings are designed and constructed on the basis of aesthetics which happens to ignore the basic principles of earthquake resistant structure, where we come across many buildings having irregular configurations both in elevation and plan. Openings in the floors are common for many reasons like staircases, lighting, architectural and etc. these openings develop stresses at discontinuities.

IS (1893-2016) Diaphragm discontinuity irregularity is defined to exist where there is a diaphragm with an abrupt discontinuity or variation in stiffness.

Index Terms **– Diaphragm, Diaphragm discontinuity, story shear, story drift, story displacement, stiffness, IS code**

Introduction

Diaphragm is the building element that transfers slab load to beams and columns which is Horizontal configuration to vertical elements

Diaphragm discontinuity is discontinuity in stiffness and mass in the form of slab and staircase opening, and Difference in slab like floor slab or staircase mid-landings

In this paper, E-tabs software is used to find effectiveness in structure for earthquake zonal area to find story drift, story displacement due to irregularities in building structure (L-Shaped, C-Shaped, Rectangular Shaped building Structures) with different openings as center, corner and periphery.

IS (1893-2016) is used to define the irregularities to exist where there is a diaphragm with an abrupt discontinuity or variation in stiffness, including one having a cut-out or open area greater than 50% of gross enclosed diaphragm area, or change in effective diaphragm stiffness of more than 50%

Relevance

Diaphragm discontinuity includes those having openings greater than 50% of the total diaphragm area or changes in the effective diaphragm stiffness of more than 50% from one story to the next story.

Popularity, Influence and Development

In existing building plan, there are many Similarities and dissimilarities in model analysis and it also reflects whether respective model analysis have considered or not considered the various criteria while assessment. The work focuses on the strategies best developed to evaluate the existing building plan and conduct Comparison to decide the best standards followed by the model calculation for three building plan with different diaphragm opening.

Comparison Criteria

1. To Compare Analysis for three Building plan with change in Diaphragm placing for every building by using E-TABS Software, the structural parameters like base shear, base moment and lateral displacement, Story Drift analysed critically.
2. To suggest Suitability of best Structure for Seismic region using various parameters

Methodology

The objectives of the study have been achieved through following steps:

1. Thorough literature study will be carried out to understand fundamentals,
2. Implementation, benefits and limitations of Diaphragm Discontinuity for Multistorey Buildings in Seismic Region
3. Study Diaphragm Discontinuity model using E-TAB, preparing building plan and dimensions using Auto-cad drawing, Modelling, Loads Considered (D.L And L.L) with details of seismic load, Load Combinations (IS-875 Part-V)

Story Drift

Drift is defined as a lateral displacement, story drift is a drift of a multistory building relative to the level below. Inter story drift is a difference between the roof and floor displacements of any given story as the building ways during the earthquake, normalized by the story height.

1.1 Experimental Details of Rectangular shaped (G+17) storey building

For the study purpose, an existing building plan in Hyderabad region was taken which is meant for residential purpose, even though this area is in zone II, it is taken as Zone III for study purpose.

1.1.1 Dimensional details of the rectangular shaped building

Plan dimension	16.65m*14.40m
Type of building	Ordinary moment resisting frame residential building
Number of Stories	18
Floor Height	2.87m
Grade of concrete	30MPa
Grade of steel	500MPa
Beam dimension	1. 230mm*700mm 1. 230mm*900mm 2. 2120mm*1200mm
Column dimension	1. 300mm*2120mm
Slab depth	150mm

1.1.2 Details of seismic load

Zone	III
Soil type	Medium (type 2)
Zone factor	0.16
Importance factor	1.5
Response reduction factor	5

1.1.3 Loads considered (as per IS:1893:2016)

Load	Value
DL	1KN/m²
LL	1 KN/m²

A) **Building (rectangular) Description**

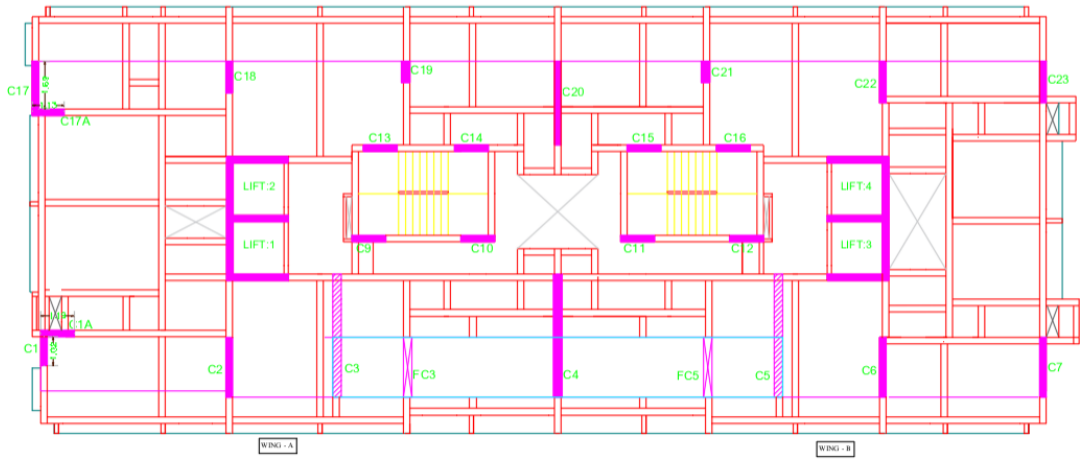


Figure I Building Geometrical Details

Modelling description

CASE I: FULLY COVERED SLAB

Story Response - Maximum Story Drifts:

PLOT REFER ABOVE FIGURE I

SUMMARY DESCRIPTION

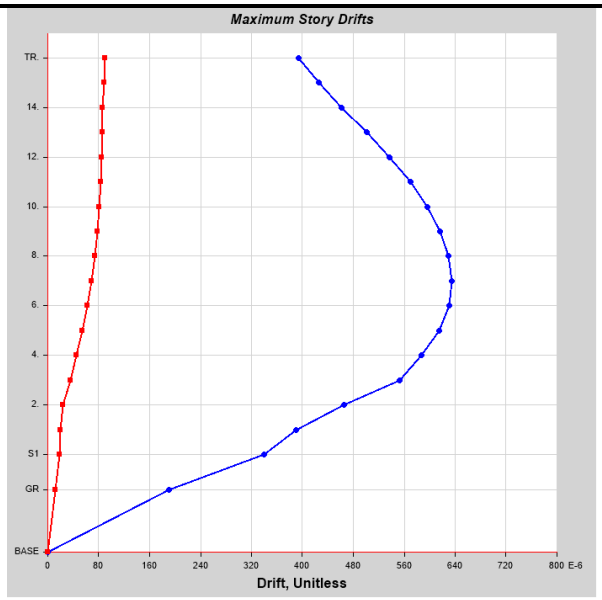
This is story response output for a specified range of stories and a selected load case or load combination.

INPUT DATA

Name	StoryResp2		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EQX	Top Story	TR.
Output Type	Not Applicable	Bottom Story	BASE

In the plot I, red line shows story drift values along Y-direction from base to terrace, which gives the value for drift less than that along X-direction, this is the seen values from plot I. The plot I along X-axis gives the value of maximum story drift of 0.000635 between story 6 and story 8 rectangular structure along X-axis

Now, We will see stability checks in this case I, drift ratio should be less than 0.004 along both the direction, hence it is passed



Plot I-Maximum Story Drift Fully Covered Rectangular Slab

Table I: Story Drift Values for Each Story Rectangular Shaped Building

Story	Elevation	Location	X-Dir	Y-Dir
	m			
TR.	57.2	Top	0.000394	0.00009
15.	54.33	Top	0.000426	0.000089
14.	51.46	Top	0.000462	0.000087
13.	48.59	Top	0.000501	0.000086
12.	45.72	Top	0.000537	0.000085
11.	42.85	Top	0.00057	0.000084
10.	39.98	Top	0.000596	0.000081
9.	37.11	Top	0.000617	0.000078
8.	34.24	Top	0.00063	0.000074
7.	31.37	Top	0.000635	0.000068
6.	28.5	Top	0.000631	0.000062
5.	25.63	Top	0.000616	0.000054
4.	22.76	Top	0.000587	0.000044
3.	19.89	Top	0.000553	0.000035
2.	17.02	Top	0.000465	0.000024
1.	14.15	Top	0.00039	0.000019
S1	11.25	Top	0.00034	0.000018
GR	7.2	Top	0.000191	0.000012
BASE	0	Top	0	0

CASE II: RECTANGULAR SLAB WITH CORNER OPEN

Story Response - Maximum Story Drifts:

PLOT REFER ABOVE FIGURE I

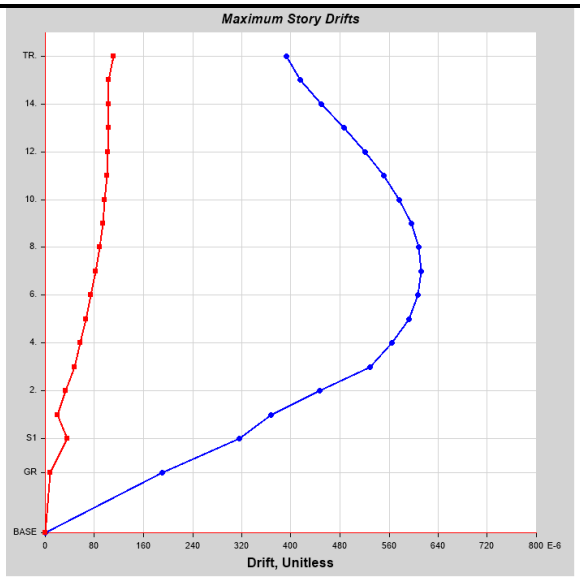
SUMMARY DESCRIPTION

This is story response output for a specified range of stories and a selected load case or load combination.

INPUT DATA

Name	StoryResp2		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EQX	Top Story	TR.
Output Type	Not Applicable	Bottom Story	BASE

The plot II gives the value of maximum story drift of 0.000612 between story 6 and story 8 which is less than for case I model I due to diaphragm opening of 7% than that of case I of model I, which is allowed rectangular structure along X-Direction.



Plot II: Story Drift for corner open (Rectangular shaped building)

Table II: Story Drift Value Rectangular with Corner Open

Story	Elevation	Location	X-Dir	Y-Dir
	M			
TR.	57.2	Top	0.000392	0.00011
15.	54.33	Top	0.000415	0.000104
14.	51.46	Top	0.000449	0.000103
13.	48.59	Top	0.000486	0.000103
12.	45.72	Top	0.000521	0.000102
11.	42.85	Top	0.000552	0.0001
10.	39.98	Top	0.000577	0.000097
9.	37.11	Top	0.000596	0.000093
8.	34.24	Top	0.000608	0.000088
7.	31.37	Top	0.000612	0.000082
6.	28.5	Top	0.000607	0.000075
5.	25.63	Top	0.000592	0.000066
4.	22.76	Top	0.000564	0.000057
3.	19.89	Top	0.000529	0.000047
2.	17.02	Top	0.000446	0.000033
1.	14.15	Top	0.000368	0.00002
S1	11.25	Top	0.000317	0.000036
GR	7.2	Top	0.000191	0.000007
BASE	0	Top	0	0

1.2 Experimental details of C-shaped building Description

1.2.1 Dimensional details of the C-shaped building

Plan dimension	19.91m*17.48m
Type of building	Ordinary moment resisting frame residential building
Number of Stories	G+20
Floor Height	2.8m
Grade of concrete	30MPa
Grade of steel	500MPa
Beam dimension	a. 230mm*700mm b. 230mm*900mm
Column dimension	2. 300mm*750mm
Slab depth	150mm

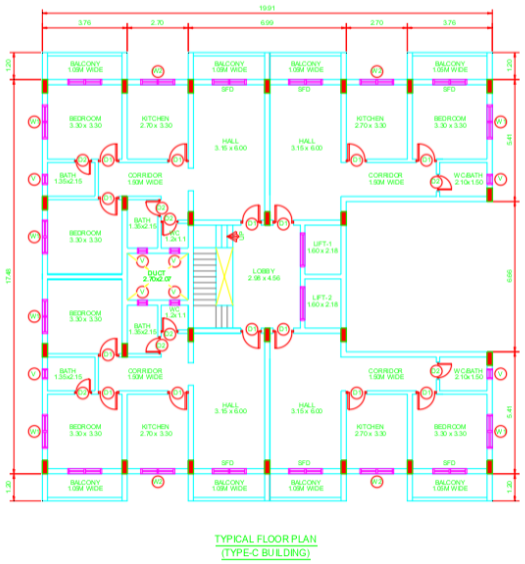


Figure II: Typical Floor Plan Type-C

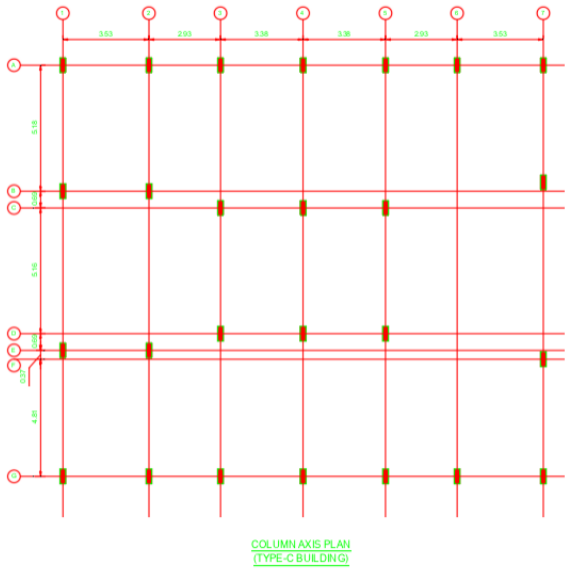


Figure III: Column Position for C-shaped Building

1.2.1 Modelling description:

CASE I: FULLY COVERED SLAB (C-SHAPED BUILDING)

Story Response - Maximum Story Drifts:

SUMMARY DESCRIPTION

PLOT REFER ABOVE FIGURE II

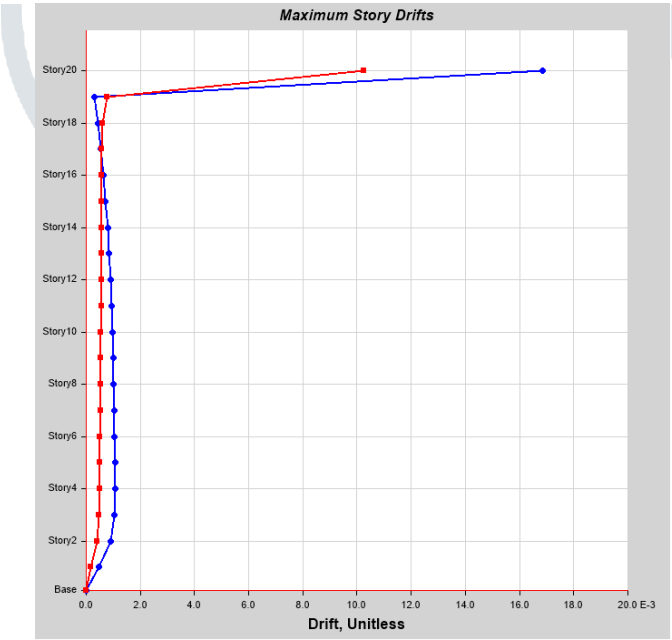
The plot III gives the value of maximum story drift of 0.01685 for story 20 due to staircase cabin, rectangular structure along X-axis and drift value is changing drastically from 0.000235 to maximum from story 18 to story 20

But if we check the value for drift between story 6 and story 8, the value for drift is 0.001034 along X direction and 0.000523 along Y direction. We will check the efficiency of this case I to case II for model 2 form plot IV

This is story response output for a specified range of stories and a selected load case or load combination.

INPUT DATA

Name	StoryResp3		
Display Type	Max story drifts	Story Range	All Stories
Load Case	Seismic	Top Story	Story20
Output Type	Step Number 1	Bottom Story	Base



PLOT III Story Drift C Shaped Residential Building

Table III: Story Drift Value Fully Covered Slab C Shaped Building

Story	Elevation	Location	X-Dir	Y-Dir
	M			
Story20	55.7	Top	0.016855	0.010243
Story19	52.9	Top	0.000298	0.000778
Story18	50.1	Top	0.000427	0.000599
Story17	47.3	Top	0.000539	0.000582
Story16	44.5	Top	0.000634	0.000568
Story15	41.7	Top	0.000718	0.000564
Story14	38.9	Top	0.000791	0.000564
Story13	36.1	Top	0.000853	0.000563
Story12	33.3	Top	0.000905	0.000561
Story11	30.5	Top	0.000946	0.000557
Story10	27.7	Top	0.000978	0.000551
Story9	24.9	Top	0.001001	0.00054
Story8	22.1	Top	0.001018	0.000529
Story7	19.3	Top	0.001034	0.000523
Story6	16.5	Top	0.001047	0.000516
Story5	13.7	Top	0.001057	0.000507
Story4	10.9	Top	0.001062	0.000493
Story3	8.1	Top	0.001044	0.000465
Story2	5.3	Top	0.00092	0.00039
Story1	2.5	Top	0.000459	0.000165
Base	0	Top	0	0

CASE-II: C SHAPED BUILDING WITH CORNER OPEN FOR C SHAPED BUILDING

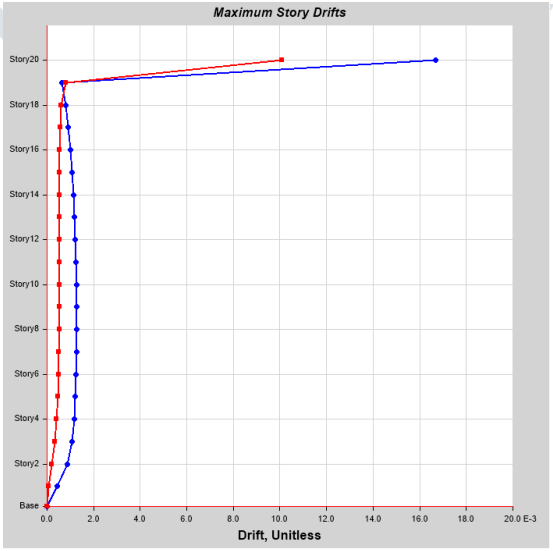
Story Response - Maximum Story Drifts:

SUMMARY DESCRIPTION

The plot IV gives the value of maximum story drift of 0.01669 for story 20 for C shaped Building structure along X-Direction. This plot IV gives the value of drift between 6 and story 8 is 0.001271 along X direction and 0.000514 which is less than above case I for model 2. this is due to variation of slab from 120mm to 150mm and diaphragm opening of 20% than case I for model 2

INPUT DATA

Name	StoryResp4		
Display Type	Max story drifts	Story Range	All Stories
Load Case	Seismic	Top Story	Story20
Output Type	Step Number 1	Bottom Story	Base



Plot IV Story Drift Open Corner C Shaped Building

Table IV: Story Drift Value Corner Open C Shaped Building

Story	Elevation	Location	X-Dir	Y-Dir
	m			
Story20	55.7	Top	0.016697	0.010076
Story19	52.9	Top	0.000639	0.000814
Story18	50.1	Top	0.000807	0.00061
Story17	47.3	Top	0.000904	0.000573
Story16	44.5	Top	0.000991	0.000553
Story15	41.7	Top	0.001065	0.000545
Story14	38.9	Top	0.001127	0.000546
Story13	36.1	Top	0.001179	0.000548
Story12	33.3	Top	0.001221	0.000548
Story11	30.5	Top	0.001252	0.000548
Story10	27.7	Top	0.001272	0.000545
Story9	24.9	Top	0.001282	0.000539
Story8	22.1	Top	0.001282	0.00053
Story7	19.3	Top	0.001271	0.000514
Story6	16.5	Top	0.001249	0.000491
Story5	13.7	Top	0.001212	0.000457
Story4	10.9	Top	0.001157	0.000402
Story3	8.1	Top	0.001066	0.00032
Story2	5.3	Top	0.00087	0.000203
Story1	2.5	Top	0.000443	0.00008
Base	0	Top	0	0

1.3 Experimental details of L-shaped building Description

1.3.1 Dimensional details of the L-shaped building:

Plan dimension	19.91m*17.48m
Type of building	Ordinary moment resisting frame residential building
Number of Stories	G+20
Floor Height	2.8m
Grade of concrete	30MPa
Grade of steel	500MPa
Beam dimension	1. 230mm*700mm 2 230mm*900mm
Column dimension	300mm*750mm 300mm*450mm
Slab depth	a. 150mm b. 120mm

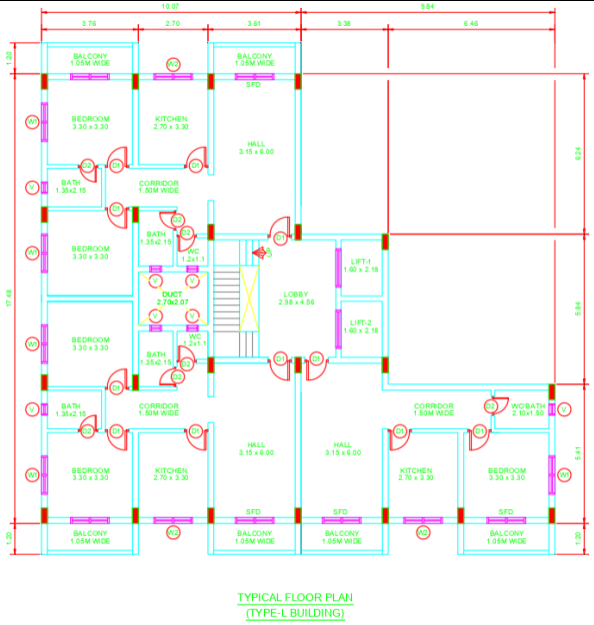


Figure IV: Typical floor plan for L-shaped building

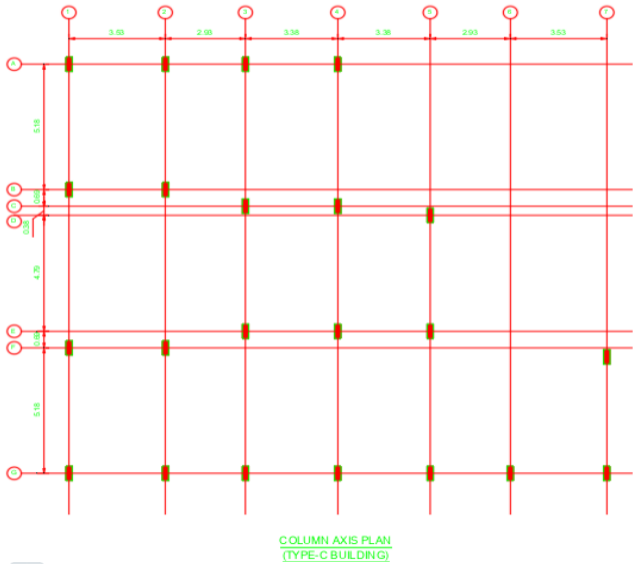


Figure V: Column position for L-shaped Building

1.3.2 Modelling description:

CASE I: FULLY COVERED SLAB (L-SHAPED BUILDING)

Story Response - Maximum Story Drifts:

SUMMARY DESCRIPTION REFER FIGURE III

The plot V gives the value of maximum story drift of 0.001916 between story 8 and story 10 for L shaped Building structure along X-Direction. The value for drift between story 6 and story 8 is 0.001897 and 0.000419 along X and Y direction respectively.

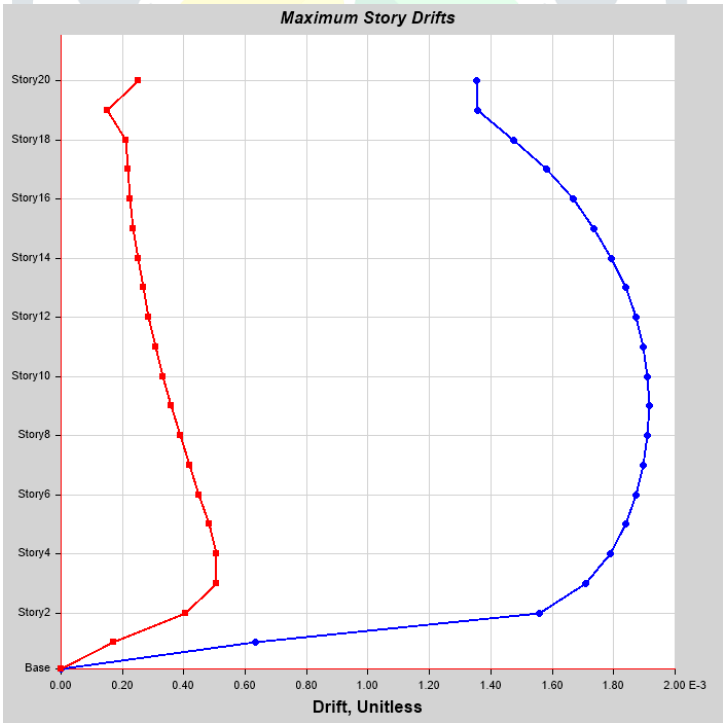
We will check the response of model 3 for case II for diaphragm opening of 24%.

This is story response output for a specified range of stories and a selected load case or load combination.

INPUT DATA

Name	StoryResp5		
Display Type	Max story drifts	Story Range	All Stories
Load Case	seismic1	Top Story	Story20
Output Type	Step Number 1	Bottom Story	Base

PLOT



Plot V: Story Drift for L Shaped Building

Table V: Story Drift Value for L-Shaped Building

Story	Elevation	Location	X-Dir	Y-Dir
	M			
Story20	55.7	Top	0.001354	0.000251
Story19	52.9	Top	0.001358	0.00015
Story18	50.1	Top	0.001474	0.000211
Story17	47.3	Top	0.001583	0.000218
Story16	44.5	Top	0.001668	0.000225
Story15	41.7	Top	0.001736	0.000236
Story14	38.9	Top	0.001793	0.00025
Story13	36.1	Top	0.001838	0.000267
Story12	33.3	Top	0.001873	0.000286
Story11	30.5	Top	0.001897	0.000307
Story10	27.7	Top	0.001911	0.000332
Story9	24.9	Top	0.001916	0.000359
Story8	22.1	Top	0.001911	0.000388
Story7	19.3	Top	0.001897	0.000419
Story6	16.5	Top	0.001874	0.00045
Story5	13.7	Top	0.001841	0.000481
Story4	10.9	Top	0.00179	0.000507
Story3	8.1	Top	0.001709	0.000505
Story2	5.3	Top	0.001559	0.000405
Story1	2.5	Top	0.000634	0.000172
Base	0	Top	0	0

CASE-II: L SHAPED BUILDING WITH CORNER OPEN

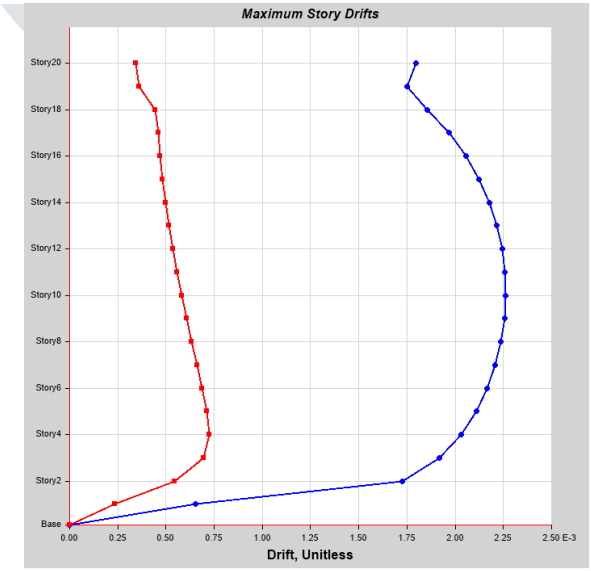
Story Response - Maximum Story Drifts:

SUMMARY DESCRIPTION

The plot IV gives the value of maximum story drift of 0.000001 for story 6 for L shaped Building structure along X-direction. The value between story 6 and story 8 is 0.002206 along X direction and 0.00066 along Y direction which is more than that for case I for model 3. Therefore the case I for model 3 is more preferable than case II.

INPUT DATA

Name	StoryResp6		
Display Type	Max story drifts	Story Range	All Stories
Load Case	seismic1	Top Story	Story20
Output Type	Step Number 1	Bottom Story	Base



Plot VI: Story Drift for L Shaped open corner structure

Table VI: Story Drift Value for L-Shaped corner open Building structure

Story	Elevation	Location	X-Dir	Y-Dir
	m			
Story20	55.7	Top	0.001795	0.000344
Story19	52.9	Top	0.001752	0.000358
Story18	50.1	Top	0.001853	0.000443
Story17	47.3	Top	0.001967	0.000459
Story16	44.5	Top	0.002055	0.000468
Story15	41.7	Top	0.002123	0.000481
Story14	38.9	Top	0.002176	0.000497
Story13	36.1	Top	0.002216	0.000515
Story12	33.3	Top	0.002243	0.000535
Story11	30.5	Top	0.002259	0.000557
Story10	27.7	Top	0.002263	0.00058
Story9	24.9	Top	0.002255	0.000606
Story8	22.1	Top	0.002236	0.000633
Story7	19.3	Top	0.002206	0.00066
Story6	16.5	Top	0.002165	0.000687
Story5	13.7	Top	0.002109	0.000712
Story4	10.9	Top	0.00203	0.000725
Story3	8.1	Top	0.001917	0.000696
Story2	5.3	Top	0.001727	0.000546
Story1	2.5	Top	0.000651	0.000233
Base	0	Top	0	0

Comparison for result (Graphical representation)

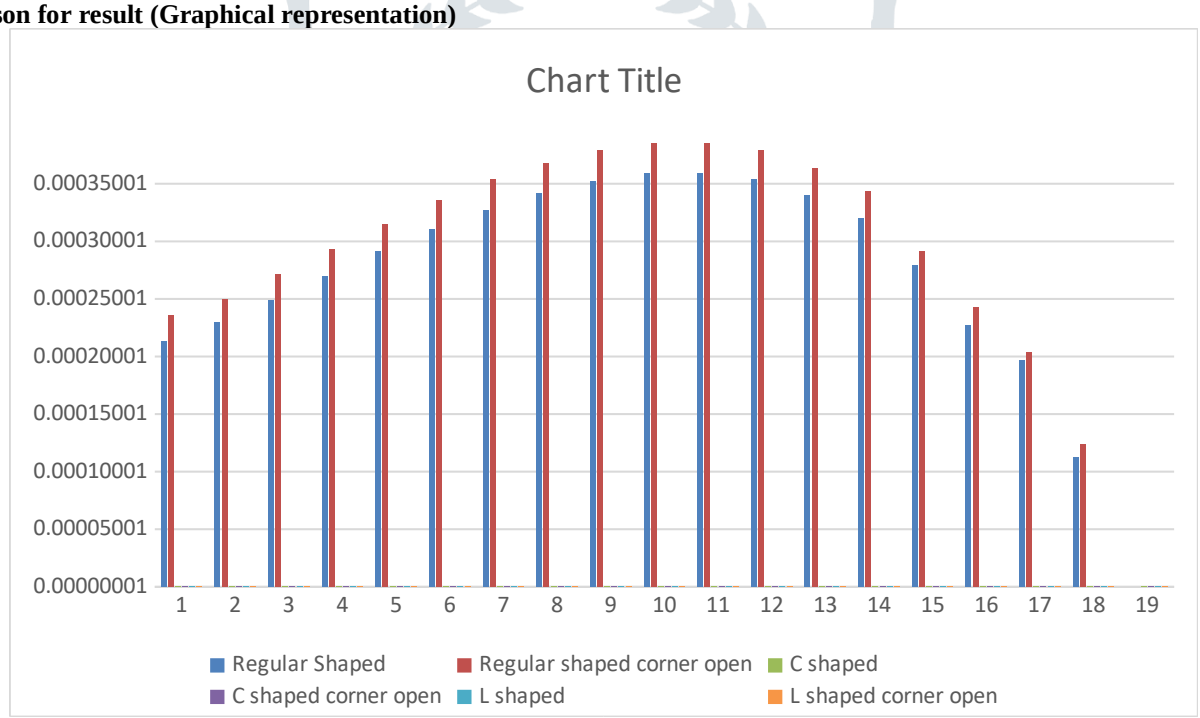


Chart I Graphical representation of maximum drift value for rectangular shaped building for modal load combination

We have check drift ratio, it should be less than 0.004 in EX and EY

From the case result, Model 1(Rectangular shaped building structure) have maximum drift value at story 6 of 0.000359 which is less than for model 2(Rectangular shaped which is open at corner) as the above ratio is checked both these cases are efficient, hence it is safe.

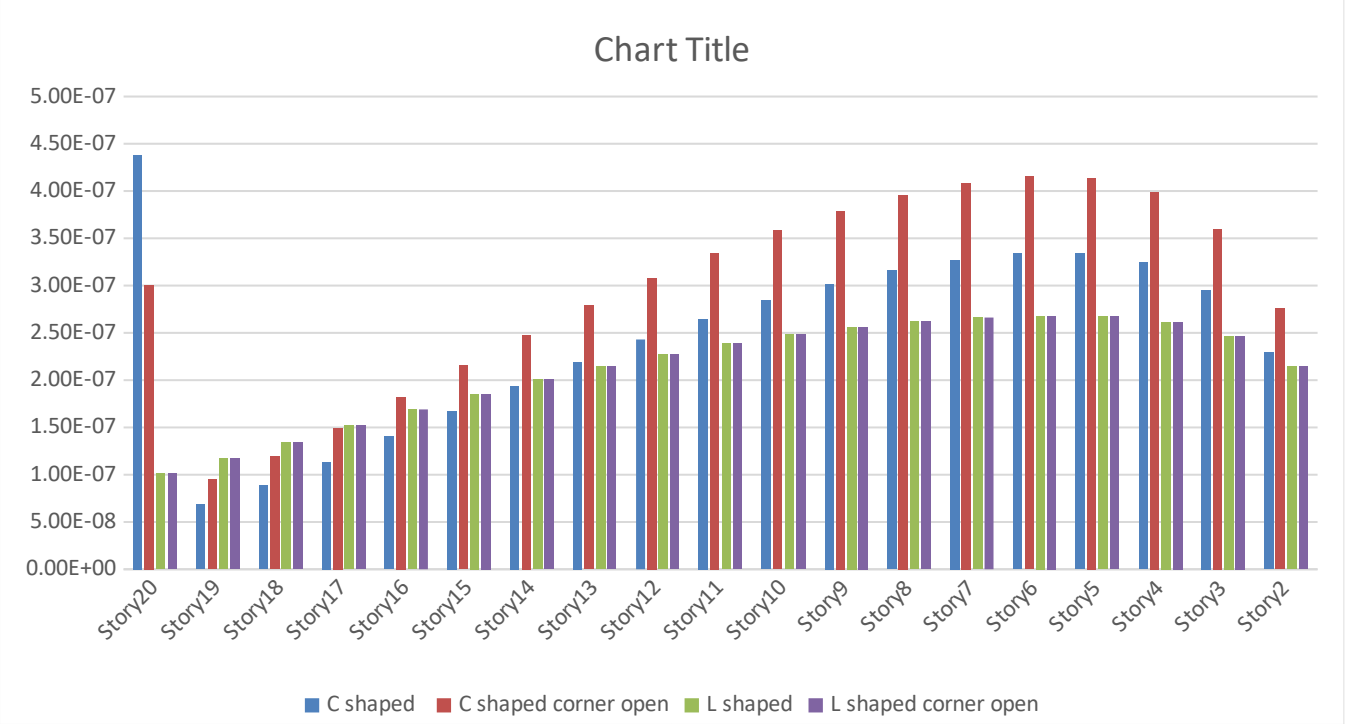


Chart II Graphical representation of maximum drift for L & C shaped building for modal load combination

We have check drift ratio, it should be less than 0.004 in Ex and Ey in our model

From the case result, Model 3(C shaped building Structure) have maximum drift value at story 6 of 0.000001 which is less than for model 4(C shaped open at corner structure) as we have provided staircase room, the Value of drift from floor 19 to floor 20 suddenly changes from 8.875E-08 to 4.381E-07 as the above ratio is checked both this cases are efficient, hence it is safe.

Similarly, Model 5 (L shaped building Structure) have maximum drift value at story 6 of 0.000001 which is safe.

Conclusion:

a. In Rectangular building structure, column C4 & C20 are taken as 300mm*2120mm, other column like C9,C10 and C13,C14 are taken as 300mm*750mm, due to these maximum story displacement is 27.028mm

b. I would be much more concerned about the design of the building and how well the builders did their job rather than the shape of the building. However, if I were force to choose a structure BY SHAPE ALONE in which to be for earthquake I would choose a short, wide building rather than a tall, thin building. Not only is there less chance of collapse in a short, wide building but even if it did collapse there is less to fall on me. As my study purpose is find structure efficient at earthquake zones with better results

c. In this paper, we have modelled building with regular (rectangular) shaped and Irregular (L & C) shaped building to find its efficiency at earthquake zones (III), In case of eccentric model 1 with has 7% opening in case II, model 2 has 20% opening in case II, model 3 has 27% opening in case II. In this case, increase in percentage of diaphragm opening reduces the displacement and drift.

d. Drift values for model 1 are more as we have taken limited column than that of (L & C) shaped building to make this irregular shape effective at seismic area. In model 3,4,5,6, Column taken are 300m*750mm, and checked for drift value which is less than that for model 1 & model 2 as mention above.

e. It is concluded that with irregularities in shape of building with effective column dimension can give better result at seismic area, as we have already calculated story drift which is less for model 3 case II than that for Model 2, for modal load combination.

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