SEISMIC ANALYSIS OF MULTISTORIED BUILDING HAVING DIAPHRAGM DISCONTINUITIES AND RE-ENTRANT CORNERS USING ETABS

(Earthquake Analysis)

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***Abstract*— The main reason for structural failure during an earthquake is irregularity. Currently, many buildings have irregular configurations in terms of both height and floor plan. These buildings may collapse due to devastating earthquakes in the future. The seismic behavior of structures is reduced due to structural irregularities. Earthquake damages usually occurs at weakened locations in multi-story frame buildings. Buildings with openings in slabs and changes in slab thickness are subject to damage due to the action of lateral loads. In every building structures , floor and roof system together serve as a horizontal diaphragm. They collect and transfer inertial forces to vertical elements of lateral load-resistant systems, i.e. columns and structural walls. These diaphragms also make sure that the vertical components act together under gravitational and earthquake loads. Diaphragm openings are intended for staircases, lighting, architectural elements, or manholes. While changes in slab thickness are caused by applied load, number of floors, type of support, quality of concrete, or span length. This work provides holes in the slabs at different locations such as the center, corners, and perimeter with square-shaped columned buildings. Three cases are randomly selected when analyzing the effect of slab thickness. They are the L-shaped variation, the same variation, and the outer thick inner thin variation. In addition to the discontinuity effect of re-entrant corners, it is also studied. The corners of the return inlet are provided with diaphragm openings. Shear walls will also become part of the entering corners to reduce the combined effect of entering corners and discontinuities. And all the parameters of the irregular building are compared with the regular building. Response spectrum analysis in ETABS software determines the seismic performance of multi-story buildings. This study attempts to determine the difference between a building with and without diaphragm discontinuities and also the effect when re-entrant corners are formed in the same building. The investigated parameters are storey drift and base shear.**

Keywords—Irregularity, Diaphragm ,Diaphragm discontinuities, story drift, Response spectrum analysis, ETAB, Re-entrant corners.

I. INTRODUCTION

The diaphragm is a structural element that transfers the lateral loads to the vertical resistance members of the structure. If excessive openings are provided in a diaphragm, it leads to a flexible response of the diaphragm along with the concentration of forces and this causes load path deficiencies at the borders of the openings. In the floor plan, openings in the diaphragms can significantly reduced the capacity of the plates. Discontinuities in diaphragm are caused by openings at various locations, cut-outs, adjacent floors at different levels, or changes in diaphragm thickness. The diaphragm of a structure often serves a dual function as a floor or roof system in a building or bridge deck that simultaneously carries seismic loads. Generally diaphragms are constructed by using plywood or composite metal plates. Openings for floor diaphragms are intended for staircases, shafts, or other architectural elements. The change in slab thickness is caused by the applied load, the number of floors, the type of support, the quality of the concrete, or the length of the span. Gravitational and earthquake loads moves in a continuous and smooth path through the horizontal and vertical elements of the structures and are transferred directly to the ground. In the plan, the holes in the diaphragms weaken the capacity of the plate. Discontinuities are present in both the plan and elevation of the structure. In this work, the effect of diaphragm discontinuities, re-entrant corners and the seismic behavior of buildings isprocessed. Response spectrum analysis in Etabs is used to find out the effect of diaphragm with and without diaphragm discontinuities and re-entrant corners.

In civil engineering, a diaphragm is a structural element used to transfer lateral loads to shear walls or frames. Wind and earthquake loads are usually considered as lateral loads. The two primary types of diaphragms are rigid and flexible. Flexible diaphragms resist lateral forces, and it is depend up on the area, regardless of the flexibility of the elements to which they transfer the forces. Rigid diaphragms transfer loads to frames or shear walls depending on their flexibility and location in the structure.The flexibility of the diaphragm affects the distribution of lateral forces on the vertical components of the transverse force elements in the structure.Re-entrant corners are defined as any inside corner that forms an angle of 180 degree or less. Diaphragm openings along with re-entrant corners will affect the structure severely during earthquake. The effect of re- entrant corners can be overcome by using shear walls. Shear wall is one of lateral resisting structure which is used commonly. Shear walls give high stiffness to the structure so that the structure become more stable. Applying shear walls helps to reduce the base shear and story-drift of the structure effectively . Response spectrum analysis in Etabs is used to find the effect of buildings with diaphragm discontinuities and re-entrant corners.

II. OBJECTIVES

- To model and analyze the seismic performance of a multi-storied building having diaphragm discontinuity using Response spectrum analysis in ETABS.
- To study the seismic behaviour of a 20 storied building with different slab openings.
- To obtain the suitable location for the openings & to analyse the effect of the size of openings in the slab.
- To study the effect of variation of slab thickness on the performance of the same building.
- Find out the location of re-entrant corners in the same building.
- Analyse the effect of building with re-entrant corners and diaphragm discontinuities.
- Also analyse the effect of shear walls in the case of re-entrant corners.
- To obtain parameters such as base shear,and story drift and compare them with the regular model.

III. SCOPE OF THE STUDY

- In this study, a multi-storied building is analyzed using ETABS of Response spectrum analysis.
- This study is done for 1-5% of slab openings.
- This study is done of columns having a rectangular shape.
- Variation of slab thickness is studied by using 3 different cases.
- All the analysis are carried out in a structure with and without diaphragm discontinuities and the results obtained are compared.
- This study is done of RC framed multi-storied building with fixed support condition.
- For further studies re-entrant corners are also included, then the effect of the provision of shear walls is also included.
- Seismic analysis of the building is done considering both diaphragm discontinuities and re-entrant corners.

IV. METHODOLOGY

A. Modelling of the 20 storied building

Regular building configuration is used in this work. This study is done of a G+19 Storied Building, having a floor height of 3m. 7 models of buildings are prepared with and without diaphragm discontinuity. 3 models in which slab openings are provided at different locations like center, corner and periphery with rectangular column geometry. 1%,2%, 3%.,4% and 5% openings are provided on floor area. The other 3 models show the variation in slab thickness. Variation of slab thickness 1) L-shaped variation 2) Equal variation 3) Outer thick and inner thin. Excluding the regular model and models having variation in slab thickness , the remaining 3 models are analyzed by considering re-entrant corners. Shear walls are then provided with re-entrant corners.

The effect of both irregularities during an earthquake are studied . Dead load of the building is considered as per IS 875 Part 1 and the live load is considered as per IS 875 Part II, lateral load confirming IS 1893:2016.

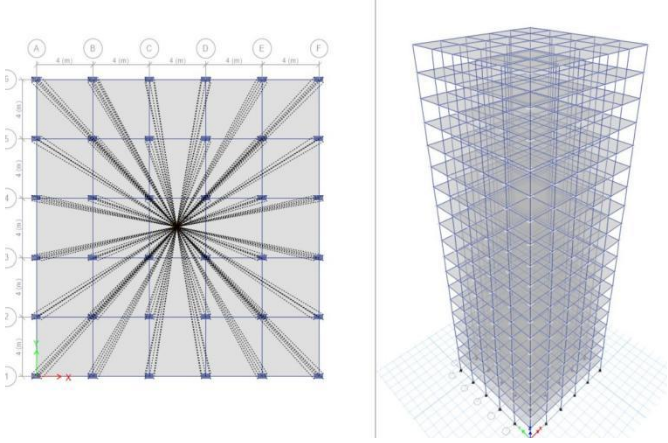

Fig 1: Diaphragm of regular building

B. Building plan and dimensions

An ordinary building having 20 stories is considered for the analysis. The dimensional details of the building model is given in Table below,

Table 1: Dimensions and details of the building

Plan dimension	20m*20m
Type of building	Ordinary moment resistant frame
Number of stories	20
Total Floor height	3m
Grade of concrete	30Mpa
Grade of steel	Fe 500
Beam dimension	450mm*850mm
Column dimension	350mm*650mm
Slab depth	150mm

C. Loads that are considered

Table 2: Load details

Load	Value
Dead load	1.5kN/m2
Live load	2kN/m2
SIDL	12kN/m2

Table 3: Details of seismic load

Zone	V
Soil type	Type II
Zone factor	.36
Importance factor,I	1.5
Response reduction factor	3

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D. Load combinations as per IS code

1. DL
2. DL+LL
3. 1.5(DL + LL)
4. 1.2(DL + LL + EQX)
5. 1.2(DL + LL + EQY)
6. 1.2(DL + LL - EQX)
7. 1.2(DL + LL - EQY)
8. 1.5(DL + EQX)
9. 1.5(DL + EQY)
10. 1.5(DL - EQX)
11. 1.5(DL - EQY)
12. .9DL + 1.5EQX
13. .9DL + 1.5EQY
14. .9DL - 1.5EQX
15. .9DL - 1.5EQY

V. MODELLING

At first 3D model of regular building is developed using ETABS. From the model diaphragm of the building is also developed. Total of 7 models are prepared. One regular building model, building with diaphragm having opening at centre,corners and periphery & slab having variation in thickness such as L shaped variation, equal variation and outer thick inner thin variation.

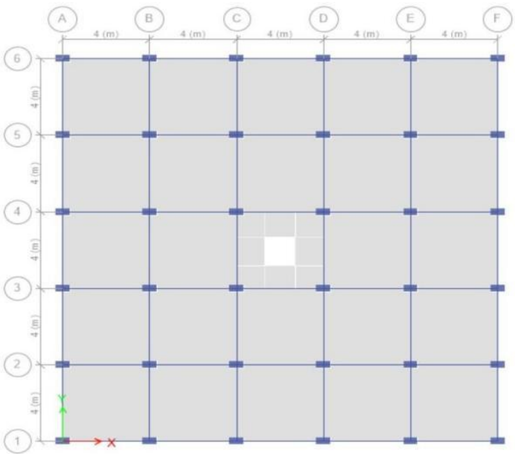


Fig 2: Plan of slab having opening at Centre

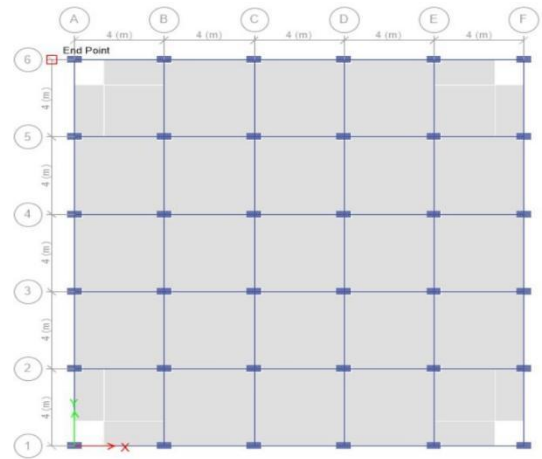


Fig 3: plan of slab having opening at corner

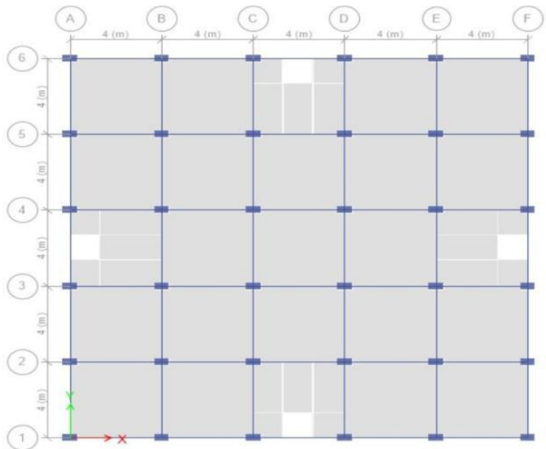


Fig 4: Plan of slab having opening at periphery

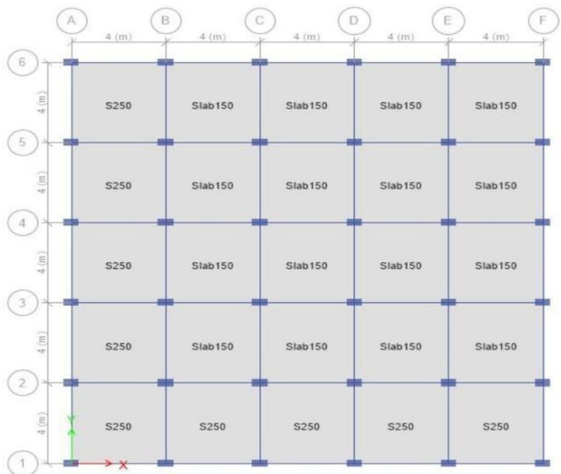


Fig 5: Plan of slab having L shaped variation in thickness

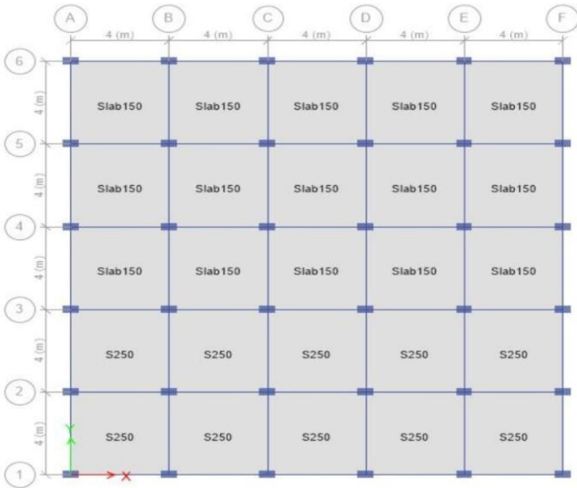


Fig 6: plan of slab having equal variation in thickness

Fig 7: Plan of slab having outer thick inner thin variation in thickness

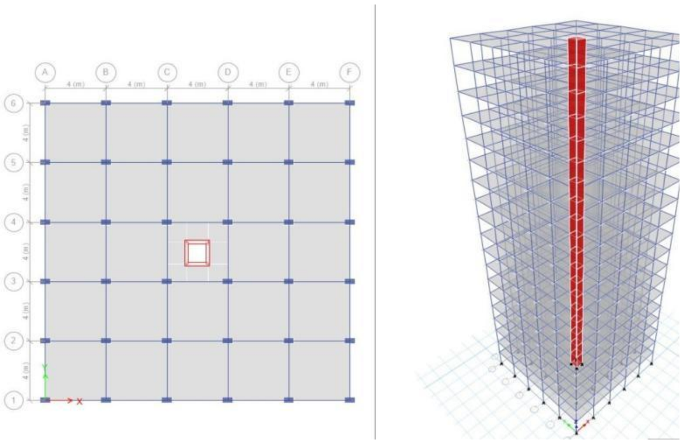


Fig 8: Diaphragm having opening at the centre with re-entrant corners having shear walls

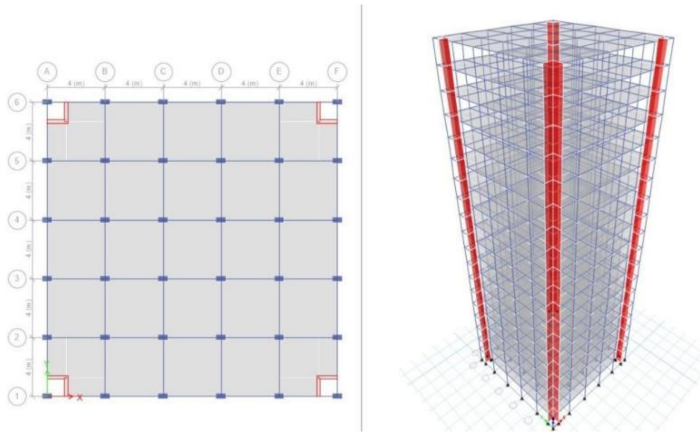


Fig 9: Diaphragm having openings at the corners with re-entrant corners having shear walls

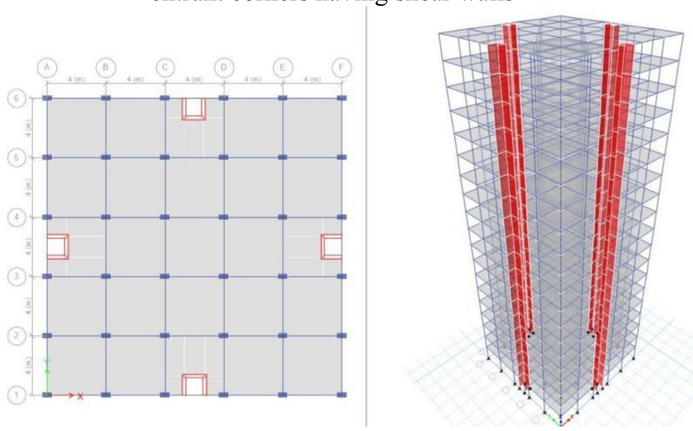


Fig 10:Diaphragm having openings at the periphery with re-entrant corners having shear walls

VI. ANALYZING RESULTS

Table 4: Base shear of the building with different slab openings

Openings	Center	Corner	Periphery	Regular
0%	-	-	-	2215
1%	3272.2	6133	7963.56	-
2%	6558.92	6628.96	8135.12	-
3%	6681.76	6930.98	8977.82	-
4%	7441.68	7892	9152.64	-
5%	7946.12	9218.16	9466.88	-

Table 5: Storey Drift of the building with different slab openings

Openings	Center	Corner	Periphery	Regular
0%	_	_	_	0.00079
1%	0.00087	0.00186	0.00243	_
2%	0.00176	0.002010	0.00250	_
3%	0.001766	0.001976	0.00233	_
4%	0.00457	0.00480	0.00494	_
5%	0.004574	0.00480	0.00494	_

Table 6: Base shear of various slab thickness in both X&Y direction

	X-direction	Y-direction
L-shaped variation	17500	17500
Equal variation	21500	20500
Outer thick inner thin	19500	20500

Table 7: Storey drift of various slab thickness in both X&Y direction

	X-direction	Y-direction
L-shaped variation	0.0012	0.0012
Equal variation	0.0014	0.0014
Outer thick inner thin	0.0012	0.0012

Table 8: Base shear of the building with re-entrant corners

Openings	Center	Corner	Periphery	Regular
0%	-	-	-	2215
1%	6869	7568	9530	-
2%	8895	9638	10483	-
3%	9524	10240	11425	-
4%	11242	11584	12830	-
5%	12435	13958	14285	-

Table 9: Storey Drift of the building with re-entrant corners

Openings	Centre	Corner	Periphery	Regular
0%	_	_	_	0.00079
1%	1.2598	1.3584	1.9523	_
2%	1.8542	1.8659	2.3256	_
3%	1.9896	1.9942	2.5465	_
4%	2.1532	2.2586	2.6894	_
5%	2.3256	2.4586	2.7554	_

Table 10: Base shear of the building with re-entrant corners having shear walls

Openings	Centre	Corner	Periphery	Regular
0%	-	-	-	2215
1%	3212.2	6055	7654	_
2%	6512.85	6421	8024	_
3%	6542.32	6850	8616	_
4%	7201	7450	8954	_
5%	7545.12	8853	9025	_

Table 11: Storey Drift of the building with re-entrant corners having shear walls

Opening	Centre	Corner	Periphery	Regular
0%	_	_	_	0.00079
1%	0.00083	0.00180	0.00240	_
2%	0.00173	0.002004	0.00242	_
3%	0.001764	0.001970	0.00260	_
4%	0.00451	0.00472	0.00485	_
5%	0.004565	0.00472	0.00485	_

VII. COMPARISON OF RESULTS

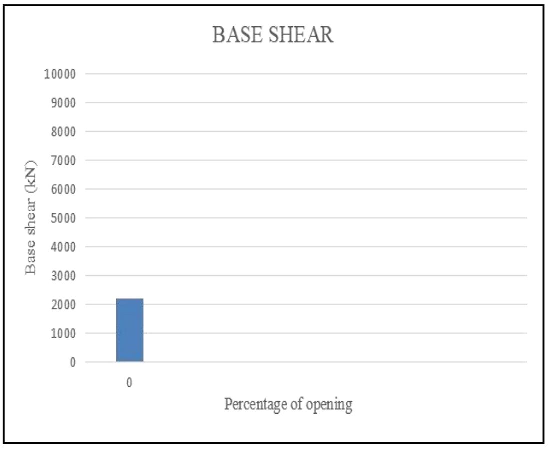


Fig 11: Regular Building

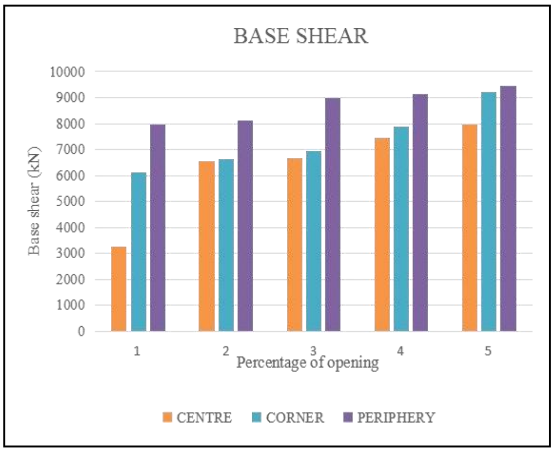


Fig 12: Diaphragm having opening at centre, corner and periphery

Diaphragm having centre opening is more stable than corner and peripheral openings. The value of base shear is less for centre opening. And it increases with increase in the percentage of opening. Regular building have least value of base shear.

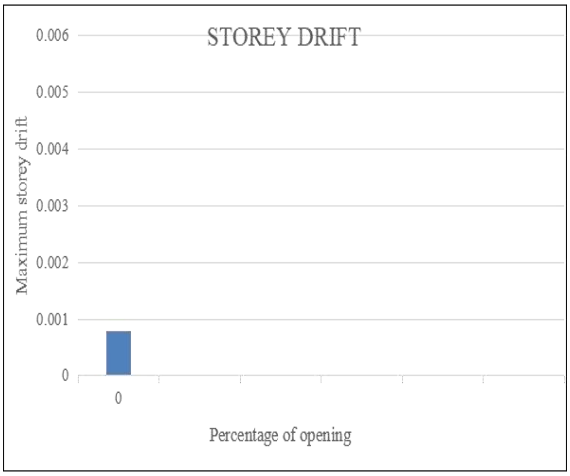


Fig 13: Regular Building

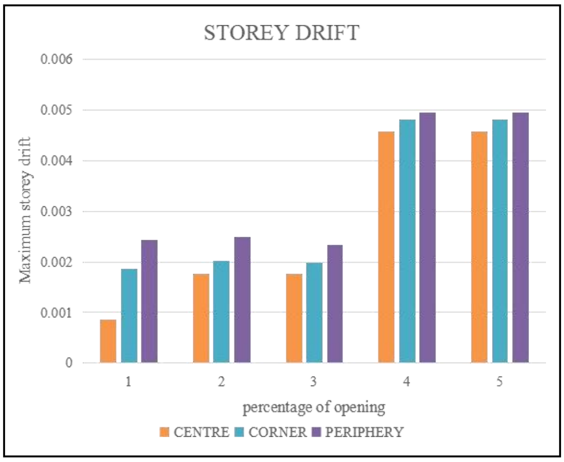


Fig 14: Diaphragm having opening at centre,corner & periphery

Diaphragm having centre opening is more stable than corner and peripheral openings. The value of storey drift is less for centre opening. And it increases with increase in the percentage of opening. Regular building have least value of storey drift.

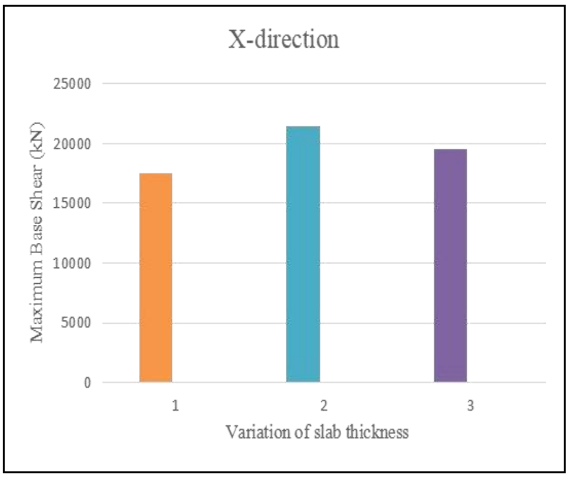


Fig 15: Base shear of slab in X-direction

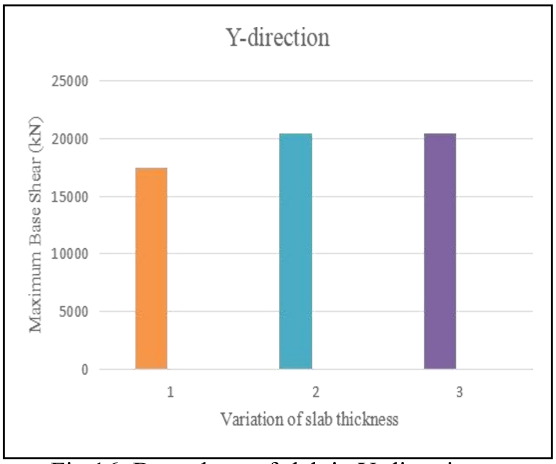


Fig 16: Base shear of slab in Y-direction

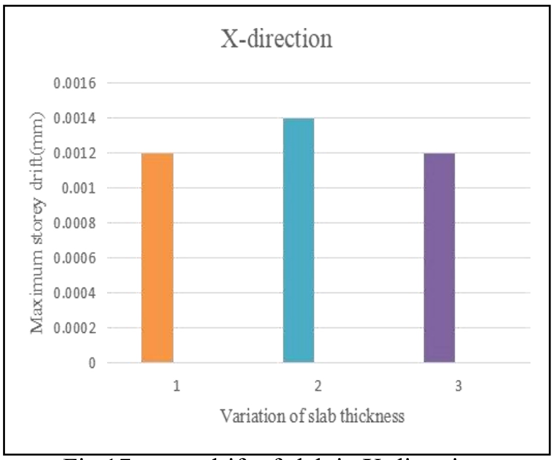


Fig 17: story drift of slab in X-direction

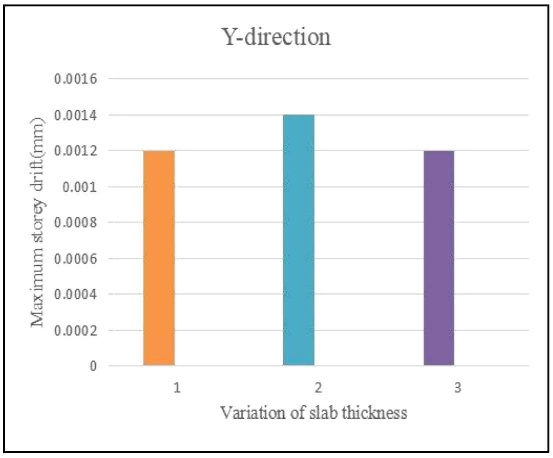
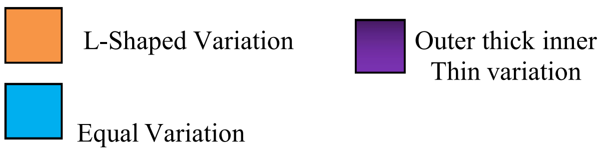


Fig 18:Storey drift of slab in Y- direction



L-shaped variation and Outer thick inner thin variations have least value of base shear and storey drift in both X & Y direction. Equal variation have maximum values in both cases.

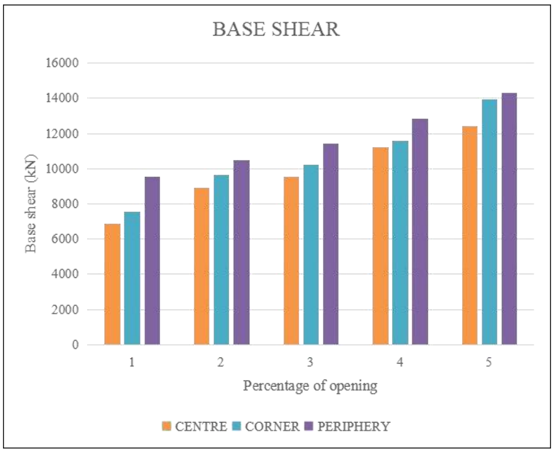


Fig 19:Graphical representation of base shear of re-entrant corners

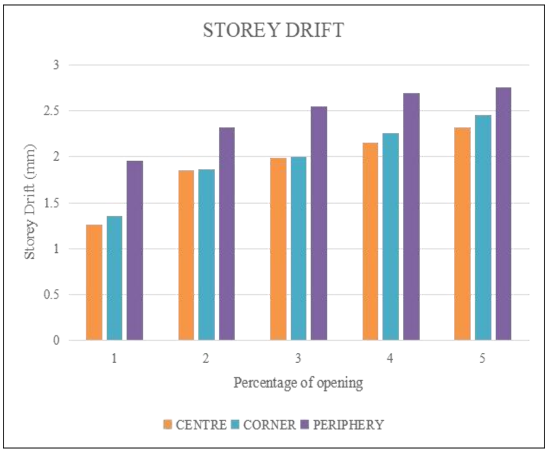


Fig 20: Graphical representation of storey drift of re-entrant corner

When both diaphragm openings and re-entrant corners are come together the values of base shear and storey drift are increases enormously. Here also centre opening with 1% of slab opening have least value of both the parameters. Maximum value is obtained for peripheral opening with 5% of opening.

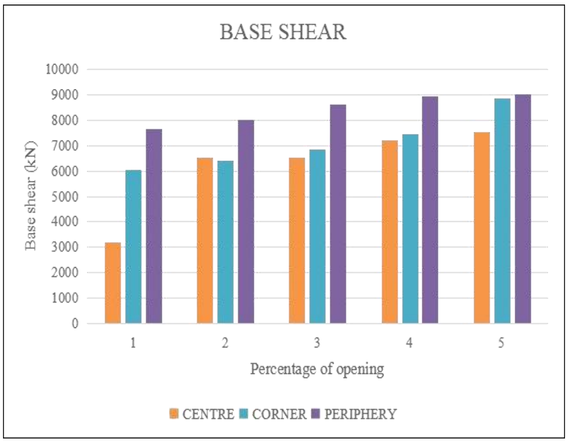


Fig 21: Graphical representation of base shear of re-entrant corners having shear walls

Fig 22: Graphical representation of storey drift of re-entrant corners having shear walls

To reduce the combined effect of slab openings and re-entrant Corners shear wall provision is adopted as a remedy. When shear walls are provided the value that are much increased in the previous case is start decreasing. Thus the structure become more stable. But here also centre opening with 1% of slab opening have least value of both the parameters. Maximum value is obtained for peripheral opening with 5% of opening.

VIII. CONCLUSIONS

- The story drift is reduced for slab opening at the center up to 53.22% compared to the corner and 64.19 % compared to the periphery position for 1% of slab opening.
- The base shear is reduced for slab opening at the center up to 46.64 % compared to the corner and 58.91 % compared to the periphery position for 1% of slab opening.
- From the above results it can be concluded that, slab opening at the center is found to be more effective in resisting lateral forces.
- The base shear of the regular building is less compared to the base shear values of the diaphragm having openings.
- Maximum story drift of a regular building is less compared to the maximum story drift values of the diaphragm having an opening.
- As the percentage of slab openings increases base shear and story drift also increases for all cases.
- In the case of thickness, L-shaped variation has minimum base shear and story drift both in X and Y direction compared to the other two cases.
- It is found that base shear and storey drift increases when there is an increase in variation of thickness of the slab.
- Presence of re-entrant corners with slab openings adds an extra adverse effect on the stability of the structure.
- The values of both base shear and story drift gradually increase when the structure possesses re-entrant corners.
- For 1% of opening base shear and story drift have lesser values and 5% of openings have greater values.

- The effect of re-entrant corners can be reduced by providing shear walls.
- By providing shear walls, base shear of slab opening at the center is reduced up to 46.94 % compared to the corner & 58.03 % compared to the periphery position for 1% of slab opening.
- By providing shear walls, story drift of slab opening at the center is reduced up to 53.89 % compared to the corner & 65.41% compared to the periphery position for 1% of slab opening.

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