Analysis of Buildings with Varying Percentages of Diaphragm Openings

Arya V Manmathan[1],
[1]PG Scholar,
Sree Buddha College of Engineering,
Alappuzha/Pathanamthitta cluster of APJ Abdul Kalam Technological University,
Ayathil, Elavumthitta P.O, Pathanamthitta-689625

Aiswarya S[2]
[2]Assistant Professor,
Sree Buddha College of Engineering,
Alappuzha/Pathanamthitta cluster of APJ Abdul Kalam Technological University,
Ayathil, Elavumthitta P.O, Pathanamthitta-689625

Abstract: **The major reasons of structures failure during earthquakes are Irregularities. Damages from earthquake generally initiates at locations of structural weaknesses in multi-storeyed framed buildings. Buildings with openings in slabs are subjected to damages due to the action of lateral loads. Floor and roof systems act as horizontal diaphragms in building structures. They collect and transmit inertia forces to the vertical elements of lateral load resistant systems, i.e. columns and structural walls. They also ensure that vertical components act together under gravity and seismic loads. Diaphragm openings are provided for the purpose of stairways, architectural features or shafts. In this works, openings in slabs are provided at various locations such as centre, at corners and at periphery with buildings having various shaped columns. The effects of size of openings in slabs were investigated. The seismic performance of multistory regular building is determined by Response Spectrum analysis in ETABS software**

Keywords: Regular buildings, Diaphragm openings, story drift, Response spectrum analysis, ETABS

I. INTRODUCTION

Diaphragm is the structural element that transmits lateral loads to the vertical resisting elements of structure. Excessive openings in diaphragm can results in flexible diaphragm response along with force concentrations and it leads to load path deficiencies at boundaries of the openings. In plan, openings in diaphragms may considerably weaken slab capacities**.** Discontinuities in the lateral stiffness of the diaphragm are due to openings, cut-outs, adjacent floors at different levels or change in the thickness of diaphragm. The diaphragm of a structure often does double duty as the floor system or roof system in a building, or the deck of a bridge, which simultaneously supports gravity loads. Diaphragms are constructed of plywood or composite metal deck in steel construction; or a concrete slab in concrete construction. Floor diaphragm openings are for the purpose of stairways, shafts or other architectural features**.** Gravity and earthquake loads flow in a continuous and smooth path through the horizontal and vertical elements of structures and transferred to the supporting ground. Sidestepping and offsetting are vertical discontinuities, leads to unfavourable stress concentrations. In plan, openings in diaphragms weakens the slab capacities. Discontinuities are present in plan and elevation. In this work, the effect of diaphragm discontinuity and seismic performance of buildings is done. Response spectrum analysis is used to find the effect of buildings with diaphragm discontinuity. This chapter describes about the diaphragm and diaphragm discontinuity

II. OBJECTIVES

- To investigate the seismic performance of a multistory building with slab openings by Response Spectrum analysis
- To obtain the suitable location of openings
- To study the effect of size of openings in slab
- To investigate the effect of shape of column in buildings with diaphragm discontinuity

III.SCOPE

The study is limited to

- 5% slab opening
- Response Spectrum Analysis
- columns having rectangular, square and circular shape

IV.LITERATURE REVIEW

This chapter gives a brief review of previous studies conducted in the field of diaphragm discontinuity

Momen M. M. Ahmed, Shehata E. Abdel Raheem, Mohamed M. Ahmed and Aly G. A. Abdel-Shafy (2016) [1] submitted a paper on "Irregularity effects on the seismic performance of l-shaped multi-story buildings**"**. They studied the seismic behaviour of the buildings with irregular plan of L-shape floor plan. Measured responses include inter-story drift; story shear force; overturning moment; torsion moment at the base and along the building height; top floor displacement; and torsional Irregularity Ratio. The models are analysed with ETABS using Equivalent Static Load and Response Spectrum Methods. The results proved that buildings with severe irregularity are more vulnerable than those with regular configuration resulting from torsion behaviour.

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Babita Elizabeth Baby, Sreeja S (2015) [2] published a paper on “Analysis of Buildings with Slab Discontinuity”. In their work slab openings are provided as discontinuity at different locations such as at centre, at corners and at periphery. A typical multi storeyed building is analysed using the commercial software ETABS for nonlinear static (pushover) and dynamic analysis. This study is done for RC framed multi-storeyed building (G+10) with fixed support conditions. The analyses were performed considering diaphragm discontinuity and results were compared. So, the openings are more effective to be located at periphery. Comparison were done for the linear and nonlinear analysis. Around 4% variation was shown for linear static analysis and response spectrum analysis.

Md Zibran Pawaar, Khalid Nayaz Khan, Syed Ahamed Raza (2015) [3] published a paper on “Performance Based Seismic Analysis of Rc Building Considering the Effect of Dual Systems” They analysed and designed the buildings constructed in high seismic zones for the unpredictable earthquakes with unpredictable magnitudes by various lateral load resisting systems. Present study includes linear-static and non-linear static analysis with different shear wall arrangements on dual systems such as flat slabs and shear walls & moment resisting frames and shear walls for different irregular plans using ETABS 9.7.4 software. Parameters such as point displacements, base shears, pushover curves are studied

Studies have been conducted on the dynamic response of structures with diaphragm discontinuity. But there is no study conducted to investigate the performance of buildings with diaphragm discontinuity as the percentage of discontinuity increases. Therefore, in this study the performance of buildings with increase in percentage of opening and different locations is investigated. Also, performance of buildings having diaphragm discontinuity with different column geometry also investigated

V.METHODOLOGY

Methodology employed is response spectrum method of analysis.

A. Modelling of Building

This study involves regular building configuration. Here the study is carried out for the behaviour of G+19 Storied Buildings, Floor height provided as 3m and also properties are defined for the building structure.9 models of buildings are prepared in which slab openings are provided at different positions of slab such as centre, corner and periphery with different column geometry such as rectangle, square and circular shape and with 1%,2%, 3%.,4% and 5% opening of floor area. For static behaviour dead load of the building is considered as per IS 875 Part 1and live load is considered as per IS 875 Part II, lateral load confirming IS 1893(part 1)2002.

B. Building Plan and Dimensions

The details of frame are obtained from literature review. An ordinary moment resisting framed building of 20 storeys is considered for analysis. The details and dimension of the building model is given in Table 1

Table 1

Dimensional Details of The Building

Plan dimension	20m×20m
Type of building:	Ordinary moment resisting frame
Number of stories	20
Floor height	3m
Grade of Concrete	30Mpa
Grade of steel	Fe 500
Beam dimension	450mm×850mm
Column dimension	350mm ×650mm
Slab depth	150mm

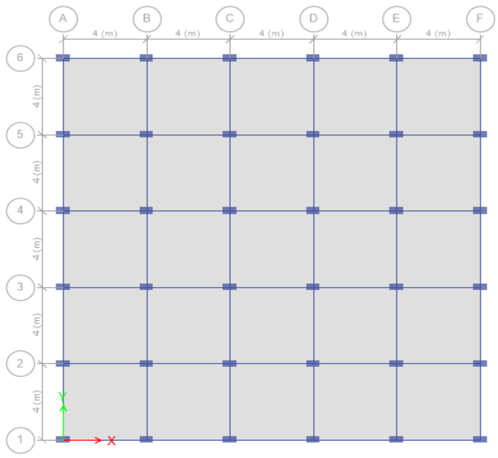

Fig.1 Plan of Building

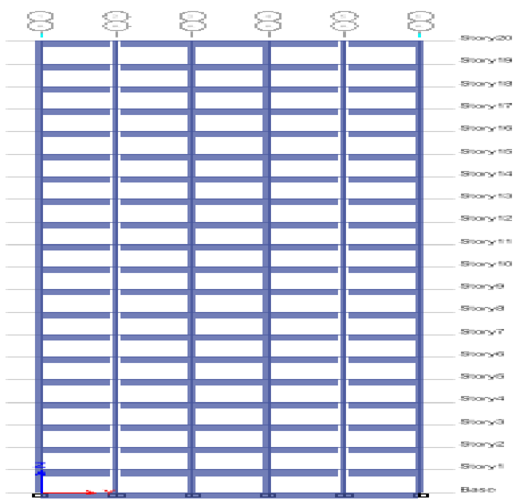

Fig.2 Elevation of Building

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C. Loads Considered

Table 2
Details of Dead Load and Live Load

Load	Value
DL	1.5kN/m^2
LL	2kN/m^2

Table 3
Details of Seismic Load

Zone	V
Soil type	Type 11
Zone factor	0.36
Importance factor, I	1.5
Response reduction factor	3

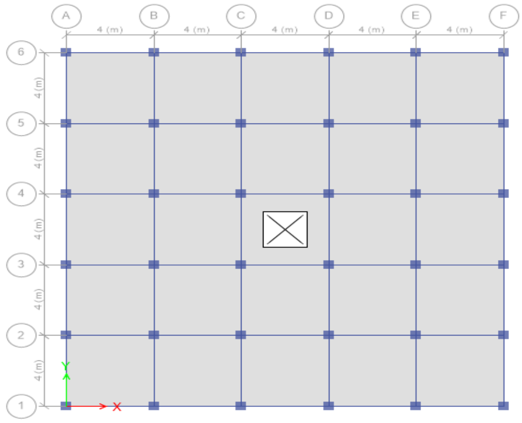
D. Load Combinations

The following Load combinations have been considered for the analysis

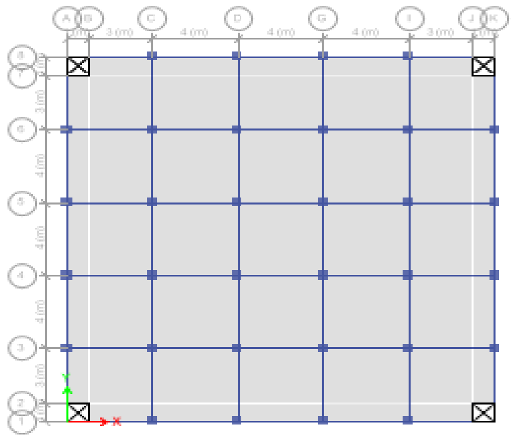
1. DL
2. DL+LL
3. 1.5(DL+LL)
4. 1.2(DL+LL+ EQX)
5. 1.2(DL+LL+ EQY)
6. 1.2(DL+LL - EQX)
7. 1.2(DL+LL - EQY)
8. 1.5(DL+EQX)
9. 1.5(DL+EQY)
10. 1.5(DL- EQX)
11. 1.5(DL- EQY)
12. 0.9DL+1.5EQX
13. 0.9DL+1.5EQY
14. 0.9DL - 1.5EQX
15. 0.9DL - 1.5EQY

VI.MODELLING

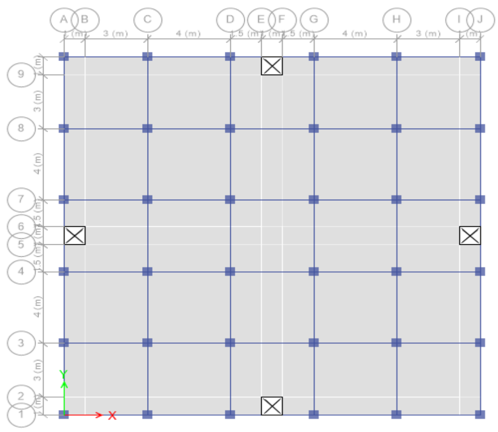
The building is modelled for the slab openings of 1%,2%,3%,4% and 5% and with rectangular, square and column geometries. The Figure.3 shows1% slab openings at centre, corner and periphery for a building with square column.



a) Slab Opening at Centre



b) Slab Opening at Corner



c) Slab Opening at Periphery

Fig.3 Plan of building with 1% slab opening and square column

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VII.ANALYSIS RESULTS

The building with three different column geometries is analysed by Response spectrum analysis for slab openings provided at centre, corner and periphery. The maximum storey drifts data is taken for comparison from the analysis results. Storey drift is the displacement of one level relative to other level above or below. The maximum storey drift values are tabulated.

A. Storey Drift

Table 4

Maximum storey drift for slab openings at various positions

Slab opening %	Column geometry	Slab opening position		
		Centre	Corner	Periphery
1%	Rectangle	0.001138	0.002404	0.00325
	Square	0.00088	0.00188	0.00246
	Circle	0.00092	0.001969	0.00249
2%	Rectangle	0.00229	0.002574	0.00360
	Square	0.00177	0.002011	0.00253
	Circle	0.00185	0.002102	0.00262
3%	Rectangle	0.002246	0.002529	0.00358
	Square	0.001768	0.001978	0.00237
	Circle	0.001851	0.002089	0.00257
4%	Rectangle	0.004723	0.00532	0.00576
	Square	0.00458	0.00481	0.00497
	Circle	0.00463	0.00492	0.0052
5%	Rectangle	0.004723	0.00532	0.00576
	Square	0.004576	0.00481	0.00497
	Circle	0.00463	0.00489	0.0052

The building with three different column geometries is analysed by Response spectrum analysis for slab openings. The Base shear data is taken for comparison from the analysis results. Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at base of a structure. The base shear values are tabulated.

B. Base Shear

Table 5

Base shear(kN) for slab openings at various positions

Slab opening %	Column geometry	Slab opening position		
		Centre	Corner	Periphery
1%	Rectangle	3707.46	6890.05	8632.63
	Square	3274.22	6134.97	7964.29
	Circle	3100.48	5799.19	7038.15
2%	Rectangle	7366.04	7536.34	8941.67
	Square	6559.29	6629.98	8136.23
	Circle	6214.38	6255.18	7973.54
3%	Rectangle	7478.93	7935.28	9009.343
	Square	6682.31	6931.64	8978.579
	Circle	6284.96	6560.09	8013.23
4%	Rectangle	8821.23	9118.10	9346.53
	Square	7442.19	7893.27	9153.94
	Circle	6389.32	6630.41	8999.32
5%	Rectangle	8825.71	9623	9834.85
	Square	7947.34	9219	9467.93
	Circle	7032.36	8317.79	9013.82

VIII.COMPARISON OF RESULTS

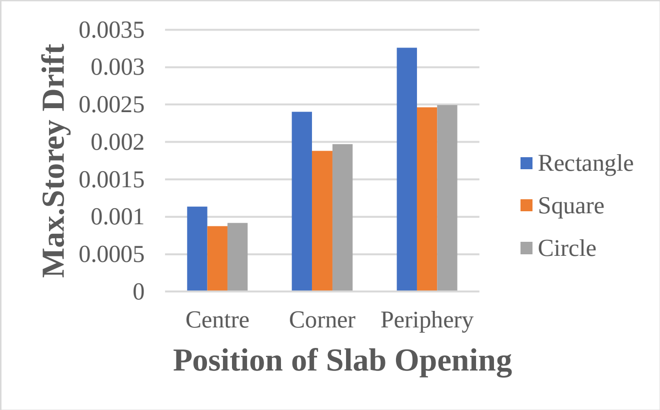

Fig. 6 Comparison of maximum storey drift for 1% slab openings for building with different column geometry

From Fig.6, it is observed that slab opening at centre has lesser drift value comparing corner and periphery. Square column also has less drift values in comparison with rectangular and circular geometry

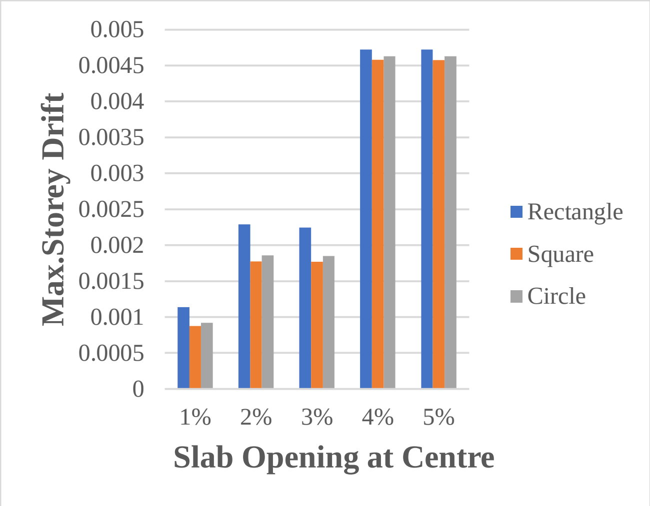

Fig.7 Comparison of maximum storey drift for slab openings in building with different column geometry

From Fig.7, it is observed that drift value increases 2% opening and it slightly decreases for 3% opening but at 4% and 5% opening, drift values remains constant

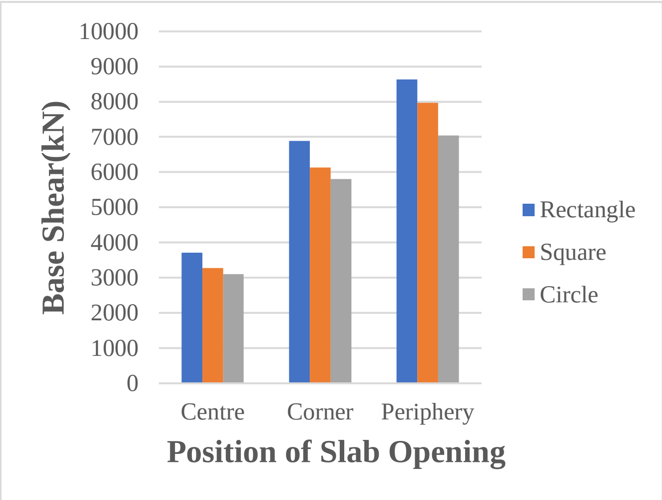

Fig. 8 Comparison of Base shear for 1% slab openings for building with different column geometry

From Fig.8, it is observed that slab opening at centre has lesser base shear value comparing corner and periphery. Square column also has less base shear values in comparison with rectangular and circular geometry

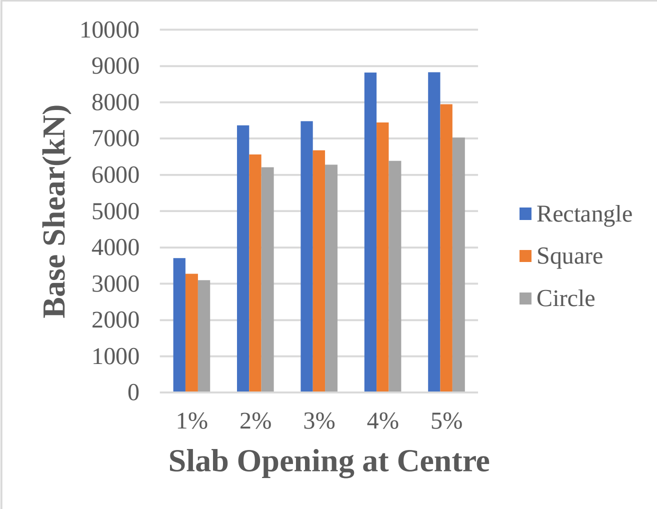

Fig.9 Comparison of Base shear for slab openings for building with different column geometry

From Fig.9, it is observed that base shear increased with increase in percentage of opening

IX.CONCLUSIONS

- The percentage reduction of storey drift for slab opening at centre is 53.02% compared to corner and 64.13% compared to periphery position.
- The percentage reduction of base shear for slab opening at centre is 46.44% compared to corner and 57.3% compared to periphery position.
- From Maximum Storey drift and Base shear view, slab openings at centre is found to be more effective in resisting lateral forces.
- Lateral displacement for slab opening at centre is lesser compared to other positions.
- The percentage reduction of storey drift for square column is 22.97% compared to rectangular column and 3.38% compared to circular column.
- The percentage reduction of storey base shear for circular column is 10.12% compared to rectangular column and 7.5% compared to square column.
- Considering the drift point of view, square column is better and from base shear point of view, Circular column is better
- The percentage of slab openings at centre, corner and periphery positions in case of storey drift increases up to 2% opening and it reduces for 3% opening. It attains a constant value for 4% and 5% slab opening.
- As the percentage of slab opening increases, base shear also increases

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