COMPARATIVE STUDY ON SEISMIC ANALYSIS OF FLOOR DIAPHRAGM OPENINGS WITH RING BEAMS

Sreelakshmi Ranjit[1] and Nincy Jose[2]

[1]*PG student, Dept of civil engineering, Federal Institute of Science and Technology, Angamaly, Ernakulam*
[2]*Assistant Professor, Dept of civil engineering, Federal Institute of Science and Technology, Angamaly, Ernakulam*

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Abstract - *Diaphragms, which transmit lateral forces to the vertical elements of the lateral force resisting system, must be designed as part of the seismic force resisting system of a building. Openings in the floor diaphragms are commonly used for a variety of purposes such as staircases, escalators, lifts, architectural lighting, and so on. These diaphragm openings put stress on the discontinuous joints with the building elements. Unaccounted for diaphragm openings may result in structural instability or diaphragm failure. The correct placement of openings will provide the structure with effective strength and serviceability. This study focuses on the general effects of floor diaphragm openings on seismic response of RC multistoried building having ring beam around openings of various shapes. The effect of ring beams around openings in the diaphragm is studied using structural parameters such as maximum storey displacement, storey drift, storey shear, slab stress and slab deflection of the building by time history analysis with the help of ETABS 2018 software. The results are compared with models having no ring beams around the openings.*

***Key Words*: Diaphragm openings, Ring beams, Time history analysis, ETABS 2018.**

1. INTRODUCTION

Earthquakes typically begin in multi-story framed structures in the lateral load resisting frames at structurally weak points. During strong earthquakes, the action of multi-story framed buildings is dependent on the distribution of mass, stiffness, and intensity in each of the horizontal and vertical planes of the building. Changes in the stiffness, strength, or mass of the diaphragm can also cause these vulnerabilities in a few cases. Buildings with normal geometry and uniformly distributed mass and stiffness in plan and elevation sustain far less damage than irregular configurations.

IS 1893-2002 part 1;clause 4.8 defines a diaphragm as a horizontal or nearly horizontal system that transmits lateral forces to vertical resisting elements such as reinforced concrete floors and horizontal bracing systems [8]. A diaphragm is a structural system used to transfer lateral loads to shear walls or frames in structural engineering. Wind and earthquake loads are the most common lateral loads, but diaphragm action can also resist other lateral loads such as lateral earth pressure or hydrostatic pressure. Horizontal diaphragms cause the walls or frames to resist lateral forces as a group.

1.1 DIAPHRAGM OPENINGS

Openings are provided in reinforced concrete slabs in buildings to allow lifts, cables, or other instruments, such as escalators, to pass from one floor to the next. Escalators and lifts are increasingly being used in high-rise buildings to facilitate movement from one floor to another. The use of floor openings is also rising, introducing a new design aspect in architectural ways.

The purpose of this research is to compare the seismic performance of RC structures with and without ring beams around diaphragm openings of various shapes using ETABS, as well as to investigate the effect of ring beams around openings in symmetric building plans. All analyses will be performed in RC structures with and without ring beams, with diaphragm openings of various shapes. Only the building's storey displacement, storey drift, storey shear, slab stress concentration, and slab deflection will be considered.

2. METHODOLOGY ADOPTED

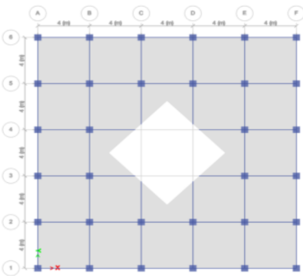
In ETABS 2018, 3D models of symmetric plan configurations with 10% openings of square, circular, and diamond shapes were created. Models with and without ring beams around the openings were created. Time history analysis is carried out. To reach conclusions, the results are evaluated using the parameters maximum storey displacement, storey drift, base shear, slab stress concentration, and slab deflection. Data from the El Centro California time history function was entered for the analysis process (magnitude 6.9). The Indian Standard Code IS 1893-2002 (Part I) [8] was used for modeling of the structures. Fixed joints are provided at the building's foundation. All structural sections are assumed to be rectangular.

3. MODELING OF STRUCTURE

G+10 storey buildings with symmetric plan configurations are considered for this study. Each has four models: no opening, 10% square, circular, and diamond shaped openings with and without ring beams around the openings. The storey height is set at 3m for the upper storey and 3.5m for the lower storey. The structural members are made of M30 grade concrete and Fe 415 steel. The thickness of the slab is 120mm. All beams are 300 x 550 mm in size, and columns are 550 x 550 mm in size. Fig-1 depicts the plan view of all models without ring beams around the floor diaphragm openings. Fig-2 shows opening provided with ring beams.

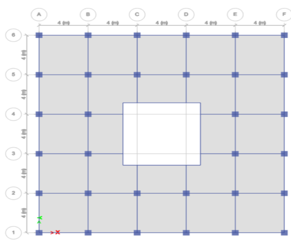
(a) Square

(b)Circle

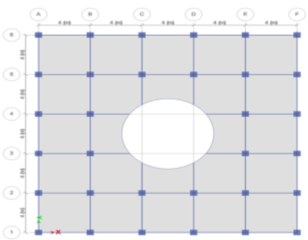


(c) Diamond

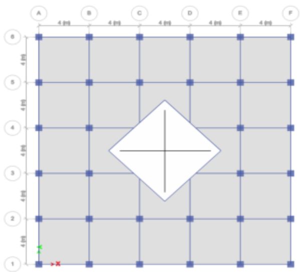
Fig-1: Plan view of models without ring beams



(a) Square



(b)Circle



(c) Diamond

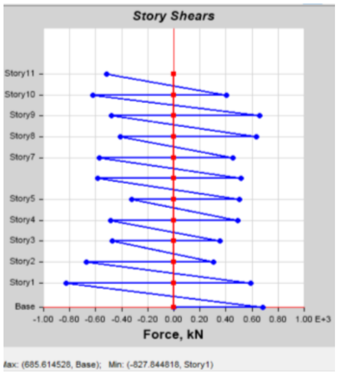
Fig-2: Plan view of models with ring beams

3.1 Loading

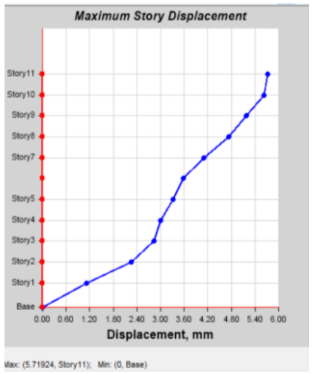
A live load of 3 kN/m² is applied in accordance with IS: 875 (Part II) 1987, and the dead load is assigned by software. According to IS 1893-2002, lateral loads are used as seismic loads in the X and Y directions (Part 1). The design earthquake load is calculated using a zone factor of 0.16, medium soil, an importance factor of one, and a response reduction factor of five (IS: 1893 (Part-I), 2016).The support conditions are assumed as fixed.

4. ANALYSIS RESULTS

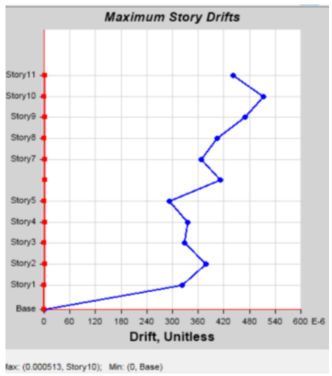
Fig-3 shows the storey shear, storey displacement ad storey drift plot of models without ring beams provided in square shaped openings.



(a) Storey shear



(b)Storey displacement



(c) Storey drift

Fig-3: Square model results

Table -1: Analysis results of models without ring beam

	Max storey shear (kN)	Max storey displacement (mm)	Max drift (10^{-4})
Square	685.61	5.719	5.13
Circle	670.43	5.706	5.17
Diamond	701.56	5.702	5.11

Table -2: Analysis results of models with ring beam

	Max storey shear (kN)	Max storey displacement (mm)	Max drift (10^{-4})
Square	668.64	5.716	5.08
Circle	692.13	5.702	5.13
Diamond	695.02	5.701	5.09

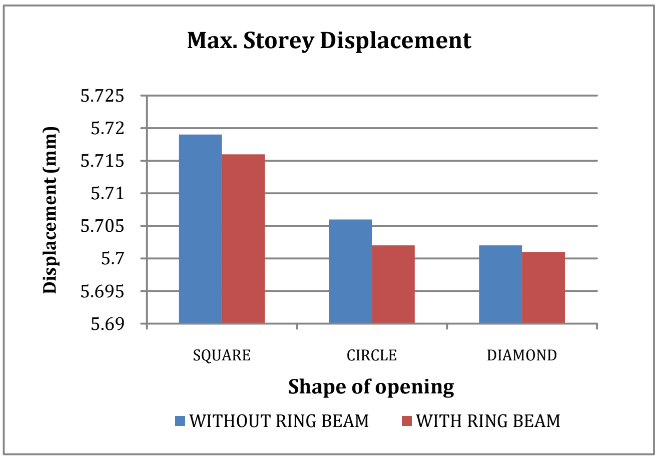


Chart -1: Storey Displacement comparison

For all cases models with ring beam had better performance. Maximum storey displacement value decreases by providing ring beams around the openings. The effect is more visible in case of circular openings provided with ring beams.

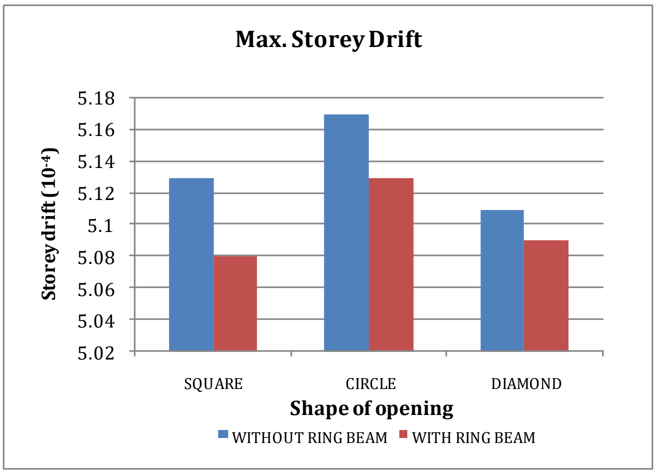


Chart -2: Storey Drift comparison

For both case of openings with and without ring beam around openings maximum storey drift value is more for circular shaped openings.

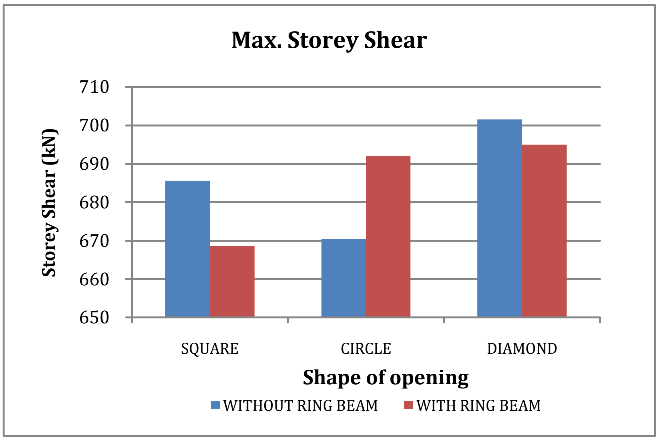
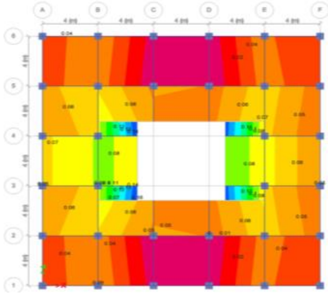
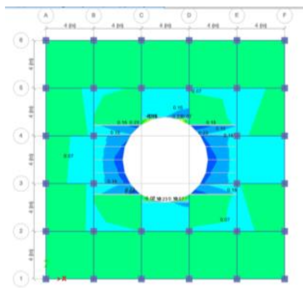


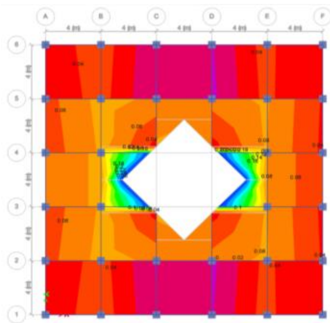
Chart -3: Storey Shear comparison

Storey shear increased in case of circular openings provided with ring beams around the openings. For square shaped openings maximum storey shear reduced by 3% by providing ring beams around the openings.



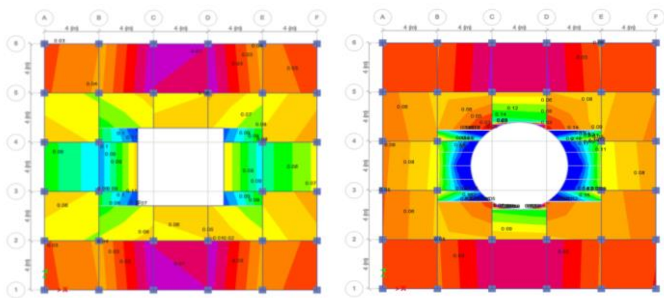


(a) Square (b)Circle

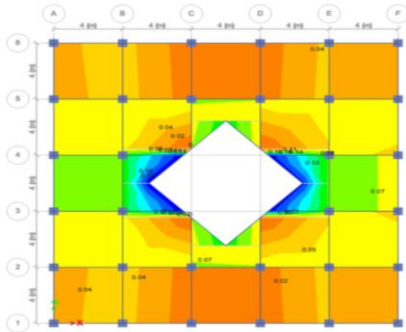


(c) Diamond

Fig-4: Slab stress concentration of openings without ring beam



(a) Square (b)Circle



(c) Diamond

Fig-5: Slab stress concentration of openings with ring beam

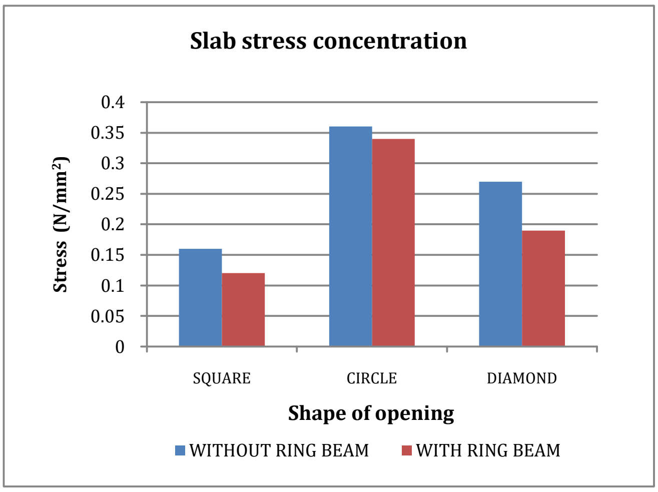
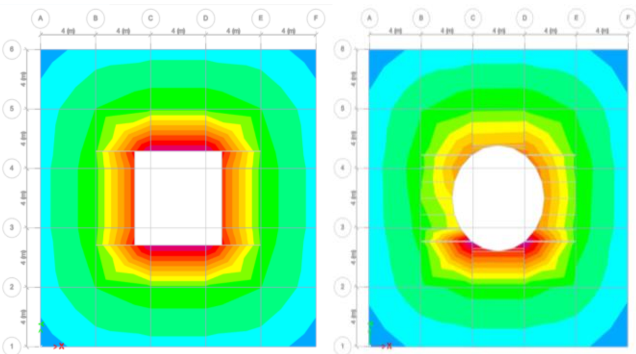
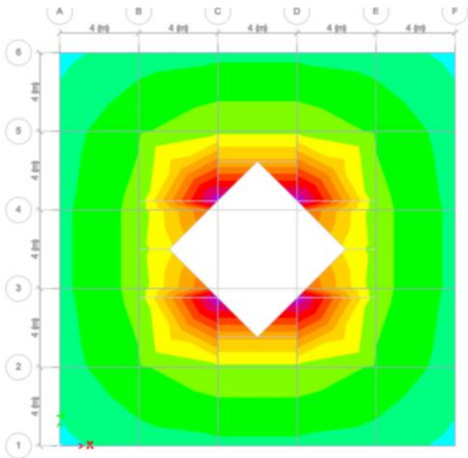


Chart -4: Slab stress comparison

For diamond shaped openings slab stress around openings without ring beams is 42% more than that provided with ring beams and 33% in case of square openings. From chart 4 we can see that the effect of ring beams is more evident in diamond shaped openings.

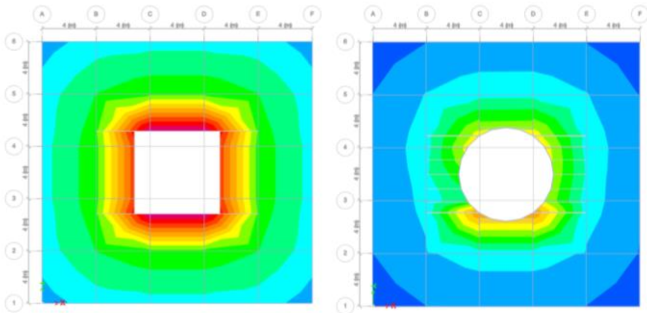


(a) Square (b)Circle

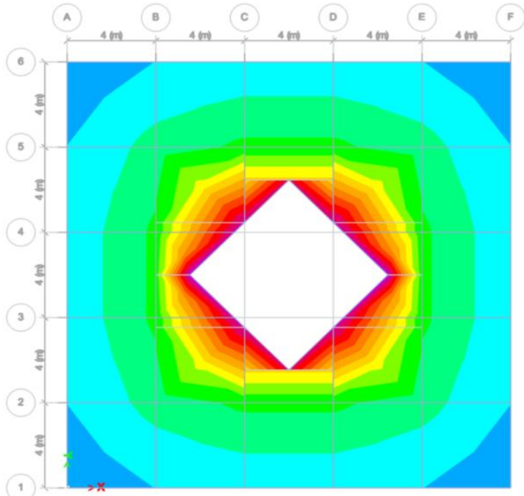


(c) Diamond

Fig-6: Slab deflection of openings without ring beam



(a) Square (b)Circle



(c) Diamond

Fig-7: Slab deflection of openings with ring beam

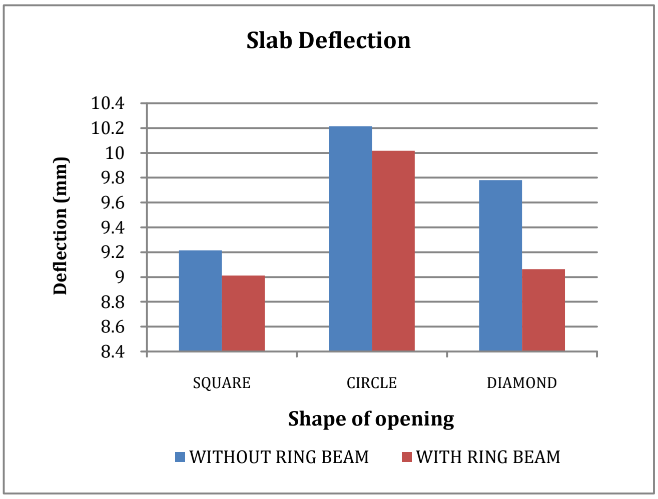


Chart -5: Slab deflection comparison

By providing ring beams, slab deflection is reduced by 7% in case of diamond shaped opening and 2% for that of square and circular openings. From chart 5 it can be observed that the influence of ring beams around openings is more prominent in diamond shaped openings in comparison with other opening shapes. Table 3 and 4 shows the member forces of model without and with ring beams.

Table -3: Member forces of models without ring beam

	Bending moment B1 (kNm)	Shear force B1 (kN)	Axial force C1 (kN)
Square	239.98	153.06	6290.32
Circle	173.83	100.06	6767.79
Diamond	263.96	142.59	6254.54

Table -4: Member forces of models with ring beam

	Bending moment B1 (kNm)	Shear force B1 (kN)	Axial force C1 (kN)
Square	336.59	208.61	6678.40
Circle	208.65	108.33	7006.25
Diamond	351.81	209.45	6791.95

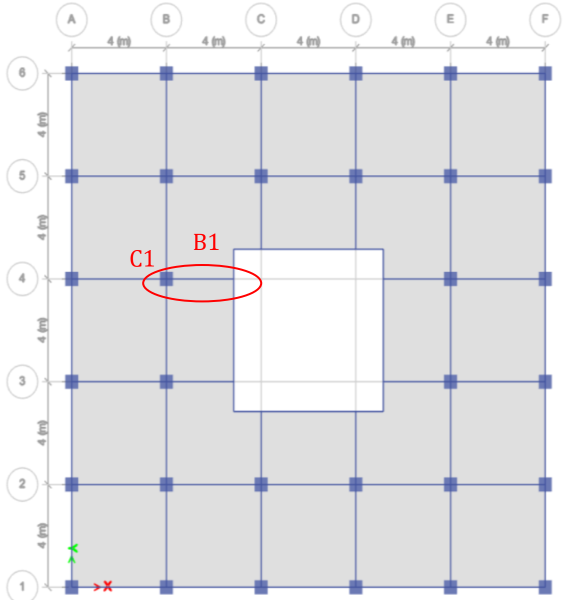


Fig-8: Member forces of openings with ring beam

Comparing the bending moment on beam B1 we can see that maximum value is obtained for diamond openings. In case of openings without ring beam bending moment of diamond shaped opening is 51% than that of circular openings. In both the cases axial force on column C1 is greater for circular opening.

5. CONCLUSIONS

From the above research the following conclusions were made:

- From the comparison of building models with and without ring beams around the openings, different shapes had different responses for all parameters
- The effect of ring beams is more evident for diamond shaped openings. By providing ring beams, slab deflection is reduced by 7%.
- There is a significant variation seen in values of slab stress, deflection and member forces in models without and without ring beams.
- The effect of ring beams around the openings is more evident in structural element values such as bending moment, axial force, slab stress and deflection than building parameters of storey drift and displacement.
- The behaviour of building is better when they are provided with ring beams around the openings
- Comparing all the values of the analysis there is significant difference in values of diamond shaped opening provided with and without ring beams.

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