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Effect of Slab Opening in Seismic Resistance of Structure

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Abstract

In these days, many buildings have irregular configurations both in elevation and plan. Generally, the floor slab has been neglected or only partially considered as a strength contributing factor for seismic performance of buildings. But the floor slab plays a crucial role in imparting strength and stiffness to a frame when subjected to lateral loads. Several factors that affect the degree of slab participation, like influence of transverse beams and beam growth effect are also mentioned. Hence in the present study, symmetrical and unsymmetrical buildings with various slab type– with openings, without openings, eccentric openings and framed structures were analyzed using finite element based software ETABS for nonlinear static condition. The results of parameters considered being displacement, story drift and story shear of the diaphragm discontinuity models were compared with that of diaphragm continuity model

Keywords: *diaphragm discontinuity, nonlinear analysis, seismic behavior, story drift, story shear*

I. INTRODUCTION

In multistoried building, damages caused by the earthquake were initiated at the locations where there the load resisting frames has low structural strength. It is mainly due to the distribution of loads, structural stiffness, and discontinuities in the diaphragm. In few cases, it might be due to discontinuities in strength, stiffness or mass along the diaphragm. In construction industry ,a diaphragm is a structural element used to transmit lateral loads (earthquake and wind load) to vertical resisting structures - frames or shear walls. Diaphragms are of two category, flexible diaphragm resist horizontal forces based on the area and irrespective of the members in which it is transferring those force whereas rigid diaphragm transmits lateral load to shear walls or frames based upon their location in the structure. In this study, a comparative nonlinear static condition is being carried out for models with different diaphragm discontinuities by using finite element based software ETABS.

II. LITERATURE REVIEW

S. N. Tande et al (2014) studied the influence on the flexibility of diaphragm based on number of stories and aspect ratio using finite element based software ETABS. Buildings with four, seven and 10 stories with variation in aspect ratio was considered for this and it is concluded that the effect of flexibility of diaphragm decreases as the number of storey increases whereas increase in aspect ratio will increases the flexibility.

Siddhartha Y Vekariya et al (2015) studied that diaphragm discontinuities at the floor level reduces the rigidity and also affects the load distribution on the lateral resisting element. It is concluded that the models with opening requires greater section as compared to that without openings in diaphragm.

S. Monish et al (2015) studied the effect of opening in the slab with various shapes and height of high rise buildings on their seismic performance. Opening area greater than fifteen percent of its dimension was considered in different shapes. It is observed that displacement increased with increase in building height and H shaped is the most vulnerable.

III. MODEL SPECIFICATIONS

The ten story models are designed for symmetrical and unsymmetrical building with different slab

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January - February 2020
ISSN: 0193 - 4120 Page No. 14850 - 14855

conditions (without opening, with concentric opening, with eccentric opening and framed structure)

Table - I: Details of the building

Building Parameters	Details
Number of floors	10
Typical Story height	3 m
Bottom Story height	4 m
Number of bays in x direction	6
Number of bays in y direction	6
Spacing of bays in x direction	6 m
Spacing of bays in y direction	6 m
Size of Beam	300 mm x 600 mm
Size of Column	500 mm x 500 mm
Thickness of Slab	150 mm
Thickness of wall	200 mm

Symmetrical models are created with the above specifications in ETABS with various type – without opening, with concentric opening, with eccentric opening and framed structures. These symmetrical models are numbered below:

Model 1: Symmetrical without opening.
Model 2: Symmetrical with 11.11% concentric opening
Model 3: Symmetrical with 44.44% concentric opening
Model 4: Symmetrical with 22.22% eccentric opening
Model 5: Symmetrical with 33.33% eccentric opening
Model 6: Symmetrical framed structure.

Fig.1, Fig.2 and Fig.3 represent the plan and elevation of the symmetrical model without opening, with11.11%concentric opening and with 22.22% eccentric opening respectively.

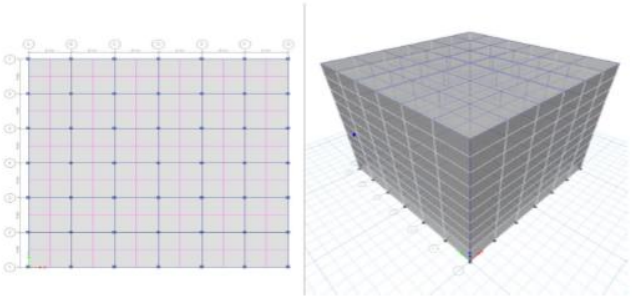

Fig.1.Symmetrical model without opening.

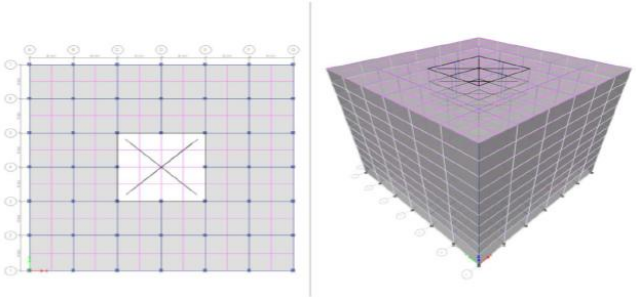

Fig.2 Symmetrical model with11.11% concentric opening.

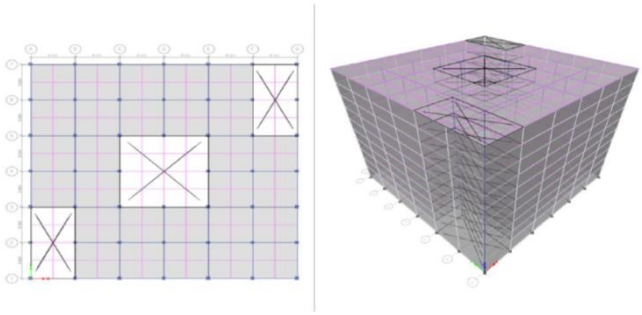

Fig.3. Symmetrical model with 22.22% eccentric opening.

Similarly, unsymmetrical models are also created with the above specifications in ETABS with various type – without opening, with concentric opening, with eccentric opening and framed structures. These unsymmetrical models are numbered below:

Model 7: Unsymmetrical without opening.
Model 8: Unsymmetrical with 2.77% concentric opening
Model 9: Unsymmetrical with 5.55% concentric opening
Model 10: Unsymmetrical with 7.40% eccentric opening
Model 11: Unsymmetrical framed structure.

Fig.4, Fig.5 and Fig.6 represent the plan and elevation of the unsymmetrical model with 2.77%

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ISSN: 0193 - 4120 Page No. 14850 - 14855

concentric opening, with 7.40% eccentric opening, framed structure model respectively.

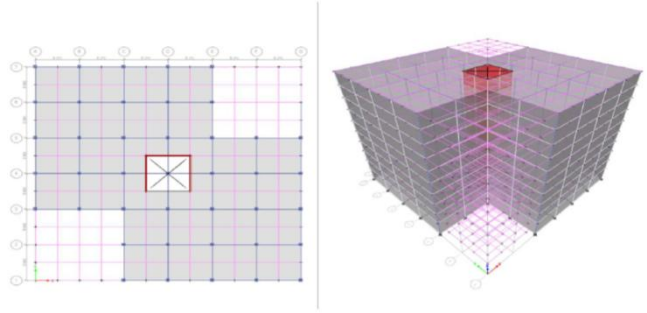

Fig.4.Unsymmetrical model with 2.77% concentric opening.

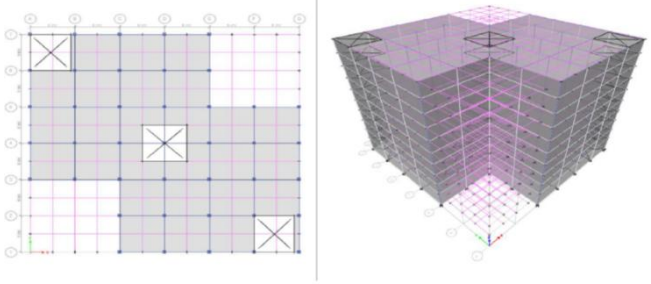

Fig.5.Unsymmetrical model with 7.40% eccentric opening.

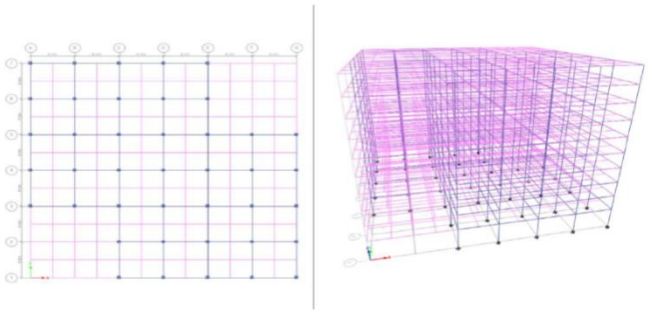

Fig.6. Unsymmetrical framed structure model.

IV. RESULT AND DISCUSSION

The symmetrical models with four types of irregularities such as Model 2, Model 3, Model 4, and Model 5 are stiffness irregularity. This structures are compared model 1(without openings)to study the basic difference between these structures. Then, the results are compared to show that slab has different effects on different type of models.

A. Displacement – without and concentric opening

Fig.7. shows the displacement of model 1, model 2 and model 3 in x- direction.

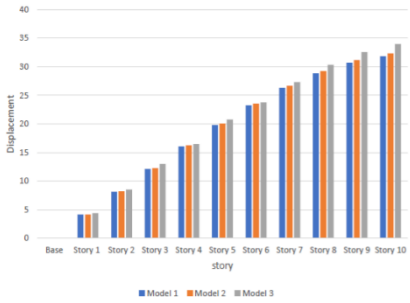

Fig. 7. Displacement in x-direction

It can be observed that, model 2 shows greater displacement than Model 1but it has less displacement when compared to model 3.

B. Story Drift – without and concentric opening

Fig.8. shows the story drift of model 1, model 2 and model 3 in x- direction.

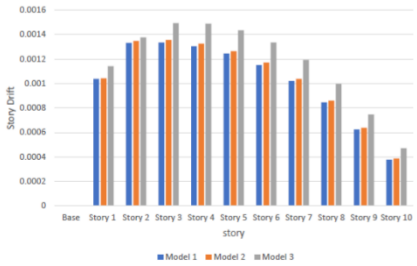

Fig. 8. Story drift in x-direction

It can be observed that, model 2 has greater story drift when compared to model 1 but it has less story drift when compared to model 3.

C. Story Shear – without and concentric opening

Fig.9. shows the story shear of model 1, model 2 and model 3 in x- direction.

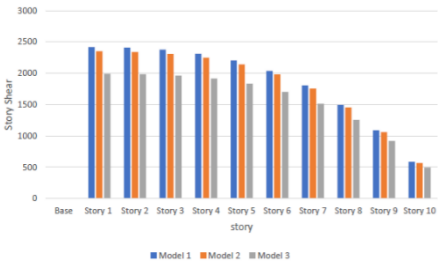

Fig. 9. Story shear in x-direction (KN)

It can be observed that, model 1 has high story shear when compared to model 2 and model 3

D. Displacement – without and eccentric opening

Fig.10. shows the displacement of model 1, model 4 and model 5 in x- direction.

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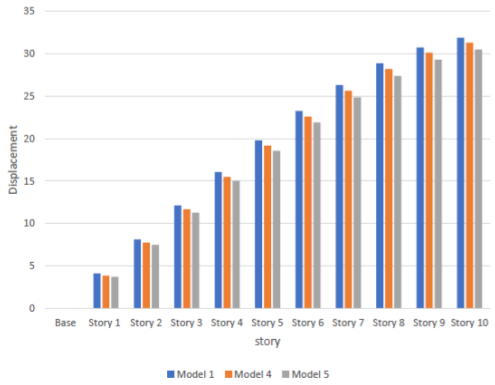

Fig. 10. Displacement in x-direction

It can be observed that, model 4 has lesser displacement when compared to model 1 but it has greater displacement when compared to model 5.

E. Story Drift – without and eccentric opening

Fig.11. shows the story drift of model 1, model 4 and
model 5 in x- direction.

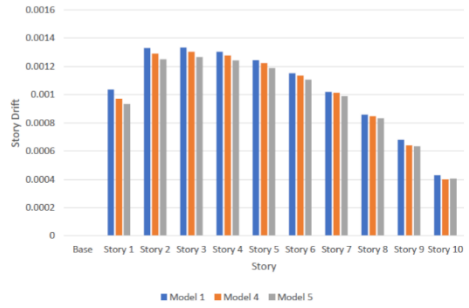

Fig. 11. Story drift in x-direction

It can be observed that, model 4 has lesser story drift when compared to model 1 but

it has greater story drift when compared to model 5.

F. Story Shear – without and eccentric opening

Fig.12. shows the story shear of model 1, model 4 and
model 5 in x- direction.

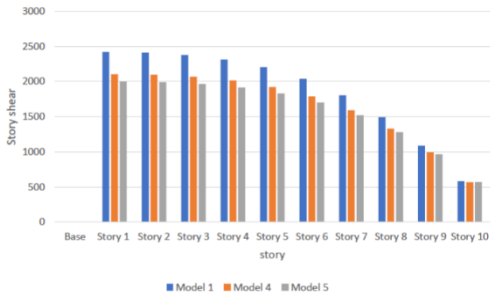

Fig. 12. Story shear in x-direction (KN)

It can be observed that, model 1 has high story shear when compared to model 4 and model 5.

G. Displacement – without opening and framed structure

Fig.13. shows the displacement of model 1and model 6 in x- direction.

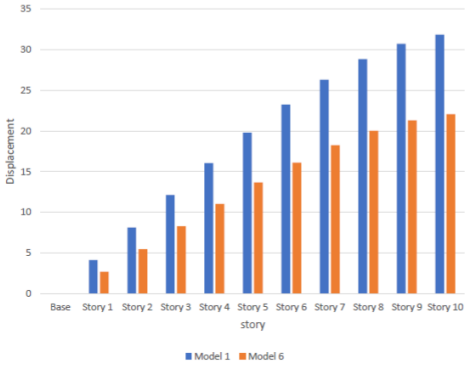

Fig. 13. Displacement in x-direction

It can be observed that, model 1 has greater displacement when compared to model 6.

H. Story Drift – without opening and framed structure

Fig.14. shows the story drift of model 1and model 6 in
x- direction.

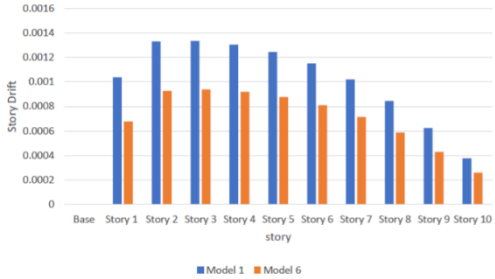

Fig. 14. Story drift in x-direction

It can be observed that, model 1 has greater story drift when compared to model 6.

I. Story Shear – without opening and framed structure

Fig.15. shows the story shear of model 1and model 6 in
x- direction.

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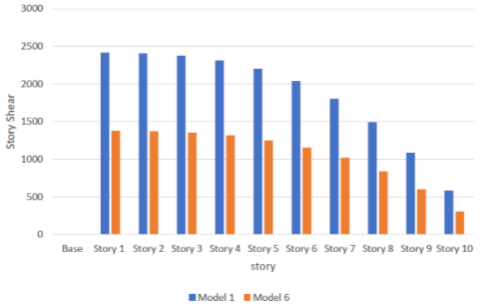

Fig. 15. Story shear in x-direction (KN)

It can be observed that, model 1 has high story shear when compared to model 6.

Unsymmetrical models with three types of irregularities such as Model 8, Model 9, and Model 10 are stiffness irregularity. This structures are compared model 7 (without openings) to study the basic difference between these structures. Then, the results are compared to show that slab has different effects on different type of models.

J. Displacement – Unsymmetrical Models

Fig.16 and Fig.17 shows the displacement of unsymmetrical models in x and y direction respectively.

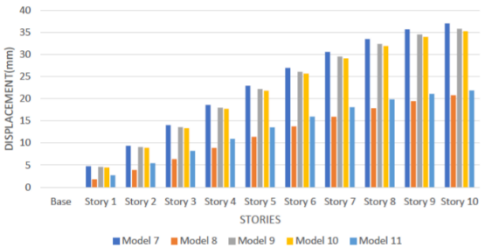

Fig. 16. Displacement in x-direction

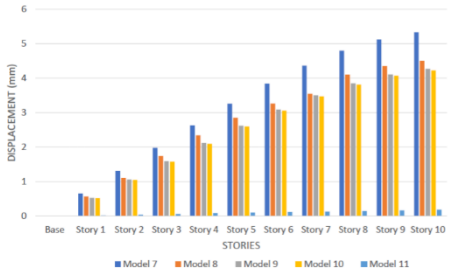

Fig. 17. Displacement in y-direction

It can be observed that, in x direction, model 8 has lesser displacement when compared to all models and model 10 has lesser displacement when compared to model 7 and model 9 whereas in y direction, model 11 has lesser displacement when compared to model 9 and model 10 but it has higher displacement when compared to model 7.

K. Story Drift – Unsymmetrical Models

Fig.18. and Fig.19. shows the story drift of unsymmetrical models in x and y direction respectively.

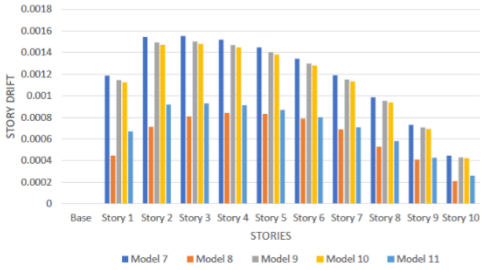

Fig. 18. Story drift in x-direction

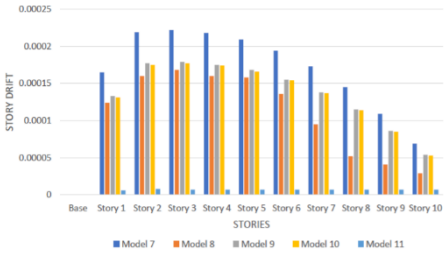

Fig.19. Story drift in y -direction

It can be observed that, in x direction, model 8 has lesser story drift when compared to all models, model 10 has higher story drift when compared to model 7 but it has lower story drift when compared to other models and model 9 has higher story drift when compared to model 10 whereas in y direction, model 11 has lesser story drift when compared to all models and model 8 has lesser story drift when compared to all models except model 11.

L. Story Shear – Unsymmetrical Models

Fig.20. shows the story shear of unsymmetrical models in x direction.

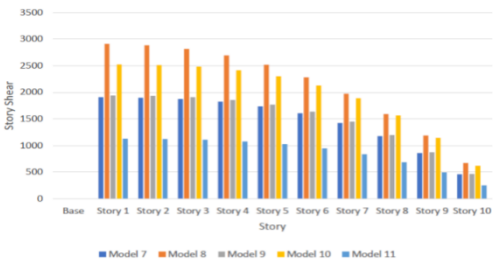

Fig. 20. Story shear in x-direction (KN)

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It can be observed that, model 8 has higher story shear when compared to all models, model 11 has lower story shear when compared to all models, model 10 has higher story shear when compared to all models except model 8 and model 9 has higher story shear when compared to model 7.

V. CONCLUSION

From the analysis concerning the effect of created slab openings on structural behavior under seismic loads. The following conclusions can be drawn based on the analysis of results.

1) The percentage of increase of concentric openings in symmetrical structures will have higher displacement when compared to symmetrical structures without openings.
2) The percentage of increase of eccentric openings in symmetrical structures will have lesser displacement when compared to symmetrical structures without openings.
3) In unsymmetrical structures the slab openings provided with shear wall will have lesser displacement when compared to unsymmetrical structures without openings.
4) The percentage of increase of openings in unsymmetrical models will have decrease in displacement when compared to unsymmetrical structures without openings.

From the analysis it is concluded that the slab has different effects in the structures when the properties of slab is changed. Therefore, it proves that slab is not rigid during seismic performance.

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Dr. Binu Sukumar, Professor and Head of Civil engineering, R.M.K. Engineering college. She has more than 28 years of teaching and industrial experience. She has obtained her B.Tech in Civil Engineering, from Govt. College of Engineering, Trivandrum, Kerala University, M.Tech in Structural Engineering from Indian Institute of Technology, Madras and PhD from the faculty of Civil Engineering, Anna University, Chennai. She has authored many textbooks and journals. She is acting as member of Editorial Board for International Journals, reviewer for many International Journals published by Elsevier and Springer publishers and reviewer for many text books. She is a Recognized Research Supervisor of Anna University. She is a fellow of Institution of Engineers (I) and life member of various professional societies like Indian Society for Technical Education (ISTE) and Indian Concrete Institute (ICI).

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