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Seismic Performance of RC Structure with and without Shear Wall Using Flat Slab with Huge Openings Subjected to Diaphragm Discontinuity - A Literature Review

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ABSTRACT—

A horizontal structural module called a diaphragm transfers seismic loads to the structure's vertical module. Discontinuities in the diaphragm are used for visual appeal and other purposes, but these openings in the diaphragm root stresses at discontinuities at joints with the building modules. When subjected to seismic loads, buildings with diaphragm discontinuity characteristically uphold damage. However, the structure's receptiveness to damage can be reduced by strategically positioning this diaphragm discontinuity with the introduction of shear wall in the system from which the strength and serviceability can be improved. Additionally, their existence can significantly change how the diaphragm functions. In this study, the effects of variables like the position of the diaphragm discontinuity with the different positions of shear wall are also investigated. The objective of this study is to review, how a diaphragm discontinuity will affect a flat slab multi-story building with and without shear wall at different locations. The objective of this study is to determine how a diaphragm discontinuity will affect a flat slab multi-story building (G+5) with and without shear wall at different locations. The ETABS v13.2.0 software is used to model a 5-story flat slab R.C.C.-framed building for response spectrum analysis for severe seismic zone as per IS 1893:2016. For this study, results after analyzing the different models in the form of maximum story displacement, base shear, story drift and overturning moment are computed and then compared.

Keywords: Diaphragm Discontinuity, Flat Slab System, Shear Wall, Response Spectrum Analysis, Story Displacement, Story Drift, Base Shear, ETABS.

1. Introduction -

The modern trend is towards taller and slender structures and there has been a considerable increase in the construction of tall buildings both residential and commercial. In the building type of structures, the primary purpose of all kinds of structural systems is to transfer gravity loads effectively. Lateral loads like wind loads, earthquake loads and blast forces are attaining importance and every designer is facing with the problems of providing stability and adequate strength against lateral loads. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

Residential, commercial, and contemporary trend buildings have all become significantly taller. The two most appealing and widely used systems today are the shear wall and flat slab systems. Flat slabs are RC slabs with vast spans that are spread over numerous bays and merely supported by columns, without beams. It is fairly easy to design a flat slab system, and it is effective in that it just calls for the bare minimum building height for a specified number of stories. A zone of supports experiences vertical forces, and the structure in question has a significant bending moment. In comparison to reinforced concrete, this results in a very efficient structure that uses less material and has a shorter economic lifespan. The structural behavior of steel is enhanced by post tensioning. The structural behavior of flat slab structures is significantly improved by post tensioning. Many designers find this concept to be more acceptable. In some office buildings, it is used. The flat slabs are plates that have drop panels or column capitals to reinforce them close to the column supports (which are generally concealed under drop ceilings). Because of its improved ability to withstand shear and hogging moments close to the supports, it is appropriate for higher loads and longer spans. For spans of 4 to 9 meters, the slab thickness ranges from 125 mm to 300 mm. The flat slab system has the largest dead load per unit area when compared to the other floor types.

Without the aid of beams, solid concrete slabs of uniform depths called flat plates are transfer loads directly to the supporting columns. Today, the most commonly used slab systems used for multi-storied buildings are Flat Slabs. Their lack of resistance to lateral loads is the main disadvantage of Flat slab. Hence, in high rise constructions special features like shear walls to be provided. Shear wall can be defined as structural elements, which provide strength, stability and stiffness lateral loads deriving strength. To reduce ill-effects of twist of buildings, shear walls must be located symmetrically in plan.

2. Concept of Flat Slab & Lateral Load Resisting System –

In common practice of design and construction is the slabs supported by the beams and beams supported by the columns. This type of construction is called beam-slab construction in which due to the beam depth, the available net clear ceiling height reduces. Mostly beams are avoided in warehouses, offices and public halls, slabs are directly supported by columns. This type of design & construction is aesthetically better. These slabs which don't have beams & are directly supported by columns are called Flat slabs. To overcome the negative bending moments near the column of flat slab column capital and drop panels are used to support. This type of system has been adopted in many buildings which are constructed recently because of the advantage of reduced floor heights, cost effective and aesthetically better. Floor slab supported on beams or walls are called as conventional slab. In this type, slab thickness is less for supporting this slab, depth of beam will be large & loads are transferred by the slab to beams then to columns or shear walls.

While a conventional slab is supported by beams on two parallel or opposite side & bending in the direction perpendicular to supports are called as one way slab. Slabs supported on four sides carrying loads and bending in two perpendicular directions such slabs are known as two-way slab.

The design of reinforced concrete (RC) multi-storeyed structure for seismic cases, determination of lateral load-resisting system is an important matter. The choosing of lateral load resisting system for special building is clearly a design decision of fundamental importance, yet there is no system that is best for all buildings. Some of the factors to be consider while selecting a seismic force resisting system include architectural, construction cost, performance, design budget & non-structural coordination. Configuration of the lateral load resisting system within the building should satisfy the following condition of good design, concerning such problems torsion, structural irregularities, redundancy & the combination of systems. The most regularly used structural system are as follows moment resisting frames, shear wall system, braced system, tube in tube systems with interior columns & bundled tubes.

SHEAR WALLS are the walls provided in a structure that withstand horizontal forces such as those caused by wind or earthquakes. SHEAR WALLS are structural walls that are provided parallel to the direction of horizontal force and are exposed to bending moments and shear (in-plane) forces.

Types of shear wall -

- Core type shear wall
- C shaped shear wall
- L shaped shear wall at corners
- Parallel shear wall along the outskirts
- Non-Parallel shear wall along the outskirts
- + Shaped shear wall at center
- E Shaped shear wall

Shear Wall Position -

- At corners of building
- At centre (core) of structure
- At periphery of building

3. Objectives of the Study –

The main objective of this work includes the following:

- To carry out response spectrum analysis of RC flat slab building with diaphragm discontinuity using ETABS.
- To study the seismic behavior of RC flat slab building with & without shear.
- To understand the behavior of the building with change in the position of the diaphragm discontinuity as well as of shear wall.
- To study the influence of symmetry of the diaphragm discontinuity on the seismic performance of RC flat slab building with shear.
- To study the parameters such as storey drift, storey displacement, story shear in RC flat slab building.

4. Methodology –

The aim of this study is to see how flat slab and shear wall interacts under earthquake loads. This takes into account multi-story buildings. This study examines the structural behaviour of the structural composition proportionate to the interaction of flat slab and shear wall with the huge openings considering the effect of diaphragm discontinuity. Shear walls are provided at particular locations in a multi-story building to mitigate storey-drift and column-shear. Different models which are prepared for the study are listed below:

Model Details –

Model 1 – SMRF RC structure with Flat Slab

Model 2 – SMRF RC structure with Flat Slab with shear wall at centre

Model 3 – SMRF RC structure with Flat Slab with shear wall at corner

Model 4 - SMRF RC structure with Flat Slab with opening at centre

Model 5 - SMRF RC structure with Flat Slab with opening at centre & shear wall at centre

Model 6 – SMRF RC structure with Flat Slab with opening at centre & shear wall at corner

Model 7 - SMRF RC structure with Flat Slab with opening at corner

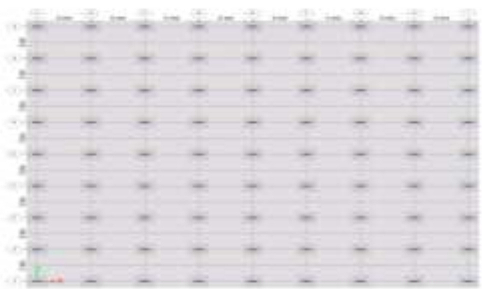
Model 8 - SMRF RC structure with Flat Slab with opening at corner & shear wall at centre

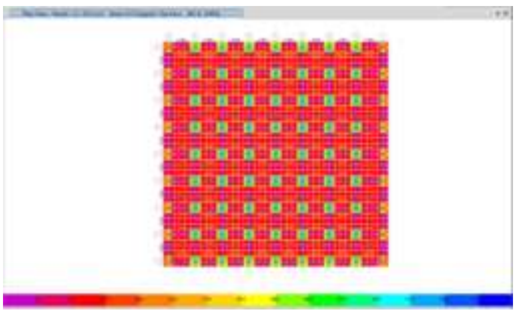
Model 9 – SMRF RC structure with Flat Slab with opening at corner & shear wall at corner

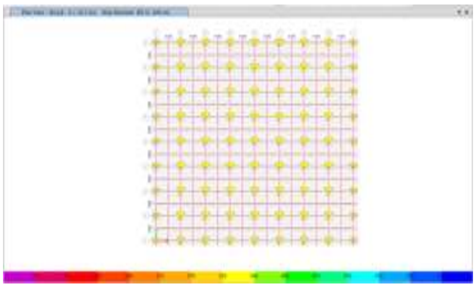
Building Parameters –

General Properties	
No. of storeys	G+5
Size of Building	42 m x 42 m
Typical Storey Height	3.5 m.
Size of Column	300 mm x 900 mm
Thickness of Slab	150 mm.
Thickness of Drop	350 mm.
Size of Drop	2 m x 2 m
Size of Opening	8 m x 8 m
Thickness of Shear wall	300 mm
Material Properties	
Grade of Concrete	M 30
Grade of Steel Rebar	Fe 500
Type of Loading	
Live Load	3 KN/m^2
Floor Finishing	1.0 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	V
Zone Factor	0.36
Importance Factor	1
Type of Soil	II - Medium
Building Type (R)	5 (SMRF)

MODEL 1







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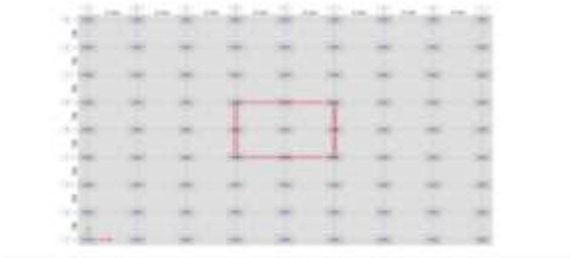
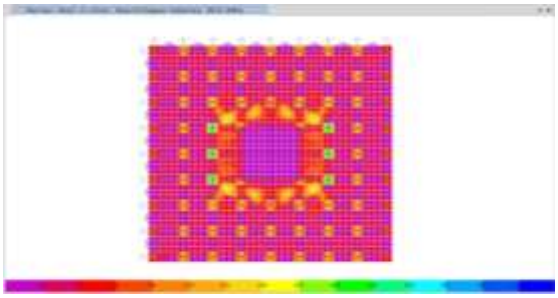
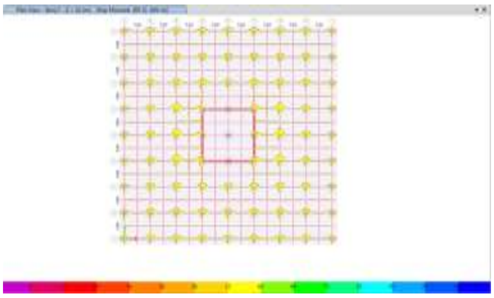
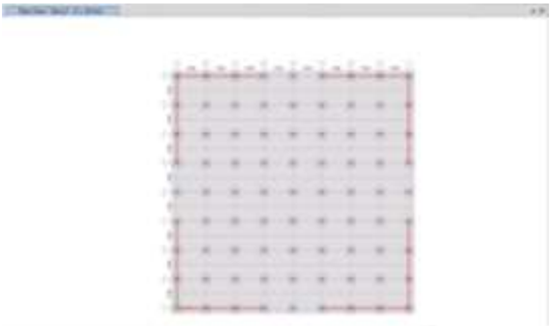
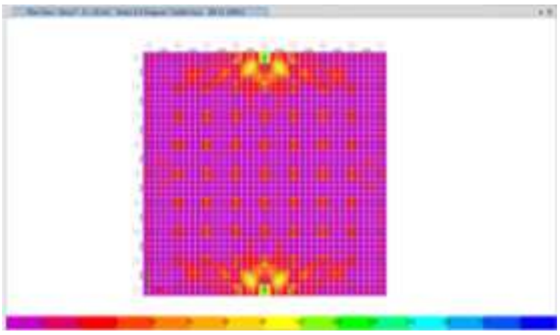


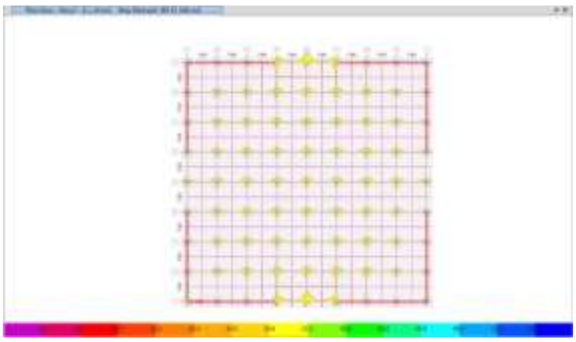




MODEL 3 –







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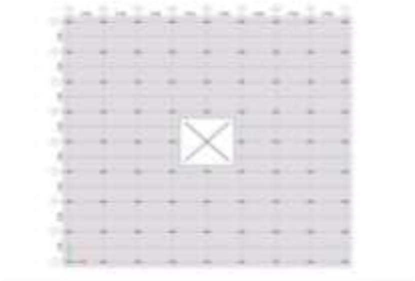
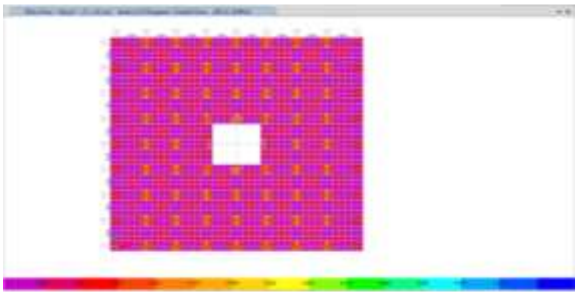
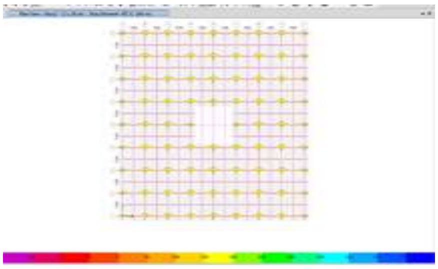
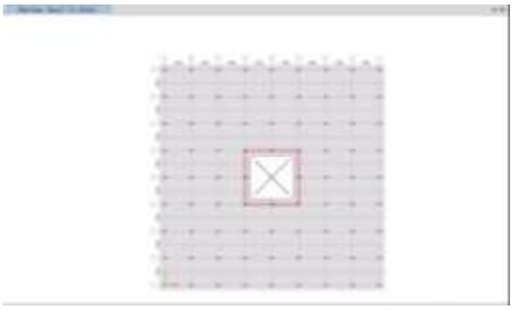
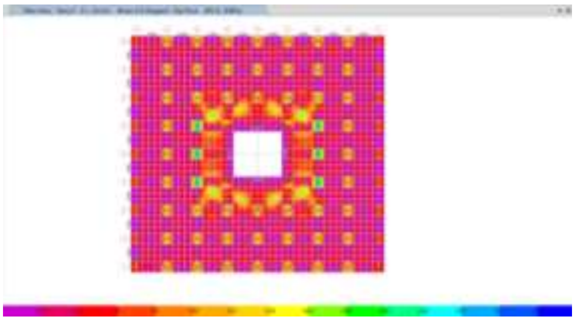


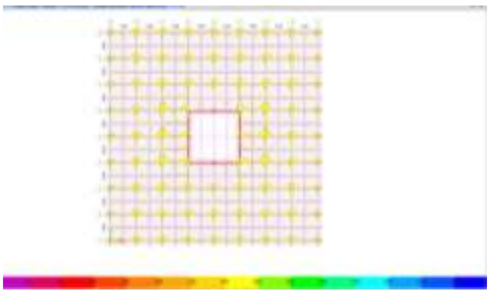




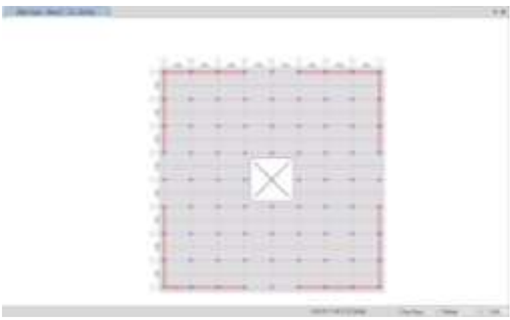
Model -5

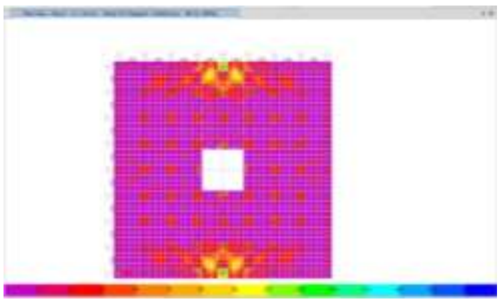


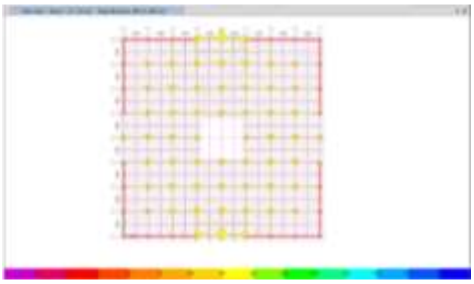




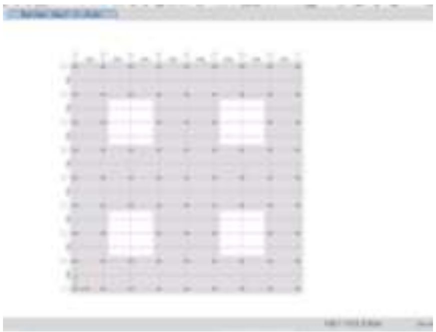
Model – 6 –

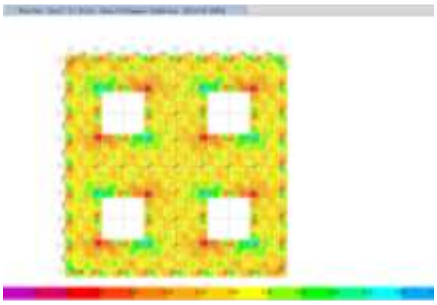


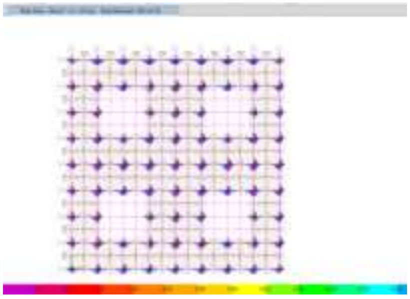




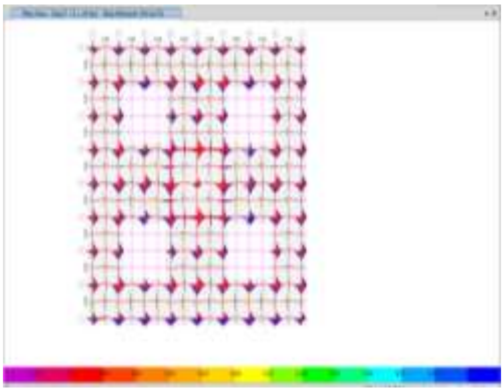
MODEL – 7

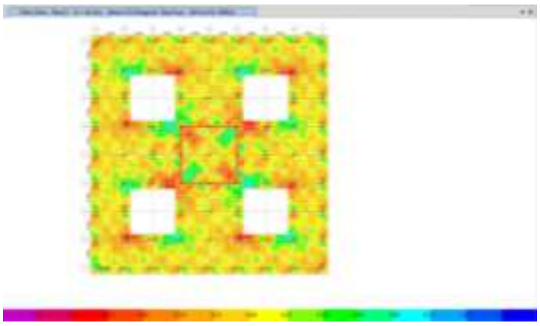


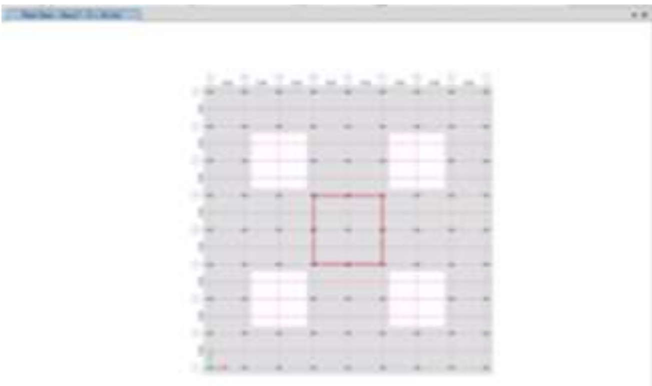




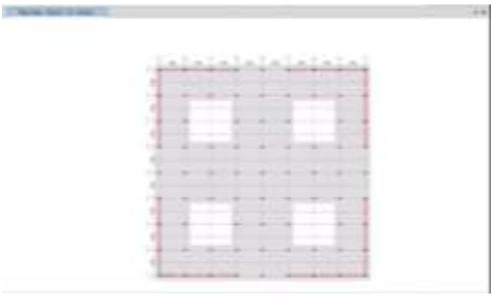
Model – 8

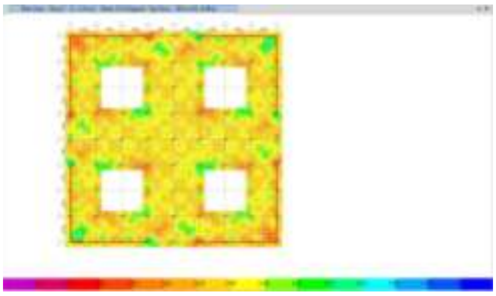


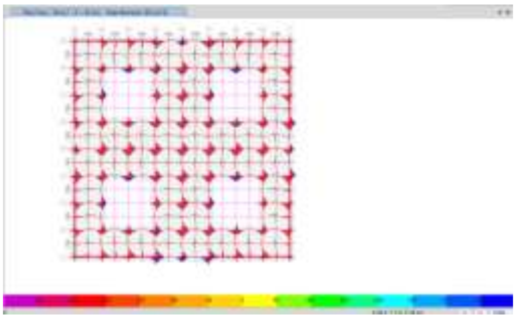




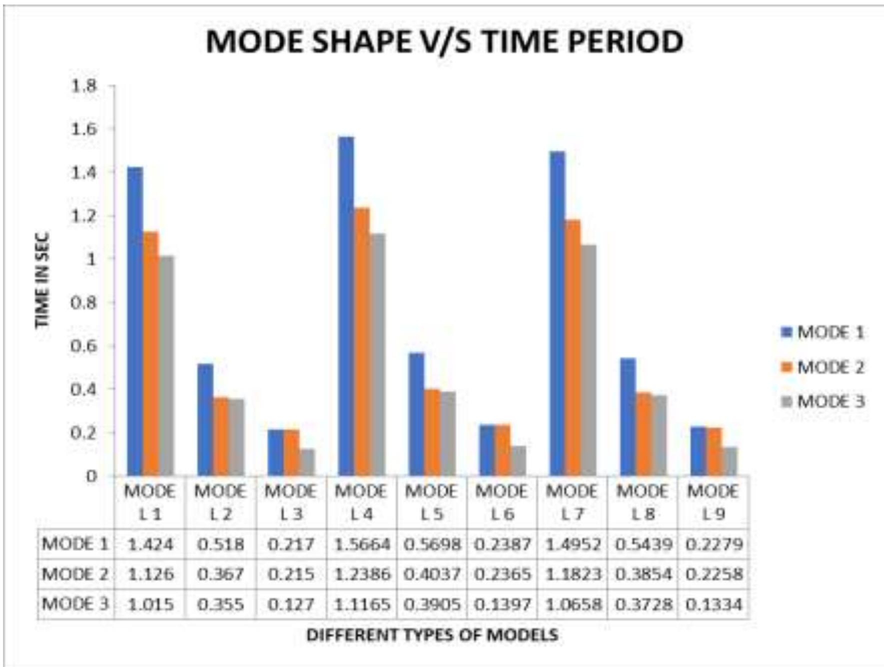
Model – 9



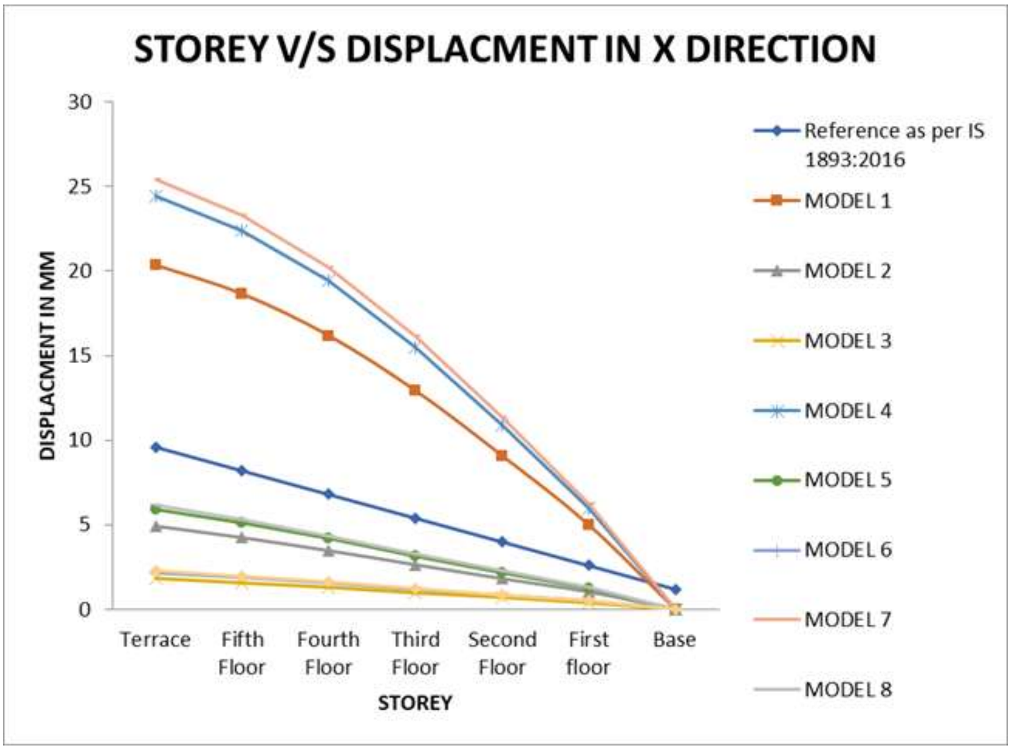


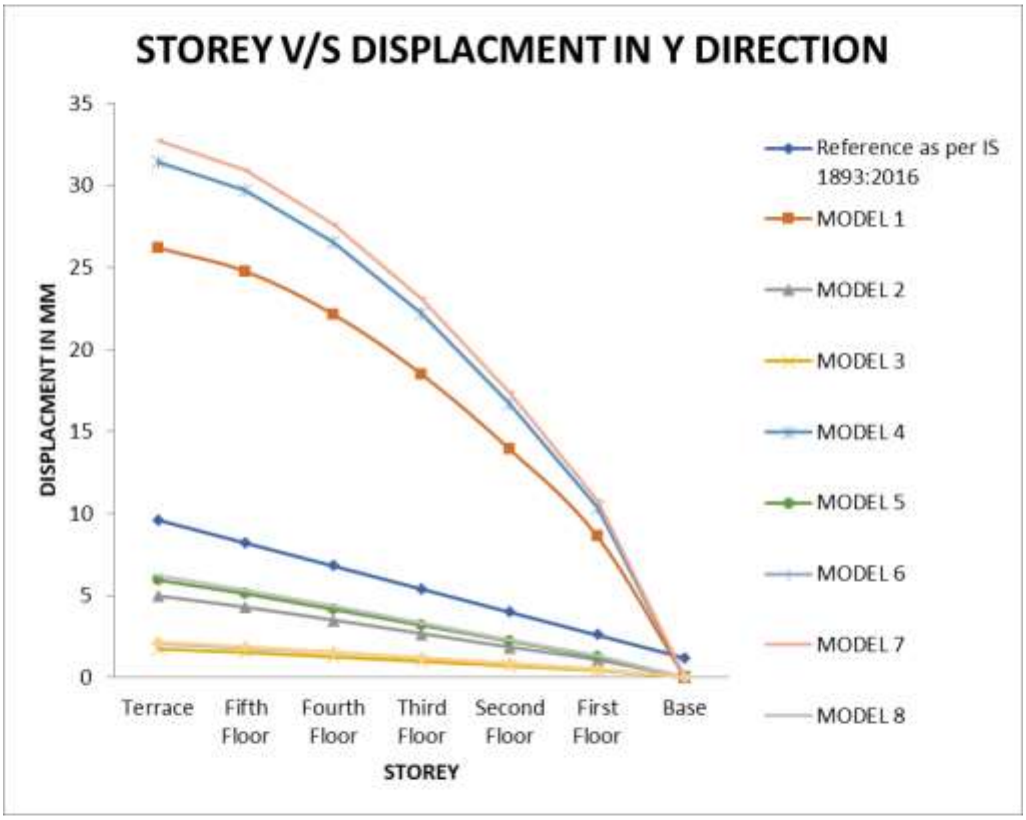


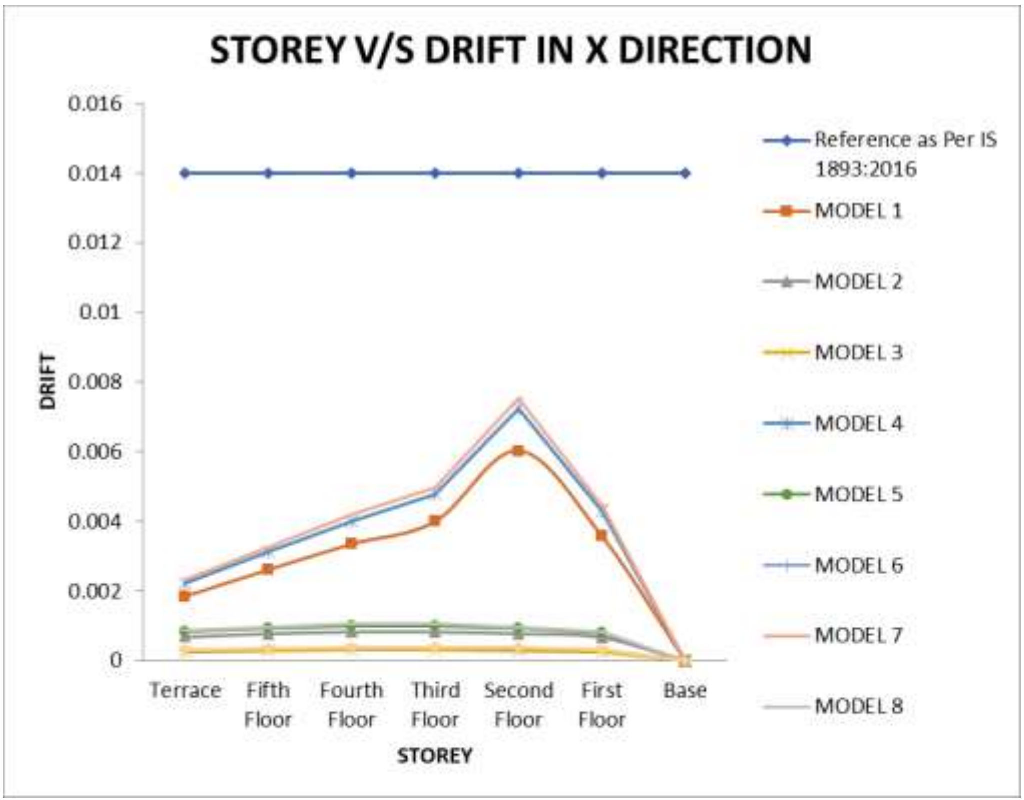
5. Results –

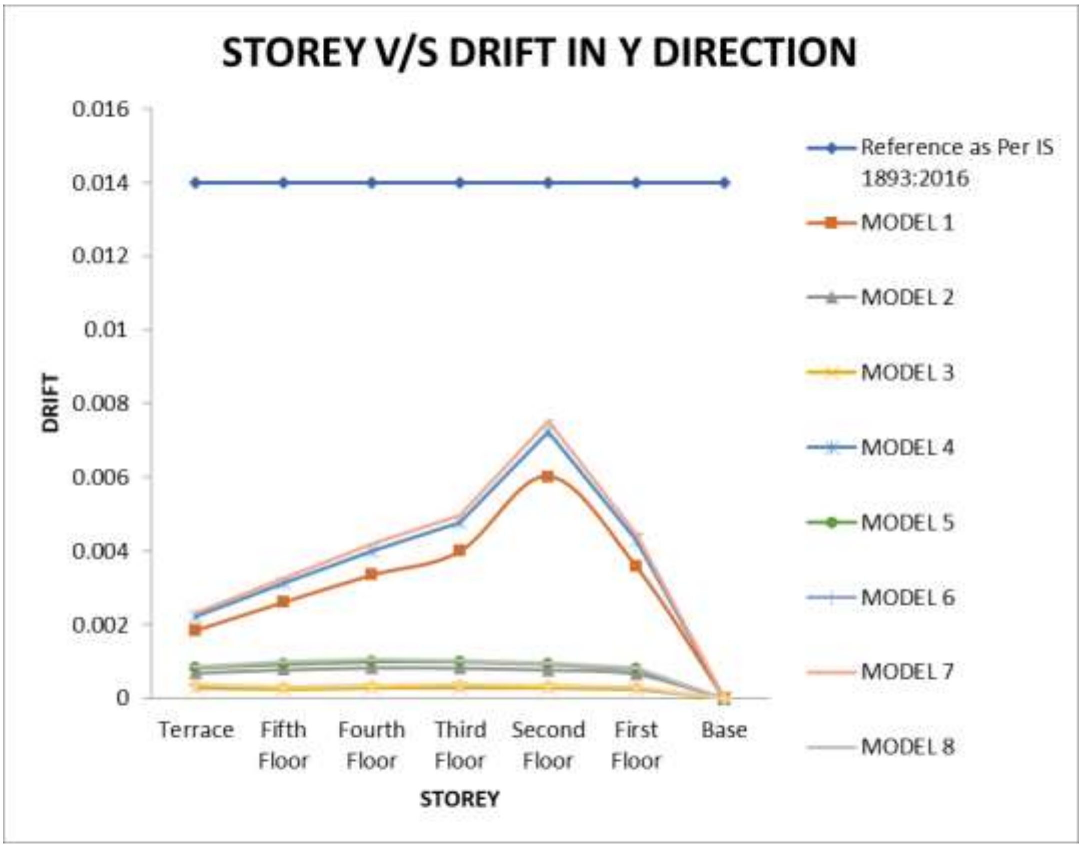


	MODE L1	MODE L2	MODE L3	MODE L4	MODE L5	MODE L6	MODE L7	MODE L8	MODE L9
MODE 1	1.424	0.518	0.217	1.5664	0.5698	0.2387	1.4952	0.5439	0.2279
MODE 2	1.126	0.367	0.215	1.2386	0.4037	0.2365	1.1823	0.3854	0.2258
MODE 3	1.015	0.355	0.127	1.1165	0.3905	0.1397	1.0658	0.3728	0.1334


STOREY V/S DISPLACMENT IN X DIRECTION
DISPLACMENT IN MM
30
25
20
15
10
5
0
Terrace
Fifth Floor
Fourth Floor
Third Floor
Second Floor
First floor
Base
STOREY
Reference as per IS 1893:2016
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8


STOREY V/S DISPLACMENT IN Y DIRECTION
DISPLACMENT IN MM
35
30
25
20
15
10
5
0
Terrace
Fifth Floor
Fourth Floor
Third Floor
Second Floor
First Floor
Base
STOREY
Reference as per IS 1893:2016
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8


STOREY V/S DRIFT IN X DIRECTION
DRIFT
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Terrace
Fifth Floor
Fourth Floor
Third Floor
Second Floor
First Floor
Base
STOREY
Reference as Per IS 1893:2016
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8


STOREY V/S DRIFT IN Y DIRECTION
DRIFT
0.016
0.014
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0.01
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Terrace
Fifth Floor
Fourth Floor
Third Floor
Second Floor
First Floor
Base
STOREY
Reference as Per IS 1893:2016
MODEL 1
MODEL 2
MODEL 3
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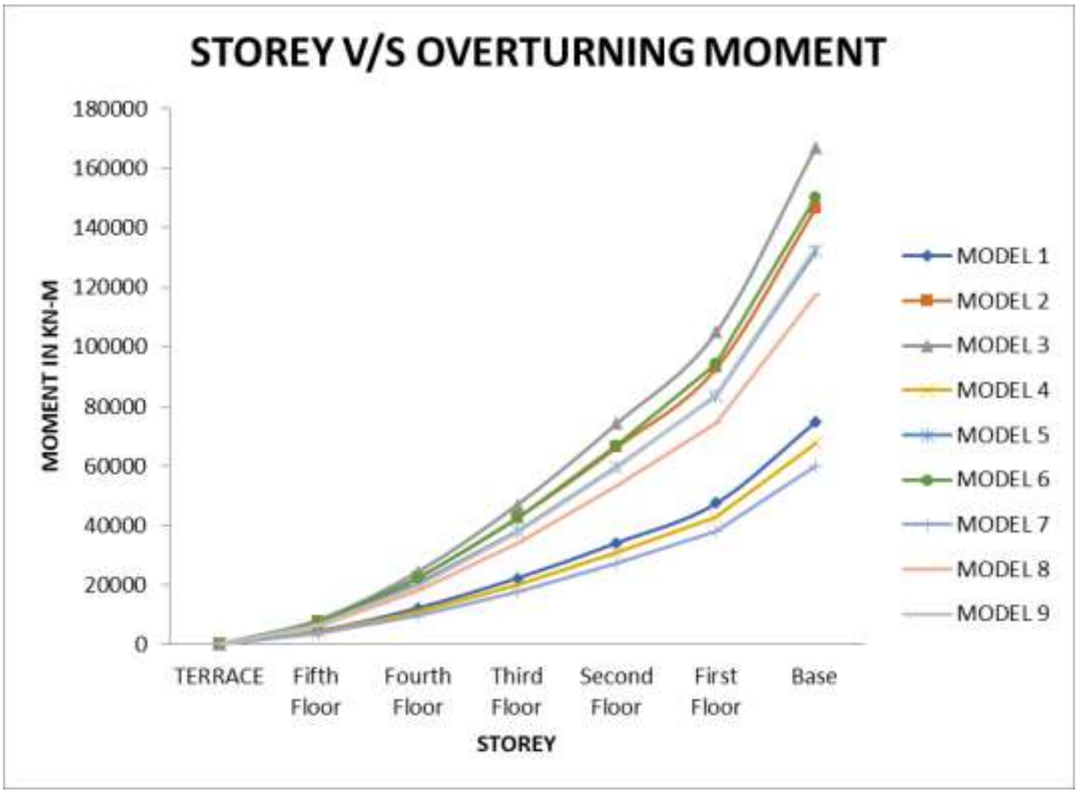
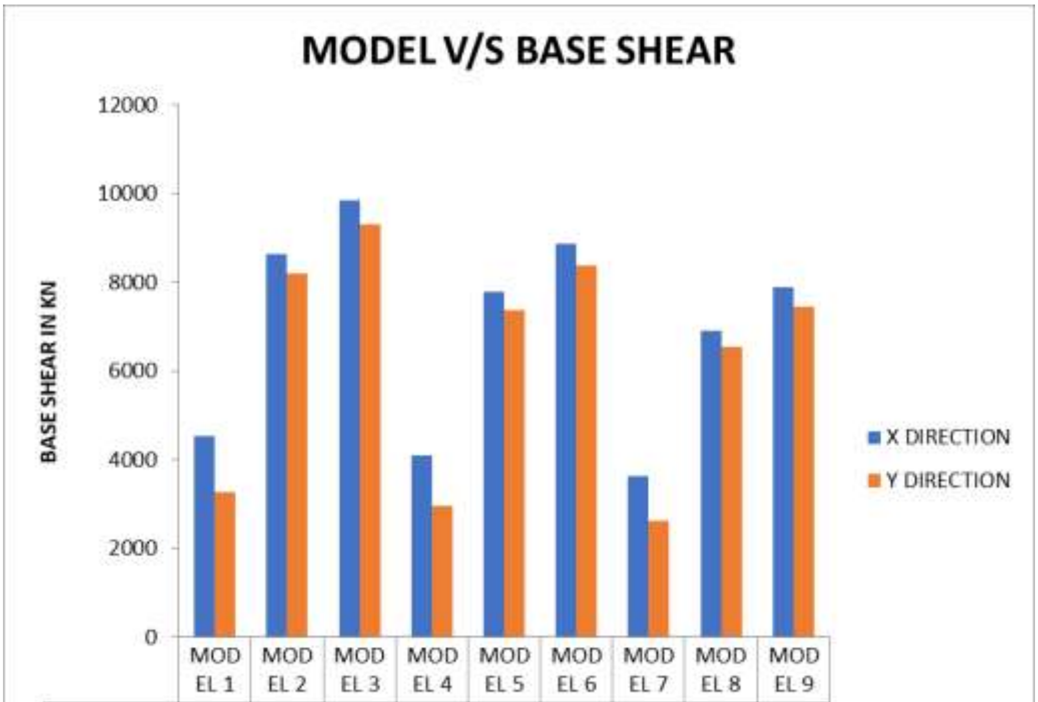
MODEL 7
MODEL 8





	MOD EL 1	MOD EL 2	MOD EL 3	MOD EL 4	MOD EL 5	MOD EL 6	MOD EL 7	MOD EL 8	MOD EL 9
X DIRECTION	4544	8645	9849	4089.6	7780.5	8864.1	3635.2	6916	7879.2
Y DIRECTION	3281	8193	9308	2952.9	7373.7	8377.2	2624.8	6554.4	7446.4

6. Conclusion –

From the results obtained by the analysis, following conclusions are drawn.

1) Opening located at centre offers least displacement and drift than openings located at corners.

2) Also, highest displacement and drift has been observed for opening located at corners.

3) Seismic base shear is more at diaphragm discontinuity located at centre and less in corner as the seismic weight of the building reduces but if we introduce the shear wall to the building then it attracts higher seismic forces which ultimately increase the base shear.

4) Hence diaphragm discontinuity located at centre is more effective in terms of displacement, drift, and base shear.

5) Stresses also plays vital role in terms of diaphragm discontinuity. This study reveals that with the opening at the corner induces higher stress than the diaphragm discontinuity at centre.

6) Least story displacement and story drift are observed for the models having shear wall at corners and diaphragm discontinuity at centre.

7) With the shear wall at corners the first two modes remains pure translational as per IS 1893:2016. In remaining conditions, the criteria have not been satisfied and the building need to be checked for torsion.

8) The displacement and drift are proportional to the height of the building. Story drift acting on all models are with the limit as per the code. For less value of displacement, shear wall need to be introduced in the system at the corners.

From the study it can be concluded that a symmetric diaphragm discontinuity at the centre position of the given regular plan area will be the optimum one.

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