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Effect of diaphragm discontinuity of RC structure with different percentage of Diaphragm Discontinuities

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Abstract
The irregularity in plan and elevation of the building may cause damage to the building during earthquake. The structure may fail due to the major damage of a building so it is necessary to know the performance of the structure to withstand against the disaster for both new and existing buildings. The behavior of multistoried building at the time of earthquake depends on the distribution of mass, stiffness, strength in both the horizontal and vertical planes of buildings. The discontinuities in stiffness, strength or mass along the diaphragm are the causes of structural weaknesses. This study presents the effect of diaphragm discontinuity and optimization of structural response of RC structure with varying percentage of diaphragm discontinuities. In the content of the study, A plan of school building is considered with the different percentage of opening for analysis and modelling using E-tabs software. Seismic behaviour of the model is obtained by performing model analysis to compare the results of base shear, story drift, maximum story displacement. The graphs and figures are obtained after the complete analysis of the model.

Keywords:*Diaphragm discontinuity, Shear wall patterns, Opening percentages, E-Tabs Software.*

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I. INTRODUCTION

GENERAL

The damages are occurred in a high-rise framed building structure from earthquake which is natural phenomenon. A vibration and shaking are caused due to earthquake at locations of structural weaknesses present in the lateral load resisting frames. When the earthquake happens the behaviour of multi-storied building in the horizontal and vertical plane depends on the mass distribution, stiffness in the frames, strength of buildings. The discontinuities in stiffness of frames, strength of building or mass along the diaphragm are the causes of structural weaknesses. The sudden variations due to earthquake causes discontinuities along the length of the building between diaphragms.

According to Indian Standard, structures are classified as regular or irregular structure. Regular structures has no significant discontinuities in plan, vertical or lateral force resisting systems where Irregular structure can cause damage easily. The confidence of the Structural engineer in the design of buildings in which the distributions of mass, stiffness and strength of the building structure are more or less uniform.

The earthquake in Nepal (2015) caused damages in which many reinforced concrete structures have been probably collapsed which shows that the need to assess the seismic adequacy for those buildings which already exists. Many buildings are having irregular configurations in both plan and elevation. So, they are subjected to earthquake. The muscular earthquake motion depends on the sharing of mass, unyielding and force in both horizontal and vertical planes of the building. The seismic force of the resisting system of the building requires designed diaphragm which distributes the lateral forces and gravity forces to the vertical elements of the resisting system consists of lateral forces.

Diaphragm Discontinuity

Diaphragm is defined as the discontinuities or variations in stiffness and mass in the form of slab openings. The variation in slab thickness is called as diaphragm discontinuity. Diaphragm is the structural element that transmits lateral loads to resisting elements of structure. According to IS-1893:2002:The immediate discontinuities or variations in Diaphragms stiffness, which includes those having cut-out or open areas greater than 50 percent of the gross surrounded diaphragm area or substitute in effective diaphragm stiffness of more than 50 percent from one floor to the next.

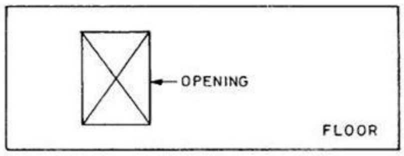

Figure 1. Diaphragm Discontinuity

As per structural engineering, a diaphragm discontinuity is a structural system which transmit lateral load to framed structure that is shear walls essentially through in-plane shear stress. The wind load and earthquake loads are known to be lateral loads.

The diaphragm is classified in two types as Rigid and Flexible. Rigid diaphragms transfer load to frames or shear walls depending on their flexibility and their location in the structure. Flexible diaphragms resist lateral forces depending on the area, irrespective of the flexibility of the members to which they are transferring the loads. The distribution of lateral forces is caused due to the flexibility of a diaphragm to the vertical components of the lateral force resisting elements in a high-rise building structure. The openings in diaphragm are causes discontinuities in the lateral stiffness, cut-outs to the adjacent floors at different levels or change in the thickness of diaphragm.

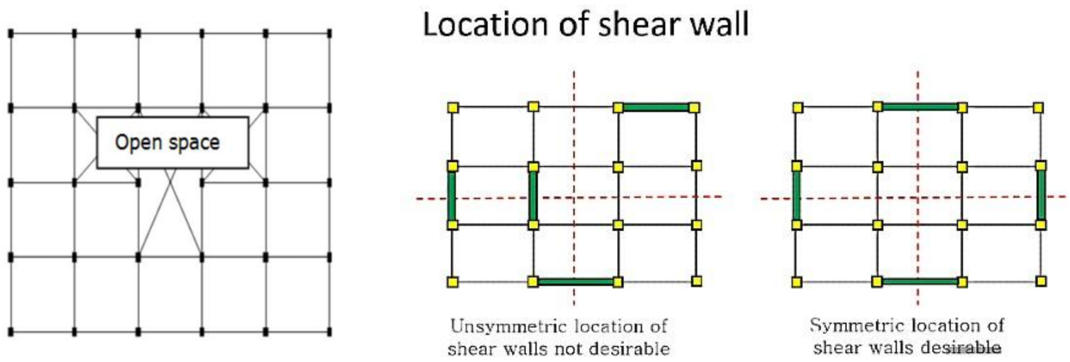

Figure 2. Frame with diaphragm discontinuity

As shown in the above figure the diaphragm discontinuity is occurred if there is an opening in middle of the floor slab. The Floor diaphragm openings are used for the purpose of stairways, shafts or other architectural features. The Response spectrum analysis is used to find the diaphragm discontinuity effect in a building structure.

Shear Wall

Shear walls are mainly constructed to resist the torsion and bending moments of the high-rise structures by the action of wind loads and gravity loads. For the lifts, staircase and columns where torsion will occur, the shear walls are constructed. The stiffness in the high-rise building structures is increased using shear wall construction, so that in seismic design or in earthquake resistance designs shear walls are mainly used in construction to keep building structure secure and strong against earthquake. Hence the construction of shear wall in high-rise structure is economical. For the diaphragm discontinuity it is impossible to transfer the forces to the shear wall. The horizontal bracing system is included in the diaphragm.

- The size and location of openings may vary depending on purposes of the openings. The size and location of shear walls is extremely critical.
- Shear walls are generally located at the sides of buildings or arranged in the form of core that houses stairs and lifts.
- Shear walls in a building is a structurally efficient solution to stiffen the building because they provide the necessary lateral strength and stiffness to resist horizontal forces.

II. METHODOLOGY

- Selection of appropriate plan of a multistorey building for studying effect of diaphragm discontinuity on its performance.
- Fixing parameters with respect to percentage of diaphragm discontinuity, layout and percentage of shear walls.

- Modeling of the structures as per IS standard guidelines relative to choose of loads and their combination.
- Performing analysis and consolidation of results.
- To formulating recommendations.
- Analyze the results and arrive at conclusions.

Objectives:
- To develop the RC framed structural model with varying percentage of diaphragm discontinuities.
- To study influence of varying percentages of shear walls on performance of RC framed structural model with diaphragm discontinuities.
- To investigate variation in storey drifts, story displacements, base shear and story shear under the earthquake load and gravity loads.
- To formulate recommendations for choosing diaphragm discontinuity based on the results of the analysis performed.

Scope Of the Study:
- To develop the RC framed structure with varying percentage as 20%, 25%, 30% of slab opening having G+5 story has been modelled.
- To develop the RC framed structure with varying percentage of slab openings for without shear walls and with shear walls at corners (case 1) and shear walls at the slab opening periphery as well as corners (case 2).
- The models have developed as per static analysis as per IS 1893-2002 (Part 1).
- The seismic parameters like base shear, story shear, story displacement and story drift have been obtained for Equivalent static analysis for all developed RC framed models.

III. MODELING AND ANALYSIS

Design Parameters

- Grade of concrete: M25
- Grade of steel: Fe500
- Size of column(mm): 300x500
- Size of Beam (mm): 300x600
- Slab depth (mm): 125
- Story height: 3m
- Plinth height: 1.5m
- Wall thickness: 8"

Loads

All moving loads come under Live Load.

-L. L on floors- 3kN/m^2- L.L on Roofs :1.5kN/m^2

- F.F on Floors: 2kN/m^2- F. F on Roofs: 1kN/m^2

Codes Used for Analysis
- IS 456:2000
- IS 1893 (Part 1): 2002
- IS 1893 (Part 2): 2002
- SP 16: 1980
- IS 875 (Part 1): 1987
- IS 875 (Part 2): 1987

Models
1. The plan of dimension (38m x 48.7m) with story height 3m and plinth beam height as 1.5m have been considered by few specifications by undergoing trial and error method to keep the structure safe (against earthquake) and limitations are applied as per IS 1893-2002 to investigate the response of RC framed structures with and without shear walls for varying percentages of slab openings.
2. The percentages of slab openings for RC frames are varied as 20% , 25% ,and 30% fixed support is considered as the type of support at the base of the building.
3. The analysis is done for different models as- a. Percentage varying of slab opening without shear walls. b. Percentage Varying of slab opening with shear wall at corners (Case 1) and shear walls at center and periphery of the wall (Case 2).
4. Seismic parameters (for OMRF building) such as type of soil, zone factor, response reduction factor are derived from the IS codal provisions of IS1893-2002 (part 1).

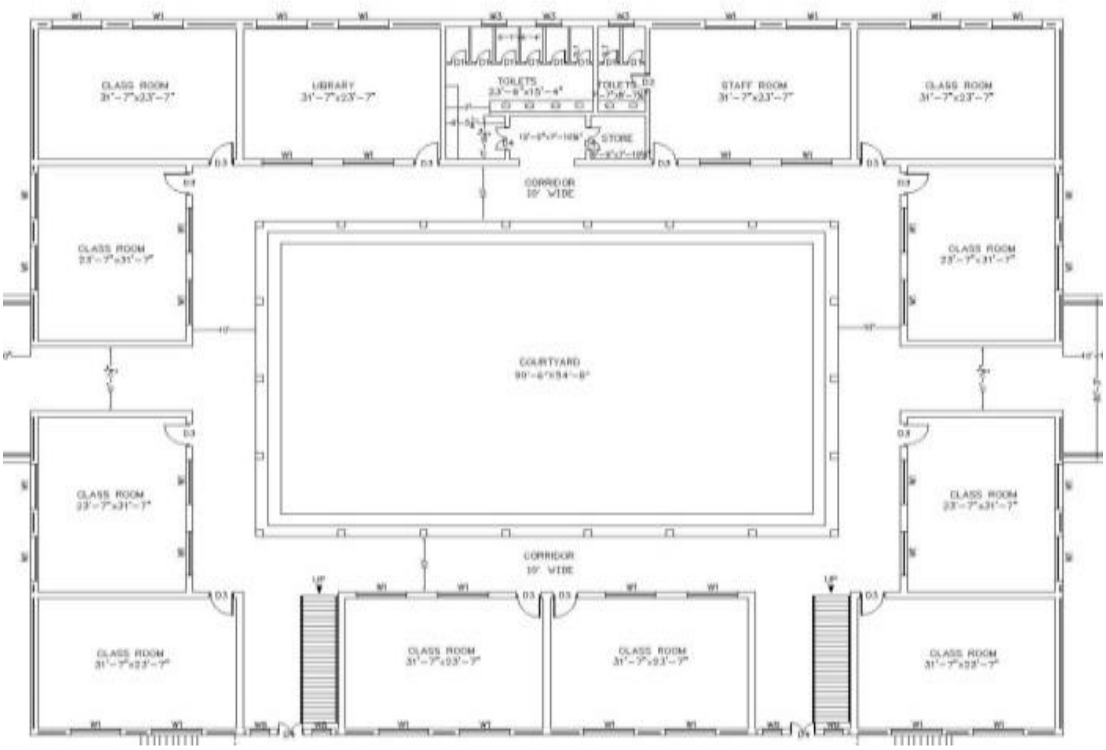

Figure 3.1. School Building Plan

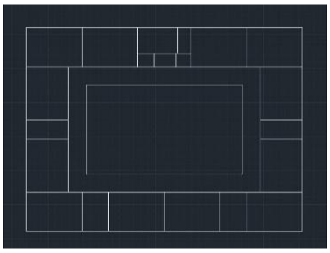

Figure 3.2. centerline Plan

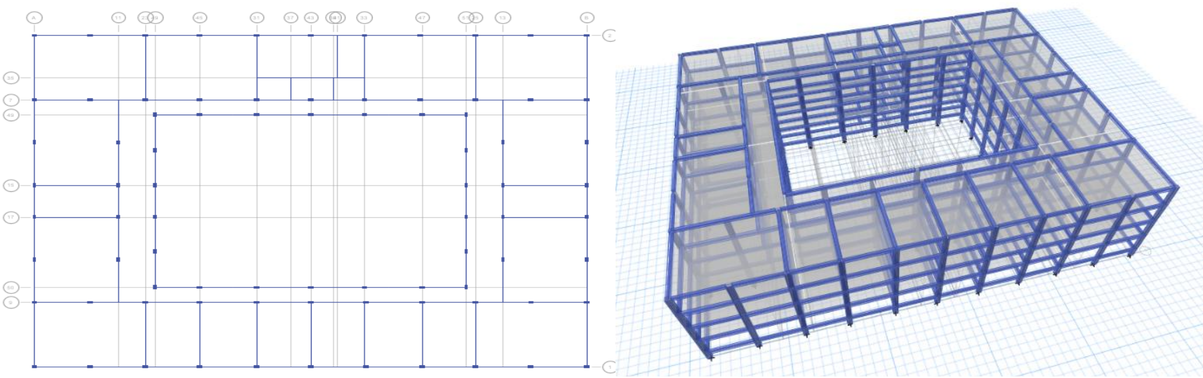

Fig. 3.3 Elevation plan & 3D view for 20% slab opening without shear wall.

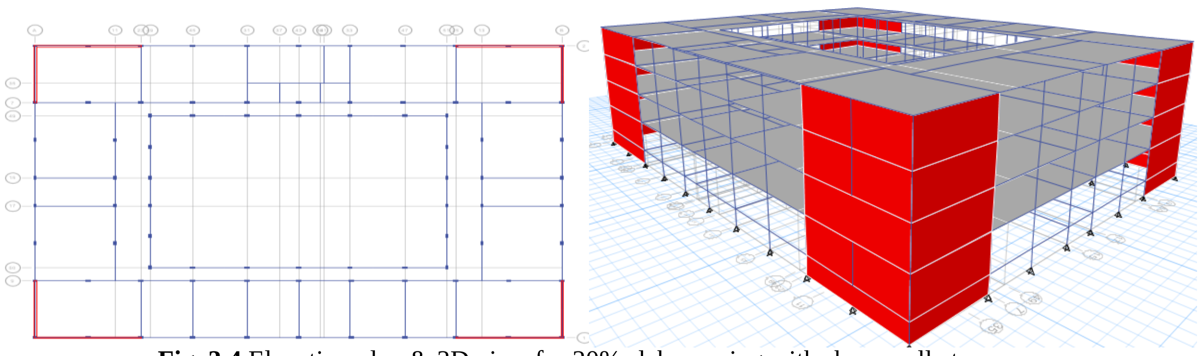

Fig. 3.4 Elevation plan & 3D view for 20% slab opening with shear wall at corner.

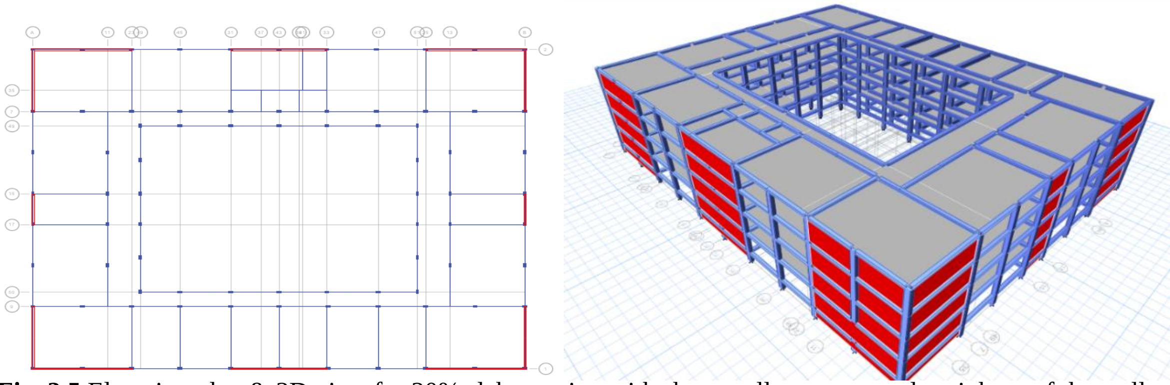

Fig. 3.5 Elevation plan & 3D view for 20% slab opening with shear wall at corner and periphery of the wall.

IV. RESULTS AND DISCUSSION

DISCUSSION ON STORY SHEAR RESULTS

The maximum story shear results for different percentages of diaphragm openings without shear wall, with shear walls case 1 and case 2 along X and Y direction are shown in the table given below:

Table 4.1: MAXIMUM STORY SHEAR ALONG X DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	2875.70	5290.95	5185.70
Model 2	2595.75	4990.45	4905.80
Model 3	2135.95	4275.05	4225.90

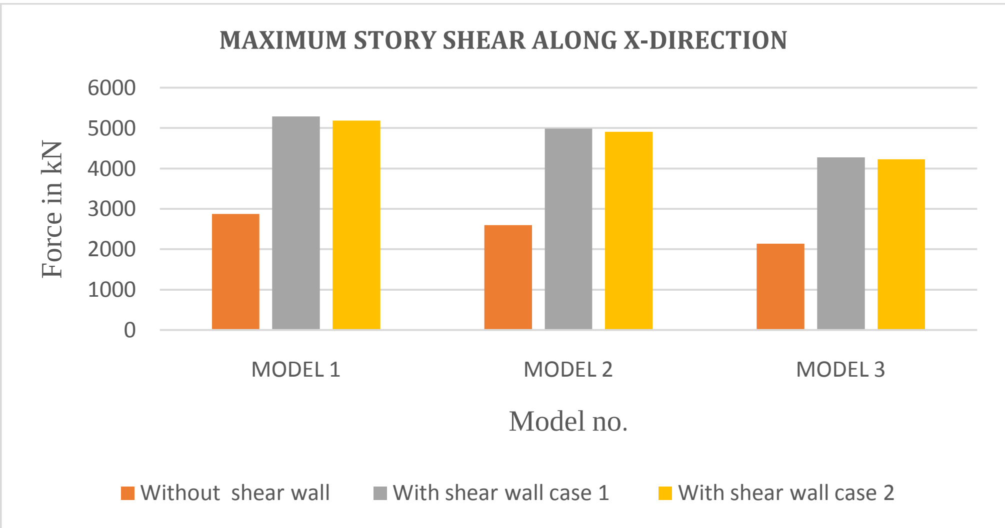

Fig 4.1: Maximum story shear along X-Direction

Table 4.2: MAXIMUM STORY SHEAR ALONG Y DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	2875.70	6470.95	6285.45
Model 2	2595.75	6150.95	5990.65
Model 3	2135.95	5865.50	5690.85

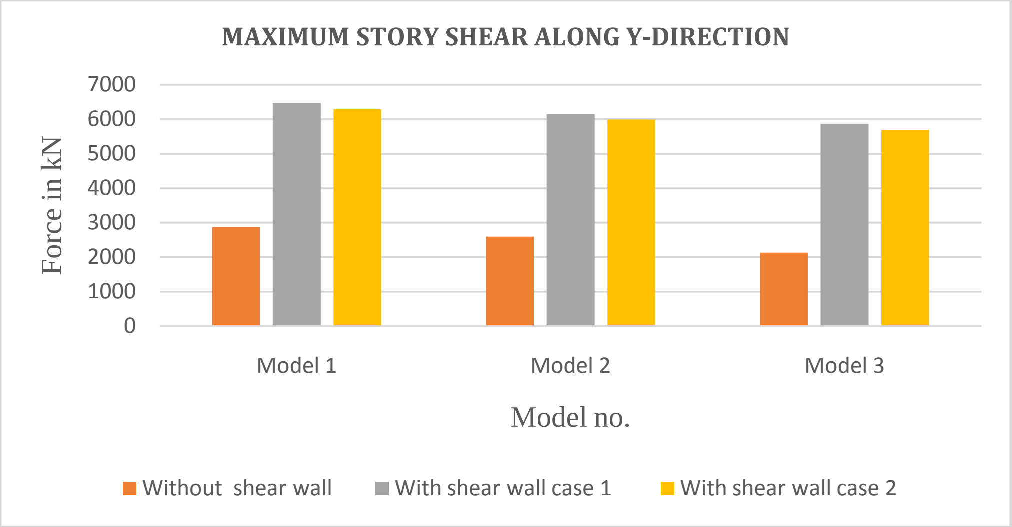

Fig 4.2 Maximum story shear along Y-Direction

Fig. 4.1 and 4.2 shows the maximum story shear for all three developed models along X-direction and Y-direction. It has been observed that Model 1 with shear wall pattern at every corner is having maximum values of story shear and Model 3 is having minimum values.

DISCUSSION ON STORY DISPLACEMENT RESULTS

The maximum story displacement results for both along X & Y direction for a different percentage of diaphragm opening for various models and various cases of shear walls are shown in Table 4.3 & 4.4 and plotted on fig 4.3 & 4.4.

Table 4.3: MAXIMUM STORY DISPLACEMENT ALONG X DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	0.247	0.246	0.25
Model 2	0.106	0.109	0.167
Model 3	0.752	0.118	0.102

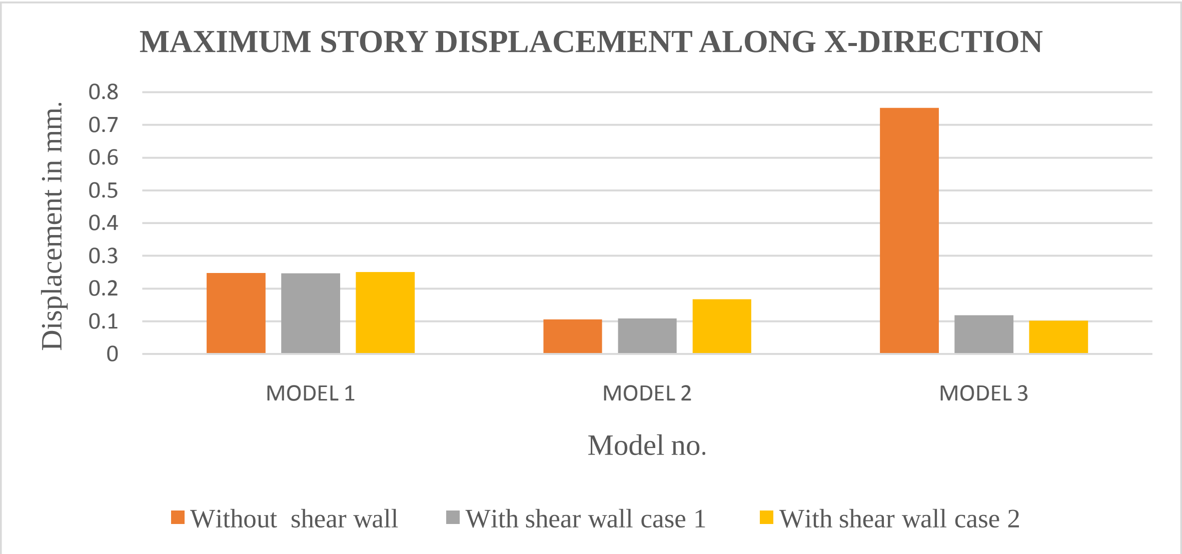

Fig 4.3: Maximum story displacement along X-Direction

Table 4.4: MAXIMUM STORY DISPLACEMENT ALONG Y DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	0.509	0.463	0.369
Model 2	0.224	0.216	0.245
Model 3	0.804	0.164	0.243

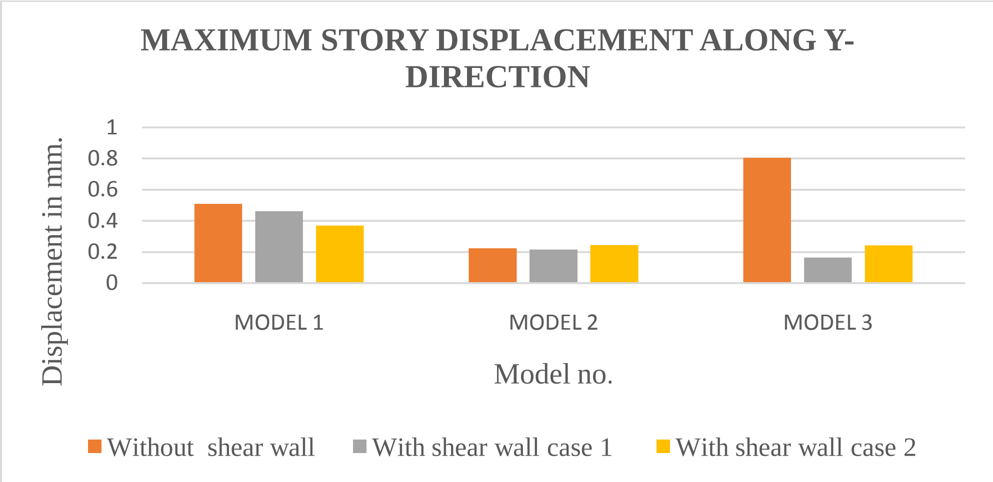

Fig 4.4: Maximum story displacement along Y-Direction

Fig. 4.3 & 4.4 shows that the maximum story displacement along both X and Y directions. From the above graph it has been observed that the Model 1 of without shear wall pattern have maximum values of story displacement and Model 3 have the minimum values for story displacement.

DISCUSSION ON STORY DRIFT RATIO RESULTS

The maximum story drift ratios along X and Y directions for the different percentages of slab/Diaphragm openings for all models of having different cases of with shear wall and without shear wall case 1 and case 2 are shown in table given below and chart is plotted for all 3 models. The maximum story drift ratio results for all the models are within the limits of 0.004H.

Table 4.5: MAXIMUM STORY DRIFT RATIO ALONG X DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	0.000165	0.000164	0.000167
Model 2	0.00007	0.000072	0.000111
Model 3	0.000093	0.000029	0.000042

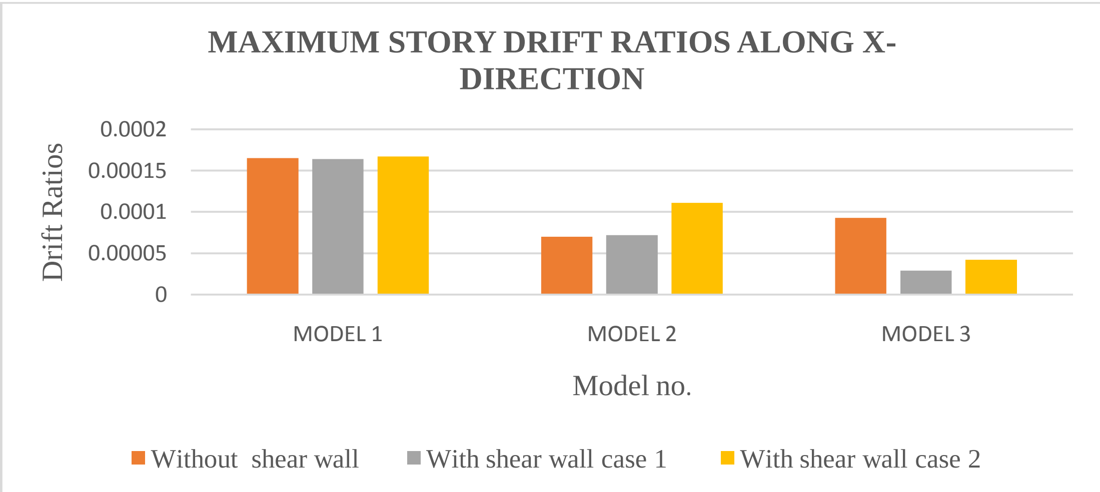

Fig 4.5: Maximum story drift along X-Direction

Table 4.6: MAXIMUM STORY DRIFT ALONG Y DIRECTION

MODELS	WITHOUT SHEAR WALL	WITH SHEAR WALL CASE 1	WITH SHEAR WALL CASE 2
Model 1	0.000339	0.000308	0.000246
Model 2	0.000149	0.000144	0.000083
Model 3	0.000165	0.00014	0.000112

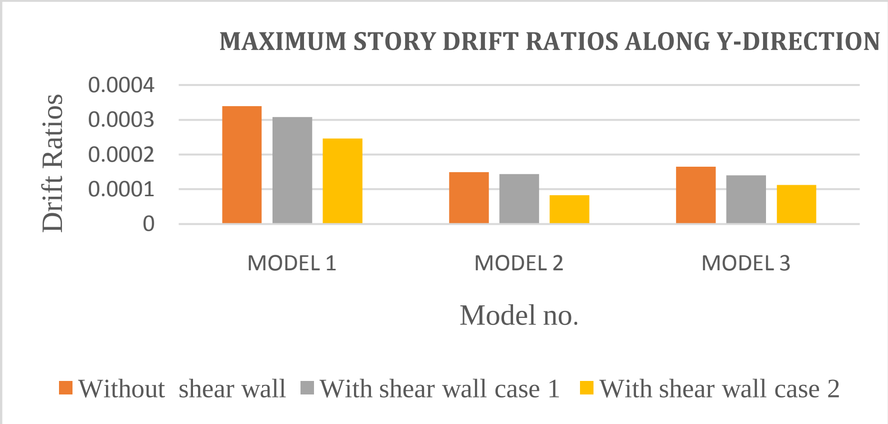

Fig 4.6: Maximum story drift along Y-Direction

Fig. 4.5 & 4.6 shows that the maximum story drift values along both X and Y direction. From the above graphs it is noted that the outcome of Model 1 without shear wall pattern is having maximum values for story drift ratio and Model 3 is having minimum values for story drift ratio.

V. CONCLUSION

- The results shows that the story shear is maximum for 20% opening having shear wall at corners. Which shows that decrease in the story shear increases opening percentage.
- Comparative results for storey displacement are higher without shear walls as compared to the model with shear wall.
- Story drift ratios for all models within the limits of 0.004H as per codal provision of IS 1893-2002.
- Base shear is greater only in case 2 of with shear walls at corners and at the periphery of wall.
- Based on results, I can conclude that the variation of graph varies in model 1 of having 20% opening.

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