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Seismic Response of Multi-Storey Building with Various Openings in Shear Wall

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ABSTRACT

Shear walls are introduced in modern tall buildings to make the structural system more efficient in resisting the horizontal loads that arises from wind and earthquake. The introduction of shear wall represents structurally efficient solution to stiffen a building structural system. The main function of shear wall is to increase the rigidity of lateral load resistance. It is a structural element which provides stability to structure from lateral loads like wind load and seismic loads. Shear walls are placed parallel to the plane of the wall, thus providing adequate strength and stiffness to control lateral displacements. The stiffness and strength of wall may decreased by the reduction in the concrete area and the discontinuity of the reinforcement due to opening. To know the responses of providing openings and the behaviour of shear wall without openings is the aim of the given study. Hence, it is necessary to demonstrate work on the analysis, design and post effects of shear walls when seismic forces are applied. In this project the analysis of various opening percentages are analysed under the opening taken with respect to door sizes. There are total 7 different cases are taken with door with ventilation opening. The opening percentages taken as 11.23%, 12.81%, 14.38%, 14.5% 16.53% 18.56% in different six cases compare with building model without opening. The A G+15 building is taken with plinth area of 900 sq. m. The structure can be analysed under zone III by response spectrum method.

Keywords: Shear wall, Door with Ventilation opening, Zone III, Response Spectrum Method, G+15 building.

1.INTRODUCTION

For an engineer who is new to the design of multi-storey buildings, it is important that they follow a logical sequence at different stages of the design process. The design part involves calculating the load-bearing capacity, finding the dimensions of all building elements, planning and orienting, and placing other parts such as doors, windows, grilles, ducts. Other things of construction are resistance to lateral loads. This is also satisfied by the Code provision and construction by law. It is important for the designer to understand some general principles of good design so that the result is not only reasonable but also good.

The shear wall and its opening concept: A shear wall is a structural component used to attack seismic forces or forces equivalent to a wall plane. Typically, it is provided in high-rise buildings to prevent complete failure of the structure under seismic load. We can control the lateral bending of the structure by providing a cutting wall. The cutting wall absorbs the shear forces and prevents the location of the structure from changing and eventually collapsing. However, it should be noted that the structure of the retaining wall must be very clear, if not, the result will be negatively affected. The shear wall consists of reinforced panels (shear panels) to counteract the lateral loading effect on the structure. Seismic loads and wind shear walls are among the most common loads they can withstand. When a cutting wall is built, it is created in the form of a line of solid, reinforced panels. Therefore, they are also known as solid wall lines in some areas. The wall seamlessly connects the two outer walls and reinforces the other intersecting walls in the structure. Supporting is done with heavy beams and metal brackets or support beams that keep the wall strong and sturdy. It is now an integral part of medium and high-rise buildings. In order for the building to have an earthquake-resistant design, these walls are placed on the planes of the building, which reduces lateral displacements under seismic loads. In this way the cut wall frame structures are achieved.

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2. OBJECTIVES & METHODOLOGY

A. Objectives of the Work:

- To study the variation opening concept of shear wall.
- To model the various models with variation in opening % with respect to door/window/duct area requirement.
- To analyze the building under earthquake analysis for India under zone 3 by Response spectrum Analysis method.
- To find different result parameters.
- To find optimum percentage opening for the multistory building.

B. Building Configuration:

Various models are framed for analysis and assessment of structure to accomplish the a foresaid objectives of the current study.

Table 1: Building cases with and without openings

S. no.	Abbreviations	Door size (in foot)	Door size (in m)	Ventilation used	Bay (m)	Opening (%)
1	NOC	-	-	-	5 x 4	0%
2	OCD1	3’6” x 7’	1.07 x 2.1	-	5 x 4	11.23%
3	OCD2	4’ x 7’	1.22 x 2.1	-	5 x 4	12.81%
4	OCD3	4’6” x 7’	1.37 x 2.1	-	5 x 4	14.38%
5	OCDV4	3’6” x 7’	1.07 x 2.1	3’6” x 2’ (1.07m x 0.61m)	5 x 4	14.5%
6	OCDV5	4’ x 7’	1.22 x 2.1	4’ x 2’ (1.22m x 0.61m)	5 x 4	16.53%
7	OCDV6	4’6” x 7’	1.37 x 2.1	4’6” x 2’ (1.37m x 0.61m)	5 x 4	18.56%

Case NOC means when no opening is considered, case OCD means when only door opening is considered and OCDV means when door + ventilation opening is considered.

3.MODELLING AND ANALYSIS

A. Modeling and Seismic Data:

Table 2: Structural Modeling Data

Constraint	Assumed data for all buildings
Type of building	Semi-Commercial
Built up area of building	900 sq. m
Floors configuration	G + 15
Height of building	67.50 m
Floor to floor height	4 m
Depth of foundation	3.5 m
Beam sizes	0.40 m X 0.30 m, 0.45 m X 0.30 m, 0.60 m X 0.40 m
Column sizes	0.45 m X 0.45 m, 0.50 m X 0.50 m, 0.65 m X 0.65 m
Slab thickness	190 mm (0.19 m)
Shear wall thickness	270 mm (0.27 m)
Material properties	M 30 Concrete, Fe 500 grade steel

Table 3: Seismic Data

S. No.	Description	Details
1	Seismic Zone	Zone-3
2	Zone Factor	0.16
3	Soil Type	Medium
4	Importance Factor	1.2
5	Response Reduction Factor	4
6	Direction	Both X and Y
7	Damping ratio	5%
8	Fundamental natural period of vibration (T_a)	$0.09*h/(d)^{0.5}$
9	T_{ax}	0.9606 seconds

B. Models plans:

Details of the building models

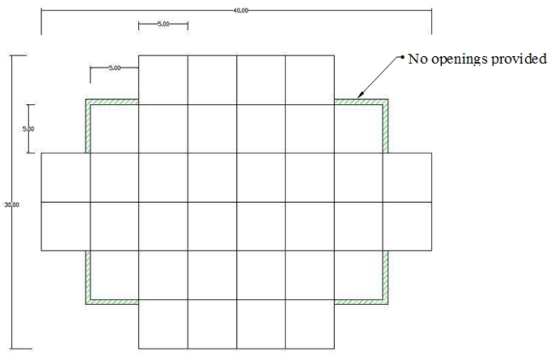


Fig. 1: Building cases (NOC)

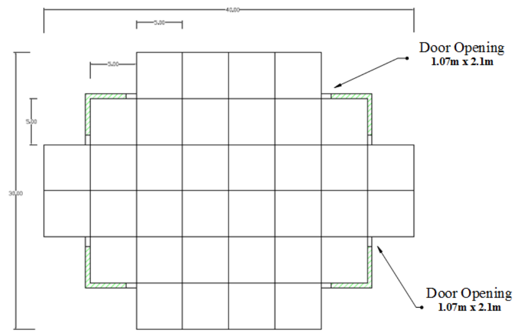


Fig. 2: Building cases (OCD1)

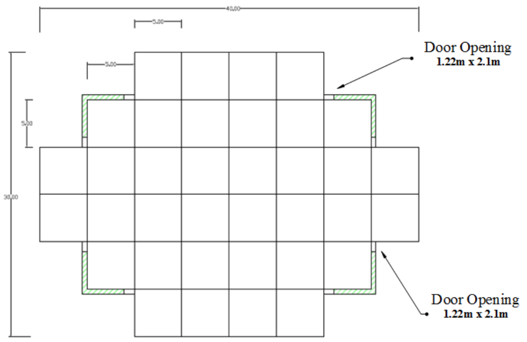


Fig. 3: Building cases (OCD2)

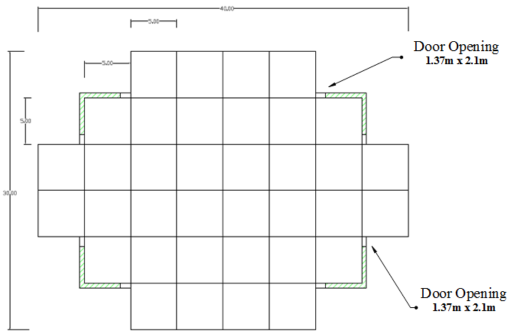


Fig. 4: Building cases (OCD3)

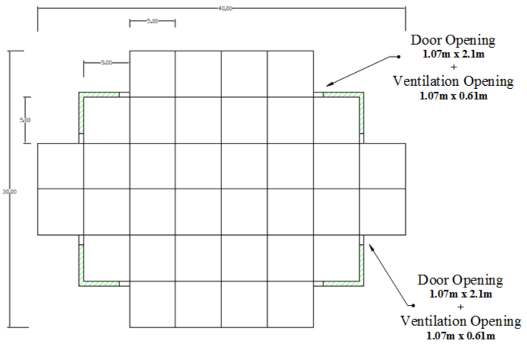


Fig. 5: Building cases (OCDV4)

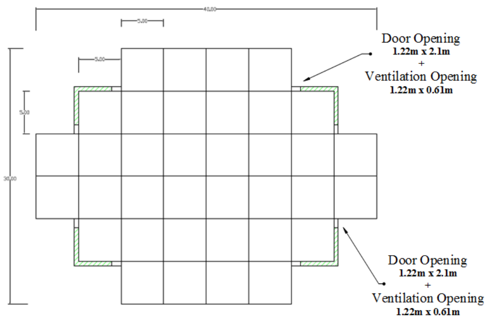


Fig. 6: Building cases (OCDV5)

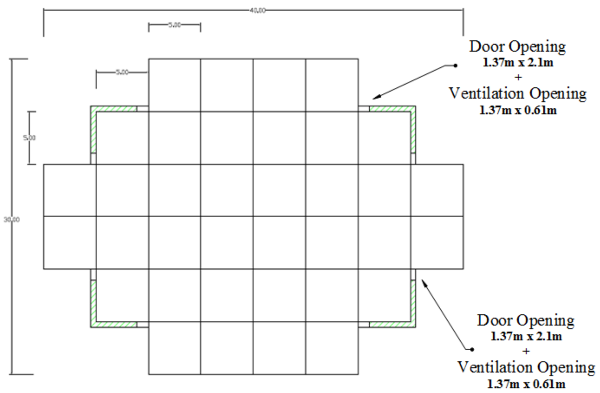


Fig. 7: Building cases (OCDV6)

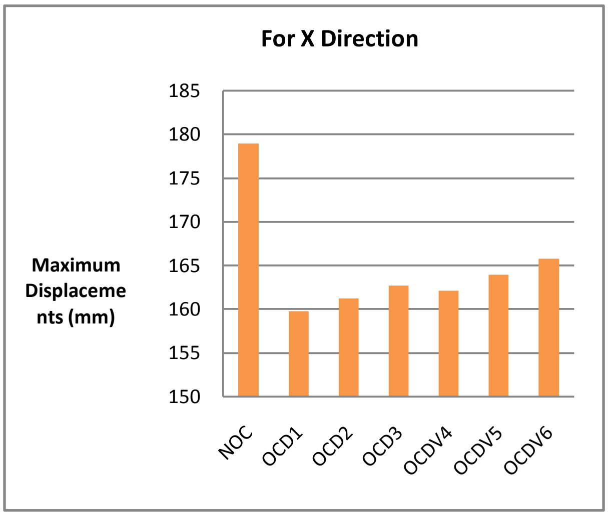
RESULTS AND DISCUSSIONS

The results are based on the modeling and analysis of various models is as follows:

A. Maximum Displacement

Table 4: Maximum Displacement in X and Z directions

Case	Maximum Displacement (mm)	
	For X Direction	For Z Direction
NOC	178.929	157.138
OCD1	159.702	140.745
OCD2	161.171	142.062
OCD3	162.669	143.404
OCDV4	162.053	142.940
OCDV5	163.888	144.595
OCDV6	165.756	146.283



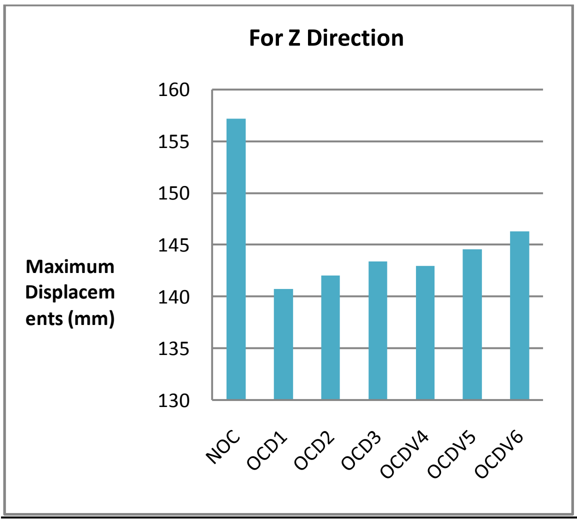


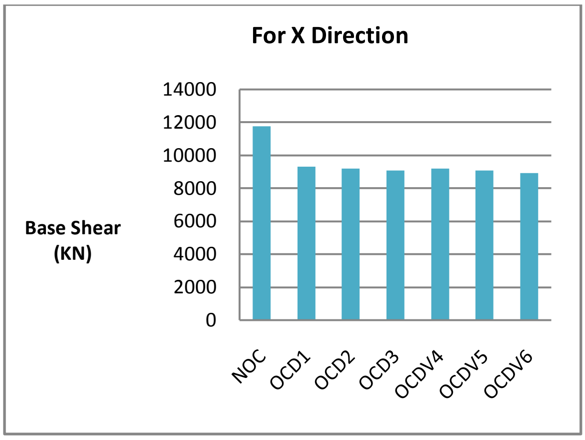
Fig. 8: Max. Displacement in X direction

Fig. 9: Max. Displacement in Z direction

B. Base Shear

Table 5: Base Shear in X and Z directions

Case	Base Shear (KN)	
	X direction	Z direction
NOC	**11757.92**	**10193.92**
OCD1	**9293.30**	**8050.28**
OCD2	**9177.63**	**7950.56**
OCD3	**9058.91**	**7848.11**
OCDV4	**9182.35**	**7954.19**
OCDV5	**9051.52**	**7841.25**
OCDV6	**8918.80**	**7726.55**



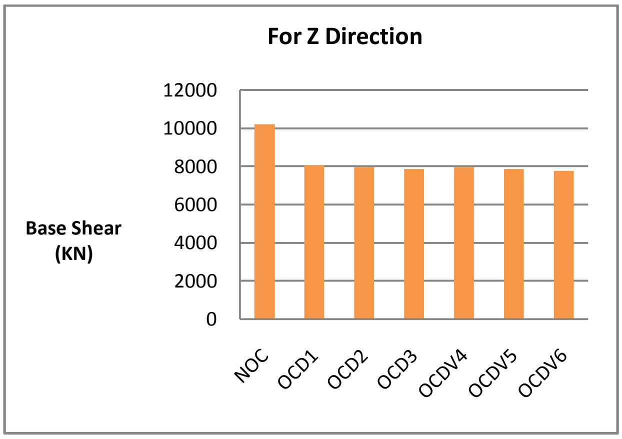


Fig 10 : Base Shear in X direction

C. Maximum Axial Forces in Column

Table 6: Maximum Axial Forces in Column

Case	Column Axial Force (KN)
NOC	9831.031
OCD1	6978.11
OCD2	7137.708
OCD3	7281.758
OCDV4	6820.174
OCDV5	6820.823
OCDV6	7056.439

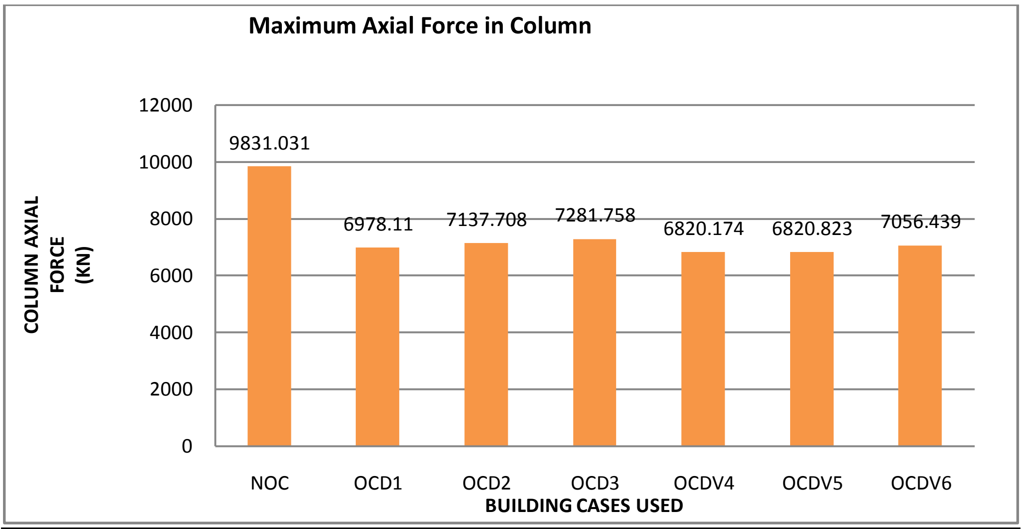


Fig.11: Maximum Axial Forces in Column

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D. Maximum Shear Forces in Columns

Table 7: Maximum Shear Forces in Columns

Case	**Column Shear Force (KN)**	
	Shear along Y	**Shear along Z**
NOC	442.223	350.060
OCD1	276.221	244.379

OCD2	293.138	260.829
OCD3	333.853	277.579
OCDV4	549.608	475.496
OCDV5	541.078	515.974
OCDV6	538.061	492.721

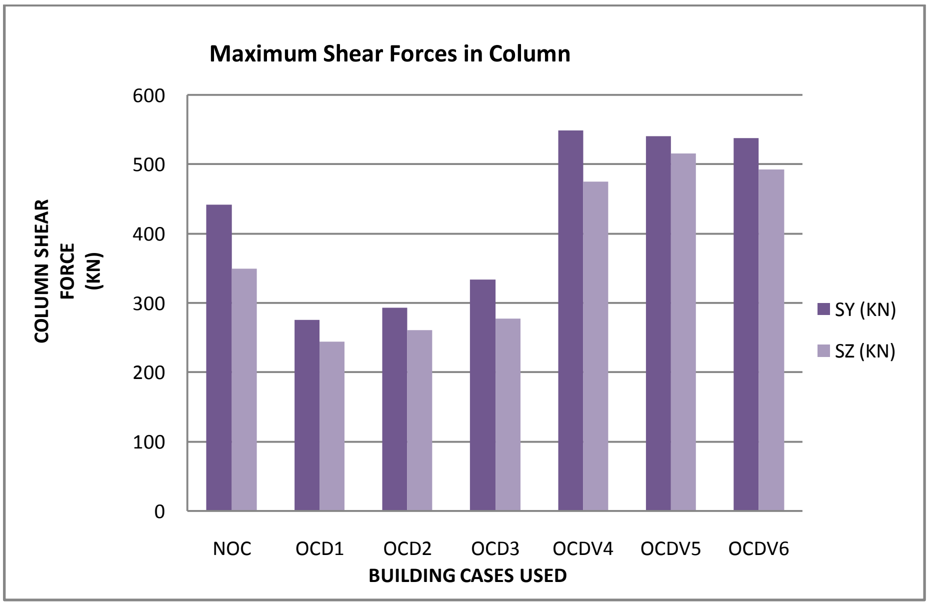


Fig. 12: Maximum Shear Forces in Columns

E. Maximum Bending Moment in Columns

Table 8: Maximum Bending Moment in Columns

Case	**Column Bending Moment (KN.m)**	
	Moment along Y	**Moment along Z**
NOC	712.631	903.695
OCD1	398.632	472.991
OCD2	402.528	475.741
OCD3	406.468	478.479
OCDV4	401.379	475.093
OCDV5	414.988	465.809
OCDV6	409.734	481.303

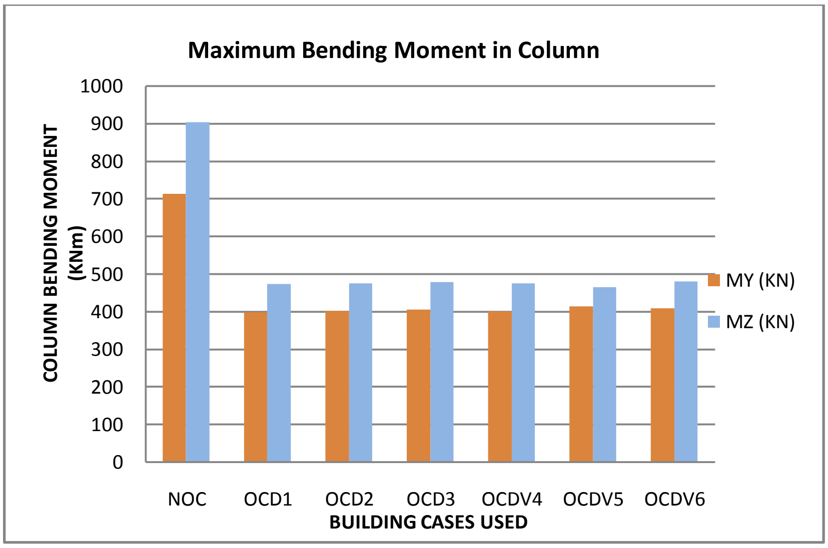


Fig.13: Maximum Bending Moment in Columns

F. Maximum Shear Forces in beams

Table 9: Maximum Shear Forces in beams parallel to X & Z direction

Case	Beam Shear Force (parallel to X direction) (KN)	Beam Shear Force (parallel to Z direction) (KN)
NOC	196.619	184.225
OCD1	173.527	162.955
OCD2	173.877	163.3
OCD3	174.201	163.62
OCDV4	173.822	163.246
OCDV5	174.241	163.649
OCDV6	174.617	164.012

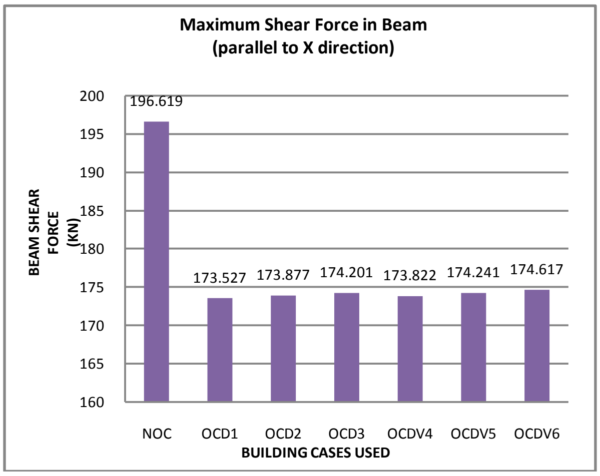


Fig. 14 : Maximum Shear Forces in beams parallel to X direction

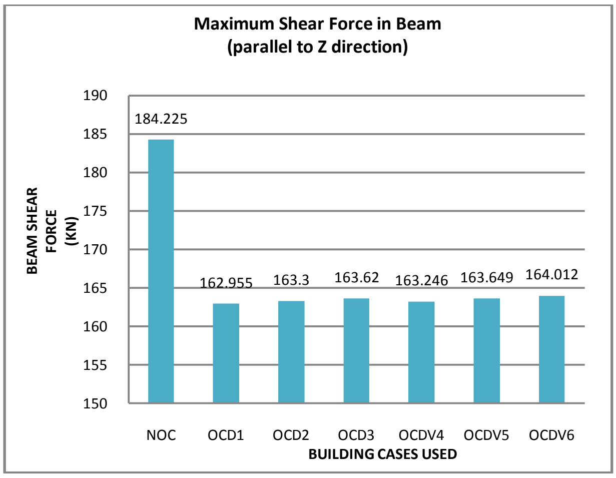
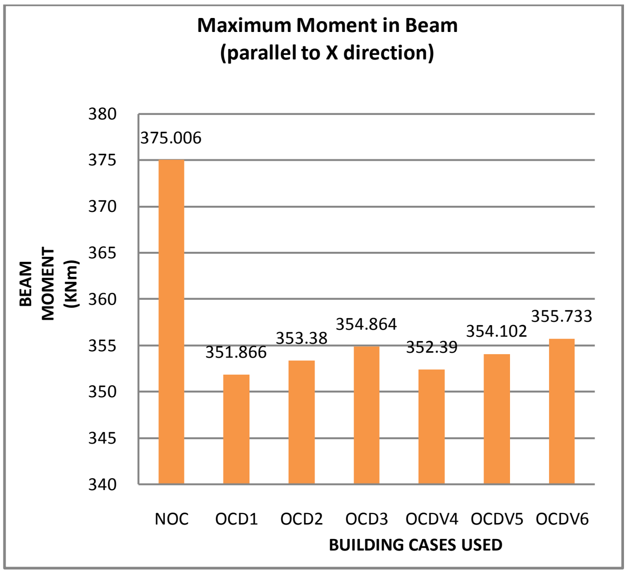


Fig. 15: Maximum Shear Forces in beams parallel to Z direction

Table 10: Maximum Bending Moment in beams parallel to X direction

Case	Beam Bending Moment (parallelto X direction) (KNm)	Beam Bending Moment (parallel to Z direction) (KNm)
NOC	375.006	339.877
OCD1	351.866	321.507
OCD2	353.38	322.982
OCD3	354.864	324.428

OCDV4	352.39	321.974
OCDV5	354.102	323.621
OCDV6	355.733	325.194



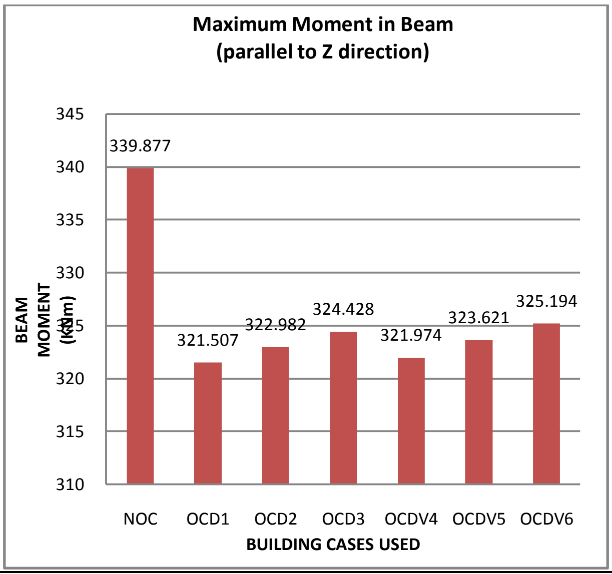


Fig.16 : Max. BM in beams parallel to X dir. **Fig. 17: Max. BM in beams parallel to Z dir.**

Maximum Torsional Moment

Table 11: Maximum Torsional Moment in beams parallel to X and Z direction

Case	**Beam Torsional Moment (parallel to X direction) (KNm)**	**Beam Torsional Moment (parallel to Z direction) (KNm)**
NOC	10.297	11.707
OCD1	38.575	42.592
OCD2	35.147	38.769
OCD3	32.362	35.656
OCDV4	39.408	43.476
OCDV5	36.008	39.683
OCDV6	33.233	36.583

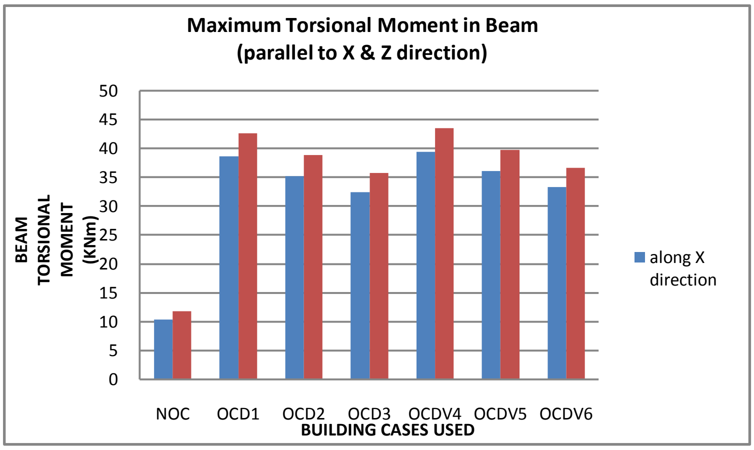


Fig 18: Maximum Torsional Moment in beams parallel to X and Z direction

CONCLUSIONS

The conclusions can be pointed out are as follows:-

- Maximum displacement in X direction and Z direction increases due to reduction in Shear Wall area. When the opening crosses 14.38% in case of door opening and when opening crosses 18.56 % in case of door with ventilation opening, the components of the structure fails.
- Base shear values decreases as the weight of the structure decreases since there is an increase in opening area percentage. For this, in both X and Z directions, when the opening crosses 14.38 % in case of door opening and when opening crosses 18.56 % in case of door with ventilation opening, the components of the structure fails.
- Time period for both X and Z direction, Case OCD1 and OCDV4 values seems less among all for both lateral and transitional seismic effects. Among all buildings, case OCD1 and OCDV4 suited the best in the current parametric values.
- Mass participated in both X and Z direction case OCD1 and OCDV4 values seems less among all for both lateral and transitional seismic effects.
- Values of Maximum Axial forces in column first decreases when openings used. It increases from 11.23 % to 14.38 %in case of door opening and when opening crosses 18.56 % in case of door with ventilation opening, the components of the structure fails.
- Shear forces in column in both Y and Z axis in section decreasing first and then it increases from OCD1 for only door openings and OCDV4 for both door + ventilation openings. OCD1 and OCDV4 values seem less among all for both lateral and transitional seismic effects.
- Bending Moment in column in both Y and Z axis in section decreasing first and then it increases from OCD1 for only door openings and OCDV4 for both door + ventilation openings. Both cases OCD1 and OCDV4 values seems economical among all.
- No drastic values observed in both longitudinal and transverse direction beams due to decrease in Shear wall usage area in multistoried structure. A value decreasing first and then it increases from OCD1 for only door openings and OCDV4 for both door + ventilation openings. Both cases OCD1 and OCDV4 values seem economical among all.
- For maximum bending moments in beam parallel to X and Z directions, when openings increases, the bending moment increases. Case OCD1 and OCDV4 seem economical among all.
- Torsion in beam shows values in decreasing order i.e. when opening increases, the Torsional moment's decreases.

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