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Opening Area Effect of Core Type Shear Wall in Hospital Building with Highest Importance Factor

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Abstract: Multi-storey buildings have fascinated mankind from the beginning of civilization, their construction being initially for defence and subsequently for ecclesiastical purposes. These tall buildings because of its height, is affected by lateral forces due to wind or earthquake actions tends to snap the building in shear and push it over in bending. In general, the rigidity (i.e. Resistance to lateral deflection) and stability (i.e. Resistance to overturning moments) requirement become more important. Shear walls (Structural walls) contribute significant lateral stiffness, strength, and overall ductility and energy dissipation capacity. In many structural walls a regular pattern of openings has to be provided due to various functional requirements such as to accommodate doors, windows and service ducts. Such type of openings reduces the stiffness of the shear wall to some extent depending on the shape and size of the opening. In the present parametric study, efforts are made to investigate and critically assess the effects of various size of openings in shear walls on the responses and behaviours of multi-storey buildings also Opening Area Effect of Core Type Shear Wall In Hospital Building with Highest Importance Factor. Many G+20 storey prototype buildings with different types of openings in shear wall with and without incorporating the volume of shear wall reduced in the boundary elements are analysed using software Staad-Pro using Response spectrum method (1893-2016). Overall analysis shows that the most efficient case for this study has been HIF5. The hospital building can be survived with highest importance with the value of I = 1.5 as per IS 1893:2016 for opening area effect of core type shear wall. It can also be recommended that upto 25% opening will be possible without any seismic damage.
Keywords: Shear wall, Opening Criteria, Highest Importance Factor, Multi-storey Hospital Building

I. INTRODUCTION

In structural engineering, a shear wall is a structural system composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on a structure. Wind and seismic loads are the most common loads that shear walls are designed to carry. Shear walls resist in-plane loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector or drag member. They are built in wood, concrete, and CMU (masonry). Shear walls must provide the necessary lateral strength to resist horizontal earthquake forces. When shear walls are strong enough, they will transfer these horizontal forces to the next element in the load path below them. These other components in the load path may be other shear walls, floors, foundation walls, slabs or footings. Shear walls also provide lateral stiffness to prevent the roof or floor above from excessive side-sway. When shear walls are stiff enough, they will prevent floor and roof framing members from moving off their supports.

Also, buildings that are sufficiently stiff will usually suffer less non-structural damage. The strength of the shear wall depends on the combined strengths of its three components: lumber, sheathing and fasteners. Later in this section you will learn how each component affects the strength and how strength is lost by improper installations. When all of the components are properly in place, the shear wall can provide its intended strength. For shear wall sheathing, the 1994 Uniform Building Code (UBC) permits the use of gypsum wallboard, cements plaster, fiber board, wood particleboard, plywood and oriented strand board. Previous editions of the UBC also allowed wood lath and plaster, horizontal and diagonal sheathing for shear walls. All of these sheathing materials provide different strengths. The UBC shows these strengths in pounds per foot of wall length. Fasteners for shear wall construction may best places, screws or nails. Denser lumber species provide stronger fastener strengths. Values for shear wall strengths assume a dense lumber species like douglas fir-larch or southern pine. Thicker framing members also increase wood structural panel sheathing strengths. The stiffness of the shear wall, just like its strength, depends on the combined stiffness of its three components: lumber, sheathing and fasteners. The size and grade of end stud(s), thickness and grade of sheathing, and the sheathing fastener diameter determine how flexible a wood shear wall will be. When present, hold own devices also contribute to the overall stiffness of the shear wall. If hold down devices stretch or slip, the top of the shear wall will move horizontally. This horizontal movement adds to the movement allowed by the lumber, sheathing and fasteners.

Any additional movement from the hold down will reduce the effective stiffness of the shear wall. Shear walls provide stiffness in large part by the ratio of their height to width. Long short walls are stiffer than tall narrow ones. For a wall of constant height, the stiffness will grow exponentially as the wall length increases. To help control stiffness, the UBC requires a minimum wall length for any given wall height. This allowable dimension ratio changes for each type of sheathing material and its construction. Wood structural panels can have smaller shear wall lengths than cement plaster or gypsum wallboard. When this sheathing is fastened at all of its edges.

II. CONCEPT OF OPENING IN SHEAR WALL

Cantilever shear walls always act as coupled shear walls consist of openings and have connected with coupling beams. Multistoried buildings may have openings in rows which are essential for doors, ventilations, openings and windows in both internal and external walls As per architectural point of view, the opening has provided. As per structural engineering point of view, the opening has to be decided within the limit to secure the structural resisting components by adverse seismic effects. Shear walls are especially important in high-rise buildings subject to lateral wind and seismic forces. Generally, shear walls are either plane or flanged in section, while core walls consist of channel sections.

Openings in shear wall can be provided in:-

- Structure generally provided with any type of shear walls.
- Structure generally provided with Shear walls around lift areas.
- Shear wall components in Dual System buildings.

III. OBJECTIVES OF THE PRESENT STUDY

Following heads shows the point of comparison of result parameters between various models during earthquake forces for building and its various cases. They are as follows:-

A. The major research work in the above papers is to check the structure with highest importance factor by varying opening area percentage in shear wall.
B. Under the seismic behaviour of building by changing opening area percentage in shear wall can be analysed.
C. Under the behaviour of the various earthquake zones, the performance of shear wall is measured.
D. The key purpose of the investigators is to growths of structure and Stability of the structure used; hence increase is observed by diverse investigators.
E. The extreme investigation is grounded on the perfect tallness, shear wall location, various opening area percentage and tallness, differences in shear wall location etc.
F. To check various parameters based on the analysis of the selected building cases like base shear, story drift, bending moment, shear forces, nodal displacement etc.

IV. METHODOLOGY, ANALYSIS AND MODELLING

Table 1: Details of various building model cases

S. No.	Buildings framed for analysis when Highest Importance Factor with Shear Wall used	Abbreviation
1	When 100 % shear wall area used with 0 % openings	HIF 1
2	When 90 % shear wall area used with 10 % openings	HIF 2
3	When 87.5 % shear wall area used with 12.5 % openings	HIF 3
4	When 83.33 % shear wall area used with 16.66 % openings	HIF 4
5	When 75 % shear wall area used with 25 % openings	HIF 5

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Table 2: Data taken for analysis of structure

Constraint	Assumed data for all buildings
Soil type	Medium Soil
Seismic zone	III
Response reduction factor (ordinary shear wall with SMRF)	4
Importance factor (For all hospital buildings)	1.5 (Highest as per IS 1893)
Damping ratio	5%
Plinth area of building	625 sq. m
Floors configuration	G + 20 (Hospital Building)
Depth of foundation	4 m
Floor to floor height	GF + All floors-3.5 m each
Fundamental natural period of vibration (T_a)	$0.09*h/(d)^{0.5}$
Period in X & Z direction	1.449 sec. & 1.449 sec. for both direction
Slab thickness	170 mm (0.170 m)
Shear wall thickness	270 mm (0.270 m)
Beam sizes	450 mm X 600 mm
Column sizes	600 mm X 650 mm
Material properties	M 30 Concrete Fe 500 grade steel

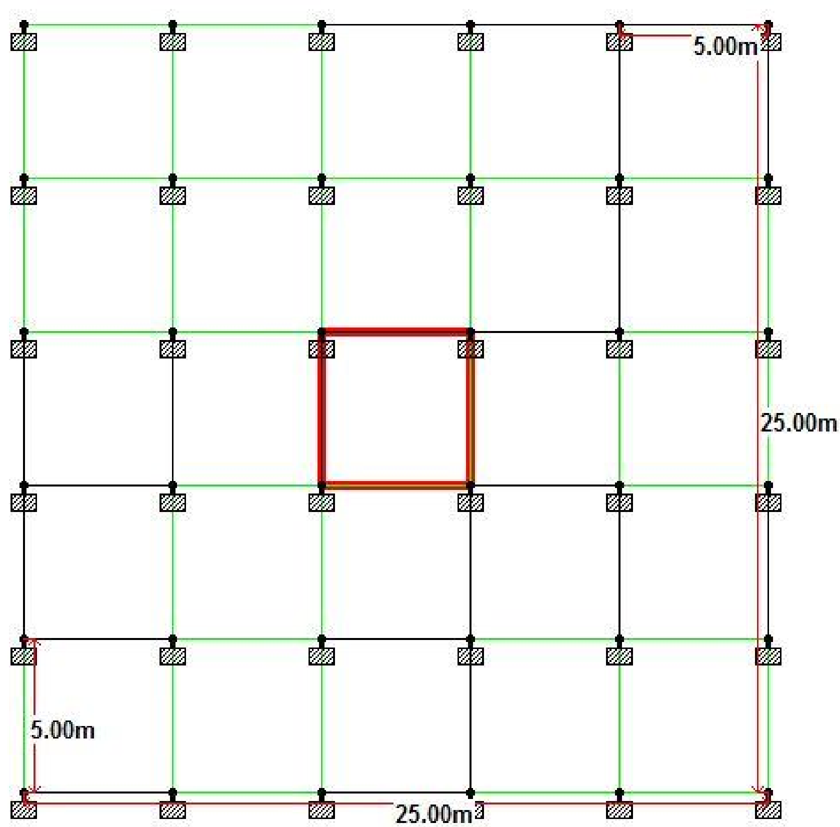

Fig. 1: Typical Floor Plan

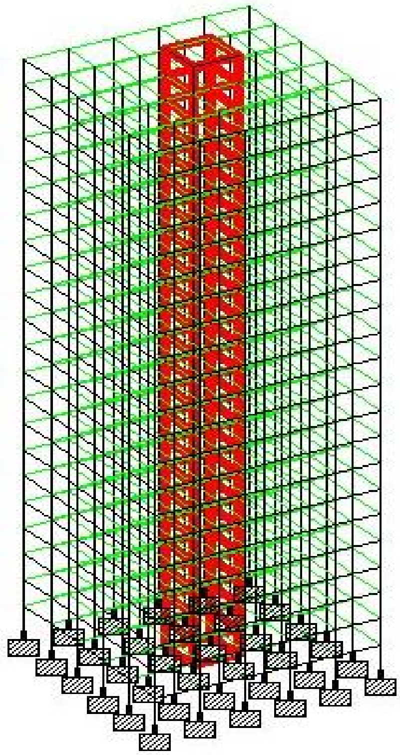

Fig. 2: 3D view of Hospital Building

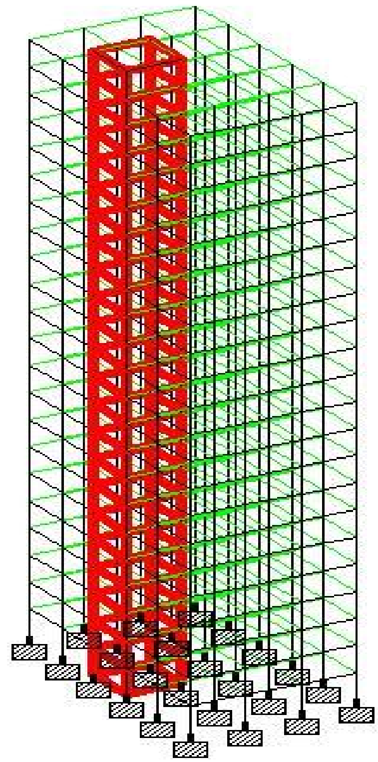

Fig. 3: 3- D sectional view of single core shear wall

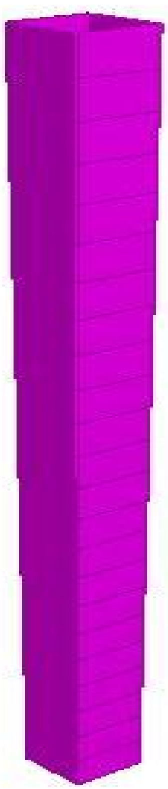

Fig. 4: Single Core Shear wall with 0 % opening and I = 1.5 (highest importance factor)

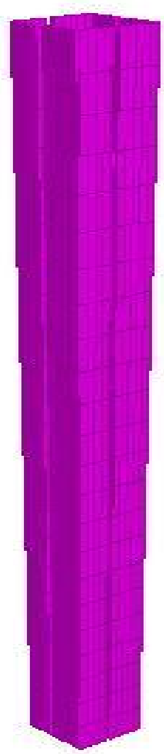

Fig. 5: Single Core Shear wall with 10 % opening and I = 1.5 (highest importance factor)

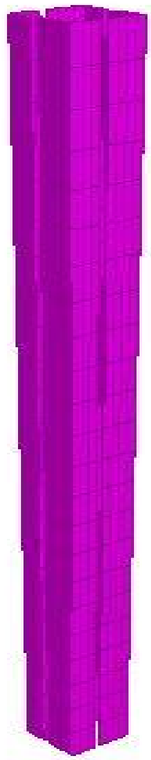

Fig. 6: Single Core Shear wall with 12.5 % opening and I = 1.5 (highest importance factor)

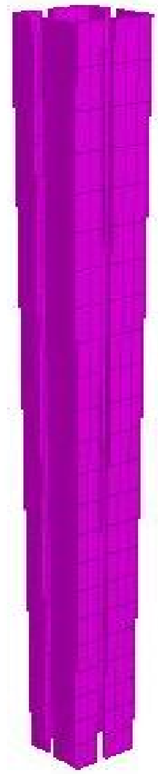

Fig. 7: Single Core Shear wall with 16.66 % opening and I = 1.5 (highest importance factor)

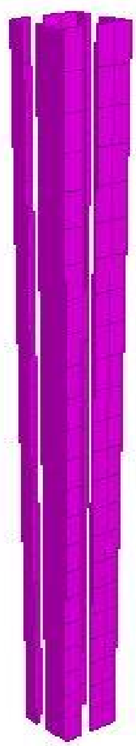

Fig. 8: Single Core Shear wall with 25 % opening and I = 1.5 (highest importance factor)

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V. RESULTS ANALYSIS

For the opening area effect of core type shear wall in hospital building with highest importance factor of the structure, parameters such as the nodal displacement in both seismic directions, storey drift in both seismic directions, beam stress values, time period and mass participation factors obtained by application of loads and their combinations on various cases of the multistorey building. Tabular result of each parameters and its optimal case is discussed with its graphical form below:-

Displacement: It is defined as the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. Figure shows the maximum value of displacement in G+20 Storey Hospital Building for different cases.

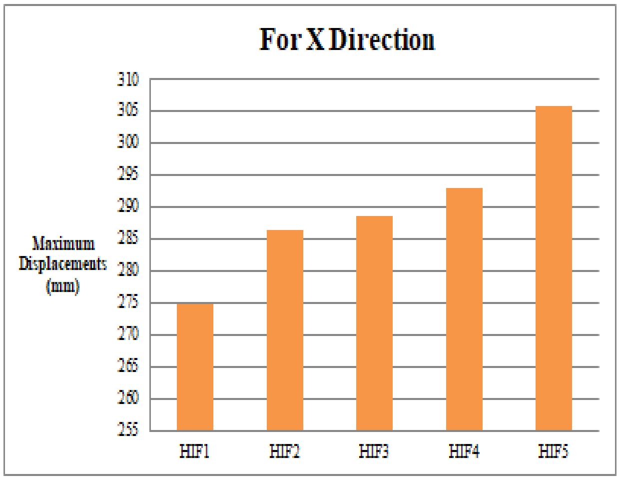

Fig. 9: Graphical Representation of Maximum Displacement in X direction for all Buildings in Zone III

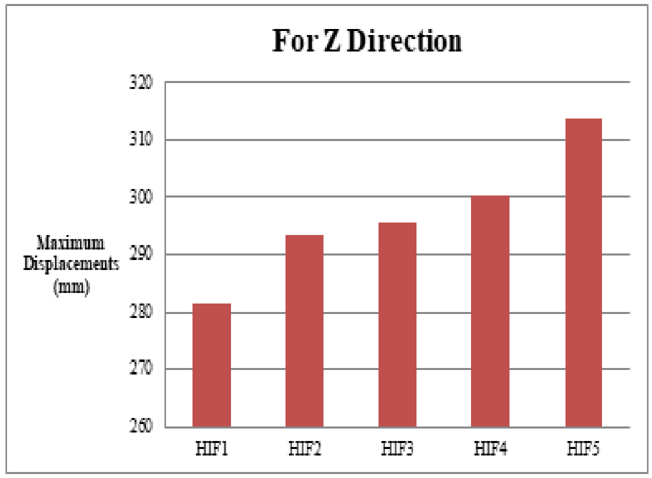

Fig. 10: Graphical Representation of Maximum Displacement in Z direction for all Buildings in Zone III

Story Drift: Story Drift is an estimate of the maximum expected inter-adjacent Storey displacement with respect to each other. Figure below shows the maximum value of drift in G+20 Storey Hospital Building for different cases.

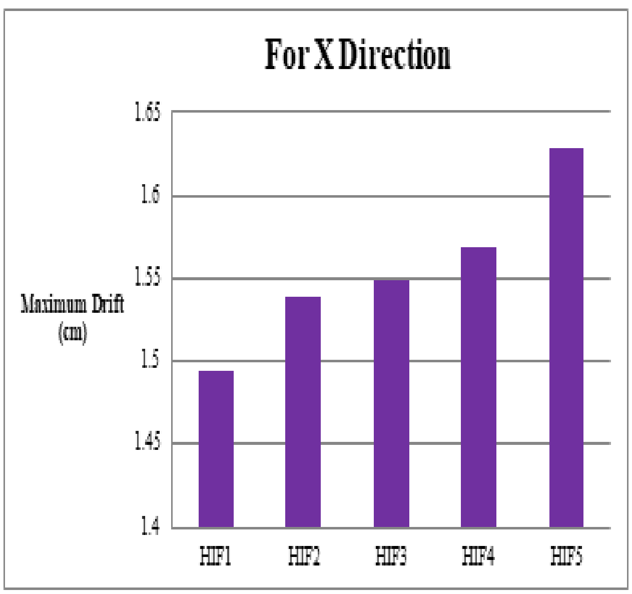

Fig. 11: Graphical Representation of Storey Drift in X direction for all Buildings in Zone III

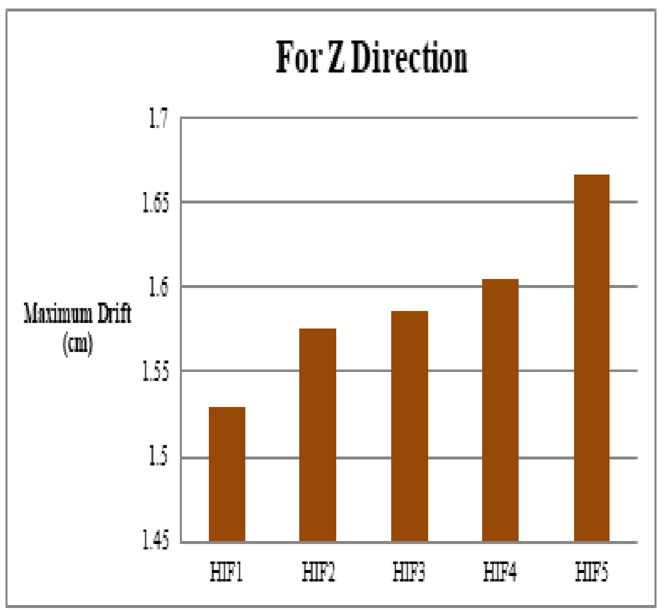

Fig. 12: Graphical Representation of Storey Drift in Z direction for all Buildings in Zone III

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Base Shear: Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. Figure shows the maximum value of base shear in G+20 Storey Hospital Building for different cases.

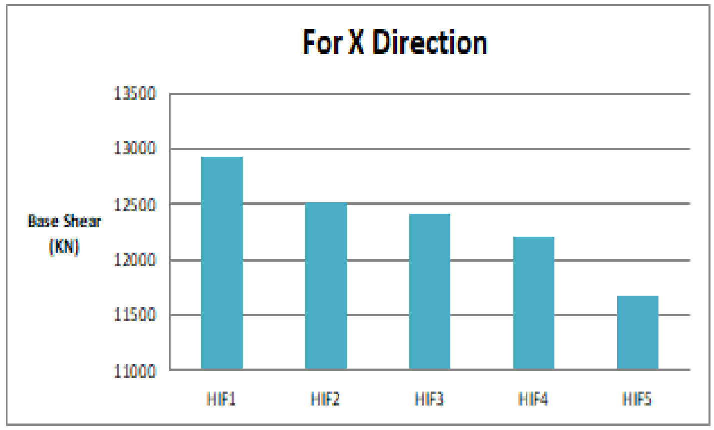

Fig. 13: Graphical Representation of Base Shear in X direction for all Buildings in Zone III

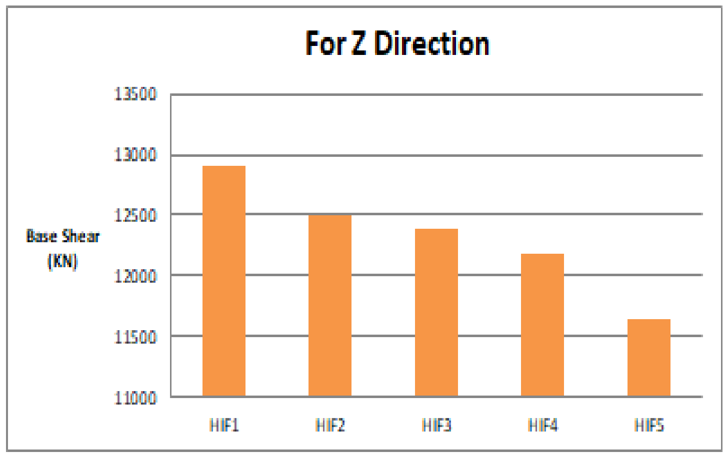

Fig. 14: Graphical Representation of Base Shear in Z direction for all Buildings in Zone III

Mass Participation Factor: If the weight of the structure (including both dead and live) participated in the seismic effects simultaneously, all the results associated with seismic effect will be accurate.

Figure shows the maximum value of Mass Participation Factor in G+20 Storey Hospital Building for different cases.

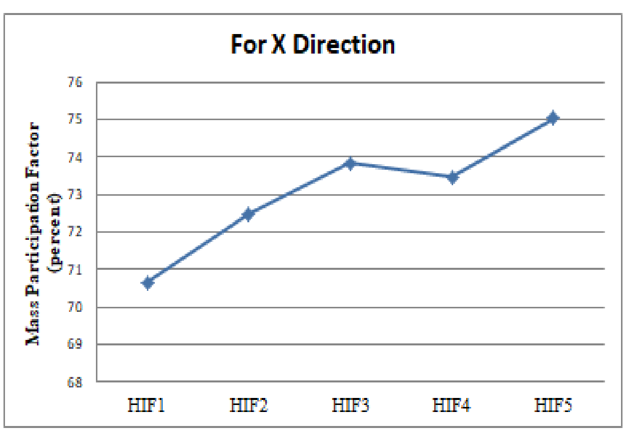

Fig. 15: Graphical Representation of Mass Participation Factor in X direction for all Buildings in Zone III

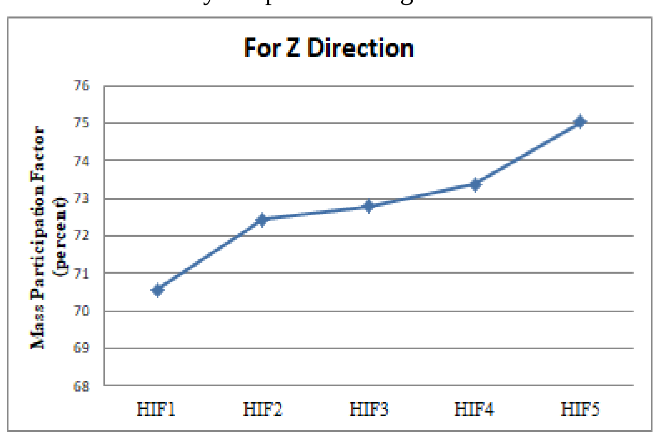

Fig. 16: Graphical Representation of Mass Participation Factor in Z direction for all Buildings in Zone III

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Axial Forces: If the load on a column is applied and the forces transfers from through the centre of the column axis of its cross section, it is called an Axial Load. Figure shows the maximum value of Axial Forces in G+20 Storey Hospital Building for different cases.

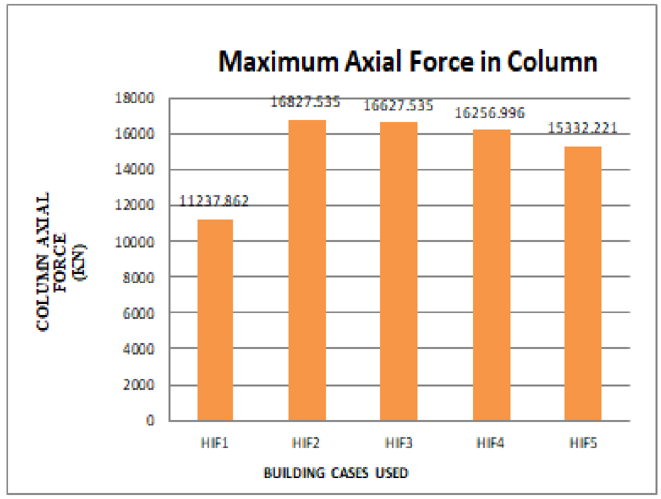

Fig. 17: Graphical Representation of Maximum Axial Forces in Column direction for all Buildings in Zone III

Shear Forces in Column: Shearing forces are unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction. Figure shows the maximum value of Shear Forces in column in G+20 Storey Hospital Building for different cases.

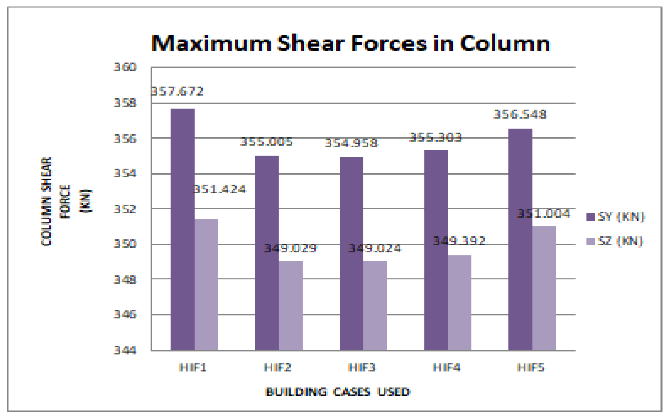

Fig. 18: Graphical Representation of Maximum Shear Forces in all direction for all Buildings in Zone III

Bending Moment in Column: A bending moment is the reaction induced in a structural element; when an external force or moment is applied to the element causing the element bend. Figure shows the maximum value of Bending Moment in column in G+20 Storey Hospital Building for different cases.

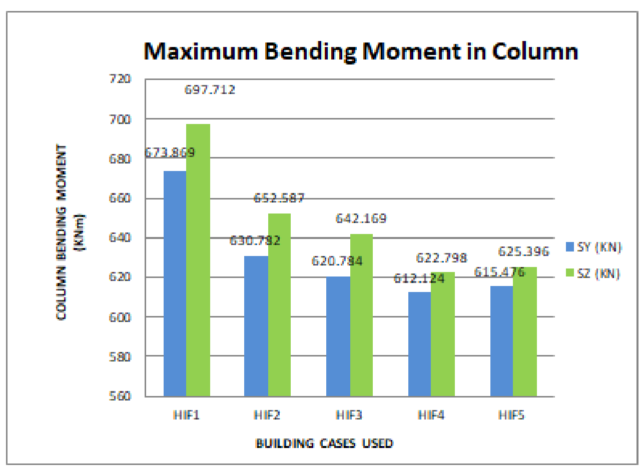

Fig. 19: Graphical Representation of Maximum Bending Moment direction for all Buildings in Zone III

Shear Force in Beam: Shearing forces are unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction. Figure shows the maximum value of Shear Forces in beams in G+20 Storey Hospital Building for different cases.

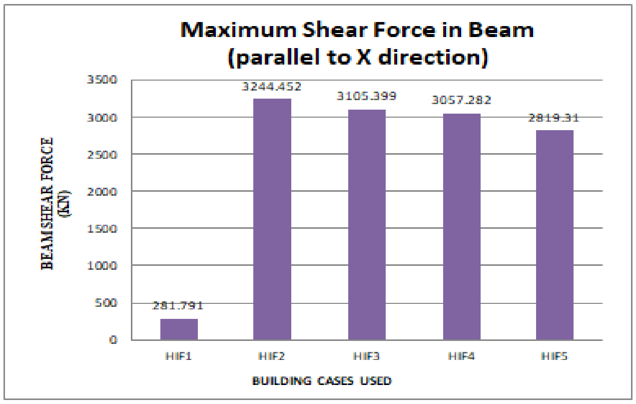

Fig. 20: Graphical Representation of Maximum Shear Forces in beams parallel to X direction for all Buildings in Zone III

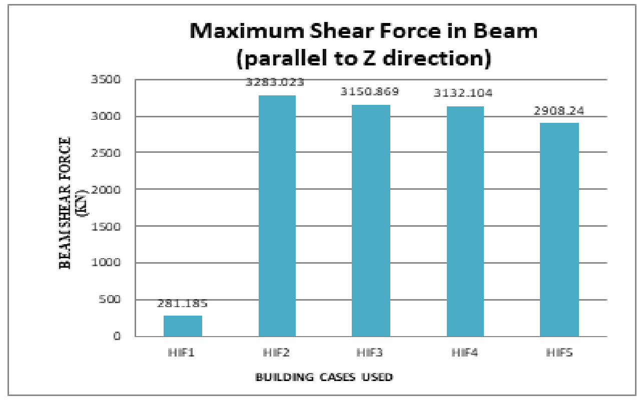

Fig. 21: Graphical Representation of Maximum Shear Forces in beams parallel to Z direction for all Buildings in Zone III

Bending Moment in Beam: A bending moment is the reaction induced in a structural element; when an external force or moment is applied to the element causing the element bend. Figure shows the maximum value of Bending Moment in beams in G+20 Storey Hospital Building for different cases.

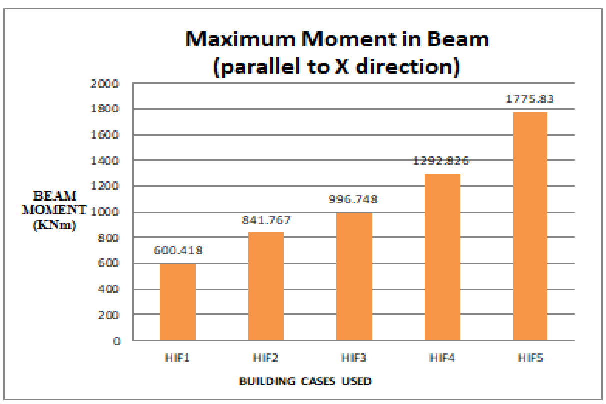

Fig. 22: Graphical Representation of Maximum Bending Moment in beams parallel to X direction for all Buildings in Zone III

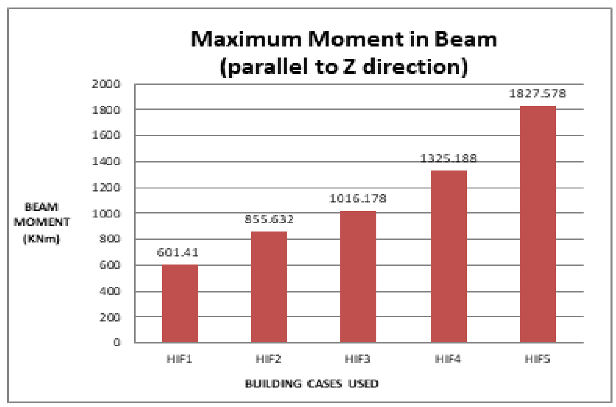

Fig. 23: Graphical Representation of Maximum Bending Moment in beams parallel to Z direction for all Buildings in Zone III

Torsional Moments in Beam: Torsion, also known as torque, describes a moment that is acting upon an object around the same axis in which the object lies. Figure below shows the maximum value of Torsional Moment in beams in G+20 Storey Hospital Building for different cases.

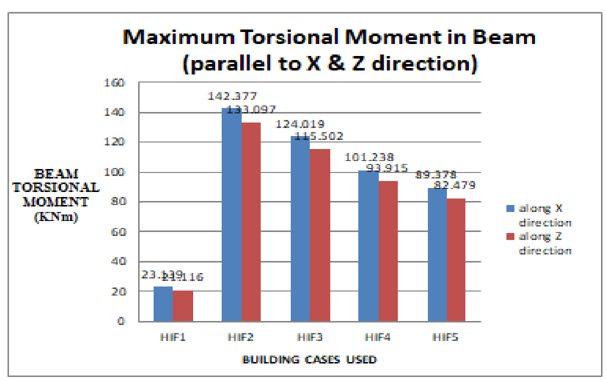

Fig. 24: Graphical Representation of Maximum Torsional Moment in beams along X and Z direction for all Buildings in Zone III

VI. CONCLUSIONS

As we have analyzed five diverse cases regarding Opening Area Effect of Core Type Shear Wall In Hospital Building with Highest Importance Factor which gives the variety of outcome regarding every cases in the structure. In term of mentioned cases subsequent outcome are obtained from this comparative analysis.

A. On comparing it has been concluded that the maximum displacement in X and Z direction found minimum in HIF1 since the graphical trend shows when we reduce the shear wall area, the stiffness got reduced.
B. Again, On comparing it has been concluded that the maximum drift in X and Z direction found minimum in HIF1 since the graphical trend shows when we reduce the shear wall area, the stiffness got reduced similar as displacement.
C. As per comparative results, case HIF5 for base shear forces in X direction and Z direction found minimum since the weight of the structure reduces due to lessening of the shear wall area.
D. On analyzing the time period and mass participation factor for both X and Z directions found minimum in HIF1 since the graphical trend shows when we reduce the shear wall area, the weight got reduced and mass participated during earthquake is more shows the accuracy of the results. The efficient case then obtained is Case HIF 5 respectively.
E. As per comparative results in axial force, HIF5 is very effective than other cases apart from HIF1 since the graphical trend shows when we reduce the shear wall area, the overall weight got reduced and efficient case then obtained is Case HIF 5 respectively.
F. Comparing the column shear force for all cases apart from HIF1, the efficient case then obtained is Case HIF 5 respectively due to reduction in shear wall area.
G. As per comparative results in column bending moment, the graphical trend shows the weight of the structure got reduced as per reduction in shear wall area. The efficient case then obtained is Case HIF4 and HIF5 respectively.
H. Comparing the beam shear force in X direction and Z directions, HIF5 is the optimum than other cases apart from HIF1.
I. As per comparative results in beam parallel to X and Z direction, bending moment increases since the shear wall area got reduced and stiffness decreases as opening increases.
J. On analyzing the Torsional Moment in beams along X direction and for Z direction in Torsional Moment in beams, HIF5 is very efficient apart from HIF1.

Overall analysis shows that the most efficient case for this study has been HIF5. The hospital building can be survived with highest importance with the value of I = 1.5 as per IS 1893:2016 for opening area effect of core type shear wall. It can also be recommended that up to 25% opening will be possible without any seismic damage.

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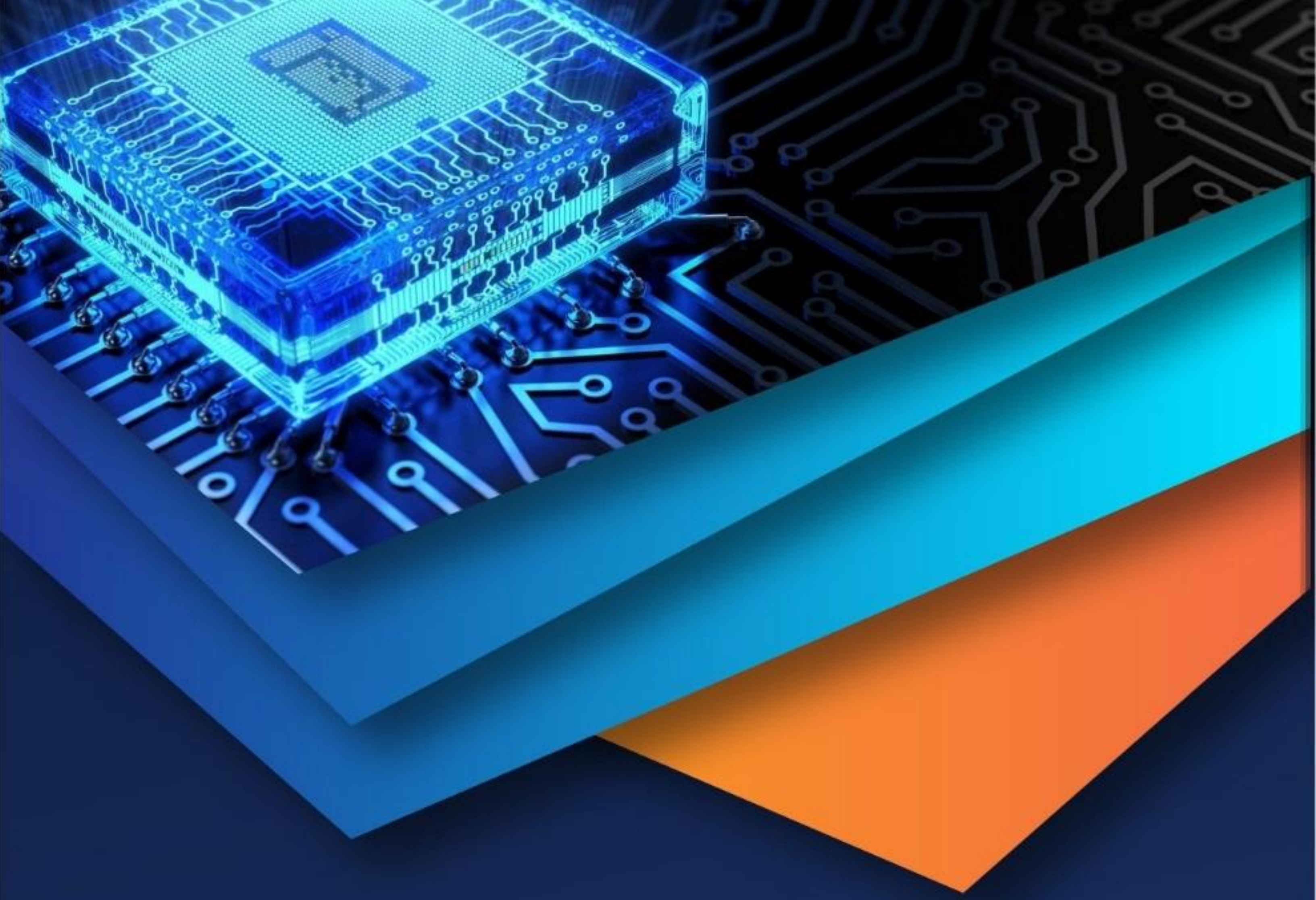

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