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EFFECT OF PERFORATION OF SHEAR WALL ON VARIOUS DESIGN PARAMETERS OF A HIGH RISE BUILDING

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ABSTRACT

Finite Element modeling now a days is an essential approach in analyzing and simulating civil engineering problem numerically. In this presentation an attempt is made to apply the finite element modeling in analyzing and exploring the behavior of shear wall with opening under seismic load actions. In modern tall buildings, shear walls are commonly used as a vertical structural element for resisting the lateral loads Shear walls are generally located at the sides of buildings or arranged in the form of core that houses stairs and lifts.

Due to functional requirements such as doors, windows, and other openings, a shear wall in a building contains many openings. The size and location of openings may vary from architectural and functional point of view. In most of the apartment building, size and location of openings in shear wall are made without considering its effect on structural behavior of the building.

Therefore this study is carried out on 20 story frame wall buildings using linear static analysis with help of finite element software, ETABS under lateral loads in equivalent static analysis 10 models of the buildings with changes in opening and its position in shear wall are analyzed.

The models are studied with increase in opening of 16 % 30% and 36% with shifting of opening form bottom center and top. The study indicates that drift displacement and the column forces have a significant affects with position of opening in shear wall.

Keywords- *Perforation, Shear wall etc.*

I. INTRODUCTION

Shear walls

This section provides an introduction to shear walls and how they resist earthquake and wind forces. Shear walls are vertical elements of the horizontal force resisting system.

Shear walls should be located on each level of the structure including the crawl space. To form an effective box structure, equal length shear walls should be placed symmetrically on all four exterior walls of the building. Shear walls should be added to the building interior when the exterior walls cannot provide sufficient strength and stiffness or when the allowable span-width ratio for the floor or roof diaphragm is exceeded. For sub floors with conventional diagonal sheathing, the span-width ratio is 3:1. This means that a 25-foot wide building with this sub floor will not require interior shear walls until its length exceeds 75 feet unless the strength or stiffness of the exterior shear walls are inadequate.

Shear walls resist two types of forces: shear forces and uplift forces. Connections to the structure above transfer horizontal forces to the shear wall. This transfer creates shear forces throughout the height of the wall between the top and bottom shear wall connections. The strength of the lumber, sheathing and fasteners must resist these shear forces or the wall will tear or “shear” apart.

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 nonstructural damage.

II. RESEARCH ELABORATIONS

Seismic and wind effects on buildings

2.1 - General

The behavior of buildings during earthquake depends critically on its overall shape, size and geometry in addition to how the earthquake forces are carried to the ground. Hence, at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and good buildings configuration chosen.

2.1.1 Importance of seismic design codes

Ground vibration during earthquake cause forces and deformations in structures. Structures need to be designed withstand such forces and deformations. Seismic codes help to improve the behavior of structures so that may withstand the earthquake effect without significant loss of life and property. Countries around the world have procedures outlined in seismic code to help design engineers in the planning, designing, detailing and constructing of structures.

2.1.2 Earthquake effect on reinforced concrete buildings

In recent times, reinforced concrete buildings have become common in India, particularly in towns and cities. Reinforced Concrete (or Simply RC) consists of two primarily materials, namely Concrete with Reinforcing Steel bars.

Concrete is made of sand, crushed stone (called aggregates) and cement, all mixed with pre-determined amount of water. Concrete can be molded into any desire shape and steel bars can be bent into many shapes. Thus structure of complex shapes is possible with RC.

A typical RC buildings is made of horizontal members (beams and slabs) and vertical members (columns and walls), and supported by foundations that rest on ground. The system comprising of RC columns and connecting beams called a Reframe. The RC frame participates in resisting the earthquakes forces. Since most of the buildings mass is present at floor levels. These forces travel downwards through slab and beams to columns a walls, and then to the foundations from where they are dispersed to three ground. As inertia forces accumulate downwards from the top of the buildings, the columns and walls at lower storey experience higher earthquake induced forces and are therefore designed to be stronger than that storey above.

2.2 Design Issues for seismic and Wind in Buildings

Design Issues: The economic structural design of high rise buildings is a complex technical challenge, with requirement for lateral stiffness, strength and deformation under wind and earthquake compounding gravity and constructability issues. In general, as building grow taller and more slender wind loading effect become more significant in comparison to earthquake effects. This is because whilst the wind overturning moment will typically increase as height cubed the elastic seismic base moment is unlikely to increase at more than height raised to the power 1.25. Accordingly, in regions of moderate seismic hazard, a buildings structure designed to resist wind effects may require only modest (although vitally important) modification to meet seismic performance targets. In contracts the design of the lateral force system in low rise buildings at the same time would be entirely governed by seismic requirements.

III. SHEAR WALLS IN BUILDINGS

3.1 General

Reinforced concrete (RC) buildings often have vertical plate like RC walls called shear walls in addition to slab, beams and columns. These walls generally start at foundation level and are continuous throughout the building height.

3.1.2 Advantages of shear walls

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the quote: “We cannot afford to build concrete buildings meant to resist server earthquakes with out shear walls” Mark Fintel, a noted consulting engineer in USA. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well- distributed reinforcement) were saved from collapse. Shear wall are efficient, both in terms of construction cost effectiveness in minimizing earthquake damage in structural and non structural element (like glass windows and buildings contents).

3.1.3 Shear walls with openings

Pipers in a wall formed by openings may be regarded as fixed at both ends which changes the bending deflection.

Rigidity of wall element fixed at both ends. It gives a curve for rapid evaluations of the rigidity of piers the rigidity of a pier in the direction of its thickness in negligibly small.

The rigidity of a wall with openings may be calculated neglecting the effect of the axial shortening of piers by the judicious use of the principles of series and parallels in the same way. It is seen that for normal window or door openings, the rigidity of the wall is not affected to any appreciable extent. The rigidity of a shear wall is due more to its form than it its mass.

In size of the openings should be relatively small and these should be spaced at least a distance equal to the size of the openings in each direction. To restrict the stresses in the shear wall, the width of openings should be limited approximately to 15% of the total length of the connected shear walls and the depth of the connecting beam should be greater than 20% of the storey height.

3.1.4 Rigidity of a wall element

Ryx is defined as the horizontal force necessary to prevent y- distortions of a wall element when Rx is applied in the x-directions producing a unit deflection Rxy is also defined. When the principal axes of the shape of a shear wall are parallel to the x and y axes, Rxy and Ryx vanish.

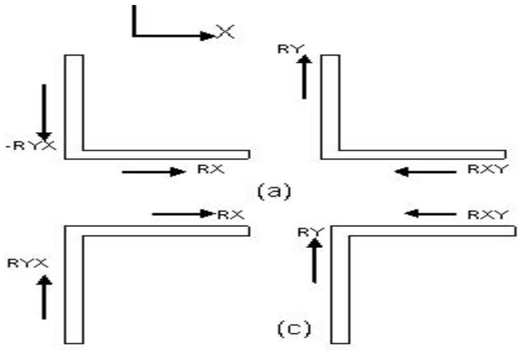

Figure.1

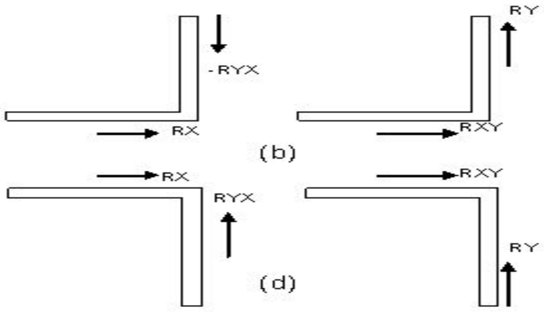

Figure.2

Figure.1&2 Direction of Rxy and Ryx for various dispositions of the angle wall element. (a) angle in position 1; (b) angle in position 2; (c) angle in position 3; (d) angle in position 4.

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3.1.5 Distribution of applied horizontal forces to shear walls

This is the problem of allocation analysis. It consists in determining the distribution of the applied forces px or py and the corresponding torsional moment tp to the carious shear walls forming the structure. Direct shear. When there is no torsion, that is, when the shear centre of structure coincides with the point of application of the resultant lateral loads, the direct shear in each shear wall due. To py or px is given by, when only py acts

With px=0,

$$F_x = P_y \frac{(R_{yx} \Sigma R_x - R_x \Sigma R_{yx})}{(\Sigma R_y \Sigma R_x - \Sigma R_{yx} \Sigma R_{xy})}$$

$$F_y = P_y \frac{(R_y \Sigma R_x - R_{xy} \Sigma R_{yx})}{(\Sigma R_y \Sigma R_x - \Sigma R_{yx} \Sigma R_{xy})}$$

IV. NUMERICAL MODELLING AND ANALYSIS

4.1 Introduction

ETABS (Extended Three Dimensional Analysis of Building Systems) is a special purpose computer program developed specifically for building systems. The concept of special purpose programs for building type structures was introduced more than 35 years ago [R. W. Clough, et al., 1963]. However, the need for special purpose programs, such as ETABS, has never been more evident as Structural Engineers put nonlinear static and dynamic analysis into practice and use the greater computer power available today to create larger, more complex analytical models. With ETABS, creating and modifying a model, executing the analysis, design, and optimizing the design are all done through a single interface that is completely integrated within Microsoft Windows. Graphical displays of the results, including real-time display of time-history displacements, are easily produced. Printed output, to a printer or to a file, for selected elements or for all elements, is also easily produced. This program provides a quantum leap forward in the way models are created, modified, analyzed and designed.

4.1.2 Advance features

ETABS offers the widest assortment of analysis and design tools available for the structural engineer working on building structures. The following list represents just a portion of the types of systems and analyses that ETABS can handle easily:

- Multi-story commercial, government and health care facilities.
- Parking garages with circular and linear ramps.
- Buildings with steel, concrete, composite or joist floor framing.
- Complex shear walls with arbitrary openings.
- Buildings based on multiple rectangular and/or cylindrical grid systems.
- Flat and waffle slab concrete buildings.

4.1.3 Modeling in ETABS

ETABS is a finite element based software and specifically uses stiffness method for analysis and generating unknowns. Unlike other software's ETABS works with Object Based Modeling whereas other FEM programs work with element based modeling. This object based modeling of ETABS reduces the time to model a structure and also reduces the voluminous outputs yielded by other FEM programs, making ETABS favorite for building analysis and design. ETABS automatically meshes the objects into finer elements and analyses the structure. There are three types of objects in ETABS:

- Line Object: Line objects are those objects which have less cross-sectional dimensions when compared to length (Beams and Columns).
- Area Object: Area objects are those objects which have less thickness compared to plan dimensions (Slabs and Walls).
- Point Object: Point objects are that object which connects between line to line, line to area, area to area etc.

There are four types of Area Objects in ETABS:

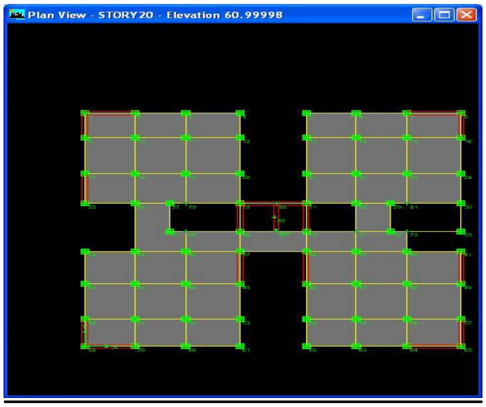
- Shell: Shell type is used to model flat slabs and walls
- Membrane: Membrane type is used to model normal conventional slabs with beams.
- Plate (thin): This is used to model raft foundations where bending is predominant.
- Plate (thick): This is used to model raft foundations where shear is predominant.

4.2 Dynamic Analysis

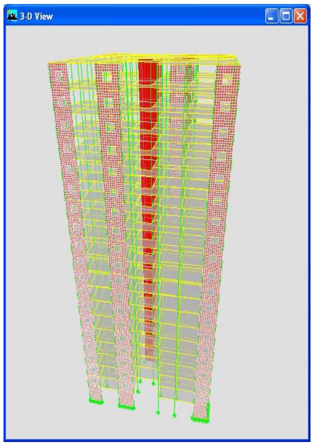
Dynamic analysis shall be performed to obtain to design seismic force, and its distribution to different levels along the height of the building and to various lateral loads resisting elements for the following buildings:
Regular buildings-those greater than 40 m in height in zones 4 and 5, those greater than 90 m in height in zones 2 and 3. The analysis model for dynamic analysis of buildings with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan irregularities (as defined in the Table 4 of IS 1893-2002) can not be modeled for dynamic analysis.

4.2.1 Seismic weight

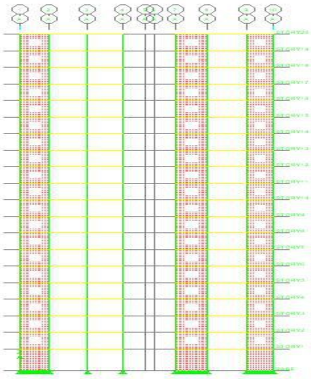
The seismic weight of building is the sum of seismic weights of all the floors. The seismic weight of each floor is its full dead load plus appropriate amount of imposed load. While computing the seismic weight of columns and walls in any story shall be equally distributed to the floors above and below the story.



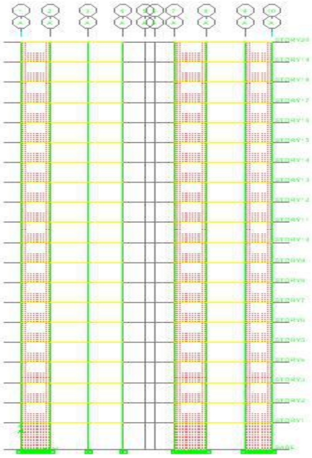
Plan of the structure



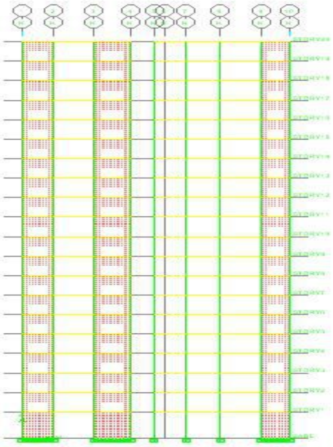
3-D Model



Model with opening in the center of the story



Model with opening in the top of the story



Model with opening in the bottom of story

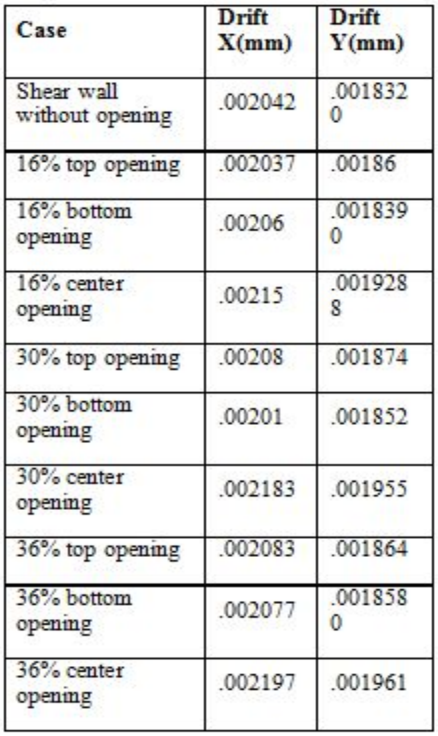
V. RESULTS AND DISCUSSIONS

Results obtained from the analysis are lateral displacement, story drift, axial forces and column moments these results are shown for static and dynamic analysis. The parameters of the investigation are perforation in shear wall for 16%, 30% and 36 % opening in the shear wall with changing opening from top to bottom.

For the purpose of study the top floor drifts and Displacements are for different opening in the shear wall at the center is considered with reference to the IS 875 loading guidance

Then the top floor displacement for different buildings models is collected considering Stories with respect to Zone 2 to different loading conditions when the openings are shifted from top bottom and center.

Similarly column moments and axial forces in columns when openings are shifted from center top and bottom in ordinate and story height are taken in abscissa. These tables and graphs are shown below.



Case	Drift X(mm)	Drift Y(mm)
Shear wall without opening	.002042	.001832 0
16% top opening	.002037	.00186
16% bottom opening	.00206	.001839 0
16% center opening	.00215	.001928 8
30% top opening	.00208	.001874
30% bottom opening	.00201	.001852
30% center opening	.002183	.001955
36% top opening	.002083	.001864
36% bottom opening	.002077	.001858 0
36% center opening	.002197	.001961

Table5.1 comparison of the drift for openings in shear wall

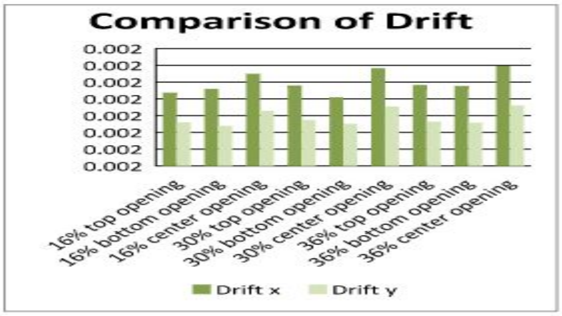


Figure.3 story drift vs opening in story at different levels

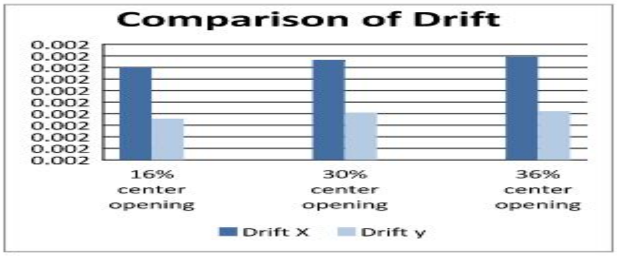


Figure.4 story drifts VS opening at the center

CASE	**Displacement X(mm)**	**Displacement Y(mm)**
Shear wall without opening	100.15	89.73
16% top opening	99.78	90.81
16% bottom opening	100.65	89.73
16% center opening	105.43	94.27
30% top opening	101.45	91.11
30% bottom opening	101.63	89.81
30% center opening	106.53	95.13
36% top opening	101.68	90.25
36% bottom opening	101.73	89.96
36% center opening	107.31	96.68

Table 5.2 Comparison of the displacement for opening in shear wall

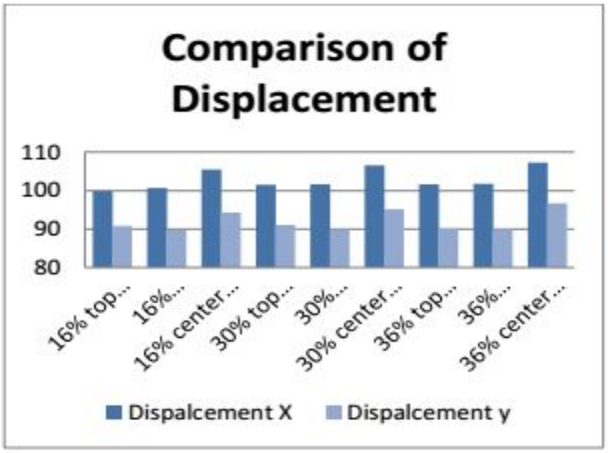


Figure.5 story displacement VS opening in story at different levels

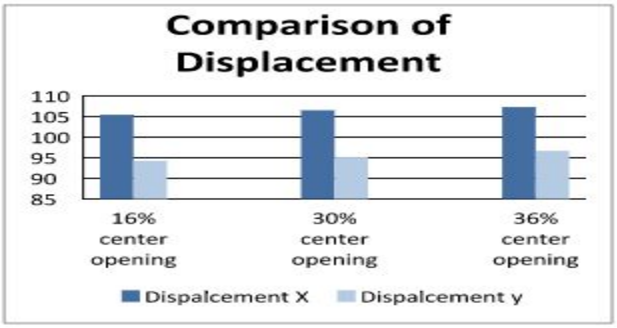


Figure.6 story displacement VS opening at the center

DISCUSSION OF RESULTS

Results obtained from the analyses are recorded in tabular form for the following cases of the building separately for comparison of beams, column and shear walls critical forces and displacements:

Case 1: When shear wall is placed in building and there is no opening in the wall

Case 2: When 16% opening is provided in bottom of the shear wall in each story

Case 3: When 16% opening is provided in center of the shear wall in each story

Case 4: When 16% opening is provided in top of the shear wall in each story

Case 5: When 30% opening is provided in bottom of the shear wall in each story

Case 6: When 30% opening is provided in center of the shear wall in each story

Case 7: When 30% opening is provided in top of the shear wall in each story

Case 8: When 36% opening is provided in bottom of the shear wall in each story

Case 9: When 36% opening is provided in center of the shear wall in each story

Case 10: When 36% opening is provided in top of the shear wall in each story

The obtained results substantiate that opening of shear wall location plays a vital role in the structural behavior of the building. The effect of shear wall opening location on design parameters is discussed below. For the study displacement and drifts and column away and a column towards the shear wall is considered and results are tabulated.

5.1 Story Drifts and Displacement

It is to be observed from Table5.1 that drifts of the building floor for an opening of 16%, 30% 36% as there is an increase in the opening the displacement increases as there is more percentage of opening the more is the displacement to the building

The figure 17 is graph which plotted for different cases of openings and the story drifts and drift is less for the opening is shifted to top or bottom rather than center the figure 18 graph shows as the opening in center increases the drift is increased

It is to be observed from Table5.2 that displacement of the building floor for an opening of 16%, 30% 36% as there is an increase in the opening the displacement increases as there is more percentage of opening the more is the displacement to the building

The figure 19 is graph which plotted for different cases of openings and the displacement and displacement is less for the opening is shifted to top or bottom rather than center the figure 20 graph shows as the opening in center increases the displacement is increased

VI. CONCLUSIONS

1. With the provision of opening in the shear wall the drift are increasing. The drift is 0.00215 for 16% 0.002183 for 30% and 0.002197 for 36% of opening drift increases with increase in percentage opening
2. The displacement is high for 36 % opening of 107.31 where as it is 106.53 for 30% opening and 105.43 for 16% opening stiffness of the structure is decreased when percentage of opening is increased
3. The drift is decreasing for 16 % opening from 0.00215 to 0.00206 when the position of opening is shifted to top and it is decreased to 0.00208 when opening is shifted to bottom of the story the same is observed for 30% and 36% of opening in wall
4. The displacement is decreasing for 16 % opening from 105.43 to 99.78 when the position of opening is shifted to top and it is decreased to 100.75 when opening is shifted to bottom of the story the same is observed for 30% and 36% of opening in wall
5. Opening in the shear walls lead to a significant increase in the bending moment and shear force in the columns connected to that shear wall and when opening is to top the percentage of the increase is about 30 to 45 percentage increase it is less for the opening is at bottom about 10 to 20 percent
6. It was observed for a particular opening in wall when the opening position is shifted from top to the Center and to the bottom. that there is no significant effect and percentage difference is only 2 to 5% on the columns that are not connected to the shear

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