IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 1 Ver. II (Jan. - Feb. 2016), PP 01-06
www.iosrjournals.org

Effects of Openings in Shear Wall

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Abstract:*In high rise building shear wall is used to resisting the lateral loads that may be induced by the effect ofwind and earthquakes. In high rise building increases sizes of structural element. As a result consumption of conventional construction materials like concrete and steel goes on increasing day by day in the structures. On the other hand time delay is the key factor that will affect overall growth of such projects. Hence in order to overcome these constraints economical construction methodology and optimization techniques should be used. Finite Element Modeling now a days is an essential approach in analyzing and simulating civil engineering problem numerically. In this paper at attempt is made to apply the finite element modelling in analyzing and exploring the behavior of shear wall with opening under seismic load action on member forces. Hence the aim of present study is to compare seismic performance of 15-Storey with openings in shear wall situated in earthquake zone V. Seismic coefficient method and Response spectrum method are used for seismic analysis. SAP software is used and the results are compared. Position of shear wall by changing the sizes and shape of openings in shear wall for all buildings models is determined. Finite element analysis of opening in shear wall is also studied. Comparative study concludes that changing the position of shear wall of reinforced concrete structures with various opening sizes in buildings openings are economical.*

Keywords: *Shear Wall, Column Moment Axial Force Seismic Coefficient Method, Response Spectrum Method andFinite Element Analysis.*

I. Introduction

Reinforced concrete multi-storey buildings are adequate for resisting both the vertical and horizontal load. When such building is designed without shear wall, the beam and column sizes are quite heavy, steel quantity is also required in large amount thus there is lot of congestion at these joint and it is difficult to place and vibrate concrete at these places and displacement is quite heavy which induces heavy forces in member. The buildings with shear wall and greater lateral load resisting capacity, uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to building without shear wall or any lateral load resisting system. But now a days need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of different type of buildings on different type of soil. Hence earthquake engineering has developed the key issues in understanding the role of behavior of different type of buildings on different type of soil conditions.

An introduction of shear wall represents a structurally efficient solution to stiffen a building structural system because the main function of a shear wall is to increase the rigidity for lateral load resistance. In modern tall buildings, shear walls are commonly used as a vertical structural element for resisting the lateral loads that may be induced by the effect of wind and earthquakes. The usefulness of shear walls in framing of buildings has long been recognized. Walls situated in advantageous positions in a building can form an efficient lateral-force-resisting system, simultaneously fulfilling other functional requirements. When a permanent and similar subdivision of floor areas in all stories is required as in the case of hotels or apartment buildings, numerous shear walls can be utilized not only for lateral force resistance but also to carry gravity loads`. In such case, the floor by floor repetitive planning allows the walls to be vertically continuous which may serve simultaneously as excellent acoustic and fire insulators between the apartments.

Shear walls in apartment buildings will be perforated by rows of openings that are required for windows in external walls or for doors ways or corridors in internal walls. However, the size and location of openings in the shear wall may have adverse effect on seismic responses of frame-shear wall structures. Relative stiffness of shear walls is important since lateral forces are distributed to individual shear wall according to their relative stiffness. As a designer, it is necessary to know the effects of openings sizes and configurations in shear wall on stiffness as well as on seismic responses and behavior of structural system so that a suitable configuration of openings in shear walls can be made.

Wall openings are inevitably required for windows in external walls and for doors or corridors in inner walls or in lift cores. The size of openings may vary from architectural and functional point of view.

II. Alternative Procedures For Seismic Analysis And Design

In the preliminary design process, equivalent static seismic forces are used to determine the design internal forces of structural members using linear elastic analyses of structure and, in turn, determine the design member strength demands. Such static seismic forces are simply determined.

2.1 Equivalent Static Method

Seismic analysis of most structures is still carried out on the assumption that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. This method requires less effort because, except for the fundamental period, the periods and shapes of higher natural modes of vibration are not required. The base shear which is the total horizontal force on the structure is calculated on the basis of the structures mass, its fundamental period of vibration, and corresponding shape. The base shear is distributed along the height of the structure in terms of lateral force according to codal formula. Planar models appropriate for each of the two orthogonal lateral directions are analyzed separately, the results of the two analyses and the various effects, including those due to torsional motions of the structure, are combined. This method is usually conservative for low to medium- height buildings with a regular configuration.

2.2 Response Spectrum Method

This method is also known as Modal Method or Mode Super-Position Method. This method is applicable to those structures where modes other than the fundamental one significantly affect the response of structures. Generally, this method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have geometrical areas of discontinuity or irregularity, in their linear range of behavior. In particular, it is applicable to analysis of forces and deformation in multi-storey buildings due to intensity of ground shaking, which causes a moderately large but essentially linear response in the structure. This method is based on the fact that, for certain forms of damping which are reasonable models for many buildings the response in each natural mode of vibration can be computed independently of the others, and the modal responses can be combined to determine the total response. Each mode responds with its own particular pattern of deformation (mode shape), with its own frequency (the modal frequency), and with its own modal damping.

2.3 Finite Element Analysis

The Finite Element Method (FEM) is a numerical technique to find approximate solutions of partial differential equations. It was originated from the need of solving complex elasticity and structural analysis problems in Civil, Mechanical and Aerospace engineering. In a structural simulation, FEM helps in producing stiffness and strength visualizations. It also helps to minimize material weight and its cost of the structures. FEM allows for detailed visualization and indicates the distribution of stresses and strains inside the body of a structure. Many of FE software are powerful yet complex tool meant for professional engineers with the training and education necessary to properly interpret the results.

Several modern FEM packages include specific components such as fluid, thermal, electromagnetic and structural working environments. FEM allows entire designs to be constructed, refined and optimized before the design is manufactured. This powerful design tool has significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications. The use of FEM has significantly decreased the time to take products from concept to the production line. One must take the advantage of the advent of faster generation of personal computers for the analysis and design of engineering product with precision level of accuracy.

III. Finite Element Analysis And Modeling Technique

Last few decades, the building environment in India had extensively utilized high-rise R.C. buildings. These building are built with different configurations and structural systems having varying stiffness parameters that may have great influence on their seismic behavior. Typical buildings with fifteen stories are chosen for this study by changing position of shear wall with openings as shown in Fig.1, 2, 3 and 4; building's layout is essentially unsymmetrical- metric in plan, and regular plans of nine bays in X-direction and five bays in Y-direction with a typical bay width of 4 m in both directions. The height of every story is taken equal to 3.2 m, as a normal height for residential buildings. Beams are assumed on all grid lines. The building is considered in zone V. Slab thickness was taken 200 mm and beam section was taken 300X600mm, 350X600mm. The materials used in the design are M30 for concrete and Fe500 for steel; the material for the building structure is taken as a reinforced concrete. Sizes of columns havebeen varied according to soil conditions. Thickness of slab and brick wall is taken as 200 mm and 150 mm; floor finish load is 1.5 KN/ m^2, Live load on floor slabs is 4

KN/ m^2, thickness of shear wall is 250 mm and size of meshing 200X 200mm. Density of concrete and brick masonry is taken as 25 KN/ m^3 and 20 KN/ m^3 respectively.

Mathematical model and finite element solution

In shear wall construction, openings are introduced for different purposes. Hence a shear wall with openings is another alternative which has been taken to study the performance of shear wall. The four model is considered for study as model I: bare frames, model II: frames with core shear wall, model III: frames with core and internal shear wall, and model IV: frames with internal and external shear wall. Analysis results have been presented later in this paper in the form of tables and graphs. In second part, analysis of shear wall with openings has been carried out for following cases: -

1. Shear wall having different size of openings.
2. Shear wall having different shape of openings.

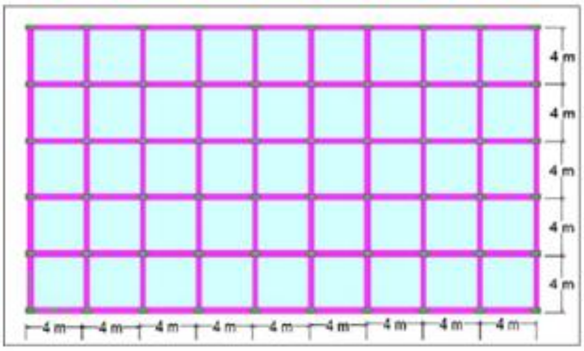

Figure 1: Plan for Model I

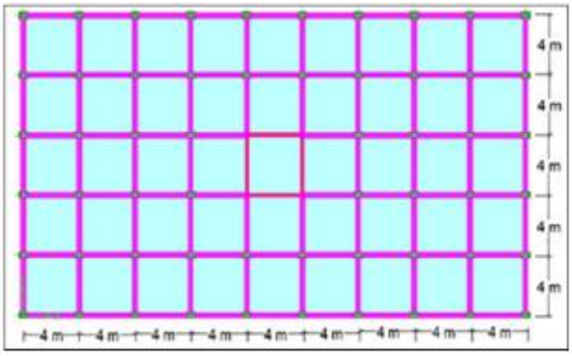

Figure 2: Plan for Model II

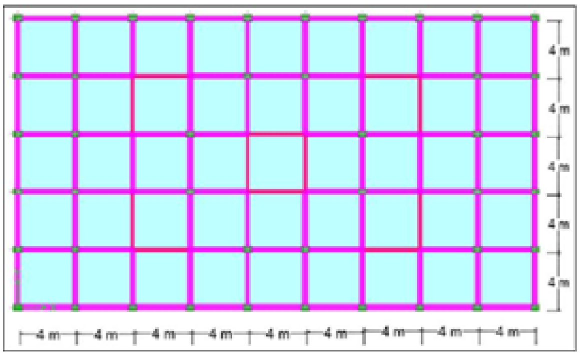

Figure 3: Plan for Model II

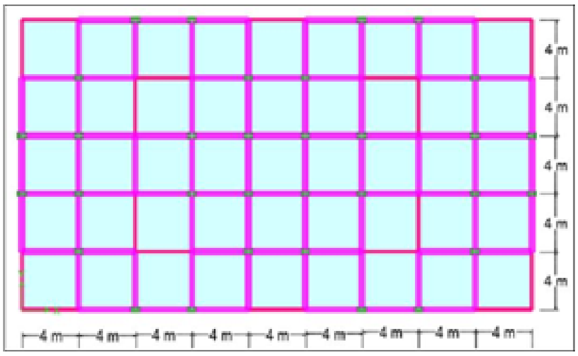

Figure 4: Plan for Model IV

IV. Numerical Results And Discussions

Finite element modeling and numerical analysis are formulated to quantify the effects of openings in shear wall on the structural response. The seismic response demands are compared for different alternative analysis methods based on Indian Code seismic provisions for seismic design. Seismic coefficient method and the Response Spectrum analysis methods has been used. A parametric study is carried out to evaluate the design parameters effects on the building seismic demands in different approaches of analysis and to assess the column moment, axial force for the two methods of analysis. The linear analysis is performed using SAP2000. The response of structures has been studied in the form of column moment, column axial force. Based on the outcome results of the numerical study, the seismic response demands including column moment and axial force, are evaluated.

Various sizes of openings and changing shape of openings have been performed and investigation the optimum results of model has been studied. The various sizes and shape of openings in shear wall as shown in Table 1. The results presented in the form of Figures from 4.5 to 4.10 respectively.

Table 1- Variation of Sizes of Openings

Sizes of Window Openings				Door Openings	
Rectangular Openings	Percentage of Openings	Square Openings	Percentage of Openings	Sizes of openings	Percentage of Openings
0.8X0.6	3.75	0.8X0.8	5.00	0.8X2.0	12.50
1.2X1.4	13.13	1.2X1.2	11.25	0.8X2.2	13.75
2.0X1.4	21.88	1.6X1.6	20.00	1.2X2.0	18.75
2.4X1.6	30.00	2.0X2.0	31.25	1.2X2.2	20.63

4.2.1 Column Moment (KNm)
The variation of Central Column Moments have been studied. The Column Moments are observed as maximum for 1.5(Dead+EQx) case. The variation of base shear for 15-Storey frame building is shown in figure 5, 6 and 7.

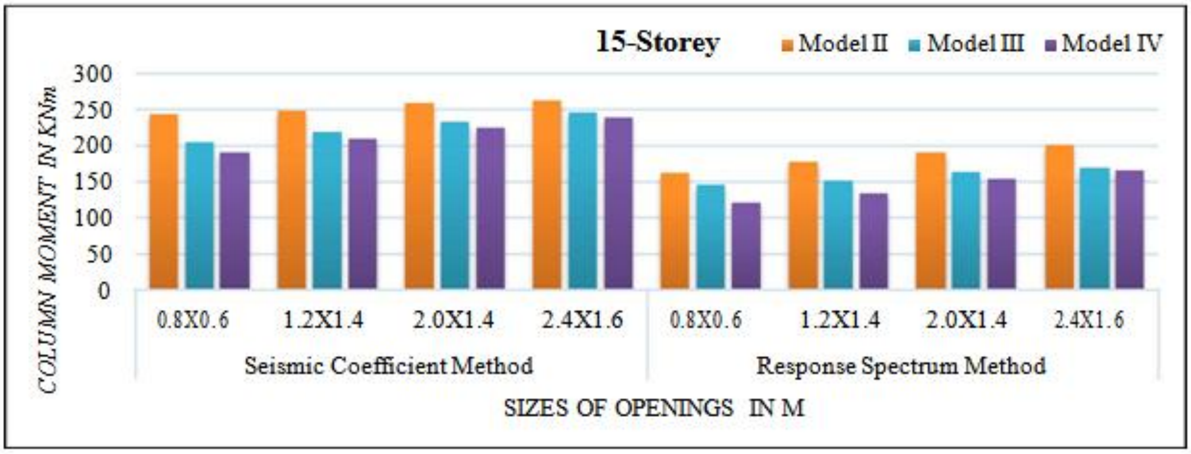

Figure 4.5: Variation of Column Moment for Rectangular Window Opening

Figure 4.6: Variation of Column Moment for Square Window Opening

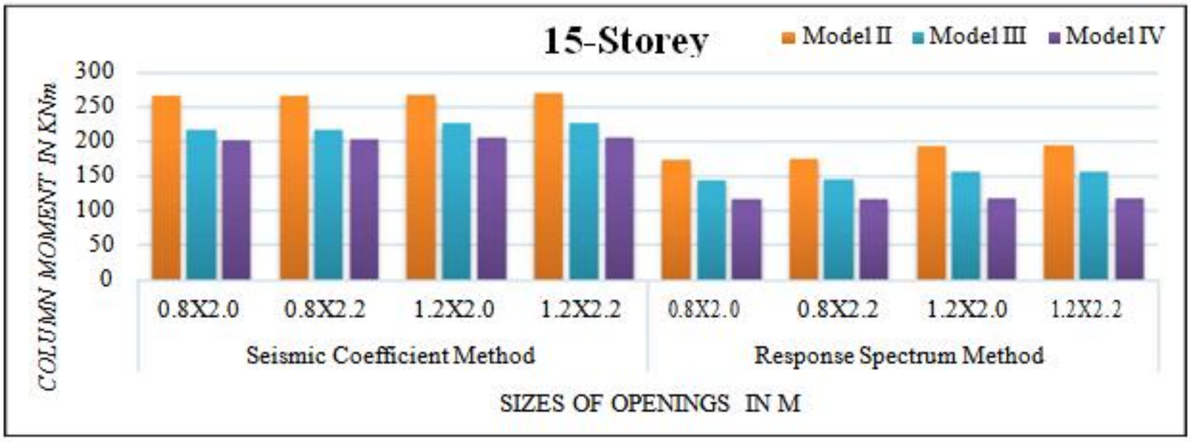

Figure 4.7: Variation of Column Moment for Door Opening

4.2.2 Column Axial Force (KN)
The variation of Central Column Axial Forces have been studied. The Column Axial Forces are observed as maximum for 1.5(Dead+EQx) case. The variation of base shear for 15-Storey frame building is shown in figure 8, 9 and10.

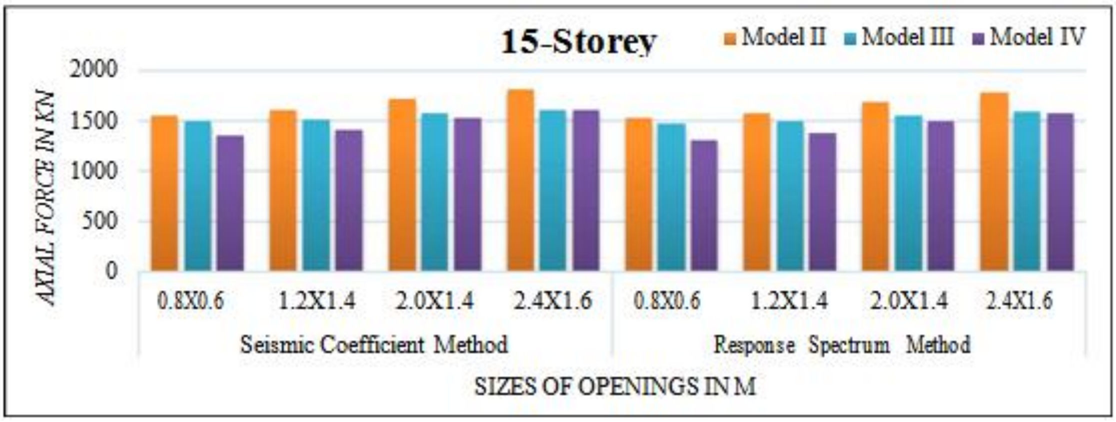

Figure 4.8: Variation of Column Axial Force for Rectangular Window Opening of 15-Storey

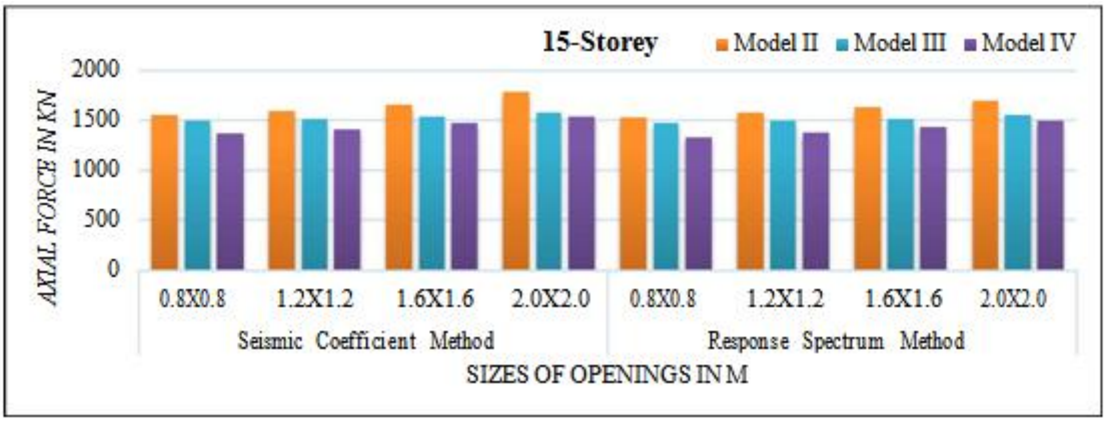

Figure 4.9: Variation of Column Axial Force for Square Window Opening

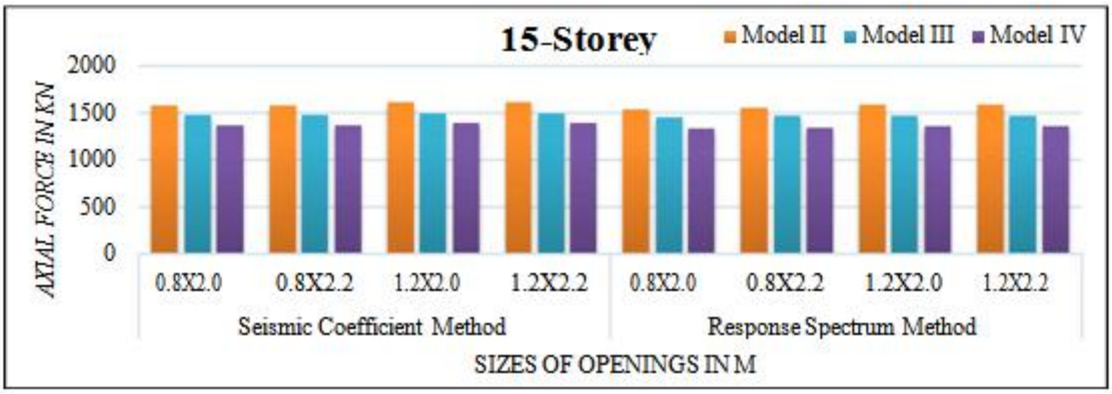

Figure 4.10: Variation of Column Axial Force for Door Opening

V. Conclusions

In the present study, linear finite element analysis of reinforced concrete buildings by changing position of shear wall with opening is carried out for different storey heights. The sizes and shape of openings in shear wall is changed. The buildings are analyzed for severe earthquake load (seismic zone V). Comparison is made between various parameters such as column moment and axial force.

Few prominent conclusions for shear wall with openings are as follows:

1) The external as well as internal shear wall reduces column moment and axial force as compared to core and core with internal shear wall
2) Performance of shear wall model IV is more effective than the other models, as the stiffness of building is more.
3) Response Spectrum Method predicts lesser forces as compared to Seismic Coefficient Method.
4) The presence of openings in shear wall decreases the strength and rigidity of the shear wall depending on

the sizes and shapes of opening.

5) The column moment and axial force increase as sizes of opening increase because stiffness of shear wall with openings decreases.
6) As length of shear wall in plan increases the opening effect is reduced and also shape of opening do not affect the responses of structure but the height and width of openings do affect.
7) The frames with shear wall is affected by the size of openings than their locations in the shear walls on the stiffness and response of structure with opening area ≤15% of solid shear wall area. However, it is considerably affected by the opening locations in shear walls with opening area >15% of solid wall area.

In the present study, types of shear wall is not considered. Therefore work can be repeated by type of shear wall. Flexible foundation is not considered. Therefore work can be repeated by soil structure interaction. The study of changing position of shear wall with openings can be done by variation of shape and sizes of openings. All the analysis can be done for different seismic parameters.

Acknowledgement

The present authors Reshma Chavan, Prof. Prakarsh Sangave and Prof. Ashok Kankuntla thank Dr. J. B. Dafedar, Principal, Nagesh Karajagi Orchid College of Engg. and Tech., Solapur, for his invaluable support on this research. The authors also thank Prof. Metan S., Dept. of Mechanical Engg., Nagesh Karajagi Orchid College of Engg. and Tech., Solapur, for guiding regarding paper writing skills.

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