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Analysis And Design Of Shear Walls For Earthquake Resistant Buildings Using Etabs

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ABSTRACT: The approach for estimating the seismic performance of tall structures is presented in this paper and is based on the idea of the capacity spectrum technique. Thirty-story structures have been analysed using the structural analysis programme ETABS, with normal and irregular building models created in 3D. Every significant element that affects the building's mass, strength, stiffness, and deformability is included in the analytical model. Through the use of linear static, linear dynamic, and non-linear static procedures, seismic analysis has been carried out in order to examine the impact of the concrete core wall and shear wall at various points during an earthquake. The Response Spectrum Method was used to examine the deflections at each storey level in order to ascertain the capacity, demand, and performance level of the building models under consideration. According to the research listed below, the non-linear Response spectrum technique yields accurate estimates of both local and global inelastic deformation demands. It also identifies design flaws that would go unnoticed in an elastic analysis and the structure's performance level. Storey drifts are discovered using the Response spectrum approach within the limits given by code (IS: 1893-2002).

Keywords: Shear walls, displacement, story drift, ETABS, and high-rise structures.

I. INTRODUCTION

1.1 GENERAL:

Many medium-rise apartment buildings are being constructed, in India, using shear walls to provide earthquake resistance to reinforced concrete frames. These shear walls may have openings for the windows, doors and duct spaces for functional reasons. The number, location and size of openings affect the behavior of a structure as well as stress in the shear wall.

Framed structures with shear wall are frequently adopted as the structural system for high-rise building structures. This structural system would also have many openings for the entrance to elevators or staircases etc. Generally, plane stress elements and beam elements are used to model the shear wall and frames respectively in the analysis of this kind of building. A plan stress element should have drilling degrees of freedom to represent the connection of shear wall core and frames. Otherwise, the bending moment at the end of a beam cannot be transferred to the shear wall.

The openings may be of large size that is in the case where it is like function halls, conference halls, and movie theaters. The number, location, size, and shape of opening affects the behavior of structure in the form of deflection, stress in the members. These openings seriously effects the efficiency and accuracy of the analysis.

1.2 FRAME:

A rigid jointed R.C frame consists of Rectangular components, beams and columns connected together in the same plane by means of rigid joints. The lateral stiffness of such a frame depends upon the building stiffness of columns, beams, and connections in the plane. The frame may be in the with an interior wall of the building, or plane with the façade. The rigid frames principle advantage is its open rectangular arrangement, which allows freedom of planning and easy fitting of doors and windows. The rigid frame principle seems to be economical up to approximately 25stories for steel framing and up to 15 stories for concrete framing. Above these relatively low lateral flexibilities of frame calls for economical large numbers in order to control the drift.

The horizontal stiffness of a rigid frame is governed mainly by the bending resistance of the girders, the columns, and the connections, and in tall frame, by the axial rigidity of the columns. The accumulated horizontal shear above any story of ridig frames resisted by shear in columns in that story the shear causes. The story-height columns to bend in double curvature with points of contraflexture at mid-story height levels. The moments applied to a joint from the column above and below are resisted by attached girders, which also bend in double curvature, with points of contraflexture at approximately mid span.

These deformations of the columns and girders allow racking of the frame and horizontal deflection in each story. The overall deflected shape of a rigid frame structure due to racking has a shear configuration with concavity upward. A maximum inclination near the base and a minimum inclination at the top.

Rigid frame construction is ideally suited for reinforced concrete buildings because of the inherent rigidity of reinforce concrete joints. The rigid frame form is also used for steel frame buildings, but moment resistant connections in steel tend to costly. The size of the columns and girders at any level of the rigid frame are become directly influenced by the magnitude of external shear at that level, and they therefore increase towards the base. Consequently the design of the floor framing cannot be repetitive as it is in the case of some braced frames.

1.3 MASONRY IN FILLED FRAMES

The lateral stiffness against forces due to wind or earthquake is primary consideration in the design of multistoried building. The one of the method to increase the lateral stiffness of a multistory frame is by using composite stiffness and strength of the structural framework and the infill walls. Brick masonry is the most commonly used material in construction of in filled frames. The behavior of an in filled frame depends upon the interaction of the frame and the in fill. The guiding characters of behavior are panel proportion and the quality of an in fill work. The location of the infill also plays an important role in the behavior of the system

Under lateral loads, the mortar cracks, causing sliding and separation at the interface between the frame and infill. This cracking of infill causes stiffness degradation results in the change in the structural behavior. Due to continuous cracking the moment of inertia and the stiffness reduces continuously results in failure.

1.4 SHEAR WALL

Shear walls are vertical stiffening elements designed to resist lateral forces exerted by wind or earthquake. The shape and location of shear wall have significant effect on their structural behavior under lateral loads. Lateral loads are distributed through the structure acting as a horizontal diaphragm, to the shear walls, parallel to the force of action. These shear wall resist horizontal forces because their high rigidity as deep beams, reacting to shear and flexure against overturning. A core eccentrically located with respect to the building shapes has to carry tension as well as bending and direct shear. However torsion may also develop in building symmetrical featuring of shear wall arrangements when wind acts on the facades of direct surface textures (i.e, roughness) or when wind does not act through the center of building's mass (schueller, 1977).

Shear walls are much stiffer than horizontal rigid frames. Therefore shear walls are economical up to 35 stories. If, in low to medium rise buildings, shear walls are combined with frames, it is reasonable to assume that the shear walls attract all the lateral loading so that frame may be designed for gravity loads only.

Resistance of a shear wall increases linearly with its thickness. However, the effect of width is much higher.

A coupled shear wall structure is a particular, but very common, form of shear wall structure. It consists of two or more shear walls in the same plane, or almost the same plane, connected at floor levels by means of stiff beams or slabs. These results in a horizontal stiffness very much greater than if the walls acted as a set of separate uncoupled cantilevers.

1.5 SHEAR WALL COMPONENTS:

Reinforced concrete and reinforced masonry shear walls are seldom-simple walls. Whenever a wall has doors, windows, or other openings, the wall must be considered as an assemblage of relatively flexible components like column segments and wall piers and relatively stiff elements like wall segments

1. **Column segments:** A column segment is a vertical member whose height exceeds three times its thickness and whose width is less than two and one-half times its thickness. Its load is usually predominantly axial. Although it may contribute little to the lateral force resistance of the shear wall, its rigidity must be considered. When a column is built integral with a wall, the portion of the column that projects from the face of the wall is called a pilaster. Column segments shall be designed according to ACI 318 for concrete.
2. **Wall piers:** A wall pier is a segment of a wall whose horizontal length is between two and one-half and six times its thickness and whose clear height is at least two times its horizontal length.
3. **Wall segments:** Wall segments are components that are longer than wall piers. They are the primary resisting components in the shear wall.

1.6 OBJECTIVE OF THE STUDY

The following are the main objectives of the project

1. To study the seismic behavior of multi story building by using IS 1893:2002
2. To compare the multi story buildings with and without shear wall at different locations on multi story Building with regular and irregular shapes .
3. To compare the results of Story Drift, Shear force, Bending moment, Building torsion of buildings without shear wall at different locations on multi story Building with regular and irregular shapes.
4. To study the buildings in ETABS in Response spectrum analysis.

1.7 SUMMARY:

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. LITERATURE REVIEW

Ehsan Salimi Firoozabad, Dr. K. Rama Mohan Rao, Bahador Bagheri.,et al[1] (2012)

In the present study main focus is to determine the effect of shear wall configuration on seismic performance of buildings. Time history analysis has been done to buildings with different number of stories and various configurations with same plan. The top story displacements have been obtained and compared to each other for all models to meet the effect of shear wall configuration on seismic performance of buildings. The analysis and design of models have been studied based on IS codes, and SAP 2000 software have been used for this purpose.

From this study, it was concluded that different position of shear walls can reduce the top story drift at least twice, which means the drift of building is reduced 100 percent from highest value to lowest one. Maximum drift limitation of 0.004 as per IS code is satisfied for all height of the building using ELCENTRO earthquake, whereas the above limitation is not satisfied by TABAS earthquake. For configuration sixth, the maximum drift limitation is satisfied by both ELCENTRO and TABAS earthquakes, this shows that, the location of shear walls plays major role for the limitation of drift. The quantity of shear walls cannot guarantee the seismic behavior of buildings, which means, if you provide more shear walls, it will not guarantee the better seismic behavior of buildings.

Shahzad Jamil Sardar and Umesh. N. Karadi., et al[2] (2013)

In this project, study of 25 storeys building in zone V is presented with some investigation which is analyzed by changing various location of shear wall for determining parameters like storey drift, storey shear and displacement is done by using standard package ETAB. Creation of 3D building model for both linear static and linear dynamic method of analysis and influence of concrete core wall provided at the center of the building.

From this study it was concluded that the seismic analysis of reinforced concrete frame structure is done by both static and dynamic analysis to determine and compare the base shear; it has been found that maximum base shear in model-5 along longitudinal and transverse direction as compared to the other models. In equivalent static analysis it has been found that model-5 shows lesser displacement as compared to other models in longitudinal direction. In response spectrum analysis model-5 shows lesser displacement as compared to other models in longitudinal direction. In equivalent static analysis it has been found that model-5 shows lesser interstorey drift as compared to other models in longitudinal direction. In response spectrum analysis model-5 shows lesser inter-storey drift as compared to other models in longitudinal direction.The presence of shear wall can affect the seismic behavior of frame structure to large extent, and the shear wall increases the strength and stiffness of the structure.It has been found that the model-5 shows better location of shear wall since lateral displacement and inter-storey drift are less as compared to other models.

Najma Nainan., et al[3] (2012)

Structures on the earth are generally subjected to two types of load: static and dynamic. Static loads are constant with time while dynamic loads are time- varying. In general, the majority of civil engineering structures are designed with the assumption that all applied loads are static. The effect of dynamic load is not considered because the structure is rarely subjected to dynamic loads; more so, its consideration in analysis makes the solution more complicated and time consuming. This feature of neglecting the dynamic forces may sometimes become the cause of disaster, particularly, in case of earthquake. Reinforced concrete (RC) shear walls are used in buildings to resist lateral forces due to wind and earthquakes. They are usually provided between column lines, in stair wells, lift wells, and in shafts that house other utilities. Shear walls provide lateral load resistance by transferring the wind or earthquake loads to the foundation. Besides, they impart lateral stiffness to the system and also carry gravity loads. A well-designed system of shear walls in a building frame improves its seismic performance significantly. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness, and sufficient ductility. Among the various structural systems, shear wall-concrete frame could be a point of choice for the designer. Hence, the present study include: the effect of height of shear wall in the dynamic response of building frame.

From this study it was concluded that the analytical study on the dynamic response of seismo-resistant building frames was done. The storey displacements for various heights of shear wall in the dynamic response of building frames are obtained. From the study, the following conclusion can be drawn out. If the height of shear wall extended up to mid height of building frames, the displacement goes on decrease. But if the shear wall extended to full length of building there will not much reduction in the displacement. Hence, there is no need for providing shear wall throughout the height of high rise buildings. That is the response of shear wall beyond mid height of the building against lateral forces is least.

Mr.K.LovaRaju, Dr.K.V.G.D.Balaji., et al[4] (2015)

This paper deals with the non-linear analysis of frame for various positions of shear wall in a building frame. In this present study, the focus is to identify effective location of shear wall in multi-storey building. Considering model one is bare frame structural system and other three models are dual type structural system. An earthquake load is applied to a building of eight storey is located in zone II, zone III, zone IV and zone V as per Code Provision IS1893- 2002. The analysis has been carried out using ETABS software. Pushover curves have been developed and compared for various models. It has been observed that structure with shear wall at appropriate location is more significant in case of displacement and base shear.

In the present study four models of eight-storey structure is considered, which one of model is bare frame and other models with shear wall location in position-1,position2,position-3 in all seismic zones and corresponding baseshear and lateral displacement derive from the pushover curve using Etabs software. Provision of a shear wall influences the seismic performance of the structure with reference to strength and lateral displacement. Shear wall in position-3 performs better and the base shear increased by 9.82% when compared to the frame without shear wall. Shear wall in position-3 performs better with reference to lateral displacement and it reduces by 26.7% when compared to the frame without shear wall. The provision of shear wall position in an appropriate location is advantageous and the structure performs better for an existing or a new structure.

Varsha R. Harne et al[5]., (2014)

In this paper, main focus is to determine the solution for shear wall location in multistory building. A RCC building of six storey placed in NAGPUR subjected to earthquake loading in zone-II is considered. An earthquake load is calculated by seismic coefficient method using IS 1893 (PART–I):2002. These analyses were performed using STAAD Pro. A study has been carried out to determine the strength of RC shear wall of a multistoried building by changing shear wall location. Three different cases of shear wall position for a 6 storey building have been analyzed. Incorporation of shear wall has become inevitable in multi-storey building to resist lateral forces.

From this study it was concluded that among all the load combination, the load combination of 1.5DL+1.5EQX is found to be more critical combination for all the models. The lateral deflection of column for building with type 2 shear wall is reduced as compared to all models. The shear force is maximum at the ground level for model III as compared to model II and IV. The shear force of model IV at middle level is more as compared to model III. The bending moment is maximum at roof level for model III among all the models. It has been observed that the top deflection is reduced after providing type 2 shear wall of the frame in X-direction as well as in Y-direction. For the load 1.5DL+1.5EQZ, both the shear force and bending moment is maximum for model III of the frame in X-direction. It has also been observed that for the load

1.5DL+1.5 EQX, the shear force is more for model III as compared to model II of the frame of Y-direction. The bending moment of model IV is more than model III for the load 1.5DL+1.5 EQX of the frame in Y-direction. Hence, it can be said that building with type 2 shear wall is more efficient than all other types of shear wall.

III. MODELLING OF SHEAR WALL

In this chapter, shear wall models developed for the lateral load analysis of multistorey structures in elastic region are presented. Since the methods for modelling building structures are analyzed separately. Shear wall modelling studies can also be investigated in according to the two and three dimensional approaches.

3.1 TWO DIMENSIONAL (PLANAR) SHEAR WALL MODELS

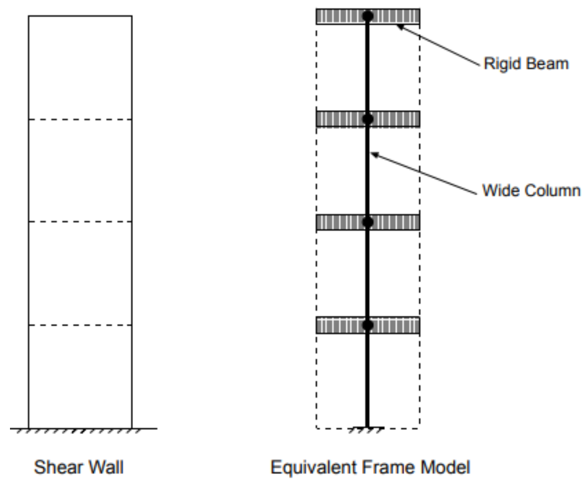
The literature mentions several shear wall models that were developed for two dimensional elastic analysis of multistorey building structures. In this part, a review of these models is given.

3.1.1 EQUIVALENT FRAME MODEL (WIDE COLUMN ANALOGY)

The equivalent frame model was developed by Clough et al. [47], Candy [48] and MacLeod [49] for the analysis of plane coupled shear wall structures. The model was limited to lateral load analysis of rectangular building frames without torsion. It was improved in the 1970's by Mcleod [50, 51] and McLeod and Hosny [52] for the analysis of nonplanar shear walls.

In the equivalent frame method, which is also known as wide column analogy, each shear wall is replaced by an idealized frame structure consisting of a column and rigid beams located at floor levels. The column is placed at the wall's centroidal axis and assigned to have the wall's inertia and axial area. The rigid beams that join the column to the connecting beams are located at each framing level [8]. A sample model is shown in Figure 3.1. In this method, the axial area and inertia values of rigid arms are assigned very large values compared to other frame elements.

Due to its simplicity, the equivalent frame method is especially popular in design offices for the analysis of multistorey shear wall-frame structures.



3.1 Equivalent Frame Model of a Shear Wall

3.1.2 ANALOGOUS FRAME METHOD

This alternative method, proposed by Smith et al.[53], was developed for modelling planar and nonplanar shear walls. The purpose of their study was to overcome the artificial flexure and excessive shear deformations due to discrete modelling of continuous vertical joints between adjacent planar wall units in the conventional equivalent frame method. In their study, they proposed two different frame models for shear wall analysis: the braced wide column analogy and the braced frame analogy.

The braced wide column analogy is similar to the conventional wide column analogy presented above, but with diagonal braces. A single module consists of rigid horizontal beams, equal in length to the width of the wall, connected by a single central column. Hinged-end diagonal braces connect the ends of the beams [53]. A typical braced wide column module is shown in Figure 3.2. A planar shear wall modelled by braced wide column analogy is given in Figure 3.3.

The stiffness properties of the column (Ic, moment of inertia of the column and Ac, area of the column) and braces (Ad, axial area of the diagonal brace) are determined by the following three equations:

$$I_c = \frac{tb^3}{12} \tag{3.1}$$

$$\frac{12EI_c}{h^3} + \frac{2EA_d \cos^2\theta}{l} = \frac{btG}{h} \tag{3.2}$$

$$\frac{EA_c}{h} + \frac{2EA_d \sin^2\theta}{l} = \frac{EA_w}{h} \tag{3.3}$$

These equations are based on the simulation of the bending, shear and axial stiffnesses of

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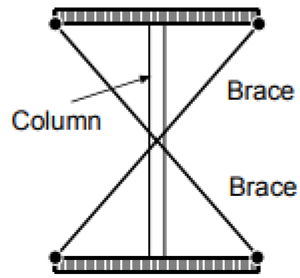
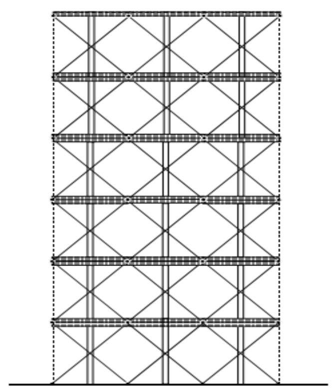
corresponding wall segments. In the equations, t is the thickness and b is the width of the shear wall, E is the modulus of elasticity, h is the height of the shear



3.2 Braced Wide Column Module



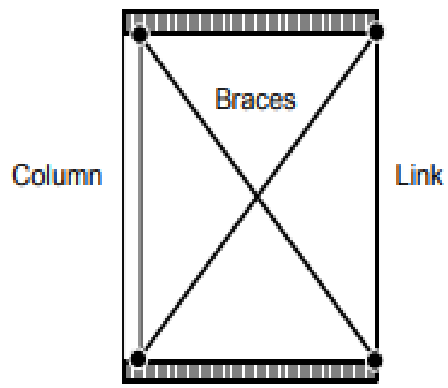
3.3 A Planar Shear Wall Modelled by Braced Wide Column Analogy

wall, θ is the slope of the diagonal, l is the length of the diagonal brace, G is the shear modulus and Aw is the sectional area of the shear wall.

In braced frame analogy, the module is asymmetric and consists of a column on the left hand side connected to the rigid beams, a hinged-end on the right hand side and diagonal braces. The left-hand end of the beam and the ends of the column rotate with the nodes, while the right-hand end of the beam and the link are rotationally released from the nodes [53]. Similar equations (Eqn.3.1, 3.2 and 3.3) are used for obtaining the stiffness properties of the column, braces and the link. In Figure 3.4, a sketch of a braced frame module is given.

One of the deficiencies of the two analogies is the probability of obtaining negative stiffness values for the column and braces for certain aspect ratios of the framework modules. Since most of the frame analysis computer programs cannot perform analysis with negative area and inertia values, these methods may be ineffective.

Koumousis and Peppas [54] derived the stiffness matrices for the two proposed analogies. In their study, the two dimensional braced wide column module and the braced frame module are presented as modified three dimensional modules which can be introduced to other structural analysis programs. Then negative stiffness value problem is solved by creating new shear wall geometry, in which the original shear wall is divided into a series of adjacent horizontal shear walls having positive stiffness values.



3.4 Braced Frame Module

An improved wide column-frame analogy was proposed by Kwan [55] in 1991 in order to overcome the artificial flexure problem of the conventional wide columnframe analogy. It is an alternative method of the braced wide column and braced frame analogies developed by Smith et al., in which the shear deformation factor of the wall elements are adjusted to compensate for the errors in deformation due to artificial flexure. In another study by the same author [56], the analogous frame modules developed by Smith et al. [53] and the improved wide column frame module that he developed later [55] are shown to be equivalent to each other.

The three dimensional applications of the proposed models are discussed in the following parts

3.1.3 FINITE ELEMENT MODELS

In the finite element modelling of a two dimensional shear wall, the wall is divided into smaller elements having finite size and number. These elements may be triangular, rectangular or quadrilateral. The most common plane stress element used for modelling shear walls is the two dimensional shell element. It has three degrees of freedom at each node (two translation and one rotation). The finite element method is widely used not only in modelling multistorey structures but also for all kinds of engineering problems. In Figure 3.5, a finite element model of a coupled shear wall is given. A rectangular shell element is given in Figure 3.6.

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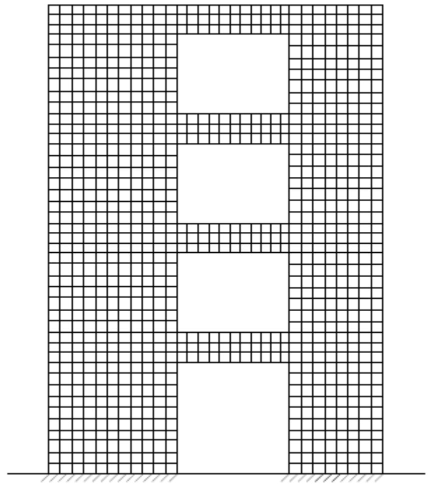
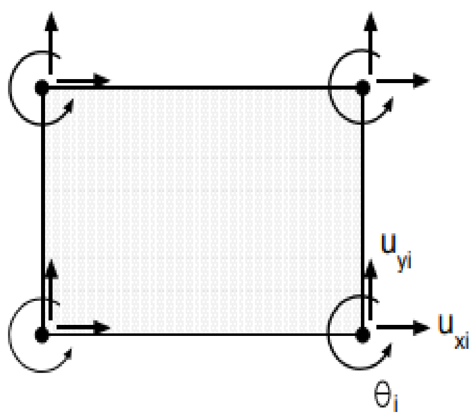


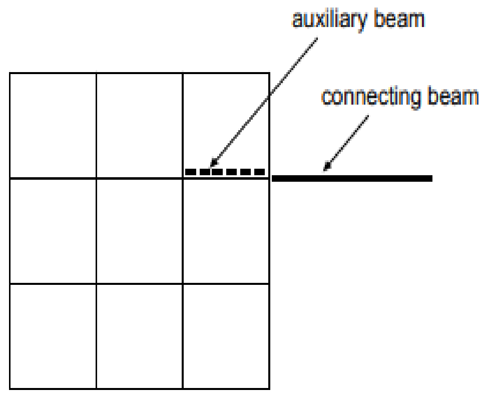
3.5 Finite Element Model of a Coupled Shear Wall

For the planar analysis of shear wall–frame structures, two dimensional frame members with three degree of freedom at each node (Figure 2.2) are used to model beams and columns and two dimensional plane stress elements are used for modelling shear walls.

An important factor in finite element analysis is the decison on the total number of elements that will be used in modelling the shear walls. More accurate results can be obtained with a finer mesh, but the total running time may be longer. An optimum number of finite elements should be included in analysis.



3.6 A Rectangular Shell Element with Three D.O.F. at Each Node



3.7 Plane Stress Elements with Horizontal Auxiliary Beam

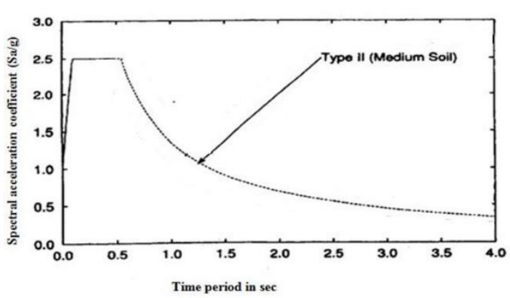
Starting in the late 1960's, different forms of finite elements were developed for the analysis of shear walls [57, 58, 59, 60, 61]. A review of these methods can be found in [62]. In order to improve the efficiency of the finite element method and to deal with the parasitic shear problem, finite strip elements [63] and high order elements were developed [64] for modelling shear walls.

IV. METHODOLOGY AND MODELLING OF BUILDING

4.1 METHODOLOGY:

RESPONSE SPECTRUM METHOD:

The representation of maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. This analysis is carried out according to the code IS 1893-2002 (part1). Here type of soil, seismic zone factor should be entered from IS 1893-2002 (part1). The standard response spectra for type of soil considered is applied to building for the analysis in ETABS 2013 software. Following diagram shows the standard response spectrum for medium soil type and that can be given in the form of time period versus spectral acceleration coefficient (Sa/g).



Response spectrum for medium soil type for 5% damping

This approach permits the multiple modes of response of a building to be taken in to account (in the frequency domain). This is required in many building codes for all except very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the “harmonic” computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

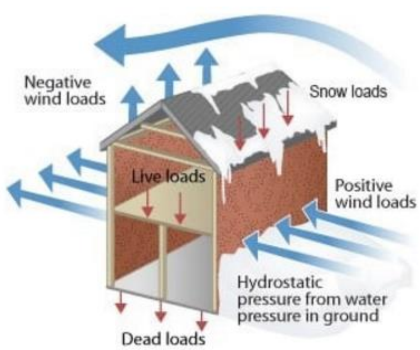
- absolute - peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

In cases where structures are either too irregular, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

4.2 DIFFERENT TYPES OF LOADS ACTING ON THE STRUCTURE

The types of loads acting on structures for buildings and other structures can be broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead loads, live load and impact load. The horizontal loads comprises of wind load and earthquake load. The longitudinal loads i.e. tractive and braking forces are considered in special case of design of bridges, gantry girders etc.



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In a construction of building two major factors considered are safety and economy. If the loads are adjusted and taken higher then economy is affected. If economy is considered and loads are taken lesser then the safety is compromised.

So the estimation of various loads acting is to calculated precisely. Indian Standard code IS: 875-1987 and American Standard Code ASCE 7: Minimum Design Loads for Buildings and Other Structures specifies various design loads for buildings and structures.

Types of loads acting on the structure are:

- Dead loads
- Imposed loads
- Wind loads
- Snow loads
- Earthquake loads
- Special loads

V. RESULTS AND ANALYSIS

I. Irregular Building:

5.1 Story Drift:

X-Direction

Story	DriftX with out Shear wall	DriftX with Shear wall at corner	DriftX with alternative position
STORY22	0.005584	0.002766	0.004437
STORY21	0.007351	0.002782	0.004515
STORY20	0.00927	0.002791	0.004614
STORY19	0.011168	0.002791	0.004733
STORY18	0.012998	0.002782	0.004863
STORY17	0.014744	0.002761	0.004996
STORY16	0.016398	0.00273	0.005123
STORY15	0.017959	0.002689	0.005237
STORY14	0.019461	0.002637	0.005329
STORY13	0.02088	0.002575	0.005392
STORY12	0.022214	0.002501	0.00542
STORY11	0.023459	0.002415	0.005405
STORY10	0.024606	0.002314	0.005338
STORY9	0.025641	0.002198	0.005212
STORY8	0.026546	0.002063	0.005016
STORY7	0.027295	0.001907	0.004743
STORY6	0.027859	0.001728	0.004383
STORY5	0.028197	0.001521	0.003923
STORY4	0.028226	0.001283	0.00335
STORY3	0.027654	0.00101	0.002644
STORY2	0.025206	0.000699	0.001787
STORY1	0.01442	0.000334	0.000742

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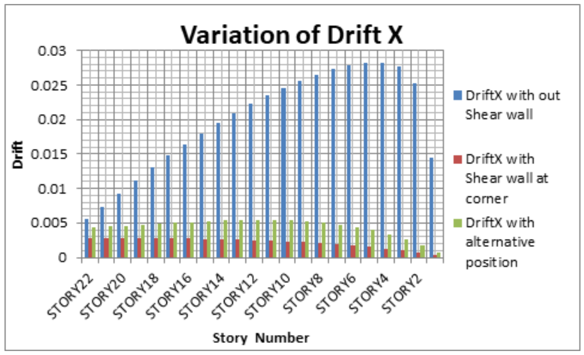
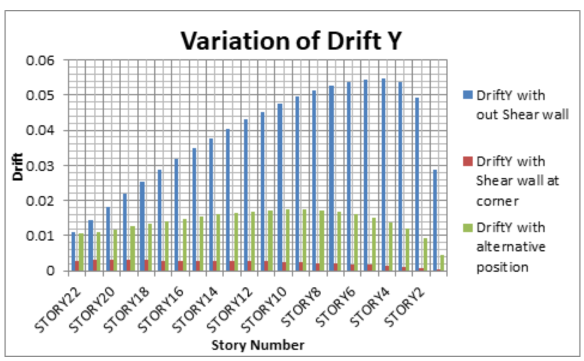


Y-Direction

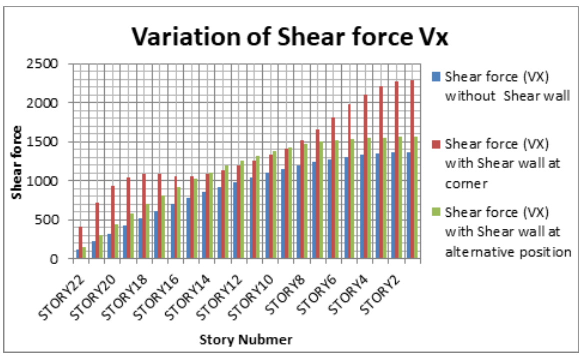
Story	DriftY with out Shear wall	DriftY with Shear wall at corner	DriftY with alternative position
STORY22	0.011064	0.002985	0.010547
STORY21	0.014338	0.003008	0.011148
STORY20	0.018095	0.003022	0.011868
STORY19	0.021781	0.003027	0.012618
STORY18	0.025319	0.00302	0.013367
STORY17	0.028685	0.003003	0.014103
STORY16	0.031872	0.002976	0.014812
STORY15	0.034883	0.002938	0.015474
STORY14	0.037728	0.00289	0.016067
STORY13	0.040413	0.002831	0.01657
STORY12	0.042941	0.002758	0.016967
STORY11	0.045307	0.00267	0.017245
STORY10	0.047493	0.002566	0.017382
STORY9	0.049472	0.002442	0.017357
STORY8	0.051207	0.002297	0.017142
STORY7	0.052653	0.002128	0.016715
STORY6	0.053758	0.001934	0.016052
STORY5	0.054452	0.001711	0.01512
STORY4	0.054596	0.001458	0.013852
STORY3	0.053675	0.001174	0.012088
STORY2	0.049284	0.000859	0.009401
STORY1	0.028635	0.000494	0.004426



5.2 Shear Force:

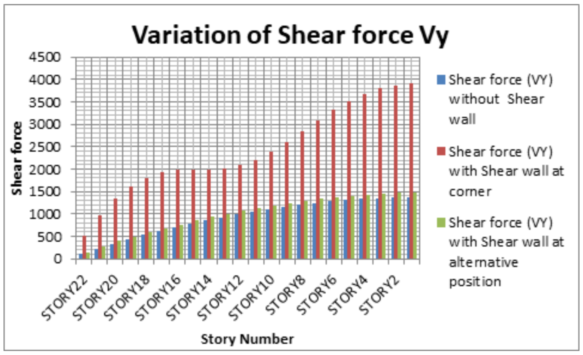
X-Direction:

Story	Shear force (VX) without Shear wall	Shear force (VX) with Shear wall at corner	Shear force (VX) with Shear wall at alternative position
STORY22	110.12	406.17	149.25
STORY21	219.08	724.16	298.06
STORY20	324.4	933.94	438.87
STORY19	425.25	1047.82	571.55
STORY18	520.98	1087.06	695.94
STORY17	611.2	1081.07	811.87
STORY16	695.76	1063.16	919.22
STORY15	774.73	1061.48	1017.85
STORY14	848.38	1088.5	1107.67
STORY13	917.06	1138.92	1188.65
STORY12	981.15	1199.63	1260.8
STORY11	1040.96	1262.32	1324.19
STORY10	1096.67	1329.45	1378.98
STORY9	1148.27	1411.99	1425.4
STORY8	1195.53	1521.18	1463.79
STORY7	1238.05	1659.29	1494.57
STORY6	1275.27	1816.1	1518.28
STORY5	1306.55	1972.77	1535.57
STORY4	1331.3	2109.01	1547.23
STORY3	1348.99	2209.48	1554.19
STORY2	1359.43	2267.85	1557.52
STORY1	1363.15	2288.76	1558.46



Y-Direction:

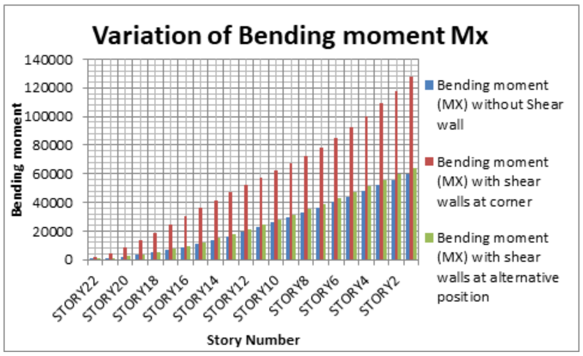
Story	Shear force (VY) without Shear wall	Shear force (VY) with Shear wall at corner	Shear force (VY) with Shear wall at alternative position
STORY22	112.72	516.35	143.3
STORY21	223.64	973.51	277.9
STORY20	330.4	1338.91	395.06
STORY19	432.29	1614.22	497.12
STORY18	528.82	1804.84	589.81
STORY17	619.68	1920.73	678.76
STORY16	704.79	1977.07	766.37
STORY15	784.23	1994.81	851.38
STORY14	858.25	2000.12	931.2
STORY13	927.18	2021.8	1004.45
STORY12	991.32	2085.39	1071.84
STORY11	1050.92	2205.66	1134.96
STORY10	1106.11	2382.31	1194.4
STORY9	1156.86	2602.17	1249.07
STORY8	1202.95	2845.41	1297.21
STORY7	1244.01	3091.33	1338.21
STORY6	1279.6	3321.69	1373.32
STORY5	1309.2	3522.26	1404.63
STORY4	1332.37	3683.33	1432.96
STORY3	1348.79	3799.82	1456.57
STORY2	1358.41	3871.35	1472.14
STORY1	1361.84	3901.99	1477.88



5.3 Bending Moment:

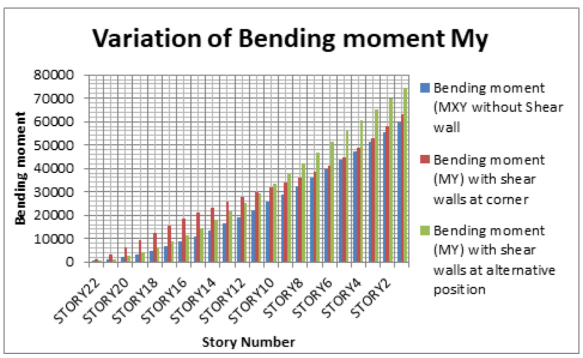
X-Direction:

Story	Bending moment (MX) without Shear wall	Bending moment (MX) with shear walls at corner	Bending moment (MX) with shear walls at alternative position
STORY22	338.148	1549.047	429.905
STORY21	1009.045	4468.975	1262.944
STORY20	2000.106	8482.62	2444.15
STORY19	3296.563	13315.21	3922.251
STORY18	4881.926	18703.47	5660.422
STORY17	6738.557	24405.75	7640.038
STORY16	8848.264	30212.7	9855.978
STORY15	11192.86	35957.83	12307.18
STORY14	13754.6	41527.24	14988.64
STORY13	16516.57	46867.37	17888.82
STORY12	19462.77	51989.28	20992.11
STORY11	22578.2	56967.62	24282.57
STORY10	25848.65	61932.2	27745.68
STORY9	29260.44	67051.09	31367.28
STORY8	32800.06	72505.84	35131.46
STORY7	36453.82	78462.86	39019.86
STORY6	40207.44	85047.15	43013.17
STORY5	44045.89	92324.99	47093.64
STORY4	47953.21	100299.2	51246.33
STORY3	51912.66	108916.5	55458.03
STORY2	55907.17	118084	59714.86
STORY1	59920.69	127688.2	64001.5



Y-Direction:

Story	Bending moment (MXY without Shear wall	Bending moment (MY) with shear walls at corner	Bending moment (MY) with shear walls at alternative position
STORY22	330.366	1218.498	447.744
STORY21	987.591	3389.612	1341.932
STORY20	1960.694	6183.738	2658.557
STORY19	3236.068	9300.398	4373.208
STORY18	4797.993	12488.48	6461.015
STORY17	6629.29	15563.1	8896.636
STORY16	8712.011	18414.58	11654.29
STORY15	11028.1	21006.23	14707.84
STORY14	13559.95	23360.26	18030.85
STORY13	16290.82	25534.58	21596.8
STORY12	19205.06	27598.21	25379.19
STORY11	22288.17	29614.67	29351.75
STORY10	25526.63	31639.93	33488.68
STORY9	28907.56	33733.77	37764.88
STORY8	32418.38	35975.25	42156.25
STORY7	36046.24	38469.51	46639.95
STORY6	39777.63	41336.76	51194.77
STORY5	43598	44684.25	55801.47
STORY4	47491.55	48573.98	60443.16
STORY3	51441.2	53003.06	65105.73
STORY2	55429.04	57907.72	69778.28
STORY1	59437.86	63188.95	74453.66



VI. CONCLUSIONS

The aforementioned investigation led to the following findings

1. Shear walls at corners will provide better results than shear walls at alternative positions for both X and Y direction. For both regular and irregular structures, the values of drift in both X and Y direction are fewer when constructing with shear walls than when building without herar walls.
2. Shear force values in both the X and Y directions were found to be lower for structures without shear walls, as well as for buildings with shear walls at corners and in alternate positions. Also, compared to the shear wall at the corner position, the shear wall at the alternate location has greater values.
3. Structures without shear walls, as well as those with shear walls at corners, have lower values of Building Torsion (T) than other types of structures. Also, compared to the

shear wall at the corner position, the shear wall at the alternate location has greater values.

4. The building with the alternative shear wall location has lower bending moment values than the building at the corner, according to the bending moment (M) point of view.
5. Shear wall openings cause the bending moment and shear force in the columns attached to the shear wall to significantly rise; when the opening is at the top of the percentage increase, the opening percent decreases.
6. It was noted that when the opening position of a certain wall opening was changed from one position to another.
7. This research found that as the fraction of shear wall rises, drift decreases and shear force, bending moment, and building torsion increase.

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