Effect of Shear Wall on Sesmic Behavior of Unsymmetrical Reinforced Concrete Structure

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***Abstract*: - Shear wall are used in tall buildings as supporting element to resist earthquake loading. In order to enhance the ductility of the structural system the walls are connected together with lateral beams. Many researchers have investigated the behavior of shear walls using different methods. Analytical methods are one of the early techniques used in analysis of shear walls. During an earthquake, damage to building is largely caused by dynamic loads. Therefore, in order to design buildings resistant to earthquake, dynamic characteristics of building must be known.**

Generally asymmetric tall buildings may consist of any combination of structural forms, such as frames, shear walls, structural cores, and coupled shear walls. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and people living; create torsion in structure.

In this study Response Spectrum method is used to analyse horizontally unsymmetrical structure. Aim of this study to decrease torsion using shear wall in structure. ETABS is computer software used to prove the point. Five different cases to analyse the structure i.e. four concentric shear walls at lift, shear wall parallel to X axis, shear wall parallel to Y axis, shear walls placed at exterior corners and two shear wall placed parallel to X axis and three parallel to Y axis. Different thicknesses of shear wall i.e. 150mm, 200mm, 300mm, and 400mmare used in all these cases. It has been observed that the torsion, drift and displacement in structure decreased by using concentric shear wall at corners. This study will be useful while positioning of shear wall in structure.

***Keywords*-Torsion; Concentric shear wall; Drift; Displacement; Positioning; Thickness.**

I. INTRODUCTION

1.1 General

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called shear walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation.

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and people living; create powerful torsion. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces.

In the last few decades, shear walls became an important part of mid and high-rise residential buildings. As part of an earthquake resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads. So shear-wall frame structures are obtained. Shear wall buildings are usually regular in plan and in elevation.

1.2 Purpose of constructing shear walls

Shear walls designed for lateral loads of earthquakes and wind. The walls are structurally connected with diaphragms and other lateral walls at right angles, therefore gives stability to the building structures. Shear wall structural systems are more stable than RCC framed structures.

Walls have to resist the uplift forces caused by the pull of the wind. Walls have to resist shear forces that try to push the walls over. Walls have to resist the lateral force of e wind that tries to push the walls in and pull them away from the building. These walls will consume shear forces and will prevent changing locations and positions of construction and consequently destruction. Constructing the shear wall in tall, medium and even short buildings will reinforce the structure significantly, and either more economic than the bending frames.

1.3 Comparison of shear wall with construction of conventional load bearing walls

Load bearing masonry is very brittle material. Due to different kinds of stresses such as shear, tension, torsion, etc., caused by the earthquakes, the conventional unreinforced brick masonry collapses instantly during the unpredictable and sudden earthquakes. The RCC framed structures are slender, when compared to shear wall concept of box like three-dimensional structures. Though it is possible to design the earthquake resistant RCC frame, it requires extraordinary skills at design, detailing and construction levels, which cannot be anticipated in all types of construction projects. On the other hand even moderately designed shear wall structures not only more stable, but also comparatively quite ductile. In safety terms it means that, during very severe earthquakes they will not suddenly collapse causing death of people. They give enough indicative warnings such as widening structural cracks, yielding rods, etc., offering most precious moments for people to run out off structures, before they totally collapse.

For structural purposes we consider the exterior walls as the shear-resisting walls. Forces from the ceiling and roof diaphragms make their way to the outside along assumed paths, enter the walls, and exit at the foundation.

1.4 Forces on shear walls

Shear walls resist two types of forces: shear forces and uplift forces. Shear forces are generated in stationary buildings by accelerations resulting from ground movement and by external forces like wind and waves. This action creates shear forces throughout the height of the wall between the top and bottom shear wall connections. Uplift forces exist on shear walls because the horizontal forces are applied to the top of the wall. These uplift forces try to lift up one end of the wall and push the other end down. In some cases, the uplift force is large enough to tip the wall over. Uplift forces are greater on tall short walls and less on low long walls. 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. When exterior shear walls do not provide sufficient strength, other parts of the building will need additional strengthening.

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 buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non structural elements (like glass windows and building contents).

1.5 Architectural aspects of shear walls

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e. those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a moment-resistant frame) must be provided along the other direction to resist strong earthquake effects. Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net cross sectional area of a wall at an opening is sufficient to carry the horizontal earthquake force. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

1.6 Methods of seismic analysis

Once the structural model is selected, it is necessary to perform analysis to determine the seismically induced forces in the structure. Lot of research is carried out in this area to propose simplified methods that will predict results with reasonable accuracy. So there are different methods of analysis are invented which provide different degrees of accuracy. The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behavior of structure or the structural materials and the type of structural model selected.

Based on the type of external action and behavior of structure, the analysis can be further classified as linear dynamic analysis, nonlinear static analysis or non-linear dynamic analysis as shown in following dig. Linear static analysis or equivalent static analysis used only for regular structure with limited height. Linear dynamic analysis considers the effect of the higher mode of vibration and the actual distribution of forces in the elastic range in a better way.

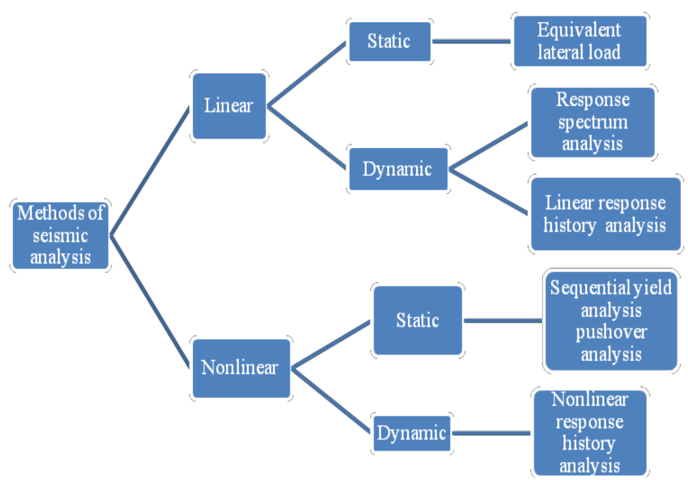


Fig.1 Flowchart for Seismic Analysis

This analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method.

1.7 Response Spectrum Method

In response spectrum method the peak response of structure during an earthquake is obtain directly from the earthquake response spectrum. This procedure gives an approximate peak response, but this is quite accurate for structural design applications. In this approach the multiple modes of response of building to an earthquake are taken in account. For each mode, a response is read from design spectrum, base on modal frequency and modal mass. In this method the load vectors are calculated corresponding to predefined number of modes. These load vectors are applied at the design centre of mass to calculate the respective modal responses. These modal responses are then combined according to Square Root of Sum of Squares (SRSS) or Complete Quadratic Combination (CQC) rule to get the total response. From the response of the structure fundamentals of dynamics it is quite clear that modal response of the structure subjected to particular ground motion, is estimated by combination of the results of static analysis of the structures subjected to corresponding modal load vector and dynamic analysis of the corresponding single degree of freedom system subjected to same ground motion. Static response of Multiple Degrees of Freedom (MDOF) system is then multiplied with the spectral ordinate obtained from dynamic analysis of Single Degree of Freedom (SDOF) system to get that modal response. Same procedure is carried out for other modes and the results are obtained through SRSS or CQC rule.

In response spectrum analysis the spectral values are read from the design spectrum which are directly multiplied with the modal load vector and the static analysis is performed to determine the corresponding modal peak responses. This method is known as the Classical Modal Analysis.

The loads acting on the structure are contributed from slabs, beams, columns, walls, ceilings and finishes. They are calculated by conventional methods according to IS 456 -2000 and are applied as gravity loads along with live loads as per IS: 875 [Part II) in the structural model. The lateral loads and their vertical distribution on each floor level are determined as per IS 1893 — 2002 and calculated. These loads are then applied in response spectrum method.

1.8 Need of this study

Reinforced concrete wall, which include lift walls or shear walls, are the usual requirements of multi storey building. Design by coinciding centroid and center of mass of building is the ideal for structure. However on many occasion the design has to base on the off center posing of lift and stair case walls with respect to the centre of mass. The design in this case results into an excessive stresses in most of the structural members, unwanted torsional moment and sways.

It is found that structure forces are found to increase on to the eccentric position of shear wall away from the centroid of the building. Twisting moments in members are observed to be having increasing trend with enhancement in the eccentricity between geometrical centroid of the building and shear wall position. Stresses in shear wall elements have more pronounced effect in elements parallel to displaced direction of shear wall as compared to those in perpendicular direction. The lateral loads acting on high-rise buildings, induced by wind and earthquake, are generally resisted by shear walls.

1.9 Aim and objectives of project

Most of the designer adopts approximate methods for the torsional analysis of building. However this may be an inaccurate assessment. Several studies of structural damage during the past earthquake reveal that torsion is the most critical factor leading to major damage or complete collapse of building. It is therefore, necessary that irregular buildings should be analyzed for torsion. A three dimensional analysis using Etabs is able to calculate the center of rigidity; by getting these values we can perform torsional analysis.

The aim of the present analytical research work is to investigate influence of positioning of shear wall on the torsional value of building. The present study focused on to find out how we can minimize torsion in building by using concentric shear wall and eccentric shear wall. The literature surveys carried out on the topic has not enabled me to trace any research work carried out on the optimum value of torsion for structure. Many times merely providing shear wall in structure didn't solve problem. Proving shear wall at eccentric position can increase force on structure. This can lead to uneconomical structure. Five different cases of shear wall position for 11-storey building have been analyzed as a space frame system using ETABS.

Objectives of the project:

- Study of different shear wall position to reduce torsion, base shear in the structure due to seismic forces.
- Checking the effect of thickness of shear wall in seismic analysis.
- Comparing all the cases with structure without shear wall.

1.10 Closure

This chapter clears the exact image of the present study; it gives the general introduction of what this project work is all about. It specifies the requirement and the objective of present study in this introductory chapter.

II. TORSION IN BUILDING

Translations and rotations at floor levels are obtained for different shear wall models. In the second part, the behavior of the shear walls located in shear wall-frame building structures is investigated. Building structures having different floor plans and a different number of storeys are subjected to ax symmetric lateral loads and pure floor torsions. The performance of the proposed models is tested by comparing floor displacements and total resultant forces on shear walls at the floor levels. In the last part of the static analyses, the results of analysis and experiments of some previous studies are compared with the proposed models.

Torsional response in structure arise from two sources (a) Eccentricity in mass and stiffness distribution, which cause a torsional response coupled with translational response and (b) torsion arising from accidental causes, including the rotational component of ground motion about a vertical axis, the difference between assumed and actual stiffness and mass, uncertain live load distribution, uncertainties in dead load due to variation in workmanship and material, asymmetrical patterns of non linear force deformation relations and subsequent alternation that may be made in building which not only change the dead load but may change the position of the centre.

For symmetrically building, the elementary analysis does not disclose the slightest torque; while actually, the probability that there will be such a generalized force during the earthquake is one. Even non linear behavior can introduce torque that is not accounted by conventional analysis. The current state of scientific advancement in this field predicts an accurate estimate of this accidental additional torsion. Torsion in buildings during earthquake shaking may be caused from a variety of reasons, the most common of which are non-symmetric distributions of mass and stiffness. Modern codes deal with torsion by placing restrictions on the design of buildings with irregular layouts and also through the introduction of an accidental eccentricity that must be considered in design. The lateral-torsional coupling due to eccentricity between centre of mass (CM) and centre of rigidity (CR) in asymmetric building structures generates torsional vibration even under purely translational ground shaking. During seismic shaking of the structural systems, inertia force acts through the centre of mass while the resistive force acts through the centre of rigidity as shown in Fig. .

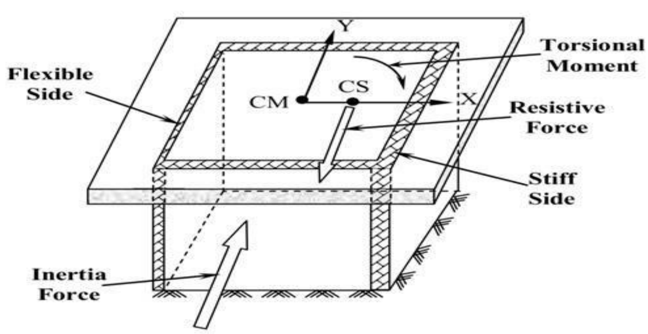


Fig.3-Generation of torsional moment in asymmetric structures during seismic excitation.[17]

To allow for effects such as the ones listed above, seismic codes often required that buildings be designed to resist the additional torsional moment Provision should be made in all the buildings for increase in the shear forces and lateral forces resisting elements, which is a result of horizontal torsional moment arising due to an eccentricity between the centre of mass and centre of rigidity. The design forces calculated are to be applied at the centre of mass, which is appropriately displayed so as to cause the designed eccentricity between the displaced centre of mass and centre of rigidity.

The designed eccentricity e_{di} , to be used at the floor I should be

$$e_{di} = 1.5\,est + 0.05\,bi \quad \textbf{or} \quad e_{st} - 0.05\,b_i$$

Whichever gives the more severe effect in the shear of any frame. Here e_{st} is the static eccentricity at the floor i, defined as the distance between centre of mass and centre of rigidity, and bi is the floor plan dimension of the floor i, perpendicular to the direction of force. The factor 1.5 represents dynamic amplification factor, while the factor 0.05 represents the extent of accidental eccentricity. The dynamic and amplification factor is also known as response amplification factor, is used to convert the static torsional response. Highly irregular buildings are analyzed by using modal analysis. The value of accidental eccentricity is assumed as 5% of the planned dimension of the building storey, particularly for the accidental torsional response during the applied ground motion. Therefore additive shear have been superimposed for statically applied eccentricity $\pm 0.05b_i$ with respect to centre of rigidity.

Torsion arises from no. of causes: building shape, and dynamic response. Torsion cannot be eliminated but can possibly be minimized, or at least designed for if recognized. Building codes and standards have lagged behind the recognition of this important load type: most ignore torsion.

If torsion is resisted by shear walls placed near the ends of the building then a given torque may increase the shear stresses only slightly, and the wind direction of maximum overall building shear may well represent the design case. However, if the shear walls are concentrated near the core then the same torque will produce a much greater shear stress, and the design condition is more likely to occur at the direction of maximum eccentricity.

III. LITERATURE REVEIW

3.1 General

In this analytical study of subject it is required to search different existing cases and the available study material regarding that subject. In order to collect the necessary and valuable information, the literature survey is done. So the study of topic and the related literature published in different journals and papers are as follows

Earthquake analysis of three dimensional shear wall-frame assembly on pile foundations considering soil structure interaction, Clifford D'souza, Prof. D. N. Buragohain (1984)

In this paper the earthquake response of a three dimensional shear will-frame assembly on pile foundations considering soil-structure interaction is evaluated by the Frequency Domain general Substructure method (FDGS). The building-pile foundation system is treated as two substructures: building and pile foundation, For the building, the analysis incorporates the rigidity of floor slabs in their planes, the effect of three dimensional shear walls and the eccentricity of beam connections to shear walls. Tremendous saving in computational effort is achieved. A numerical example is solved to illustrate the above approach. Two different values of shear wave velocity of soil, Vs = 140 and 313 m/s are considered.

The results of this analysis are presented in graphical and tabular forms and compared for the two soil conditions to bring forth the effects of soil-structure on the response of the building. The maximum earthquake response of the building alone by assuming it to be fixed at its base is evaluated by the Response Spectrum method for buildings (RSB) and compared with the absolute maximum response obtained by FDGS for the two soil conditions. The evaluation of the mode shapes and natural frequencies of the building-pile foundation system for this purpose shows that these are not significantly different from those of the building on fixed base. This means that RSB can still be used for predicting satisfactorily the earthquake response of the buildings on soft soil provided a correct damping ratio is chosen. Computer programs have been developed to carry out the different aspects of the numerical work. The results of this investigation bring forth the actual effects of soil-structure interaction in a building-pile system for the first time.

The main conclusion drawn from the study is that : A Component Element idealization method is developed for idealizing shear-wall cores, the method considers all significant factors that affect earthquake response behavior of typical cores. The method has wider range of applicability than the (DE) method. Although the number of d.o.f. needed to adequately represent the core behavior in both methods is comparable, the main advantage of the (CE) method is that the cross-sectional properties need not to be computed, therefore, the method can be used to idealize all practical shear-wall core systems; Shear and warping de4formations are shown to be of significant effect in cases of squat cores and affect the torsional behavior of these cores.

Simplified model for damage in squat RC shear walls, Edward D. thomsona, Maria E. Perdomob, Ricardo Picon, Maria E. Marante3b, Julio Florez-Lopez, Engineering Structures 31 (2009) 2215-2223

In this paper, a new simplified model for simulating damage of squat RC shear walls under lateral loads is proposed. The proposed numerical model is implemented in a commercial finite element program and validated against experimental results. This simplified model is based on damage and fracture mechanics. It describes the reduction in stiffness and strength due to diagonal cracking, permanent deformations due to yielding of transverse reinforcement and sliding across shear cracks. A yield function to describe permanent deformations due to yielding of transverse reinforcement is proposed. Then, a crack resistance function is introduced and experimentally identified. Analytical expressions are developed for hysteretic behavior. It is shown that the model can predict well the response of RC shear walls. A good correlation between experiment and model can be appreciated. Most parameters of the model can be determined from conventional reinforced concrete theory. In its present state, the model does not account for the combined damage due to shear and bending, as in tall shear walls, where cracking due to bending may be more significant than cracking due to shear.

The main conclusion drawn form study that stiffness and strength degradation mainly due to diagonal cracking of the concrete; plastic deformations due to yield of the horizontal reinforcement; and sliding shear across diagonal cracks (“pinching effect”). A good correlation between experiment and model can be appreciated. Most parameters of the model can be determined from conventional reinforced concrete theory.

The design algorithm makes use of properties of section which is quite useful in describing deformations and stresses when the plane cross section no longer remains plane. A numerical procedure presented in this study automates the computation of sectional properties in addition to the determination of the shear center of reinforced concrete thin walled sections. Furthermore an iterative procedure is developed for finding the location of the neutral axis in reinforced concrete thin walled section subjected to axial force, biaxial bending moments and torsional moment.

A simplified approach for seismic calculation of a tall building braced by shear walls and thin-walled open section structures, Sid Ahmed Meftah, Abdelouahed Tounsi, Adda Bedia El Abbas, Engineering Structures29 (2007) 2576-2585

In this paper an approximate hand-method for seismic analysis of an asymmetric building structure having constant properties along its height is presented. The building is stiffened by a combination of shear walls and thin-walled open section structures. Based on the continuum technique and D’Alembert’s principle, the governing equations of free vibration and the corresponding Eigen value problem were derived. A generalized method is proposed for the free vibration analysis of coupled vibration of a building braced by shear walls and thin-walled open section structures. Simplified formulae are given frequencies and internal forces of a building structure subjected to earthquakes.

The utility and accuracy of the method is demonstrated by a numerical example, in which he proposed method is compared with finite element calculations. In this paper, a dynamic analysis of tall buildings braced by shear walls and thin-walled open section structures is presented. In such a structural configuration, the lateral displacements in two perpendicular directions and the torsional rotation can no longer be treated separately due to their coupling in the governing differential equations of free vibration. Hence, if the flexural vibrations in one direction are coupled with the torsional vibrations, the resulting phenomenon is called double coupling.

Analysis of shear wall structures on elastic foundations, S. S. Badiet, D. C. Salmon and A. W. Beshara Computers & Structures Vol.65. No.2 (1995)

In this paper, method for analyzing shear wall structures on elastic foundations is presented. The shear walls are modeled using a nine-noded isoperimetric quadrilateral plane stress element and the soil is modeled using a three-noded quadratic element that includes the vertical sub grade reaction and soil shear stiffness. It is observed that analyzing shear wall structures as fixed cantilevers, i.e. ignoring soil-structure interaction, significantly underestimates the wall drift.

Lateral stiffness and vibration characteristics of composite plated RC shear walls with variable fibres spacing, S. A. Meftah, R. Yeghnem, A. Tounsi, E.A. Adda Bedia, Materials and Design 29 (2008) 1955-1964

In this paper, a finite element model for static and free vibration analysis of reinforced concrete (RC) shear walls structures strengthened with thin composite plates having variable fibres spacing is presented. An efficient analysis method that can be used regardless to the sizes and location of the bonded plates is proposed in this study. In the numerical formulation, the adherents and the adhesives are all modeled as shear will elements, using the mixed finite element method. Several test problems are examined to demonstrate the accuracy and effectiveness of the proposed method. Numerical results are obtained for six non uniform distributions of E-glass, graphite and boron fibers in epoxy matrices. The fibre redistributions of the bonded plates are seen to increase the frequencies modes and reduce substantially the lateral displacements. In the numerical formulation of the present study, the adherents and the adhesives layers are all modeled as shear walls, by using a mixed finite element method to find the stiffness matrix of the equivalent composite shear wall element having variable fibres spacing. The finite element method (FEM) is employed to determine the deflection and dynamic characteristics in free vibration analyses problem. Numerical results are presented that relate to the performance of RC shear walls strengthened with composite sheets having parallel and variable fibres spacing.

The numerical investigation on the representatives RC shear walls structures strengthened with thin composite plates having variable fibres spacing shows that good efficiency in dynamic and lateral stiffness characteristics are obtained by redistribution of the fibres so that they are concentrated more in wall edges. This study can be extended to provide an efficiency concept in the field of RC shear walls structures strengthened by bonded composite plates.

A new approach on the strengthening of primary school buildings in Turkey : An application of external shear wall, M. Yasar Kaltakcia, M. Hakan arslana, Ulku S. Yilmaza, H. Derya Arslan, Building and Environment, 43 (2008) 983-990

In this study, a new strengthening type of reinforced concrete buildings namely “external reinforced concrete shear will” application method is discussed, Considerable life and property losses have occurred because of the devastation due to the earthquakes happened in Turkey during the last 10 years. Especially, the damages that occurred on the public buildings were more serious and unchangeable when compared with the damages that took place on private buildings. In this study, a new strengthening type of reinforced concrete buildings namely “external reinforced concrete shear wall” application method is discussed. For this purpose, three typical projects, which have been built commonly, are mentioned. The structural deficiencies observed in these buildings are given. According to these tests, the strengthening and system improvement performed through adding external reinforced concrete shear wall to the reinforced concrete building will add improved behavior, strength and rigidity to the system with its low cost besides the ease of construction and application. Developing this method for the existing primary school buildings will be able to be implemented in most of the primary school buildings without any problems.

External shear wall application will be a practical and economical solution for the4se detached buildings. There will be no changes made to the interior architecture of these buildings. The mixed system formed through the reinforcement of the reinforced concrete frame type of buildings with external shear wall (on the outside and on one side only) significantly increases the lateral load resistance capacity and rigidity of the existing weak system.

Torsional Behavior of asymmetrical Buildings, Sachin G. Maske, Dr. P. S. Pajgade. International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.2, March-April. 2013 pp-1146-1149

In this paper focus is on torsion and Ast in columns. Torsional behaviour of asymmetric building is one of the most frequent sources of structural damage and failure during strong ground motions. In this work a study on the influence of the torsion effects on the behaviour of structure is done. In building two cases are considered, case one is without considering torsion and case two is considering torsion. The Indian standard code of practice IS-1893 (Part I: 2002) guidelines and methodology are used to analyzed and designed building. Results are compared in terms of % Ast in columns.

Seismic damage surveys and analyses conducted on modes of failure of building structures during past severe earthquakes concluded that most vulnerable building structures are those, which are asymmetric in nature. Asymmetric-plan buildings, namely buildings with in-plan asymmetric mass and strength distributions, are systems characterized by a coupled torsional-translational seismic response. Asymmetric building structures are almost unavoidable in modern construction due to various types of functional and architectural requirements. Torsion in buildings during earthquake shaking may be caused from a variety of reasons, the most common of which are non-symmetric distributions of mass and stiffness. Modern codes deal with torsion by placing restrictions on the design of buildings with irregular layouts and also through the introduction of an accidental eccentricity that must be considered in design. The lateral-torsional coupling due to eccentricity between centre of mass (CM) and centre of rigidity (CR) in asymmetric building structures generates torsional vibration even under purely translational ground shaking.

3.2 Closure

The total overview of the literature is presented in chapter 2 which is on investigations done in past by various researchers. It also gives work done by them and the results obtained by them.

IV. CODAL PROVISIONS AND REQUIREMENTS

4.1 Codal provisions and requirements

This chapter deals with torsion in structure and shear wall, various instruction and requirements which are to be followed, given by the various codes consisting of Indian standard codes. Structure should be analyzed considering given points.

4.1.1 IS: 13920-1993

General requirements

The requirements of this section apply to the shear walls, which are part of the lateral force resisting system of the structure.

1. The thickness of any part of the wall shall preferably, not is less than 150 mm.
2. The effective flange width, to be used in the design of flanged wall sections, shall be assumed to extend beyond the face of the web for a distance which shall be the smaller of (a) half the distance to an adjacent shear wall web, and (b) $1/10^{th}$ of the total wall height.
3. Shear walls shall be provided with reinforcement in the longitudinal and transverse directions in the plane of the wall. The minimum reinforcement ratio shall be 0.0025 of the gross area in each direction. This reinforcement shall be distributed uniformly across the cross section of the wall.
4. lf the factored shear stress in the wall exceeds 0.25 or if the wall thickness exceeds 200 mm, reinforcement shall be provided in two curtains, each having bars running transverse directions in the in the longitudinal and transverse directions in the plane of the wall.
5. The diameter of the bars t o be used in any part of the wall shall not exceed 1 / 10th of the thickness of that part.
6. The maximum spacing of reinforcement in either direction shall not exceed the smaller of $L_w/5$, $3T_w$, and 450mm, where L_w, is the horizontal length of the wall, and T_w is the thickness of the wall web.

Boundary Elements

Boundary elements are portions along the wall edges that are strengthened by longitudinal and transverse reinforcement. Though they may have the same thickness as that of the wall web it is advantageous to provide them with greater thickness.

Where the extreme fibre compressive stress in the wall due to factored gravity loads plus factored earthquake force exceeds $0.2F_{ck}$, boundary elements shall be provided along the vertical boundaries of wall.

4.1.2: 1893(PART 1)-2002

Provision shall be made in all the building for increase in shear forces on the lateral force resisting elements resulting from the horizontal torsional moment arising due to eccentricity between the centre of mass and centre of rigidity. The design forces calculated are to be applied at the centre of mass appropriately displaced so as to cause design eccentricity between the displaced centre of mass and centre of rigidity. However, negative torsional shear shall be neglected.

In case of highly irregular buildings analyzed according to, additive shears will be superimposed for a statically applied eccentricity of $\pm 0.05b_i$ with respect to the centre of rigidity.

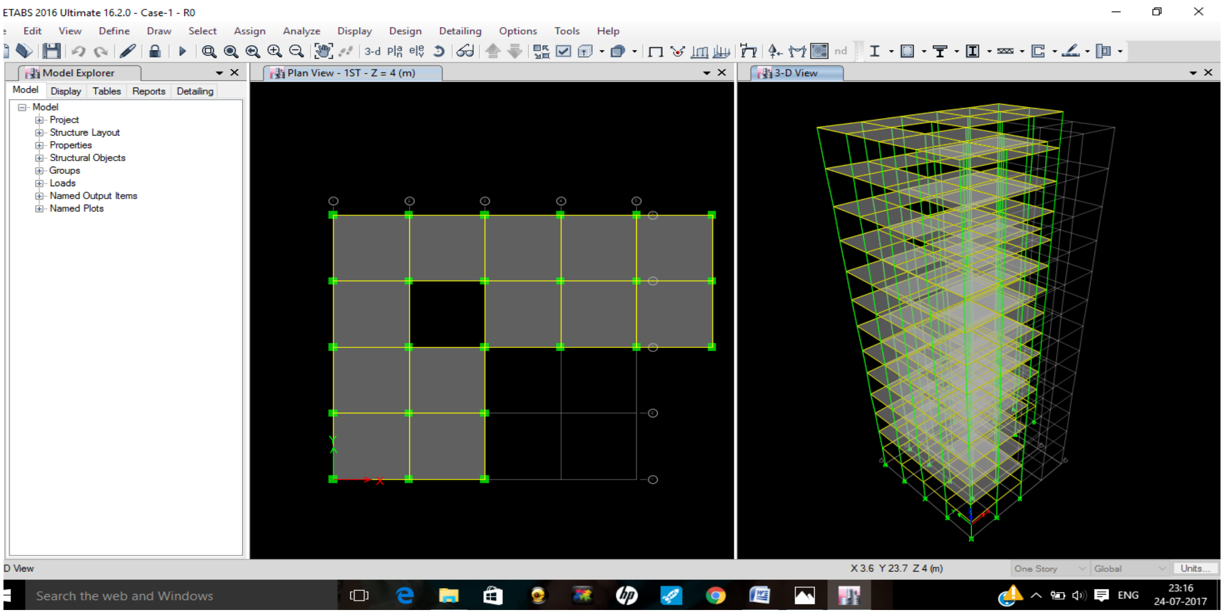
4.2 Closure

The total overview of the literature is presented in this chapter which is on investigations done by various researchers. It also gives work done them and the results obtained by them.

V. ANALYTICAL WORK

5.1 General

In this section, an 11- floor unsymmetrical structure in plan is shown. In this structure, we took various positions to shear walls. The loads acting on the structure are contributed from slabs, beams, columns, walls, ceilings and finishes. They are calculated by conventional methods according to IS: 4S6 — 2000 and are applied as gravity loads along with live loads as per IS: 875 (Part II)-1987 in the structural model. The lateral loads and their vertical distribution on each floor level are determined as per IS: 1893 —2002 and calculated. These loads are then applied in response spectrum method.



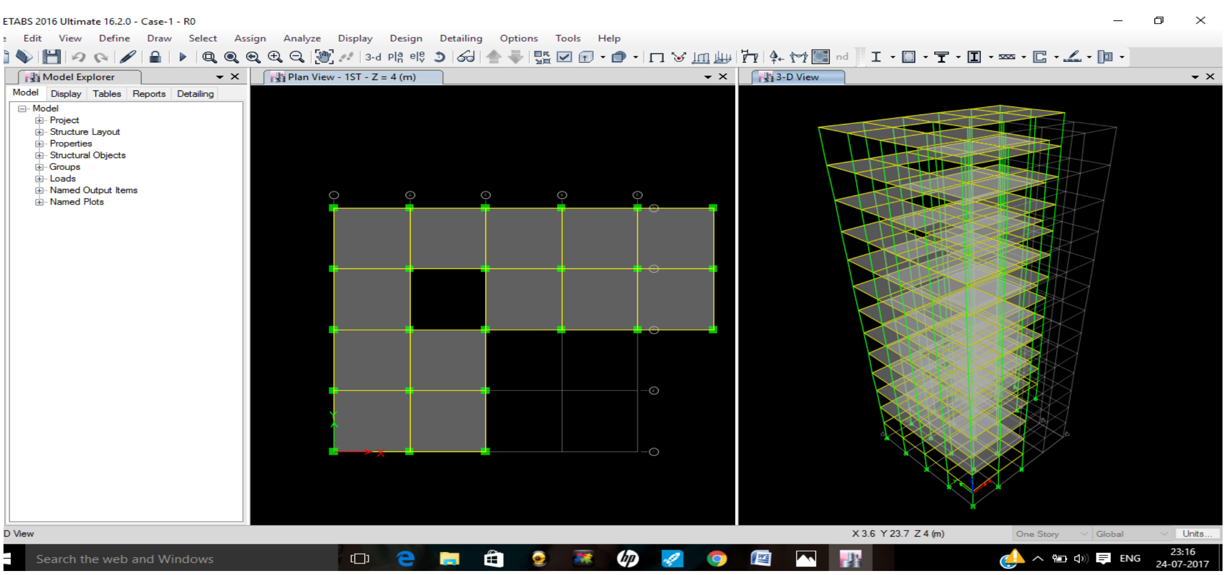
With the availability of high speed digital computers, a rigorous three-dimensional analysis of a multistory building can be performed. Three dimensional analysis is relatively more realistic. It gives more exact results than those by two dimensional analysis. 3-dimensional analysis is the only solution in case of an unsymmetrical loading geometry of the structures.

5.2 Types of cases used for analysis of structure

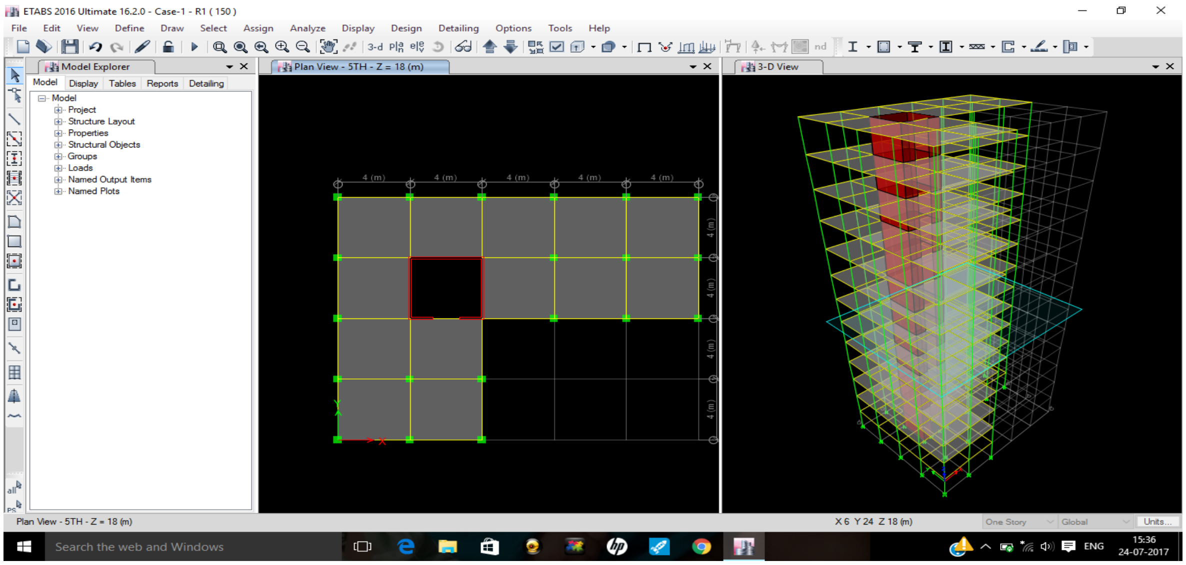
There are different cases considered to analyze 11-storey structure so that proper position of shear wall can be predicted.

1. building frame without shear wall [WOSW]
2. building frame with concentric shear wall [WSW]
3. building frame with shear wall parallel to X dir. [WSHLLX]
4. building frame with shear wall parallel to Y dir [WSWLLY]
5. Building frame with shear wall at all exterior corners of building. [WSHEXC]
6. Building frame with shear wall at specified positions. [WSWSP]

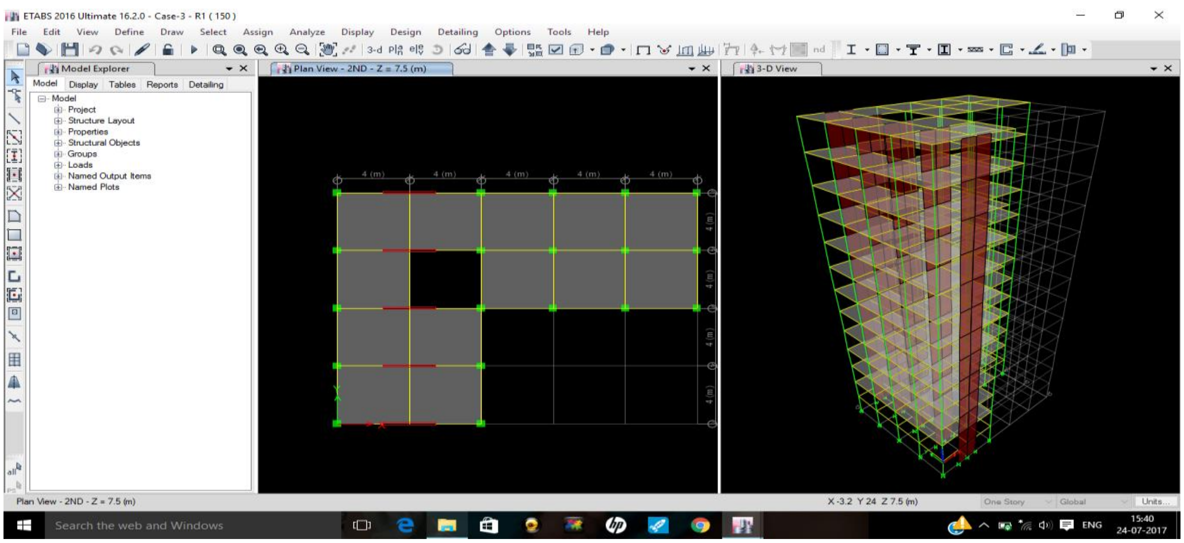
***Case** 1:- building frame without shear wall [WOSW]*



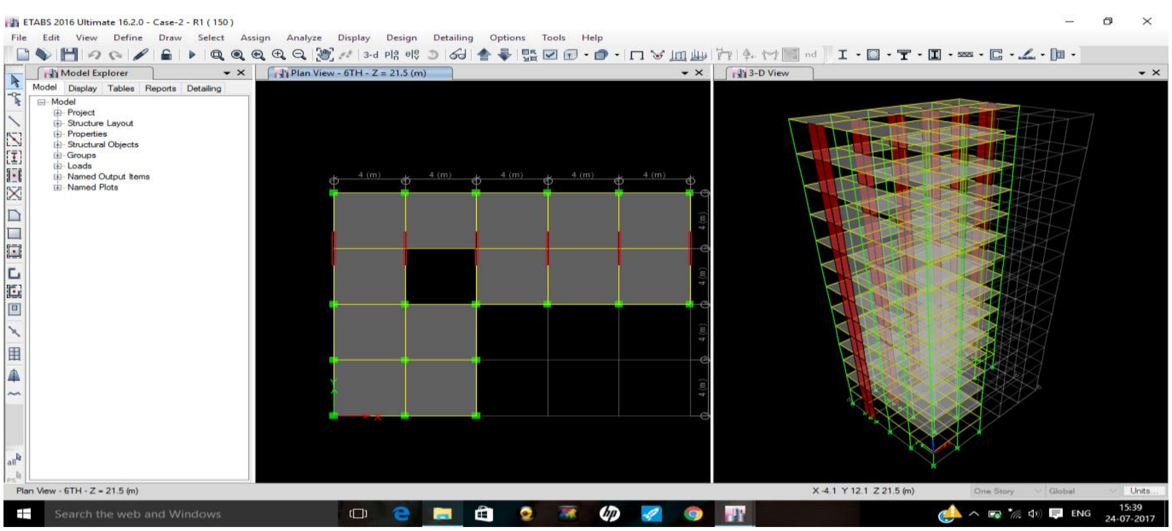
Case 2:- building frame with concentric shear wall [WSH]



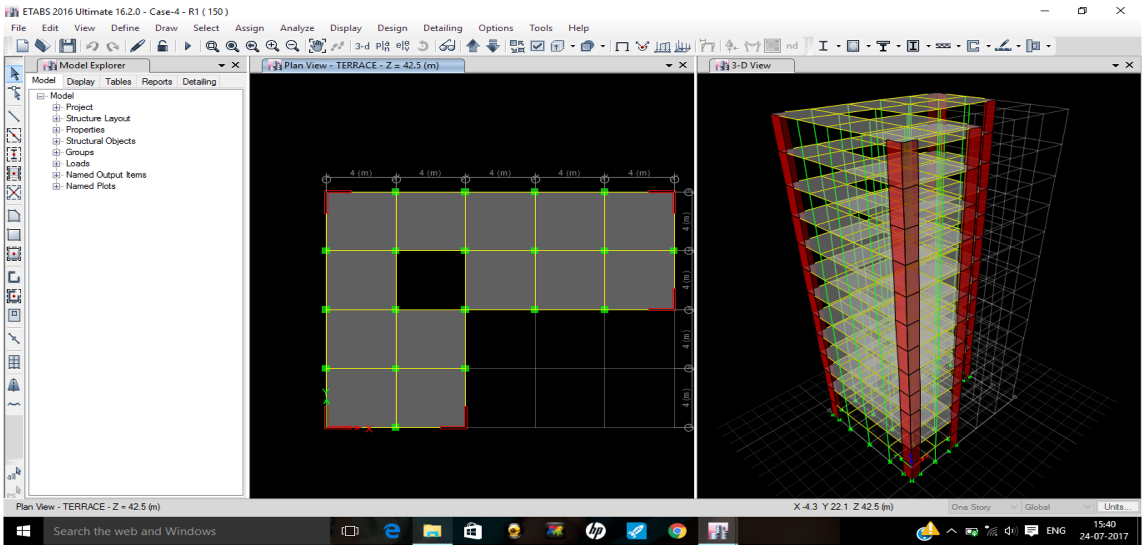
Case 3:- building frame with shear wall parallel to X dir. [WSHLLX]



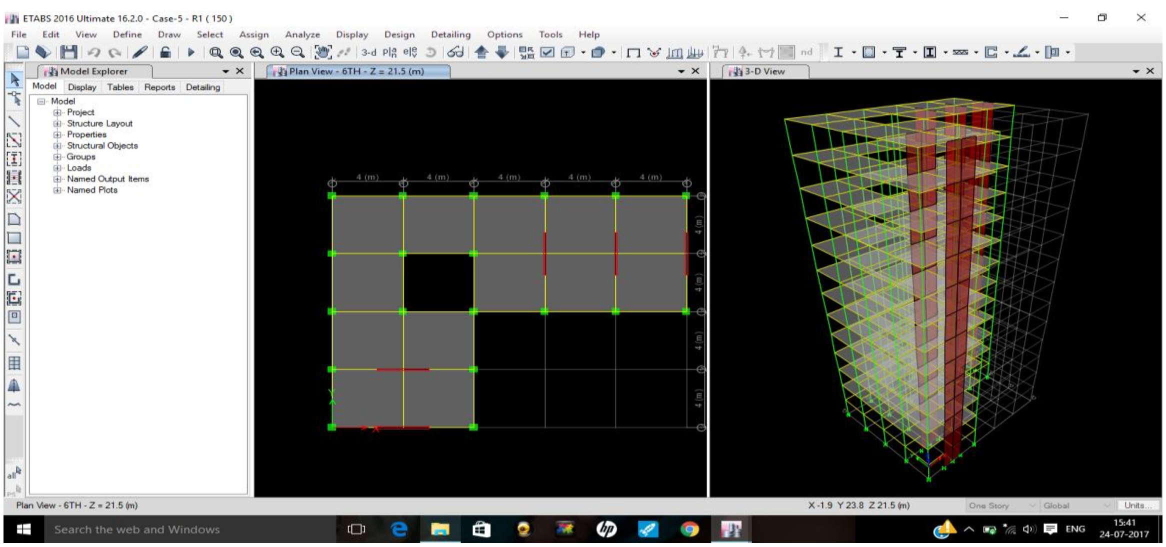
Case 4:- building frame with shear wall parallel to Y dir [WSWLLY]



Case 5:- building frame with shear wall at all exterior corners of building. [WSHEXC]



Case 6:- building frame with shear wall at specified positions. [WSWSP]



5.3 Structural data

Building consists of 16 m in short direction and 20 m long direction, so from preliminary design the sizes of various structural members were estimated as follow

Column size

Columns all around were kept of the same size i.e. 18’’ x 18’’ [450 x 450 mm] to avoid the local eccentricity.

Beam size

All beams are of uniform size of 12’’x 18’’ [300x450mm] having 7’’[165mm] think slab for all the spans.

Shear wall Thickness

150mm thick, 200mm, 300mm and 400mm thick shear wall for all storey are provided for different cases.

Storey height is kept as 3.5 for all floors .Grade Fe- 500 hot rolled deformed steel is recommended to be used. Concrete having M-40 strength for columns, beams and slabs is to be employed.

5.4 Gravity loading

Gravity loading consists of dead and live loading. Dead loading can be predicted reasonable accurately from the designed member sizes and material densities. Dead load due to structural self weights and superimposed dead loads are as follows:

Slab dead load= 4.5 KN/m^2

Imposed dead load for typical floors= 4 KN/m^2

5.6 Lateral loading

Lateral loading consists of earthquake loading. Earthquake loading has been calculated by the program and it has been applied to the mass center of the building.

Since the building under consideration was in zone – V with standard occupancy so the total base shear was computed as follows.

Case EQX and EQY
Period calculation: program calculated
Top storey-11
Bottom storey-base
R=5
I=1
Building height H= 42.5m above gr.
Soil type= II
Z= 0.16

5.7 Closure

Detailed structural analysis detailing and procedure is given in this chapter.

VI. RESULTS AND DISCUSSION

6.1 Results Obtained Using Response Spectrum Method

Torsion, base shear, maximum displacement, and maximum drift results for the 11-storey structure are obtained on five different cases. Different thickness of shear wall 150mm, 200mm, 300mm and 400mm are used to calculate torsional effect on structure. Relative torsional values of structure having above conditions are compared with a structure without shear wall.

Many times merely providing shear wall in structure didn't solve problem. Proving shear wall at eccentric position can increase force and torsion on structure. This can lead to uneconomical structure. Five different cases of shear wall position for 11 storey building have been analysed as a space frame system using ETABS.

There are different cases considered to analyze 11-storey structure so that proper position of shear wall can be predicted.

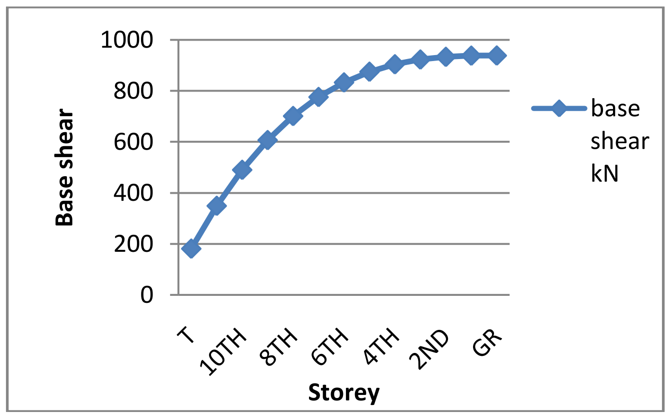
1. Building frame without shear wall [WOSW]
2. Building frame with concentric shear wall [WSW]
3. Building frame with shear wall parallel to X dir. [WSHLLX]
4. Building frame with shear wall parallel to Y dir [WSWLLY]
5. Building frame with shear wall at all exterior corners of building. [WSHEXC]
6. Building frame with shear wall at specified positions. [WSWSP]

All these cases will be analysed for various thicknesses i.e.150mm, 200mm, 300mm, 400mm

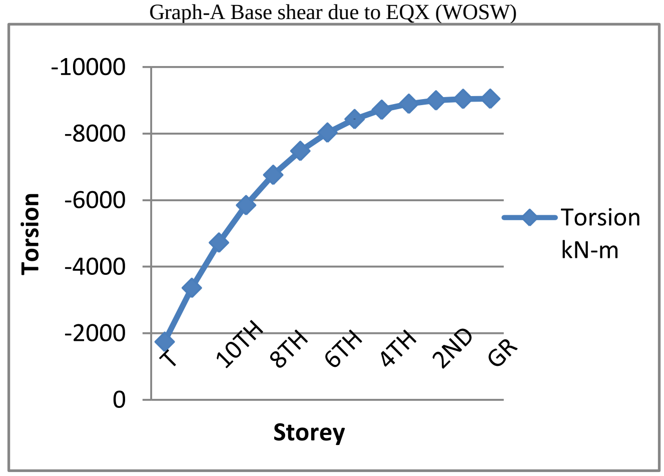
Keeping length of shear wall in each case same i.e.42.5m

Case1:- building frame without shear wall [WOSW]

TABLE A: Storey Forces due to EQX		
Storey	**base shear**	**Torsion**
	kN	kN-m
TERRACE	180.9147	-1746.1583
XI	348.9322	-3365.7295
X	490.1136	-4726.6192
IX	606.7924	-5851.3214
VIII	701.3023	-6762.3302
VII	775.9767	-7482.1396
VI	833.1493	-8033.2437
V	875.1537	-8438.1365
IV	904.3234	-8719.312
III	922.992	-8899.2644
II	933.4931	-9000.4876
I	938.1603	-9045.4757
GR	938.6687	-9050.3416



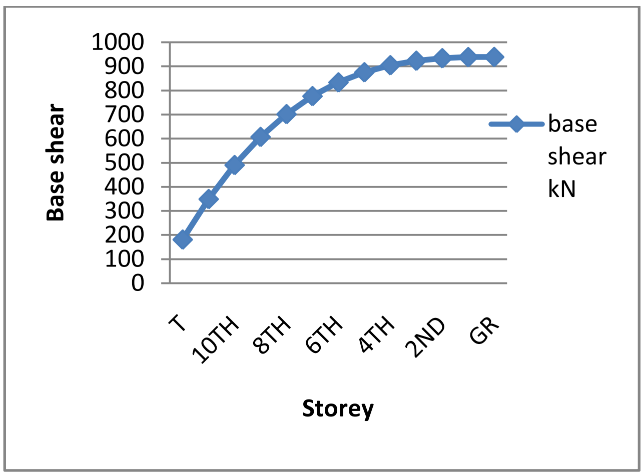
Graph-A Base shear due to EQX (WOSW)



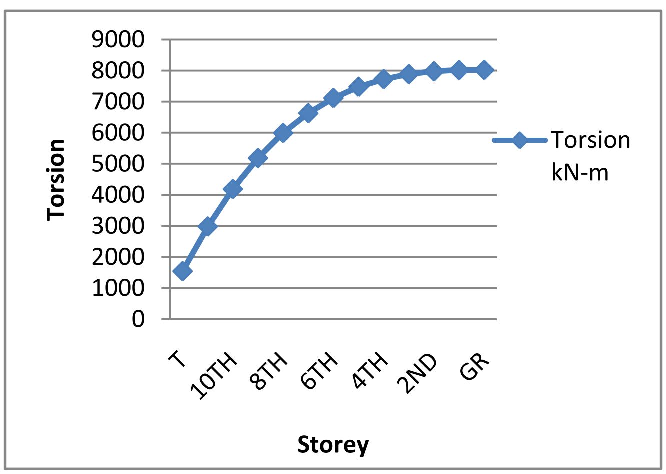
Graph-B Torsion due to EQX (WOSW)

Above table and graph shows base shear and torsion due to EQX for structure without shear wall. These results will be compared with all the cases of shear wall positions and variable thickness.

TABLE B: Storey Forces Due to EQY		
Storey	**base shear**	**Torsion**
	kN	kN-m
T	180.9147	1546.876
11TH	348.9322	2982.78
10TH	490.1136	4189.337
9TH	606.7924	5186.493
8TH	701.3023	5994.188
7TH	775.9767	6632.367
6TH	833.1493	7120.973
5TH	875.1537	7479.949
4TH	904.3234	7729.238
3RD	922.992	7888.783
2ND	933.4931	7978.527
1ST	938.1603	8018.413
GR	938.6687	8022.814



Graph-C Base shear due to EQY (WOSW)



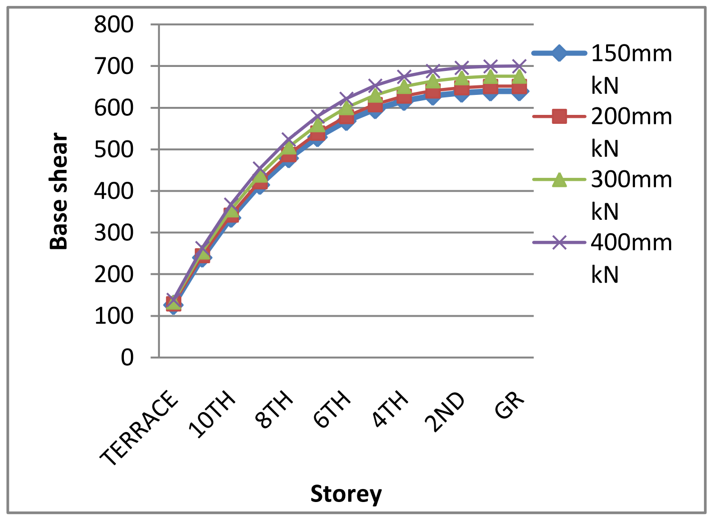
Graph-D torsion due to EQY (WOSW)

Above table and graph shows base shear and torsion due to EQY for structure without shear wall. These results will be compared with all the cases of shear wall positions and variable thickness.

6.2 Tables and graphs for variable thickness

Case 2:- building frame with concentric shear wall [wsw]

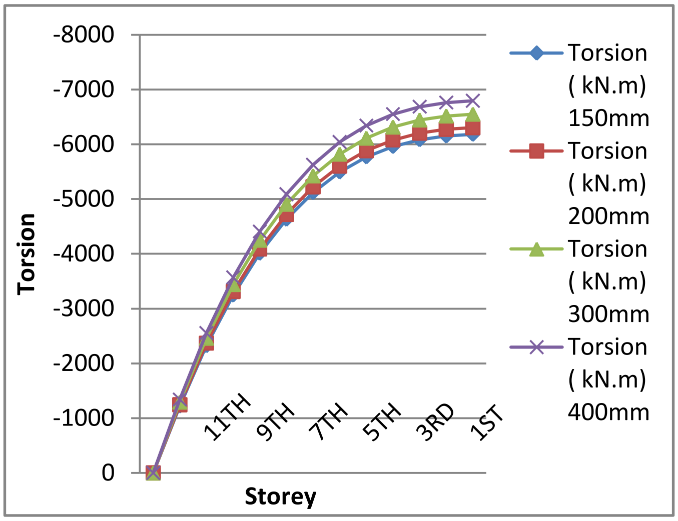
Table1- for base shear due to EQX (WSW)				
Storey	**150mm**	**200mm**	**300mm**	**400mm**
	kN	kN	kN	kN
TERRACE	126.3232	128.6768	133.3839	138.0907
11TH	240.1478	244.6593	253.6821	262.7048
10TH	335.792	342.1167	354.766	367.4152
9TH	414.8368	422.6601	438.3065	453.9528
8TH	478.8631	487.9002	505.9742	524.0482
7TH	529.4518	539.4479	559.4401	579.4323
6TH	568.1837	578.9141	600.3749	621.8357
5TH	596.6399	607.9098	630.4495	652.9892
4TH	616.4011	628.0456	651.3346	674.6236
3RD	629.0482	640.9325	664.7011	688.4696
2ND	636.1623	648.1814	672.2197	696.258
1ST	639.324	651.4032	675.5613	699.7195
GR	639.6528	651.7465	675.9339	700.1213



Graph-1 Base shear due to EQX (WSW)

Above table n graph shows decrease (25 to 31%) in base shear by providing concentric shear wall compared to structure without shear wall, when the force acting in EQX.

Table 2 for torsion due to EQX (WSW)				
Storey	**150mm**	**200mm**	**300mm**	**400mm**
	kN-m	kN-m	kN-m	kN-m
TERRACE	-1222.06	-1246.023	-1293.96	-1341.9
11TH	-2321.86	-2367.7998	-2459.68	-2551.58
10TH	-3246.01	-3310.4039	-3439.22	-3568.05
9TH	-4009.76	-4089.4156	-4248.75	-4408.11
8TH	-4628.4	-4720.415	-4904.47	-5088.55
7TH	-5117.2	-5218.9824	-5422.57	-5626.19
6TH	-5491.44	-5600.6982	-5819.24	-6037.82
5TH	-5766.39	-5881.1423	-6110.67	-6340.24
4TH	-5957.33	-6075.8953	-6313.06	-6550.25
3RD	-6079.53	-6200.5371	-6442.58	-6684.66
2ND	-6148.27	-6270.6482	-6515.44	-6760.27
1ST	-6178.82	-6301.8086	-6547.82	-6793.87
GR	-6181.98	-6305.1201	-6551.43	-6797.78

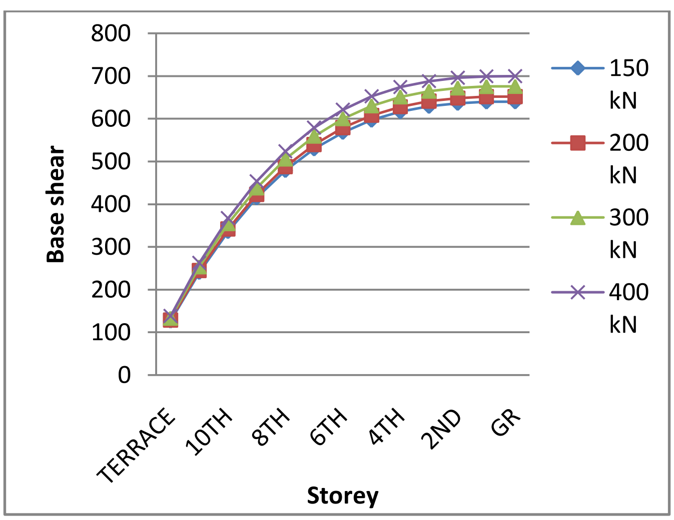


Graph- 2 Torsion due to EQX (WSW)

Above table n graph shows decrease (33to 42%) in torsion by providing concentric shear wall compared to structure without shear wall, when the force acting in EQX.

TABLE3: base shear due to EQY (WSW)

Storey	150 kN	200 kN	300 kN	400 kN
TERRACE	126.3232	128.6768	133.3839	138.0907
11TH	240.1478	244.6593	253.6821	262.7048
10TH	335.792	342.1167	354.766	367.4152
9TH	414.8368	422.6601	438.3065	453.9528
8TH	478.8631	487.9002	505.9742	524.0482
7TH	529.4518	539.4479	559.4401	579.4323
6TH	568.1837	578.9142	600.3749	621.8357
5TH	596.6399	607.9098	630.4495	652.9892
4TH	616.4011	628.0456	651.3346	674.6236
3RD	629.0482	640.9325	664.7011	688.4696
2ND	636.1623	648.1814	672.2197	696.258
1ST	639.3241	651.4032	675.5613	699.7195
GR	639.6528	651.7465	675.9339	700.1213

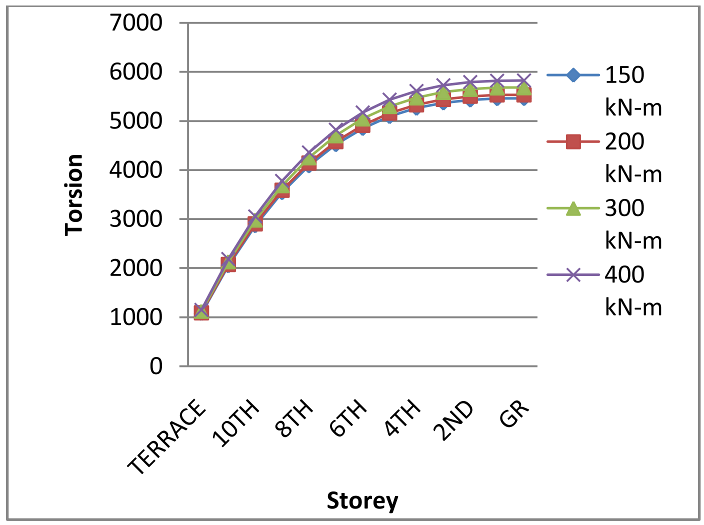


Graph- 3 Base shear due to EQY (WSW)

Above table n graph shows decrease (25 to 32%) in base shear by providing concentric shear wall compared to structure without shear wall, when the force acting in EQX.

TABLE4: for torsion due to EQY (WSW)

Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
TERRACE	1076.1653	1090.562	1119.327	1148.055
11TH	2047.5053	2075.099	2130.232	2185.298
10TH	2863.7008	2902.384	2979.673	3056.869
9TH	3538.2425	3586.09	3681.69	3777.176
8TH	4084.6213	4139.892	4250.324	4360.625
7TH	4516.328	4577.464	4699.616	4821.622
6TH	4846.8534	4912.48	5043.604	5174.572
5TH	5089.6884	5158.614	5296.33	5433.883
4TH	5258.3238	5329.54	5471.835	5613.959
3RD	5366.2505	5438.933	5584.157	5729.208
2ND	5426.9593	5500.467	5647.339	5794.036
1ST	5453.9409	5527.815	5675.42	5822.848
GR	5456.7798	5530.742	5678.523	5826.129

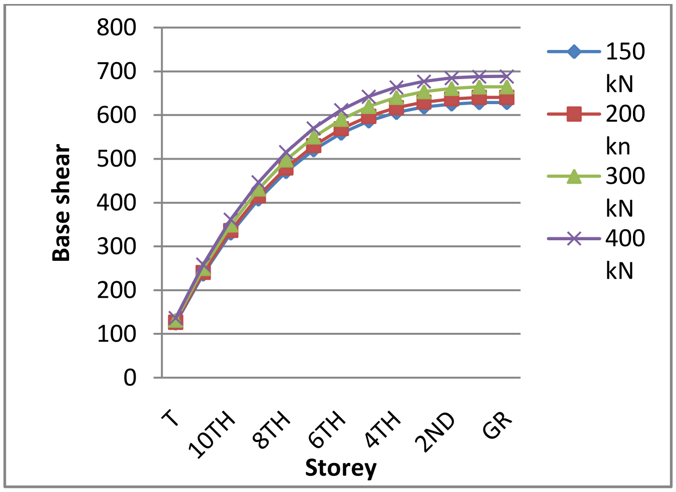


Graph- 4 torsion due to EQY (WSW)

Above table n graph shows decrease (27 to 33%) in torsion by providing concentric shear wall compared to structure without shear wall, when the force acting in EQX.

Table5- Base shear due to EQX (WSHLLX)

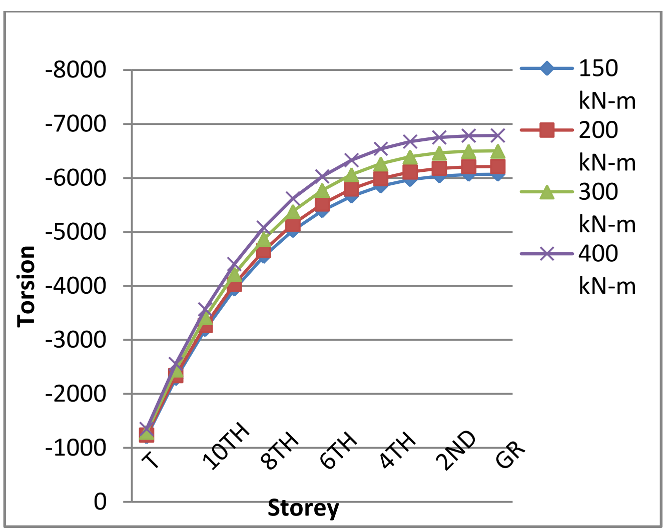
Storey	150	200	300	400
	kN	kn	kN	kN
T	124.5566	126.8944	131.5698	136.2449
11TH	236.2906	240.7713	249.7324	258.6934
10TH	330.1782	336.4595	349.0219	361.5842
9TH	407.7712	415.5407	431.0792	446.6179
8TH	470.6216	479.5965	497.5457	515.4952
7TH	520.2812	530.2085	550.0624	569.9167
6TH	558.3018	568.9583	590.2705	611.5832
5TH	586.2354	597.4276	619.8112	642.1954
4TH	605.6337	617.1979	640.3255	663.4538
3RD	618.0486	629.8509	653.4547	677.0592
2ND	625.032	636.9683	660.8399	684.7122
1ST	628.1357	640.1315	664.1222	688.1136
GR	628.4506	640.4609	664.4805	688.5009



Graph-5 Base shear due to EQX (WSHLLX)

Above table n graph shows decrease (26 to 33%) in base shear by providing shear wall parallel to X compared to structure without shear wall, when the force acting in EQX.

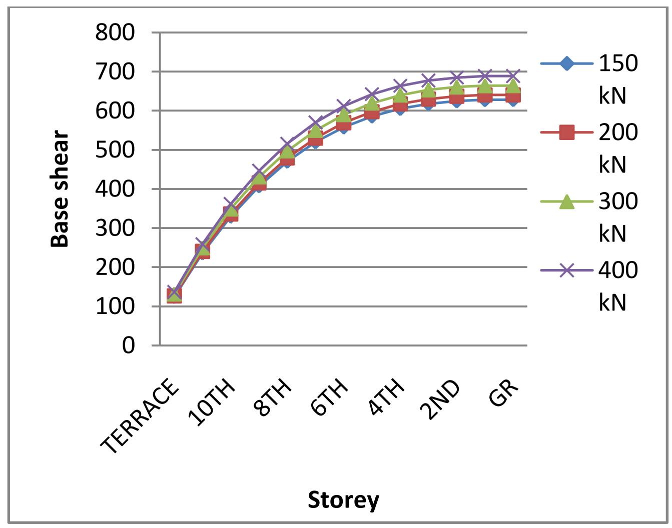
TABLE6: for torsion due to EQX (WSHLLX)				
Storey	**150**	**200**	**300**	**400**
	kN-m	kN-m	kN-m	kN-m
T	-1206.44	-1234.23	-1289.84	-1345.49
11^{TH}	-2284.42	-2337.69	-2444.29	-2550.94
10^{TH}	-3190.23	-3264.91	-3414.34	-3563.86
9^{TH}	-3938.83	-4031.2	-4216.04	-4400.99
8^{TH}	-4545.19	-4651.9	-4865.42	-5079.06
7TH	-5024.3	-5142.33	-5378.5	-5614.82
6TH	-5391.11	-5517.82	-5771.33	-6025.01
5TH	-5660.61	-5793.68	-6059.95	-6326.37
4TH	-5847.76	-5985.26	-6260.37	-6535.65
3RD	-5967.54	-6107.86	-6388.64	-6669.59
2ND	-6034.91	-6176.83	-6460.8	-6744.93
1ST	-6064.86	-6207.48	-6492.86	-6778.42
GR	-6067.87	-6210.67	-6496.4	-6782.3



Graph- 6 Torsion due to EQX (WSHLLX)

Above table n graph shows decrease (25 to 32%) in torsion by providing shear wall parallel to X compared to structure without shear wall, when the force acting in EQX.

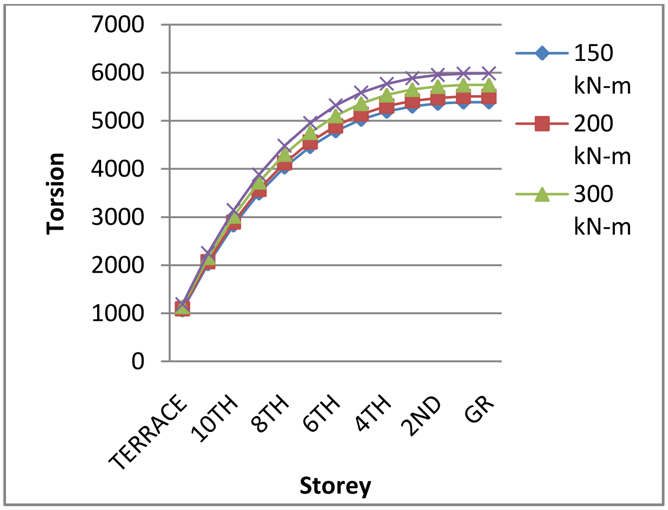
TABLE7: Base shear due to EQY(WSHLLX)				
Storey	**150**	**200**	**300**	**400**
	kN	kN	kN	kN
TERRACE	124.5565	126.8943	131.5697	136.2449
11TH	236.2903	240.771	249.7323	258.6934
10TH	330.1777	336.4591	349.0217	361.5842
9TH	407.7706	415.5401	431.0791	446.6179
8TH	470.6209	479.5958	497.5456	515.4951
7TH	520.2804	530.2077	550.0623	569.9167
6TH	558.3009	568.9574	590.2704	611.5832
5TH	586.2343	597.4266	619.811	642.1954
4TH	605.6326	617.1968	640.3254	663.4538
3RD	618.0474	629.8498	653.4546	677.0592
2ND	625.0308	636.9671	660.8397	684.7122
1ST	628.1345	640.1303	664.122	688.1136
GR	628.4494	640.4597	664.4803	688.5009



Graph 7 Base shear due to EQY **(**WSHLLX**)**

Above table n graph shows decrease (26 to 33%) in base shear by providing shear wall parallel to X compared to structure without shear wall, when the force acting in EQY.

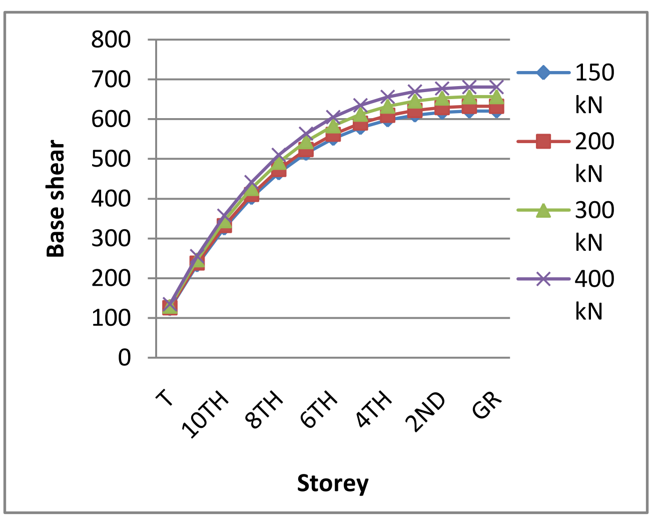
TABLE8 : Torsion due to EQY (WSHLLX)				
Storey	**150**	**200**	**300**	**400**
	kN-m	kN-m	kN-m	kN-m
TERRACE	1069.808	1093.028	1139.483	1185.955
11TH	2027.058	2071.564	2160.604	2249.681
10TH	2831.414	2893.805	3018.63	3143.506
9TH	3496.17	3573.343	3727.742	3882.205
8TH	4034.623	4123.769	4302.123	4480.551
7TH	4460.068	4558.674	4755.954	4953.318
6TH	4785.799	4891.647	5103.419	5315.28
5TH	5025.111	5136.281	5358.7	5581.212
4TH	5191.3	5306.166	5535.978	5765.886
3RD	5297.661	5414.892	5649.435	5884.078
2ND	5357.489	5476.05	5713.256	5950.561
1ST	5384.08	5503.232	5741.62	5980.109
GR	5386.826	5506.122	5744.8	5983.578



Graph 8 Torsion due to EQY (WSHLLX)

Above table n graph shows decrease (25 to 30%) in base shear by providing shear wall parallel to X compared to structure without shear wall, when the force acting in EQY.

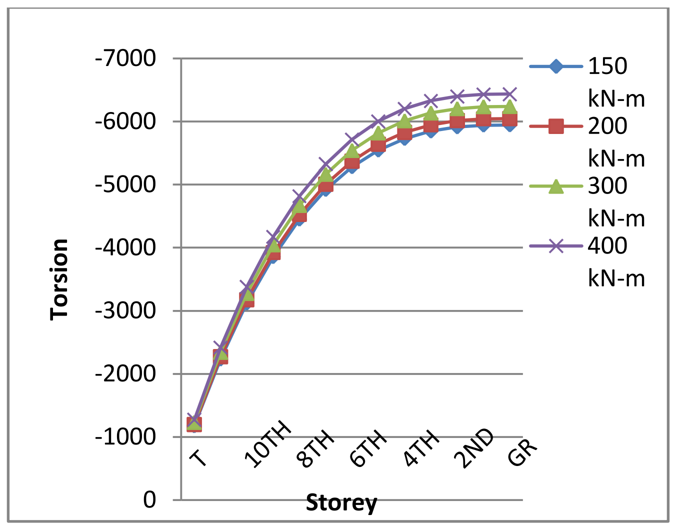
TABLE9: base shear due to EQX (WSHLLY)				
Storey	**150**	**200**	**300**	**400**
	kN	kN	kN	kN
T	122.5168	124.8706	129.5779	134.2849
11TH	232.8016	237.3132	246.3363	255.3592
10TH	325.4714	331.7962	344.4458	357.0952
9TH	402.058	409.8814	425.5281	441.1745
8TH	464.0932	473.1304	491.2047	509.2788
7TH	513.1087	523.1049	543.0974	563.0896
6TH	550.6361	561.3666	582.8277	604.2885
5TH	578.2073	589.4772	612.0173	634.5571
4TH	597.354	608.9985	632.2879	655.5769
3RD	609.6078	621.4921	645.2611	669.0296
2ND	616.5006	628.5198	652.5585	676.5968
1ST	619.5641	631.6432	655.8018	679.9599
GR	619.869	631.9627	656.1504	680.3378



Graph 9 Base shear due to EQX (WSHLLY)

Above table n graph shows decrease (27 to 34%) in base shear by shear wall parallel to Y compared to structure without shear wall, when the force acting in EQX.

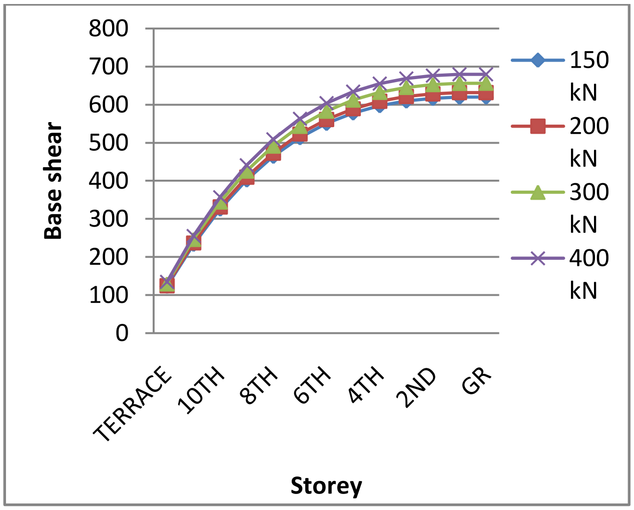
TABLE10: Torsion due to EQX (WSHLLY)				
Storey	**150**	**200**	**300**	**400**
	kN-m	kN-m	kN-m	kN-m
T	-1174.59	-1193.6	-1231.62	-1269.6
11TH	-2232.9	-2269.35	-2342.21	-2414.97
10TH	-3122.16	-3173.27	-3275.41	-3377.4
9TH	-3857.09	-3920.32	-4046.65	-4172.79
8TH	-4452.39	-4525.43	-4671.35	-4817.06
7TH	-4922.75	-5003.54	-5164.94	-5326.11
6TH	-5282.86	-5369.59	-5542.85	-5715.85
5TH	-5547.44	-5638.53	-5820.49	-6002.19
4TH	-5731.17	-5825.29	-6013.3	-6201.03
3RD	-5848.76	-5944.82	-6136.7	-6328.29
2ND	-5914.91	-6012.06	-6206.11	-6399.88
1ST	-5944.3	-6041.94	-6236.96	-6431.69
GR	-5947.19	-6044.94	-6240.19	-6435.16



Graph 10: torsion due to EQX (WSHLLY)

Above table n graph shows decrease (28 to 34%) in base shear by providing shear wall parallel to Y compared to structure without shear wall, when the force acting in EQX.

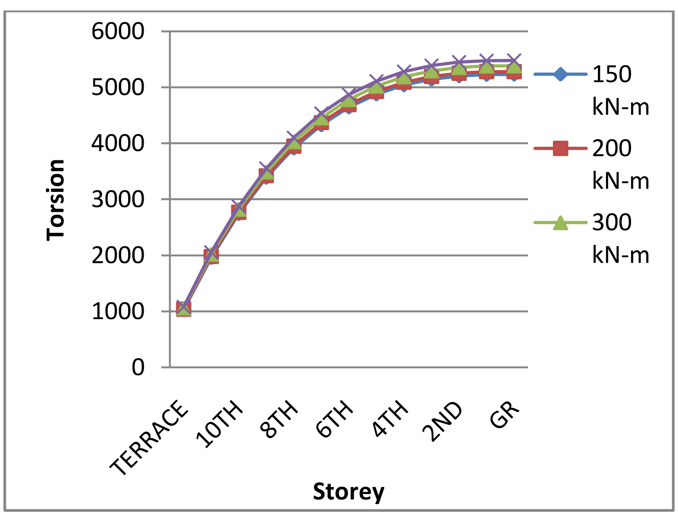
TABLE11: base shear due to EQY(WSHLLY)				
Storey	150	200	300	400
	kN	kN	kN	kN
TERRACE	122.4988	124.8532	129.6093	134.3147
11TH	232.7661	237.3296	246.3984	255.3322
10TH	325.4193	331.8447	344.5371	357.0144
9TH	401.9904	409.96	425.6468	441.0433
8TH	464.0112	473.2366	491.3485	509.1013
7TH	513.0137	523.2362	543.264	562.8704
6TH	550.5297	561.52	583.0143	604.0325
5TH	578.0911	589.6496	612.2212	634.2695
4TH	597.2297	609.1866	632.5059	655.2631
3RD	609.4771	621.6927	645.4904	668.6953
2ND	616.3652	628.7295	652.7961	676.2473
1ST	619.4256	631.8588	656.0448	679.601
GR	619.7305	632.1783	656.3934	679.9788



Graph 11 Base shear due to EQY **(**WSHLLY**)**

Above table n graph shows decrease (27 to 34%) in base shear by providing shear wall parallel to Y compared to structure without shear wall, when the force acting in EQY.

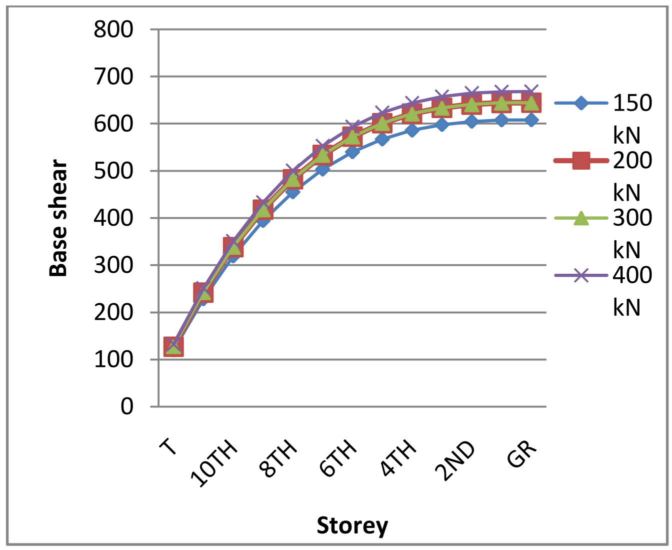
TABLE12: Torsion due to EQY (WSHLLY)				
Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
TERRACE	1028.775	1038.695	1058.899	1078.566
11TH	1959.909	1979.347	2017.635	2054.58
10TH	2742.304	2769.786	2823.27	2874.646
9TH	3388.894	3423.072	3489.114	3552.334
8TH	3912.619	3952.262	4028.473	4101.212
7TH	4326.412	4370.414	4454.659	4534.848
6TH	4643.209	4690.586	4780.981	4866.807
5TH	4875.946	4925.838	5020.751	5110.655
4TH	5037.558	5089.229	5187.277	5279.955
3RD	5140.979	5193.819	5293.874	5388.274
2ND	5199.144	5252.67	5353.853	5449.172
1ST	5224.987	5278.841	5380.525	5476.212
GR	5227.554	5281.467	5383.27	5479.077



Graph 12 Torsion due to EQY (WSHLLY)

Above table n graph shows decrease (31 to 34%) in base shear by providing shear wall parallel to Y compared to structure without shear wall, when the force acting in EQY.

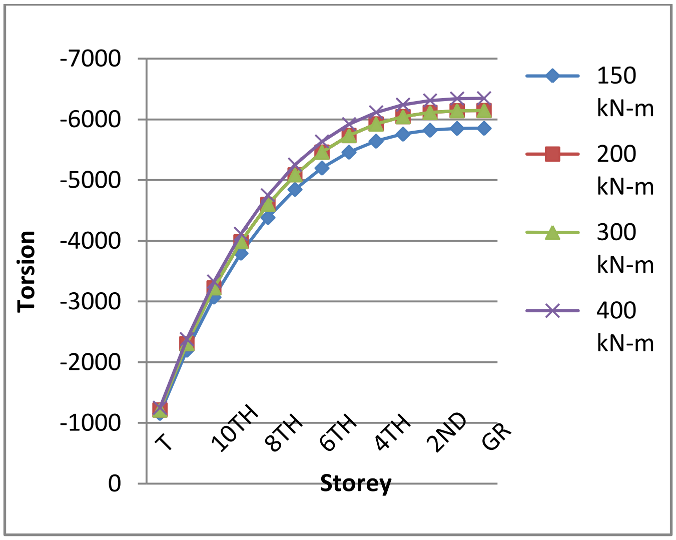
Table13: Base shear due to EQX (WSHEXC)				
Storey	150	200	300	400
	kN	kN	kN	kN
T	120.1008	127.1615	127.1615	131.848
11TH	228.3232	241.838	241.838	250.8794
10TH	319.2607	338.1969	338.1969	350.9009
9TH	394.4162	417.8313	417.8313	433.5656
8TH	455.2927	482.3342	482.3342	500.5257
7TH	503.3931	533.2985	533.2985	553.4343
6TH	540.2204	572.3173	572.3173	593.9439
5TH	567.2775	600.9834	600.9834	623.7074
4TH	586.0676	620.8898	620.8898	644.3775
3RD	598.0935	633.6295	633.6295	657.6074
2ND	604.8583	640.7951	640.7951	665.0498
1ST	607.865	643.9796	643.9796	668.358
GR	608.1559	644.3141	644.3141	668.7218



Graph 13 Base shear due to EQX (WSHEXC)

Above table n graph shows decrease (28 to 35%) in base shear by providing shear wall at the exterior corners compared to structure without shear wall, when the force acting in EQX.

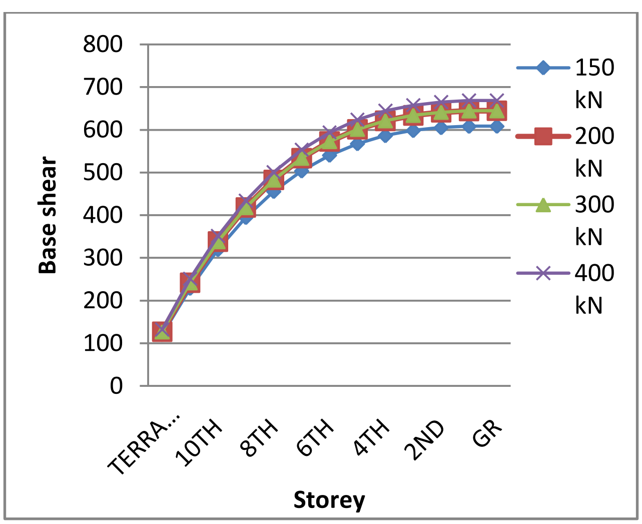
Table14 : torsion due to EQX (WSHEXC)				
Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
T	-1155.29	-1212.8	-1212.8	-1250.87
11TH	-2197.14	-2307.14	-2307.14	-2380.78
10TH	-3072.59	-3226.68	-3226.68	-3330.25
9TH	-3796.1	-3986.62	-3986.62	-4114.95
8TH	-4382.16	-4602.16	-4602.16	-4750.58
7TH	-4845.22	-5088.5	-5088.5	-5252.82
6TH	-5199.75	-5460.85	-5460.85	-5637.37
5TH	-5460.23	-5734.41	-5734.41	-5919.9
4TH	-5641.12	-5924.37	-5924.37	-6116.11
3RD	-5756.89	-6045.95	-6045.95	-6241.7
2ND	-5822.02	-6114.33	-6114.33	-6312.35
1ST	-5850.96	-6144.72	-6144.72	-6343.75
GR	-5853.73	-6147.84	-6147.84	-6347.11



Graph 14 Torsion due to EQX (WSHEXC)

Above table n graph shows decrease (29 to 35%) in base shear by providing shear wall at the exterior corners compared to structure without shear wall, when the force acting in EQX.

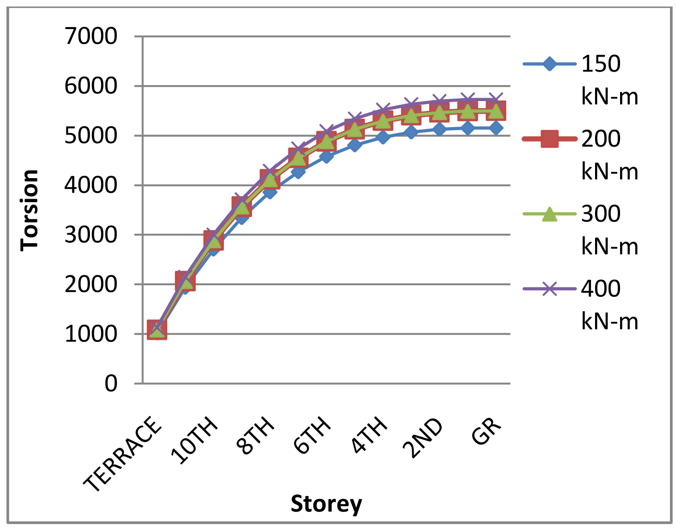
Table15 : Base shear due to EQY (WSHEXC)				
Storey	150	200	300	400
	kN	kN	kN	kN
TERRACE	120.0989	127.1592	127.1592	131.8533
11TH	228.3196	241.8399	241.8399	250.8751
10TH	319.2557	338.2025	338.2025	350.8886
9TH	394.41	417.84	417.84	433.5462
8TH	455.2854	482.3455	482.3455	500.5006
7TH	503.385	533.3119	533.3119	553.4043
6TH	540.2116	572.3324	572.3324	593.9102
5TH	567.2683	600.9998	600.9998	623.6709
4TH	586.058	620.9071	620.9071	644.339
3RD	598.0837	633.6473	633.6473	657.5676
2ND	604.8484	640.8133	640.8133	665.0093
1ST	607.8551	643.998	643.998	668.3171
GR	608.1459	644.3325	644.3325	668.6809



Graph 15: Base shear due to EQY (WSHEXC)

Above table n graph shows decrease (28 to 35%) in base shear by providing shear wall at the exterior corners compared to structure without shear wall, when the force acting in EQY.

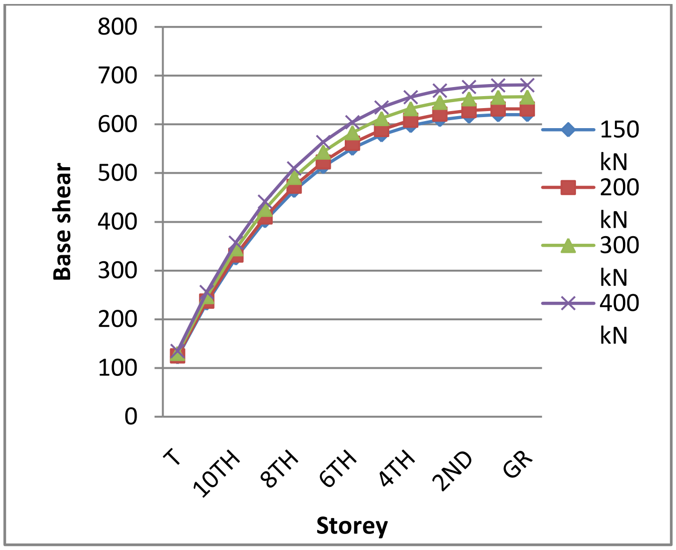
Table16 : Torsion due to EQY (WSHEXC)				
Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
TERRACE	1018.503	1085.42	1085.42	1129.994
11TH	1935.26	2063.465	2063.465	2149.101
10TH	2705.595	2885.285	2885.285	3005.451
9TH	3342.24	3564.467	3564.467	3713.194
8TH	3857.926	4114.596	4114.596	4286.479
7TH	4265.386	4549.26	4549.26	4739.459
6TH	4577.351	4882.042	4882.042	5086.284
5TH	4806.553	5126.529	5126.529	5341.105
4TH	4965.725	5296.307	5296.307	5518.074
3RD	5067.597	5404.96	5404.96	5631.342
2ND	5124.902	5466.074	5466.074	5695.062
1ST	5150.373	5493.233	5493.233	5723.386
GR	5152.841	5496.117	5496.117	5726.547



Graph 16: Torsion due to EQY (WSHEXC)

Above table n graph shows decrease (28 to 35%) in base shear by providing shear wall at the exterior corners compared to structure without shear wall, when the force acting in EQY.

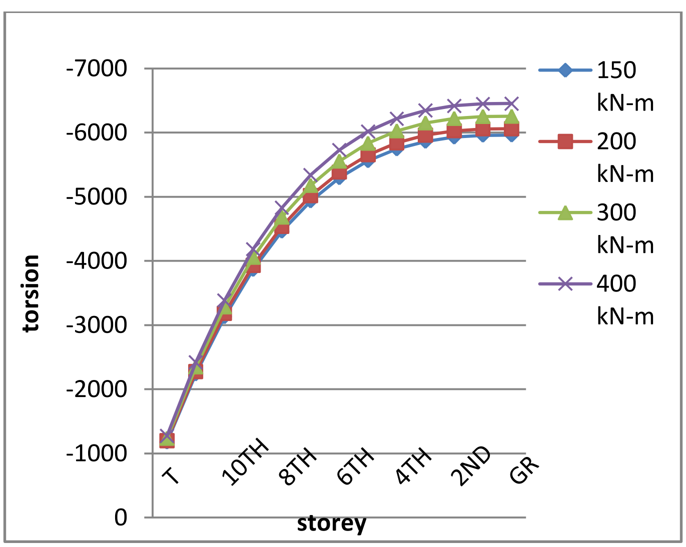
Table17 : Base shear due to EQX				
Storey	150	200	300	400
	kN	kN	kN	kN
T	122.5021	124.8557	129.5631	134.3142
11TH	232.7729	237.2842	246.349	255.4167
10TH	325.4298	331.754	344.4842	357.1785
9TH	402.0045	409.8271	425.5898	441.2815
8TH	464.0289	473.0652	491.2875	509.4068
7TH	513.0349	523.0301	543.1985	563.2359
6TH	550.5541	561.2835	582.9445	604.4504
5TH	578.1184	589.3873	612.1472	634.7319
4TH	597.2596	608.9031	632.4281	655.7619
3RD	609.5093	621.3925	645.409	669.2222
2ND	616.3992	628.4172	652.7116	676.7944
1ST	619.461	631.539	655.958	680.1605
GR	619.7659	631.8584	656.3066	680.5383



Graph 17: Base shear due to EQX (WSHSP)

Above table n graph shows decrease (27 to 34%) in base shear by providing shear wall in both the direction compared to structure without shear wall, when the force acting in EQX.

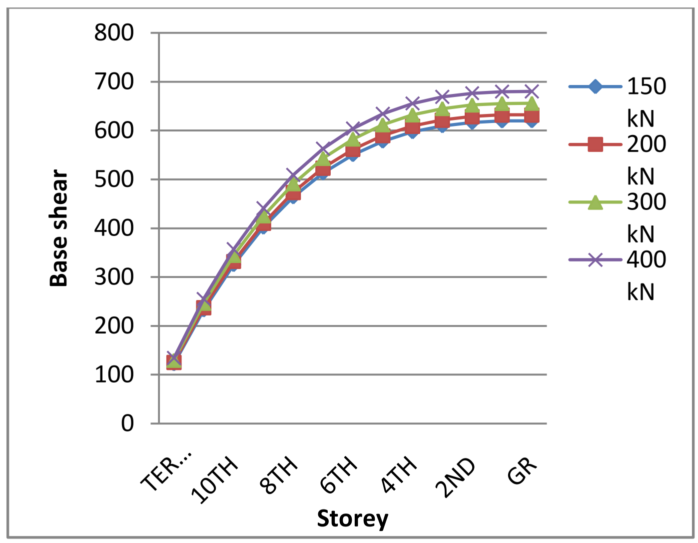
Table18 : Torsion due to EQX (WSHSP)				
Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
T	-1177.44	-1196.44	-1234.43	-1272.83
11TH	-2238.16	-2274.58	-2347.8	-2421.1
10TH	-3129.44	-3180.5	-3283.37	-3385.99
9TH	-3866.02	-3929.18	-4056.59	-4183.44
8TH	-4462.64	-4535.6	-4682.91	-4829.39
7TH	-4934.04	-5014.74	-5177.81	-5339.79
6TH	-5294.94	-5381.57	-5556.73	-5730.59
5TH	-5560.08	-5651.07	-5835.14	-6017.71
4TH	-5744.2	-5838.21	-6028.5	-6217.12
3RD	-5862.03	-5957.97	-6152.26	-6344.75
2ND	-5928.3	-6025.33	-6221.88	-6416.55
1ST	-5957.75	-6055.27	-6252.84	-6448.46
GR	-5960.65	-6058.28	-6256.09	-6451.95



Graph 18: Torsion due to EQX (WSHSP)

Above table n graph shows decrease (28 to 34%) in base shear by providing shear wall in both the direction compared to structure without shear wall, when the force acting in EQX.

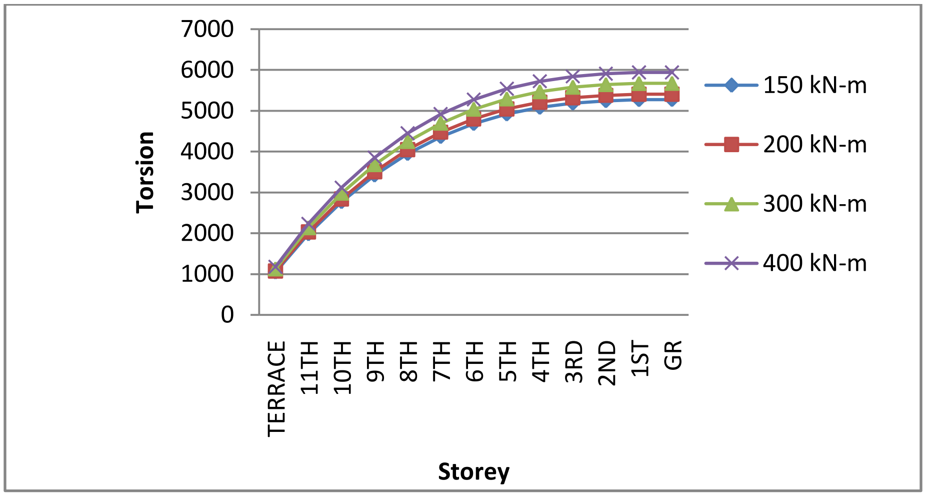
Table19 : Base shear due to EQY (WSHSP)				
Storey	150	200	300	400
	kN	kN	kN	kN
TERRACE	122.5221	124.8758	129.569	134.2772
11TH	232.8121	237.3234	246.3189	255.3666
10TH	325.4868	331.8111	344.4203	357.1171
9TH	402.078	409.9006	425.4949	441.2101
8TH	464.1174	473.1536	491.1646	509.3268
7TH	513.1365	523.1317	543.0508	563.1489
6TH	550.6672	561.3965	582.7756	604.3577
5TH	578.2412	589.5098	611.9605	634.6346
4TH	597.39	609.0333	632.2273	655.6613
3RD	609.6456	621.5285	645.1975	669.1192
2ND	616.5396	628.5573	652.4929	676.69
1ST	619.6038	631.6814	655.7349	680.0552
GR	619.9087	632.0009	656.0836	680.4331



Graph 19: Base shear due to EQY (WSHSP)

Above table n graph shows decrease (27 to 34%) in base shear by providing shear wall in both the direction compared to structure without shear wall, when the force acting in EQY.

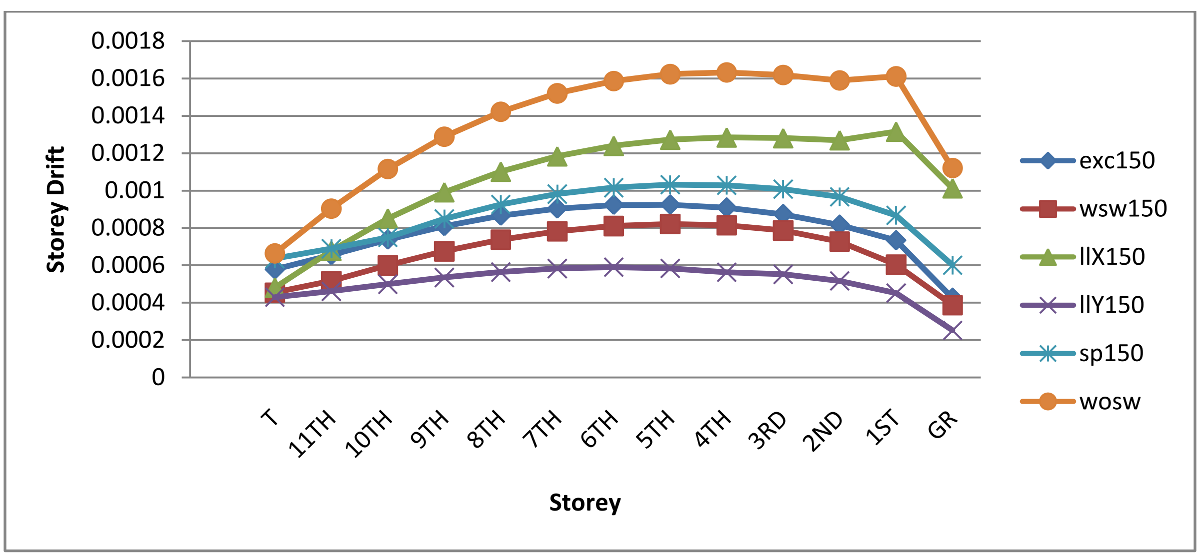
Table20 : Torsion due to EQY (WSHSP)				
Storey	150	200	300	400
	kN-m	kN-m	kN-m	kN-m
TERRACE	1044.279	1070.335	1122.378	1174.464
11TH	1981.479	2031.429	2131.09	2231.225
10TH	2768.994	2839.023	2978.675	3119.209
9TH	3419.839	3506.462	3679.145	3853.089
8TH	3947.029	4047.093	4246.516	4447.541
7TH	4363.58	4474.264	4694.797	4917.239
6TH	4682.506	4801.321	5038.003	5276.858
5TH	4916.825	5041.614	5290.145	5541.074
4TH	5079.55	5208.488	5465.235	5724.562
3RD	5183.699	5315.291	5577.285	5841.997
2ND	5242.286	5375.372	5640.306	5908.057
1ST	5268.328	5402.077	5668.309	5937.418
GR	5270.935	5404.847	5671.404	5940.839



Graph 20: Torsion due to EQY (WSHSP)

Above table n graph shows decrease (25 to 34%) in base shear by providing shear wall in both the direction compared to structure without shear wall, when the force acting in EQY.

TABLE21: Storey drift EQX (150mm THK)						
Storey	exc150	wsw150	llX150	llY150	sp150	wosw
T	0.000577	0.000454	0.000481	0.000429	0.000636	0.000663
11TH	0.000654	0.000515	0.000678	0.00046	0.000689	0.000903
10TH	0.000737	0.0006	0.000851	0.000498	0.000749	0.001115
9TH	0.000809	0.000675	0.000991	0.000534	0.000848	0.001288
8TH	0.000865	0.000737	0.001101	0.000563	0.000925	0.001422
7TH	0.000903	0.000782	0.001183	0.000582	0.000981	0.00152
6TH	0.000923	0.00081	0.001239	0.000589	0.001015	0.001586
5TH	0.000924	0.000821	0.001272	0.000583	0.001031	0.001623
4TH	0.000908	0.000814	0.001284	0.000562	0.001028	0.001632
3RD	0.000873	0.000786	0.00128	0.000551	0.001007	0.001619
2ND	0.000816	0.000727	0.001269	0.000516	0.000966	0.00159
1ST	0.000733	0.000603	0.001315	0.000451	0.000867	0.001611
GR	0.000425	0.000387	0.001012	0.000252	0.000601	0.00112



Graph 21: Storey Drift due to EQX

Above table and graph shows comparison of storey drift for all cases with 150mm thick shear walls. This shows storey drift is maximum for structure without shear wall. And minimum for shear walls parallel to Y direction

VII. CONCLUSION AND RECOMMENDATIONS AND FUTURE SCOPE

A study has been carried out to determine the optimum configuration of an eleven storey building by changing shear walls location. Five different cases of shear wall position for eleven storey building have been analyzed as a space frame system using standard package ETABs subjected to lateral and gravity loading. Four different thickness of shear wall i.e. 150, 200,300 and 400mm are also used in all five cases keeping length of wall constant in all cases i.e. 42.5m

7.1 Conclusion

This study leads to following results:

- Twisting in building is observed to have increasing trend with enhancement in the eccentricity between geometrical centroid of building and center of mass.
- It is observed that torsional value of structure for shear wall at lift is much less i.e. 24% for 400mm and 34% for 150mm for EQX and EQY than a structure without shear wall.
- Base shear for concentric shear wall is less as compared to building without shear wall in EQX and EQY (31% for450mm & 25% for 150mm)
- There is no significant change in base shear and torsion when shear walls are kept parallel to Y direction due to EQX & EQY.
- Torsion at top floors is not more affected due to shear walls parallel to Y direction due to EQX and EQY. At bottom ground floor torsion is reduced by 16% to 24%.
- No significant change in base shear and torsion when shear walls are provided in X and Y direction.
- When shear walls are placed at exterior corners base shear reduced to 28% to35% for EQX and EQY. Same with torsion it is reduced by 29% to 35%.
- Increasing thickness of shear wall doesn’t give much strength n resulting in uneconomical design in all five cases.
- Top floor displacement is much less in all cases compared to without shear wall, but it is less when shear walls are provided at corners than other places of shear wall.
- Storey drift is maximum for shear wall parallel to Y direction and minimum in parallel to X direction for EQX and EQY.
- In all shear walls placed at the corners of structure base shear due to EQX & EQY is minimum, so as Torsion.

7.2 Recommendation

- Considering all above points the optimum benefit will be in case shear walls provided at all exterior corners of the building.
- Higher thicknesses of shear wall are uneconomical and effect on torsion and base shear is comparatively less. So thickness of 150mm and 200mm is more recommended.

7.3 Future Scope

- In the present study analysis of 11-storey building has been performed using ETABS. The same exercise can be carried out for more tall buildings.
- The effect of the location of the shear walls can also be studied by shifting these walls symmetrically towards the center.
- Thickness of shear walls throughout the height of building is constant. Analysis can be performed considering different thickness in building height.

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REFERENCES

[1]. Adnan Fadih Ali Albasry ,Prof.P.Banerji, Structure idealization for Earthquake response of shear wall core system, (1993)

[2]. A.Jalali, F.Dashti; Nonlinear behavior of reinforced concrete shear walls using macroscopic and microscopic models, , Engineering Structures 32(2010)2959-2968

[3]. Ashraf, Z.A. Siddiqi and M.A. Javed; Configuration of a multi storey building subjected to lateral forces Department of Civil Engineering, University of Engineering and Technology, Lahore ,Pakistan Asian journal of Civil engineering (building and housing)(2008) 525-57

[4]. Clifford D'souza, Prof. D.N.Buragohain; Earthquake analysis of three dimensional shear wall-frame assembly on pile foundations considering soil structure interaction , (,1984)

[5]. Ho jung Leea, Mark A. Aschheimb, Daniel Kuchma; Inter-story drift estimates for low-rise flexible diaphragm structures, ,Engineering Structures 29 (2007) 1375-1397

[6]. H.S.Kim, D.G.Lee; Analysis of shear wall with opening using super element, Architectural Engineering Sungkyunkwan University ,25(2003)981-991

[7]. J.L. Humar and S.Yavari; Design of concrete shear wall building for earthquake induced forces. Department of civil and Environmental Engineering, Carleton University, Ottawa, Canada, 4^{th} Structural Specialty Conference of the Canadian Society for Civil Engineering (2002)

[8]. J.Kobaynshi, T.Korenaga, A.Shibata, K.Akino, T.Taira; Effect of small opening on strength and stiffness of shear walls in reactor building, Nuclear Engineering and Design(1995)17-27

[9]. llker Fatih Kara, Cengiz Dundar; Prediction of deflection of reinforced concrete shear walls, Advances in Engineering Software 40(2009)777-785

[10]. M.Paknahad, J.Noorzaei, M.S.Jaafar, Waleed A.Thanoon, Analysis of shear walls structure using optimal membrane triangle element, Finite Elements in Analysis and Design 43(2007)861-869

[11]. O.A.Pekau, Yuzhu Cui; Progressive collapse simulation of precast panel shear walls during earthquakes, Computers and Structures 84(2006)400-412

[12]. Paulay T.; Earthquake resisting shear walls NEW Zealand Design Trends, Journal ACI, (1980, No.3)

[13]. R.K.L.Su, S.M.Wong; Seismic behavior of slender reinforced concrete shear walls under high axial load ratio, The University of Hong Kong ,29 (2007) 1957-1965

[14]. Saher Raffat Ibrahim EI-khoriby, Prof.P.Banerji,(Structure–foundation interaction in coupled shear wall subjected to earthquake ground motion , 1992)

[15]. S.A.Meftah, R.Yeghnem, A.Tounsi, E.A.Adda bedia; Seismic behavior of RC coupled shear walls repaired with CFRP laminates having variable fibers spacing , Construction and Building Materials 21(2007)1661-1671

[16]. S.A.Meftah, A.Tounsi, A.Megueni, E.A.Adda Bedia; Lateral stiffness and vibration characteristics of RC shear walls bonded with thin composite plates, Composite Structure 73(2006)110-119

[17]. Sachin G. Maske, Dr. P. S. Pajgade; Torsional Behavior of asymmetrical Buildings, International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.2, March-April. 2013 pp-1146-1149

[18]. S Edward D.Thomsona, Maria E.Perdomob, Ricardo Picon, Maria E.Maranteb, Julio Florez-Lopez; Simplified model for damage in squat RC shear walls, Engineering Structures 31 (2009) 2215-2223

[19]. S.S.AI-Mosawi, M.P.Saka, Optimum design of single core shear walls, Computers and Structures 71(1999)143-162

[20]. Sid Ahmed Mehtaf, Abdelouahed Tounsi, Adda Bedia Ei Abbas; A simplified approach for seismic calculation of a tall building braced by shear walls and thin-walled open section structures, Engineering Structures 29 (2007) 2576-2585

[21]. S.S.Badiet, D.C.Salmon and A.W.Beshara; Analysis of shear walls structures on elastic foundation , Computer & Structures Vol.65.No.2 (1995)

[22]. Y.F. Rashed; Analysis of building shear walls using boundary elements, Engineering analysis with Boundary Elements 24(2000)287-293

[23]. Youssef Belmouden, Pierino Lestuzzi; Analytical model for predicting nonlinear reversed cyclic behavior of reinforced concrete structure walls, Engineering Structures 29(2007)1263-1276