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Dynamic Analysis of Multistoreyed Frame Shear Wall Building Considering SSI

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ABSTRACT

The structural system of a high-rise building often has a more pronounced effect than a low rise building on the total building cost and the architecture aspect of building. Shear walls are lateral load resisting structural systems which provide stability to structures from lateral loads like wind and seismic Loads. The design of multi storey building is to have good lateral load resisting System along with gravity load system for safety of occupant and for better performance of structure even in most adverse condition. The main scope of this project is to apply class room knowledge in the real world by designing a multi-storied residential building. Shear walls are more efficient in resisting lateral loads in multi storied buildings. Steel and reinforced concrete shear walls are kept in major positions of multi storied buildings which are made in consideration of seismic forces and wind forces. To solve this purpose shear walls are a very powerful structural elements, if used judiciously can reduce deflections and stresses to a very great extent. Our project contains a brief description of building with shear wall and without shear wall thoroughly discussed structural analysis of a building to explain the application of shear wall. The design analysis of the multi storied building in our project is done through STAAD-PRO, most popular structural engineering software. It is featured with some ultimate power tool, analysis and design facilities which make it more users friendly.

KEYWORDS: *Shear wall, Building Drift, Response spectrum method, Time period, OMRF, Base shear*

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1. INTRODUCTION

1.1. General

Soil-structure interaction (SSI) has been recognized as an important parameter that may significantly affect the motion of base, relative building response and motion of surrounding soil. Generally building soil interaction consists of two parts kinematic interaction and dynamic interaction. The former result of wave nature is excitation and is manifested through the scattering of incident waves from foundation system and through filtering effect of the foundation that may be stiffer than the soil. Therefore it may not follow the higher frequency deformations of soil. This interaction depends on angle of incidence, frequency, type of incident waves, shape of foundation and depth of foundation. It develops due to presence of stiff foundation elements on or in soil cause foundation motion to deviate from free-field motions. The later is due to inertia forces of building and of the foundation which act on soil due to contact area. And it depends on the mass and height of the building and the mass and depth of foundation, on the relative stiffness of soil compared with the building and on the shape of foundation. It develops in structure due to its own vibrations which gives rise to base shear and base moment, which in turn cause displacements of the foundation relative to free field. At low level of ground shaking, kinematic effect is more dominant causing increase of period. Observations from recent earthquakes have shown that the response of the foundation and soil can greatly influence the overall structural response.

SSI analysis procedures are important in various cases of structural and soil conditions. Some are briefly defined here.

Type A - Structures like Rigid Tower. In this type of structures the supporting soil media will go to nonlinearity and the structure will remain in linear state only.

Type B-Structures like pile supported Jetties. In this type of structures the supporting pile and soil will go to nonlinearity and the structure will remain in linear state only.

Type C- Structures like Frame Buildings. In this type of structure the soil, pile and structure will go to nonlinear state under strong earthquake shaking.

Type D- Structures like Pipes. In this type of structure the supporting soil media will go to nonlinear state under differential settlement and pipe will also go to nonlinear state etc.

1.2. Scope of the study

The lateral behavior of the multistory building designed according to the IS-456 and IS- 1893 part-I is evaluated using dynamic analysis of framed structures using Response Spectrum Method. The inadequacies of multi-storied frame shear wall building are discussed comparing the lateral behavior, building drift, axial force, and seismic base shear. Two important parameters zone factor and Soil-structure interaction (SSI), which influence the lateral behavior of building is also considered in this study. Software STAAD-ProV8i is used for this purpose. In this study number of stories, zone factor and soil condition are varying parameters

1.3. Factors influencing SSI effects

SSI is very complex phenomenon and its effect depends up on the soil stratification, wave propagation frequency and soil density. Few factors are discussed below.

1.3.1. Impedance contrast

It defined as the product of density and velocity of the material. It varies the ground motion amplitude while travelling to the most heterogeneous soil media like soil. Earthquake wave's travels faster in hard rock's as compare to softer rocks and sediments. As the waves passes from harder to softer media waves travels slower and in order to maintain the same earthquake energy attains the bigger amplitude.

1.3.2. Resonance

It is the earthquake phenomenon defined as the matching the magnitude of an excitation frequency with the fundamental natural frequency of the system. Early attempts have been shown that the structural response against earthquake is different for fixed base analysis than the SSI analysis in frequency.

1.3.3. Soil Damping

In dynamic analysis when the excitation seismic waves travel through the soil mass the energy of the wave is dissipated due to the scattering the waves in to the infinite domain.

Thus the energy loss takes place in this phenomenon is called as the radiation damping. The energy of the input waves also can be used in deformations of the soil mass due to which the changes the soil material properties and referred as a material damping.

Absorption of energy occurs due to inelastic properties of medium in which the particle of a medium do not react perfectly elastically with their neighbor and a part of the energy in the waves is lost instead of being transferred through medium, after each cycle.

1.3.4. Waves Trapping

The wave trapping in the soil mass is due to the Impedance contrast between adjacent layers of soil mass. Kawas has brought in observation in the 1995 Japan earthquake which was the most destructive earthquake in Japan even though it was moderate magnitude.

1.3.5. Lateral discontinuities

It can be defined as the softer material lies besides a more rigid and vice versa. The damages observed in the village Bhatwari- Sonar in the year 1999. Earthquake due to the layer of debris damped situated below the stiff soil in Chamoli. Number of research works has been carried out on SSI analysis founded on the different types of foundation system. It has been observed that much research gap is left with the attempts made on the interaction analysis of building founded on piles.

2. LITERATURE REVIEW

Venkata Sai Ram Kumar N et al (2014) "Utilization of reinforced concrete flexural (shear) Walls in multistory buildings with effect of lateral loads under flat terrain". Analyzed behavior of RCC shear walls by considering increase of height of buildings from ground level to G+7 of height of each floor as 3.5m. The analysis involved in developing of capacity curves which relates wind drift, shear wall length, wind drift, wind shear, wind moment, seismic drift, seismic shear, seismic moment, base moment and base shear with increase in height the base shear of medium and soft soils have no change and varied linearly, but for rocky soils there is a slight decrease in base shear after 20 mts of building height.

Ugale Ashish B. and Raut Harshalata R. (2014) "Effect of steel plate shear wall on behavior of structure". Consider a building frame with (G+6) storey situated in seismic zone III as per Indian code 1893:2002, steel plate shear wall behavior was analyzed using STAAD PRO software, with shear wall and without shear wall also. Found steel plate shear wall enhances the stiffness of the structure. Compared without SPSW building, building with SPSW has very less deflection, bending moment, shear force, deflection and also quantity of steel is also reduced. SPSW occupies less space compared to RC shear wall which have economical and architectural aspect.

P.P.Chandurkar et al (2013) "Seismic analysis of RCC Building with and without shear wall".. present a paper in determining the shear wall location of four different types of models varying with earthquake load with zones II, III, IV, V as per IS : 1893 : 2002 and calculated lateral displacement, story drift and total cost required for ground floor are calculated by replacing column with shear wall. It was found that shear wall in short span at corner in model 4 was economical and effective in high rise buildings. Shear wall with large dimensions are effective in high amounts of horizontal forces and providing shear wall at suitable location, displacements can be reduced due to earthquake.

Venkatasai ram kumar.N et al (2013) "Influence of reinforced concrete shear wall on multistorey buildings" analyzed the reinforced concrete shear walls in multistory buildings with effect of lateral loads under flat terrain with varying seismic zones as per IS: 1893: 2002 and wind loads as per IS : 875 : 1987(Part : 3). In all the considered G + 2, G + 4, G + 6, building frames, the base moment varied in power equation pattern and for base shear the graphs varied linearly. With increase in base area the stability of building increased and minimum thickness to prevent buckling of shear wall also decreased as the stability increased.

H.Veladi et al (2013) "Experimental investigation on cyclic behavior of steel shear walls" conducted cyclic tests with varying aspect ratio of shear walls and in filled panels on steel shear walls. Height reduction in shear panels results in decrease of drift and enhancement of shear strength. Increase in height of panel improves drift of panel and causes significant plastic energy absorption which leads to reduction in shear strength. Use of wide panel with cyclic tests and varying aspect ratio increase of shear strength and reduction of drift was found.

Zhiyuan sun, Jiliang Liu and Mingjin Chu (2013) "Experimental study on behaviors of adaptive slit shear walls" conducted cyclic loading test on a new type of adaptive slit shear wall which is introduced to improve the seismic performance of conventional shear wall structures. When compared to conventional shear walls the new wall is high ductile and failure process is progressive and is divided into two stages i.e., whole wall stage and the slit wall stage. It was found that ductile failure can be achieved and brittle shear failure can be avoided in adaptive slit shear walls with multiple seismic fortifications.

Natalino Gattesco et al (2012) "Experimental investigation on the seismic behavior of timber shear walls with practice boards" carried experimental study to compare with code provisions on timber shear walls with particle boards and also one opening for windows. Experimental results shown that very little differences in terms of shear capacity, ductility and dissipative capacity between perforated and solid walls with equal dimensions. And a significant increase of shear capacity observed in double number nailed panels.

S. Greeshma et al (2012) "Seismic behavior of shear wall – slab joint under lateral cyclic loading". conducted experiments of type 1 model comprises two joint assemblages having joint detailing of slab bars at the joints, type 2 comprises two specimens having additional cross bracing reinforcements as per IS :13920 : 1993 for beam column joint. Experimental results showed that type 2 detailing have better performance, exhibited higher load carrying capacity with minimum cracks in the joints, enhancement in energy dissipation for type1 and type 2 specimens were observed to be 113.58% higher than that of type 1 and are matching with analytical results.

Romy Mohan and C Prabha (2011) "Dynamic Analysis of RCC Buildings with Shear Wall " - Concluded that Equivalent Static Method can be used effectively for symmetric buildings up to 25 m height. For higher and unsymmetrical buildings Response Spectrum Method should be used. For important structures Time History Analysis should be performed as it predicts the structural response more accurately in comparison with other two methods since it incorporates p - Δ effects and material non linearity which is true in real structures. From the above studies it is evident that square shaped shear wall is the most effective and L shaped is the least effective.

Max Guendel et al (2011) "Experimental and numerical investigations on steel shear walls for seismic retrofitting" conducted experimental and numerical investigations on steel shear walls for seismic retrofitting tests conducted on a pure reinforced concrete (RC) frame as reference to steel shear walls with aspect ratio $\mu = 3.5$ and 5.5 with welded shear panels, shear panels made of DX56D and DX51D with excellent ductility ($\mu = 8$)SSW'S with welded shear panels and $\mu = 3.5$ and 5.5 had failure mode which separated the shear panel from the boundary elements. SSW's with shear panels fixed with powder actuated fasteners also provide high stiffness and high strength and with limited deformation capacity due to early failure of the connection, if ordinary steel grades are used. Shear panels made with DX56D fixed by powder actuated fasteners gave improved ductility (μ = 8). Strong classifications were occurred in the shear panel before the connection fails. The advantages observed with SSW's connection to RC frame have several advantages (i) reduction of vertical reaction forces in foundations. (ii) Additional shear forces in the RC beam are prevented and only axial forces are introduced in RC beam and RC columns with.

S. V. Venkatesh, H. Sharada Bai(2011), "Effect of internal & External shear wall on performance of buildings frame subjected to lateral load", conducted linear static analysis with considering internal and external shear wall performance on a 10 storey framed structure for investigation of maximum joint displacement, support reaction, column forces and beam forces and found that performance of square shear walls gave better results than rectangular column of different orientations under lateral loads

Kevin B.D.White (2009) "Seismic performance testing of partially and fully anchored wood frame shear walls". Conducted monotonic earthquake loadings fully and partially restrained wood frame shear walls. It was found that partially anchored subduction zone earthquake tests caused wall failure modes consistent with monotonic and cyclic tests. Fully anchored subduction zone tests caused wall failure modes consistent with cyclic tests. Fully anchored monotonic tests did not cause screw fracture or nail withdrawal and therefore did not have failure modes consistent with subduction zone earthquake tests. Energy dissipation was most similar to cyclic tests rather than monotonic tests.

Ni and Karacabeyli (2008) studied the performance of shear walls anchored withhold downs, without hold downs and with dead loads and no hold downs. Static and reverse cyclic loading as per ISO (1998) protocols were used. Comparison to displacement of walls without hold downs to withhold downs and no vertical load were observed 50% corresponding displacement of walls without hold down or vertical load was found to that of walls with hold downs and no vertical load.

Hwang et al (2005) "Role of hoops on shear strength of reinforced concrete beam column joints". Found that the major function of joint hoop is to carry shear as tension tie and to constrain the width of tension cracks. The suggestion by author was that lesser amount of joint hoop with wider spacing could be used without no effect of the performance of joint.

Salenikovich and Dolan (2003) "The racking performance of shear walls with various aspect ratios" tested walls by various aspect ratios and overturning restraints with both statically and cyclically. Walls ductility and wall stiffness were same as result of two protocols. Capacity and corresponding displacement were 13% and greater than 30% respectively were found for walls tested monotonically and having aspect ratios less than or equal to 2:1.

Murty et al (2003) "Effectiveness of reinforcement details in exterior reinforced concrete beam column joints for earthquake resistance" suggested the practical joint detailing using hair pin type reinforcement is an alternative to closer ties in the joint region which was observed by testing the exterior beam column joint subjected to static cyclic loading by change of anchorage detailing of beam reinforcement and shear reinforcement.

Yamaguchi et al (2000), "seismic performance of nailed wood frame walls" Conducted monotonic, cyclic tests with various loading rates, pseudo dynamic test, El Centro shake table tests for wood framed shear walls, the tests with more load cycling and high amplitudes corresponded together post peak strength degradation. The fast reversed cyclic test results are close to shake table tests. Compared with pseudo dynamic tests and shake table test, similar amplitudes load cycles were observed but results were different.

Mc mullin and merrick (2000), conducted force controlled cyclic tests on walls sheathed on both sides with oriented strand board (OSB), 3 ply plywood, 4 ply plywood, gypsum wall board (GWB). The stiffness of GWB was found to be greater than OSB and ply wood.

T.Sonos et al (1992) "Seismic resistance of type 2 exterior beam-column joints reinforced with inclined bars" suggested the use of crossed inclined bars in joint region which is considered the most effective way to improve the seismic resistance of exterior reinforced concrete beam column joints.

Paulay (1989) "criteria for reinforced concrete beam – column joints" by using laws of statics, found that joint shear reinforcement is necessary to sustain the diagonal compression field rather than to provide internment to compressed concrete in a joint core.

Arturo E.Schultz et al (1994) "Seismic resistance of vertical joints in precast shear walls" conducted experiments on precast shear walls, to develop a calibrated experiments and accurate behavior of models and design rules of precast shear walls. Application of cyclic lateral load test was conducted of twelve 2/3 scale specimens. Vertical joint connection used are notched shear plate, slotted flexure plate, inclined flat bar, pinned tension strut, brass friction device, U-shaped flexure plate. Unlike the five connections U shaped flexure plate performance, it was not possible to proportion the U-shaped plate to resist the shear forces. Panels made with notched shear plate and slotted flexure plate, assemblage acted as a monolithic unit and found with large initial elastic stiffness.

3. SHEAR WALL

3.1. General

Vertical elements of the horizontal force resisting system are known as Shear walls. It is typically wood frame walls covered with a structural sheathing material like plywood. When the sheathing is properly fastened to the stud wall framing, the shear wall can resist forces directed along the length of the wall. If shear walls are designed and constructed properly, it will have the good strength and stiffness to resist the horizontal forces.

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls (Figure 1) 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 (Figure 1). Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation.

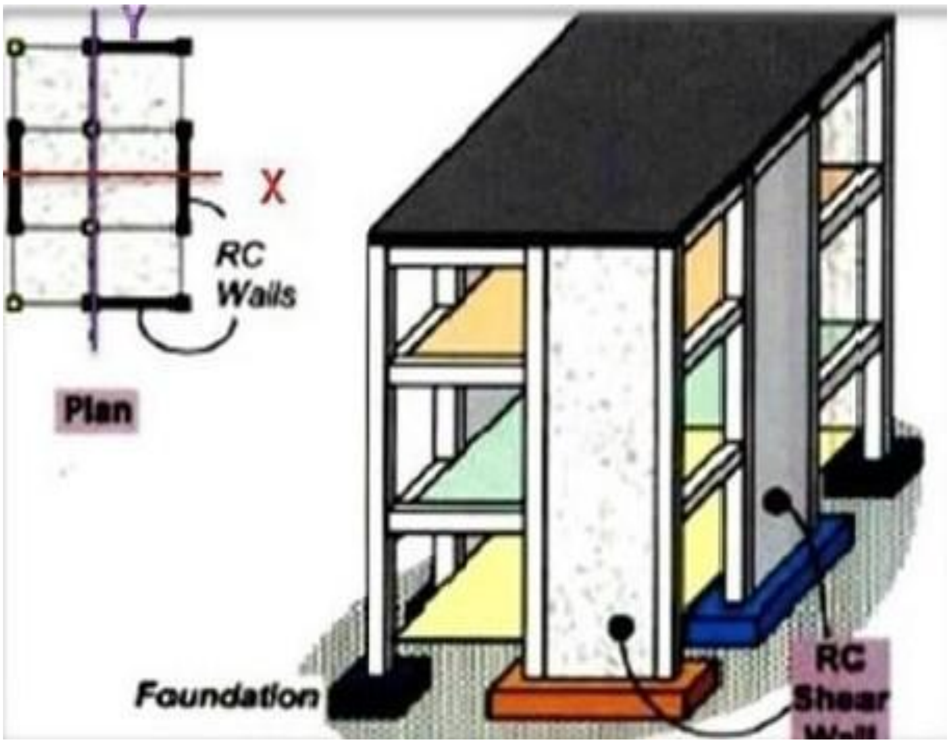


Figure-3.1 3-D Diagram of RCC shear wall

Types of Shear wall

1. Simple rectangular type
2. Coupled type
3. Rigid frame
4. Framed
5. Column supported shear wall

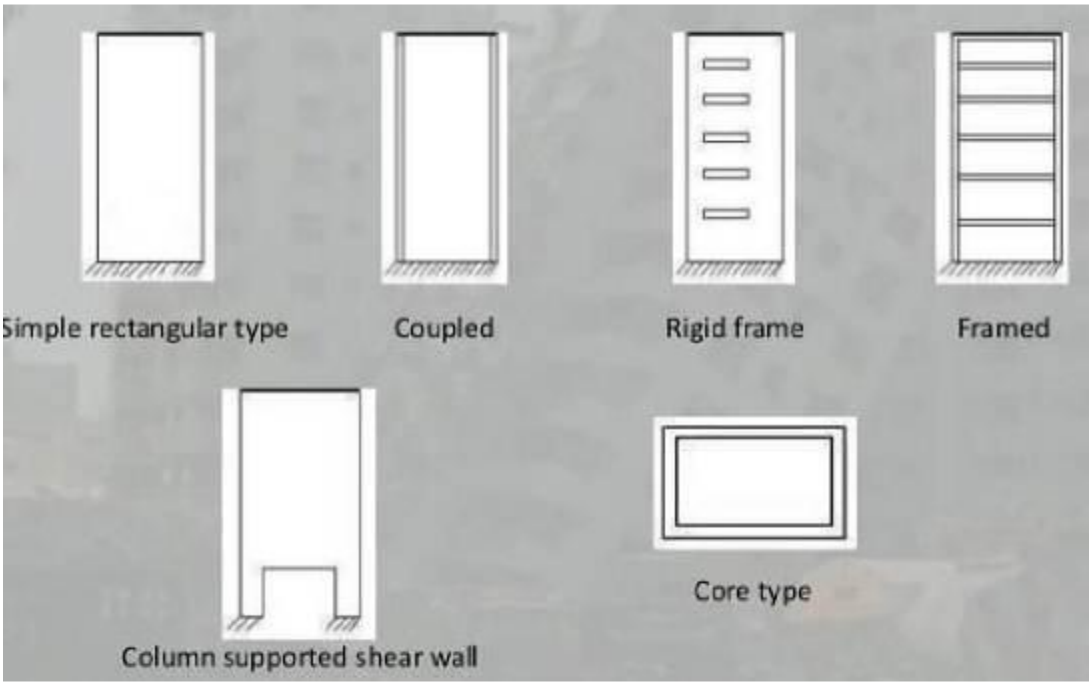


Figure-3.2 Types of shear wall

3.2. Advantages of Shear Walls in RC Buildings

- Properly designed and detailed buildings with shear walls have shown very good performance during earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the one quote given by Mark Fintel, a noted consulting engineer in USA "We can't afford to build concrete buildings meant to resist severe earthquakes without shear walls." Shear walls in high seismic regions require special detailing. In past earthquakes even buildings with sufficient amount of walls that were not specially detailed for seismic performance were saved from collapse. Shear wall buildings are a best choice in many earthquake prone countries, like New Zealand, Chile and USA. Shear walls are easy to construct because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site.
- It Provide greater strength and stiffness in the direction of orientation.
- It significantly reduces lateral sway.
- It is easily constructed and implanted.
- It wills Efficient in the terns of construction cost and effectiveness in minimizing seismic effect.

3.3. Shear Walls (Architectural Aspects)

Most reinforced concrete buildings with shear walls also have columns, these columns primarily carry gravity loads due to dead-weight and contents of building. Shear walls provide greater strength and stiffness to buildings in the direction of their orientation, which significantly minimize lateral sway of the building and thereby reduces damage to structure. Since shear walls carry large lateral earthquake forces hence the overturning effects on them are large. Thus, design of their foundations requires special attention and precautions. It should be provided along preferably both length and width. However if shear walls are provided along only one direction a proper grid of beams and columns in the vertical plane (called MRF) must be provided along the other direction to resist strong seismic 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 preventions are required to ensure that the net cross sectional area of a wall at an opening is sufficient to carry the lateral 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. It will more effective when located along exterior perimeter of the building, such as layout increases resistance of the building to twisting.

3.4. Ductile Design of Shear Walls

Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard Ductile Detailing Code for RC members (IS: 13920-1993) provides special design guidelines for ductile detailing of shear walls.

3.5. Overall Geometry of Walls

Shear walls are oblong in cross-section, i.e., one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used (Figure 3). Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces.

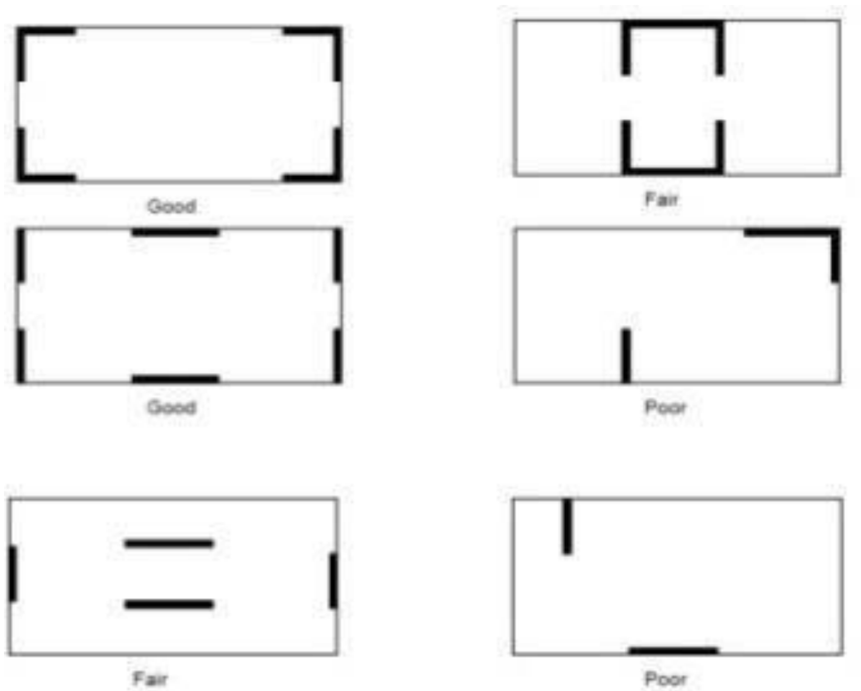


Figure-3.3 Placement of shear wall

3.6. Reinforcement Bars in RC Walls

Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids (Figure 4a). The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross- sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

Precautions during construction of shear walls

- Should be applied in a symmetric manner to the building to avoid abnormal torsion in structural members.
- Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large.
- Thus, design of their foundations requires special attention.
- 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.
- Effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

3.7. Behavior of Wall-Frame Systems

Earthquake resistant buildings should possess, at least a minimum lateral stiffness, so that they do no swing too much during small levels of shaking. Moment frame buildings may not be able to offer this always. When lateral displacement is large in a building with moment frames only, structural walls, often commonly called shear walls, can be introduced to help reduce overall displacement of buildings, because these vertical plate- like structural elements have large in-plane stiffness and strength. Therefore, the structural system of the building consists of moment frames with specific bays in each direction having structural walls. Structural walls resist lateral forces through combined axial- flexure-shear action. Also, structural walls help reduce shear and moment demands on beams and columns in the moment frames of the building, when provided along with moment frames as lateral load resisting system. Structural walls should be provided throughout the height of buildings for best earthquake performance. Also, walls offer best performance when rested on hard soil strata.

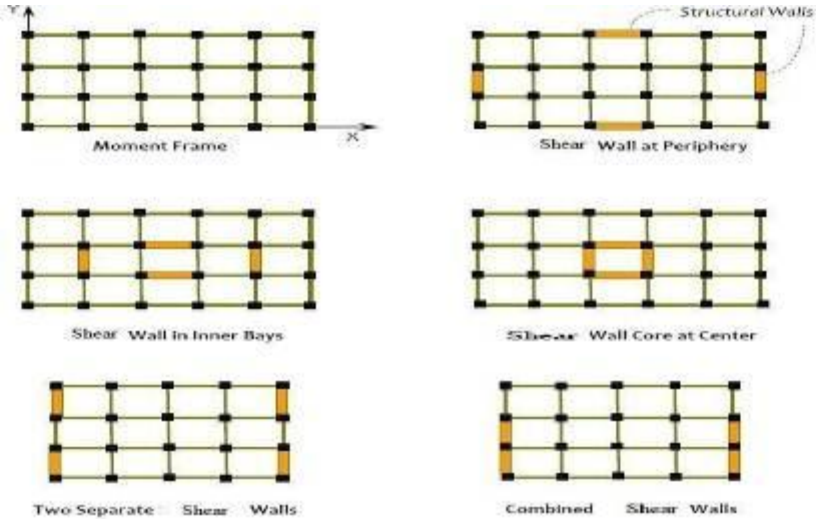


Figure 3.4 Buildings with structural shear wall

4. BEHAVIOR OF BUILDING

4.1. General building behaviour

Dynamic actions are caused on buildings by both wind and earthquakes. But, design for wind forces and for earthquake effects are distinctly different .Wind force on the building has a non-zero mean component superposed with a relatively small oscillating component (Figure 4.1). Thus, under wind forces, the building may experience small fluctuations in the stress field, but reversal of stresses occurs only when the direction of wind reverses, which happens only over a large duration of time.

The behavior of a building during earthquake is a vibrations problem. The seismic motion of the ground does not damage a building by impact, or by externally applied pressure, but by internally applied pressure and internally generated inertial forces caused by vibration of building mass (Figure 4.1). It can cause buckling or crushing of columns and walls when the mass pushes down on a member bent or moved out of plumb by the lateral forces. This effect is known as the 'P- ' effect and Greater the vertical forces, the greater the movements due to 'P- '. It is almost the vertical load that causes the duration of motion are of concern in seismic design. Although the duration of motion is an important issue, we do not consider it for seismic design. The motion of the ground during the earthquake is cyclic about the neutral position of the structure. Thus, the stresses in the building due to seismic actions undergo many complete reversals and that to over the small duration of earthquake.

In general tall buildings respond to seismic motions differently than low rise buildings. The magnitude of inertia force induced in an earthquake depends on the building mass, ground acceleration, the nature of the foundation, and the dynamic characteristics of the structure. For a structure that deforms slightly, the force 'F' tends to be less than the product of mass and ground acceleration. Tall buildings are invariably more flexible than low rise buildings, and in general, experience much lower accelerations than the low rise buildings. But a flexible building subjected to ground motions for prolonged period may experience much larger forces if its natural period is near that of ground period. Thus the magnitude of earthquake force is function of the acceleration of the ground, the type of structure and its foundation.

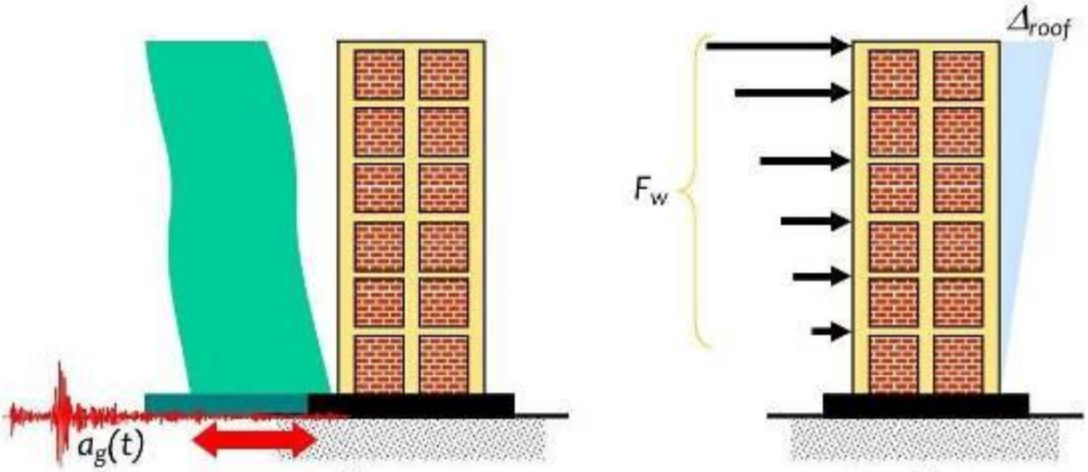


Figure 4.1: Difference in the design effects on a building during natural actions of (a) Earthquake Ground Movement at base, and (b) Wind Pressure on exposed area

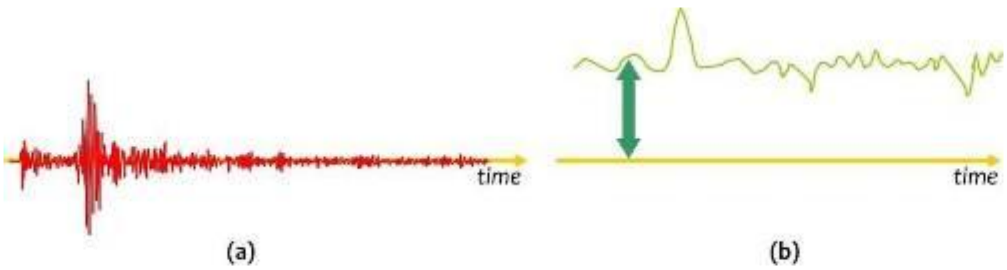


Figure 4.2: Nature of temporal variations of design actions: (a) Earthquake Ground Motion zero mean, cyclic, and (b) Wind Pressure – non-zero mean, oscillatory

4.2. Dynamic characteristics of buildings

Buildings oscillate during earthquake shaking. The oscillation causes inertia force to be induced in the building. The intensity and duration of oscillation, and the amount of inertia force Induced in a building depend on features of buildings, called their dynamic characteristics, in addition to the characteristics of the earthquake shaking itself. The important dynamic characteristics of buildings are modes of oscillation and damping. A mode of oscillation of a building is defined by associated Natural Period and Deformed Shape in which it oscillates.

4.3. Natural period

Natural Period Tn of a building is the time taken by it to undergo one complete cycle of Oscillation. It is an inherent property of a building controlled by its mass m and stiffness k. These three quantities are related by.

Tn=2(m/k)1/2

Its units are seconds (s). Thus, buildings those are heavy (with larger mass m) and flexible (with Smaller stiffness k) have larger natural period than light and stiff buildings. Buildings oscillate by Translating along X, Y or Z directions, or by rotating about X, Y or Z axes, or by a combination of the above (Figure 2.3). When a building oscillates, there is an associated shape of oscillation. The reciprocal (1/Tn) of natural period of a building is called the Natural Frequency fn; its unit is Hertz (Hz). The building offers least resistance when shaken at its natural frequency (or natural period). Hence, it undergoes larger oscillation when shaken at its natural frequency than at other frequencies (Figure 2.4). Usually, natural periods (Tn) of 1 to 20 storey normal reinforced concrete and steel buildings are in the range of 0.05 - 2.00s. In building design practice, engineers usually work with Tn and not fn.

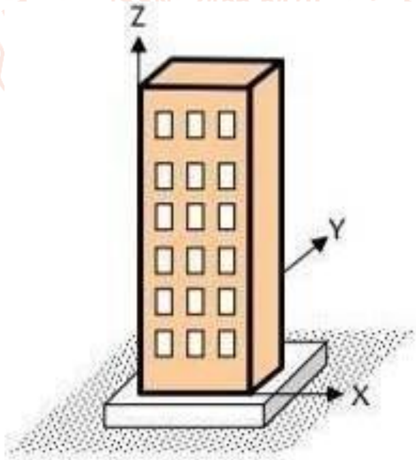


Figure 4.3 Buildings oscillate by translating along X, Y or Z directions

4.4. Fundamental natural period of building

Every building has a number of natural frequencies, at which it offers minimum resistance to shaking induced by external effects (like earthquakes and wind) and internal effects (like motors fixed on it). Each of these natural frequencies and the associated deformation shape of a building constitute a Natural Mode of Oscillation. The mode of oscillation with the smallest natural frequency (and largest natural period) is called the Fundamental Mode; the associated natural period T1 is called the Fundamental Natural Period (Figure 2.5) and the associated natural frequency f1 the Fundamental Natural Frequency.

1. Three fundamental translational natural periods, Tx1, Ty1 and Tz1, associated with its horizontal translational oscillation along X and Y directions, and vertical translational oscillation along Z direction, respectively.

2. One fundamental rotational natural period Tθ1 associated with its rotation about an axis Parallel to Z axis.

In reality, the number of natural modes of a building is infinity. But, for engineering purposes, the number of modes is finite. For instance, when the finite element model (FEM) of the building is prepared, the buildings are discredited into members meeting at nodes. Each node has a maximum of 6 degrees of freedom (freedom of movement available to the node along the Cartesian coordinate system, namely three translations and three rotations). Hence, for a building with many nodes, the maximum degrees of freedom can be counted to be finite, say N. Here, the building is said to have N natural modes of oscillation. In normal buildings, N can be large. But, often, only a few modes are necessary for engineering calculations to assess the response of buildings.

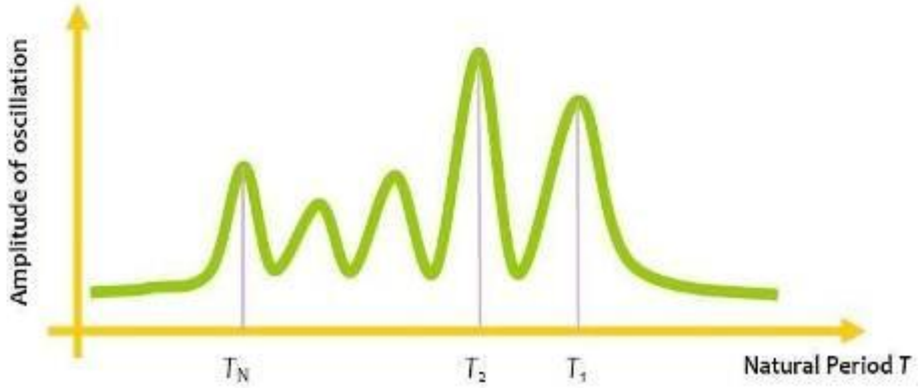


Figure 4.4- Multiple natural periods

4.5. Factors influencing natural period

4.5.1. Effect of stiffness

Increasing the column size increases both stiffness and mass of buildings. But, when the percentage increase in stiffness as a result of increase in column size is larger than the percentage Increase in mass, the natural period reduces. Hence, the usual discussion that increases in column Size reduces the natural period of buildings does not consider the simultaneous increase in mass in that context, buildings are said to have shorter natural periods with increase in column size.

4.5.2. Effect of mass

Mass of a building that is effective in lateral oscillation during earthquake shaking is called the seismic mass of the building. It is the sum of its seismic masses at different floor levels. Seismic mass at each floor level is equal to full dead load plus appropriate fraction of live load. The fraction of live load depends on the intensity of the live load and how it is connected to the floor slab. Seismic design codes of each country/region provide fractions of live loads to be considered for design of buildings to be built in that country/region. An increase in mass of a building increases its natural period.

4.5.3. Effect of building height

As the height of building increases, its mass increases but its overall stiffness decreases. Hence, the natural period of building increases with increase in height. Given buildings A, B, F and H have same plan size, but are of different heights. Taller buildings have larger fundamental natural period than shorter ones (Figure 4.5)

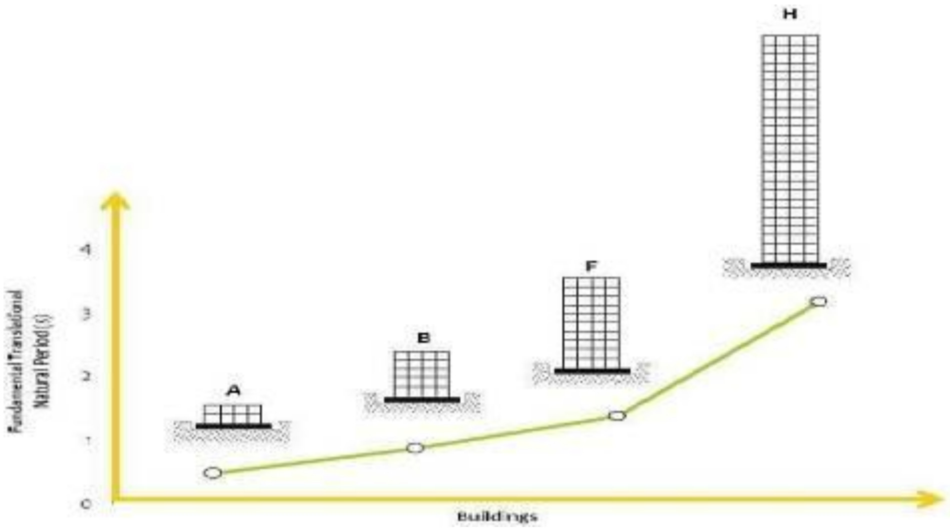


Figure 4.5: Effect of building height: Taller buildings have larger natural period

4.5.4. Effect of column orientation
Orientation of rectangular columns influences lateral stiffness of buildings along two horizontal directions. Hence, changing the orientation of columns changes the translational natural period of buildings.

4.5.5. Effect of unreinforced masonry infill walls in RC frames
In many countries, the space between the beams and columns of building are filled with unreinforced masonry (URM) infills. This infill participates in the lateral response of buildings and as a consequence alters the lateral stiffness of buildings. Hence, natural periods (and modes of oscillation) of the building are affected in the presence of URM.

4.6. Mode shape
Mode shape of oscillation associated with a natural period of a building is the deformed shape of the building when shaken at the natural period. Hence, a building has as many mode shapes as the number of natural periods. For a building, there are infinite numbers of natural period. But, in the mathematical modeling of building, usually the building is discredited into a number of elements.

The junctions of these elements are called nodes. Each node is free to translate in all the three Cartesian directions and rotate about the three Cartesian axes. Hence, if the number of nodes of discretisation is N, then there would be 6N modes of oscillation, and associated with these are 6N natural periods and mode shapes of oscillation. The deformed shape of the building associated with oscillation at fundamental natural period is termed its first mode shape. Similarly, the deformed shapes associated with oscillations at second, third, and other higher natural periods are called second mode shape, third mode shape, and so on, respectively.

4.7. Fundamental mode shape of oscillation
There are three basic modes of oscillation, namely, pure translational along X-direction, pure Translational along Y-direction and pure rotation about Z-axis (Figure 2.15). Regular buildings have these pure mode shapes. Irregular buildings (i.e., buildings that have irregular geometry, non-uniform distribution of mass and stiffness in plan and along the height) have mode shapes that are a mixture of these pure mode shapes. Each of these mode shapes is independent, implying, it cannot be obtained by combining any or all of the other mode shapes. The overall response of a building is the sum of the responses of all of its modes. The contributions of different modes of oscillation vary; usually, contributions of some modes dominate. It is important to endeavor to make buildings regular to the extent possible. But, in regular buildings too, care should be taken to locate and size the structural elements such that torsional and mixed modes of oscillation do not participate much in the overall oscillatory motion of the building. One way of avoiding torsional modes to be the early modes of oscillation in buildings is increasing the torsional stiffness of building. This is achieved by adding in-plane stiffness in the vertical plane in select bays along the perimeter of the building; this addition of stiffness should be done along both plan directions of the building, such that the building has no stiffness eccentricity. Adding braces or introducing structural walls in select bays are some common ways in which this is done.

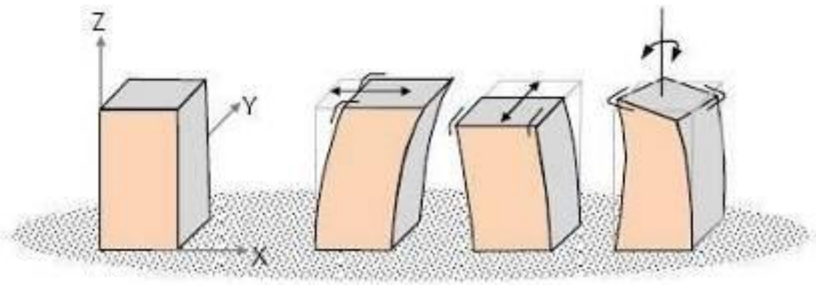


Figure 4.6: Basic modes of oscillation: Two translational and one rotational mode shapes

4.8. Factors influencing mode shapes
1. Effect of Flexural Stiffness of Structural Elements
2. Effect of Axial Stiffness of Vertical Members
3. Effect of Degree of Fixity at Member Ends
4. Effect of Building Height
5. Effect of Unreinforced Masonry Infill Walls in RC Frames

4.8.1. Damping
Buildings set to oscillation by earthquake shaking eventually come back to rest with time. This is due to dissipation of the oscillatory energy through conversion to other forms of energy, like heat and sound. The mechanism of this conversion is called damping. In normal ambient shaking of building, many factors impede its

motion, e.g., drag from air resistance around the building, micro cracking of concrete in the structural members, and friction between various interfaces in the building (like masonry infill walls and RC beams and columns). This damping is called structural damping. But, under strong earthquake shaking, buildings are damaged. Here, reinforcement bars and concrete of the RC buildings enter nonlinear range of material behavior. The damping that arises from these inelastic actions is called hysteretic damping; this further dampens oscillations of the building. Another form of damping is associated with soil. This damping occurs when the soil strata underneath the building is flexible and absorbs energy input to the building during earthquake shaking, and sends it to far off distances in the soil medium. This is called radiation damping. Modeling damping mathematically is a major challenge; many models were proposed, e.g., friction damping, viscous damping and hysteretic damping. Of these, design practice uses the mathematically simplest of them, namely viscous damping. Damping is expressed as a fraction of the critical damping (which is the minimum value of damping at which the building gradually comes to rest from any one side of its neutral position without undergoing any oscillation). Damping is said to be different for different natural modes of oscillation of a building. But, Indian seismic codes recommends the use of 5% damping for all natural modes of oscillation of reinforced concrete buildings, and 2% for steel structures.

4.8.2. Accelerograms

The record obtained from an accelerograph, i.e., the variation of ground acceleration with time recorded at a point on ground during an earthquake, is called an accelerogram. Three accelerograms are recorded simultaneously along three mutually perpendicular directions to capture the complete oscillation of the ground at a location (called a station). These three records of three mutually perpendicular correspond to two along the horizontal directions and one along the vertical direction.

4.9. Response spectrum of a ground motion

A building can be mathematically conceived to be a collection of equivalent simple structures each having only one natural period of oscillation, corresponding to one of the modes of oscillation of the building. These are called the equivalent single-degree-of- freedom (SDoF) structures corresponding to each mode of oscillation of the original building (Figure 2.32).

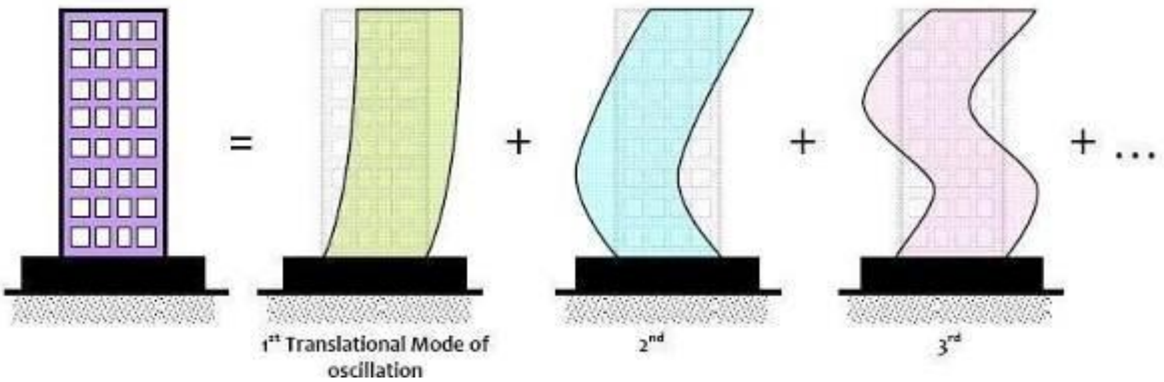


Figure 4.7: Equivalent SDoF structures corresponding to each mode of oscillation of the building

4.9.1. Elastic behaviour

Elastic earthquake behavior of buildings is primarily controlled by configuration and stiffness, out of the four virtues of configuration, stiffness, strength and ductility. Configuration is critical to good seismic performance of buildings. The important aspects affecting seismic configuration of buildings are overall geometry, structural systems, and load paths. Various issues related to seismic configuration are discussed in this section. Buildings oscillate during earthquake shaking and inertia forces are mobilized in them. Then, these forces travel along different paths, called load paths, through different structural Elements, until they are finally transferred to the soil through the foundation. The generation of forces based on basic oscillatory motion and final transfer of force through the foundation are significantly influenced by overall geometry of the building, which includes: (a) plan shape, (b) plan aspect ratio, and (c) slenderness ratio of the building.

4.9.2. Inelastic behaviour

Some structural damage is allowed during strong earthquake shaking in normal buildings, Even though no collapse must be ensured. This implies that nonlinearity will arise in the overall response of buildings, which originates from the material response being nonlinear. This nonlinearity arising from the material stress-strain curve is called material nonlinearity. But, sometimes, the stress-strain curve may be nonlinear and also elastic, whereby on unloading, the material retraces the loading path. Structural steel has definite yield behavior and does not retrace its loading path when unloaded after yielding. Such a response is more commonly referred to as inelastic response. When an inelastic material is subjected to reverse cyclic loading (of displacement type) which takes the material beyond yield, hysteresis takes place, i.e., the material under the applied loading absorbs/dissipates energy. Reinforced concrete and structural steel are candidate materials for inelastic behavior. Under strong earthquake shaking, normal reinforced concrete and steel buildings experience inelastic behavior.

4.10. Some factors which affect the building behaviour

4.10.1. Influence of soil

The seismic motion that reaches a structure on the surface of the earth is influenced by local soil conditions. Low to mid-rise buildings have time period between 0.1 to 1 sec range, while taller more flexible buildings have periods between 1 to 5 sec or greater. Harder soils and bed rock transmit short period vibrations earthquake (caused by distant earthquake) while filtering out longer period earthquakes (caused by distant earthquakes), whereas softer soils will transmit longer period vibrations.

4.10.2. Structural response

If the base of structure is moved suddenly, the upper part of the structure will not respond instantaneously, but will lag because of inertial resistance and flexibility of the structure. Because earthquake ground motions are three dimensional, building deforms in a same manner. But inertia forces considerations for seismic design since adequate seismic resistance to vertical seismic loads is provided by member capacities required for gravity load design.

4.10.3. Load path

Buildings are generally composed of vertical and horizontal structural elements. A complete load path is a basic requirement for all buildings. Seismic forces originating throughout the building, mostly in the heavier mass elements such as diaphragms, are delivered throughout the connections to diaphragm; the diaphragm distributes these forces to vertical force resisting system such as shear walls and frames. Through frame these forces are transferred to foundation: and foundation transfers these forces to supporting soil. Interconnecting, members needed to complete the load path is necessary to achieve good seismic performance.

5. METHODS OF ANALYSIS

5.1. Seismic analysis of structures

Following are some methods used for seismic analysis of multistory building and structures-

1. Linear and Nonlinear Static Analysis
2. Linear and Nonlinear Dynamic Analysis.

5.2. Equivalent static analysis

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium- rise buildings and begins with An estimate of peak earthquake load calculated as a function of the parameters given in the code. Equivalent static analysis can therefore work well for low to medium-rise buildings without significant coupled lateral–torsional modes, in which only the first mode in each direction is of Significance. Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with tensional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances.

Methods of linear and nonlinear dynamic analysis

1. Time-History Method
2. Response Spectrum Method.

5.2.1. Time history method

Time-history analysis is a step-by-step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or non linear. Time history analysis is used to determine the dynamic response of a structure to arbitrary loading.

5.2.2. Response spectrum method

The word spectrum in seismic engineering conveys the idea that the response of buildings having a broad range of periods is summarized in a single graph. For a given earthquake motion and a percentage of critical damping, a typical response spectrum gives a plot of earthquake-related responses such as acceleration, velocity, and deflection for a complete range, or spectrum, of building periods. Thus, a response spectrum may be visualized as a graphical representation of the dynamic response of a series of progressively longer cantilever pendulums with increasing natural periods subjected to a common lateral seismic motion of the base.

5.2.3. Seismic design force

Earthquake shaking is random and time variant. But, most design codes represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design Equivalent static lateral force. This force is called as the Seismic Design Base Shear VB and remains the primary quantity involved in force-based earthquake-resistant design of buildings. This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z. Also, in keeping with the philosophy of increasing design forces to increase the elastic range of the building and thereby reduce the damage in it, codes tend to adopt the Importance Factor I for effecting such decisions. Further, the net shaking of a building is a combined effect of the energy carried by the earthquake at different frequencies and the natural periods of the building. Codes reflect this by the introduction of a Structural Flexibility Factor Sa/g. Finally to make normal buildings economical, design codes allow some damage for reducing cost of construction. This philosophy is introduced with the help of Response Reduction Factor R, which is larger for ductile buildings and smaller for brittle ones. Each of these factors is discussed in this and subsequent chapters. In view of the uncertainties involved in parameters, like Z and Sa/g, the upper limit of the imposed deformation demand on the building is not known as a deterministic upper bound value. Thus, design of earthquake effects is not termed as earthquake-proof design.

Instead, the earthquake demand is estimated only based on concepts of Probability of accidence and the design of earthquake effects is termed as earthquake-resistant design against the probable value of the demand.

As per the Indian Seismic Code IS: 1893 (Part 1) - 2007, Design Base Shear VB is given by:

Where Z is the Seismic Zone Factor (Table 5.1), I the Importance Factor (Table 5.2), R the Response Reduction Factor (Table 5.3), and Sa g the Design Acceleration Spectrum Value given by:

$$\frac{S_a}{g} = \begin{cases} \begin{cases} 2.5 & 0.00 < T < 0.40 \\ \dfrac{1.00}{T} & 0.40 < T < 4.00 \end{cases} & \text{for Soil Type I : rocky or hard soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.55 \\ \dfrac{1.36}{T} & 0.55 < T < 4.00 \end{cases} & \text{for Soil Type II : medium soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.67 \\ \dfrac{1.67}{T} & 0.67 < T < 4.00 \end{cases} & \text{for Soil Type III : soft soil sites} \end{cases},$$

in which T is the fundamental translational natural period of the building in the considered direction of shaking.

Table 5.1: Seismic Zone Factor Z as per IS: 1893 (Part 1) – 2007

Seismic Zone	Z
II	0.10
III	0.16
IV	0.24
V	0.36

Table 5.2: Importance Factor Z of buildings as per IS: 1893 (Part 1) – 2007

Buildings	Importance Factor I
Normal Buildings	1
Important Buildings (*e.g.*, Critical buildings required to be functional after an earthquake, Lifeline buildings associated with utilities, like water, power & transportation)	1.5

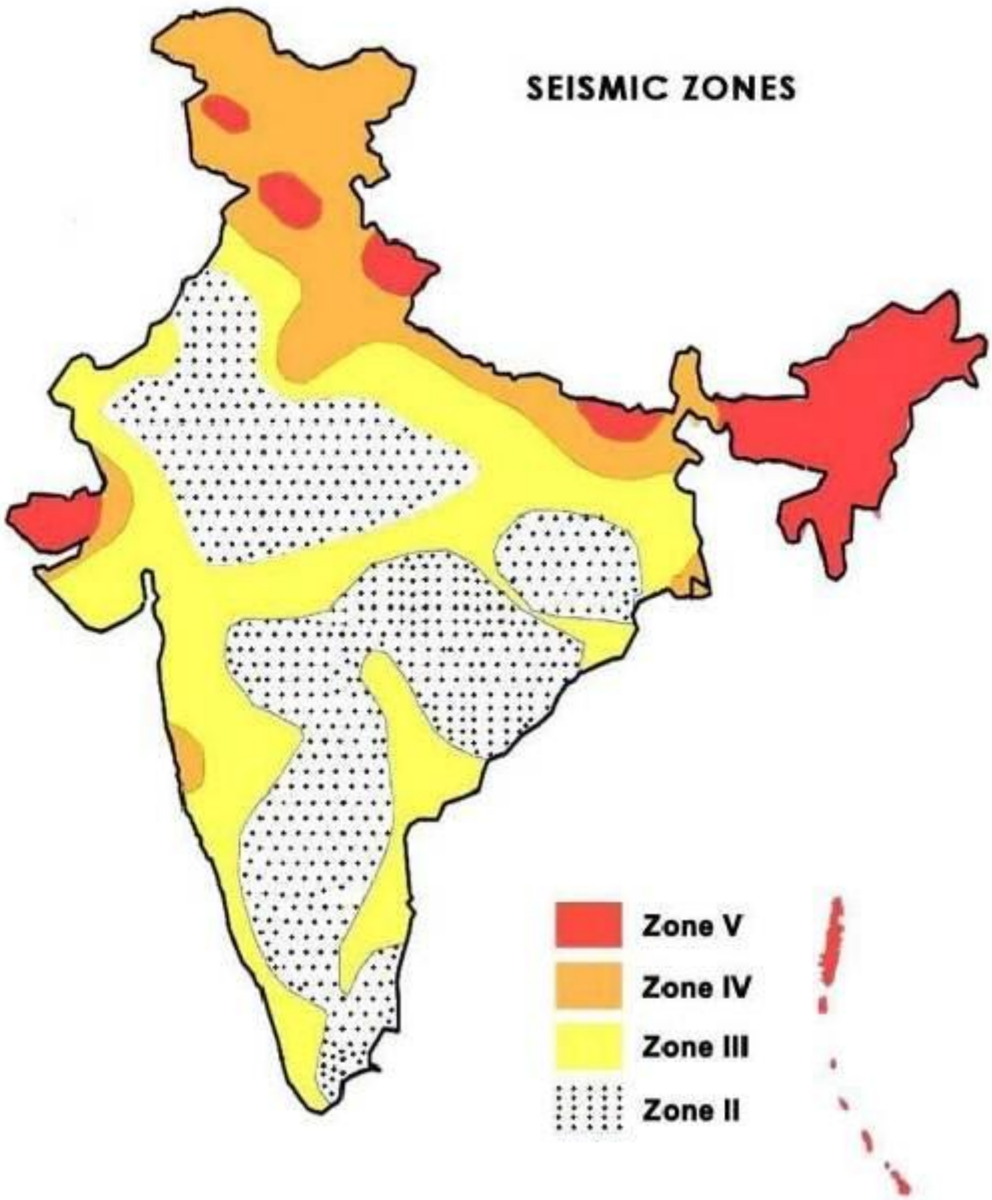


Figure 5.1 Sketch of Seismic Zone Map of India: sketch based on the seismic zone of India map given In IS: 1893 (Part 1) – 2007

Table 5.3: Response Reduction Factor R of buildings as per IS: 1893 (Part 1) – 2007

Lateral Load Resisting System	*R*
Building Frame Systems	
Ordinary RC moment resisting frame (OMRF)	3.0
Special RC moment-resisting frame (SMRF)	5.0
Steel frame with	
(a) Concentric braces	4.0
(b) Eccentric braces	5.0
Steel moment resisting frame designed as per SP 6 (6)	5.0
Buildings with Shear Walls	
Ordinary reinforced concrete shear walls	3.0
Ductile shear walls	4.0
Buildings with Dual Systems	
Ordinary shear wall with OMRF	3.0
Ordinary shear wall with SMRF	4.0
Ductile shear wall with OMRF	4.5
Ductile shear wall with SMRF	5.0

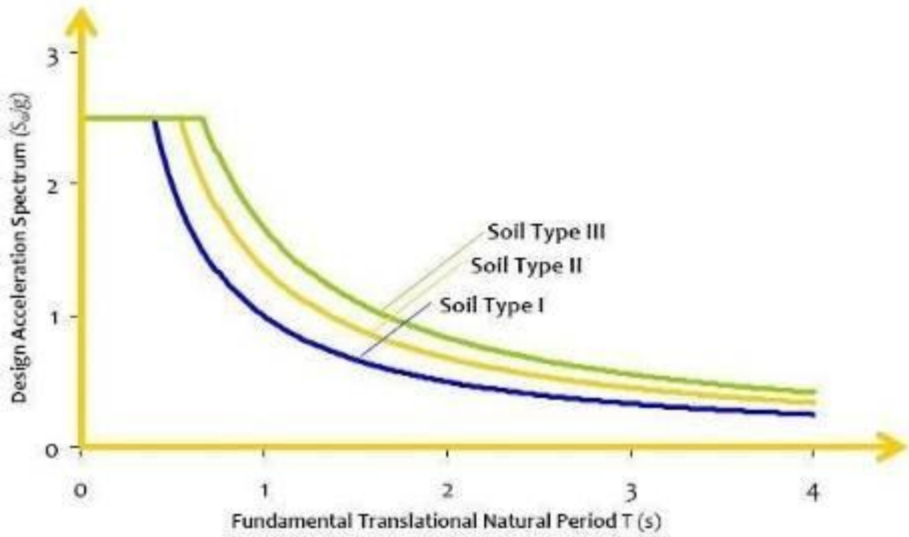


Figure 5.2: Design Acceleration Spectrum: This is based on fundamental translational natural period T of the building; this is defined in the following

W is the seismic weight of the building. For the purpose of estimating the seismic Weight of the building, full dead load and part live load are to be included. The proportion of live load to be considered is given by IS: 1893 (Part 1) as per Table 5.4 live load need not be considered on the roofs of buildings in the calculation of design earthquake force. While there is lesser control on design acceleration spectrum value Ah, designers can consciously reduce seismic weight W though the mass of the building. Choosing light materials and efficiently using the materials together help reducing the source of design earthquake force on the building. Also, the distribution of this mass in plan and elevation of the building renders earthquake-induced inertia forces to be uniformly distributed throughout the building, instead of being localized at a few parts of the building.

Table 5.4: Proportion of Live Load to be considered in the estimate of Seismic Weight of buildings as per IS: 1893-2004

Imposed Uniformity Distributed Floor Loads (KN/m^2)	Percentage of Imposed Load
Up to and including 3.0	25
Above 3.0	50

6. ANALYSIS AND DESIGN

6.1. Introduction of Staad-Pro

STAAD-Pro V8i is a comprehensive and integrated finite element Analysis and design offering, including a state-of-the-art user interface, visualization tools, and international design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, wind, earthquake, and moving loads. STAAD-Pro V8i is the premier FEM analysis and design tool for any type of project including towers, culverts, plants, bridges, stadiums, and marine structures.

STAAD-Pro is a computer program designed for structural analysis. It was developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineer International was bought by Bentley Systems.

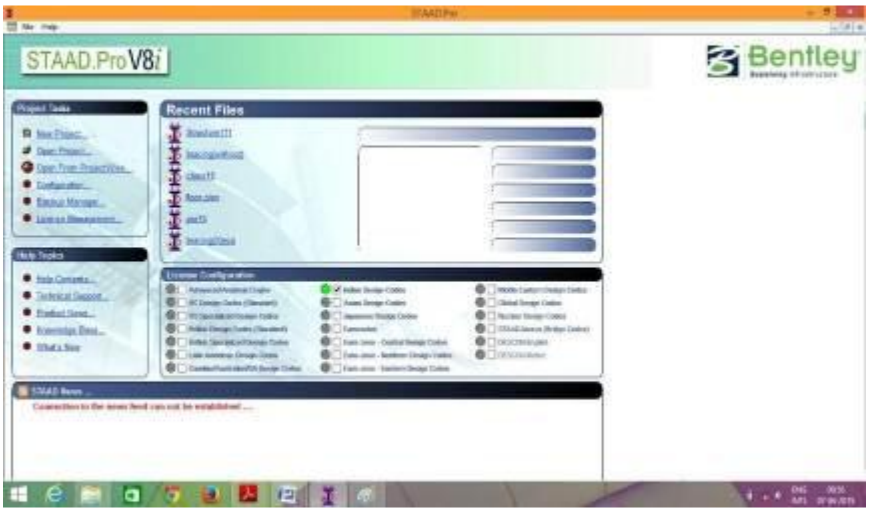


Figure 6.1: Main window of staad Pro

STAAD-Pro is very widely used for design and analysis of structure. It is used for steel concrete and timber design. We can also design for a material of our own choice by providing the required property and characteristic values of that material. In recent years it has become part of integrated structural analysis and design solutions mainly using an exposed API called Open STAAD to access and drive the program using VB macro system included in the application or other by including Open STAAD functionality in applications that themselves include suitable programmable macro systems. Additionally STAAD.Pro has added direct links to applications such as RAM Connection and STAAD. Foundation to provide engineers working with those applications which handle design post processing not handled by STAAD Pro itself. Another form of integration supported by STAAD. Pro is the analysis schema of the CIM steel Integration Standard, version 2 commonly known as CIS/2 and used by a number modelling and analysis applications. STAAD.Pro V8i will eliminate the countless man-hours required to properly load your structure by automating the forces caused by wind, earthquakes, snow, or vehicles.

6.2. Advantageous features of Staad Pro (v8i)

- Advanced analysis and design
- Extremely flexible modelling environment
- Broad spectra of design codes
- Interoperability and open architecture
- Quality assurance

6.3. Modeling steps

The following are the basic Modeling, Analysis, and Design processes-

- Set the unit.
- Save file location.
- Input geometry-Nodes, Beams and plates
- Input Section properties
- Input specifications , constant and support
- Input loading system
- Input design constant
- Input design parameters
- Input design commands
- Specify analysis type
- Run analysis
- View and verify result

6.4. Considerations for analysis and design

- Model of buildings are prepared in STAAD Pro with given loading conditions. To compare the behavior of the building with shear wall and without shear wall during lateral condition, stiffness of column is kept same. Columns are assumed to have the same size at the particular storey level.
- Beam of same dimensions are provided.
- Column size is reduced after every three stories as per requirement of gravity loads.
- Thickness of slab is provided according to the deflection requirement.
- Dynamic analysis is carried out by placing two building in all four zones and with three soil conditions. (For storey drift).
- Response reduction factor ‘3’, and importance factor ‘1’ is assumed.

6.5. Building geometry and loading

6.5.1. Preliminary Data for 12-story grid slab building

1	Type of the Building	Residential Building
2	Number of Story	G+11
3	Plan dimensions	40 m x 24 m c/c
2	Length in X- direction	40 m
3	Length in Y- direction	24 m
4	Floor to floor height	3.5 m
5	No. of Stories	12
6	Total height of Building	42 m
7	Slab Thickness	120 mm

8	Shear wall Thickness	200 mm	
9	Grid Beam	230mm x 870 mm	
10	Size of the Column	1-3 story-950 mm x 950 mm	
		3-6 story- 850 mm x 850 mm	
		6-9 story-750 mmx750 mm	
		9-12 story-650 mmx650 mm	
11	Grade of concrete	M25	
12	Grade of Steel	Fe415	
13	Zone-II	Soil Type 1- Roc k or hard soil	
		Soil Type 2- Medium soil	
		Soil Type 3 -Soft soil	
14	Loading	Terrace	Remaining Floors
	Dead load (FF)	1 KN/m^2	1 KN/m^2
	Live load	1.5 KN/m^2	3KN/m^2
	Wall load	12 KN/m	12KN/m

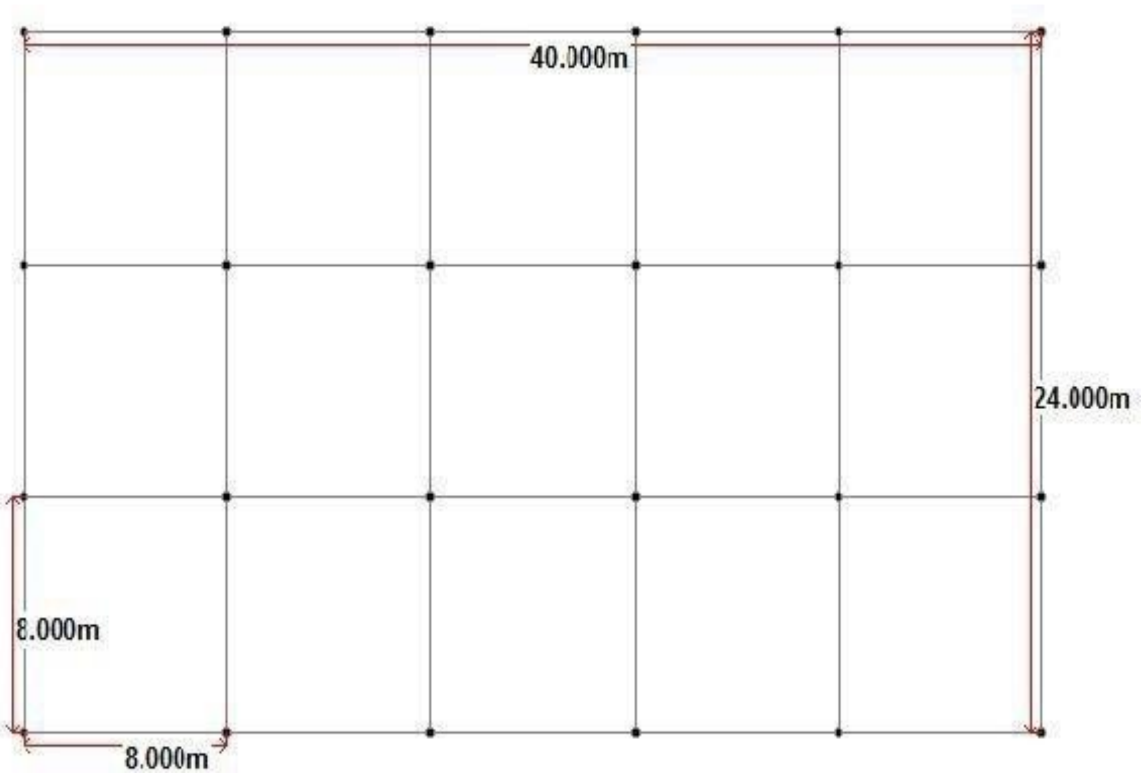


Figure 6.2: Plan of building

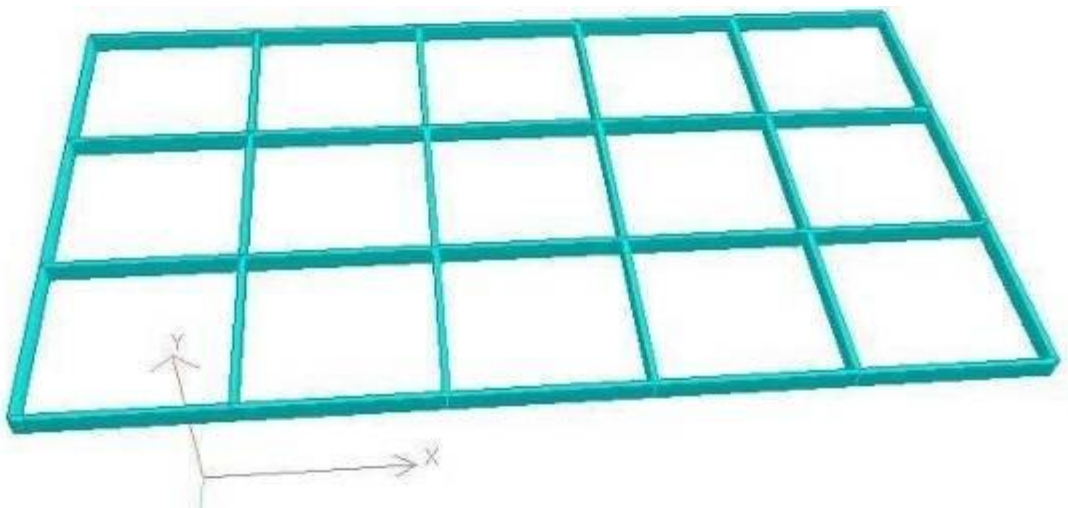


Figure 6.3 3-D Plan of building

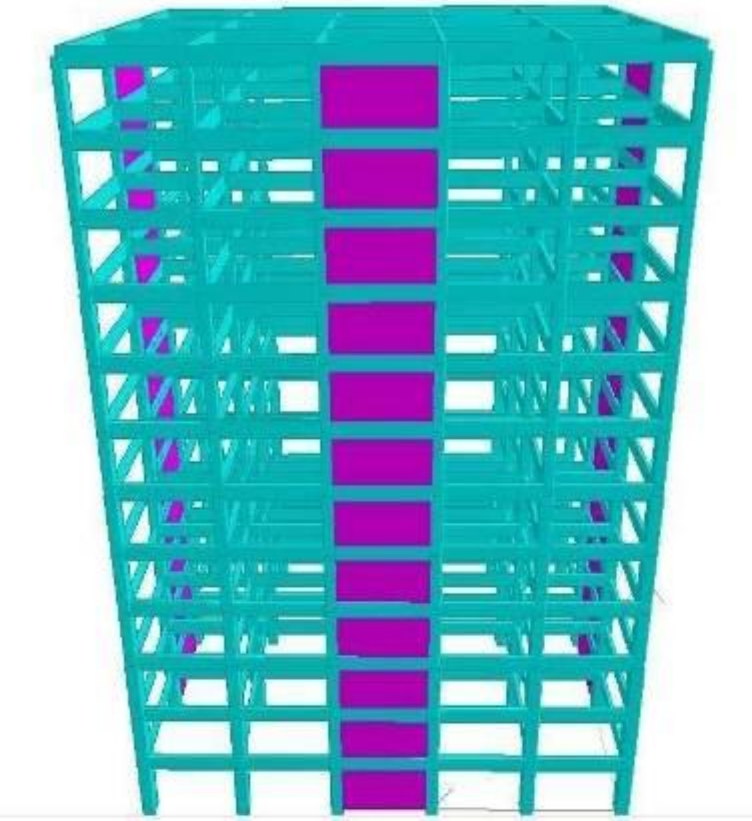


Figure 6.4: Plan of Building

6.6. Load combination

In the limit state design of reinforced and pre-stressed Concrete structures, the following load combinations shall be accounted -

- 1.5 DL + 1.5 LL
- 1.5 DL+1.5 EQX
- 1.5 DL-1.5 EQX
- 1.5 DL+1.5 EQY
- 1.5 DL-1.5 EQY
- 1.2 DL + 1.2 LL+1.2EQX
- 1.2 DL + 1.2 LL-1.2EQX
- 1.2 DL + 1.2 LL+1.2EQY
- 1.2 DL + 1.2 LL-1.2EQY
- 1.5 DL + 1.5 RSPX
- 1.5 DL-1.5 RSPX
- 1.5 DL-1.5 RSPY
- 1.5 DL+1.5 RSPY
- 1.2 DL + 1.2 LL+1.2RSPX
- 1.2 DL + 1.2 LL-1.2RSPX
- 1.2 DL + 1.2 LL+1.2RSPY
- 1.2 DL + 1.2 LL-1.2RSPY

6.7. Dynamic analysis

1. Response spectrum method and time history analysis is used for the analysis. Importance factor and response reduction factor are considered as 1 and 3 respectively.
2. For the response spectrum analysis the current code states that “at least 90 percent of the participating mass of the structure must be included in the calculation of response of each principal direction. Therefore number of modes to be evaluated must satisfy this requirement.
3. By considering 15 modes participation of flat slab and grid slab building is achieved more than 90 % Therefore for all buildings 15 modes are considered.
4. Eigen Vector analyses are used for analysis. Rigid diaphragm action is considered for analysis.
5. Centre of mass & centre of rigidity coincides, due to regularity in the plan, mass and stiffness of the building. Centre of mass & centre of rigidity lies at (20.5m, 12.3m)

7. COMPARISON OF ANALYSIS RESULTS

7.1. Comparision of seismic base shear

It is the total design lateral force at the base of a structure. The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression.

$V_B = A_h \times W$

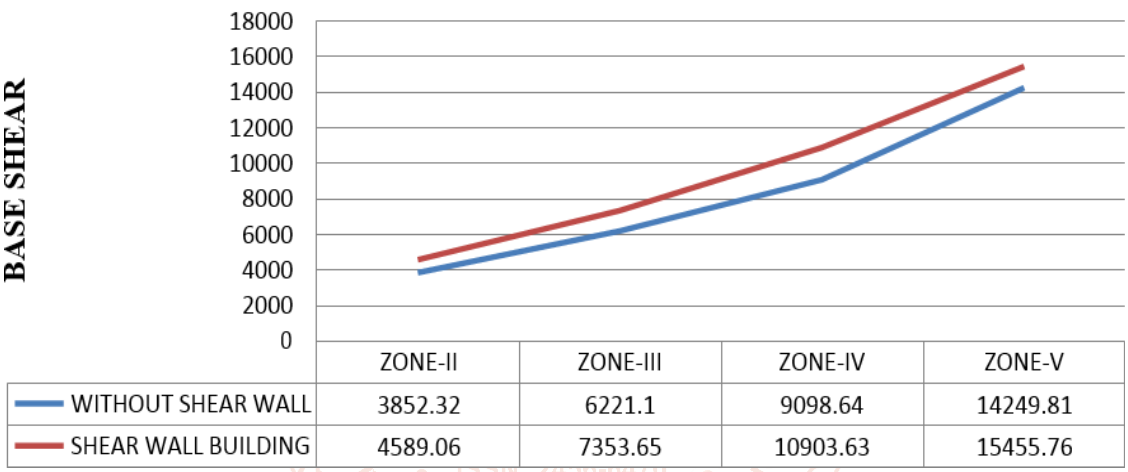
Where-
Ah =Design horizontal acceleration spectrum W= Seismic weight of the building

7.2. Seismic base shear in x-direction

Table 7.1.1(a) Seismic base shear in x-direction for soil type-

ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	WITH SHEAR WALL
ZONE-II	3852.32	4589.06
ZONE-III	6221.1	7353.65
ZONE-IV	9098.64	10903.63
ZONE-V	14249.81	15455.76

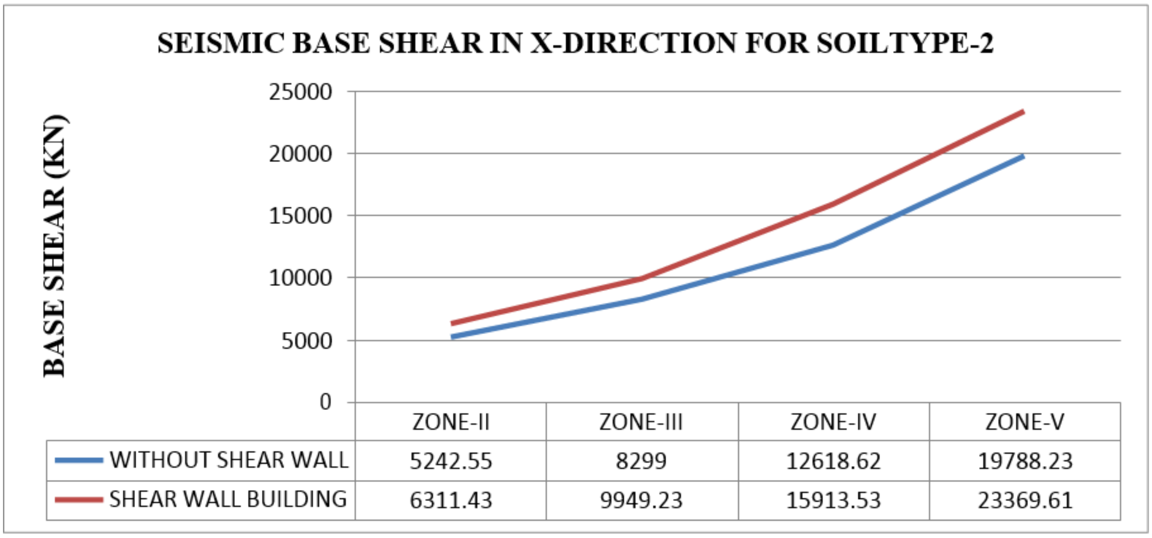
SEISMIC BASE SHEAR IN X-DIRECTION FOR SOILTYPE-1



Graph 7.1.1(a) Seismic base shear in x-direction for soil type-1

Table 7.1.1(b) Seismic base shear in x-direction for soil type-2

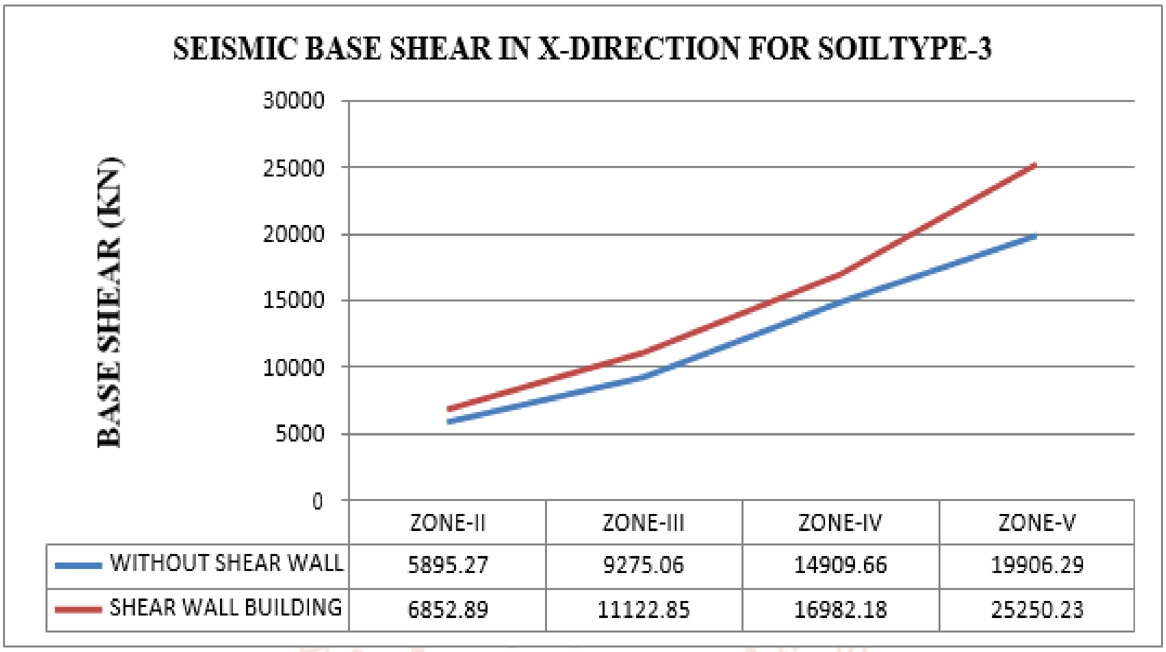
ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	WITH SHEAR WALL
ZONE-II	5242.55	6311.43
ZONE-III	8299	9949.23
ZONE-IV	12618.62	15913.53
ZONE-V	19788.23	23369.61



Graph-7.1.1(b) Seismic base shear in x-direction for soil type-2

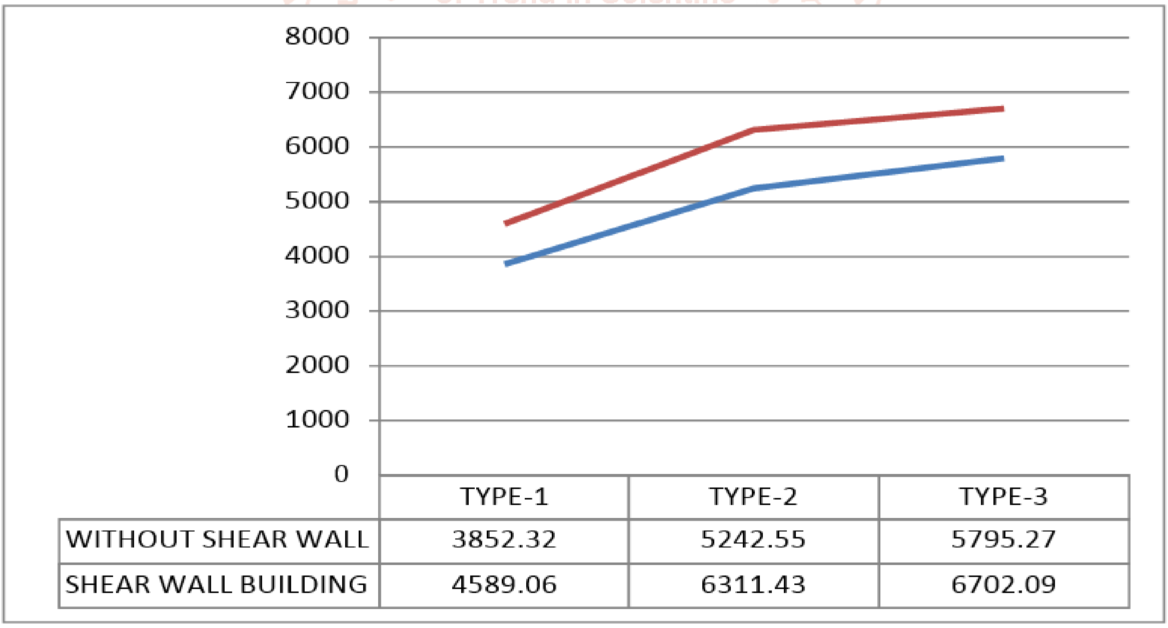
Table 7.1.1(c) Seismic base shear in x-direction for soil type-3

ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	WITHOUT SHEAR WALL
ZONE-II	5895.27	6852.89
ZONE-III	9275.06	11122.85
ZONE-IV	14909.66	16982.18
ZONE-V	19906.29	25250.23

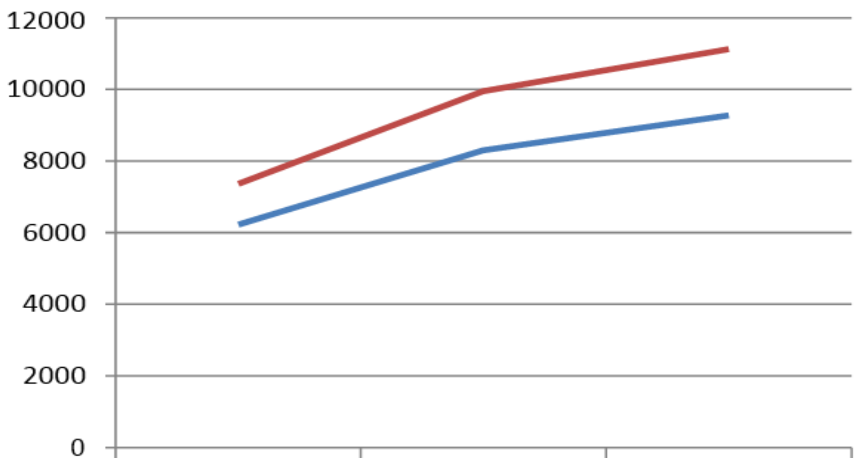


Graph-7.1.1(c) Seismic base shear in x-direction for soiltype-3

7.2.1. Seismic base shear in x-direction for different soils

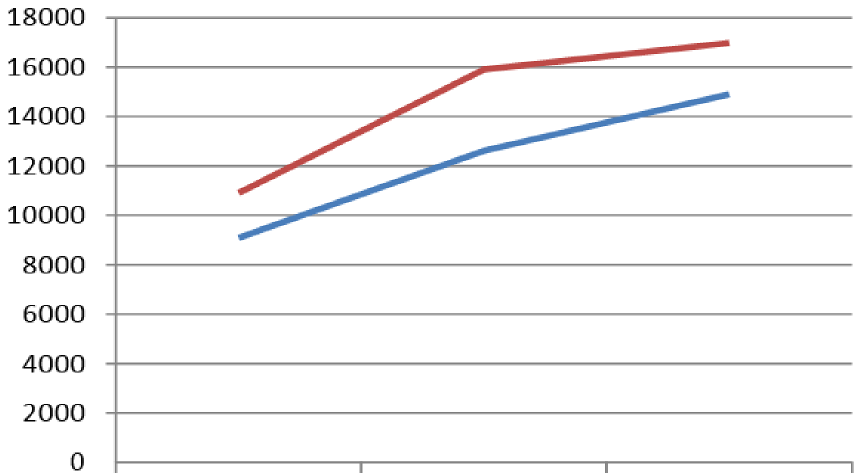


Graph 7.1.2(a) Seismic base shear in x-direction for different soils in zone II



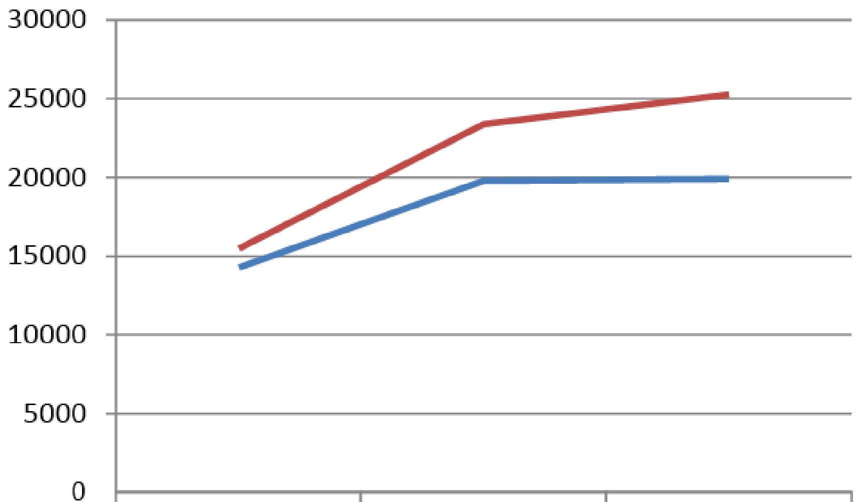
	TYPE-1	TYPE-2	TYPE-3
WITHOUT SHEAR WALL	6221.1	8299	9275.06
SHEAR WALL BUILDING	7353.65	9949.23	11122.85

Graph 7.1.2(b) Seismic base shear in x-direction for different soils in zone III



	TYPE-1	TYPE-2	TYPE-3
WITHOUT SHEAR WALL	9098.64	12618.62	14909.66
SHEAR WALL BUILDING	10903.63	15913.53	16982.18

Graph 7.1.2(c) Seismic base shear in x-direction for different soils in zone IV



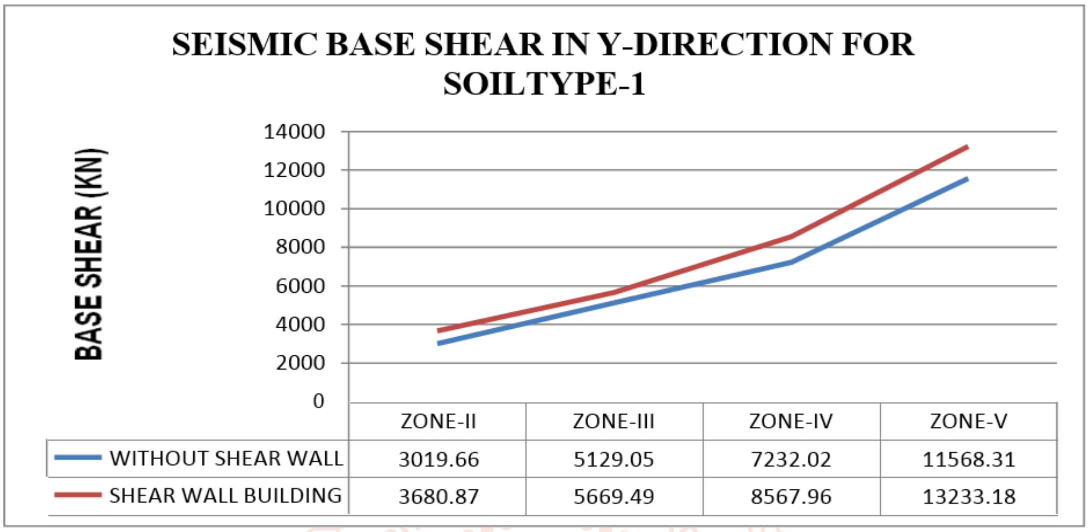
	TYPE-1	TYPE-2	TYPE-3
WITHOUT SHEAR WALL	14249.81	19788.23	19906.29
SHEAR WALL BUILDING	15455.76	23369.61	25250.23

Graph 7.1.2(d) Seismic base shear in x-direction for different soils in zone V

7.2.2. Seismic base shear in Y-direction

Table 7.1.3(a) Seismic base shear in Y-direction for soil type-1

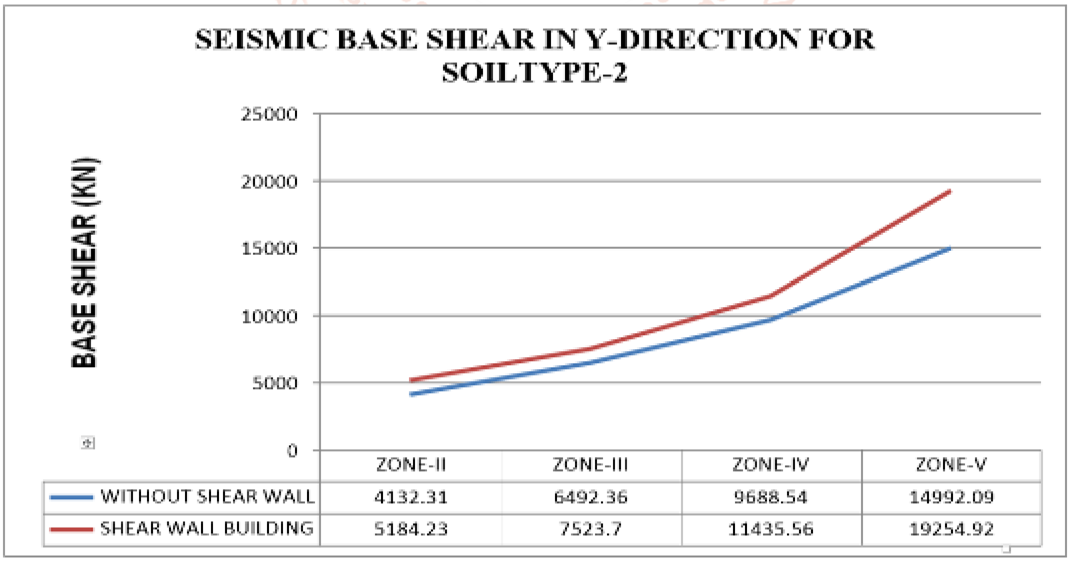
ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	SHEAR WALL BUILDING
ZONE-II	3019.66	3680.87
ZONE-III	5129.05	5669.49
ZONE-IV	7232.02	8567.96
ZONE-V	11568.31	13233.18



Graph-7.1.3(a) Seismic base shear in Y-direction for soil type-1

Table 7.1.3(b) Seismic base shear in Y-direction for soil type-2

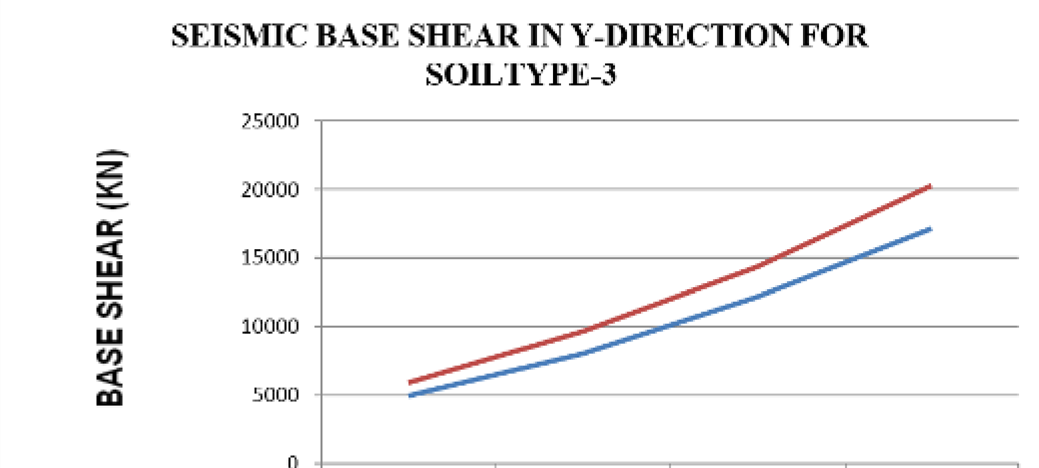
ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	SHEAR WALL BUILDING
ZONE-II	4132.31	5184.23
ZONE-III	6492.36	7523.7
ZONE-IV	9688.54	11435.56
ZONE-V	14992.09	19254.92



Graph-7.1.3(b) Seismic base shear in Y-direction for soil type-2

Table 7.1.3(c) Seismic base shear in Y-direction for soiltype-3

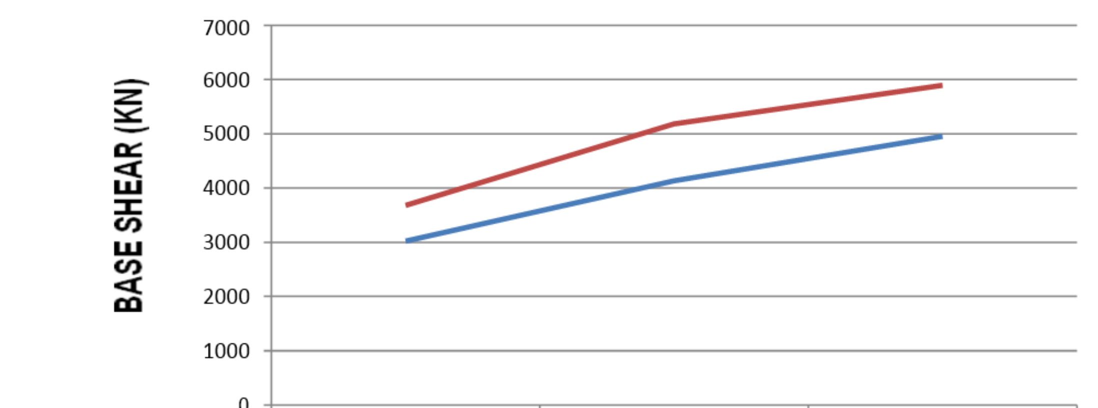
ZONE	BASE SHEAR	
	WITHOUT SHEAR WALL	SHEAR WALL BUILDING
ZONE-II	4952.74	5895.11
ZONE-III	8026.01	9654.37
ZONE-IV	12151.6	14333.75
ZONE-V	17136.92	20263.6



	ZONE-II	ZONE-III	ZONE-IV	ZONE-V
WITHOUT SHEAR WALL	4952.74	8026.01	12151.6	17136.92
SHEAR WALL BUILDING	5895.11	9654.37	14333.75	20263.6

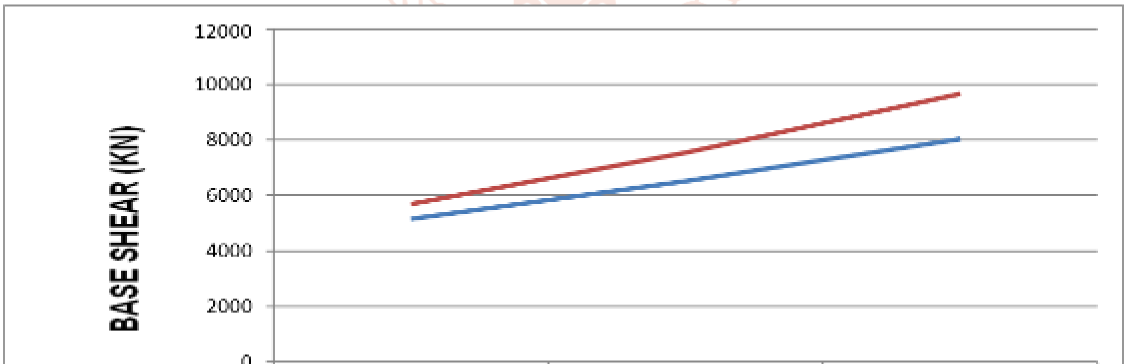
Graph-7.1.3(c) Seismic base shear in Y-direction for soiltype-3

7.3. Seismic base shear in y-direction for different soil



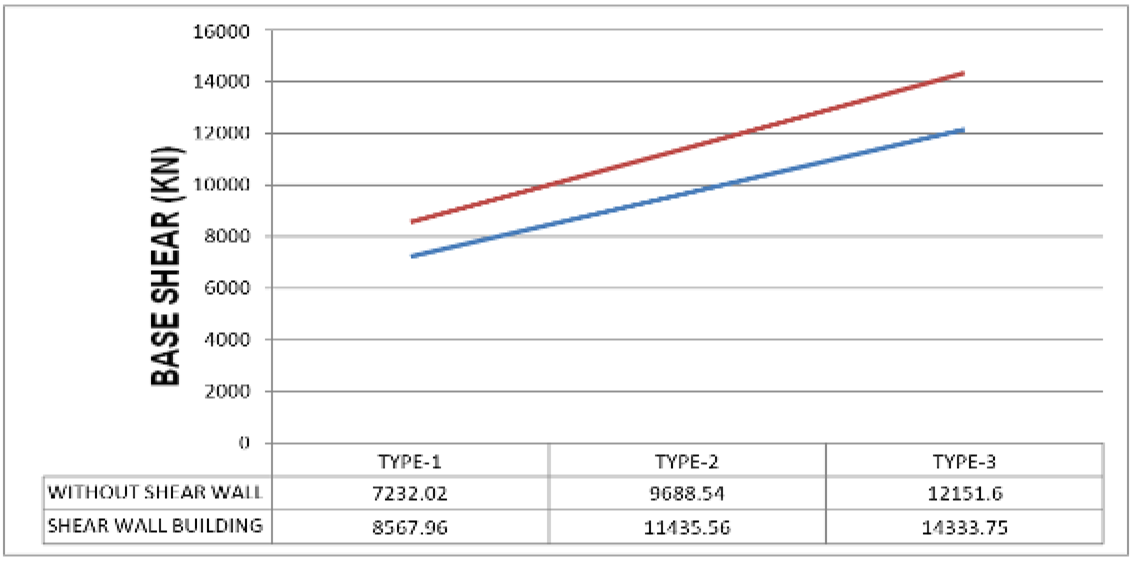
	TYPE-1	TYPE-2	TYPE-3
WITHOUT SHEAR WALL	3019.66	4132.31	4952.74
SHEAR WALL BUILDING	3680.87	5184.23	5895.11

Graph 7.1.4(a) Seismic base shear in Y-direction for different soils in zone II

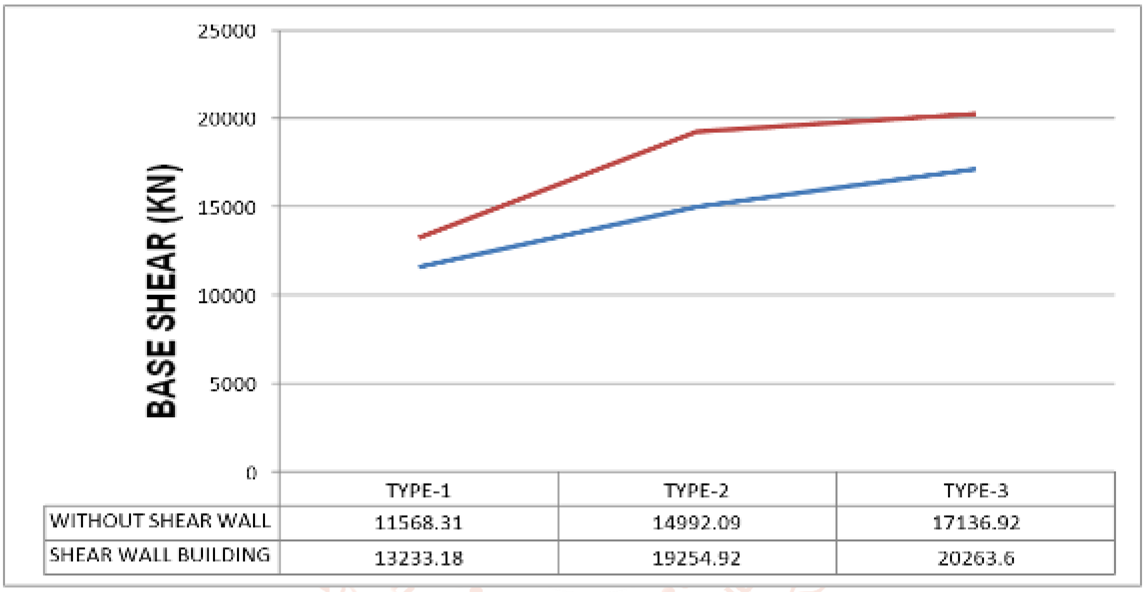


	TYPE-1	TYPE-2	TYPE-3
WITHOUT SHEAR WALL	5129.05	6492.36	8026.01
SHEAR WALL BUILDING	5669.49	7523.7	9654.37

Graph 7.1.4(b) Seismic base shear in Y-direction for different soils in zone III



Graph 7.1.4(c) Seismic base shear in Y-direction for different soils in zone IV



Graph 7.1.4(d) Seismic base shear in Y-direction for different soils in zone V

Results drawn from Graph 7.1.1 (a) to 7.2.1 (l)

1. All graph 7.1.1 (a) to 7.2.1 (l) clearly show that Base shear of building without shear wall is less than the base shear in shear wall building for all types of soil and all earthquake zones.
2. For all earhquake zones base shear is gradually increased for soil type-1 to soil type-3.
3. Base shear is maximum for soil type-3 and Zone-V in both X and Y-direction.

7.4. Comparision of building drift

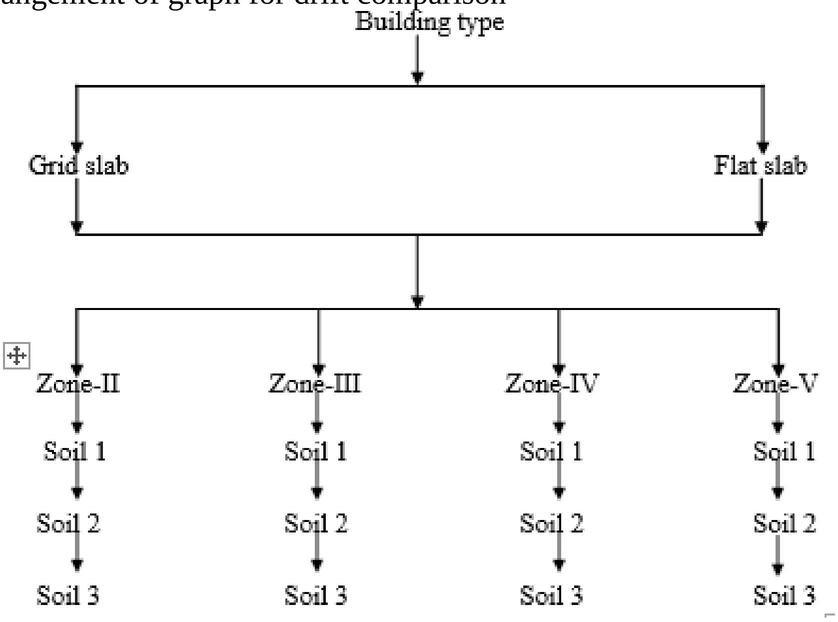
Storey drift is defined as difference between lateral displacements of one floor relative to the other floor. As per IS. 1893-2002 CL.7.11.1; the storey drift in any storey due to the minimum specified design lateral force with partial load factor 1.00 shall not exceed 0.004 times the storey height. As per I.S. requirement it is limited to 0.4% of the storey height. Drift control is necessary to limit damage to interior partition, elevator and stair enclosures, glass. & cladding systems. Stress to strength limitation in ductile materials do not always provide adequate drift control, especially for tall building with relatively flexible moment resisting frame or narrow shear walls. For lateral load analysis, moment magnification is proportional to actual lateral displacement (drifts)[1].

Total building drift is the absolute displacement of any point relative to the base. Adjoining building or adjoining sections of the same building may not have the same modes of response, and is therefore may have tendency to pound against one another. Building separation or joints must be provided to permit adjoining buildings to respond independently to earthquakes ground motion.

1. In this case storey height is 3500 mm., therefore limited storey drift is calculated as storey drift /3500 =0.004
2. Therefore, storey drift = 14 mm
3. Storey drift of grid slab and flat slab in X-direction and Y-direction, when placed in four different zones and in three soil conditions are compared.

4. Graph number and its content are summarized in the form of flow chart given below

A. Chart showing arrangement of graph for drift comparison



In each zone three soil conditions are considered as follows

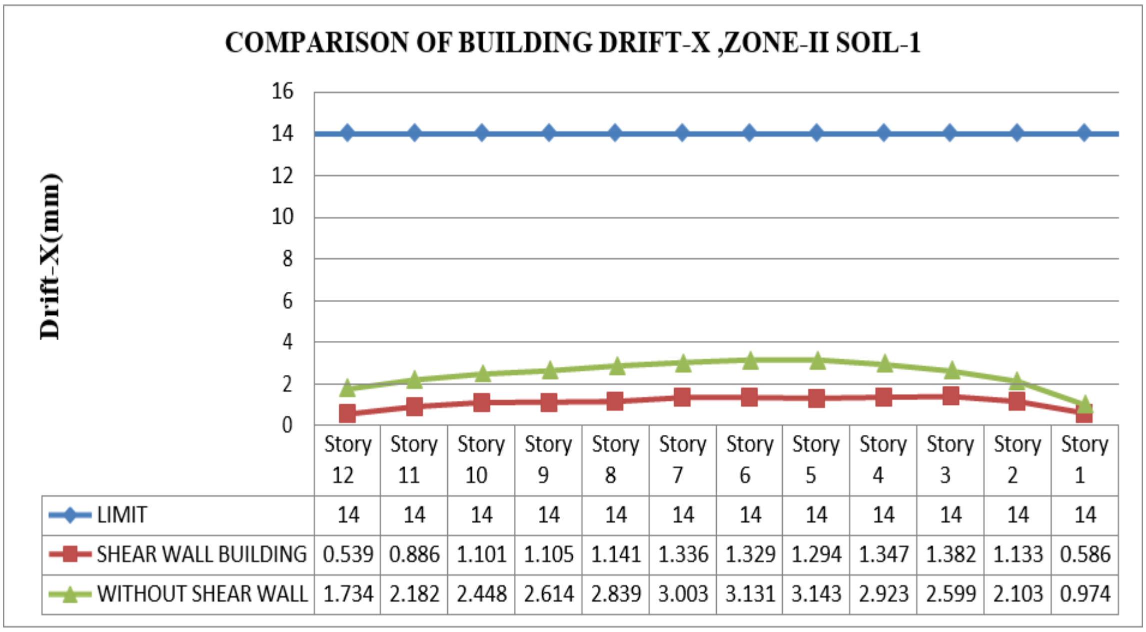
Soil 1	Type 1	Roc k or hard soil
Soil 2	Type 2	Medium soil
Soil 3	Type 3	Soft soil

7.4.1. (A) Drift-Y comparison for 12-story grid slab and flat slab building: -

Storey drifts of grid slab and Flat slab in X-direction, when placed in four different zones and in three soil conditions are compared.

Table 7.2.1(a) Comparison of building drift-X, Zone-II Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.539	1.734
STORY11	14	0.886	2.182
STORY10	14	1.101	2.448
STORY9	14	1.105	2.614
STORY8	14	1.141	2.839
STORY7	14	1.336	3.003
STORY6	14	1.329	3.131
STORY5	14	1.294	3.143
STORY4	14	1.347	2.923
STORY3	14	1.382	2.599
STORY2	14	1.133	2.103
STORY1	14	0.586	0.974

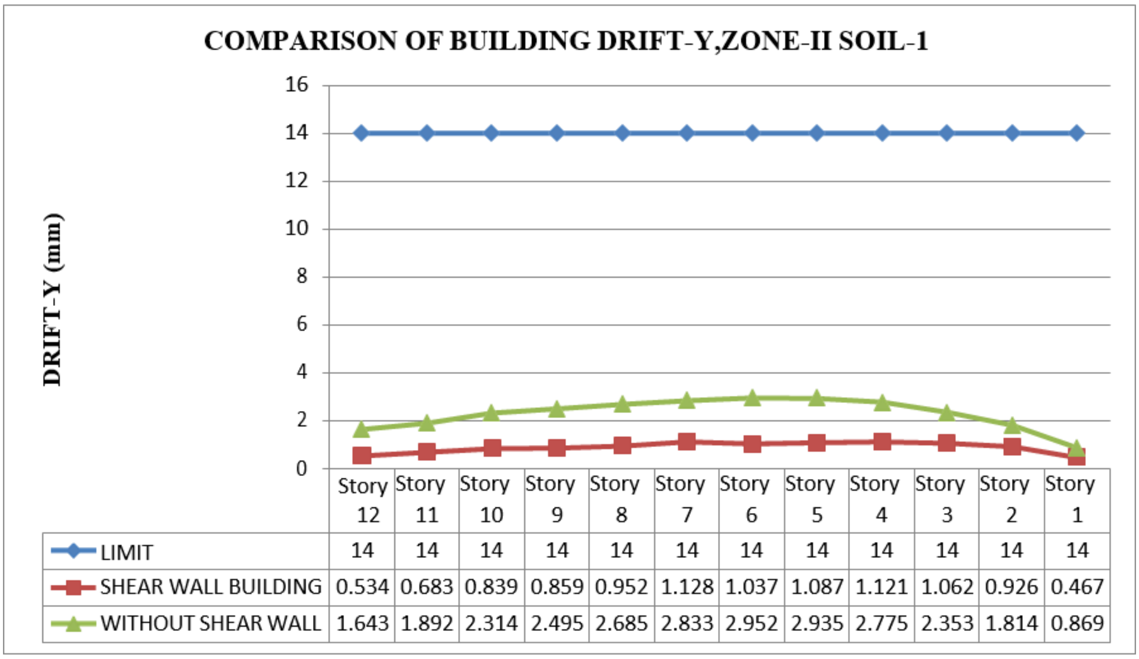


Graph 7.2.1(a) Comparison of building drift-X, Zone-II Soil-1

B) Drift-Y comparison for 12-story grid slab and flat slab building

Table 7.2.1(b) Comparison of building drift-Y, Zone-II Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.534	1.643
STORY11	14	0.683	1.892
STORY10	14	0.839	2.314
STORY9	14	0.859	2.495
STORY8	14	0.952	2.685
STORY7	14	1.128	2.833
STORY6	14	1.037	2.952
STORY5	14	1.087	2.935
STORY4	14	1.121	2.775
STORY3	14	1.062	2.353
STORY2	14	0.926	1.814
STORY1	14	0.467	0.869

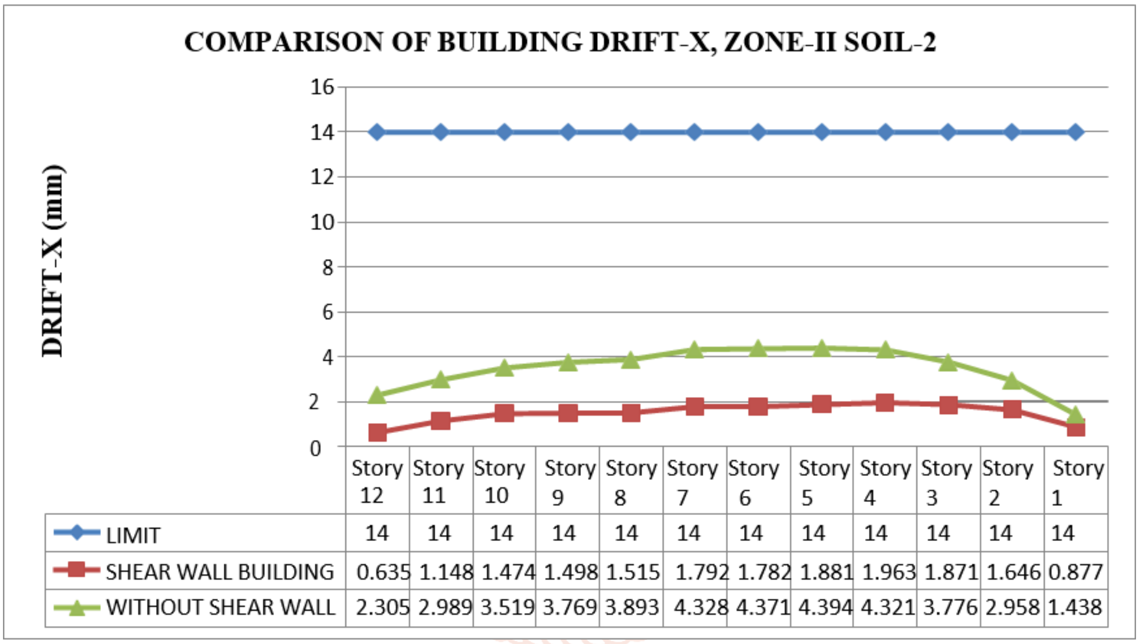


Graph 7.2.1(b) Comparison of building drift-Y, Zone-II Soil-1

C) Drift-X comparison for 12-story grid slab and flat slab building

Table 7.2.1(c) Comparison of building drift-X, Zone-II Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.635	2.305
STORY11	14	1.148	2.989
STORY10	14	1.474	3.519
STORY9	14	1.498	3.769
STORY8	14	1.515	3.893
STORY7	14	1.792	4.328
STORY6	14	1.782	4.371
STORY5	14	1.881	4.394
STORY4	14	1.963	4.321
STORY3	14	1.871	3.776
STORY2	14	1.646	2.958
STORY1	14	0.877	1.438

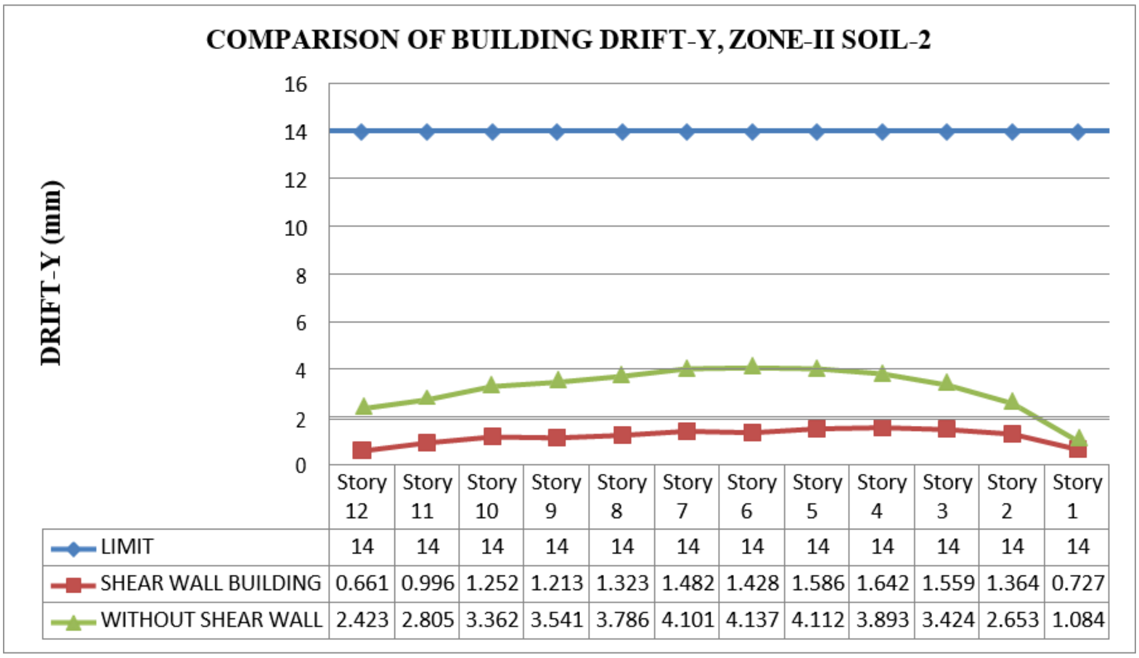


Graph 7.2.1(c) Comparison of building drift-X, Zone-II Soil-2

D) Drift-Y comparison for 12-story grid slab and flat slab building

Table 7.2.1(d) Comparison of building drift-Y, Zone-II Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.661	2.423
STORY11	14	0.996	2.805
STORY10	14	1.252	3.362
STORY9	14	1.213	3.541
STORY8	14	1.323	3.786
STORY7	14	1.482	4.101
STORY6	14	1.428	4.137
STORY5	14	1.586	4.112
STORY4	14	1.642	3.893
STORY3	14	1.559	3.424
STORY2	14	1.364	2.653
STORY1	14	0.727	1.084

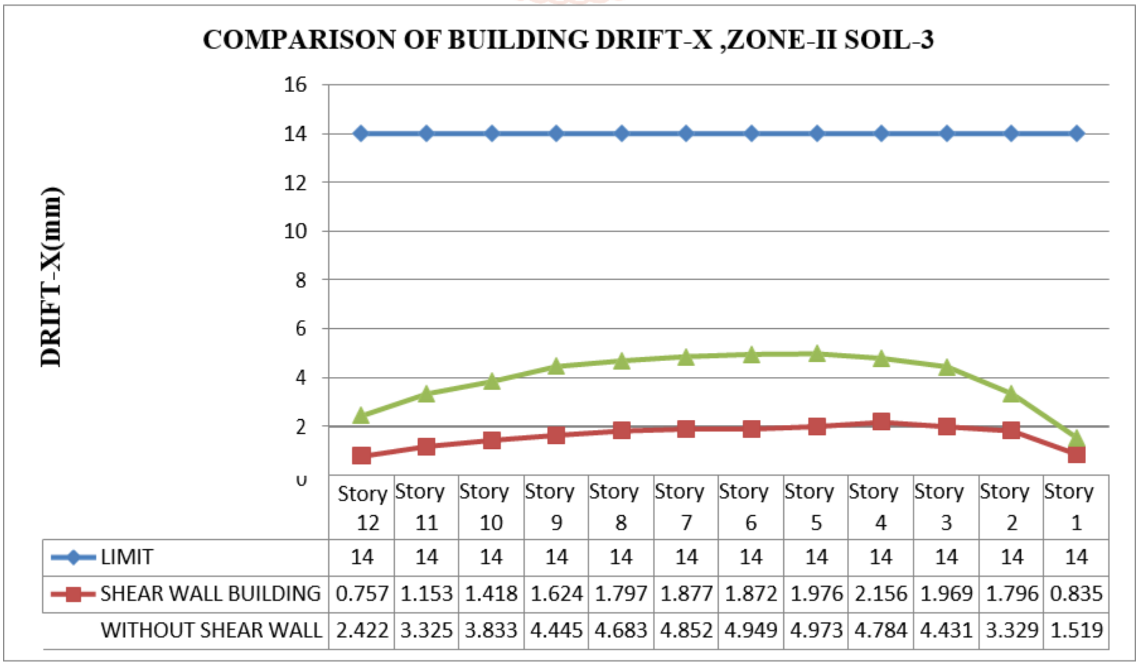


Graph 7.2.1(d) Comparison of building drift-Y, Zone-II Soil-2

E) Drift-X comparison for 12-story grid slab and flat slab building

Table 7.2.1(e) Comparison of building drift-X, Zone-II Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.757	2.422
STORY11	14	1.153	3.325
STORY10	14	1.418	3.833
STORY9	14	1.624	4.445
STORY8	14	1.797	4.683
STORY7	14	1.877	4.852
STORY6	14	1.872	4.949
STORY5	14	1.976	4.973
STORY4	14	2.156	4.784
STORY3	14	1.969	4.431
STORY2	14	1.796	3.329
STORY1	14	0.835	1.519

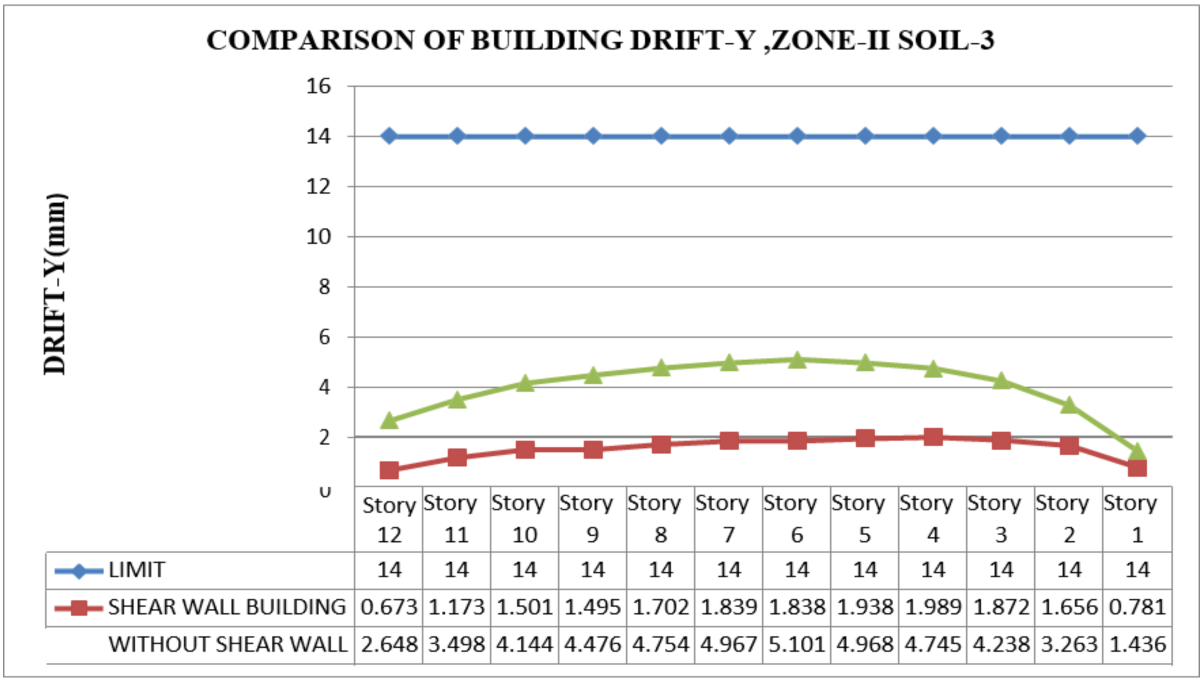


Graph 7.2.1(e) Comparison of building drift-X, Zone-II Soil

F) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-II Soil-3)

Table 7.2.1(f) Comparison of building drift-Y, Zone-II Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.673	2.648
STORY11	14	1.173	3.498
STORY10	14	1.501	4.144
STORY9	14	1.495	4.476
STORY8	14	1.702	4.754
STORY7	14	1.839	4.967
STORY6	14	1.838	5.101
STORY5	14	1.938	4.968
STORY4	14	1.989	4.745
STORY3	14	1.872	4.238
STORY2	14	1.656	3.263
STORY1	14	0.781	1.436

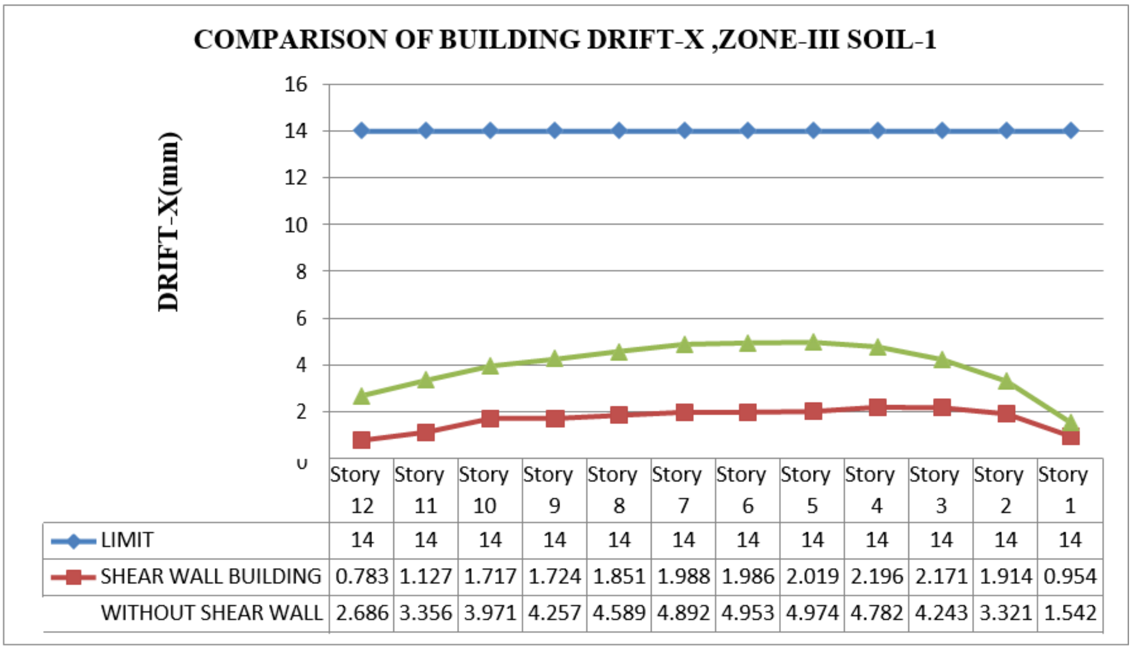


Graph 7.2.1(f) Comparison of building drift-Y, Zone-II Soil-3

G) drift-X comparison for 12-story grid slab and flat slab building (Zone-III Soil-1)

Table 7.2.1(g) Comparison of building drift-X, Zone-III Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.783	2.686
STORY11	14	1.127	3.356
STORY10	14	1.717	3.971
STORY9	14	1.724	4.257
STORY8	14	1.851	4.589
STORY7	14	1.988	4.892
STORY6	14	1.986	4.953
STORY5	14	2.019	4.974
STORY4	14	2.196	4.782
STORY3	14	2.171	4.243
STORY2	14	1.914	3.321
STORY1	14	0.954	1.542

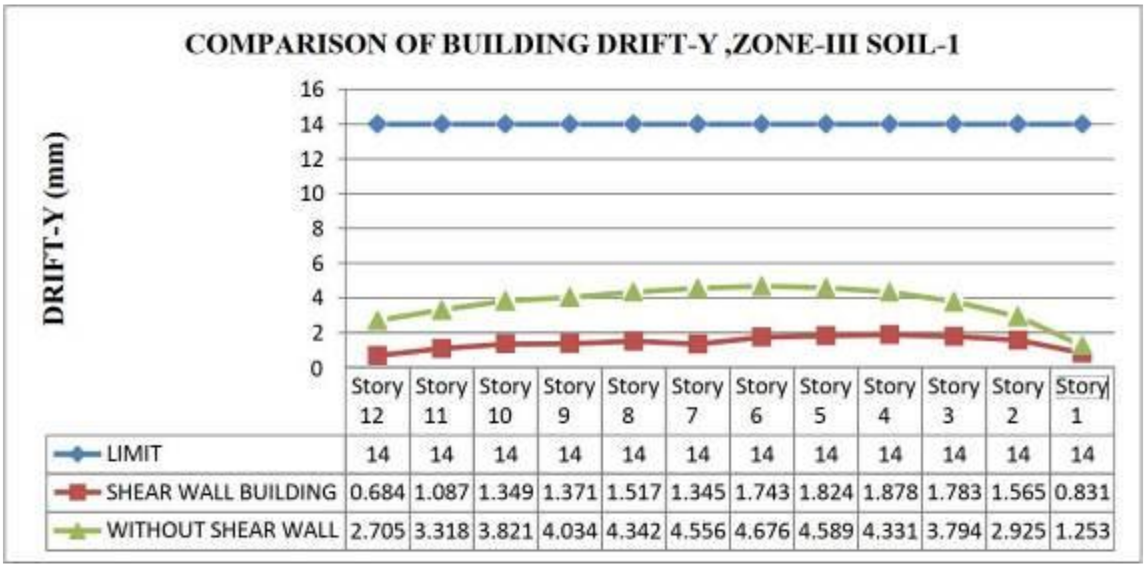


Graph 7.2.1(g) Comparison of building drift-X, Zone-III Soil

H) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-III Soil-1)

Table 7.2.1(h) Comparison of building drift-Y, Zone-III Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.684	2.705
STORY11	14	1.087	3.318
STORY10	14	1.349	3.821
STORY9	14	1.371	4.034
STORY8	14	1.517	4.342
STORY7	14	1.345	4.556
STORY6	14	1.743	4.676
STORY5	14	1.824	4.589
STORY4	14	1.878	4.331
STORY3	14	1.783	3.794
STORY2	14	1.565	2.925
STORY1	14	0.831	1.253

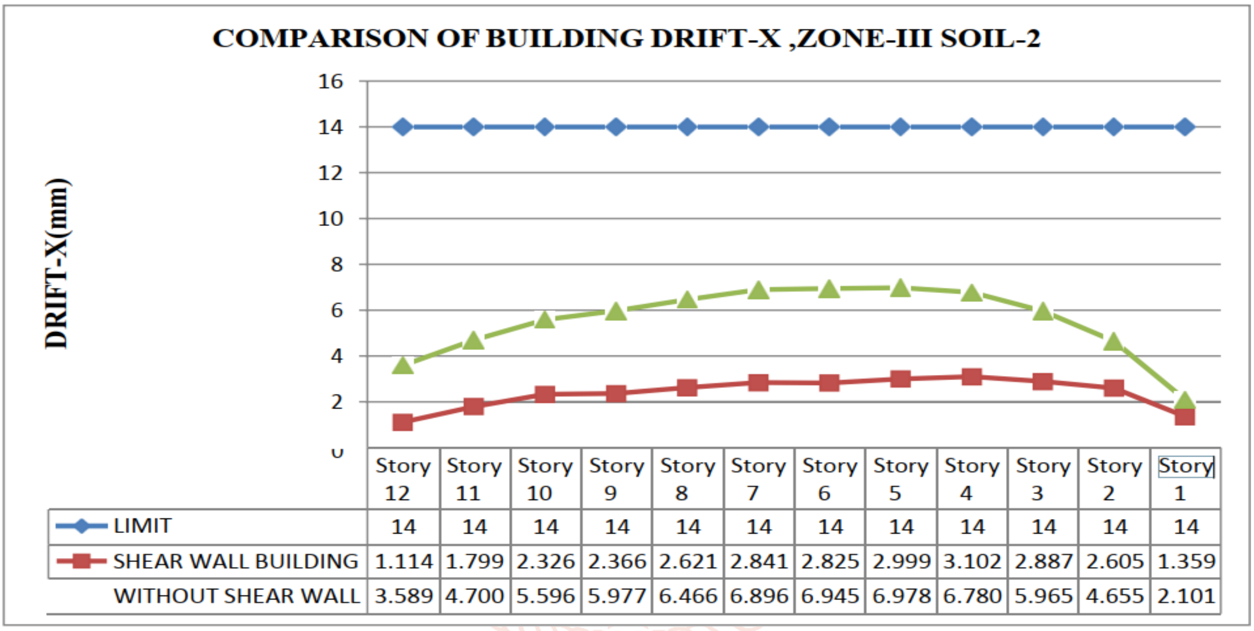


Graph 7.2.1(h) Comparison of building drift-Y, Zone-III Soil-1

I) Drift-X comparison for 12-story grid slab and flat slab building (Zone-III Soil-2)

Table 7.2.1(i) Comparison of building drift-X, Zone-III Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.114	3.589
STORY11	14	1.799	4.700
STORY10	14	2.326	5.596
STORY9	14	2.366	5.977
STORY8	14	2.621	6.466
STORY7	14	2.841	6.896
STORY6	14	2.825	6.945
STORY5	14	2.999	6.978
STORY4	14	3.102	6.780
STORY3	14	2.887	5.965
STORY2	14	2.605	4.655
STORY1	14	1.359	2.101

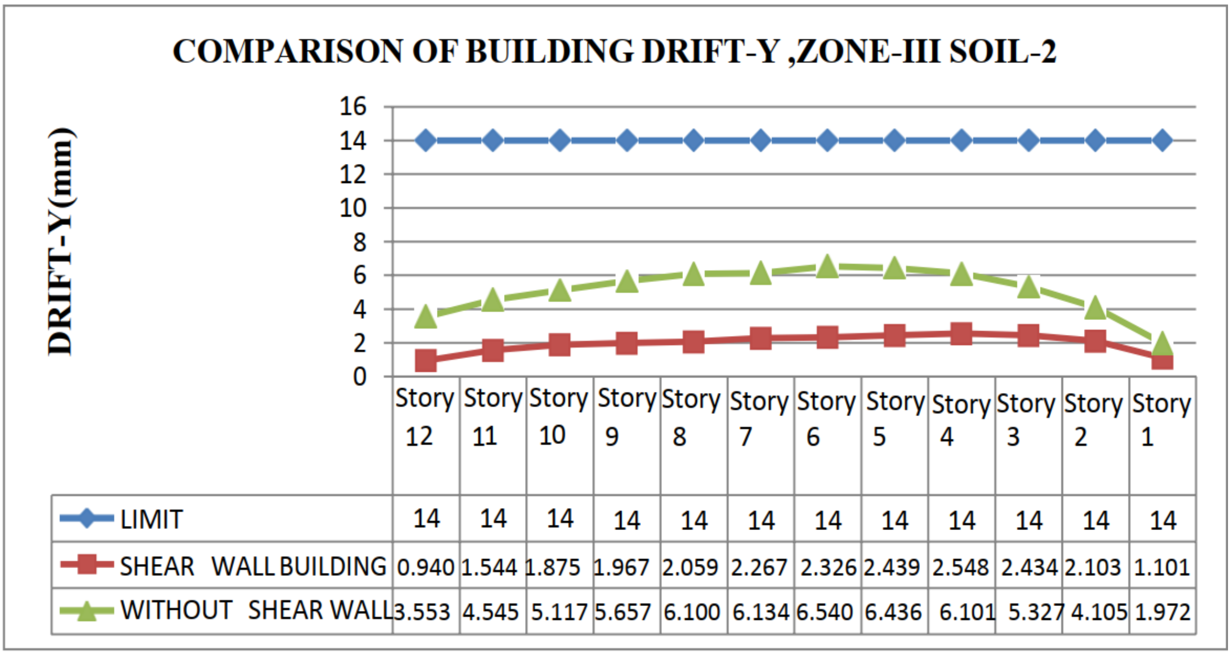


Graph 7.2.1(i) Comparison of building drift-X, Zone-III Soil-2

J) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-III Soil-2)

Table 7.2.1(j) Comparison of building drift-Y, Zone-III Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	0.940	3.553
STORY11	14	1.544	4.545
STORY10	14	1.875	5.117
STORY9	14	1.967	5.657
STORY8	14	2.059	6.100
STORY7	14	2.267	6.134
STORY6	14	2.326	6.540
STORY5	14	2.439	6.436
STORY4	14	2.548	6.101
STORY3	14	2.434	5.327
STORY2	14	2.103	4.105
STORY1	14	1.101	1.972

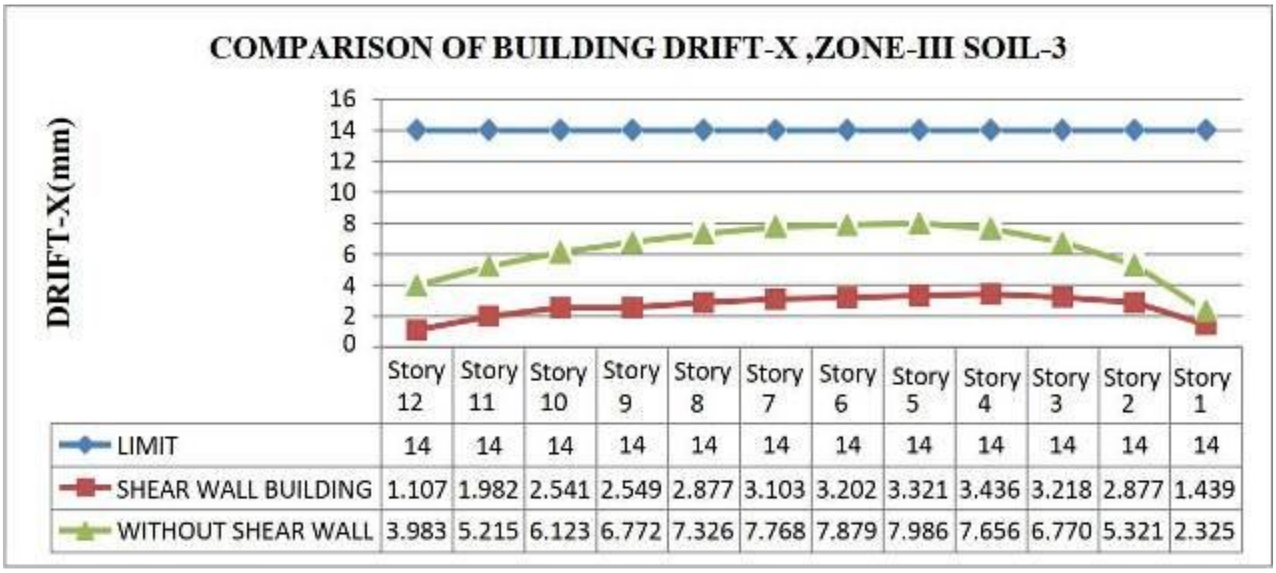


Graph 7.2.1(j) Comparison of building drift-, Zone-III Soil-2

K) Drift-X comparison for 12-story grid slab and flat slab building (Zone-III Soil-3)

Table 7.2.1(k) Comparison of building drift-X, Zone-III Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.107	3.983
STORY11	14	1.982	5.215
STORY10	14	2.541	6.123
STORY9	14	2.549	6.772
STORY8	14	2.877	7.326
STORY7	14	3.103	7.768
STORY6	14	3.202	7.879
STORY5	14	3.321	7.986
STORY4	14	3.436	7.656
STORY3	14	3.218	6.770
STORY2	14	2.877	5.321
STORY1	14	1.439	2.325

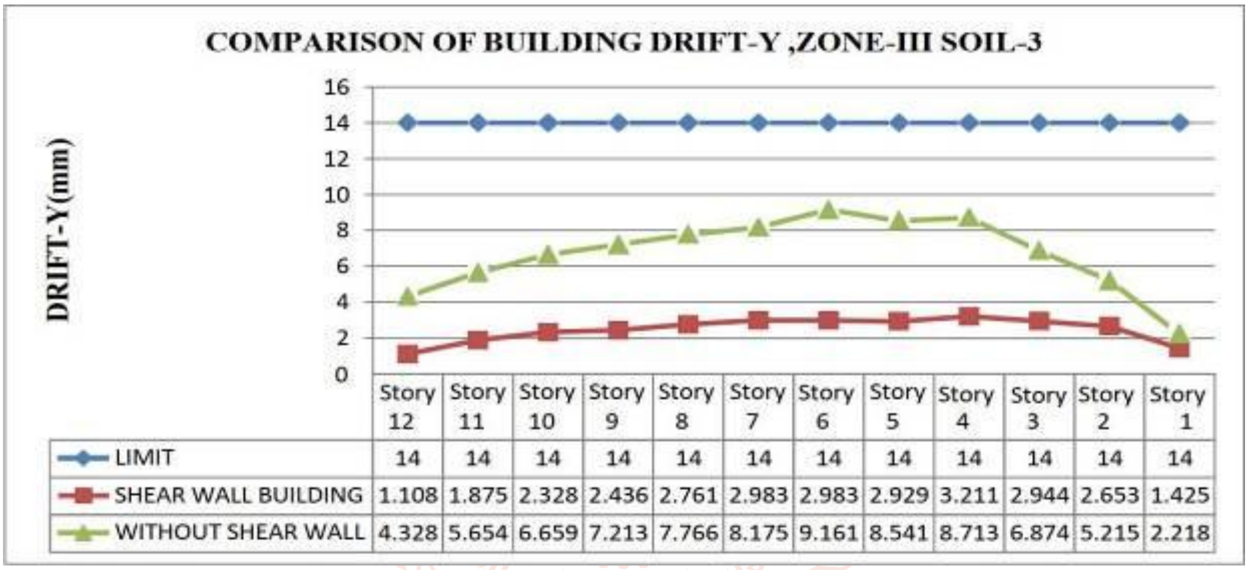


Graph 7.2.1(k) Comparison of building drift-X, Zone-III Soil-3

L) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-III Soil-3)

Table 7.2.1(L) Comparison of building drift-Y, Zone-III Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.108	4.328
STOREY11	14	1.875	5.654
STORY10	14	2.328	6.659
STORY9	14	2.436	7.213
STORY8	14	2.761	7.766
STORY7	14	2.983	8.175
STORY6	14	2.983	9.161
STORY5	14	2.929	8.541
STORY4	14	3.211	8.713
STORY3	14	2.944	6.874
STORY2	14	2.653	5.215
STORY1	14	1.426	2.218



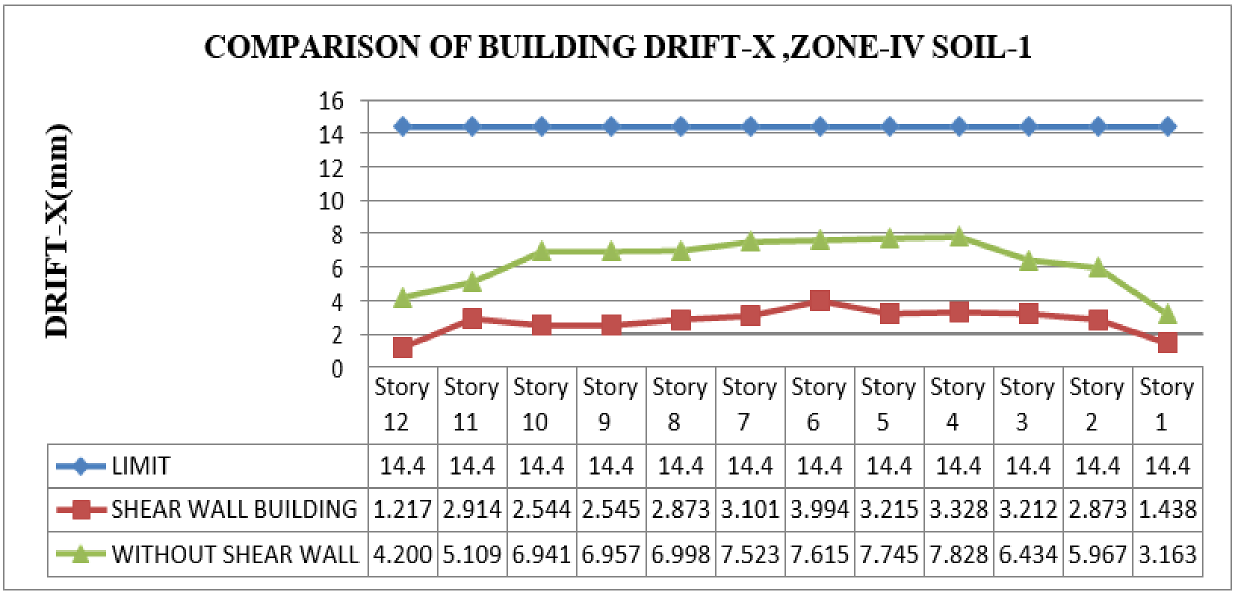
Graph 7.2.1(l) Comparison of building drift-Y, Zone-III Soil-3

7.3.2 (A) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-IV Soil-1)

Storey drifts of grid slab and Flat slab in Y-direction, when placed in four different zones and in three soil conditions are compared.

Table 7.3.1(a) Comparison of building drift-Y, Zone-VI Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14.4	1.217	4.200
STORY11	14.4	2.914	5.109
STORY10	14.4	2.544	6.941
STORY9	14.4	2.545	6.957
STORY8	14.4	2.873	6.998
STORY7	14.4	3.101	7.523
STORY6	14.4	3.994	7.615
STORY5	14.4	3.215	7.745
STORY4	14.4	3.328	7.828
STORY3	14.4	3.212	6.434
STORY2	14.4	2.873	5.967
STORY1	14.4	1.438	3.163

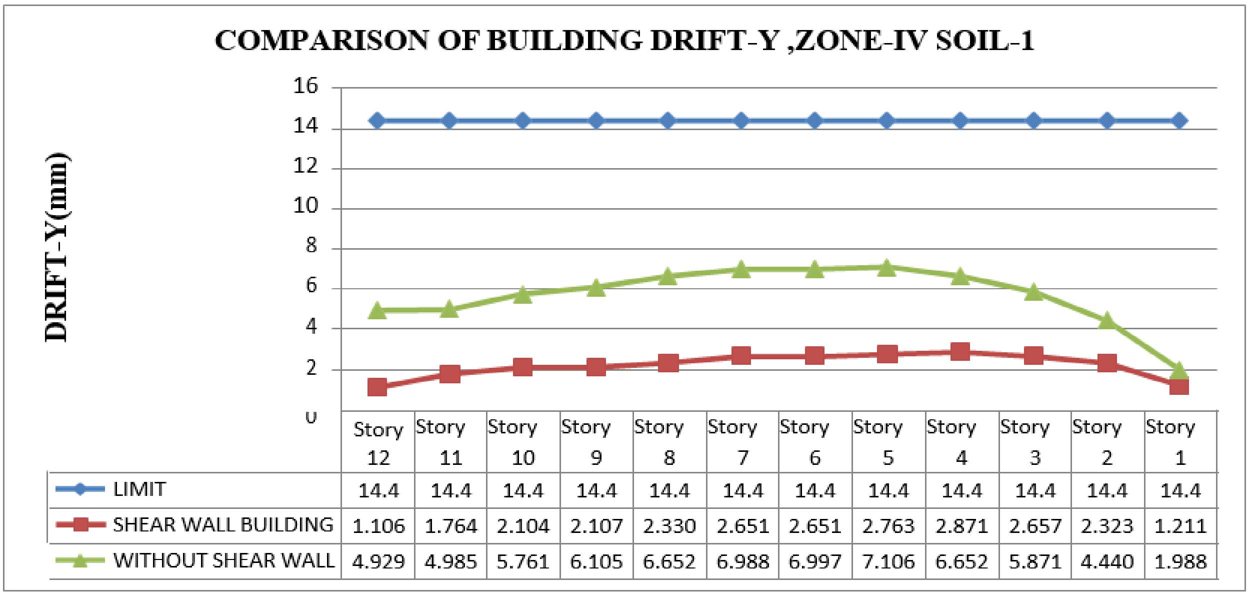


Graph 7.2.2(a) Comparison of building drift-X, Zone-IV Soil-1

B) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-IV Soil-1)

Table 7.2.2(b) Comparison of building drift-Y, Zone-IV Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14.4	1.106	4.929
STORY11	14.4	1.764	4.985
STORY10	14.4	2.104	5.761
STORY9	14.4	2.107	6.105
STORY8	14.4	2.330	6.652
STORY7	14.4	2.651	6.988
STORY6	14.4	2.651	6.997
STORY5	14.4	2.763	7.106
STORY4	14.4	2.871	6.652
STORY3	14.4	2.657	5.871
STORY2	14.4	2.323	4.440
STORY1	14.4	1.211	1.988

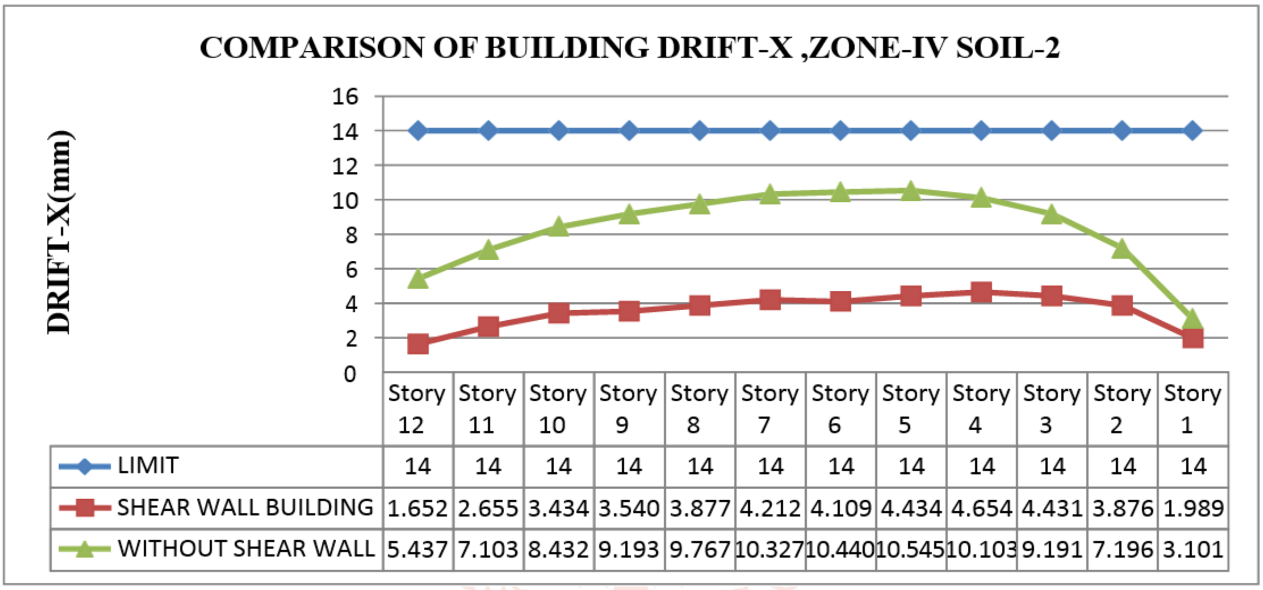


Graph 7.2.2(b) Comp Story arison of building drift-Y, Zone-IV Soil-1

C) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-IV Soil-2)

Table 7.2.2(c) Comparison of building drift-Y, Zone-IV Soil-2

STORY	DRIFT		
	LIMIT	GRID	FLAT
STORY12	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY11	14	1.652	5.437
STORY10	14	2.655	7.103
STORY9	14	3.434	8.432
STORY8	14	3.540	9.193
STORY7	14	3.877	9.767
STORY6	14	4.212	10.327
STORY5	14	4.109	10.440
STORY4	14	4.434	10.545
STORY3	14	4.654	10.103
STORY2	14	4.431	9.191
STORY1	14	3.876	7.196

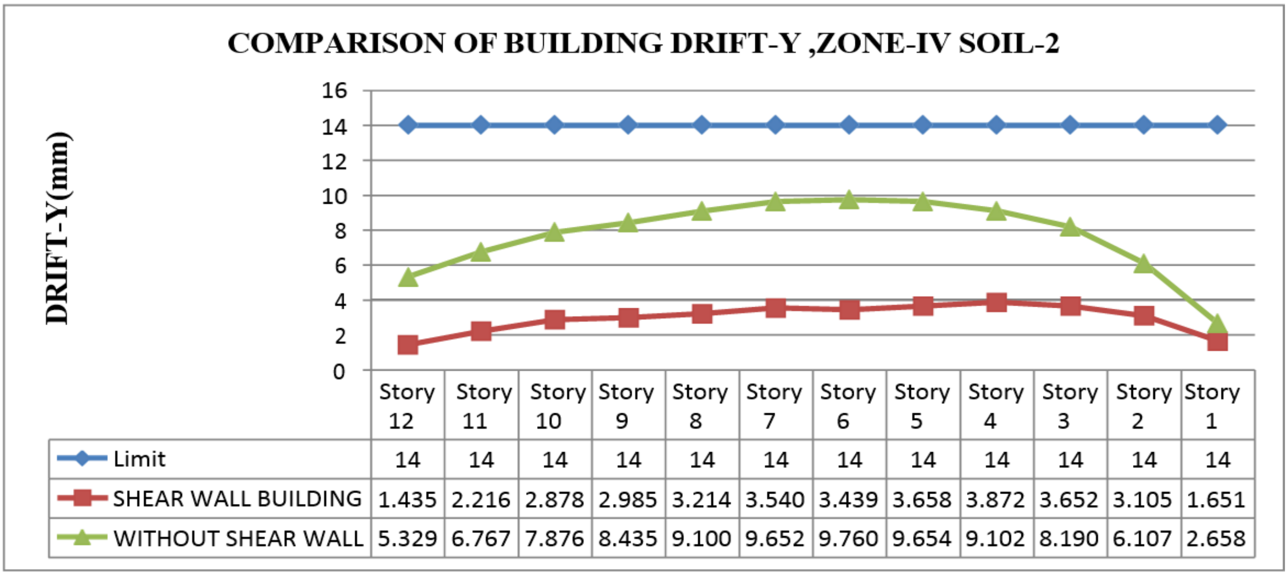


Graph 7.2.2(c) Comparison of building drift-Y, Zone-IV Soil-2

D) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-IV Soil-2)

Table 7.2.2(d) Comparison of building drift-Y, Zone-IV Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.435	5.329
STORY11	14	2.216	6.767
STORY10	14	2.878	7.876
STORY9	14	2.985	8.435
STORY8	14	3.214	9.100
STORY7	14	3.540	9.652
STORY6	14	3.439	9.760
STORY5	14	3.658	9.654
STORY4	14	3.872	9.102
STORY3	14	3.652	8.190
STORY2	14	3.105	6.107
STORY1	14	1.651	2.658

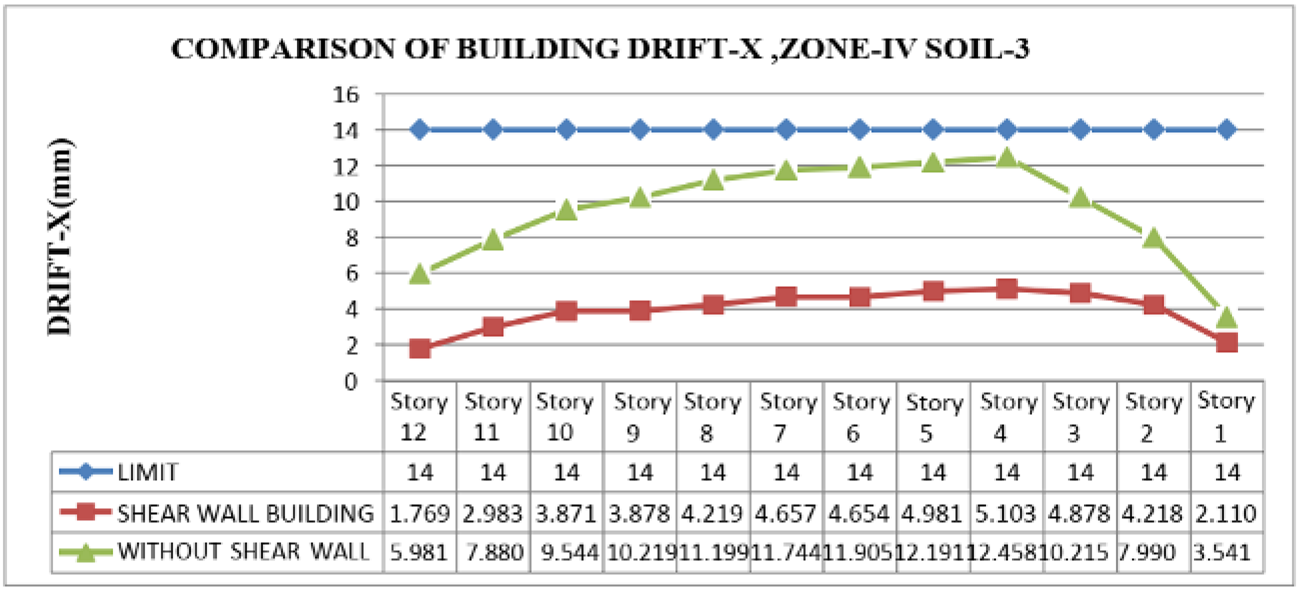


Graph 7.2.2(d) Comparison of building drift-Y, Zone-IV Soil-2

E) Drift-X comparison for 12-story grid slab and flat slab building (Zone-IV Soil-3)

Table 7.2.2(e) Comparison of building drift-Y, Zone-IV Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.769	5.981
STORY11	14	2.983	7.880
STORY10	14	3.871	9.544
STORY9	14	3.878	10.219
STORY8	14	4.219	11.199
STORY7	14	4.657	11.744
STORY6	14	4.654	11.905
STORY5	14	4.981	12.191
STORY4	14	5.103	12.458
STORY3	14	4.878	10.215
STORY2	14	4.218	7.990
STORY1	14	2.110	3.541

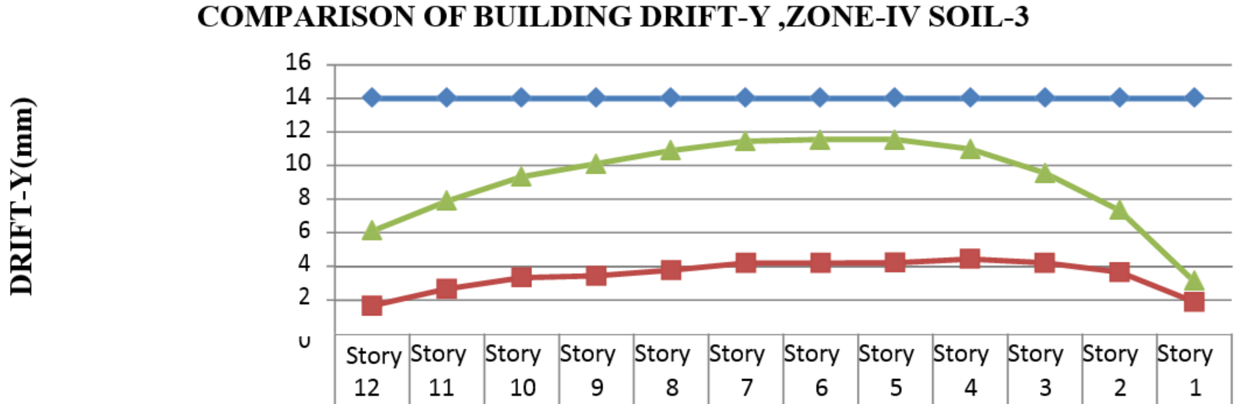


Graph 7.2.2(e) Comparison of building drift-Y, Zone-IV Soil-3

F) Drift-y comparison for 12-story grid slab and flat slab building (Zone-IV Soil-3)

Table 7.2.2(f) Comparison of building drift-Y, Zone-IV Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.658	6.102
STORY11	14	2.653	7.879
STORY10	14	3.325	9.327
STORY9	14	3.433	10.103
STORY8	14	3.767	10.878
STORY7	14	4.198	11.436
STORY6	14	4.197	11.548
STORY5	14	4.219	11.545
STORY4	14	4.435	10.985
STORY3	14	4.211	9.548
STORY2	14	3.656	7.325
STORY1	14	1.877	3.106



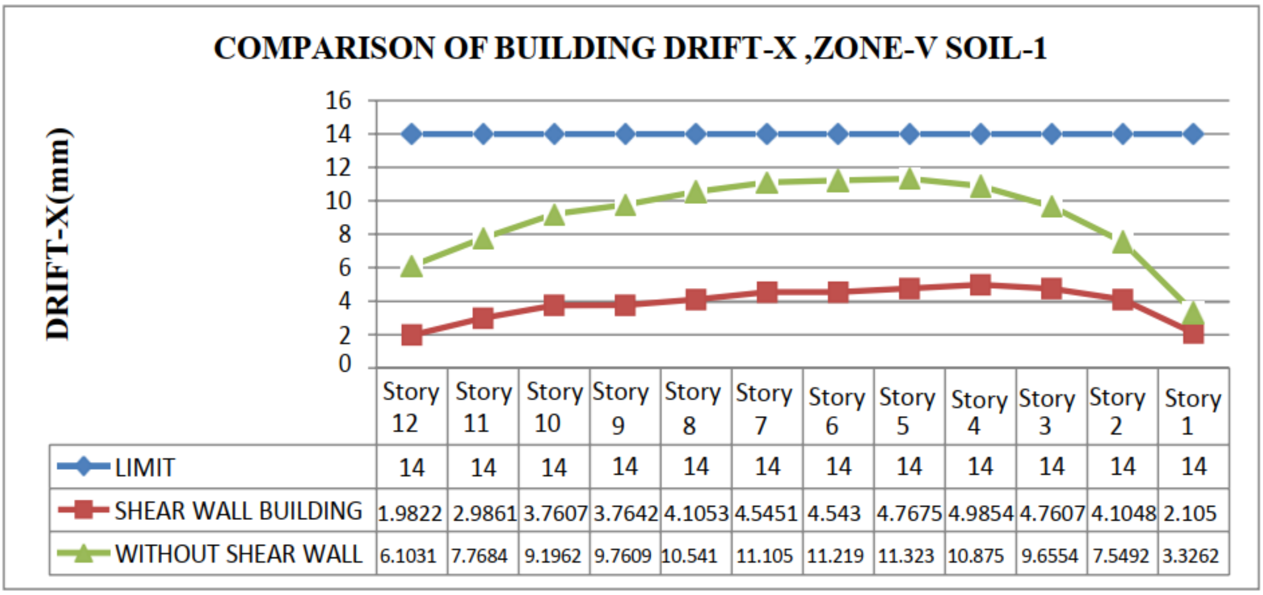
	Story 12	Story 11	Story 10	Story 9	Story 8	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
LIMIT	14	14	14	14	14	14	14	14	14	14	14	14
SHEAR WALL BUILDING	1.658	2.653	3.325	3.433	3.767	4.198	4.197	4.219	4.435	4.211	3.656	1.877
WITHOUT SHEAR WALL	6.102	7.879	9.327	10.103	10.878	11.436	11.548	11.545	10.985	9.548	7.325	3.106

Graph 7.2.2(f) Comparison of building drift-Y, Zone-IV Soil-3

G) Drift-X comparison for 12-story grid slab and flat slab building (Zone-V Soil-1)

Table 7.2.2(g) Comparison of building drift-X, Zone-V Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.9822	6.1031
STORY11	14	2.9861	7.7684
STORY10	14	3.7607	9.1962
STORY9	14	3.7642	9.7609
STORY8	14	4.1053	10.5405
STORY7	14	4.5451	11.1046
STORY6	14	4.543	11.2185
STORY5	14	4.7675	11.3231
STORY4	14	4.9854	10.8752
STORY3	14	4.7607	9.6554
STORY2	14	4.1048	7.5492
STORY1	14	2.105	3.3262

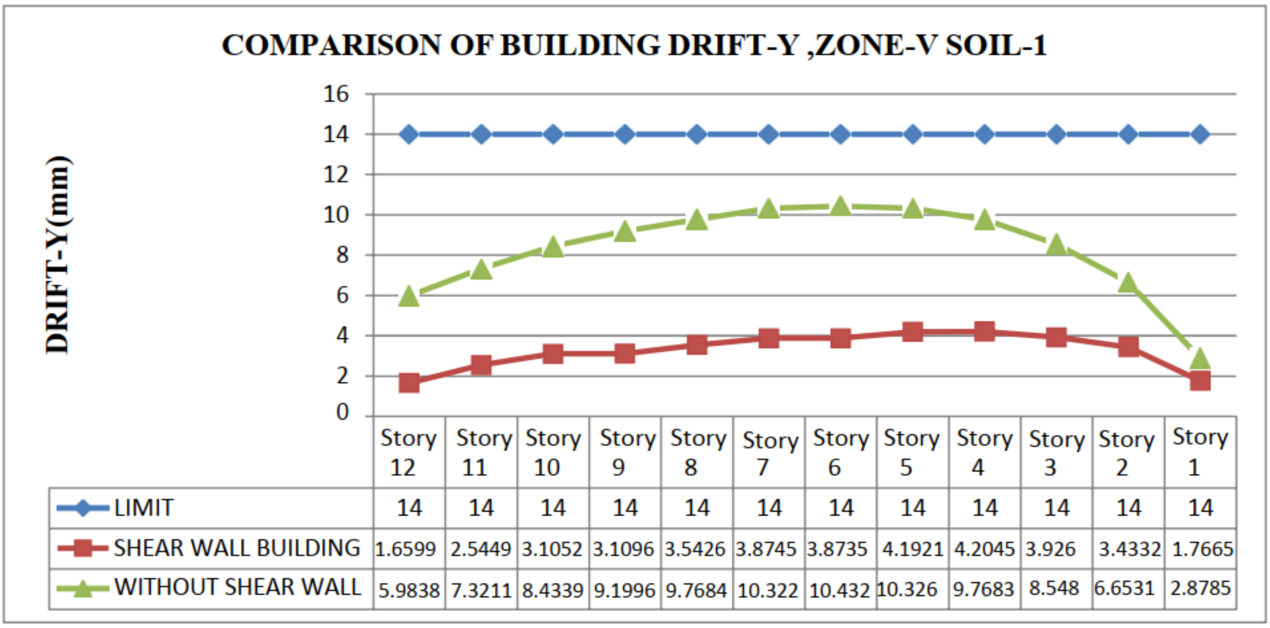


Graph 7.2.2(g) Comparison of building drift-X, Zone-V Soil-1

H) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-V Soil-1)

Table 7.2.2(h) Comparison of building drift-Y, Zone-V Soil-1

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	1.6599	5.9838
STORY11	14	2.5449	7.3211
STORY10	14	3.1052	8.4339
STORY9	14	3.1096	9.1996
STORY8	14	3.5426	9.7684
STORY7	14	3.8745	10.3218
STORY6	14	3.8735	10.4322
STORY5	14	4.1921	10.3261
STORY4	14	4.2045	9.7683
STORY3	14	3.926	8.548
STORY2	14	3.4332	6.6531
STORY1	14	1.7665	2.8785

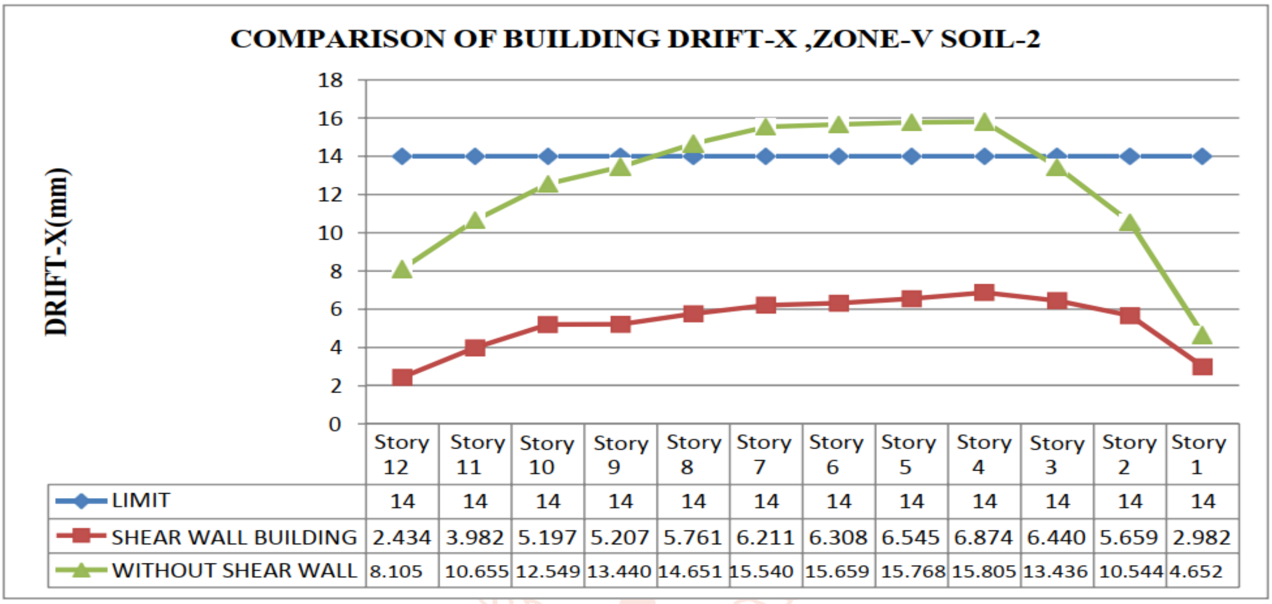


Graph 7.2.2(h) Comparison of building drift-Y, Zone-V Soil-1

I) Drift-X comparison for 12-story grid slab and flat slab building (Zone-V Soil-2)

Table 7.2.2(i) Comparison of building drift-X, Zone-V Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	2.434	8.105
STORY11	14	3.982	10.655
STORY10	14	5.197	12.549
STORY9	14	5.207	13.440
STORY8	14	5.761	14.651
STORY7	14	6.211	15.540
STORY6	14	6.308	15.659
STORY5	14	6.545	15.768
STORY4	14	6.874	15.805
STORY3	14	6.440	13.436
STORY2	14	5.659	10.544
STORY1	14	2.982	4.652

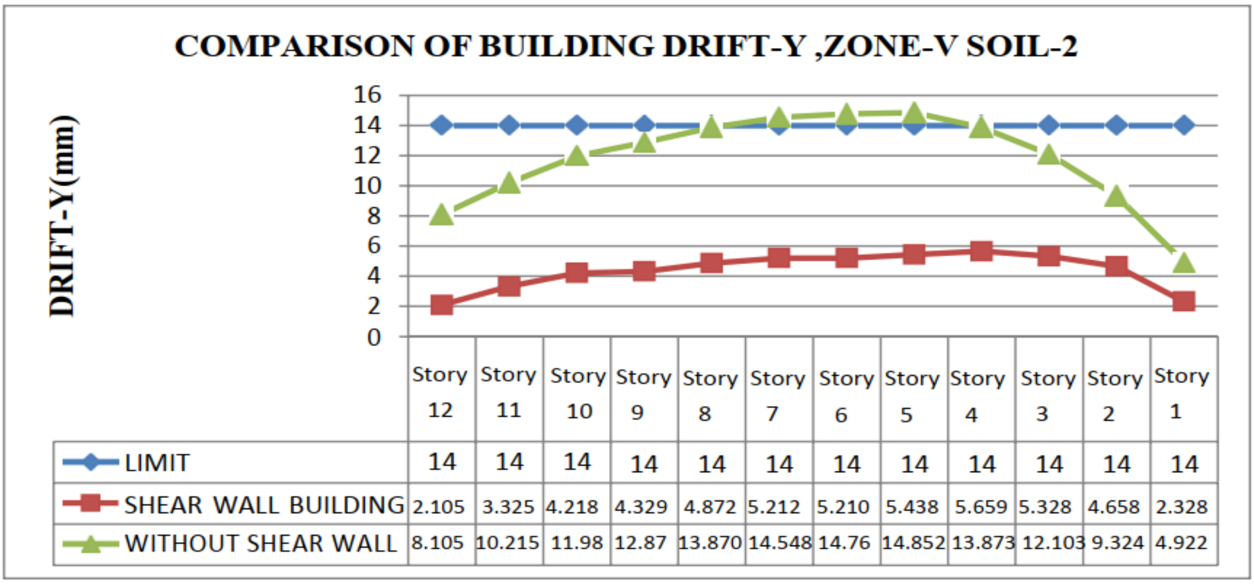


Graph 7.2.2(i) Comparison of building drift-X, Zone-V Soil-2

J) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-V Soil-2)

Table 7.2.2(j) Comparison of building drift-Y, Zone-V Soil-2

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	2.105	8.105
STORY11	14	3.325	10.215
STORY10	14	4.218	11.981
STORY9	14	4.329	12.871
STORY8	14	4.872	13.870
STORY7	14	5.212	14.548
STORY6	14	5.210	14.761
STORY5	14	5.438	14.852
STORY4	14	5.659	13.873
STORY3	14	5.328	12.103
STORY2	14	4.658	9.324
STORY1	14	2.328	4.922

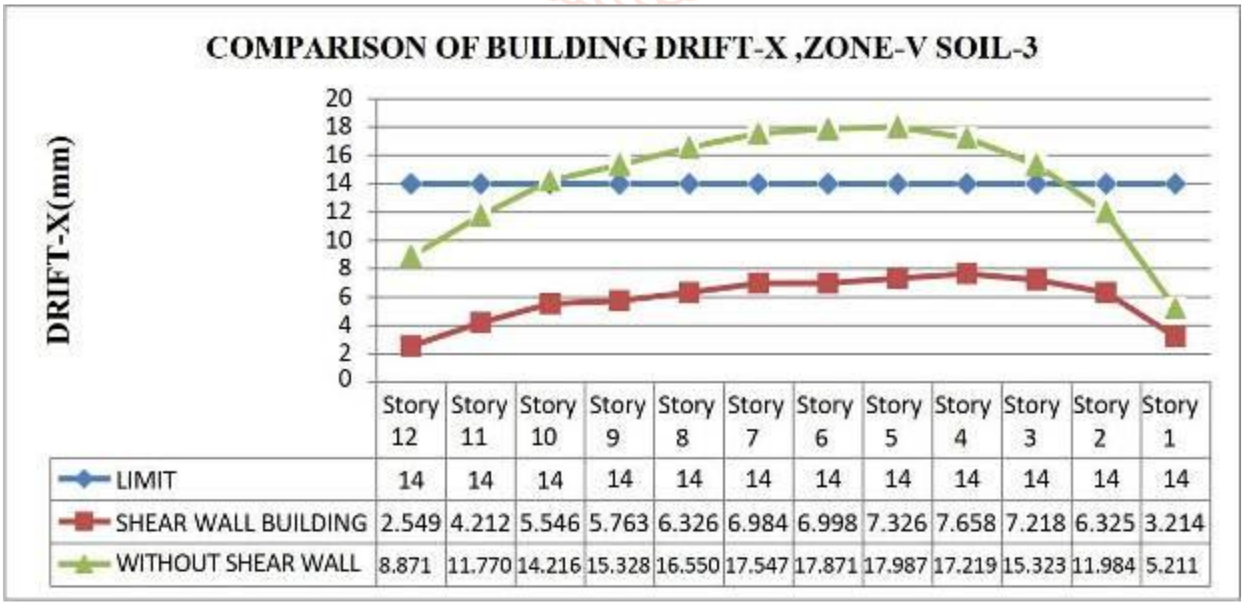


Graph 7.2.2(j) Comparison of building drift-Y, Zone-V Soil-2

K) Drift-X comparison for 12-story grid slab and flat slab building (Zone-V Soil-3)

Table 7.2.2(k) Comparison of building drift-X, Zone-V Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	2.549	8.871
STORY11	14	4.212	11.770
STORY10	14	5.546	14.216
STORY9	14	5.763	15.328
STORY8	14	6.326	16.550
STORY7	14	6.984	17.547
STORY6	14	6.998	17.871
STORY5	14	7.326	17.987
STORY4	14	7.658	17.219
STORY3	14	7.218	15.323
STORY2	14	6.325	11.984
STORY1	14	3.214	5.211

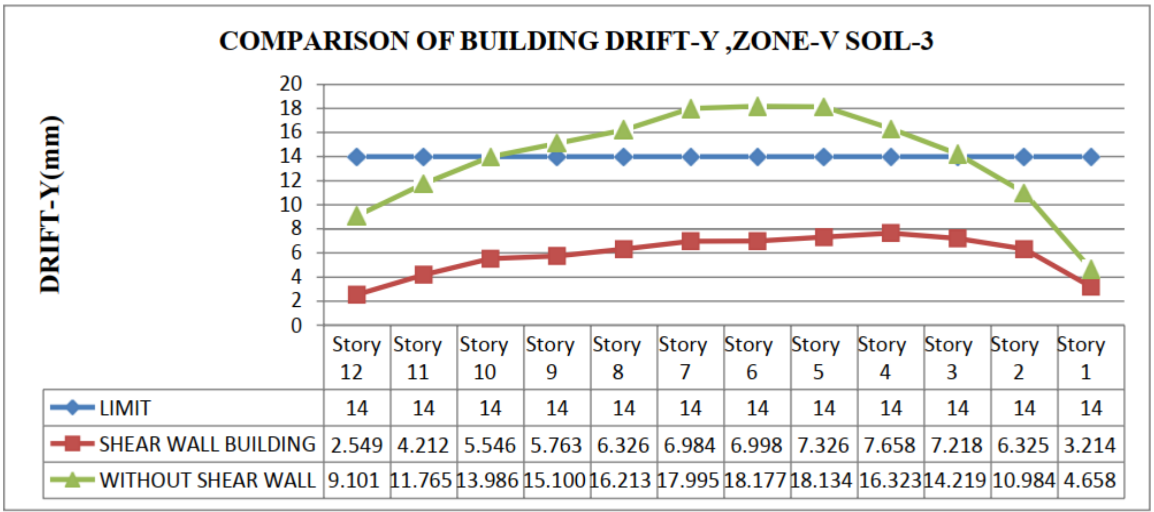


Graph 7.2.2(k) Comparison of building drift-X, Zone-V Soil-3

L) Drift-Y comparison for 12-story grid slab and flat slab building (Zone-V Soil-3)

Table 7.2.2(l) Comparison of building drift-Y, Zone-V Soil-3

STORY	DRIFT		
	LIMIT	SHEAR WALL BUILDING	WITHOUT SHEAR WALL
STORY12	14	2.549	9.101
STORY11	14	4.212	11.765
STORY10	14	5.546	13.986
STORY9	14	5.763	15.100
STORY8	14	6.326	16.213
STORY7	14	6.984	17.995
STORY6	14	6.998	18.177
STORY5	14	7.326	18.134
STORY4	14	7.658	16.323
STORY3	14	7.218	14.219
STORY2	14	6.325	10.984
STORY1	14	3.214	4.658



Graph-7.2.2(l) Comparison of building drift-Y, Zone-V Soil-3

Results drawn from Graph:-

1. Graphs clearly show that drift for all storey of without shear wall building is about 34 % more than that of shear wall building.
2. Both building deflect more in seismic zone V.
3. Considering soil conditions, building on soft soil (Type 3) deflects more in both shear wall building as well as without shear wall building.
4. Considering building drift, without shear wall building becomes unsafe for seismic zone V.

7.5. Axial force comparision

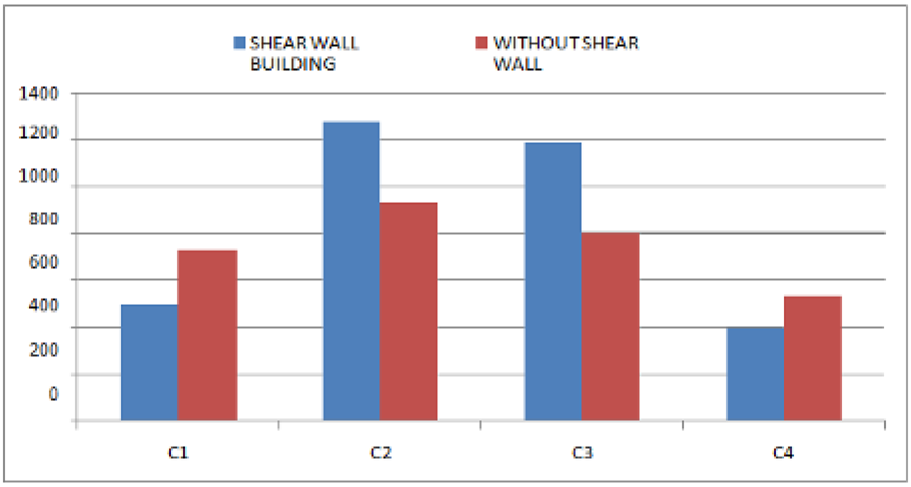
Axial force experienced by each storey of Flat slab and Grid slab is compared for three columns of each story. Building in zone II and type of strata is medium soil i.e. (soil type 2)

Table 7.3 Comparison of axial force

Story	AXIAL FORCE							
	C1		C2		C3		C4	
	Shear wall Building	Without shear Wall	Shear wall Building	Without shear Wall	Shear wall Building	Without shear Wall	Shear wall Building	Without shear Wall
STORY12	498.33	731.43	1276.23	930.1	1277.23	930.1	498.33	731.43
STORY11	969.94	1328.324	2672.91	1772.24	2672.591	1772.24	969.94	1328.324
STORY10	1447.91	1814.283	3877.61	2643.45	3877.661	2643.45	1447.91	1814.283
STORY9	2122.45	2435.171	5201.64	3631.85	5202.64	3631.85	2122.45	2435.171
STORY8	2623.21	3112.189	6726.19	4419.209	6726.2	4419.209	2623.21	3112.189
STORY7	3234.48	3804.12	7957.52	5404.61	7957.53	5404.61	3234.48	3804.12
STORY6	3893.47	4528.97	9316.144	6308.84	9316.134	6308.84	3893.47	4528.97

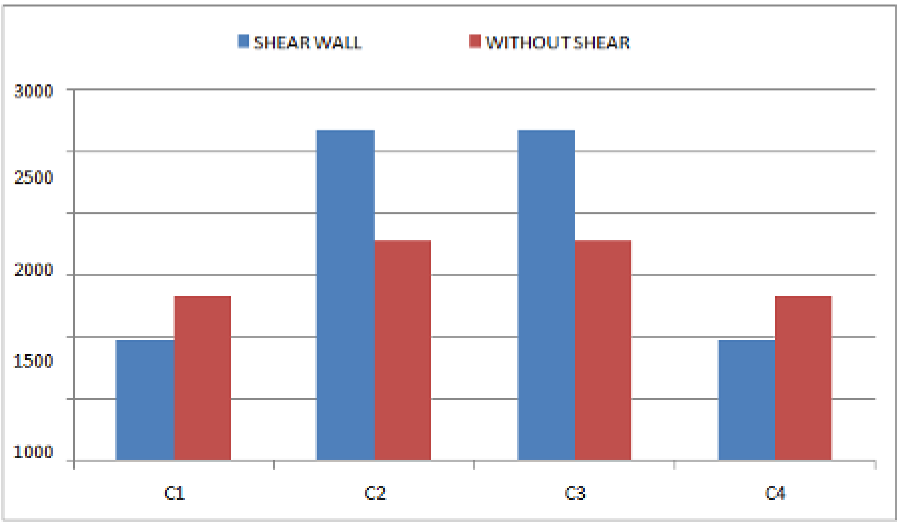
STORY5	4550.36	5359.22	11479.88	7211.09	11479.89	7211.09	4550.36	5359.22
STORY4	5186.87	6019.08	12950.73	8011.803	12951.73	8011.813	5186.87	6019.08
STORY3	5925.92	6831.4	14256.45	9031.254	14256.46	9031.254	5925.92	6831.4
STORY2	6426.18	7453.83	15687.71	9849.947	15687.71	9849.947	6426.18	7453.83
STORY1	6934.58	8219.48	16878.18	11864.47	16898.18	11865.483	6934.58	8219.48

Axial force comparison for story-12



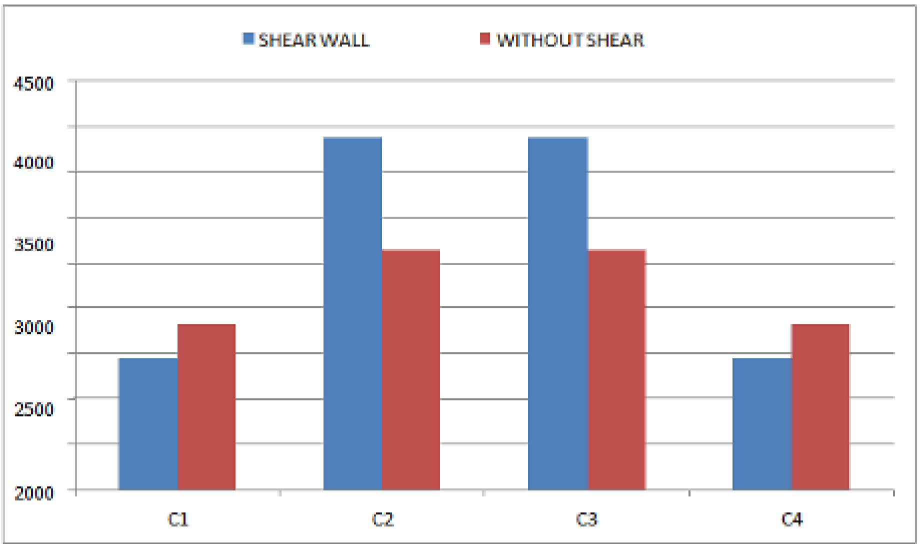
Graph 7.3(a) Axial force Comparison (Story-12)

Axial force comparison for story-11



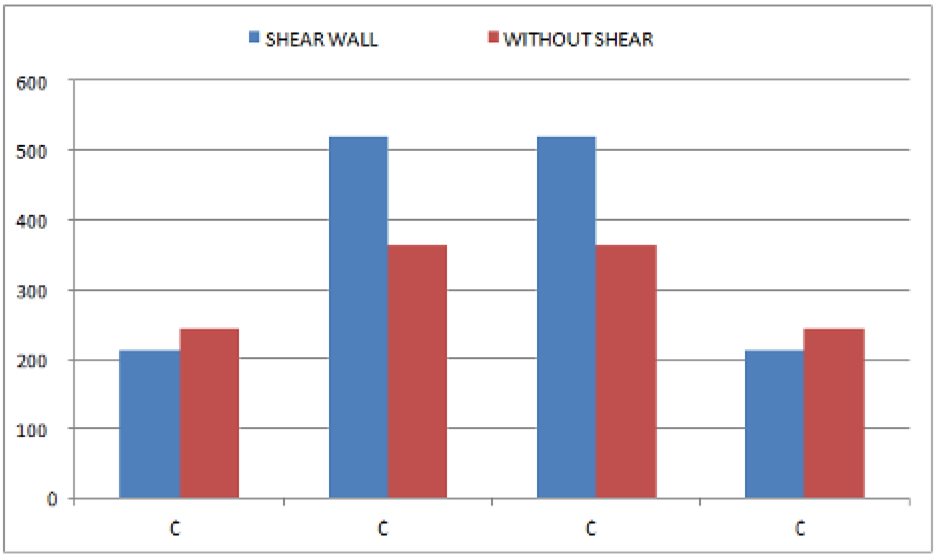
Graph 7.3(b) Axial force Comparison (Story-11)

Axial force comparison for story-10



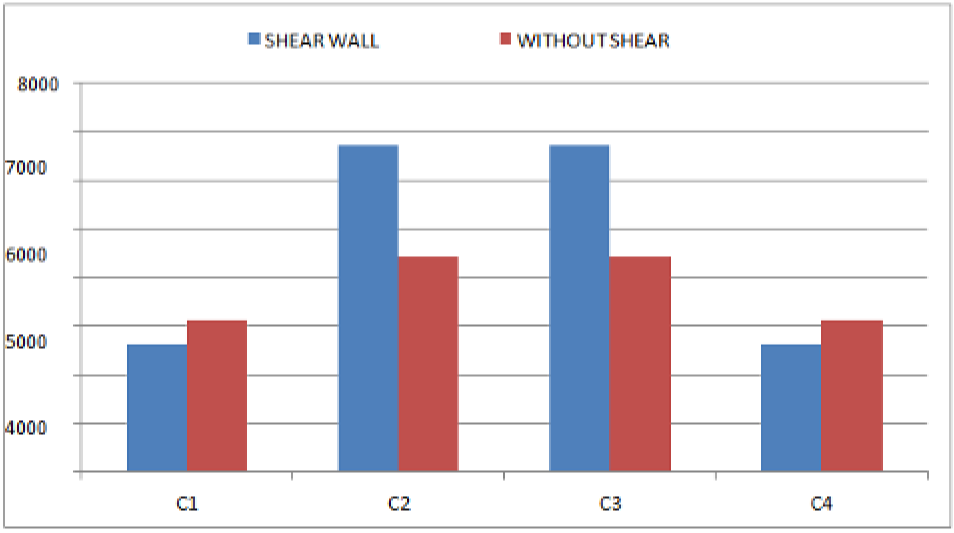
Graph 7.3(c) Axial force Comparison (Story-10)

Axial force comparison for story-9



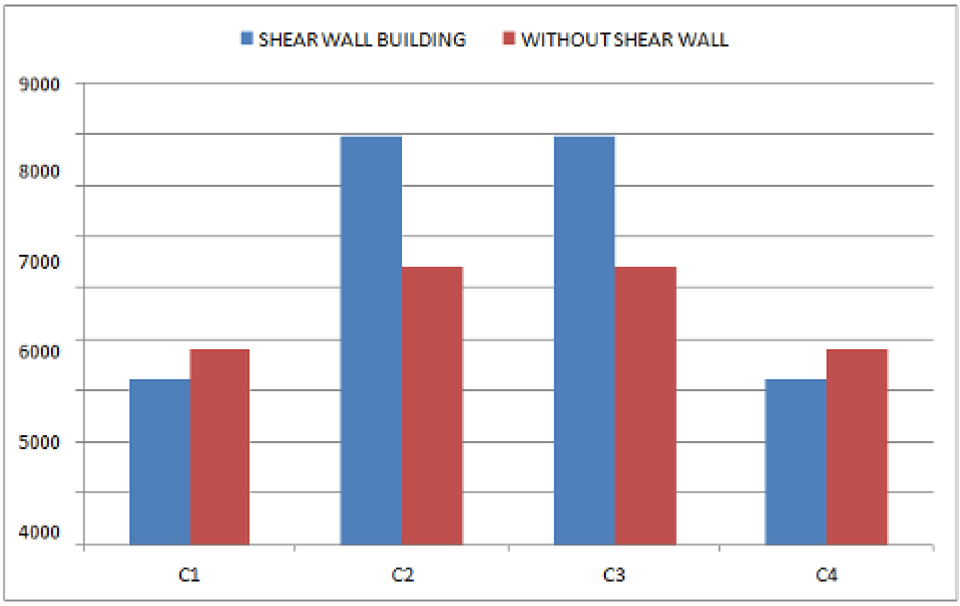
Graph 7.3(d) Axial force Comparison (Story-9)

Axial force comparison for story-8



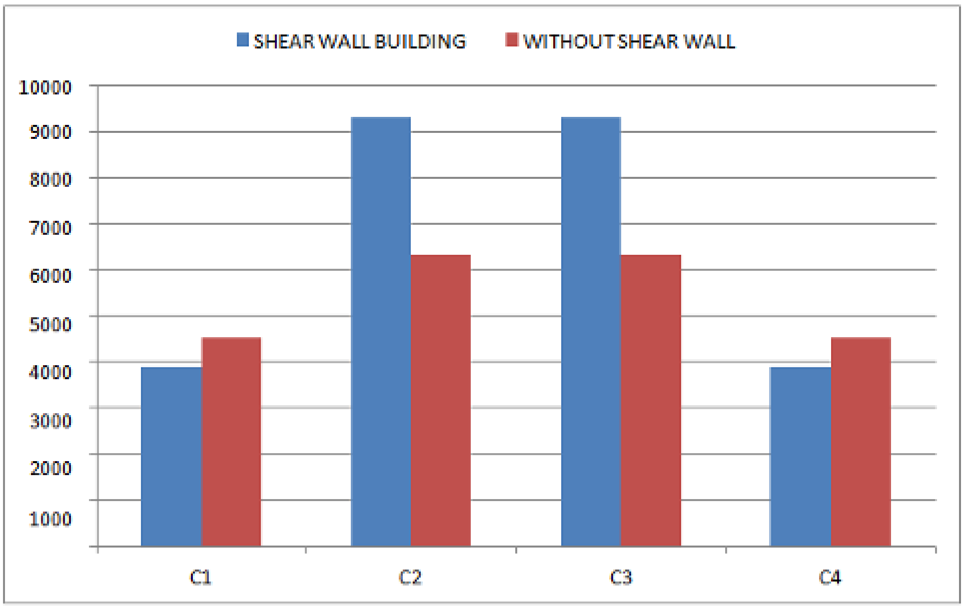
Graph 7.3(e) Axial force Comparison (Story-8)

Axial force comparison for story-7



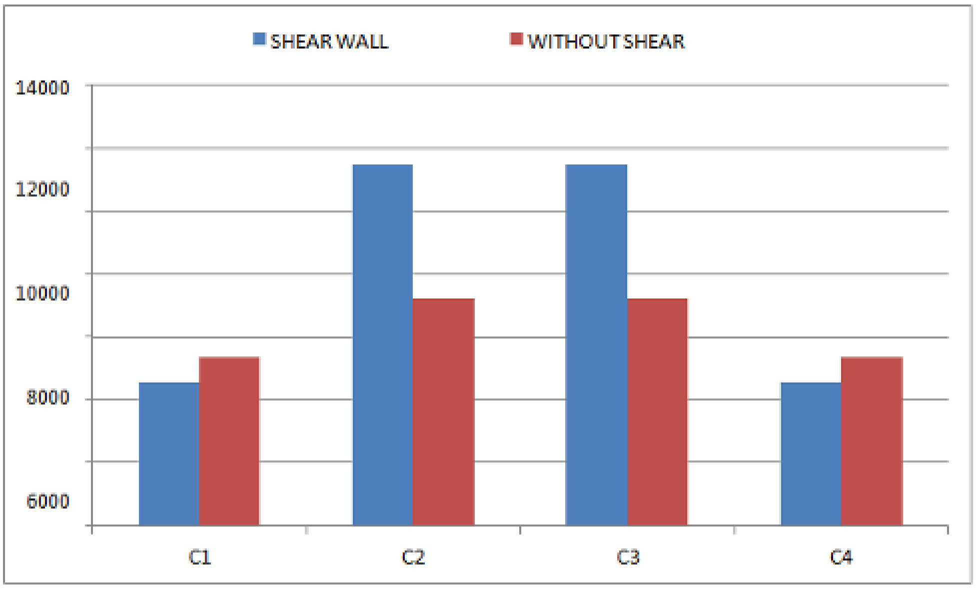
Graph 7.3(f) Axial force Comparison (Story-7)

Axial force comparison for story-6



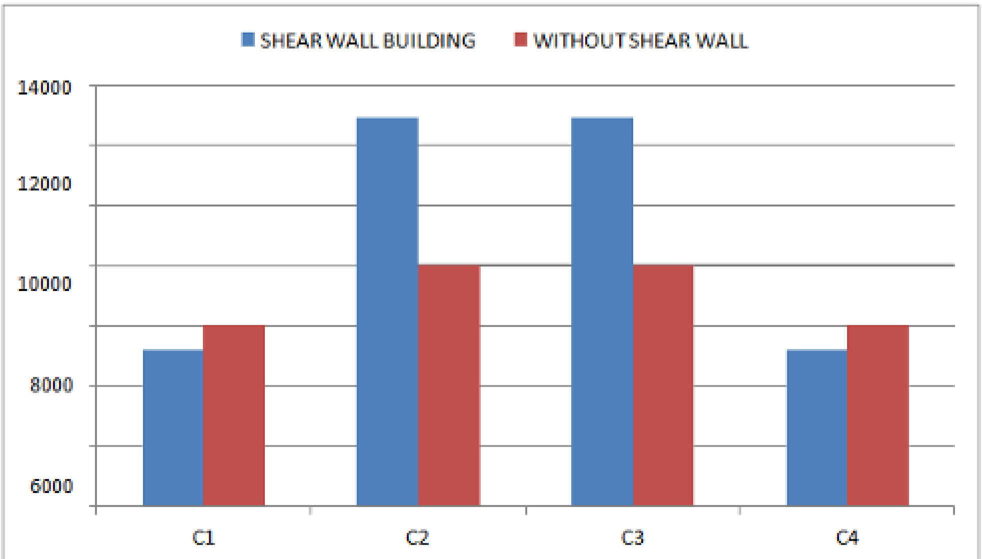
Graph 7.3(g) Axial force Comparison (Story-6)

Axial force comparison for story-5



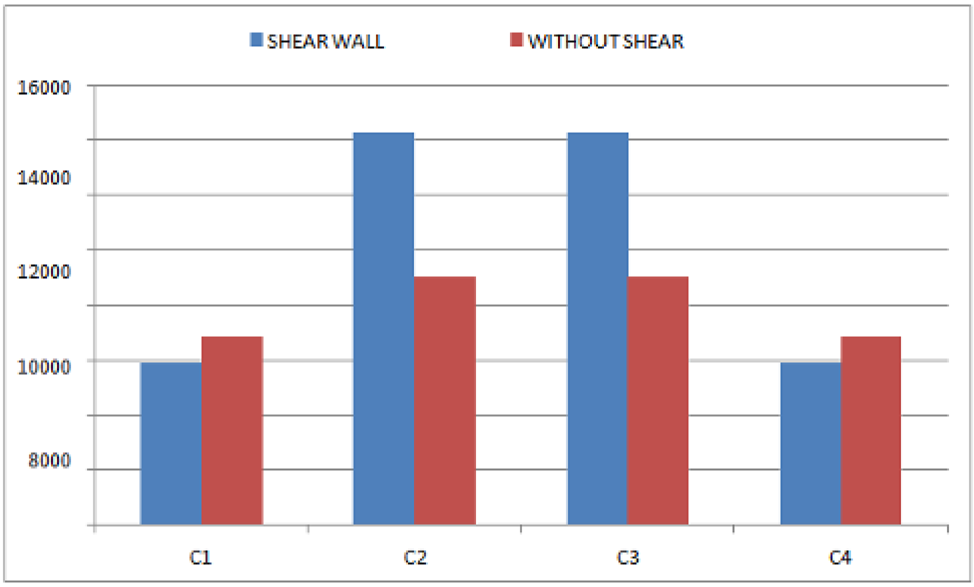
Graph 7.3(h) Axial force Comparison (Story-5)

Axial force comparison for story-4



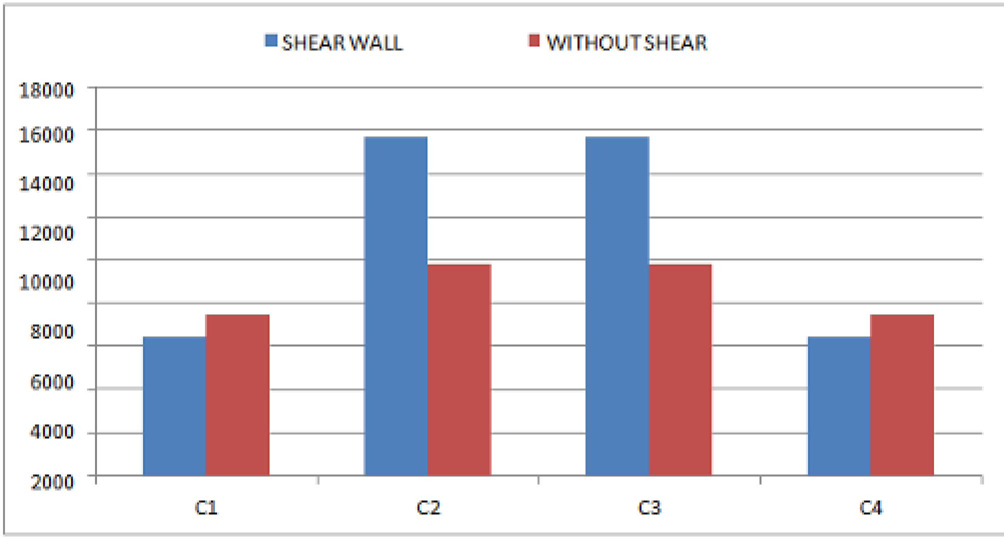
Graph 7.3(i) Axial force Comparison (Story-4)

Axial force comparison for story-3



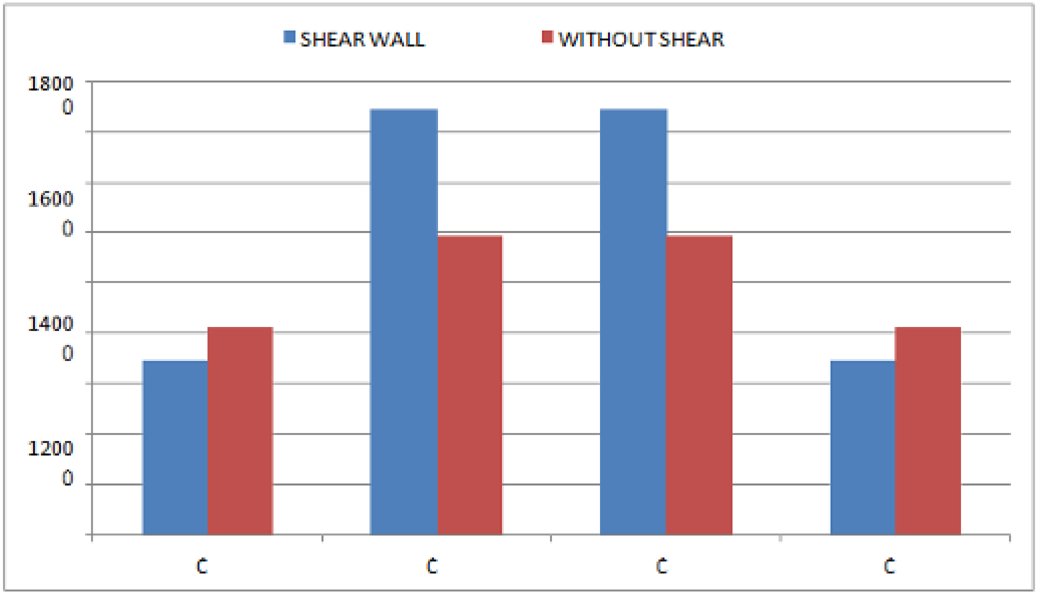
Graph 7.3(j) Axial force Comparison (Story-3)

Axial force comparison for story-2



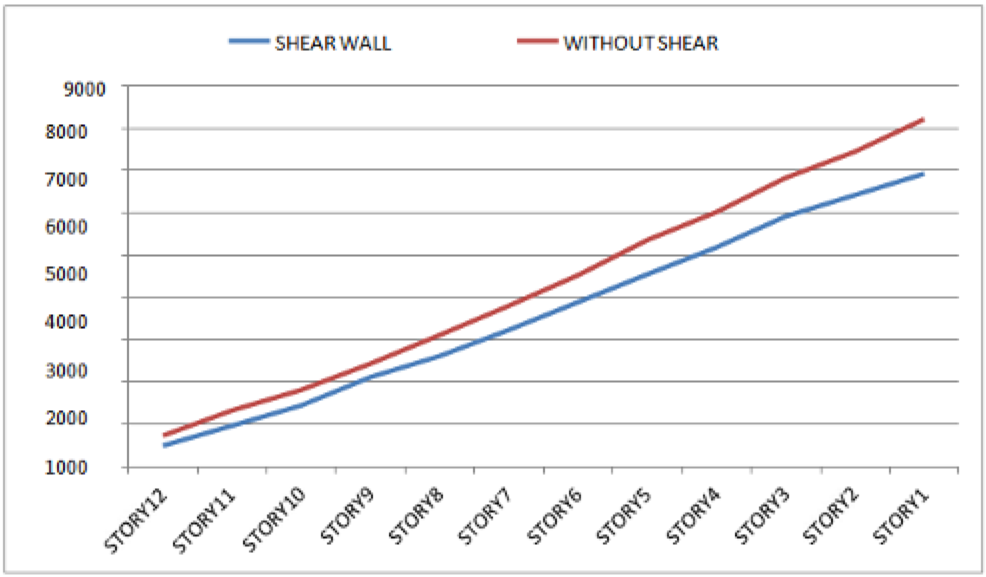
Graph 7.3(k) Axial force Comparison (Story-2)

Axial force comparison for story-1



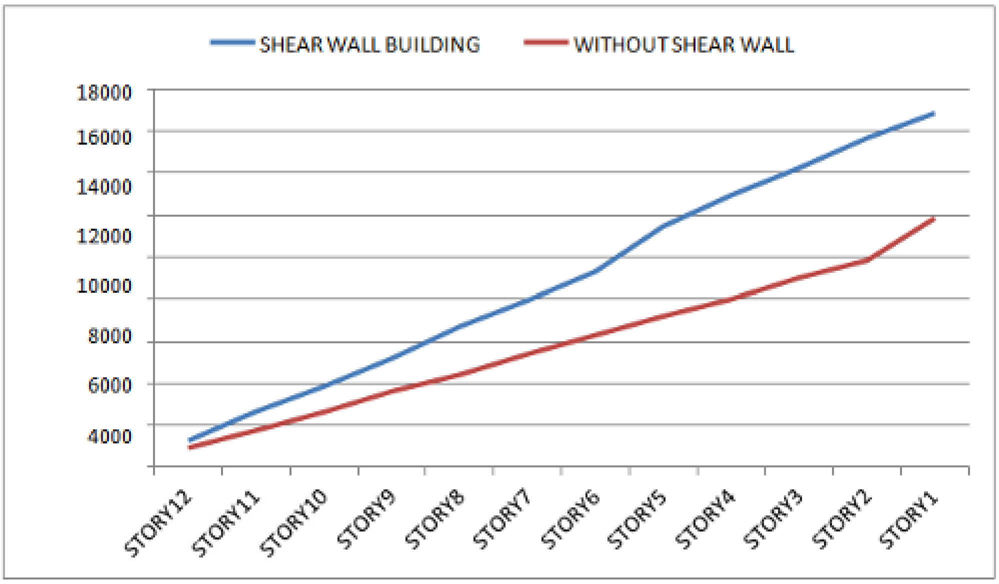
Graph 7.3(l) Axial force Comparison (Story-1)

Axial force comparison for column C1



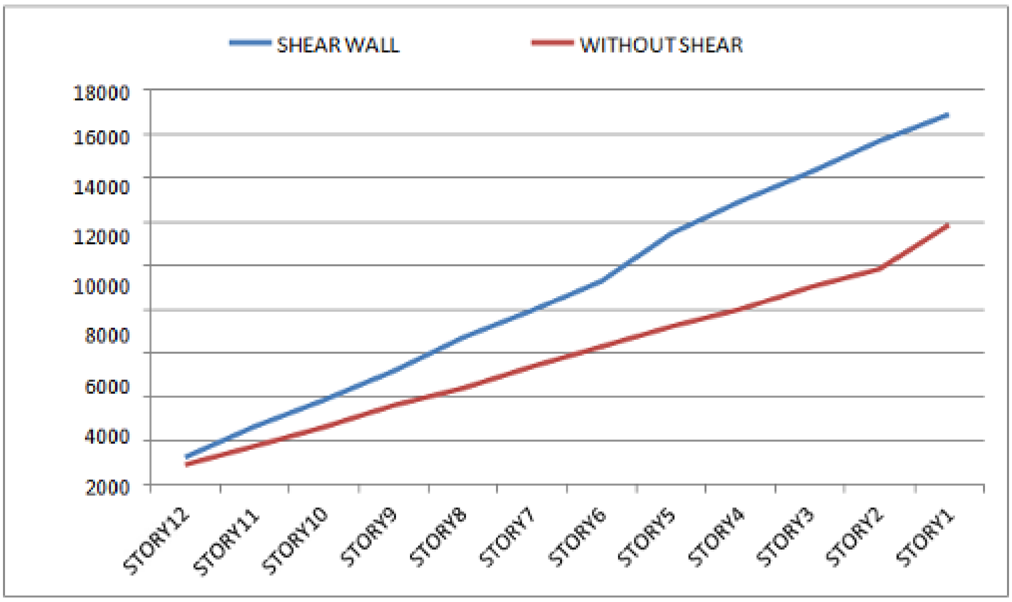
Graph 7.3 (m) axial force in column C1

Axial force comparison for column C2



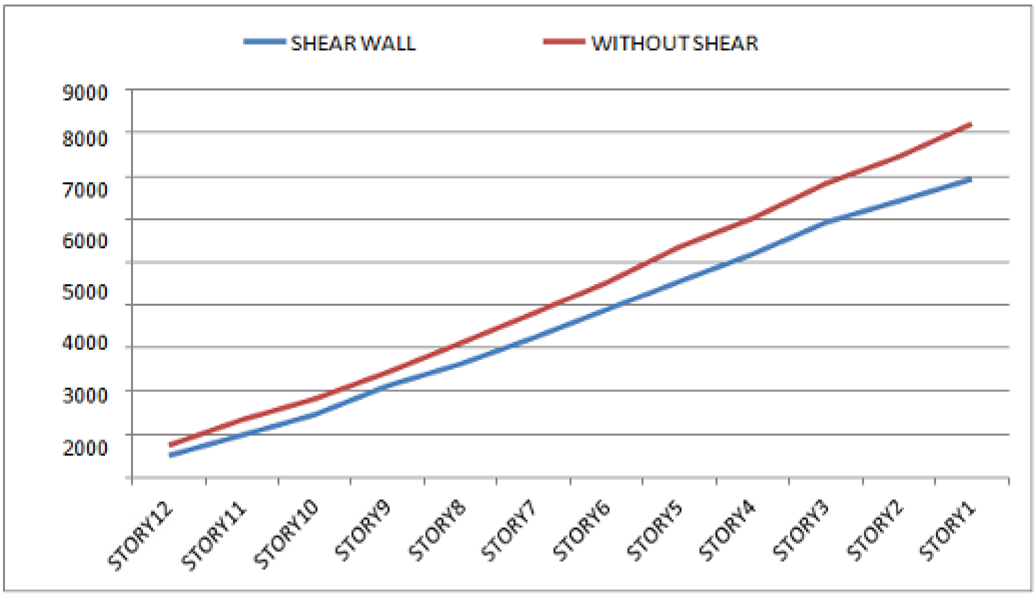
Graph 7.3(n) axial force in column C2

Axial force comparison for column C3



Graph 7.3(o) axial force in column C3

Axial force comparison for column C4



Graph 7.3(p) axial force in column C4

Result of Graph:-

1. Graphs clearly shows that axial force of building without shear wall is more than as compaired to shear wall building for column C1 and C4.
2. Graphs clearly shows that axial force of shear wall building is more than as compaired to building whiout shear wall for column C2 and C3.
3. Graphs clearly shows that due to symetry Axial force of shear wall building and without shear wall building for column C1 and C4 are approximately equal.
4. Graphs clearly shows that axial force are linearly increase from story 12 to story 1.
5. Graphs clearly shows that Axial force of shear wall buiding and without shear wall building for column C2 and C3 are approximately equal.

8. CONCLUSIONS AND FUTURE SCOPE

Lateral response of multi storied building is studied by dynamic analysis. Dynamic characteristics of the same building are compared with shear wall building. Change in axial force, shear force, bending moment, seismic base shear and building drift due to change in zone factor and soil conditions are studied.

8.1. Conclusion

1. Quantity of Concrete and steel required in shear wall building is more as compared to without shear wall building, which makes, it uneconomical.
2. Base shear of building without shear wall is less than the base shear in shear wall building for all types of soil and all earthquake zones.
3. Building drift for all storey of without shear wall building is about 34 % more than that of shear wall building.
4. Considering building drift, without shear wall building becomes unsafe for seismic zone V.
5. Both building deflect more in seismic zone V.
6. Axial force of building without shear wall is more than as compaired to shear wall building for column C1 and C4.
7. Graphs clearly shows that axial force of shear wall building is more than as compaired to building whiout shear wall for column C2 and C3.
8. Graphs clearly shows that due to symetry Axial force of shear wall building and without shear wall building for column C1 and C4 are approximately equal.
9. Graphs clearly shows that axial force are linearly increase from story 12 to story 1.
10. Graphs clearly shows that axial force of shear wall buiding and without shear wall building for column C2 and C3 are approximately equal.

8.2. Future Scope

Present work is related to a specific plan. It can be modified with respect to following plan.

1. Plan selected is rectangular, simple and without opening. Opening in the shear wall and slab. Considerably affects the behavior of the building. So by providing opening in wall and slab, change in behavior can be studied.
2. Study of effect of plan irregularities on behavior of building. Since structure with, irregular arrangement of columns, re-entrant corners are mostly used in practice.

3. Study of shear wall using Pre-stressed and post tensioning modeling.
4. Behavior of conventional building and shear wall in building can be compared and behavior of slab during lateral loads can be studied
5. Behavior of Flat slab building and shear wall in building can be compared and behavior of slab during lateral loads can be studied

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