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DESIGN AND SEISMIC RESPONCE OF HIGH RAISE RCC BUILDING WITH DIFFERENT ZONES WITH SHEAR WALLS

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ABSTRACT:
Shear wall systems are one of the most commonly used lateral load resisting systems in high-rise buildings. Shear walls have very high in plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous in many structural engineering applications. There are lots of literatures available to design and analyze the shear wall. However, the decision about the location of shear wall in multi-storey building is not much discussed in any literatures. In this paper, therefore, main focus is to determine the solution for shear wall location in multi-storey building. In this study, a G+ 10 storeyed reinforced concrete (RC) building with varying ground slope as 0º, 5º, 10º, 15º and 20º without shear walls and incorporating shear walls symmetrically in plan and at peripheral corners have been considered for the analysis. Buildings are designed as per IS 456:2000 and later subjected to earthquake loads. The modelling and analysis of the building has been carried by Liner Static, Linear Dynamic analysis (Response Spectrum and Linear Time History analysis) using structure analysis tool SAP 2000. The main objective is to understand the behaviour of the building on sloping ground for the effect of varying height of the column in bottom storey and various positions of shear walls and to study the effectiveness of shear wall on sloping ground.

Keywords: Shear seismic strength, linear static method, shear failure, nonlinear static analysis.

1. INTRODUCTION:

Generally shear wall can be defined as structural vertical member that is able to resist combination of shear, moment and axial load induced by lateral load and gravity load transfer to the wall from other structural member. Reinforced concrete walls, which include lift wells or shear walls, are the usual requirements of Multi Storey Buildings. Design by coinciding centred and mass centre of the building is the ideal for a Structure. An introduction of shear wall represents a structurally efficient solution to stiffen a building structural system because the main function of a shear wall is to increase the rigidity for lateral load resistance. In modern tall buildings, shear walls are commonly used as a vertical structural element for resisting the lateral loads that may be induced by the effect of wind and earthquakes which cause the failure of structure as shown in figure Shear walls of varying cross sections i.e. rectangular shapes to more irregular cores such as channel, T, L, barbell shape, box etc. can be used. Provision of walls helps to divide an enclose space, whereas of cores to contain and convey services such as elevator. Wall openings are inevitably required for windows in external walls and for doors or corridors in inner walls or in lift cores. The size and location of openings may vary from architectural and functional point of view. The use of shear wall structure has gained popularity in high rise building structure, especially in the

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construction of service apartment or office/ commercial tower. Earthquakes demonstrate vulnerability of various inadequate structures, every time they occur. The lessons taught from the aftermath of earthquakes and the research works being carried out in laboratories give better understanding about the performance of the structure and their components. Damage in reinforced concrete structure was mainly attributed to the inadequate detailing of reinforcement, lack of transverse steel and confinement of concrete in structural elements. Typical failures were brittle in nature, demonstrating inadequate capacity to dissipate and absorb inelastic energy. This necessitates a better understanding of the design and detailing of the reinforced concrete structures under various types of loading. In modern tall buildings, shear walls are commonly used as a vertical structural element for resisting the lateral loads that may be induced by the effect of wind and earthquakes.

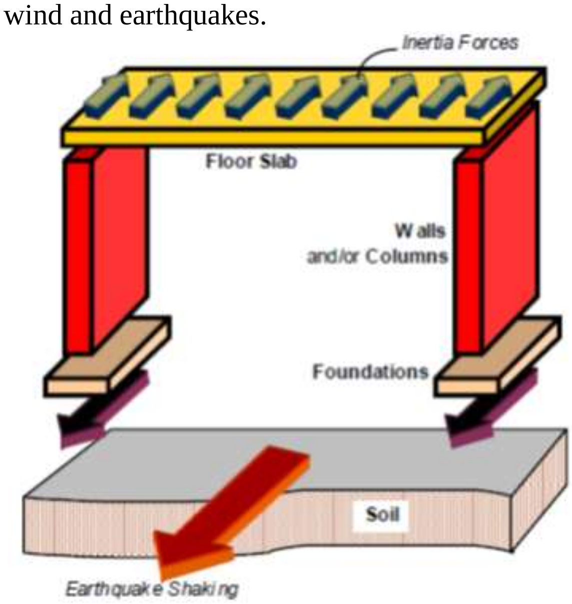

Fig.1.1. Flow of seismic inertia forces.

2. RELATED STUDY:

An earthquake may be defined as a wave-like motion generated by forces in constant turmoil under the surface layer of the earth (the lithosphere), travelling through the earth's crust. It may also be defined as the vibration, sometimes violent, of the earth's surface as a result of release of energy in the earth's crust. This release of energy can be caused by sudden dislocations of segment of the crust, volcanic eruptions or even explosions created by humans. Dislocations of crust segments, however, lead to the most destructive quakes. In the process of dislocation, vibrations called seismic waves are generated.

The present buildings, which were designed and constructed according to earlier code provisions, do not satisfy requirements of current seismic code and design practices. Therefore it is essential to safe unacceptable hazards to property and life of occupants, posed during future expecting earthquake. The safety of hazards is possible by means of seismic evaluation and performance, retrofitting of inadequate existing building structures. Framed buildings are getting pace in sloped areas particularly in hills, because of increased population and the land value. And thus, many of them are constructed on slopes and curved grounds. Shear walls meeting each other at right angles result in flanged configurations and are referred to as flanged walls. In such cases, a portion of the intersecting wall can be treated as a flange of the shear wall (e.g., as an I-section or a T-section). Such walls are normally required to resist earthquake forces in both principal directions of the building. The flanges will considerably boost the moment capacity of tall cantilever shear wall. Hence the shear resistance of their webs may become a critical design item. The large demand for web reinforcement can be conveniently met by using steel with higher yield strength. Efficiency of shear walls is described in terms of rigidity (or stiffness). Solid shear walls are most efficient so it is highly desirable. Often openings are required in shear walls for functional necessity (e.g., doors and windows); such walls are referred to as perforated (i.e., wall with openings). The portion of a shear wall between two adjacent openings is called a pier, whereas, the segment of shear wall above the adjacent openings is called a spandrel or a beam. A shear wall with openings can be analysed as a frame composed of short stiff wall segments (also called piers). In many shear walls, a regular pattern of windows or doors, or both, is required for functional considerations. In such cases, the walls between the openings may

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be interconnected by spandrels (or beams), resulting in coupled shear walls. The connecting elements (i.e., beams) between coupled shear walls typically require horizontal and vertical reinforcement to transfer shear from one segment of the wall to the other. When the connecting elements are incapable of transferring shear from one shear wall to the other, the walls are referred to as non-coupled and can be analysed as cantilevers fixed at the base.

3. METHODOLOGY:

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. 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. 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. Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. 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.

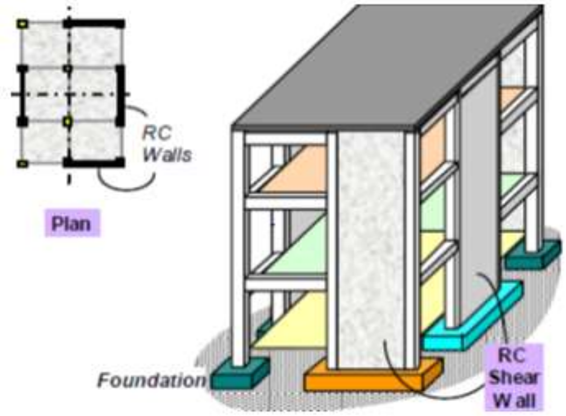

Fig.3.1. Reinforced shear walls in buildings.

Earthquake or seismic analysis is a subset of structural analysis which involves the calculation of the response of a structure subjected to earthquake excitation. After selecting the structural model, it is possible to perform analysis to determine the seismically induced forces in the structures. The analysis can be performed on the basis of the external action, the behaviour of the structure or structural materials and the type of structural model selected. The analysis of the process can be classified as linear static analysis, linear dynamic analysis, non- linear static analysis and non linear dynamic analysis. In this chapter linear static analysis, response spectrum and linear time history are discussed. The models for analysis are generated through the structural software SAP 2000 and analysis is carried by three analysis methods, i.e., linear static analysis, response spectrum analysis and linear time history analysis. The design of buildings to resist earthquakes involves controlling the damage to acceptable levels at a reasonable cost. Earthquake-resistant design is therefore concerned about ensuring that the damages in buildings during earthquakes are of the acceptable variety, and also that they occur at the right places and in right amounts. Ductility is one of the most important factors affecting the building performance. Thus, earthquake-resistant design strives to predetermine the locations where damage takes place and then to provide good detailing at these locations to ensure ductile behaviour of the building.

Seismic codes are unique to a particular region or country. In India, IS 1893(Part 1):

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2002 is the main code that provides outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests, and its ductility. IS 1893(Part1):2002 deals with assessment of seismic loads on various structures and buildings. Depending on the height of the structure and zone to which it belongs, type of analysis i.e., static analysis or dynamic analysis is performed. Basic theory includes the idealization of whole structure into a lumped mass at each floor level. Quite a few methods are available for the earthquake analysis of buildings; two of them are presented here:

1. Linear static analysis
2. Linear dynamic analysis
   i. Response spectrum method.
   ii. Linear Time history method.

LINEAR STATIC ANALYSIS

In the equivalent static method, the lateral force equivalent to the design basis earthquake is applied statically. The equivalent lateral forces at each storey level are applied at the design ‘centre of mass’ locations. It is located at the design eccentricity from the calculated ‘centre of rigidity (or stiffness)’.

$$V_b = A_h W$$

DYNAMIC ANALYSIS:

Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

Regular buildings: Those greater than 40m in height in zones IV and V, those greater than 90m in height in zone II and III.

Irregular buildings: All framed buildings higher than 12m in zones IV and V, and those greater than 40m in height in zones II and III.

4. EXPERIMENTAL ANALYSIS:

Only seldom will a single cantilever wall be called upon to resist the whole of the lateral load acting upon a multistorey structure. It is more 1ikely that a number of such walls wi1l share in the total load resistance. In the majority of multistorey buildings shear wal1s wi1l occur around the service core and rigid jointed frames are likely to carry the gravity load over the remainder of the floor. The response of rigid jointed frames and cantilever shear walls to lateral loads can be so markedly different, particularly in the upper storeys, that undesirable interaction may ensure. The two types of structures may work against each other, and an unusually large ductility demand may possibly result in the process of developing the ultimate strength of the whole structure. Most of the seismic codes recommend an equivalent static procedure for the design of regular buildings where the design base shear is calculated as a fraction of the seismic weight, based on factors such as seismic zone, importance of the building, design ductility, fundamental natural period and type of soil.

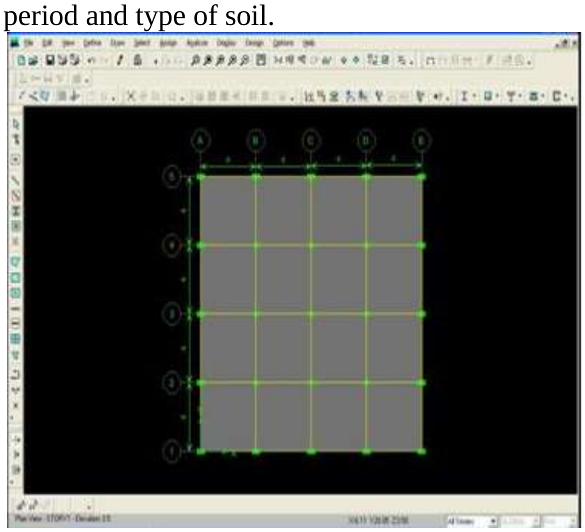

Fig.4.1. Model of Building without shear wall

When shear walls are strong enough, they will transfer these horizontal forces to the next element in the load path below them. These other components in the load path may be other shear walls, floors, foundation walls, slabs or footings. Shear walls also provide lateral stiffness to prevent the roof or floor above from excessive side-sway. When shear walls are stiff enough, they will prevent floor and roof framing members from moving off their supports. Also, buildings that are sufficiently stiff will usually suffer less non-structural damage.

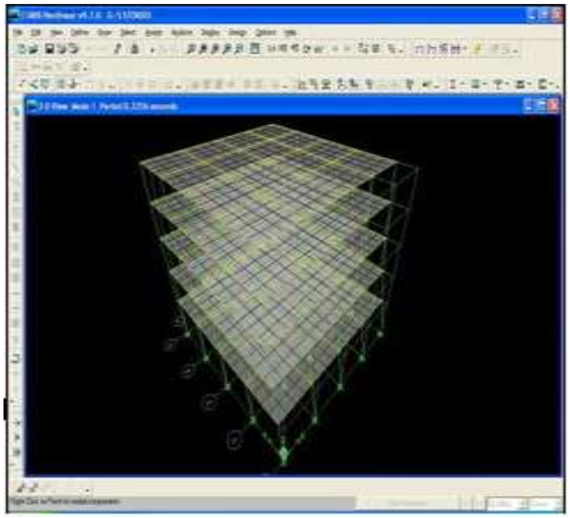

Fig.4.2. Model I: Structure without shear wall.

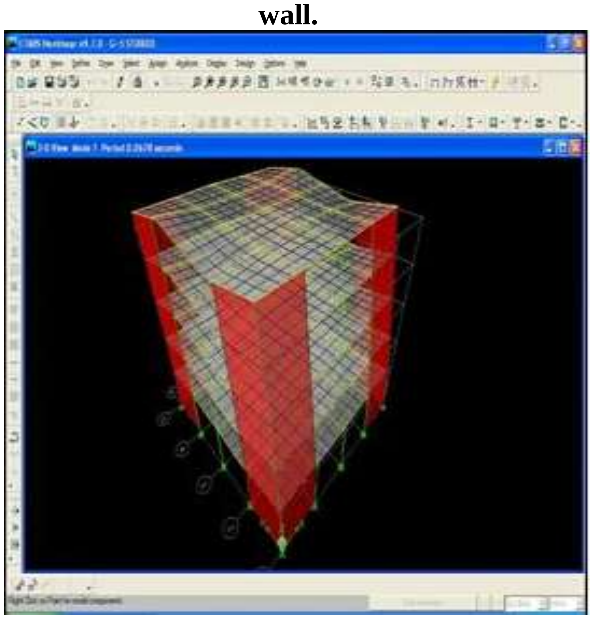

Fig.4.3. Structure with L type shear wall.

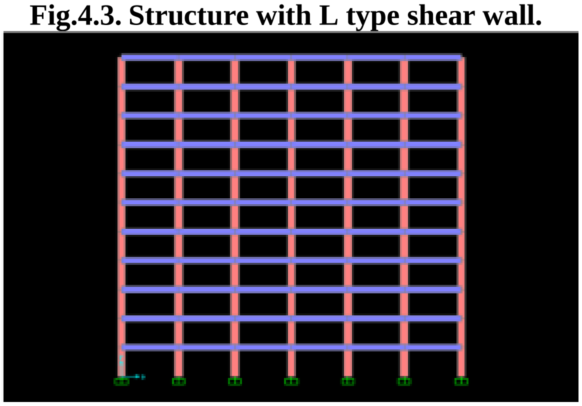

Fig.4.4. Building model without shear wall on plane ground.

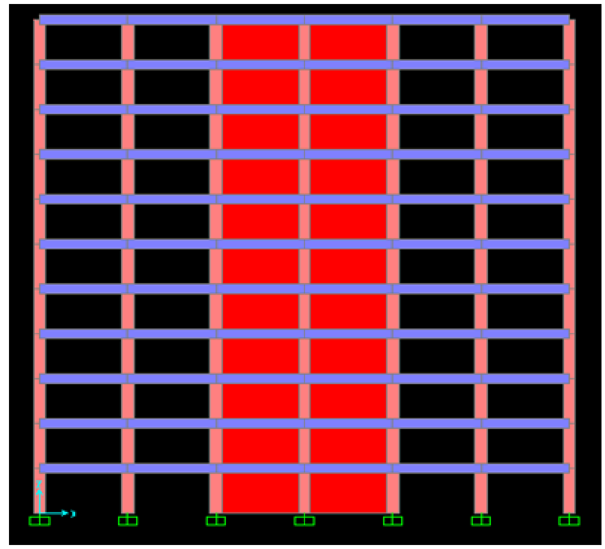

Fig.4.5. Building model with shear walls provided symmetrically in plan on plane ground.

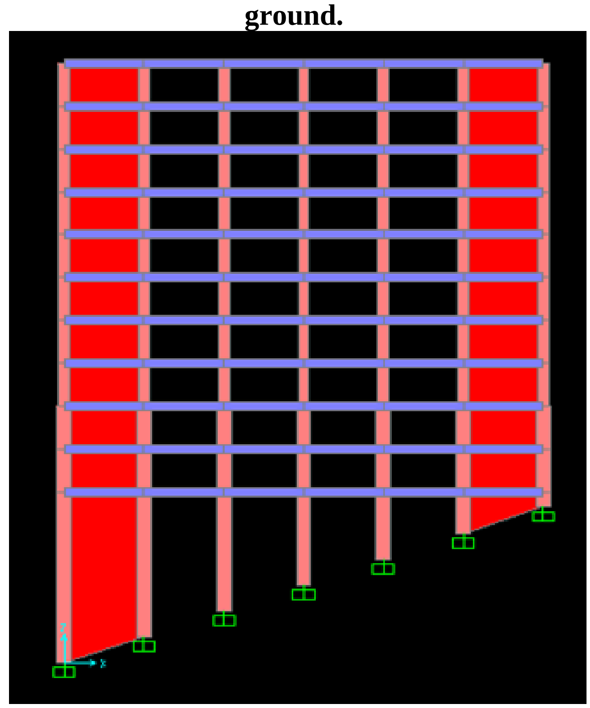

Fig.4.6. Building model with shear walls provided at peripheral corners on 20º slope ground.

The displacements for the building resting on flat ground are found to be relatively higher than the building resting on sloped ground. As the slope of the ground is increasing the displacements in the building are getting reduced.

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Storey level	Step back building without providing shear walls(mm)				
	0°	5° slope	10° slope	15° slope	20° slope
10	20.23	13.99	16.26	13.65	10.68
9	19.51	13.51	15.63	13.25	10.29
8	18.39	12.75	14.62	12.61	9.67
7	16.87	11.71	13.24	11.74	8.82
6	15.03	10.44	11.55	10.66	7.77
5	12.95	8.99	9.61	9.42	6.55
4	10.68	7.41	7.50	8.04	5.20
3	8.29	5.73	5.28	6.56	3.77
2	5.85	4.02	3.10	5.00	2.33
1	3.42	2.53	1.38	3.59	1.15
0	1.23	1.18	0.19	2.21	0.25

Fig.4.7. Displacement for buildings without providing shear walls in X Direction.

It is observed that building on plane ground without providing shear walls are having relatively higher displacements when compared to buildings with shear walls placed at different locations. When the shears walls are provided symmetrically in plan, displacements are reduced compared to building with shear walls provided at peripheral corners.

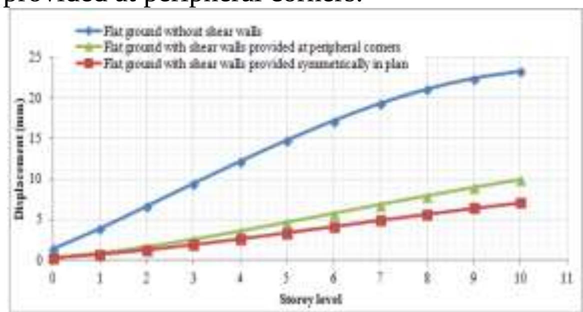

Fig.4.8. Displacements in Y-direction of buildings resting on flat ground without shear wall and with shear wall.

5. CONCLUSION:

Short columns are the most critical members for the building on the slope ground. To have a good control over the forces such as shear force and bending moment, it is preferable to locate the shear wall towards the shorter column side. Time period of vibration for building with shear walls located towards shorter column is found to be least than any other location. There is a significant improvement in seismic performance of building on slopes by providing shear walls with different configurations since storey displacement, storey drifts and bending moments reduces considerably in building due to provision of shear walls. It is observed that the displacements are getting reduced when the shear walls are provided symmetrically in plan and as the sloping angle is increasing there is a decrease in displacements. The displacements in Linear Static analysis are relatively higher compared to the displacements in Response Spectrum analysis. There is a large increase in the displacements in Linear Time History Analysis compared to the Linear Static and Response Spectrum analysis.

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