Seismic Analysis of Assymetrical Multistoried R.C. Structures Using Shear Wall In Severe Seismic Zones as Per Is 1893:2016 – A Review

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Abstract— 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. Structures must perform safely when subjected to numerous types of loading while still remaining aesthetic and fully functional. The nature of shear wall design in building structures is a difficult task, particularly if one wants to place the shear walls in such a way that the cost is minimal while still satisfying specific performance objectives when subjected to natural and human-induced loads. This study was conducted to study the effects of shear wall in the multi-storey buildings for different height, study on nodal displacement and storey drift of the building for different cases been carried out. Nodal displacement of stories and storey drift under consideration were evaluated using structural analysis software in accordance with IS 456:2000, IS 1893:2016 and IS 13920.

Keywords: Shear Wall, Assymetrical Building, RC Structures, Storey Drift, Displacement, IS1893:2016

I. INTRODUCTION

Almost 80% of about 1 million deaths turn out to have been caused by just ten great earthquakes, together affecting a tiny proportion of the territory at risk from heavy ground shaking.

Is my building safe against earthquakes? This is a question that everybody should be concerned about. Many earthquakes have taken place recently in India and its neighborhood [e.g., Uttarkashi (1991), Latur (1993), Jabalpur (1997), Bhuj (2001), Sumatra and Andaman Islands (2004), Kashmir (2005)] (Fig.- 1.1 & 1.2) , and these have proved to be disastrous. A large number of buildings have collapsed and countless lives have been lost. There is usually a huge public outcry after every disaster. But public memory is short lived, and people tend to forget, until another major tremor occurs to wake them up. When and where will that quake happen? Nobody can predict this. But when it comes one day, unexpectedly, it destroys our buildings and takes our lives.

An earthquake is a sudden motion or shaking of the Earth's crust, caused by the abrupt release of slowly accumulated strain stored in the rocks beneath the surface. An earthquake is an oscillatory movement produced due to release of strain energy below or within the crust of earth surface. It generates elastic vibration or waves which movement all direction from the point of origin and cause earthquake. No building can remain entirely free of damage during quake, still, all houses, big or small; can be made to withstand earthquakes of a particular magnitude by taking certain precaution. Building collapses as a result of inertia forces. During an earthquake the lower portion of a building tends to vibrate, as it is indirect contact with ground. The forces of inertia however keep upper position static.

There are four basic causes of earthquake:
1) Ground shaking
2) Ground failure
3) Tsunamis
4) Fire.

To design a structurally safe building, it is necessary to find the load taken by each component, so that each component can be design accordingly. For that reason structural analysis is needed. The next stop is to proportion the components such that the criteria for the stresses and deflection. In high-rise buildings the consideration of deflection due to lateral load becomes particularly important. For this reason it is necessary to provide adequate lateral stiffness can be provided by using various specially designed structural systems. In such a system, the high in-plane stiffness of the shear walls is employed to resist the lateral loads.

A. Special Systems to Resist Lateral Load

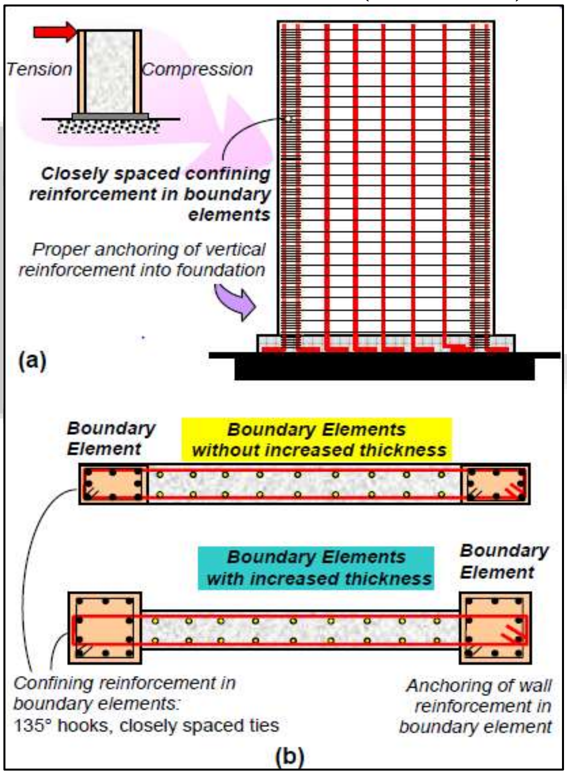
In tall buildings lateral loads are premier one which will increase rapidly with increase in height. The design takes care of the requirements of strength, rigidity and stability. The structural system designed to carry vertical load may not have the capacity to resist lateral load or even if it has, the design for lateral load will increase the structural cost substantially with increase in number of storey.

To achieve economy in tall buildings special systems to resist lateral load should be adopted. Some of the systems are:-
1) Moment Resistant Frames
2) Shear Wall Structures
3) Braced Frames
4) Tube Structures
5) Multi-Tube Structures.

B. Shear Walls

One of the most popular methods of strengthening of seismically deficient structure is to provide shear walls. “Shear walls” are defined as vertically oriented wide beams that carry earthquake loads to the foundation. These are slender vertical cantilever RC walls resisting the lateral load with or without frames. RC walls are often introduced into multistory buildings at certain locations to resist lateral forces when frame systems alone are insufficient. The term “shear wall" covers elevator shafts, stairwells and central core units, in addition to plane walls. Shear walls acting with frames increase the rigidity for lateral load resistance. When walls are situated in advantageous position in a building, they can be very efficient in resisting lateral loads originating from wind or earthquake.

Analysis for lateral loads of buildings containing shear walls is generally carried out by assigning all lateral loads to the shear walls, since it is felt that the very big difference in stiffness between the shear walls and the frame would cause the shear walls to attract the total lateral loads. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear walls are easy to construct because reinforcement detailing of walls (Shown in Fig.-1.11) is relatively straight-forward and therefore easily implemented at site. The general method of providing a shear wall is to fill the gaps between columns of the moment resisting frame with partial or complete reinforced concrete wall is termed as Internal Shear Wall (Buttress Wall).



C. Purpose of Constructing Shear Walls

Shear walls are not only designed to resist gravity / vertical loads (due to its self-weight and other living / moving loads), but they are also designed for lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors (diaphragms) and other lateral walls running across at right angles, thereby giving the three dimensional stability for the buildings structures. Shear wall structural systems are more stable. Because, their supporting area (total cross-sectional area of all shear walls) with reference to total plans area of building, is comparatively more, unlike in the case of RCC framed structures. Walls have to resist the uplift forces caused by the pull of the wind. Walls have to resist the lateral force of the wind that tries to push the walls in and pull them away from the building.

There are different types of shear walls such as given below:-

- Cantilever shear walls
- Flanged cantilever shear walls
- Coupled shear walls
- Shear wall with openings
- Box system

D. Parameters Influencing the Response of Shear Walls

- Height to Width Ratio
- Type of Loading
- Flexural Reinforcement
- Shear reinforcement
- Diagonal Reinforcement
- Special Transverse reinforcement
- Concrete Strength
- Construction Joint
- Axial Compressive stress
- Moment to Shear Ratio.

II. LITERATURE REVIEW

The design of these shear wall for wind are design as simple concrete walls. The design of these walls for seismic forces requires special considerations as they should be safe under repeated loads. Shear walls may become imperative from the point of view of economy and control of lateral deflection. There are lots of literatures available [Cardan, B. (1961), Syngellakis et al. (1991), Wight et al. (1991), Qiusheng et al. (1994), White et al. (1995) and Rosowsky, D.V. (2002)] to design and analyze the shear wall. However, any of these literatures did not discuss much about the location of shear wall in multi-storey building. Some of the studies have been reviewed on this topic as follows:

1) G. Jaeger et al. (1973) have done the Structural Analysis of Tall Buildings Having Irregularly Positioned Shear Walls and an analytical theory for the analysis of tall three dimensional multiple shear wall buildings is developed. The basis of the theory is the continuum approach in which the floors of the building are replaced by an equivalent continuous Medium.
2) V. Singh (2005) concludes that the shear wall at the outermost frame is most economical & safe for Asymmetrical multistory building in hilly area. From the study he also conclude that least displacement and drift for the earthquake from both the direction occur when the shear wall are placed at outer most frame of the building (9 stories) in hilly area.
3) Ashraf et al. (2008) carried out a study to determine the optimum configuration in location of shear wall (lift core) in a multistory building and concluded that shear wall should be placed at a point by coinciding center of mass and center of rigidity of the building.
4) M.Y. Kaltakci et al. (2008) formed an experimental program in order to evaluate the performance of the external shear wall application. In the experimental schedule, four reinforced concrete test specimens are produced by using the design and detailing data of the considered school buildings. According to these tests, the

strengthening and system improvement performed through adding external reinforced concrete shear wall to the reinforced concrete buildings will add improved behaviour, strength and rigidity to the system with its low cost besides the ease of construction and application.

5) M.Y. Kaltakci et al. (2010) study the importance of the strengthening process (comparison in terms of applicability, usability and cost) using Shear Walls (SW) in RC buildings of poor earthquake performance and an experimental study also carried out to analyze the influence of the location of a SW on the existing system. And conclude that ESW (External Shear Walled) type was expected to display a higher horizontal load bearing capacity than that of the PISW (Partial In filled Shear Walled) type, the PISW type presented higher horizontal load bearing and lower horizontal displacement with respect to the ESW type, during the tests.
6) During the application of the ESW type, the existing column contributed to the performance, since it was located at the end point, and the SW worked monolithically with the exterior column of the frame. In both strengthening methods, any serious damage was not observed on the frame elements until the maximum horizontal load level was reached.
7) Anshuman S. et al. (2012) focused on the solution for shear wall location in multistory building based on its both elastic and elastic-plastic behaviors.
8) H. Kaplan et al. (2013) studied a new strengthening alternative for RC structures, namely exterior shear walls, has been experimentally investigated under reversed cyclic loading. Using the proposed technique, it is possible to strengthen structures without disturbing their users or vacating the building during renovation. Post attached exterior shear walls behaved as a monolithic member of the structure In this technique, shear walls are installed in parallel to the building‟s exterior sides. It has been observed that the usage of exterior shear walls considerably improve the capacity and sway stiffness of RC structures.
9) M.Y. Kaltakci et al. (2014) The results of the experimental tests and analytical studies showed that the RC external shear wall improved the seismic character of the existing RC frame as much as RC infill walls, therefore this method can be used as an alternative strengthening method. Also, the method provides effective, practical and economical strengthening that minimizes the need for additional works and does not restrict the use of the RC building.
10) Venkatesh and Bai (2015) attempt to study the difference in structural behavior of 3- dimensional (3D) single-bay three- bays 10 storey basic moment resisting RC frames when provided with two different types of shear walls as lateral load resisting system (LLRS). And he concluded that the provision of both external and internal shear walls effectively reduce large joint displacements found in bare frame. Change in column size / orientation gives rise to varying forces in support reaction and forces in structural members. Provision of external and internal shear walls in general results in reducing support reactions and member forces, but may give rise to additional forces such as shear force and torsional moment in columns and beams which need to be accounted for during design. Thickness of shear wall does not have much influence on the member forces or stresses of the structure. Even though the performance of internal shear walls is better that external shear walls, External shear walls serve as an alternative to internal shear walls in retrofitting seismically deficient structures particularly when it is not possible to vacate the building during retrofitting.
11) A. Chandiwala (2016) analysis of the different position of shear wall in the "L" Shape (Plan) building configuration and the comparison in maximum base shear in X & Y-direction has been done. From the analysis of the building configuration, it is concluded that shear wall at end of the "L" Plan building is best suited due to end stiffness for the base shear during earthquake.
12) Agrawal and Charkha (2017) from preliminary investigation reveals that the significant effects on deflection in orthogonal direction by the shifting the shear wall location. Placing Shear wall away from centre of gravity resulted in increase in most of the members forces. Location of shear wall effects on static and dynamic axial load on the column. The displacement of building is uni-directional and uniform for all the grids in the case of Zero eccentricity for seismic loading. With the increase in eccentricity, the building shows non-uniform movement of right and left edges of roof due to torsion and induces excessive moment and forces in member.
13) Karamlou and Kabir (2018) research conduct to assess behavioural aspects of an L-shaped shear wall constructed with this system. Two levels of confinement were applied to the specimens by using additional confining hoops and the panel‟s spot welded crossties. All the specimens exhibited a flexural mode of failure characterized by a crushing of the boundary elements. However, the occurrence of the web crushing phenomenon was shown to decrease the stiffness, strength and ductility and increase the rotation of the walls. Higher flexural strength of the walls in one direction against the other and the application of large inelastic lateral loads were important factors in increasing the possibility of web crushing.
14) The aim of the research was to evaluate the behaviour of a wall with an asymmetric cross section and to assess characteristics including the walls‟ cracking pattern, strength, failure, post failure mechanisms, and rotation. In addition, the performance of spot welded crossties in confining the concrete and in preventing vertical rebars from buckling has been studied.
15) P. S. Kumbhare and A. C. Saoji (2018) investigated the effectiveness of RC shear wall in medium rise building. And found shear wall frame interaction systems are very effective in resisting lateral forces induced by earthquake. For residential building shear walls can be used as a primary vertical load carrying element, thus serving the load and dividing space. The frame type structural system become economical as compared to the dual type structural system can be used for medium rise residential building situated in high seismic zone.

16) Rahangdale and Satone (2019) investigate that Different location of shear wall effect on axial load on the column. In absence of shear wall axial load and moments are maximum on column. And by constructing shear walls damages due to effect of lateral forces due to earthquake and high winds can be minimized.
17) S.J. Sardar et al. (2019) Investigated that in case of shear wall at exterior corners the structure is subjected to less displacement against the structure with shear wall at Centre.
18) BK raghuprasad, Vinay s amarnathK (2020) represented seismic analysis of buildings symmetric and asymmetric in plan. In this paper, efforts were made to check torsional effect in asymmetric plan building. They modelled the frame in two ways fist one is spring model and second one is column model in spring model column replaced by spring. By dynamic analysis of structure they concluded that natural frequency of asymmetric spring model is greater than of symmetric spring model. Maximum displacement occurs in asymmetric spring model as compared to symmetric spring model the base shear is also more than the symmetric spring model.
19) Desai RM, khurd V.G, patil SP, Bavane N.U(2020) presented paper on" Behavior of symmetric and asymmetric structure in high seismic zone". In this paper they modeled three building G+3,G+6 and G+9 and effort is made to study the effect of eccentricity between centre of mass and centre of rigidity .By sap 2000 commercial software they analyzed as low rise mid rise and high rise building they concluded that symmetrical building has more time period as compared to asymmetrical building .Natural time period increases as height increases The time period of high rise is more as compared to low rise and mid rise building The time period decreases as the no of storey decreases.
20) G.V.S. Siva Prasad Dr.P.Jyotsna devi Manikanta Patnaik (2020) This study aims to determine the differences in seismic performance of Symmetric and Asymmetric structures in vertical geometric irregularities. Models of square-shaped, G+25 storied buildings are considered for analysis in STAAD Pro software. From the static and dynamic analyses of these models, various parameters like storey shear, base shear, storey drift and natural period have been calculated and compared. It is concluded that symmetrical structures are superior to asymmetric structures in view of resistance against seismic forces.
21) Kamalroop Kaur, Balwinder Singh (2021) In this paper the correlation of seismic behaviour of G+15 story structures having plan irregularities was finished utilizing ETAB programming. For this reason different multi-storey structure plans are viewed as that are regular plan without shear wall, regular plan with shear wall, L shape without shear wall, L shape with shear wall, irregular plan of C shape without shear wall, irregular plan of C shape with shear wall structures. For the correlation, boundaries taken are displacement, story float and storey-shear. Every one of the six structures was dissected for zone V. The fundamental objective is to contemplate the behaviour of both symmetric and Asymmetric structures during seismic tremor having abnormalities in plan but the plan area is same. The another aim of the study is to examine the taken boundaries like storey shear, storey displacements, Maximum storey float of all structures that are build in this paper during seismic tremor and also to study the impact of shear wall on the behaviour of different structures.

A. Concluding Remarks

On the basis of the above previous studies, The following location of the shear wall has been selected for the program formulation:

1) Locate the shear wall externally.
2) Locate the shear wall at core or near core area.
3) Locate the shear wall at corner of the building.

III. CONCLUSION

Earthquake causes shaking of ground, which results in activation of inertia forces. This inertia force so generated is a function of mass of the building and is primarily located on the floors and is transferred to the soil system underneath through walls and columns. Walls and columns are most critical elements in transferring the inertia forces. Earthquake induces ground motion in all three directions but along the horizontal directions (X and Z, - X and - Z) is of utmost importance.

The horizontal twisting of building occurs due to lateral loads, when centre of mass and center of rigidity of structures do not coincide. Therefore building configuration should be such that minimum torsional moments are developed due to horizontal twisting of structure in addition to normal seismic force.

To investigate the Effect of shear wall position in a building by changing it location and find out its effectiveness during earthquake on the bases of Nodal Displacement, Storey drift and used steel quantity for the asymmetric building. This study was conducted to develop a methodology for performance- based design of asymmetric building by investigating the performance of different location of shear wall in asymmetric building.

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