Study of Irregular Shear Wall in Reinforced Concrete Structures – A Review

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Abstract— Urbanization has been lead to housing troubles. This has resulted in the rise of several Multi-storied and high rise buildings. Hence Structural Dynamics study has been steadily increasing over the years. The modern trend is towards tall and slender structures which have been designed as irregular due to innovative and architectural aspect. These buildings are affected by environmental factors like wind, earthquake and waterways. Millions of people world-wide annually die due to earthquakes which are responsible for billions of rupees of property damage. This has necessitated the study of Earthquake Engineering. However, study and research in the field of Irregular Buildings under seismic conditions is gaining momentum. The provision of shear wall in building has been found effective and economical. Shear walls are structural members used for providing strength of RCC (Reinforced Cement Concrete) structures against seismic load. Their very high in-plane stiffness and strength makes them ideally best for using in tall structure. They act as vertical cantilevers in the form of separate planer wall. In this paper, the behavior of the structures with and without shear wall has been studied having different types of vertical irregularities. This study concludes the research has been required to get economical & efficient lateral stiffness system for high seismic prone areas. Also for optimization & design of high rise building with different structural framing systems subjected to seismic loads and to improve the understanding of the seismic behavior of building structures with vertical irregularities.

Key words: Base Shear, Multi-storey Buildings, Response Spectrum Analysis, Seismic loading, Shear wall-framed structures, Vertical Irregularity Stiffness, SAP2000

I. INTRODUCTION

Stability of earth is always disturbed due to internal forces which causes vibrations or jerks in the earth's crust known as an earthquake. Earthquakes which are unpredictable and a devastating natural disaster produces low - high waves which vibrate the base of the structure in various manners and directions, so that lateral force is developed on the structure. Oscillation / Vibration (motion which repeats itself after an interval of time) in structural systems results due to wind, earthquake, height etc. Dynamics is concerned with the study of forces and motions which are time dependent. When a structure is subjected to dynamic load, it starts vibrating resulting in the displacement of the structure. Seismic zones IV & V are high intensity earthquake zones. After the recent Bhuj earthquakes, tsunami in Indonesia, there is a growing interest in the process of designing civil engineering structures capable of withstanding dynamic (earthquake induced) loads. Shear walls are Concrete/masonry vertical walls serving both architecturally as partitions and structurally to carry gravity & lateral loading. Their very high in-plane stiffness and strength makes them ideally suited for bracing tall buildings. They are usually continuous down to the base to which they are rigidly attached to form vertical cantilevers.

II. REGULAR & IRREGULAR CONFIGURATION AS PER IS 1893:2002

Buildings having simple & regular geometry and uniformly distributed mass and stiffness in plan as well as elevation, suffer much less damage than buildings with irregular configurations. Irregular buildings are of two types.

A. *Plan Irregularities*

1) Torsion Irregularity,
2) Re-entrant Corners,
3) Diaphragm Discontinuity,
4) Non- parallel Systems

B. *Vertical Irregularities*

1) Stiffness Irregularity
2) Mass Irregularity
3) Vertical Geometric Irregularity
4) Discontinuity in Capacity – Weak Storey

Buildings are designed as per Design based earthquake (DBE), but the actual forces acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design approach is preferred as it narrows the gap. The primary objective in designing an earthquake resistant structure is to ensure ductility to withstand the earthquake forces.

III. SHEAR WALL

A shear wall is a structural system composed of braced panels known as shear panels. Shear panels are used to counter the effects of lateral load acting on a structure. In the centre of a large building a structure of shear walls often encasing an elevator shaft or stairwell form a shear core. Shear wall resist in plane loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector or drag member. They are built in wood, concrete and (masonry) .Plywood is the conventional material used in wood (timber) shear walls, but with advances in technology and modern building methods, other prefabricated options have made it possible to inject shear assemblies into narrow walls that fall at either side of an opening. Sheet steel and steel-backed shear panels in the place of structural plywood in shear walls has proved to provide stronger seismic resistance. A typical timber shearwall is to create braced panels in the wall line using structural plywood sheathing with specific nailing at the edges and supporting framing of the panel.

Shear walls are especially important in high rise building subject to lateral wind and seismic forces .Generally, shear walls are either plane or flanged in section, while core walls consist of channel sections. They also provide adequate strength and stiffness to control lateral displacement.

IV. Literature review

A brief review of previous studies on the application of shear wall under different structural configuration been enhanced here. This literature review also includes previous studies on vertical irregularities. This literature review on recent contribution related to analysis of irregular structure with shear wall.

Sayyed (2017) focused his study on the effect of infill and mass irregularity on different floor in RC buildings. The results were concluded that the brick infill enhances the seismic performance of the RC buildings and poor seismic responses were shown by the mass irregular building, therefore it should be avoided in the seismic vulnerable regions.

Salunkhe and Kanase (2017) investigated that response of mass irregular structure need to be studied for the earthquake scenario. In this paper researcher dealt with RCC framed structure in both regular and mass irregular manner with different methods of analysis.

Khan & Dhamge (2016) highlighted the effect of mass irregularity on different floor in RCC buildings with as Response Spectrum analysis using STAAD-Pro V8i software. In the project work seismic analysis of RCC buildings with mass irregularity 10 at different floor level were carried out. Models are compared with each other for response in terms of drift and deflection.

Mukundan (2015) Shear wall provision in building has been found effective and economical. A 10 storey building in Zone IV is tested to reduce the effect of earthquake using reinforced concrete shear walls in the building. The results are presented after analyzing model using ETABS software and RSA method is used. Researchers also studied results varying thickness of shear walls. It is concluded that shear walls are more resistant to lateral loads in regular/Irregular structure and for safer design, the thickness of the shear wall should range between 150mm to 400mm.

Sagar et al. (2015) analyzed the performance on various type of irregularity Considered i.e. (a) Horizontal Irregularity-plan irregularity (b) Vertical Irregularity - Mass Irregularity. To achieve objective of the project Time history Analysis & Response spectrum analysis method were carried out.

Venkata Sairam Kumar. N & et al (February 2014) carried out research mainly on application of cyclic load tests and behaviour of different types of shear walls in cyclic application of loads. Shear walls can be used as lateral load resisting Systems and also retrofitting of structures. Internal shear walls are more efficient than External shear walls when compared with cyclic load tests by researchers.

Ravikanth Chittiprolu, Ramacharla Pradeep Kumar, (June 2014) performed study on dynamic linear analysis using response spectrum method and lateral load analysis was done for structure with shear wall and structure without shear wall. Results were compared for the frame lateral forces and storey drifts of both the cases. It was inferred that shear walls are more resistant to lateral loads in an irregular structure. Storey drift is reduced in case of structure with shear wall. Also they can be used to reduce the effect of torsion.

Varsha R. Harne (2014) carried out a study to determine the strength of RC Shear wall of a multi-storied building by changing shear wall location. 3 different cases of shear wall position for a 6 storey building have been analyzed. Incorporation of shear wall has become inevitable in multi-storey building to resist lateral forces. Among all the load combination, the load combination of 1.5 DL + 1.5 EQX is found to be more critical combination for all the models. It was found that shear walls are more effective when located along exterior perimeter of the building. Such a layout increases resistance of the building to twisting.

Shaikh Abdul Aijaj, Abdul Rahman & Girish Deshmukh (2013), made attempts to investigate the proportional distribution of lateral forces evolved through seismic action in each storey level due to changes in stiffness of frame on vertically irregular frame. As per the Bureau of Indian Standard (BIS) 1893:2002 (part 1) provisions, a G+10 vertically irregular building was modelled as a simplified lump mass model for the analysis with stiffness irregularity at Fourth floor. To response parameters like story drift, story deflection and story shear of structure under seismic force under the linear static & dynamic analysis was studied. This analysis showed focus on the base shear carrying capacity of a structure and performance level of structure under severe zone of India. The result remarks the conclusion that, a building structure with stiffness irregularity provides instability and attracts huge storey shear. A proportionate amount of stiffness is advantageous to control over the storey and base shear. The soft computing tool and commercial software which was used was CSI-ETABS (version 9.7) for modelling and Analysis.

S.Kumbhare, A.C. Saoji (2012) had carried out study on the effect of seismic Loading on placement of shear wall in medium rise building at different alternative location. They found that frame type structural system becomes economical as compared to dual type structural system and can be used for medium rise residential building situated in high seismic zone.

Ashish S. Agrawal, S.D.Charkha (2012) carried out study on 25storey building in Zone V by changing various position of shear wall with different shapes for determining parameters like storey drift, axial load and displacement. From the results of analysis they came to a conclusion that placing shear walls away from centre of gravity resulted in increase in most of the member forces. Also they found that displacement of the building floor at storey 25 has been reduced due to the presence of shear wall place at the centre.

Y.M. Fahjan & J. Kubin & M.T. Tan (2010) found that in the countries with active seismicity, reinforced concrete structural walls are widely used in multi-storey structure systems. Therefore, a proper modelling of the shear walls is very important for both linear and nonlinear analyses of building structures. The shell element can be used efficiently for the analysis of building structures with shear walls. The shell element considered in most of the design software has 6 degrees of freedom at each node and an in-plane rotational degree of freedom, which makes it compatible with three-dimensional beam-type finite element models. Shear wall modelling requires mesh discretization in order to get realistic behaviour. The advantage of using shell elements is the ability to model very long, interacting and complex shear walls within the three dimensional model.

G. Nandini Devi, K.Subramanian & A.R.Santhakumar (June 2009) studied a three bay R.C frame without and with shear wall in middle bay which was subjected to static cyclic lateral load. Shear wall of one bay was subjected to static reversed cyclic lateral load to assess its individual behaviour. Cyclic effects on the shear wall frame were considered for comparison. Shear wall frame and dual frame was compared to assess the individual behaviour of shear wall and when it is designed with beam column Frame. It was found that in spite of carrying large load, the dual frame exhibited less top storey deflection. At the initial stage of loading the dual frame was 7.84 times stiffer than the bare frame and 4.84 times higher than the shear wall frame. At service load (50% of the ultimate load, the dual frame is 10.56 times stiffer than the bare frame and 6.76 times stiffer than the shear wall frame. When the frames are compared at service load, it was found that the dual frame can be used for a larger service load and can withstand higher seismic loads with small deflection.

J.Kubin, Y.M.Fahjan and M.T.Tan (2008) studied the different approaches of modelling the shear walls in structural analyses of buildings and compared their results. The shear walls within the building structures are generally modelled by either a composition of frame elements or a mesh of shell elements. In modelling shear walls with "shell elements" the drilling moment of the shear walls and the bending moment of the in-plane connected beams are changed dramatically with mesh density. For finer meshes, 10% reduction of the drilling moment can be estimated. Introduction of top Chord frame stabilize the results considerably. Good estimation of the properties of the top chord frame is very important to not affect the overall stiffness of the structural system. Best results are obtained using a top chord frame element to enhance the fixity of the beams framing into the shear wall.

N.S. Potty, W.A.Thanoon, H.H. Hamzah, et al (ICCBT2008) investigated the suitability, simplicity, accuracy, effectiveness of different structural models used in the analysis of shear wall and coupled shear wall structures. They found that the beam element model is simple compared with shell element model. As the size of the SW increases, the modelling and analysis of the wall with shell element become more complex and tedious. Beam element shows very good result compared to the shell element. Finite element method is widely used for analyzing structural systems.

Devesh P. Soni and Bharat B. Mistry (2006) studied the seismic response of vertically irregular building frames and found that the largest seismic demand is found for the combined–stiffness–and–strength irregularity. The methodology proposed by Fragiadakis et al (2006) proposed a methodology based on Incremental Dynamic Analysis (IDA) to evaluate the response of structures with „single-story vertical irregularities in stiffness and strength using a nine-story steel frame. The methodology proposed by him enables a full range performance evaluation via a highly accurate analysis method that pinpoints the effects of any source of irregularity. He concluded that vertical irregularities produce different effects which depend on the type of irregularity, the storey where it happens and most importantly, on the intensity of earthquake or equivalently on the response level or damaged state of the structure.

V. CONCLUSIONS

Recently there has been a greater increase in the number of tall buildings, thus the effect of lateral loads like earthquake forces are attaining increasing importance. Shear wall system are the commonly adopted lateral load resisting system in tall buildings. Vertical Irregular Structure may need to accommodate for architectural purposes, passing utilities, and structural reasons, hence a study regarding the seismic response of shear wall in vertical irregular structure are necessary. This study is planned to focus for analysis of RC framed building with vertical irregularities using shear wall under response spectrum analysis is studied. Irregular buildings constitute a large portion of the modern urban infrastructure. Structures are never perfectly regular and hence the designers routinely need to evaluate the likely degree of irregularity and the effect of this irregularity on a structure during an earthquake. Need for research is required to get economical & efficient lateral stiffness system for high seismic prone areas. Also for optimization & design of high rise building with different structural framing systems subjected to seismic loads and to improve the understanding of the seismic behavior of building structures with vertical irregularities.

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