Scientific Journal of Impact Factor (SJIF): 4.14
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 12, December -2016

A REVIEW ON COMPARATIVE STUDY OF SEISMIC BEHAVIOR OF FLAT SLAB AND CONVENTIONAL RC FRAMED STRUCTURE

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Abstract — *In present era, flat slab buildings are commonly used for the construction as it has many advantages over conventional RC frame building in terms of architectural flexibility, use of space, easier formwork and shorter construction time. In the present work a G+5, G+8 and G+11multistiried building having flat slab with drop, flat slab without drop and conventional slab has been analyzed using ETABS software for the parameters like storey displacement, storey shear, storey drift, axial force, base shear. The performance and behavior of all the models in seismic zone III has been studied. The main objective of the present work is to compare the behavior of multi storey buildings having conventional RC frame, flat slab with drop and flat slab without drop and to study the effect of height of building on the performance on these types of buildings under seismic forces. Linear dynamic response spectrum analysis and non linear dynamic time history analysis is performed on the structure to get the seismic behavior.*

Keywords- *conventional RC frame, flat slab with drop, response spectrum analysis, time history analysis, ETABS.*

I. INTRODUCTION

The scarcity of space in urban areas has led to the development of vertical growth consisting of low-rise, medium-rise and tall buildings. Generally framed structures are used for these buildings. They are subjected to both vertical and lateral loads. Lateral loads due to wind and earthquake governs the design rather than the vertical loads. The buildings designed for vertical load may not have the capacity to resist the lateral loads. The lateral loads are the premier ones because in contrast to vertical load that may be assumed to increase linearly with height; lateral loads are quite variable and increase rapidly with height. Under a uniform wind and earthquake loads the overturning moment at the base is very large and varies in proportion to the square of the height of the building. The lateral loads are considerably higher in the top storey rather than the bottom storey due to which building tends to act as cantilever. These lateral forces tend to sway the frame. In many of the seismic prone areas there are several instances of failure of buildings which have not been designed for earthquake loads. All these reaction makes the study of the effect of lateral loads very important. [1]

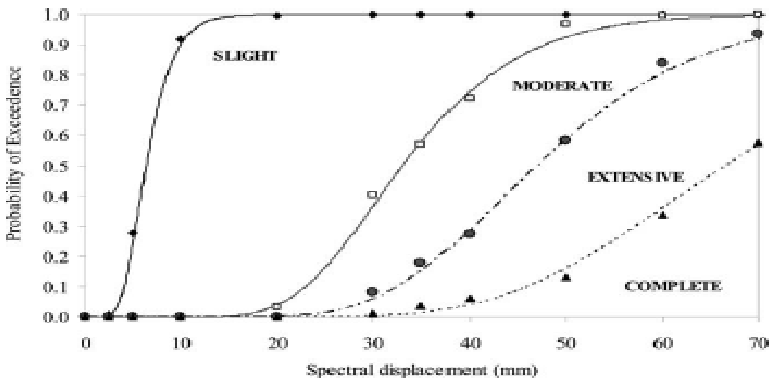
Pure rigid frame system or frame action obtained by the interaction of slabs, beam and column is not adequate. The frame alone fails to provide the required lateral stiffness for buildings taller than 15 to 20 (50m to 60m) stories. It is because of the shear taking component of deflection produced by the bending of columns and slab causes the building to deflect excessively. There are two ways to satisfy these requirements. First is to increase the size of members beyond and above the strength requirements and second is to change the form of structure into more rigid and stable to confine deformation. First approach has its own limits, whereas second one is more elegant which increases rigidity and stability of the structure and also confine the deformation requirement. In earthquake engineering, the structure is designed for critical force condition among the load combination. [1]

Flat slab is system of construction is one in which slab is directly rest on the column. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads, the thickness of slab near the support is increased and these are called drops and columns are generally provided with enlarged heads called column heads or capitals. [2] These increasing thickness of flat slab in the region supporting columns provide adequate strength in shear and to increase the amount perimeter of the critical section, for shear and hence, increasing the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support. Flat slab structure is preferred over conventional structure in construction due to their advantages in reducing storey height and construction period as compared with conventional structure leading to reduction of construction costs. [3]

Because of absence of deep beam flat slab building structures are more significantly flexible than conventional concrete structures, thus becoming more vulnerable to seismic loading. Thus the seismic analysis of these structures is necessary to know the vulnerability of these structures to seismic loading. [1]

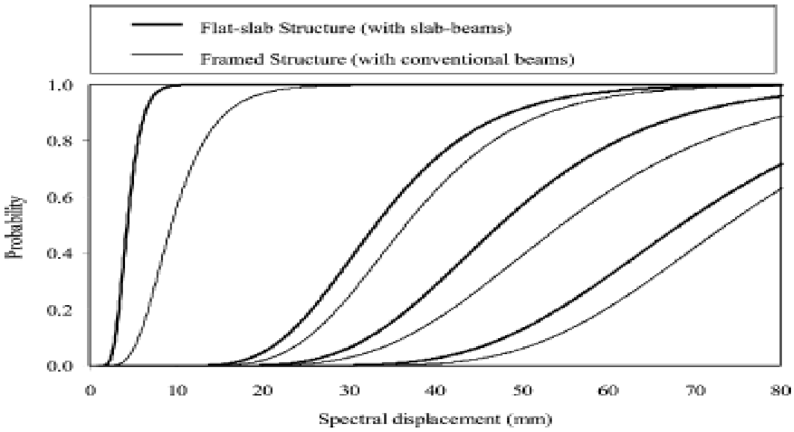
II. REVIEW OF LITERATURE

M. Altug Erberik, Amr S. Elnashai [2004] focused on the derivation of fragility curves using medium rise flat slab buildings with masonry infill walls. The study employed a set of earthquake records compatible with the design spectrum selected to represent the variability in ground motion. Inelastic response-history analysis was used to analyze the random sample of structures subjected to the suite of records scaled in terms of displacement spectral ordinates, whilst monitoring four performance limit states. The fragility curves developed from this study were compared with the fragility curves derived for moment-resisting RC frames. The study concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames. Differences, however, exist. The study also showed that the differences were justifiable in terms of structural response characteristics of the two structural forms. [4]



"Figure 1. Vulnerability curves for the flat slab structures" [4]

Figure 1.represents the fragility curves of medium-rise flat-slab structures. The curves become flatter as the limit state shifts from slight to complete because of the nature of the statistical distribution of the response data. Vertical curves would represent deterministic response. The variability of inter story drift at high ground motion intensity levels is much more pronounced relative to the variability at low intensity levels. Hence, small variations in low intensity cause significant differences in the limit state exceedance probabilities. This observation points towards the high sensitivity of the structure to changes in seismic demand. The steep shape of the slight limit state curve is due to the infill panels dominating the response at this low-level limit state. This continues till the panels reach their deformation capacity. Thereafter, the response is dictated by the bare flexible flat-slab system. [4]



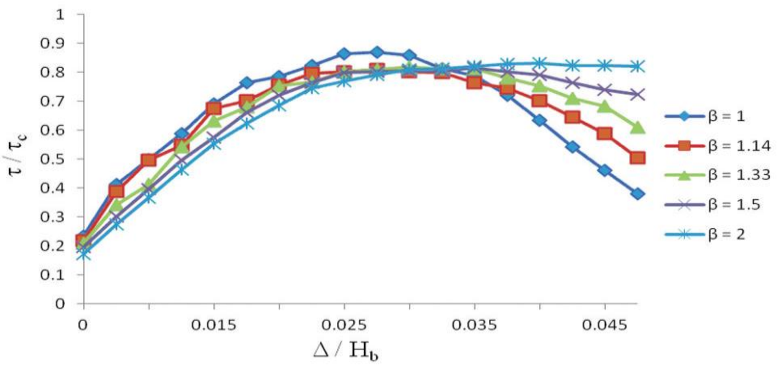
"Figure 2. Comparison of fragility curves for flat slab and framed structures" [4]

Figure 2 shows that the flat-slab structure is more vulnerable to seismic damage than the moment-resisting frame across the entire range of seismic hazard. It is also interesting to observe that the difference between the flat-slab structure and the framed structure is more pronounced at the lower limit states. This is because of the inherent flexibility of flat-slab structures, as mentioned in previous sections. Small variations at low levels of seismic intensity can create amplified effects on the fragility curves whereas even large variations at high levels of seismic intensity may not have that much effect on the curves. [4]

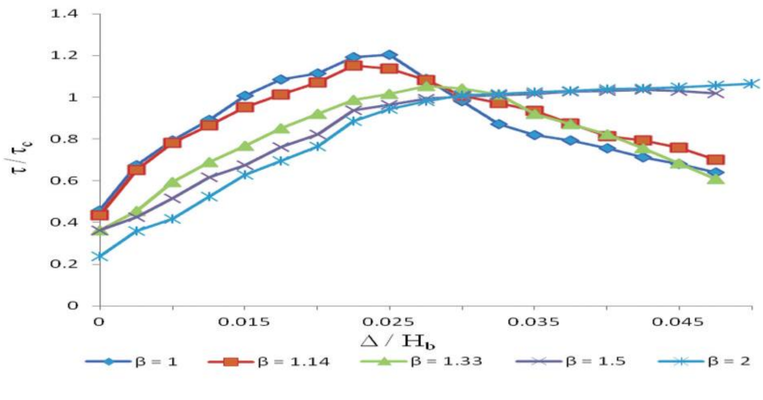
S.W.Han [2009] told about the effective beam width model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studies on slab stiffness with respect to crack formation. This studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors estimated from collected test results. [5]

A.B.Climent [2012] investigated about the effective width of reinforced concrete flat slab structures subjected to seismic loading on the basis of dynamic shaking table tests. The study is focused on the behavior of corner slab column connections with structural steel I- or channel-shaped sections (shear heads) as shear punching reinforcement. To this end, a 1/2 scale test model consisting of a flat slab supported on four box-type steel columns was subjected to several seismic simulations of increasing intensity. It is found from the test results that the effective width tends to increase with the intensity of the seismic simulation, and this increase is limited by the degradation of adherence between reinforcing steel and concrete induced by the strain reversals caused by the earthquake. Also, significant differences are found between the effective width obtained from the tests and the values predicted by formula proposed in the literature. These differences are attributed to the stiffening effect provided by the steel profiles that constitute the punching shear reinforcement. [6]

Saraswati Setia [2015] discussed about flat plate slabs exhibit higher stress at the column connection and are most likely to fail due to punching shear rather than flexural failure. To avoid shear failure, parameters influencing the punching strength need to be clearly investigated by realistic analytical or experimental studies. The present analytical study investigates the influence of some of the parameters governing the behavior of connections under punching shear, which are concrete strength, column aspect ratio, slab thickness and gravity loading. Computer program Structural Analysis Program 2000 V14 is used to model columns and slabs as frame and shell elements, respectively. Parametric studies on aspect ratio and depth-to-span ratio have been carried out using displacement control non-linear static pushover analysis to investigate the influence of these parameters on punching shear capacity of the intermediate and corner column connections, which proved to be the governing criteria to prescribe drift limits for flat plate systems in seismic zones. [7]



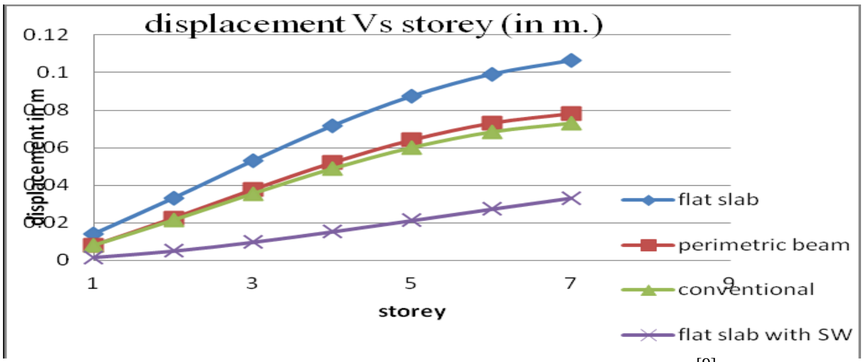
"Figure 3.Punching shear capacity of flat plate intermediate column connection with varying aspect ratio" [7]



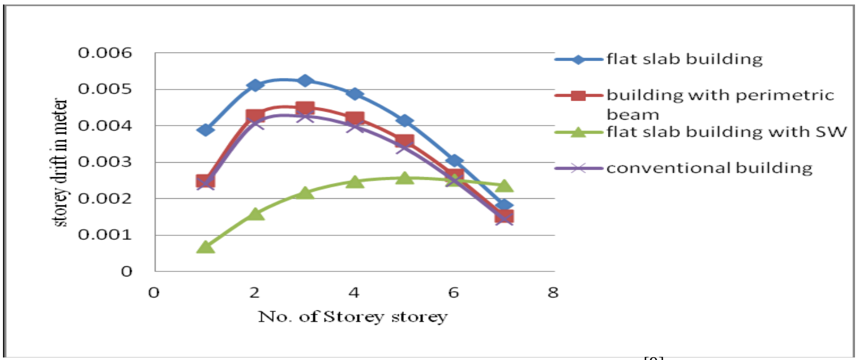
"Figure 4. Punching shear capacity of flat plate corner column connection with varying aspect ratio" [7]

V.K.Tilva [2011] studied about a cost comparison between flat slab panel with drop and without drop in four storey lateral load resisting building for analyzing punching effect due to lateral loads. On the basis of permissible punching shear criteria according to IS: 456-2000, economical thickness of flat slab with drop and without drop are selected and cost comparison is done by using S.O.R. [8]

Prof. P. S. Lande [2015] discussed about flat slab structure is most vulnerable to the seismic excitation therefore the careful analysis of flat slab is important. In this paper the seismic analysis on flat slab is performed and compared it with the conventional RC building. To improve the performance of flat slab system shear wall and beam at periphery is applied and the seismic response of the same is determined and compared it with the flat slab building. [9]



"Figure 5. Storey displacement vs. no. of stories" [9]



"Figure 6. Storey drift vs. no. of stories" [9]

Widianto [2006] performed experimental research on 2/3-scale slab-column connections was conducted to quantify the effects of earthquake-damage and low reinforcement ratios on the punching shear strength, and to study the efficiency of various rehabilitation techniques. [10]

K. S. Patil [2013] studied about optimum design of reinforced concrete flat slab with drop panel according to the Indian code (IS 456-2000) is presented. The objective function is the total cost of the structure including the cost of slab and columns. The cost of each structural element covers that of material and labour for reinforcement, concrete and formwork. The structure is model and analyzed using the direct design method. The optimization process is done for different grade of concrete and steel. Optimization for reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared. The model is analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT). [11]

A.A.Sathawane [2012] studied about the most economical slab between flat slab with drop, flat slab without drop and grid slab. The proposed construction site is Nexus point apposite to vidhan bhavan and beside NMC office, Nagpur. The total length of slab is 31.38 m and width is 27.22 m. total area of slab is 854.16 sq m. It is designed by using M35 Grade concrete and Fe415 steel. Analysis of the flat slab and grid slab has been done both manually by IS 456-2000 and by using software also. Flat slab and Grid slab has been analyzed by STAAD PRO. Rates have been taken according to N.M.C. C.S.R. It was observed that the flat slab with drop is more economical than flat slab without drop and grid slabs. [12]

Ramos [2006] studied about the punching failure mechanism results from the superposition of shear and flexural stresses near the column, and is associated with the formation of a pyramidal plug of concrete which punches through the slab. It is a local and brittle failure mechanism. The present work reports the experimental analysis of reduced scale pre-stressed flat slab models under punching. [13]

K.S.Sable [2012] analyzed seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes. It was concluded that story drift in buildings with flat slab construction is significantly more as compared to conventional R.C.C building. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moment caused by the drift. [14]

K. Venkatarao [2016] studied the seismic behavior of conventional RC framed building, flat slab with drop and without drop building in all seismic zones of India. Different parameters like lateral drift, base shear, time period and axial force are compared. It was concluded that lateral displacement of conventional RC frame is less as compared to flat slab without drop building. [15]

III. CONCLUSION

1. In fragility analysis of flat slab structure the steep light-damage curve shows the role of the infill panels. When the infill panels are damaged and no longer contribute to the lateral resistance, then the buildings reach inter story drift limits more quickly than their moment-resisting frames. Therefore, using vulnerability curves of moment-resisting frames to analyze seismic damage of flat-slab buildings is not worthy.
2. When aspect ratio increases the punching shear strength around the flat plate column connection both for intermediate and corner decreases until the peak shear strength is reached.
3. When punching shear stress increases for corner connection it gets additional torsional moment due to loading on only one side of the connection leading to punching shear failure.
4. High aspect ratio of intermediate and corner connections appear to be more ductile in comparison to connections with low values of aspect ratio.
5. The storey displacement is maximum for the flat slab building and minimum for the flat slab building with shear wall.
6. The axial force is minimum in flat slab building as compared with other buildings. The bending moment is maximum in the flat slab building and minimum in the conventional RC building.
7. When the height of the building increases storey shear decreases. The base shear increases as the zone factor increases. Base shear of flat plate building without drops is less than the conventional RC frame building.

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