A REVIEW ON SEISMIC BEHAVIOUR & RETROFITTING OF OPEN GROUND STOREY

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***Abstract* –** It is an indisputable fact that the world is facing a risk of natural calamities from decades. These calamities cause destruction of structures and other properties, loss of human lives which ultimately affects the natural economy. Improper design and detailing of structure can amplify the effect of seismic forces. As the occurrence of any natural hazard cannot be foreseen or prevented, it becomes more important to design the structure resisting seismic forces. The existing buildings with open ground storey are more susceptible to these seismic forces with its stiffness irregularity, as these vibrations of earthquake search for every structural weakness. Therefore it is necessary to understand the response of such building in the event of an earthquake to reduce their vulnerability. For this purpose different papers have been studied in this paper with different types of retrofitting.

Keywords* – *insufficient stiffness, open ground storey, retrofitting, seismic response

I. INTRODUCTION

Open ground storey building is the one in which infill walls are present in all of the floors except the ground floor. The absence of these infill walls leads to sudden change in stiffness as well as strength creating stiffness irregularity. RC frame buildings with open ground storey have shown very poor performance in the event of past earthquakes. If special provisions are not followed it might end up in the formation of weak storey. Under lateral loading, irregular stiffness of building leads to larger inter-storey drift which gets concentrated to soft storey rendering to an early formation of plastic hinges, further impending collapse of structure.

When earthquake forces excites the building, upper storeys of building moves nearly together acting like a single block. The major portion of horizontal displacement of the building occurs in open ground storey itself. In alternative words, this kind of building sways back and forth like inverted pendulum as shown in figure 2. It produces huge stresses in columns and if those columns are not capable of withstanding these stresses or do not possess sufficient ductility; they get severely damaged. This further tends to collapse of building after formation of plastic hinges.

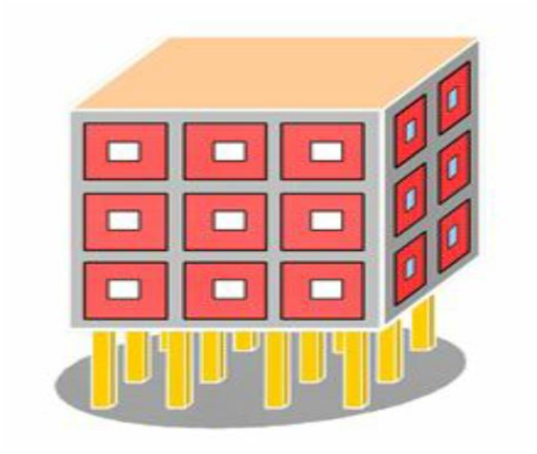

Figure 1: Typical Open Ground Storey Building

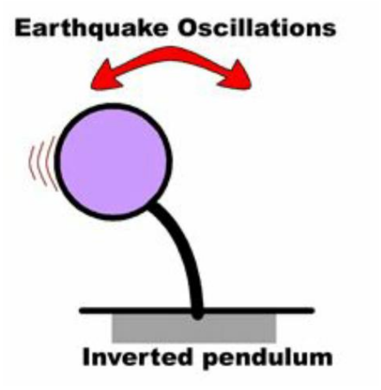

Figure 2 Behaviour of OGS Building in the event of Earthquake

II. LITERATURE REVIEW

[1] Manabu Yoshimura [1997]

In this paper RC building with OGS which was collapsed in Hyogoken-Nanbu earthquake was analysed. A nonlinear analysis was conducted for analysing dynamic response of the building during earthquake. The analysis showed the actual behaviour of the structure and how it collapsed during earthquake. It reproduced the damages occurred in structure which was observed after earthquake. It was concluded that the columns of first storey collapsed due to huge horizontal displacement in addition to massive axial compression. Study revealed that the collapse was unavoidable for open ground storey structure which was considered.

[2] F. Hejazil et. Al [2011]

In this paper, the soft storey effect produced at ground floor of high rise buildings subjected to earthquake forces has been studied. Bracings have been provided at various positions in different patterns for reducing the soft storey effect of structure and enhancing the seismic performance of the building. The important factors which were observed were location and number of bracings provided. Results showed that the displacement at the top floor was very high even after the provision of bracings at soft storey level as there were no bracings at top floor. Thus, it was concluded that bracings gives different result and enhances the performance at those locations only where they are provided and does not give any advantage to other floors. The horizontal as well as vertical movements of building are reduced where bracings were provided in most bays than other models.

[3] Nevzat Kirac et. Al [2011]

In this paper, performance of OGS during earthquake is studied. Analysis of building models consisting of different storeys, different height of storeys and spans are carried out. Also, some OGS models of existing buildings which were severely damaged during earthquake are also studied. The results are analysed with current seismic code and compared. It was observed that these negative effects produced due to irregularities can be reduced up to certain level during construction stage. It was concluded that lightweight materials can be utilize in order to prevent soft storey effect partially. The provision of gaps in between the columns and infill walls help to reduce harmful effects. Result showed that OGS was more effective in high-rise buildings and torsion must be prevented by carefully placing the columns and concrete walls.

[4] Ibrahim Serkan Misir [2014]

In this paper, the results of replacement of infill called as latched brick infill in reducing the soft storey effect are studied. Non-linear static time history analysis was performed on multi-storey frames. The results showed that use of latched bricks to form infill walls has ability to reduce the formation of soft storey when compared to standard conventional bricks due to its mechanism which allows shear sliding and reduced upper storey stiffness, even in building structure which have no infill at first storeys.

[5] Dipti Ranjan Sahoo Et.Al [2013]

In this paper, design and analysis of two retrofit techniques to enhance the seismic behaviour of the existing building with open ground storey level is carried out. The two techniques are column retrofit (CR) & full retrofit (FR). The performance of the existing and the retrofitted frames are analysed by carrying out the nonlinear static as well as dynamic analysis. At the failure stage, all hinges were formed only within the open storey columns owing to their inadequate shear strength. The CR frame exhibited the higher lateral strength and thus, the potential for energy dissipation. However, such modified frames are not capable of withstanding all strong ground motions of earthquake. The FR frame showed the excellent seismic behaviour.

[6] Adrian Fredrick C. Dyaa et.al [2015]

In this paper, the properties as well as the number of structural members for each storey were kept constant. Therefore, soft storey formation and their effect was observed and analysed by varying the height of open storeys. A nonlinear static analysis was carried out to study the performance of the building under different irregular conditions. Due to constraint of pushover analysis, the study was limited to low-rise buildings. It was observed that forces were saturated at the section of the structure where reduction in stiffness occurs. This can be ascertained by formation of storey drift, plastic hinge in structure as well as in design. The vulnerability of building increases the severeness of soft storey of building. Thus, the soft storey irregularity modifier is further categorized to contemplate its severeness. It was concluded that any structure which is properly designed may withstand seismic forces without undesired damage in structure.

[7] Ritukesh Bharali et.al[2014]

In this paper, a study has been made to cut back seismic vulnerability of mid-rise building with open ground storey by introducing masonry walls at specific locations within ground storey as an economical retrofitting option. Masonry infill walls of varied thickness are modelled and placed at strategic locations at ground level, keeping required space for existing parking facilities. Comparative analysis of seismic behaviour of model and existing building has been carried out using static nonlinear analysis. Results are examined to characterize the result on few response parameters for different possible locations of masonry walls. It has been discovered that, provision of appropriately positioned masonry infill in open ground storey of existing building increases the lateral stiffness considerably and improves the lateral load capability of the structure as a whole, thereby preventing collapse. It was concluded that strategically introduced masonry infill walls provides cost effective, quicker and reliable option when compared to extremely interventional options such as shear walls or steel bracings to reduce vulnerability of existing open ground storey multi-storeyed buildings.

[8] D. J. Chaudhari et.al [2015]

In this paper, the estimation and comparison of performance of open ground storey building designed with multiplication factors given by major international codes is carried out. A typical G+9 OGS framed building is taken into account and design forces for ground storey columns are evaluated based on numerous codes and ground storey columns are designed. Models of buildings designed with different multiplication factors are developed in ETABS software for nonlinear dynamic analysis on which a set of twenty natural time histories are applied. The relative performances of various storeys of each building are compared using fragility curves for different performance levels. Result showed that performance of upper storeys needs to be checked while applying multiplication factors only to the ground storey. Performances of OGS frames i.e., the ground storey drift increases with increasing order of multiplication factors. Relative vulnerability of first storey increases due to strengthening of ground storey. Application of magnification factors only within ground storey may not provide required performance in all of the other storeys where multiplication factor is not applied. It is seen that OGS building designed using Israel code which considered MF in adjacent storey, performed better as compared to Indian code which indicates that application of multiplication factor in adjacent storey is also essential to enhance the performance of OGS buildings.

[9] S R Satish Kumar et.al [2012]

In this paper, the performance of twenty six two-storeyed and fifty eight four-storeyed OGS plane frames are designed and detailed as per IS codes and further evaluated by nonlinear static pushover analysis. The frames were designed and analysed by varying the parameters like no. of storeys, ground floor to upper floor stiffness ratio, share of reinforcement within columns and also intensity of ground motions. Single bay 2 and 4 storey RC plane frames which are situated in seismic zones 3, 4 and 5 for varying system parameters listed above were designed and analysed for gravity loads as per IS 456: 2000 and seismic loads as per IS 1893(Part I): 2002 for maximum considered earthquake (MCE) and elaborated as per IS 13920: 1993. OGS frames designed and detailed as per current codal provisions showed widely different performance under severe earthquakes having high magnitudes. It was ascertained that inter-storey drift likewise ductility demand increase with increase in intensity of ground motion, increase in percentage of steel reinforcement but it was independent of stiffness ratio. Some of the design parameters such as ground motion levels, percentage of longitudinal steel reinforcement have significant effect on seismic performance of OGS building and thus it must be considered in performance based design. The variation of storey stiffness ratio within the range considered in this paper had no such specific effect on ground floor storey drift and thus need not to be considered in the performance based design of OGS frames.

[10] Ashutosh V. Mahashabde et.al [2003]

In this paper, the two buildings which were damaged during Bhuj earthquake (2001) are studied. One building had open ground storey with infill walls and other had open ground storey with partial infill walls. Both were analysed using static pushover analysis with shear distribution specified in code. The determined failure modes confirmed to substantial damages sustained by buildings throughout the earthquake. The methods of retrofitting for strengthening of structure selected were column jacketing in soft storey, structural infill walls in soft storey at some selected parts and structural infill walls in all storeys in selected parts. The lateral strength does not increased considerably with first two retrofitting schemes. The maximum strength was gained in scheme 3. Comparable displacement ductilities were determined for schemes 1 & 2. Maximum lateral strength and stiffness of RC frame building were obtained with retrofitting scheme 3. The shear wall provided in few storeys which was properly designed in addition with selected strengthening of frame members was predicted to give maximum strength, stiffness and ductility of deficient RC buildings. From all the strategies mentioned above, the mix of jacketing of column in soft storey and reinforced concrete wall along the height of structure with some selected strengthening of above storey frame members, gave the foremost cost effective and excellent performance.

III. DISCUSSION

In recent years there has been a substantial advancement in research on repair and seismic retrofitting of existing building as evident from increasing no. of research papers are published in this area. In this study, the literature survey from work of various authors is done and identified that researchers follow different strategies for various open ground storey structures for minimizing and eliminating the soft storey effect thus improving the seismic performance of building.

IV. CONCLUSION

The rapid increase in population and urbanization all over the world increased the demand of multi-storeyed buildings. For solving parking issues & to provide space for different purpose most of multi-storeyed buildings have open ground storey. The sudden change in the stiffness at ground floor leads to stiffness irregularity making it more vulnerable to earthquake. The provision of open ground storey in building renders soft storey condition. The infill walls are considered as non-structural members in most of structures while designing. But in reality it acts like compression member and it is concluded from above papers, that it should be taken into account and considered as structural member while designing earthquake resisting design. The researchers have discussed various types of retrofitting techniques and strategies for existing building like brick walls at specific locations, latched brick infill, column jacketing, provision of shear walls, bracings etc. Retrofitting of OGS buildings with different strategies has shown different responses according to their locations after nonlinear analysis. As discussed earlier past earthquakes has shown very devastating effects on OGS structures causing collapse of structure, it has become necessary to strengthen the existing structure by retrofitting which gives effective and quicker results & satisfies the condition to enhance the performance of building during earthquake.

V. REFERENCES

[1] Yoshimura M. (1997). “Nonlinear Analysis of a Reinforced Concrete Building with a Soft First Storey Collapsed by the 1995 Hyogoken-Nanbu Earthquake”, Cement And Concrete Composites 19, pp.: 213-221.

[2] Hejazil F., Jilani S., Noorzaei J., Chieng C. Y., Jaafar M. S. and Abang Ali A. A. (2011). “Effect of Soft Storey on Structural Response of High Rise Buildings”, Materials Science and Engineering, 17, pp.: 1-13.

[3] Kirac N., Dogan M. and Ozbasaran H. (2011). “Failure of Weak-Storey during Earthquakes”, Engineering Failure Analysis, 18, 572-581.

[4] Ibrahim Serkan Misir (2014). “Potential Use of Locked Brick Infill Walls to Decrease Soft Storey Formation in Frame Buildings”, J. Perform. Constr. Facil., 2015, 29(5):04014133.

[5] Sahoo D. R. and Rai D. C. (2013). “Design and Evaluation of Seismic Strengthening Techniques for Reinforced Concrete Frames with Soft Ground Storey”, Engineering Structures, 56, 1933-1944.

[6] Dyaa A. F. C. and Oretaa A. W. C. (2015), “Seismic Vulnerability Assessment of Soft Storey Irregular Buildings using Pushover Analysis”, Procedia Engineering, 125, 925-932.

[7] Ritukesh Bharali, Bhargob Deka and Jayanta Pathak (2014), “Retrofitting Open Ground Storey Building with Masonry Walls in Guwahati City”, 15th Symposium On Earthquake Engineering, Indian Institute Of Technology, Roorkee, December 11-13, 2014 Paper No. A126.

[8] D. J. Chaudhari, Prajakta T. Raipure (2015). “Seismic Performance of Open Ground Storey RC Buildings for Major International Codes”, Journal of Civil Engineering and Environmental Technology, Volume 2, Number 10; April-June, 2015 pp.: 42-48.

[9] S. R. Satish Kumar & J. L. Srinivasan (2012). "Performance Based Design of Reinforced Concrete Open Ground Storey Buildings", 15 WCEE 2012.

[10] Ashutosh V. Mahashabde, Kaustubh Dasgupta, Murty CVR, (2013). "Seismic Strengthening of Gravity Load Designed RC Frame Buildings", 4th International Conference on Earthquake Engineering and Seismology.

[11] Wibowo A., Wilson J. L., Lam N. TK And E. F. Gad (2010). "Collapse Modelling Analysis Of A Precast Soft Storey Building In Australia", Engineering Structures 32, 1925-1936.

[12] Lee H. S. And Ko D. W. (2007), "Seismic Response Characteristics of High-Rise RC wall Buildings Having Different Irregularities in Lower Stories", Engineering Structures, 28, 3149-3167.

[13] IS 1893 Part 1 (2002) "Indian Standard Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi.