Seismic Drift control in soft storied RCC buildings: A Critical Review

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Abstract— **Open ground storey RC frame buildings are common in India; they are the dominant set of urban buildings today. But, poor performances of such buildings worldwide were known from almost a century ago. Numerous such buildings constructed in recent times have a special aspect - the ground storey is left open, which means the columns in the ground storey do not have any partition walls between them.**

These types of buildings having no infill masonry walls in ground storey, but having infill walls in all the upper storeys, are called as 'Open Ground Storey (OGS) Buildings'. This open ground storey building is also termed as building with 'Soft Storey at Ground Floor'. The open ground storey buildings are generally designed as framed structures without regard to structural contribution of masonry infill walls. The presence of infill walls in all the upper stories except in the ground storey makes the upper stories much stiffer as compared to the open ground storey. Thus the upper stories move almost together as a single block and most of the horizontal displacement of the building occurs in the soft ground storey itself and hence the ground storey columns are heavily stressed.

IS 1893 (2002) recommends a magnification factor of 2.5 to be applied on bending moments and shear forces in the columns of ground storey calculated for the bare frame under seismic loads. But, there must be compelling reasons (e.g. aesthetics and functionality) other than safety that continues to push the construction of such buildings even today .When glass is used as infill material in the ground storey for aesthetics in place of brick masonry infills,the building becomes weak in that storey. This happens commonly in buildings housing shopping areas and restaurants in their ground storey.

Index Terms— **Soft Storey, seismic force, seismic response, pushover analysis, drift demand,**

I. Introduction

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the building itself for parking. Also for offices or for any other purpose such as communication hall etc. soft storeys at different levels of structure are constructed.

Many urban multistory buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first stories. Also for offices or for any other purpose such as communication hall etc. soft storeys at different levels of structure are constructed IS 1893 (Part1): 2002 classifies a soft storey as one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. Hence in multistory building with no infill walls in the first storey or any intermediate storey is known as soft storey. Infill panels are generally not considered in the design process and treated as architectural (non-structural) components.

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II. Behavior of Soft Storey

The presence of masonry walls has a significant impact on the seismic response of an RC frame building, increasing structural strength and stiffness (relative to a bare RC frame), but, at the same time, introducing brittle failure mechanisms associated with the wall failure and wall-frame interaction.

The seismic force distribution is dependent on the distribution of stiffness and mass along the height. The essential characteristics of soft storey consist of discontinuity of strength or stiffness which occurs at the second floor column connection

Experience in the past earthquake has shown that a building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building that a building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building . Thus different modeling or experiment enables the understanding how the behaviour of a multi-storey building changes with the introduction of soft storeys and different soft storey condition

III. LITERATURE REVIEW

A significant amount of research work on seismic behaviour of soft storey building has been done by many investigators research area Such as

Wakchaure M.R & Ped S. P. (2012) this study exibits the effect of masonry walls on high rise building is studied. Linear dynamic analysis on high rise building with different arrangement is carried out. For the analysis G+9 R.C.C. framed building is modelled. Earthquake time history is applied to the models. Various cases of analysis are taken. All analysis is carried out by software ETABS. The result shows that Due to infill walls in the High Rise Building top storey displacement is reduces. Base shear is increased. The presence of non-structural masonry infill walls can modify the seismic behavior of R.C.C Framed High Rise building to large extent. In case of infill having irregularities in elevation such as soft storey that is damage was occur at level where change in infill pattern is occur.

Xiao-Kang ZOU and Chun-Man CHAN (2004) this paper presents an effective computer-based technique that incorporates pushover analysis together with numerical optimization procedures to automate the pushover drift performance design of reinforced concrete (RC) buildings. Steel reinforcement, as compared with concrete materials, appears to be the more cost-effective material that can be effectively used to control drift beyond the occurrence of first yielding and to provide the required ductility of RC building frameworks. In this study, steel reinforcement ratios are taken as design variables during the design optimization process.

Hirde Suchita and Tepugade Ganga (2014) this paper attempt has been made to study performance of a building with soft storey at different level along with at GL. The nonlinear static pushover analysis is carried out. The hinges formed in the basic models are seen at performance point and to increase the performance, it is retrofitted with shear walls. Then the result obtained for basic models and retrofitted models are compared in the form of performance point and hinge formation pattern at performance point. This study highlights the poor seismic performance of G+20 RCC building with soft storey at different level along with soft storey at ground level. It is observed that plastic hinges are developed in columns of ground level soft storey which is not acceptable criteria for safe design. After retrofitting of all the models with shear walls hinges are not developed in any of the columns. Provision of shear walls results in reduction in lateral displacement.

Md. Arman Chowdhury and Wahid Hassan (2013) this paper highlight the comparison of isolated and non-isolated building performances with Time History Analysis and Response Spectrum Analysis. Results of comparison between isolated and non-isolated building under different earthquake show that the displacement obtained by non-isolated building is much higher than isolated structure. Provision of isolator in building often increase the total cost, but as reinforcement requirement and construction material cost is reduced due to isolator. So, isolator may be incorporated at the bottom of the structure to exploit economic and structurally safe alternative

Setia Saraswati and Sharma Vineet (2012) the present analytical study investigates the influence of some parameters on behavior of a building with soft storey. The modeling of the whole building is carried out using the computer program STAAD.Pro 2006. Parametric studies on displacement, inter storey drift and storey shear have been carried out using equivalent static analysis to investigate the influence of these parameter on the behavior of buildings with soft storey. The selected building analyzed through five numerical models.

Building having masonry infill in upper floors and with increased column stiffness of bottom story and building with shear wall in core has a small first storey displacement of about 18% and 16% respectively of that of building having masonry infill in upper floors only. This implies that crucial displacement may be effectively reduced if the stiffness of the first storey is made with in the order of magnitude equal to the stiffness of storey above.

Manabu Yoshimura (1999) the first part of this paper introduces an example of a weak first-story building that collapsed during the Kobe earthquake, and highlights significant effects of the strength balance along the height on the first-story drift demand. In the second part, nonlinear dynamic analyses are conducted for a model representing weak-first-story buildings, where the first-story strength and strength balance along the height are taken as analysis variables. Presented also are conditions that the two parameters should satisfy for controlling the first-story drift demand within an allowable level. The major findings obtained from the studies are as follows.

The first story drift demand is governed not only by the first story strength but also by the strength of the upper stories and the strength balance between the first story and upper stories. The first-story strength (in terms of the shear coefficient) required to limit the maximum first-story drift demand within 1% is 0.67, 0.63 and 0.44 for second-story strengths (also in terms of the shear coefficient) of 1.5, 1.0 and 0.5, respectively. The required first- story strength decreases as the second-story strength decreases. If only the first story drift demand is of concern, excessive strength of the second story and above is not desirable for effective design.

When an allowable first-story drift of 2% is adopted, the required first-story strength is reduced to 0.52, 0.51 and 0.39 for second- story strengths of 1.5, 1.0 and 0.5, respectively

Gary R. Searer1 and Sigmund A. Freeman (2004) presents a brief history of design drift requirements, technical background for the requirements, and the reasoning behind the changes, starting with the 1961 Uniform Building Code (UBC) through present day .Based on the above discussion, it appears that a more restrictive drift limit for longer-period structures as is currently the case in the 1997 UBC is unwarranted, since low-rise and mid-rise structures have historically performed far worse in the U.S. than modern high-rises. Finally, as stated earlier, since shorter period structures can have difficulty escaping from the constant acceleration region of the response spectrum, it appears that reversal of the 1997 UBC prescriptive drift limits may be warranted, with shorter-period structures allowed smaller drift limits and longer-period structures allowed larger drift limits.

There are definite advantages to using a strong and stiff lateral system, such as reinforced concrete shear walls, since structural damage can be limited to cracking and spalling of the shear walls, which protects the vertical load resisting elements from significant damage.

Jayachandran P. (2009) examined design issues for preliminary design and optimization have been briefly summarized, and a rational methodology of design was shown. This enables optimization of initial structural systems for drift and stresses, based on gravity and lateral loads. The cost of systems depends on their structure weight. This depends on efficient initial design. Efficient structural design also leads to a better foundation design, even in difficult soil conditions. **Ahmed M. et al. (2008)** present study, the effect of concrete cracking on the lateral response of building structures has been investigated and discussed .The cracking of concrete is a dominant component in RCC buildings response. It is observed that substantial differences exist between the research recommendations for degrees of concrete cracking due to loadings and guidelines of different countries for incorporation of concrete cracking in the structural analysis and design. The significant results are summarized below. The significant increase in deflections and drifts is observed with concrete cracking considerations. An average 50% increase, as predictable, in top storey absolute deflections is computed whereas an increase of 40% in drifts is estimated.

The effect of cracking is slightly enlarged the percentage increase on drift for the higher aspect ratio of the building. It is concluded that with the present guidelines of country codes with no mention of effective rigidity, the drift requirements may fail after incorporation of concrete cracking effect.

Kasliwal Sagar K et al.(2012) deals with the Dynamic linear Response spectra method and static non-linear pushover method on multi-storey shear wall building with variation in number and position of shear wall.Dynamic responses under prominent earthquake, This paper highlights the accuracy of linear and non-linear method and comparison with the above two model analysis results Thus shear walls are one of the most effective building elements in resisting lateral forces during earthquake. By providing shear walls in proper position can be minimized effect and damages due to earthquake and winds. Stiffness of building increases due to adding shear wall, hence reducing the damage to structure

Jakim T. PETROVSKI (2004) told that most of the existing seismic design codes are based on the empirical knowledge accumulated through systematic earthquake damage data collection and their analysis. The main source of damage to structural systems and in particular nonstructural elements are deformations and inte rstory drifts imposed by earthquake ground motions. Therefore, to control damage, it is necessary to control deformation and particularly to control interstory drift

Sinha Ajay Kumar and Bose Pratima Rani (2004) examined that due to several reasons structures acquire asymmetry. Asymmetry in structures makes analysis of the seismic behaviour very complicated. Seismic demand in peripheral elements is enhanced. Uniformity in load distribution gets disturbed. The paper first concentrates in understanding the complex behaviour of structure under asymmetric form. Non symmetric or torsionally unbalanced buildings are prone to earthquake damage due to coupled lateral and torsional movements producing non-uniform displacement demands in building elements and concentrations of stresses and forces on structural members.

Vijayakumar A. babu , and. D.L.Venkatesh (2011) examined many guidelines are reviewed for linear, non-linear analysis and also discuss about the seismic evaluation and various retrofitting techniques. Most of the researchers have been reviewed that the buildings are assumed to be placed in various zones of India, which is carried out the non-linear analysis (pushover analysis), then show the performance of the building components. Maximum base shear capacity of the structures for various zones is compared. Many papers discussed different amount of masonry infill walls are considered to investigate the effect of infill walls on earthquake response of the structures. SAP2000, ETABS and IDARC-2D software are mainly used to find the seismic evaluation and performance of the structures mainly used.

Suresh P. et. al.(2012) demonstrated that Structures are classified as rigid and flexible. Tall structures are more flexible and susceptible to vibrations by wind induced forces. In the analysis and design of high-rise structures estimation of wind loads and the inter storey drifts are the two main criteria to be positively ascertained for the safe and comfortable living of the inhabitants. Estimation of wind loads is more precise with gust factor method. Inter storey drift can be controlled through suitable structural system.

Rao S D V S N and J Vikranth (2013) explored that the measures to be adopted in case of inadequacy without making structural retrofitting are adequately discussed in this study. A the structural retrofitting is costlier, time consuming and inconvenience for the occupants, the study has been taken up to evolve a scientific approach for retrofitting. The following are the some of the recommendations:

(1) If the strength of the column in the building found to be deficit, they are strengthened / retrofitted .Beams and foundations are adequately safe.

(2)To perform well in an earthquake, a building should possess four main attributes, namely simple and regular configuration, adequate lateral strength, stiffness and ductility.

(3) The cantilever overhang should be minimized and the efforts should be made to ensure direct vertical transfer of the gravity loads.

Ravi Kumar C.M et. al. (2012). This paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with vertical irregularity. The study as a whole makes an effort toevaluate the effect of vertical irregularity on RC buildings, in terms of dynamic characteristics and identifies the influencing parameters which can regulate the effect on Base Shear, Time Period, Story Displacement & Story Drift. Also, the analysis has been carried out for various zones of India and soil conditions taken in to consideration. The study as a whole identifies the influencing parameters, which can regulate the effect of vertical irregularities on time period, base shear, drift and displacement of building frames.

Asim Bashir et. al. (2014) examined that the buildings with soft storeys resist smaller forces as compared to the stiff structures. The base shear and the shear forces at different floor levels are lesser for the buildings with soft storeys as compared to the stiff buildings. This can be attributed to the fact that on introduction of soft storey in a building, its stiffness decreases and its time-period increases. The higher time-period leads to smaller accelerations in the building and hence the smaller lateral force. As a result of this, lesser values of storey shear are obtained in the buildings with soft storeys. It is observed that the storey drift in case of buildings with soft storey is very large as compared to a stiff building. Large changes in relative storey drifts are observed across the soft storey. These high relative drifts in the buildings lead to a large amount of undesirable additional bending moments in columns which leads to the failure of the structure as a whole.

Soni Ashish and Svita Maru (2014) presents their study based on the performance based seismic design and the pushover analysis (nonlinear static analysis) literature survey .Performance based seismic design is a very new and modern approach for seismic analysis and seismic engineering of structures, under different levels of earthquake motions in performance based seismic (PBSD) the aim of the design is to deliver a structure which is capable of meeting certain predictable performance objectives

Dohare Devendra and .Savita Maru (2014) examined that the study of seismic behaviour of soft storey building with different arrangement in soft storey building when subjected to static and dynamic earthquake loading. It is observed that, providing infill improves resistant behaviour of the structure when compared to soft storey provided. Calculation shows that, when RC framed buildings having brick masonry infill on upper floor with soft ground floors subjected to earthquake loading, base shear can be more than twice to that predicted by equivalent earthquake force method with or without infill or even by response spectrum method when no infill in the analysis model.

Ahmed S.Zubair et. al. (2014) In this case study R.C.C. building is modeled and analyzed in three cases. I) Model with no infill wall (Bare Model). II) Model with bottom storey open. III) Model with steel bracing system at bottom storey. Dynamic analysis of the building models is performed in ETABS. The performance of the building is evaluated in terms of Storey Drifts, Lateral Displacements, Lateral Forces, Storey Stiffness, Base shear, Time period, Torsion. It is found that the steel bracing system at open bottom storey significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement of R.C.C building.

Fukuyama. H et. al. (2014) proposes a new technique for structural control of RC buildings with soft-first story by using HPFRCC devices, which are placed beside the existing columns in the first story. The advantage of the HPFRCC devices is selective structural performance by varying the configuration, bar arrangements and type of materials used. Also, since the HPFRCC devices can resist to the axial force, axial force acting in the existing columns due to overturning moment can be reduced. As the result of analysis, the seismic response of the buildings was successfully controlled to meet high level of structural performance requirements by using HPFRCC devices.

KASNALE A.S. and JAMKAR S.S (2008) presented an investigation has been made to study the behavior of RC frames with various arrangement of infill when subjected to dynamic earthquake loading. It is observed that, providing infill below plinth improves earthquake resistant behavior of the structure when compared to soft basement. Framed structure after excavation below plinth level. generally filled with loose soil material. This gives effect of soft basement to the structure. However, in such case, if it is modelled with infill masonry, its lateral stiffness changes.. According to relative values of all parameters, it can be concluded that provision of infill wall enhances the performance in terms of displacement control, storey drift and lateral stiffness.

IV. Conclusions

For drift and damage control study will be for the first story drift demand by conducting nonlinear analysis for the model representing soft story with keeping first story strength balance along the height as analysis variable. Since lateral deflection and drift affects the entire building or structure ,design of non structural element is also designed to allow the expected movement of structural system otherwise it will have adverse effect on whole system Hence for the optimization the performance of RCC Building to control the damage judging criteria to control drift of whole structure by performing the different modeling of the whole building using STAAD-Pro for different conditions for soft story building. 1. With shear wall on outer side of the building.2. The Shear wall at the core of the building.3. Keeping upper storey with masonry infill in upper floors 4. By increasing the column stiffness of bottom storey having masonry infill in upper floors. So on the above basis it will be the moto to find a concept of risk reduction of earth quake building criteria with different type of modeling by computer programming software and keeping drift control as per the prescribed IBC codes of Japan. America, and euro-code including Indian earthquake code-13920 and BIS-1893 with a new suggestions if any for safety point of view with economy consideration also .A brief review of the available above literature shows that still some important consideration are to be taken to have a control on critical drift and failure function parameter for a soft storey during earthquake.

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