Review on Seismic Vulnerability Assessment of Open Ground Storey Building Using Pushover Analysis And Response Spectrum Analysis

Vishnu Bhakad[1], D.H. Tupe[2], G.R. Gandhe[3]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] Deogiri Institute of Engineering and Management Studies, Aurangabad, Maharashtra, India.

Abstract- *Increasing population in overall world due to this vehicle parking should be providing in high-rise building to solving parking that is called as the open ground storey building or soft story. There are various author are studied seismic performance of building using various country codes also used various design and analysis software's like ETAB , STAD-PRO, SAP2000 etc. In this paper we have studied various papers on Seismic Vulnerability Assessment of Open Ground Storey Building using Pushover analysis with story of building.*

Keywords- Base Shear, Pushover analysis, Capacity, Soft story, Open Ground Storey Structure, Response Spectrum method, Nonlinear Hinges.

I. INTRODUCTION

Due to increasing population in world there is providing high rise building or high storied building in the world, so there is require providing earthquake resistance building. In high rise building bottom story is the Open ground story (soft story) for parking should providing. This soft story earthquake point of view much vulnerable, due to this point is important design point of view. There are many authors have studied on seismic Vulnerability Assessment of Open Ground Storey Building using Pushover analysis. They are used many country codes and various analysis software's for Earthquake resisting building.In this paper we have studied review on seismic effect on the open ground storey building, pushover analysis, response reduction factor and vulnerability assessments.

II. LITERATURE SURVEY

Here in this chapter we will be discussing about four different sub topics. In the very first unit we will discuss about different concepts and literatures given by the researchers based on seismic effect on the open ground storey building. In the next one we will discuss response reduction factor studies and In the next one we will discuss pushover analysis for seismic performance assessment of structures finally in the last unit we will discuss about vulnerability assessments.

A. Seismic Effect on the Open Ground Storey Building

The concept of seismic behavior of open ground storey building is first introduced by Holmes during the time of dynamic loading on frame, and infill wall are intact initially and when lateral load increases then the infill wall started separating from unloaded corner and still intact at the compression corner infill wall is act as the imaginary diagonal strut. At a time only one corner will be act as a diagonal strut. and the length of the wall and frame on which is in contact is known as contact length. During the time of loading the loads will be transfer through te diagonal struts because the behavior of infill wall. The infill wall is modelled as diagonal struts. And the struts are active only when subjected to compressive loads. Using the effect of slip and interface between frame and infill wall was studies by the Mallick and Severn (1967). The infill wall between the frames as simulated by means that of linear elastic rectangular finite component with 2 degree of freedom at the all four corner nodes. The contact length between the infill wall and frame is calculated and modelled. Using the link element between frame and infill was considered by considering frictional shear force. All the node has two translational degree of freedom. The infill elements are able to transfer the compressive forces but not able to transfer the tensile forces. Rao et. Al (1982) studies infill frame by theoretically and experimentally with opening strength by opening beams. And concluded that the effect of lintel lateral stiffness of an infilled frames. The effect of the opening and their location on the behavior of the one storey reinforced concrete frames with brick infill walls was investigated by Karisiddapa and Rahman (1988) Choubey and Sinha studied about the various parameter of the infill wall such as separation of infill wall from frames, plastic deformation, stiffness and energy dissipation of infilled wall under cyclic loading, Arlekar et al (1997) conducted and studied about the behavior of reinforced concrete frames open ground storey building when subjected to seismic loads. A four storey frames analyzed using static analysis and response spectrum analysis and to find displacement and resultant forces. It shows that the bare frame is different from the open ground storey frames.

Riddington and smith (1997) studied about the effect of different parameter such as plan aspect ratio, relative stiffness and number of bays was studied. Scarlet (1997) studies the earthquake force in the open ground storey building and the multiplication factor for base shear of open ground storey building was proposed. The qualification of seismic forces in the open ground storey building requires modelling the stiffness of the infill wall in the analysis. It is proposed the multiplication factor ranging from 1.86 to 3.28 as the number of storey increases from 6 to 20 The effect of brick masonry as infill frames are included to non-structural and they have a considerable influenced on the lateral response to the structure was pointed out by Deodhar and Patel (1998). Davis and Menon (2004) ended that the presence of masonry infill panels modifies the structural force distribution considerably in associate degree OGS building. the whole construction shear force will increase because the stiffness of the building will increase within the presence of masonry infill at the higher floor of the building. Also, the bending moments within the ground floor columns increase (more than 2 fold), and also the mode of failure is by soft construction mechanism (formation of hinges in ground floor columns).

Das and Murthy (2004) ended that infill walls, once gift during a structure, generally bring down the harm suffered by the RC framed members of a completely infilled frame throughout earthquake shaking. The columns, beams and infill walls of lower stories are a lot of prone to harm than those in higher stories.

Asokan (2006) studied however the presence of masonry infill walls within the frames of a building changes the lateral stiffness and strength of the structure. This analysis planned a plastic hinge model for infill wall to be employed in nonlinear performance primarily based analysis of a building and concludes that the last word load (UL) approach in conjunction with the planned hinge property provides a higher estimate of the non-resilient drift of the building.

Hashmi and Madan (2008) conducted non-linear time history and pushover analysis of OGS buildings. The study concludes that the radio frequency prescribed by IS 1893(2002) for such buildings is adequate for preventing collapse.

Sattar And Abbie (2010) in their study over that the pushover analysis showed an increase in initial stiffness, strength, and energy dissipation of the infilled frame, compared to the clean frame, despite the wall's brittle failure modes. The better collapse performance of fully-infilled frames was related to the larger strength and energy dissipation of the system, related to the value-added walls. There are a unit various analysis efforts found on the unstable behavior of OGS buildings and on the modelling infill walls for linear and nonlinear analysis. However, no printed literature found on the look criterion given in IS 1893:2002 (Part-1) for OGS low rise buildings. this can be the first motivation behind the current study.

Devendra Dohare and Dr.SavitaMaru(2014) are studied about the seismic behavior of soft storey building RC frame buildings with soft story are known to perform poorly during in strong earthquake shaking. Because of the stiffness at lower floor is 70% lesser than stiffness at storey above it causing the soft storey to happen. For a building that is not provided any lateral load resistance component such as shear wall or bracing, the strength is considering very weak and easily fail during earthquake. In such a situation, an investigation has been made to study the seismic behavior of such buildings subjected to earthquake load so that some guideline could be developed to minimize the risk involved in such type of buildings.

Vipin V. Halde and Aditi H. Deshmukh(2015) are studied the Review on Behavior of Soft Storey Effect in Building and concluded the behavior of the soft storey is different during a quake, the structural member undergoes damage and to provide member to withstand that additional forces due to soft storey heavy or bulky member need to be provided.

B. Response Reduction Factor

There are The concept of Response Reduction Factor is also commonly known as Force Reduction Factor, has emerged as a single most important number, reflecting the capability of the structure to dissipate energy through inelastic behaviour. Following are observation of some author regarding response reduction factor.

Mondal et al. (2013) conducted performance-based evaluation of the response reduction factor for ductile RC frames. Reinforced Concrete (RC) regular frame structures are designed and detailed as per Indian standards IS 456, IS 1893 and IS 13920. Four typical symmetric-in-plans RC framed structures having two, four, eight and 12-storied configurations, intended for a regular office building are performed by NSPA using the DRAIN-2DX analysis software. Based on their results, according to Performance Limit 1 (ATC-40 limits on inter storey drift ratio and member rotation capacity), the Indian standard overestimates the R factor, which leads to the potentially dangerous underestimation of the design base shear. Based on Performance Limit 2, the IS 1893 recommendation is on the conservative side. It should however be noted that this limit does not include any structure level behaviour such as interstorey drift. R (for PL1) comes to be close to the IS 1893 recommended value if P–Δeffects are not considered. So, R = 5.0 may be safe for a design where P–Δ effects are actually negligible at the ultimate state.

Maram et al. (2013) have studied the effect of location of lateral force resisting system on seismic behaviour of RC building. 4 types of 10 stories RC frame structure with different positions of shear wall on the symmetrical floor plans. Nonlinear pushover analysis has been performed using ETABS software in according with IS1893-2002. Over strength and ductility were obtained from nonlinear static pushover analysis that has been suggested in FEMA365 and ATC40. All the four models are designed and analysed as per IS456:2000. Finally, it was concluded that there is no mention for the effect of torsional irregularity in IS1893-2002, thus result shows that when shear walls shift to the inner core the ratio of maximum storey drift to the average storey drift, increase to more than allowable value 1.2. In this case the value of accidental torsional (5%) must be increase. It can be seen that when structural ductility increases, response reduction factor (R), increases. In case of building without shear wall according to its value of response reduction factor R= 5.10, it can be observed that the buildings have less value of R as compared to building with shear wall.

Raut et al. (2013) made an effort to evaluate the seismic behaviour of structure with in filled walls by using nonlinear static analysis or pushover analysis. The procedure given in ATC-40 and FEMA 273 were followed. A model was created in SAP-2000 V 11.0. The loading is monotonic with the effects of cyclic behaviour load. Load reversal being estimated by using a modified monotonic force deformation criteria and with damping approximation. Analysis was performed on 3 models i.e. without infill, completely infill and without infill walls in ground storey. Comparison was done on basis of storey shear at different stories by plotting graph. The seismic performance of a masonry infill reinforced concrete structure was found to be adversely and significantly affected if infill panels were discontinued in ground storey (weak storey).

Affandi et al. (2012) have assessed an evaluation of over strength factor of seismic designed low rise RC buildings. Six frame models regular and irregular in elevation, each are designed to gravity load only and designed to resist seismic load with medium ductility and high ductility class. The nonlinear static analysis or also known as pushover analysis (POA) is used to determine the performance of the buildings. Based on their work, the seismic designed building has greater load carrying-capacity, top displacement capacity and ductility supply compared to the gravity load designed buildings and the over strength factor increases as the ductility supply of the building increases.

Khose et al. (2012) conducted a case study of seismic performance of a ductile RC frame building designed using four major codes, ASCE7, EN1998, NZS 1170 and IS 1893. The performance of the test building was evaluated using the Displacement Modification Method (DMM) as well as the guidelines of ASCE-41. The variation in capacity curves is a result of combined effect of the differences in design spectra, effective member stiffness, response reduction factors, load and material factors, as well as load combinations. The buildings designed for other codes (New Zealand and Euro-code) have significantly lower strengths than the buildings of comparable ductility classes designed for Indian and American codes. In case of DBE, all the considered codes result in Life Safety (LS) or better performance levels in both the directions, except in case of Euro-code 8 in both the directions and NZS 1170.5 in transverse direction.

Hamaydeh et al. (2011) evaluated the seismic design factors for RC special moment resisting frames in Dubai, UAE. This study investigates the seismic design factors for three reinforced concrete (RC) framed buildings with 4, 16 and 32-stories in Dubai, UAE utilizing nonlinear analysis. The buildings are designed according to the response spectrum procedure defined in the 2009 International Building Code (IBC'09). The nonlinear dynamic responses to the earthquake records are computed using IDARC-2D. Second order P-Delta effects are included in the nonlinear analyses as well as the hysteretic strength deterioration and the stiffness degradation. It was concluded that the results of the nonlinear time history analysis showed an increase in the inelastic drift, Cd, R and Rd factors in the range of 2 to 4 times. The Ωo factor, on the other hand, show a nominal 30% increase. Based on the observed trends, period-dependent R and Cd factors are recommended if consistent collapse probability in moment frames with varying heights is to be expected.

Patel and Shah (2010) investigated the formulation of key factors for seismic response modification factor of RCC framed staging of elevated water tank. The evaluation of response modification factor was done using static nonlinear pushover analysis. It was used to evaluate nonlinear behaviour and gave the sequence and mechanism of plastic hinge formation. Here displacement controlled pushover analysis was used to apply the earthquake forces at C.G. of container. The pushover curve was plotted between base shear versus roof displacement, gave the actual capacity of the structure in the nonlinear range. Case study taken was of 2.25lac litres ESR with RCC framed staging of 15m height and soil type was medium. They concluded that single value of R for all buildings of a given framing type, irrespective of plan and vertical geometry, cannot be justified. But for ESR staging (beam – column frame or shaft), where the basic system of framing and behaviour is more or less common, the method can be derived to evaluate R – factor

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Asgarian and Shokrgozar (2009) evaluated over-strength, ductility and response modification factor of Buckling Restrained Braced frames. Seismic codes consider decrease in design loads, taking benefit of the fact that the structures possess substantial reserve strength (over-strength) and capacity to disperse energy (ductility). This factor represents ratio of maximum seismic force on a structure through specified ground motion if it was to remain elastic to the design seismic force. Thus, seismic forces are reduced by the factor R to obtain design forces. The basic fault in code actions is that they use linear methods not considering nonlinear behaviour. Over-strength in structures is connected to the fact that the maximum lateral strength of a structure usually beats its design strength. It was perceived that the response modification factor drops as the height of building increases. This result was outward in all type of bracing outline.

Mendis et al. (2000) reviewed the traditional force-based (FB) seismic design method and the newly proposed displacement-based (DB) seismic assessment approach. A case study was done for reinforced concrete (RC) moment-resisting frames designed and detailed according to European and Australian earthquake code provisions, having low, medium and high ductility capacity. Response reduction factor (R) for Ordinary Moment Resisting frame is ‘4’ as per AS 3600 while for Special Moment Resisting frame, R= 8 as per ACI 318–95. It was observed that OMRF developed plastic hinges in the columns under the El Centro earthquake and SMRF generally developed plastic hinges in the beams rather than the columns. This was consistent with the ACI 318–95 strong column-weak beam detailing philosophy used in the design of this SMRF. The displacement ductility and rotation ductility demands of the SMRF during the El Centro earthquake were some 3 times that of the OMRF.

Borzi and Elnashai (2000) made an effort to evaluate response reduction factor on basis of inelastic behaviour of structure. In this work, two models were used i.e. Elastic perfectly plastic model (EPP) and Hysteretic hardening-softening model. EPP model was used since it is simplest form of inelastic force resistance as well as being the basis for early relationship between seismic motion and ‘R’. HSS model is characterized by definition of a primary curve which is defined as envelope curve under cyclic load reversals. Different ductility levels are used along with different time period values to evaluate ‘R’. It was finally concluded that behaviour factor is only slightly dependent on the period in long range (>1 second) and almost correspond to ductility value. On other hand, in short period range, the behaviour factor is dependent on both ductility and time period.]

C. Pushover Analysis

The pushover analysis method was firstly introduced by Freeman et al. (1975) as the Capacity Spectrum Method. The study combined the use of analytical methods with site-response spectra to estimate values of peak structural response, peak ductility demands, equivalent period of vibration, equivalent percentages of critical damping, and residual capacities.

Devrim et al. (2012) studies three 10 storey steel SMRF with different spans were designed as per Turkish Codes. They were analysed with OPENSEES 15 using simulated ground motion records and model frame with span length to storey height ratio of approximately 2 seems to maintain both performance and economy, while the ratio higher than 2.5 can result in relatively high deflections and high element plastic rotations in lower stories under infrequent earthquake loads.

Duan et al. (2012) designed a five storey RC frame building according to Chinese Seismic Codes and investigated the seismic performance of the same by pushover analysis and found the potential for a soft storey mechanism under significant seismic loads.

Tamboli and Karadi (2012) performed seismic analysis using equivalent Lateral Force Method for different reinforced concrete (RC) frame building models that included bare frame, in filled frame and open first storey frame. The seismic analysis of RC (Bare frame) structure lead to under estimation of base shear. Therefore, other response quantities such as time period, natural frequency, and storey drift were not significant. The under estimation of base shear might lead to the collapse of structure during earthquake shaking.

Bodige and Ramancharla (2012) modelled a 1 x 1 bay 2D four storied building using AEM (applied element method). Displacement control pushover analysis was carried out in both cases and the pushover curves were compared. As an observation, it was found that AEM gave good representation capacity curve. From the case studies, it was found that capacity of the building significantly increased when ductile detailing was adopted. Also, it was found that effect on concrete grade and steel were not highly significant.

Girgin et al. (2007) presented the pushover analysis that has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is computationally and conceptually simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure.

Shuraim et al. (2007) concluded that most columns required significant additional reinforcement, indicating their vulnerability when subjected to seismic forces. The nonlinear pushover procedure shows that the frame is capable of withstanding the presumed seismic force with some significant yielding at all beams and one column.

D. Vulnerability of Structure

The Seismic Vulnerability of a structure is described as its susceptibility to damage due to ground shaking of a given intensity. The aim of vulnerability assessment is to predict the economic loss (in terms of replacement cost) and casualties. In vulnerability assessment procedure, a parameter is selected to characterize the ground motion and it is related with the damage of buildings.

Karapetou et al. (2016) studied an integrated methodology which is presented for assessing the time-building-specific seismic vulnerability of one of the main buildings of the most important hospital in Thessaloniki (AHEPA) based on field monitoring data. the result is used update and better constrain the initial finite element model of the building, which is based the design and construction documentation plans provided by the technical service of the hospital

Peethambaran and Philip (2015) evaluated that the results of effects of plan aspect ratio on seismic response of buildings have been presented in terms of displacement and base shear behaviour parameters of the pre-analyzed structure. They also concluded that the nonlinear static pushover analysis is performed to investigate the performance point of the building frame in terms of base shear and displacement moment resisting frames also calculated.

Hezha and Sadraddin (2015) developed Fragility curves which are based on the IDA results for the three limit states including slight damage, moderate damage, and collapse to show the probabilistic comparison of seismic responses among the three buildings in both x and y-directions. It was observed from the fragility assessment results that generally shear walls improve buildings' seismic performance. They conclude that, shear walls increase buildings' resistance against the seismic loads and decreases record-to-record variability which gives predictability design results.

Dina et al. (2015) studied the vulnerability of hospitals buildings and medical facilities. The vulnerability of non-structural and functional features can lead to severe functional and indirect losses.

Bjarnietal (2014) computed fragility curves for given low-rise building typologies and by mapping how the damage was split into different subcategories of structural and non-structural damage. In total, the damage was broken down under a total of 62 headings. About 50% of all buildings in the area suffered damage. Only 0.44% of the buildings were judged to be a total loss.

Mauro Dolce et al. (2014) evaluated various damages such as; slight damage to plaster on masonry infill panels, moderate damage to the external layer of brick infill emphasizing the absence of damage to RC elements of the building, damage to the external layer of the infill panels at the first storey, diagonal cracking characterized by shear failure, structural damage in a squat RC column, zoom-in of the squat column, moderate damage and diagonal cracking of the infill panel between two openings, significant damage and partial collapse of an infill panel are seen.

Poweth (2014) compared various parameters such as storey drift, storey shear, deflection, reinforcement requirement in columns etc. of a building under lateral loads based on strategic positioning of shear walls. Following points are observed; maximum reduction in drift values is obtained when shear walls are provided at corners of the building, provision of shear walls in x-direction will reduce displacement in x-direction, requirement of steel in columns is reduced by provision of shear walls and push over analysis results provides an insight into the performance of structures.
Kappos et al. (2006) produced vulnerability curves for RC frame and wall-frame buildings, as well as for unreinforced masonry (URM) structures, according to a hybrid method. This method combines statistical data with appropriately

processed results from non-linear dynamic or static analyses, that permit extrapolation of statistical data to PGAs and/or spectral displacements for which no data are available. Vulnerability curves were derived in terms of PGA, as well as spectral displacement Sd. Analyses of several different RC building configurations were performed, representing most of the typologies of buildings in S. European countries. Low-rise, mid-rise and high-rise buildings were considered; each one was assumed to have three different configurations bare, regularly in filled and soft ground storey buildind.

III. CONCLUSION

The above research papers give following conclusions;

The Euro code performance is good than the Indian standard (IS1893:2002) and American (ATC40 and FEMA440) codes. Hence improvement is requiring in Indian and American code.
The Performance of Frame with shear wall is better than the Frame without shear wall.

The Base Shear is increased of Frame with shear wall than the frame without shear wall and it increased by 9.82% .and displacement is decreased of Frame with shear wall than the frame without shear wall by 26.70%.

The ductility of OMRF buildings is less than the SMRF buildings, splicing and usage of more number of stirrups as ductile reinforcement for the heavy confinement of concrete of OMRF.

Strengthening the soft storey building, heavy or bulky member need to be provided.

The base shear capacity of OMRF buildings is 7 to 28% more than that of SMRF buildings. So it is necessary to increase strength and stiffness of building to resist seismic loads.

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