SEISMIC ANALYSIS OF LOW RISE OPEN GROUND STOREY FRAMED BUILDING

[1]Bhumik R. Gajjar, [2]Dr. K. B. Parikh
[1]Student, Department of Applied Mechanic (Mtech. Structure), Government Engineering College, Dahod, Gujarat, India.
[2]Associate professor, Department of Applied Mechanics, Government Engineering College, Dahod, Gujarat, India.

Abstract: Today in the metropolitan cities we are rapidly constructing multi-storey building for commercial and residential purposes but proper parking space is not available everywhere. Hence the trend has been made to use ground storey for the parking purpose so that ground storey is made open for parking purpose, no infill wall is provided in ground storey. The engineers did not consider strength and stiffness of the masonry wall, they think that it is traditional design. But this design is not always acceptable, especially for vertically irregular buildings with discontinuous infill walls. Hence the behavior of infill walls in the seismic analysis of framed building is prescriptive. Indian standard IS 1893: 2002 allows analysis of open ground storey building without taking infill stiffness but with a multiplication factor 2.5 in redemption for the stiffness discontinuity. As per the code the beam and columns of the open ground storey are designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames. But as per the experienced by the engineers the multiplication factor of 2.5 is not realistic for low rise open ground storey building. Hence the assessment of the multiplication factor and the effect of strength and stiffness in the seismic analysis of low rise low rise open ground storey building should be taken into account. Infill wall can be design in commercial software using two dimensional area elements with the properties of materials for linear elastic analysis. But this type of designed may not work for non-linear analysis until the non-linear material properties for a two-dimensional orthotropic element is not very well understood. Because the problem of open ground storey cannot be identified elastic analysis as the stiffness of open ground storey and bare frame is same. As per non-linear analysis of the OGS building fails through the soft storey mechanism at a comparatively low base shear and displacement and mode of failure is looks like a brittle. Hence seismic design of an existing reinforced concrete framed building would require a non-linear analysis. Hence in this paper area recommends a linear diagonal strut approach to model infill wall for both linear (Equivalent Static Analysis and Response Spectrum Analysis) and non-linear analysis (Pushover Analysis and Time History Analysis). In this paper we analyse RC framed building (G+3) with open ground storey located in Seismic Zone- V. In this study building analyzed for two different cases: (1) considering both infill mass and infill stiffness and (2) considering infill mass but without considering infill stiffness. In this analysis support conditions of the building also affect the significant parameter for the multiplication factor.

Keywords: Infill Walls, Diagonal Strut, Open Ground Storey, Multiplication Factor, Seismic Analysis, Equivalent Static Analysis, Response Spectrum Analysis, Pushover Analysis, Low Rise Building.

I. INTRODUCTION

Since past few years the increasing population in populated cities car parking space for residential building is a major issue. Hence the engineers used the ground storey itself for parking. In this buildings there is no infill masonry wall in ground storey, but in the upper storeys, infill walls are there, are called as Open Ground Storey (OGS) buildings. Sometimes it's also known as open first storey buildings (when the storey calculating with one from the ground storey), 'pilotis', or 'stilted buildings'.

Fig.1.1 Open Ground Storey (Reference: 10)

This category of building is definitely advantageous functionally but from a seismic performance point of view this buildings are much weak. From the past few earthquakes it can be seen that the most of the failure happened in OGS building included snapping of lateral ties, crushing of core concrete, buckling of longitudinal reinforcement bars etc. In the upper storey presence of infill walls apart from ground storey makes the upper storey much stiffer then the open ground storey. Hence the upper storeys move together as a single unit and displacement of the building occurs in the ground storey itself (Fig. 1.2). We can also say that, this type of building sway back and forth like a inverted pendulum (Fig. 1.3) during earthquake shaking, so that the columns and beams are highly stressed. Hence in the ground storey columns should sufficient strong and ductile. So that compared to the upper storey the low lateral stiffness and strength of ground storey is responsible for the weakness of this type of building.

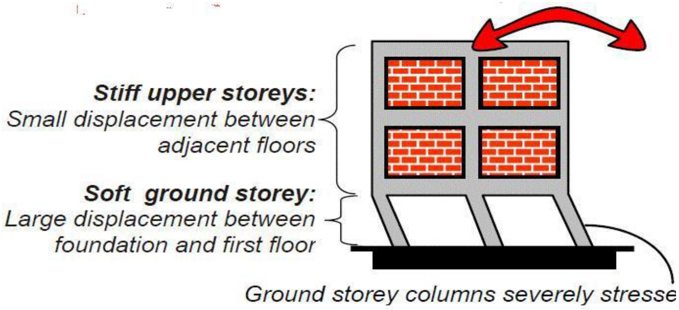

Fig. 1 .2: seismic behavior of building during earthquake shaking (Reference: 3)

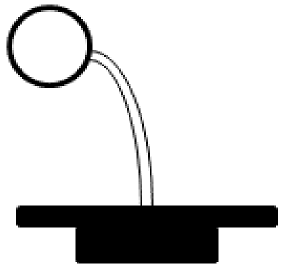

Fig. 1.3: Behaviour of OGS buildings like as inverted pendulum (Reference: 9)

The OGS building behaves not same as compared to bare framed (without any infill) buildings or a fully infilled frame building in lateral load condition. A bare frame is very much less stiff compared to fully infill frame; it resists the applied lateral load through frame action shows well-distributed plastic hinges at failure. When the framed with fully infill walls it's works as truss action. In fully infilled frame building occurs less inter-storey drift and it attracts higher base shear because increased stiffness. Also a fully infilled frame yields less force in the frame and used much energy trough infilled walls. The strength and stiffness of infill walls is not consider in the infilled frame buildings conventional design. Hence in this type of building it will be conservative design. But for the OGS building the things will be different. In OGS building it is slightly stiffer than the bare frame, has larger drift in ground storey and fails due to soft storey mechanism at the ground floor (Fig. 1.4). So that it should not be acceptable to ignore strength and stiffness of infill wall while designing OGS building.

Fig. 1.4: General mode of failure in OGS buildings (Reference: 13)

After the Bhuj earthquake, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS buildings. Clause 7.10.3(a) states: "The columns and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames." The factor 2.5 can be called as a multiplication factor (MF). This multiplication factor (MF) is may be the redemption for the stiffness discontinuity. Also the other national code gives multiplication factor for this type of buildings. This empirical recommendation of IS code was first pointed out by Kanitkar and Kanitkar (2001), Subramanian (2004) and Kaushik (2006). So that the in this paper we check the existence of the multiplication factor of 2.5 in the ground storey beams and columns for the design of OGS framed building and to study the effect of infill strength and stiffness in the seismic analysis.

Non-linear dynamic analysis (NDA) is can be say that most accurate method but it is very hard among all the method. So that we did comparative study among Equivalent static analysis (ESA), Response spectrum analysis (RSA) and Pushover analysis (PA). So that for this analysis two different cases and support conditions take into account.

a) Considering infill strength and stiffness
b) Without considering infill strength and stiffness

Support condition is affect greatly to the stiffness of building. Hence building models were analysed for two types of support conditions: (a) fixed and (b) pinned end support conditions.

Masonry infill walls are mostly used as partitions all over the world. Past experience show that continuous infill masonry walls can reduce the weakness of the RC framed structure. But masonry walls are not taken in the design because they are not act as a structural member. Separately the infill walls are like a stiff and brittle but the frame is relatively flexible and ductile. But the combine action of beam-column and infill walls provides additional strength and stiffness. The Fig. 1.5 shows the equivalent diagonal strut model for the infilled frame.

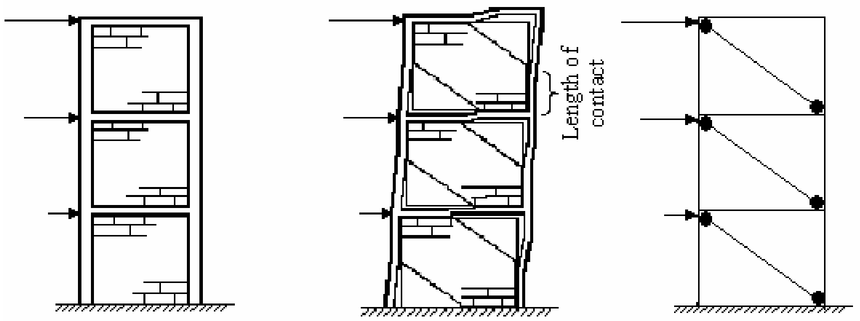

Fig. 1.5: (a) Infilled Frame (b) Deformed Fra (c) Equivalent Strut model (Reference: 13)

II. Methods (Reference: 10)

In this model we analysis the models by two methods namely Linear and Non-Linear process.

(A) Linear Analysis- linear analysis considered elastic behavior. As per height of the structure, level of force and their distribution, this method analyse the model for the static and dynamic analysis. For this method there is three approaches given in IS code 1893: 2002 which is explained below.

1. Equivalent Static Analysis- Equivalent static analysis is also known as seismic coefficient method. Seismic analysis of most structure is still performed on the basis of lateral force assumed equivalent to the dynamic loading. But earthquake force is dynamic, the regular analysis is done by assuming it to be static. The base shear which is the total horizontal force acting on the structure is considered on the basis of their weight, period of vibration and corresponding mode shapes. The base shear is distributed along the height of the structure. The horizontal and vertical forces are also known as the seismic coefficient; generally its value lies in the range of 0 to 1. It is changed according to types of structure. For example, for dams seismic coefficient may be up to 1.5 and for heavy structure like nuclear power plant its value may be 0.6 and for bridges 0.2 to 0.3. It is simplest method of analysis and requires less calculation. This method is conservative for low to medium height buildings with a regular configuration.

2. Response spectrum method- The method is applicable to analysis of dynamic response of the structures, which are asymmetrical or have a irregular area of discontinuity or irregularity, in their linear range of behavior. In this method the maximum response of a building is calculated on the basis of single degree of freedom in a certain period and damping at the time of shaking ground in earthquake. The response v/s undammed natural period graph is plotted and the result obtain is known in terms of maximum relative displacement, maximum absolute acceleration and relative velocity.

3. Elastic time history method- A linear time history analysis overcome all the disadvantages of a model response spectrum analysis, provided non-linear behaviour is not involved. This method requires greater computational efforts for calculating the response at discrete times. In this approach dynamic response is analysis for every increased value of time. For this type of analysis mathematical model are made with the help of computer. And in the mathematical we can directly put the increased value of time and the obtained result is dynamic response.

In this method base shear time period are considered, once the base shear time period is calculated one can easily find out the vale of multiplication factor. Finally the linear analysis the stiffness of open ground storey and the bare frame is almost similar. So that non linear analysis is to be performed to overcome the result. .

(B) Non-Linear Analysis: In non-linear analysis we carried out pushover analysis. Push over analysis is a static non-linear process by using non-linear methodology. In pushover analysis simple gravity load is applied to the structure and roof displacement is calculated. This method is analyse in any commercial software like STADD PRO or ETABS. In software the horizontal load is applied to the structure and the lateral displacement is calculated. Also lateral displacement is can be say that deflection of the structure for this case study. In software pushover curve is generated which shows the graph between strength of the structure and deflection. Non-linear analysis results shows that the value of multiplication is too much, it can be reduced up to 1.25.

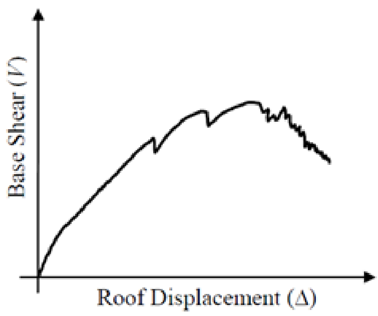

Fig. 1.6 Pushover curve (Reference: 10)

III. LITERATURE REVIEW

This review paper on seismic analysis of open ground storey has been made by many author's researches are:

1. **Bhagavathula Lohitha and S.V. Narsi Reddy (2014)** Investigate an existing RC framed building (G+3) with soft storey was analysed for two different cases (a) considering both infill mass and infill stiffness and (b) considering infill mass but without considering infill stiffness using software SAP2000. Two different support conditions were considered to check the effect of support conditions in the multiplication factors. Linear and non-linear analyses were performed for the models. Concluded that support condition influences the response considerably and can be important parameter to decide the force amplification factor.
2. **Anchal V. Sharma and Laxmikant C. Tibude (2016)** studied a RC framed building (G+3) with open ground storey was analysed for linear elastic analysis through the manually or commercial software it's concluded that the displacements for the open ground storey is lesser than the fully unfilled wall framed and bare framed building for all the seismic zones.
3. **D. J. Chaudhari, Prajakta T. Raipure (2015)** analyses RC framed building (G+10) with OGS for the effects of multiplication factor of Indian Standard codes and other international codes of the seismic loads and study fragility curves which is generated by STAAD PRO. And after the analysis they stated that the OGS frames in terms of ground storey drifts is increasing in increasing order of MF's by all codes for all the performance level. As per IS code the first storey is more weak then ground storey but for Israel code it is not true. Also they stated that as per Israel code, MF only in ground storey may not provide the expected results in all other stories. If MF applied also for the adjacent storey may improve the performance of OGS buildings.
4. **Aditya Deshmukh (2015)** studied a RC framed building (G+10) building with open ground storey for the different seismic zones with the various cases of building element: (a) bare frame building (b)building with uniform infill in all storey (c) building with OGS (d) OGS with stiffer column(e) OGS with corner shear wall (f) OGS with corner cross bracing (g) OGS with composite columns. And the models were generated through the commercial software ETABS. From the lateral displacement graphs he found out that lateral displacement is higher in OGS type compared to other building. Also he stated that with corner shear wall displacement reduction is higher so that it is best model of OGS building with corner shear wall. He also concluded that by studied that OGS building with corner shear wall and cross bracing are found to be very effective in reducing stiffness irregularity and bending moment and OGS with stiffer column and composite columns are very effective reducing stiffness irregularity and drift but there is increasing shear force and bending moment in first storey. And ductility is found more in the infill frame panel than the open ground storey building model.
5. **Prof. Dipak Jivani, Dr. R.G. Dhamsaniya, Prof. M.V. Sanghani (2017)** investigated that the dynamic analysis gives higher time period as compared to static analysis. Higher time period observed in bare frames and the time period increases as the opening space percentage of building increases which is the happened because of reduction in stiffness. It has been found out that maximum base shear and roof displacement capacity both the things is higher for the without infill case than the with infill case. And building modeled with infill stiffness has more ductility compared to building modeled with infill stiffness. He also concluded that after pushover analysis base shear multiplication factor found out is lesser than the IS code suggested.
6. **Amol karemore, Shrinivas Rayadu (2015**) studied a (G+3) building with OGS for the seismic zone 3 and they have done pushover analysis to evaluate effect of seismic behavior of building. They found that OGS building are more sensitive to earthquake than full infill building duo to soft storey effect. Infill walls increases stiffness while decreases lateral displacement. They noticed that there is no effect of zone on multiplication factor. As per IS 1893stated that magnification factor of 2.5 to be applied on calculated shaer force and bending moment is very much. After linear and non linear analysis they concluded that the magnification factor (MF) for bending moment is in the range of 1.06-1.98 for columns and for beam is in range of 0.92-1.06 of ground storey. Magnification factor (MF)) for shear force is in range of 1.42-1.52 for column and for beam is in range of 0.97-1.07 of ground storey.
7. **Akshay S. Paidalwar1 and G.D. Awcha (2017)** stated that the stiffness of the structure is an important factor in case of OGS type building. RC framed building with open ground storey is known to be performing poorly during the strong earthquake shaking. In elastic analysis it has been observed that for OGS building the stiffness is almost same to Bare Frame building.
8. **Ankita Pramod Shelke, Dr. Rajashekhar S. Talikoti(2015**) concluded from the literature reviews that the RC framed building with open ground storey perform poorly at the time of earthquake shaking. The lateral stiffness is less than 70 percent of that of the adjacent upper storey or less than 80 percent of the average stiffness of adjacent three storeys above it causing soft story effect to produce. For a OGS building without shear wall or bracing the strength is very week and easily collapsed during earthquake. Also they stated that after analysis base shear can be more than twice to that expected by equivalent earthquake force method with ir without infill or by response spectrum method when no infill in the analysis of model.

IV. CONCLUSIONS

Followings are the predominant conclusions obtained from the studied literature reviews:

1. As per IS 1893-2002 stated that the value of 2.5 to be considered as a multiplication factor which is to be multiplied to the ground storey beam and column forces when a building is to be design. The ratio of IR values for columns and DCR values of beams for both the support conditions and building models were found out using ESA and RSA and both the analyses supports that a factor of 2.5 is too great to be multiplied to the beam and column forces of the ground floor. So as per literature reviews the After linear and non linear analysis they concluded that the magnification factor (MF) for bending moment is in the range of 1.06-1.98 for columns and for beam is in range of 0.92-1.06 of ground storey. Magnification factor (MF)) for shear force is in range of 1.42-1.52 for column and for beam is in range of 0.97-1.07 of ground storey.
2. It has been concluded from the literature reviews that the RC framed building with open ground storey perform poorly at the time of earthquake shaking. The lateral stiffness is less than 70 percent of that of the adjacent upper storey or less than 80 percent of the average stiffness of adjacent three storeys above it causing soft story effect to produce.
3. Both elastic and inelastic analyses show that the beams forces at the ground storey reduce highly for the presence of infill stiffness in the upper storey. And design force amplification factor need not be applied to ground storey beams.
4. Elastic analysis shows that the stiffness of the OGS building and Bare frame is almost same. Hence the non linear analysis is required.
5. Through the non linear analysis the OGS building fails at a ground storey due to comparatively low base shear and displacement. And the manner of failure is found to be brittle.

6. It has been studied that OGS building with corner shear wall and cross bracing are found to be very effective in reducing stiffness irregularity and bending moment and OGS with stiffer column and composite columns are very effective reducing stiffness irregularity and drift but there is increasing shear force and bending moment in first storey. And ductility is found more in the infill frame panel than the open ground storey building model.
7. From the literature available it was found that the support condition for the buildings was not given much importance. Linear and nonlinear analyses show that support condition influences the response considerably and can be an important parameter to determine the force multiplication factor.

V. REFERENCES

[1] Anchal V. Sharma, Laxmikant C.Tibude (2016). " Effect of Position of Infill Wall for Seismic Analysis of Low Rise Open Ground Storey Building", International Journal of Emerging Trends in Science and Technology

[2] 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.

[3] Akhilesh Yadav, Dr. A. K. Mishra (2017), "Earthquake Resistant Design Of Open Ground Storey Low Rise Building", 2nd International Conference Of Emerging Trends In Engineering And Management Research ,28th May 2017.

[4] Bhagavathula Lohitha and S.V. Narsi Reddy (2014), "Earthquake Resistant Design of Low-Rise Open Ground Storey Framed Building", *International* Open Access *Journal of Modern Engineering Research (IJMER*), Vol. 4, Issue 6, June 2014.

[5] Amol Karemore, Shrinivas Rayadu (2015), " Study on Effect of Zone on Magnification Factor for Open Ground Storey Buildings", International Journal of Innovative and Emerging Research in Engineering, Volume 2, Issue 5, 2015.

[6] Aditya Deshmukh (2015)," Earthquake Resistant Design Of Low-Rise Open Ground Storey Framed Building**",** International Journal of Modern Trends In Engineering And Research (IJMTER), Volume 02, Issue 04, April – 2015.

[7] Prof. Dipak Jivani, Dr. R.G. Dhamsaniya, Prof. M.V. Sanghani (2017)," Effect Of Infill Wall On Seismic Performance of RC Building With Open Ground Storey", International Journal Of Advance Engineering And Research Development Volume 4, Issue 1, January -2017.

[8] Akshay S. Paidalwar1 And G.D. Awcha (2017), "Seismic Analysis Of Open Ground Storey Building", International Journal Of Civil Engineering Research, Volume 8, Number 2 (2017), PP. 69-79.

[9] Ankita Pramod Shelke, Dr. Rajashekhar S. Talikoti(2015), "Survey Paper On Seismic Analysis Of Low-Rise Soft Storey Frame Building", International Journal Of Emerging Technology And Advanced Engineering, Volume 5, Issue 6, June 2015

[10] Shailesh Ghildiyal, Sangeeta Dhyani, Chandra Prakash Gusain (2016), " Earthquake Resistant Design Of Low-Rise Open Ground Storey Framed Building: A Review", Journal Of Emerging Technologies And Innovative Research (JETIR), Volume 3, Issue 3, March 2016.

[11] Snehash Patel (2012), " Earthquake Resistant Design Of Low-Rise Open Ground Storey Framed Building", Mtech. Thesis, Department Of Civil Engineering, National Institute Of Technology, Rourkela-769008, May 2012.

[12] Piyush Tiwari, P.J.Salunke, N.G.Gore(2015), " Earthquake Resistant Design Of Open Ground Storey Building", International Research Journal Of Engineering And Technology (IRJET), Volume 2, Issue 7, Oct-2015.

[13] Ajay Kumar, Dr. S. Vijaya Mohan Rao, Dr. A. Rammohana Chary (2016), " Earthquake Resistant Design Of Low-Rise Open Ground Storey Framed Building", International Journal of Scientific Engineering and Technology Research, Volume.05, IssueNo.47, Pages: 9701-9709.