Seismic Performance Of strengthening Measures For Open ground Storey Buildings

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Abstract- *This review paper is prepared for a comparative study of strengthening measures adopted for open ground storey buildings by studying previously published research papers. Selected papers covering an area of study like seismic performance of multi-storeyed buildings having open ground storey by retrofitting with lateral load resisting systems like moment resisting frames, shear walls for different storeys at different locations, concentric and eccentric bracings for different storeys at different locations, stiffer columns, tapered columns, light weight infill walls, addition of columns in open ground storey, providing masonry infill walls in open ground storey, replacing rectangular columns by circular columns in open ground storey etc. The seismic performance is evaluated in terms of seismic parameters like lateral storey stiffness, storey displacements, storey drifts, base shears, torsion eccentricity, overturning moments, and time periods.*

Keywords- stiffness, displacement, drift, over turning moment, base shear, torsion

I. INTRODUCTION

Multi-storeyed buildings require open taller ground storey for parking of vehicles and/or for retail shopping, large space for meeting room or a banking hall. Therefore, constructions of multi-storeyed buildings with open ground storey has become a common practice. These types of buildings are having no infill walls in ground storey but all upper storeys infilled with masonry walls making it a soft storey. Due to this functional requirement, the ground storey has lesser strength and stiffness as compared to upper storeys, which are stiffened by masonry infill walls. This characteristic of building construction creates weak or soft storey problems in multi-storeyed buildings. Increased flexibility of first storey results in extreme deflections, which in turn leads to concentration of forces at the second storey connections accompanied by large plastic deformations. In addition, columns in the soft storey dissipate most of the energy developed during the earthquake. In this process, plastic hinges are formed at the ends of columns of the soft storey. Which transform the soft storey into a mechanism in such cases the collapse is unavoidable therefore the soft storeys deserve a special consideration in analysis and design. Past earthquakes have shown that such buildings are vulnerable to damage or even collapse during a strong earthquake. Devastating performance of such buildings during earthquakes discouraged construction of such buildings. While damage and collapse due to soft storey are most often observed in buildings. They can also be developed in other types of structures

As per IS1893 RC, moment resisting frame buildings, which have open storey due to discontinuation of unreinforced masonry infill walls, are flexible. In such buildings suitable measures shall be adopted which increase both strength and stiffness to the required level in the open storey. Shear wall is an effective lateral load resisting system having high in plane stiffness and strength to the required level in the open storey. The measures shall be taken along both plan directions. The said increase may be achieved by providing measures like a) RC structural walls or b) braced frames in select bays of building

When RC structural walls are provided they shall be a)founded on properly designed foundations b)continuous preferably over full height of building c)connected preferably to the moment resisting frame of the building. RC structural walls in buildings located in seismic zones III,IV and V shall be designed to comply with all requirements of IS 13920

In multi-storeyed buildings, bracing system is provided between columns to increase stiffness, strength and energy dissipation to resist lateral loads. It offers resistance to lateral forces by bracing action of inclined members. The braces simulate forces in the associated beams and columns so that all work as one like a truss with all members subjected to stresses that are for the most part axial. This axial reaction results in less moments and in turn smaller sizes of beam and column sections compared to moment resisting frames. It is easy to install, economical and occupies less space. Itis a highly efficient and economical method of resisting lateral loads due to earthquake in a framed structure. It is provided in peripheral bays and on two parallel sides of building. The two main types of bracings are concentric and eccentric and commonly used shapes of bracings are X, V, K, inverted V and inverted K

II. REVIEWS

Suchita Hirde and Ganga Tepugade [1] they have studied seismic performance of G+20 storeyed building with RC special moment resisting frames having soft storeys at different levels along with at ground level.

The study is carried on eight models without and with providing shear walls up to the level of soft storey. i)Soft storeys at ground and fifth storey levels with and without shear walls ii) Soft storeys at ground and tenth storey levels with and without shear walls iii) Soft storeys at ground and fifteenth storey levels with and without shear walls iv) Soft storeys at ground and twentieth storey levels with and without shear walls. Shear walls are provided at corners of building in L shape.

The models are analysed by nonlinear static pushover analysis. The results obtained for basic models and retrofitted models are compared in the form of performance point and hinge formation pattern at performance point

The conclusions of the study are i) The seismic performance of G+20 RCC building with soft storey at different levels along with soft storey at ground level is poor ii) it is observed that plastic hinges are developed in columns of ground level soft storey of models without shear walls iii) After retrofitting of models with shear walls plastic hinges are not formed in any of the columns. iv) Provision of shear walls results in reduction in lateral displacement. v) Displacement reduces when the soft storey is provided at higher level vi) After retrofitting base shear carrying capacity is increased by 8.45% to 13.26%

F.Hejazil, S.Jilani, J.Noorzaci, C.Y.Chiengl, M.S.Jaafar, A.A.Abang [2]RC framed buildings with open ground storeys are known to perform poorly during strong earthquake shaking. They have worked on the effect of soft storey on structural response of high-rise buildings. The seismic performance of twelve storeyed building with open ground storey has been studied by linear and nonlinear equivalent static method.

Usually the most economical way of retrofitting soft storey buildings is by adding proper bracings in various arrangements to soft storeys to reduce the soft storey effect on seismic response of buildings. In this paper, it has been tried to reduce soft storey effect by adding bracings in different arrangements in order to reduce soft storey effect on structural seismic response.

The analysis is performed for six models with i)Moment resisting frames ii)bracings in open ground storey only iii)bracings in central bay iv)bracings in alternate bays on all floors except open ground storey v)bracings in all bays on all floors except open ground storey vi)bracings on all floors and all bays. The parameters for comparison are stiffness of open ground storey in X and Y direction is compared with upper storeys.

Stiffness of open ground storey in X and Y directions is compared with that of upper storeys. For models 1, 3 and 6 it is less than 70%, For models 4 and 5 it is less than 25% but for model 2 it is greater than 70%

There is maximum displacement of open ground storey in models 1, 4 and 5; model 1 and 2 showed maximum displacement of top floor, model 3 has a greater effect on it. However, model 6 being a soft storey model has proved best model showing minimum displacement of top storey. Model 3 has greater effect on it because the bracings are added at centre only.

It was found that location and numbering of bracing is an important factor for soft storey buildings to displace during earthquake. The horizontal and vertical movements of building with bracings installed were reduced compared with other models. Therefore, the result shows that use of bracings effectively reduces effect of soft storey on structural response in earthquake excitation. Beside it increase the strength of the member; it also increases the overall stiffness of building. However, the bracings must be added at proper position in order to get good effect on earthquake resistance

J. Tanijaya[3] have compared the seismic performance of concentrically and eccentrically braced frames to examine the lateral resistance, plastic hinge mechanism, and ductility factor of CBF and EBF. Push over analysis is performed on MRF, CBF and EBF with various link lengths (e=0.4m, 0.6m, 0.8m, 1.0m) and concluded that

i) the increase in lateral resistance resulting from use of CBF is 74% and EBF 52% compared to MRF therefore CBF has higher elastic stiffness than EBF ii) The plastic hinge mechanism for CBF is marked by the formation of plastic hinges on bracing while EBF is marked by the formation of plastic hinges on the links, then beams and columns. iii)The ductility factor for CBF is 45.75% smaller than MRF while for EBF the ductility factor is 18.20% smaller than MRF but 33.68% larger than CBF therefore EBF is more ductile than

EBF iv)The understorey drifts are within limit for both CBF and EBF v)displacement is less for CBF vi)The displacement for CBF for corresponding shear force is lesser than that of EBF vii)The ultimate shear force for CBF is greater than that of EBF vii)CBF has greater strength to resist seismic forces than EBF and MRF

P.B.Lamb, Dr.R.S.Londhe [4]The study is carried out on reinforced concrete moment resisting frame building with open first storey and unreinforced brick infill walls in the upper storeys. The building is having G+6 storeys of which the ground storey is intended for parking. The building plan is symmetric in both orthogonal directions to avoid the torsional response under pure lateral forces. Columns are taken to be square keeping he discussion focused on first soft storey effect. They have performed parametric study on multi-storey building with soft first storey considering the factors that influence the mass, strength, stiffness and deformability of structure.

The study was carried on eight models having i)infill walls in all storeys ii)Open ground storey iii)Open ground storey having walls at specific locations iv)Open ground storey with concentrically braced frames v)Open ground storey with stiffer columns vi)Open ground storey with shear walls vii)Open ground storey with tapered columns viii)Open ground storey with light weight infill walls in upper storeys
The displacements observed for model 2 is maximum and for models 3,4,5,6 are reduced by 34,54,70,80 % respectively and smaller reduction for models 7 and 8

Drifts for model 2 is maximum and ductility demand is largest. For model 3, 4,5,6,7 and 8 having less ductility demand

Bending moments for models 2, 5 and 7 are higher in open ground storey. For models, three and eight less, models 3 and 8 are not effective in reducing strength demand of open ground storey columns

Shear forces for models 1 to 7 are constant, while for model 8 it reduces to 10% of model2

Time periods for models 2 and 8 are more, for models 4 and 6, it is lesser and for models 5 and 7, it is minimum

The conclusions of the study are

i) Shear walls and cross bracings are found to be very effective in reducing the stiffness irregularity and bending moments in the columns. Higher sizes of columns are effective in reducing the drift but increase the shear force and bending moment in first storey
ii) Lightweight infill is found to be very effective in reducing the stiffness irregularity and storey drift
iii) The use of masonry infills is found not effective in reducing the strength demand on the first storey columns though they considerably reduce the stiffness irregularity in this case the stiffness of the first storey is 45% of the second storey stiffness
iv) The use of cross bracings significantly increases the first storey stiffness. The first storey stiffness comes out to be 70% of the second storey stiffness .It considerably reduces the lateral displacement and shows a smooth drift profile
v) The use of cross bracings reduces the moments by 50 to 60% as compared to soft storey model. Shear walls are found to be most effective in reducing the stiffness irregularity, storey drift and strength demand in the first storey
vi) Stiffer columns are effective in reducing the stiffness irregularity and drift but there is increase in shear force and bending moment in the first storey. Higher sizes of columns increase the stiffness up to 73% and do not show abrupt change in displacement profile
vii) Shear walls are found to be most effective in reducing the stiffness irregularity, storey drift and strength demand in first storey. When the shear walls are introduced, the stiffness of first storey increased to 80% and moments are reduced by 50-60%
viii) The tapered form of columns helps in reducing the storey drift but it increases the forces in columns and induced torsion is significantly higher than soft storey model
ix) Light weight infills are found to be quite effective in increasing the stiffness of first storey (88% of second storey stiffness), storey drift and marginally reduces the strength demand in first storey columns

Christopher Arnold and Robert Reitherman [5] had suggested the solutions to the problem of soft storey, which starts with its elimination. To avoid the discontinuity of strength and stiffness due to soft storey it is necessary to investigate the means of reducing discontinuity by other design means such as increasing the number of columns in the open ground storey. This solutions require detailed analysis and refined design to alleviate the problems

Blume, Newmark and Corning advocate strong (not necessarily shear walled) perimeters· "It is strongly recommended that torsional phenomenon be given serious attention in design. It is also recommended that tall buildings have symmetrical moment resisting frames regardless of any walls and that every building have as much lateral resistance as feasible in its outermost periphery of structural support."

Tall buildings must have as much lateral resistance as feasible in its outermost periphery. In resisting torsion with the centre of twist of a symmetrical building located exactly at the geometric centre. The further the material placed from the centre the greater the lever arm through which it acts and hence greater the resisting moment that can be generated. Putting the resisting members on the perimeter whenever possible is however always desirable weather the members are walls, frames or braced frames and weather they have to resist direct lateral forces, torsion or both.

C.V.R.Murthy and Sudhir K. Jain [6] Masonry infills in RC buildings cause several undesirable effects under seismic loading: short column effect, soft storey effect, torsion and out of plane collapse. Hence, seismic codes tend to discourage such constructions in high seismic regions. However, in several moderate earthquakes such buildings have shown excellent performance even though many such buildings were not designed and detailed for earthquake forces.

They have performed cyclic tests to study performance of URM masonry walls during earthquakes and concluded that masonry infills contribute significant lateral stiffness, strength. overall ductility and energy dissipation capacity. With suitable arrangements to provide reinforcements in the masonry that is well anchored into the frame columns, it is possible to also improve out of plane response of such infills.

This paper presents experimental results of masonry infilled RC frames subjected to lateral loading. The performance of infilled masonry frames is compared with that of bare frames. Masonry infills consists of unreinforced or reinforced burnt clay bricks in cement mortar. Two cases of reinforced infills are considered: masonry with and without reinforcement anchored into frame columns. The effect of brick size on hysteretic response is discussed. Based on these experimental results and past analytical studies this paper explores the beneficial effects of masonry infill walls on seismic behaviour of RC frame buildings.

The main conclusions drawn from these tests are:1)Stiffness; Average initial stiffness of infilled RC frame is about 4.3 times that of bare frame when masonry is unreinforced and about 4.0 times that of bare frame when masonry in reinforced. 2) Strength: On an average URM infilled frames have about 70% higher strength than the bare frames this value is about 50% higher in case of RM infilled frames. 3) Ductility: The yield displacement of infilled frames is much smaller than that of bare frame. Hence, the infilled frames have a considerable large ductility. Addition of reinforcement in infills increases the ductility of infilled frames. The average ductility of URM infilled frames is about 4.0 times that of the bare frames and ductility of RM infilled frame is about 5.1 times that of bare frames.4)Energy dissipation: The average energy dissipation in unreinforced infill frames is about 22% higher than that in reinforced infill frames. 5) Influence of reinforcement in masonry: Infilled frames with unanchored reinforcement shows higher stiffness, ductility and energy dissipation than those with anchored reinforcement.6) Influence of brick size: Lateral stiffness of full size bricks is greater than that of reduced scale bricks

Shilpa V.A.,Salmab Khurshid, Prof. Virendra kumar Paul[7] The paper published by these authors shows that the seismic performance of open ground storey buildings can be regularized with the provision of suitable mitigation measures, analysis techniques and appropriate seismic design. The presence of these irregularities causes a significant increase in the structural costs and these may be optimised by introduction of suitable structural elements. The study focuses on the vertical stiffness-strength irregularities and the several features in the buildings which induce these irregularities. The suggestions provided by the Indian seismic code and different mitigation techniques for each of these features are discussed.
Methods suggested to avoid irregularities through open ground storey are as follows. I) provision of masonry walls at open ground storey level without affecting the functionality i.e. vehicle parking. ii) Selection of alternative structural system to provide earthquake resistance. A ductile frame is not an adequate choice when the number of panels in the ground floor which can be masonry filled is sufficient to offer required lateral stiffness and strength.in such cases alternatives like RC shear wall is preferred.

The special design provisions for buildings with open storeys are as follows

i) conduction dynamic analysis of structures including the effects of masonry and inelastic deformation ii) analysing the structure without infills and the dynamic forces obtained in the elements of open storey to be scaled up 2.5 times the storey shears and moments. iii) shear walls which are designed for 1.5 times the storey shear to be introduced in the open storey in both directions of structure

Kapil Verma [8]In this study seismic behaviour of a G+9 building has been analysed by using push over analysis. The effect of column shape on the stability of the structure is studied. The seismic performance evaluation has been carried out by changing the sizes of the rectangular columns for three different combinations and also by replacing the rectangular columns with circular columns. The percentage of reinforcement is also kept constant. Capacity curves (base shear verses storey drift) extracted from static push over analysis. The dimensions of the building have been kept constant.

The conclusions drawn from the study are i)The behaviour of circular columns is little better than rectangular columns when compared in terms of storey drift, base shear and roof displacement ii) The performance of circular column RC frame is also found to be better than rectangular column RC frame iii)The performance points of the capacity curves show that circular columns perform better than rectangular columns with regards to the values given iv) The storey displacement curves indicate that the storey displacements are just a bit more for rectangular columns. not much significant variation is found.

III. CONCLUSIONS

The conclusions drawn from the study of research papers are

i) Maximum storey displacements, drifts, bending moments, and oscillation periods in longitudinal and transverse directions for models with shear are smaller than those of other models are
ii) Base shears increases if shear walls, bracings, stiffer columns are provided
iii) Concentrically braced frames have higher stiffness than that of eccentrically braced frames
iv) eccentrically braced frames are more ductile than concentrically braced frames
v) Lateral storey stiffness's in longitudinal and transverse directions for models with shear walls are greater than those of other models are
vi) Discontinuity in strength and stiffness due to soft storey can be eliminated by addition of columns and resisting elements on perimeter of open ground storey
vii) Stiffness, strength, ductility, energy dissipation increases due to RM and URM infill walls
viii) URM infill walls can be added in open ground storey without affecting vehicle parking to avoid vertical stiffness irregularity
ix) Seismic performance of building improves due to circular columns in open ground storey

Based on the comparison of results in research papers it can be concluded that shear walls and bracings perform better than other types of lateral load resisting systems

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REFERENCES

[1] Suchita Hirde and Ganga Tepugade(2014 June),"Seismic performance of multi-storey building with soft storey at different levels with shear walls", International Journal of Current Engineering and Technology(online), ISSN 2277-4106,vol.4,issue3, https://inpressco.com ,pp2019-2023
[2] F.Hejazil,S.Jilani,J.Noorzaci,C.Y.Chiengl,M.S.Jaafar,A.A .Abang,(2011,November),"Effect of soft storey on structural response of high rise buildings",IOP Conference Series:Materials,Science and Engineering,IOP Publishing Ltd(online)ISSN1757-899X,Vol.17,Article No.012034,https://doi.org
[3] J.Tanijaya (2021 October),"Structural performance of concentrically and eccentrically braced frames", IOP conference series: Earth and Environmental science, IOP Publishing Ltd (online), ISSN1755-1315, Vol, 871, ArticleNo.012046, https://doi.org
[4] P.B.Lamb, Dr.R.S.Londhe (2012Dec),"Seismic behaviour of soft first storey", IOSR Journal of Mechanical and Civil Engineering (online), ISSN2278-1684, Vol.4, Issue5, www.iosrjournals.org,pp28-33
[5] Christopher Arnold and Robert Reitherman, Building configuration and seismic design: The Architecture of seismic resistance, Directorate of engineering, National science foundation, Washington D.C.: May 1981, p72-73,116
[6] C.V.R.Murthy and Sudhir K. Jain, Beneficial influence of masonry infill walls on seismic performance of RC frame buildings,12WCEE,https://www.iitk.an.in
[7] Shilpa V.A., Salmab Khurshid, Prof. Virendra kumar Paul (July 2020)." Review of mitigation measures for vertical stiffness-strength irregularities", International journal of creative research thoughts, ISSN: 2320-2882, volume8, issue7, www.ijcrt.org
[8] Kapil Verma, (2022 March),"Comparative study of seismic behaviour of open ground storey buildings after replacing rectangular columns with circular columns", International journal of advance research, ideas and innovations in technology, ISSN 2454-132X, volume3, issue3,www.ijariit.com