CASE STUDY ON SEISMIC RETROFITTING OF OPEN GROUND STOREY REINFORCED CONCRETE BUILDING

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Abstract- Many low-rise and medium rise framed buildings have been constructed in the recent past, without proper attention paid in their design for wind or earthquake loads. It causes the failure of the column of the storey during an earthquake which is more severe than the failure of the slabs or beams. The columns can fail either in shear or in bending. Shear failure occurs mainly because of the inadequate column sizes to resist the seismic loads and inadequate lateral ties. In this paper study is carried out on existing multistoried RC building with soft storey, located in seismic zone III. In this paper different mathematical 3D models are prepared for different retrofitting techniques. All models are analyzed using software STADD PRO V8i. Comparison of these models is presented in terms of displacement, storey drift, bending moment, area of steel. Quantity and cost for steel and concrete is calculated.

Keywords- Soft storey, infill, retrofitting, weak storey, flexible, stiffness

I. INTRODUCTION

Reinforced concrete (RC) is the popular material for building construction in India. Also, construction in RC is considered to be labor intensive and supposedly requires lesser high-tech tools, infrastructure and skills, than those in structural steel. Low and medium rise RC frame buildings with masonry infill are very common in urban India. The 2001 Bhuj earthquake is the first significant one in the past five decades to have struck the urban constructions of India in a big way, and to have provided revealing evaluation of the seismic resistance of engineered buildings.

Most affected multi-storey buildings are 5 storeys high (Ground+4 storeys), and many up to 11 storeys (Ground+10 storeys); in most of the buildings, the ground storey is left open to accommodate the parking. Some of the buildings have partially filled ground storeys. In contrast to the infilled upper storeys, the open ground storey may cause: (a) soft storey effect: the open ground storey may have smaller stiffness and cause increased deformation demand in the frame members of that storey; and (b) weak storey effect: the open ground storey may have lower lateral strength and cause a discontinuity in flow of lateral seismic shear in that storey.

Retrofitting of buildings is required to overcome the seismic deficiency. Three levels of improvement of existing RC frame buildings are possible, namely (a) Repair: only cosmetic modifications are made, (b) Restore: structural modifications are made such that the original seismic performance of the building is restored, and (c) Strengthen: structural modifications are made such that a higher seismic performance of the building is achieved than that of the original undamaged structure, (d) Retrofitting:

II. SOFT STOREY

Reinforced concrete (RC) frame buildings are becoming increasingly common in urban India. Many such buildings constructed in recent times have a special feature the ground storey is left open for the purpose of parking (Figure 1.1), i.e., columns in the ground storey do not have any partition walls (of either masonry or RC) between them. Such buildings are often called open ground storey buildings or buildings on stilts. The Indian seismic code IS 1893:2002 defines the soft storey as the " one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storey above ." Interestingly, this classification renders most Indian buildings, with no masonry infill walls in the first storey, to be "buildings with soft first storey".

Figure 1: Ground storey of RC building are left open for parking
"Effect of Soft Story on Structural Response of High Rise Buildings"
This picture has been downloaded from IOPscience

III. RETROFIT SCHEMES

Strengthening schemes are implemented as part of either post-earthquake restoration of buildings or as pre-earthquake preparedness. The aims of strengthening measures are to provide increased strength and increased ductility to the structures. In Indian scenario, the relevant retrofitting schemes are (a) column jacketing, (b) masonry infilling in RC frame, (c) RC structural walls, and (D) cross bracings, considering cost and feasibility of the schemes. Jacketing of columns can be done by steel encasement, steel straps, concrete or mortar or a combination of these methods. Frame jacketing with concrete was implemented for a large number of affected buildings in the past earthquake.

IV. MODELLING OF BUILDING

In this paper, the seismic analysis and its retrofitting is carried out on the existing hostel building having G+4 storeys of which the ground storey is kept open for parking. The building is located in seismic zone III and rests on hard rock. In this work, retrofitting techniques for building is carried out by attending focused on the various parameters such as bending moments, storey drifts, displacements in lateral and transverse direction and area of steel. For a building with soft first storey, the study is carried out with the help of five different mathematical models with different retrofitting techniques, considering various methods for improving seismic performance as mention below:

- Column jacketing
- Masonry infilling in RC frame
- RC structural walls
- Infill wall and shear walls at ground storey and considering cost and feasibility of the schemes

The study is carried out with the help of five different mathematical models, the dead loads of infill walls are considered in all models as per drawing.

Model I: The existing building is modelled as a bare frame and analysis is carried out by using IS 13920 (Figure 2).
Model II: Retrofitting of columns (jacketing of columns) are carried out by increasing their sizes and analyze by IS 13920 (Figure 3).
Model III: In this model infill walls are provided at the selected location of ground storeys (Figure 4).
Model IV: In this model shear wall and infill walls are provided at selected locations of ground storey (Figure 5).
Model V: In this model shear walls are introduced at ground storeys (Figure 6).

The analysis and design of building is carried out on all the five mathematical models using software STADD PRO V8i and the comparative study is done.

Walls are modelled by equivalent strut approach and wall load is uniformly distributed over beams. The diagonal length with the same thickness of strut as brick wall, only width of strut is derived. Walls are considered to be rigidly connected to the columns and beams.

Data for existing hostel building

i. Plan dimension: 22.61m X 11.69m
ii. Total height of building: 18m
iii. Height of each storey:
  3.2m (for ground story),
  3 m (for upper storey)
iv. Height of parapet: 1.2m
v. Size of longitudinal beams:
  230m x 380mm (for span 3.23m)
vi. Size of transverse beams:
  230m X450mm (for span 4.73m)
  230mm X 300mm (for span 2.32m)
vii. Size of columns:
  230mm X 380mm (For ground and 1st floor)
  230mm X 230mm (for 2nd, 3rd, 4th floor)
viii. Thickness of external walls: 230mm
ix. Thickness of internal walls: 230mm
x. Seismic zone: III

Different building models are generated using STAAD Pro.V8i. Brief description of all these building are given as follows.

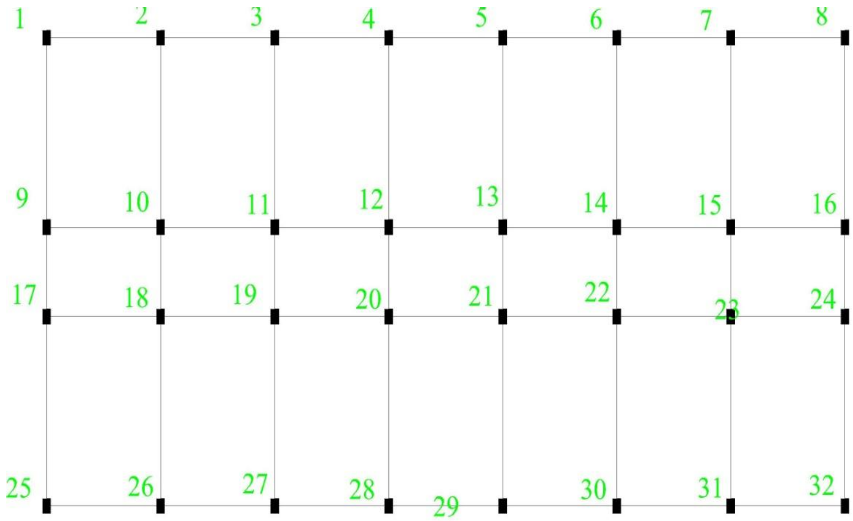

Figure 2: Plan of existing building with open ground storey

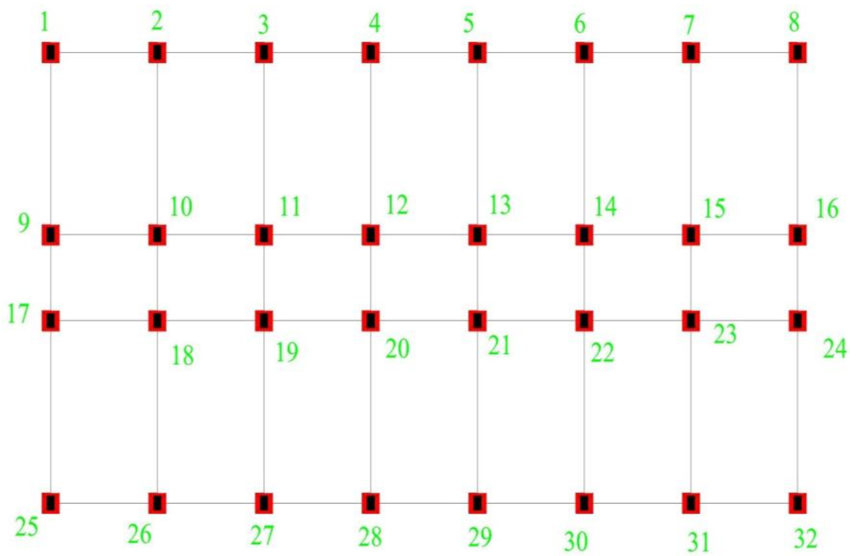

Figure 3: Plan of building with stiffer columns

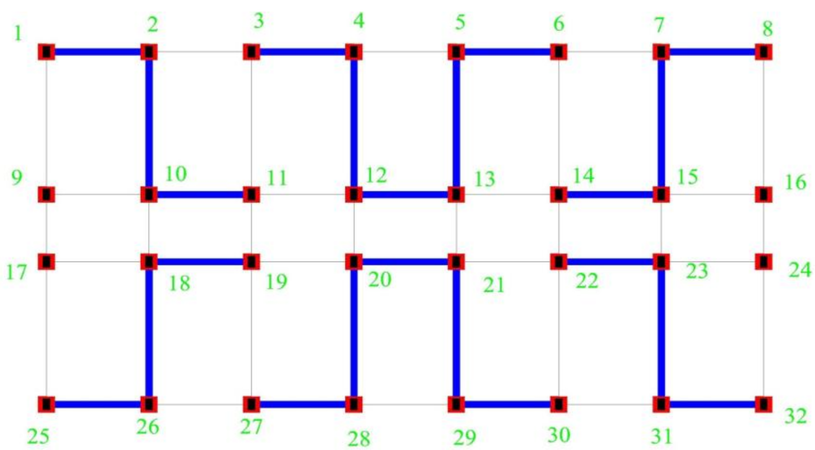

Figure 4: Plan of building with the location of infill walls at ground storey

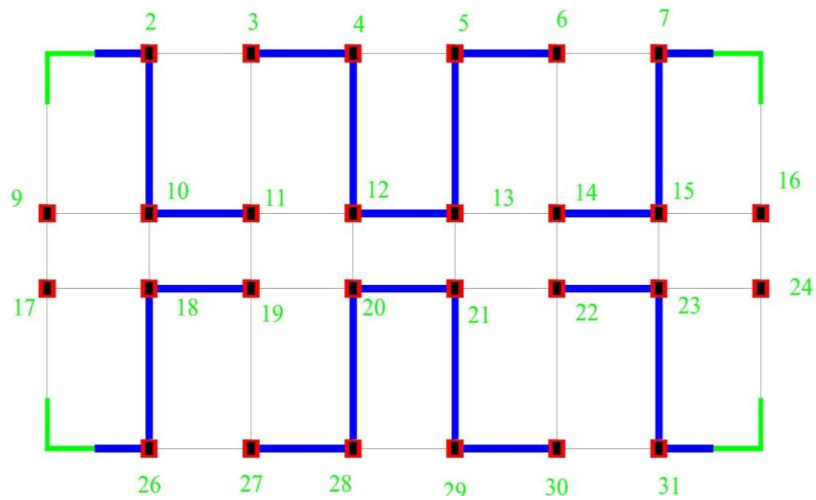

Figure 5: Plan of building with the location of infill and shear wall at parking

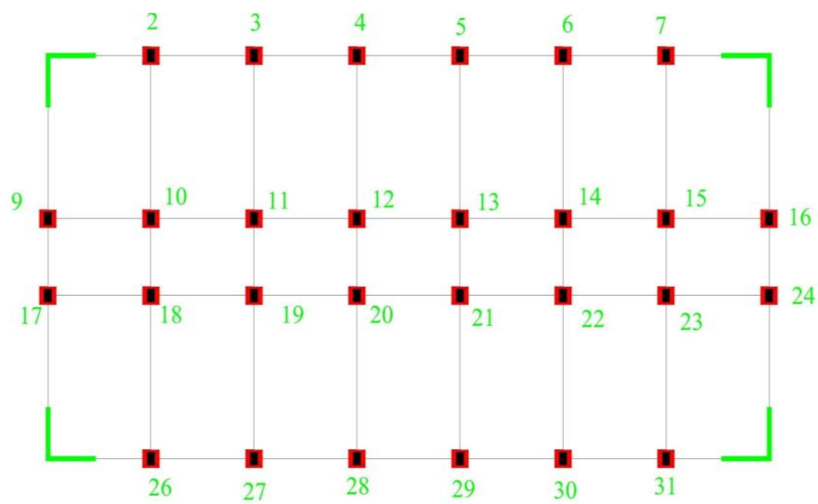

Figure 6: Plan of building with the location of shear wall at parking

V. COMPARISON OF DISPLACEMENT AND DRIFT IN LONGITUDINAL AND TRANSVERSE DIRECTION

1. Displacement

Graph is plotted by taking displacement as the abscissa and the storey level as the ordinate for different models in the transverse and longitudinal direction

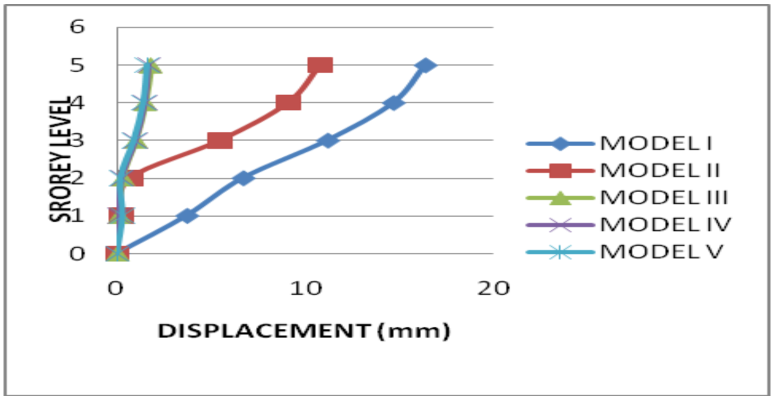

Figure 7: Comparison of displacement in longitudinal direction

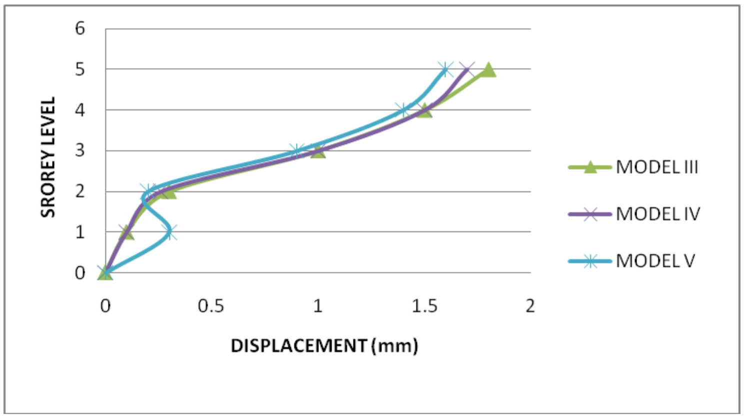

Figure 8: Comparison of displacement in longitudinal direction

From the above graphs large (within permissible limit) displacement occurs in case of soft storey building (model I). It is seen that by increasing the sizes of columns (column jacketing) (model II) reduces the displacement up to 34%. In model III and IV that is by considering the effect of infill and providing infill wall at particular location as well as providing shear wall at parking reduces the displacement by 89%. Introducing only shear wall at parking (model V) reduces the displacement by 90%.

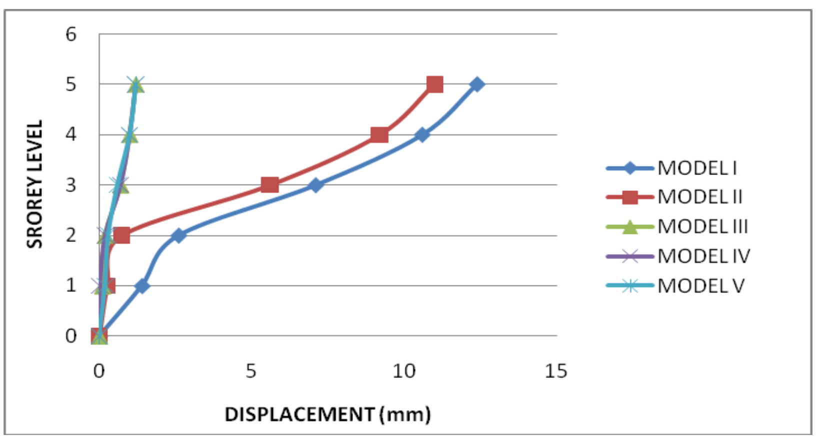

Figure 9: Comparison of displacement in transverse direction

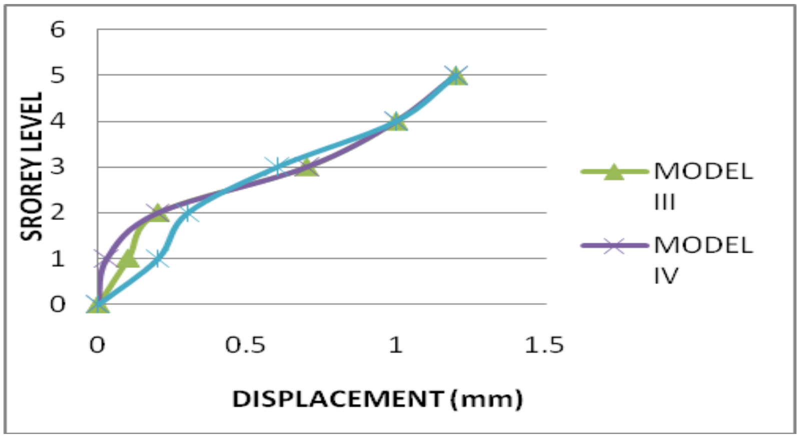

Figure 10: Comparison of displacement in transverse direction

From the above graphs large displacement (within permissible limit) occurs in case of soft storey building (model I). It is seen that by increasing the sizes of columns (column jacketing) (model II) reduces the displacement up to 11%. In model III and IV that is by considering the effect of infill and providing infill at particular location as well as providing shear wall at parking reduces the displacement by 90%. Introducing only shear wall at parking (model V) reduces the displacement by 90%.

2. Storey Drift

Graph is plotted by taking drift as the abscissa and the storey level as the ordinate for different models in the transverse and longitudinal direction is shown in figure

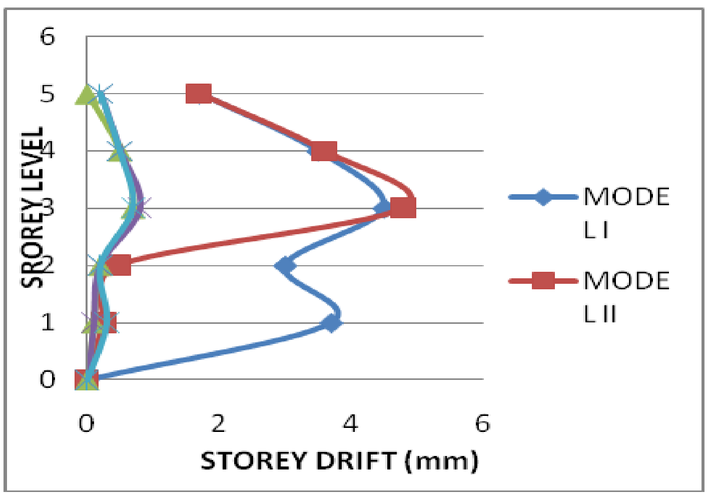

Figure 11: Comparison of storey drift in longitudinal direction

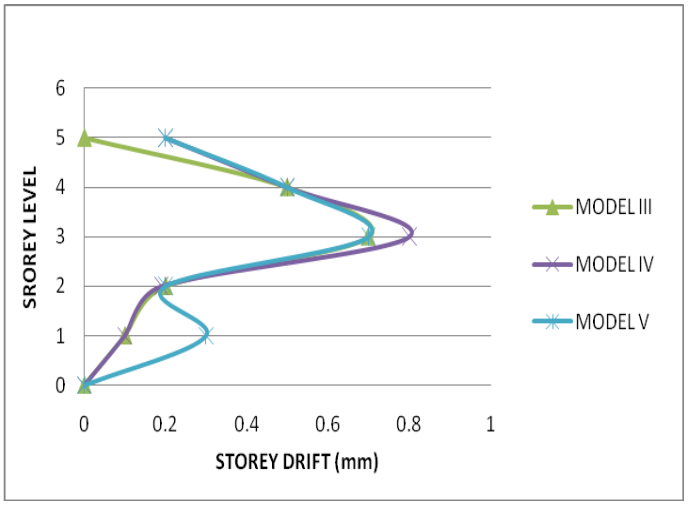

Figure 12: Comparison of storey drift in longitudinal direction

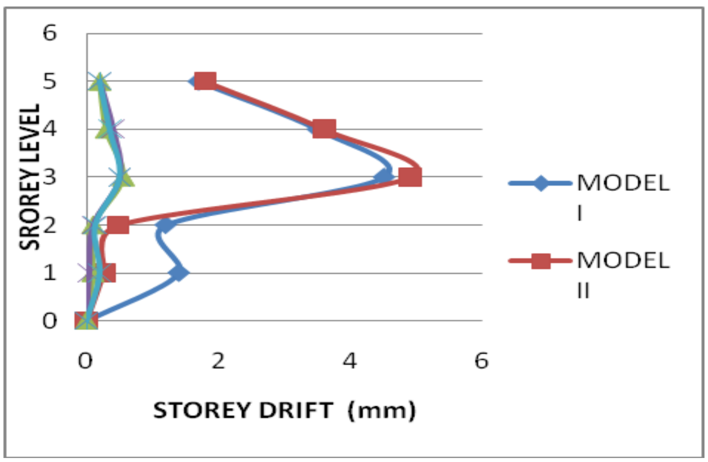

Figure 13: Comparison of storey drift in transverse direction

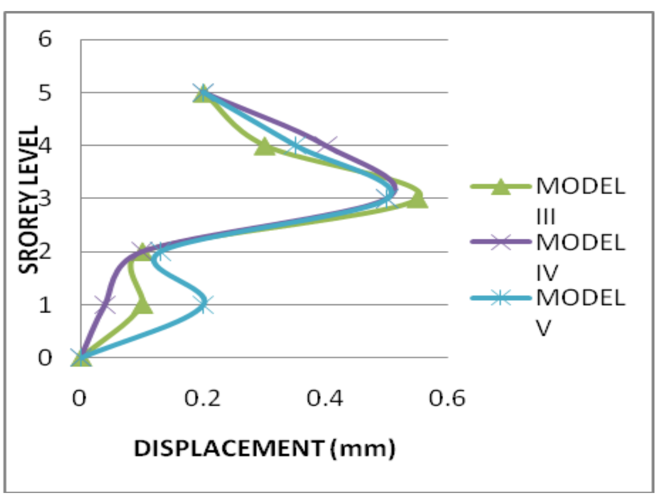

Figure 14: Comparison of storey drift in transverse direction

From graph it is observed that in case of Model I and Model II there is large variation in storey drift profile as compared to Model III, IV and V. An abrupt change in displacement profile indicates stiffness irregularity. The graph shows the storey drift is maximum for Model I and II indicate there is sudden change in the slope at first storey in case of Model I and ductility demand in the first and third storey columns for this Model is largest. However this storey drift profile becomes smoother in Model III, IV and V indicating large stiffness and less ductility demand.

3. COMPARISION OF BENDING MOMENTS IN COLUMNS

Graph is plotted by taking column number as the abscissa and bending moment (Mz) as the ordinate.

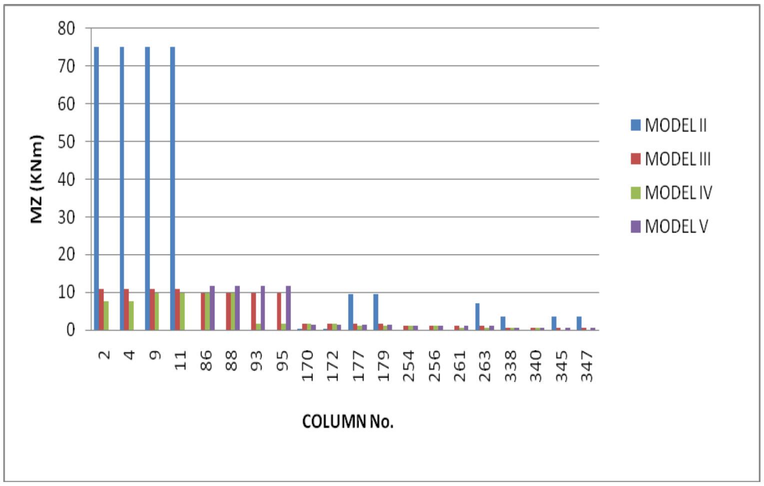

Figure 15: comparison of maximum bending moment (Mz)

Graph is plotted by taking column number as the abscissa and bending moment (My) as the ordinate.

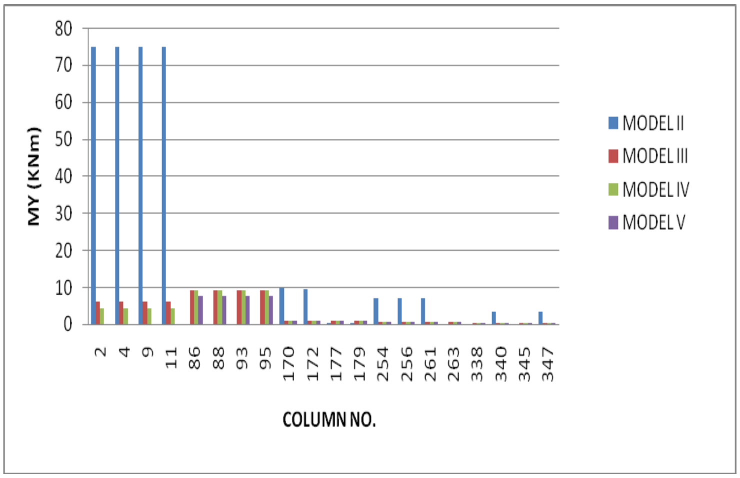

Figure 16: comparison of maximum bending moment (My)

From graph it is observed that the bending moment in model II is more for ground storey in both the direction because moments of soft storey is increased by 2.5 times the original moments(IS 1893) for bare frame and for model V ground storey moments are zero because of shear wall and frame interaction.

4. COMPARISION OF AREA OF STEEL IN COLUMNS

Graph is plotted by taking column number as the abscissa and area of steel as the ordinate.

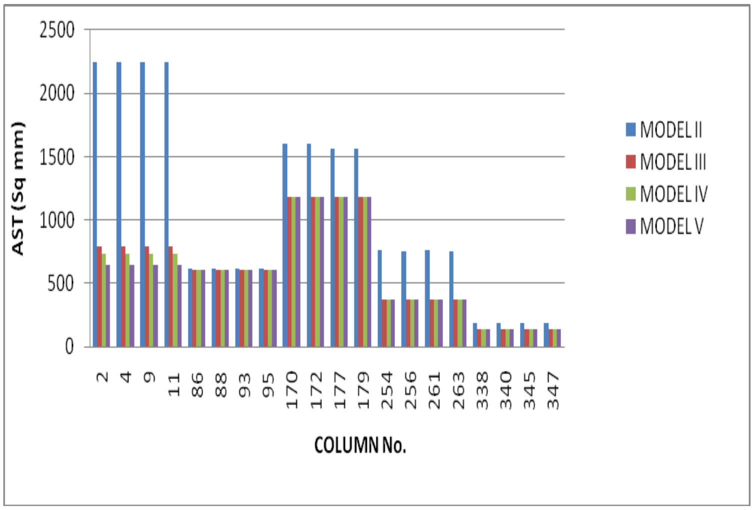

Figure 17: Comparison of steel for columns of different floors

From this graph it is observed that area of steel is more for model II because the moments of ground storey columns are increased by 2.5 times the original moments. In second and third storey for model II steel is more as we used stiffer columns for that storey. Model III, IV and V gives nearly same steel for a particular storey.

5. COMPARISION OF QUANTITY AND COST OF CONCRETE AND STEEL

Graph is plotted by taking different models as the abscissa and cost of concrete, cost of steel and total cost for retrofitting as ordinate for the following graph.

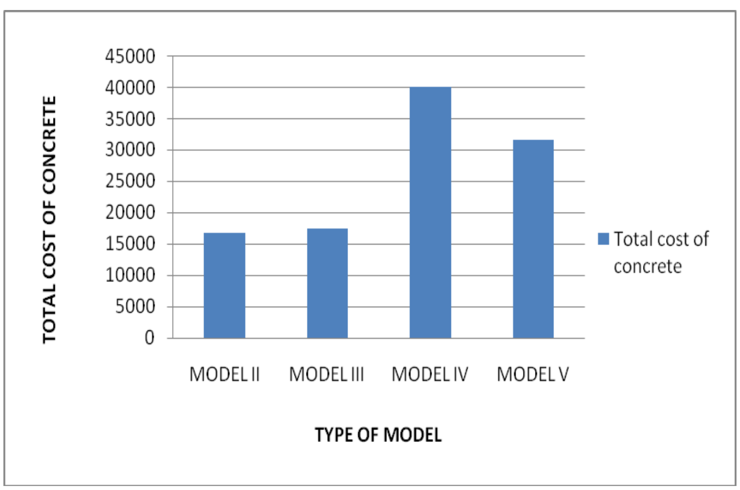

Figure 18: comparison of total cost of concrete required for retrofitting

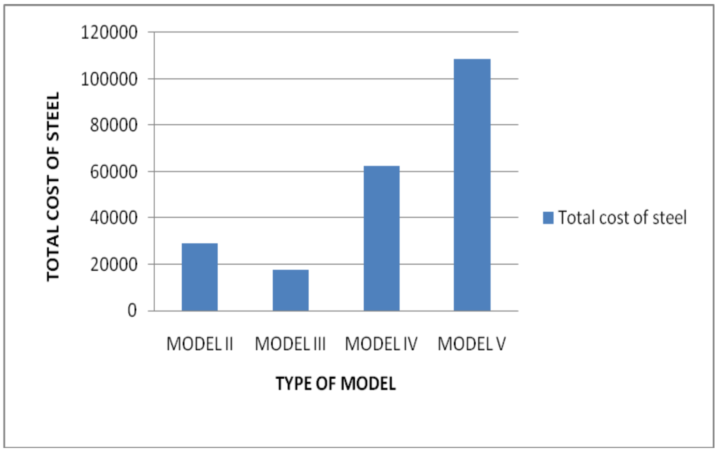

Figure 19: Comparison of total quantity of steel required for retrofitting

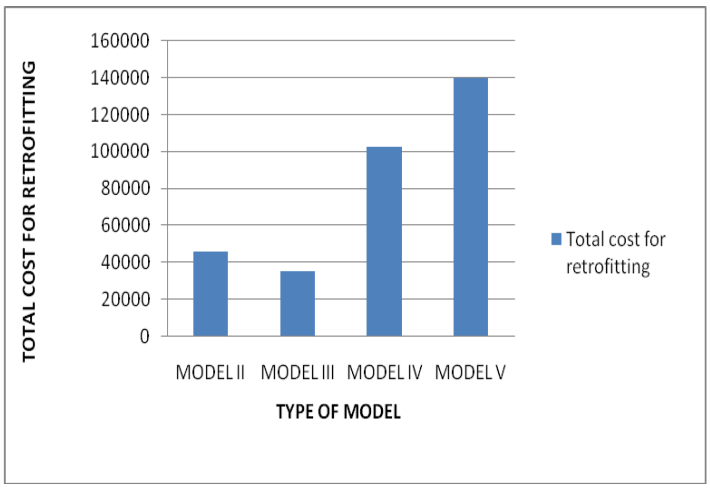

Figure 20: Comparison of total cost required for retrofitting

From the above table and graphs it is observed that quantity of steel is maximum in model V as shear wall is used in that model. In model IV quantity of concrete is more as infill wall is used in that model. Cost of steel is less in model III as compared to other models. Total cost of concrete is nearly same in model II and III. Overall cost for retrofitting of building is less in model III and more in model V.

CONCLUSIONS

Based on the analysis and design results of the case study following conclusions are drawn

- It is observed that displacement of existing building is more as compare to other building models but this displacement is within permissible limit.
- It is observed that after analysis the actual sizes of columns are inadequate hence the building was unsafe.
- After analyzing the existing building by IS 13920, it was observed that storey drift is large but within permissible limit.
- There is reduction of storey drift and displacement if we provide infill wall at the parking in the building.
- The displacement and storey drift is reduced drastically by the provision of shear wall and infill wall in the building.
- Shear walls is found to be very effective in reducing the stiffness irregularity and bending moment in the columns. Increasing the sizes of columns (column jacketing) reduces the drift than existing building.
- After providing the infill wall at selected locations of parking storey drift and displacement is very less as compare to existing building.
- For model V bending moment is zero for ground floor because of shear wall and frame interaction.
- It is observed that quantity of steel is more when shear wall is used and quantity of concrete is more when infill wall is used in the building. Cost of steel is less after provision of infill wall at parking.
- Overall cost for retrofitting of building is less when we provide infill wall at parking and its displacement, storey drift is also minimum as compared to existing building.

REFERENCES

1. Kaustubh Dasgupta and C.V.R. Murty. “Quantitative seismic Retrofitting of Open Ground Storey RC Frame Buildings.” Workshop on retrofitting of structures, , IIT Roorkee, pp 186-192, Oct 10-11, 2003.
2. Jaswant N. Arlekar, Sudhir K. Jain and C.V.R. Murty. “ Seismic Response of RC Frame Building with soft first storey.” Proceedings of CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, , New Delhi, pp 13-24, 1997
3. Selvakoodalingam, E.B Perumal Pillai, P. Govindan. “Influence of ground floor opening for parking lot in high-rise building.Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore.
4. Sharany aquea and Khan Mahmud Amanatb . “Strength and drift demand of columns of RC framed buildings with soft ground story” Journal of Civil Engineering (IEB).
5. Kaustubh Dasgupta and C.V.R. Murty. “Quantitative seismic Retrofitting of Open Ground Storey RC Frame Buildings.” Workshop on retrofitting of structures, IIT Roorkee, pp 186-192, Oct 10-11, 2003.

6. Miss Desai Pallavi T and Prof. Mrs. A. Rajan. "SEISMIC PERFORMANCE OF SOFT STOREY COMPOSITE COLUMN" International Journal of Scientific & Engineering Research, Volume 4, Issue 1, ISSN 2229-5518, January-2013
7. Hiroshi komoto1, Tatsuo kojima1, yoshinori mase1, Kazuo suzuki2, Xuefeng Wen3 Case Study On The Soft-First-Story Buildings Strengthened By Confined Concrete Columns Co" 13th World nference on Earthquake Engineering Vancouver, B.C., Canada Paper No. 654, August 1-6, 2004
8. Ravi Kanetkar and Vasant Kanetkar. "Seismic Performance of Conventional Multistorey Building with Open Ground Floors for vehicular Parking." The Indian Concrete Journal, February, 2004.
9. S.R. Satish Kumar and G. Ravi Kumar. "Seismic Retrofit of Soft-Storey Building using Steel Bracing." Workshop on Retrofitting of structures, IIt Roorkee, pp 148-158, Oct 10-11,2003
10. Yogendra Singh, D.K. Paul, S. Zafar Mehdi. "Seismic Safety of Stilt Buildings." Proceeding of Twelfth Symposium on Earthquake Engineering, Roorkee, pp 918-925, December 2002.
11. Han-Seon Lee and Sung-Woo Woo. "Effect of Masonry on Seismic Performance of a 3 Storey RC Frame with non Seismic detailing." Earthquake engineering and Structural Dynamics 2002:31:353, pp 353-379
12. M.N. Fardis and T.B. Panagiotakos. "Seismic Design and Response of Bare and Masonry Infilled RC Building." Journal of Earthquake Engineering, Vol I, No.3, pp 475-503, 1997
13. M.N. Faradis, P. Negro, S.N. Bousias, A. Colombo, "Seismic Design of Open-Storey Infilled RC Buildings." Journal of Earthquake Engineering, Vol 3, No.2, pp 173-194, 1999
14. F. Hejazi11,2 S. Jilani,1,2, J. Noorzaei1,2, C. Y. Chieng1, M. S. Jaafar1,2, A. A. Abang Ali1"Effect of Soft Story on Structural Response of High Rise Buildings" IOP conference series materials science and Engineering.
15. IS 1893 (Part I): 2002 "Criteria for Earthquake Resistant Design of structure" Bureau of Indian standard, New Delhi.
16. IS 13920: 1993 "Ductile detailing of reinforced concrete structures subjected to seismic forces-code of practice" Bureau of Indian standard, New Delhi

