COMPARATIVE STUDY OF SEISMIC PERFORMANCE BETWEEN CONVENTIONAL RC BUILDING AND RC BUILDING WITH LIGHT WEIGHT COMPONENTS IN BANGLADESH

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ABSTRACT

This thesis focuses on the seismic capacity of the light weight RC structure and the effects of the light weight components on the seismic behavior of RC structures. Housing and Building Research Institute (HBRI) is a national research institute of Bangladesh. This institute is working to develop light weight alternative building components to reduce the construction cost and seismic risk of structures. HBRI has constructed a 5-storied residential building using light weight thermal block walls and Ferrocement (FC) floor channels. To know the performance of this structure, non-linear pushover analysis is done. This analysis procedure is described in ATC-40/FEMA 273/356. A calibration of the non-linear frame analysis is performed by using the experimental data of RC frame specimens with and without infill walls which were tested at HBRI, Bangladesh. The model building analysis is divided into three cases. non-linear pushover analysis is carried out on the model structures for three cases and their performances are compared. Finally, the seismic performance of the light weight structure is found better than the conventional structure.

Keywords: Ferrocement channel, Thermal block, Pushover analysis, Seismic performance.

1. INTRODUCTION

Bangladesh is one of the most rapidly developing countries in the world. Infrastructural development is one of the key factors for the economic development. Bangladesh is already known to be in an earthquake prone region. HBRI is a national research institute of Bangladesh. The institute is entrusted to conduct research in housing problems, innovation in construction materials, technology and planning. To stop using clay burnt bricks, some innovative light weight alternative building materials has been already introduced by this institute. It is possible to reduce gravity load from structure by almost 30 to 35 percent using lightweight materials in structure. Therefore, the construction cost of the structure is reduced by up to 25 percent. On the other hand, a light weight building is safer than the heavy weight building against earthquake loads. Taking advantage of this situation, it is easily possible to construct comparatively higher capacity structures against earthquake load keeping the same cost of the construction. HBRI has constructed a 5 storied RC frame residential model building using light weight partition walls and floor channels in lieu of heavy weight conventional elements. Now it is necessary to understand how behaviors of the structures with light weight components is changed against earthquake loads.

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2. METHODOLOGY

2.1. Numerical model verification

Software simulation has been done for the frames, which were already tested at HBRI laboratory in Bangladesh. And simulation results are compared with the test result and observe the reliability of the simulation result.

2.2. Performance based analysis of model building in case-1

a) First, a model building is designed considering the conventional building elements and then pushover analysis is done.
b) Second, dead load is reduced from structure by using the light weight components keeping the same structural design and pushover analysis is done for light weight structures.
c) Third, performance is compared between the conventional structure and the light weight structure.

2.3. Performance based analysis of model building in case-2

The structural design of the light weight building is revised considering the reduction of building weight and pushover analysis of the redesigned structure is done. After that, the performance of the redesigned light weight building is compared to the conventional building.

2.4. Performance based analysis of model building in case-3

The same procedure of case-1 is repeated for the conventional and light weight buildings without taking soft ground story into consideration.

3. ANALYSIS AND DISCUSSION

3.1. Verification of bare frame simulation result

Comparison between test result and simulation result of bare frame has been done in this section. Figure 1 shows the comparison between test result and simulation result of bare frame. Shear capacities from test and simulation have been found 9.63 ton and 8.24 ton respectively at drift 1/73. The simulation result shows 14% lower capacity than the test result. Initial lateral stiffness of the bare frame has been found the same value as that from simulation and hand calculation. But from the test result, it is found 28% lower than the simulation result and hand calculation result.

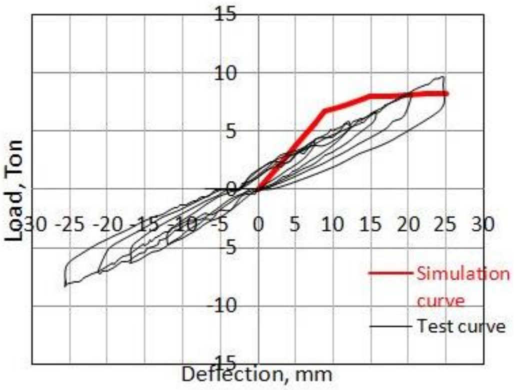


Figure 1. Comparison between test result and simulation result of bare frame.

3.2. Verification of simulation result of conventional brick infill frame

Comparison between test result and simulation result of conventional brick infill frame has been done. Figure 2 shows the comparison between test result and simulation result of infill frame. From the test result, the maximum shear capacity has been found 34.39 ton at a drift of 1/173 and from the simulation result, the maximum shear capacity has been found of 31.12 ton at a drift of 1/365. The simulation result shows 9.5% lower than the test result. The deformation at the maximum shear capacity of simulated frame has been found 52.5 percent lower than the test result.

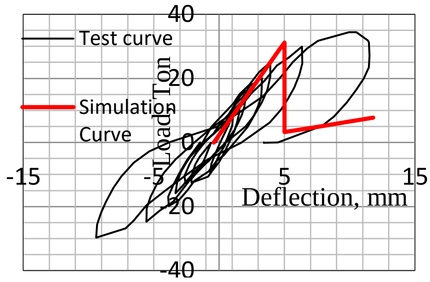


Figure 2. Comparison between test result and simulation result of brick infill frame.

3.3. Comparison of simulation result between conventional brick infill frame and thermal block infill frame

The simulation result of conventional brick infill frame and the simulation result of the thermal brick infill frame is compared here. Figure 3 shows the comparison of load-deflection curve between conventional brick infill frame and thermal block infill frame. The maximum base shear capacity of thermal block infill frame is found 25.05 ton at drift 1/257. On the other hand, the maximum base shear capacity of conventional brick infill frame is found 34.39 ton at drift 1/365. Energy dissipation at the ultimate capacity stage of thermal block infill frame has been found 14.5% higher than the conventional brick infill frame.

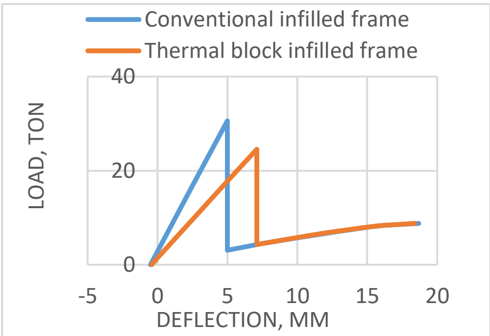


Figure 3. Comparison of capacity between conventional brick infill frame and thermal block infill frame.

3.4. Performance analysis of model building, case-1

In case-1, first, the model building is designed considering the conventional building elements and loads. And, second, the dead load is reduced from the structure by using the light weight components, keeping the same structural design. After that, pushover analysis is done for both the structures for evaluation. Pushover load has been applied along the longitudinal direction of the model building. Figure 4 shows the typical column and beam layout plan of model building. The first floor of the structure is open which is shown in Figure 5. The spectral displacement and acceleration at the performance point of the light weight building are found 27.4mm and 0.214g respectively and for the conventional building, these values are 30.6mm and 0.167g respectively, which are shown in Figure 6 and Figure 7. So the light weight building shows it has a 28 percent higher capacity than the conventional

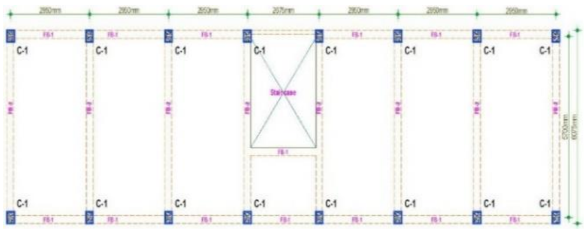


Figure 4. Typical beam layout plan of the model building.

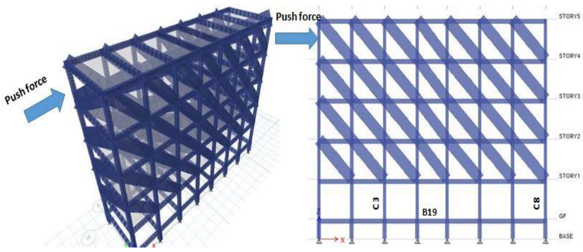


Figure 5. Isometric view and elevation of the model building from a computer model.

building. The ductility ratios of the light weight building and conventional building are found 2.03 and 2.37 respectively and the effective damping rations are 9.1 percent and 11.3 percent respectively. The effective damping ratio of the conventional building is 24 percent higher than that of the light weight building, which means 24 percent higher damage occurring in the conventional building.

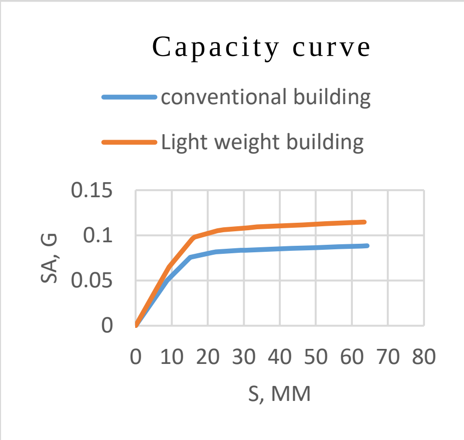


Figure 6. Comparison of capacity curve.

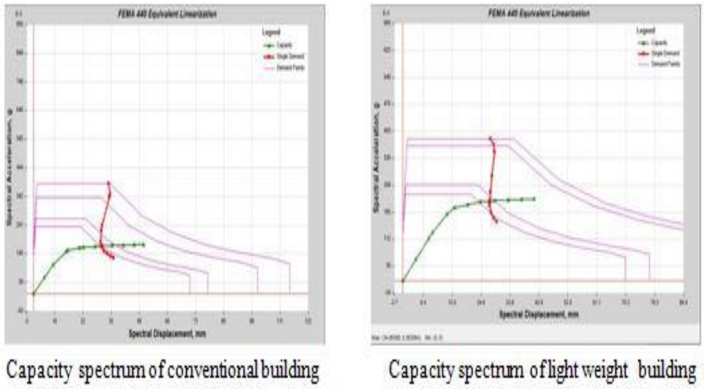


Figure 7. Comparison of performance points.

3.5. Performance analysis of model building, case-2

The structural design of the light weight building is revised considering the reduction of building weight and pushover analysis of the redesigned building is done. After that, the performance of the redesigned light weight building is compared to that of the conventional building. The spectral displacement and acceleration at performance point of the light weight building are found 27 mm and 0.17g respectively and for the conventional building these values are 30.6mm and 0.17g respectively, which is shown in Figure 9. The ductility ratios of the light weight building and the conventional building are found 2.33 and 2.37 respectively and the effective damping ratios are 11.1 percent and11.3 percent respectively. The effective damping ratios of the conventional building and the light weight building are almost the same and the acceleration capacities are also the same.

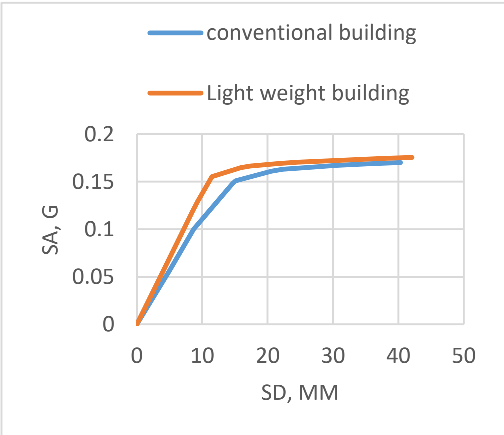


Figure 8. Comparison of capacity curve.

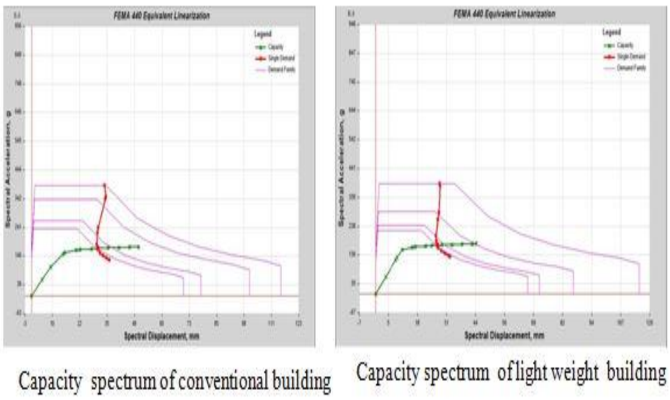
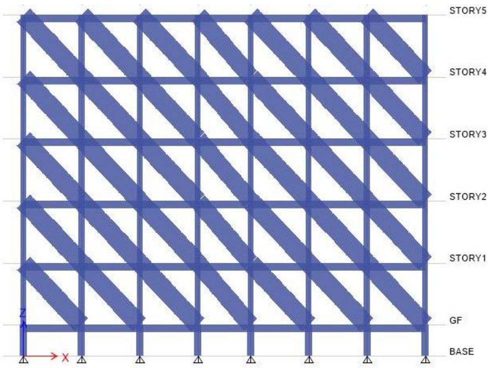
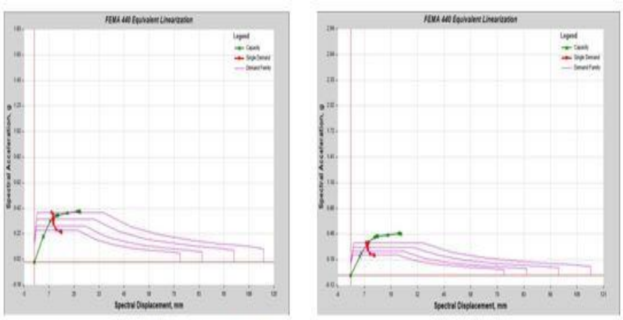


Figure 9. Comparison of performance point.

3.6. Performance analysis of model building, case-3

The same procedure as that of case-1 is repeated for the conventional and light weight buildings without taking a soft ground story into consideration. Figure 10 shows elevation of the model buildings with no soft 1st story. The spectral displacement and acceleration at the performance point of the light weight building are found 8mm and 0.37g respectively and for the conventional building, these values are 9.5mm and 0.34g respectively, which is shown in Figure 11. So the light weight building shows it has an 8.8 percent higher capacity than the conventional building. The ductility ratios at performance point of the light weight building and conventional building are found 1.61 and 1.76 respectively and the effective damping rations are 6.8 percent and 7.3 percent respectively. The effective damping ratio of the conventional building is 7.3 percent higher than that of the light weight building, which means 7.3 percent higher damage occurring in the conventional building.





Capacity spectrum of conventional building

Capacity spectrum of light weight building

Figure 10. Elevation of the model building taken from ETABS model.

Figure 11. Comparison of capacity curve.

4. CONCLUSION AND RECOMMENDATIONS

4.1. Findings of the study

The findings from the study can be summarized as follows:

a) The simulation result and the test result of the bare frame show good agreement up to story drift 1/73. The maximum story drift of the model building is 1/75 in case-3, so the model building deformation is valid.
b) In case-1 lateral deformation is not distributed along the vertical axis and whole deformation is concentrated at the 1st story because the model building contains the soft 1st story. In this case the light weight building shows 28% higher capacity and the effective damping at the performance point of the conventional building shows 24% higher, which means more damage will occur in the conventional building compared to the light weight building under the same seismic force.
c) In case-2, lateral deformation is not distributed along the vertical axis, and it is concentrated at the 1st story. Both the conventional and the light weight structures show the same seismic capacities and effective damping ratios at the performance point. That means if the structural design is carried out considering light weight of the structures, thereafter the capacity of the light weight structure remains the same as that of the conventional building. Therefore, it is possible to reduce construction cost using these light weight elements in structure.
d) In case-3 lateral deformation is not distributed along the vertical axis and whole deformation is concentrated at the footing base to grade beam level area. In this case the light weight building

shows 8.8% higher capacity and the effective damping at the performance point of the conventional building shows 7.3% higher, which means more damage will occur in the conventional building compared to the light weight building under the same seismic force.

In view of the above discussion, it can be concluded that, it is possible to construct a comparatively safer structure against earthquake forces by using light weight components at low cost.

4.2. Limitation of the study

The following are further research options considering the limitations of this study.

a) Soil reaction was not considered on the column surface whose part was below the ground surface. In case-3, whole deformation was concentrated in bare column areas, hence no strut failure was found. Therefore, it was not possible to observe the difference between the conventional and light weight infill wall contribution.
b) P- delta effect was not considered in pushover analysis. If it had been considered, the advantages of light weight structure would have been realized more clearly.

4.3. Recommendation for the further study

The following are special recommendations for the further study:

a) To get more accurate response of the structure, dynamic analysis can be done.
b) In this study the model building was 5-storied, but in further studies, a high rise structure as a model building can be chosen.
c) To know more realistic structural behaviors, a shaking table test of a full scale light weight model building can be done.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my thesis supervisor Yoshiaki NAKANO, and Dr. Toshihide KASHIMA, Dr. Matsutaro SEKI and Dr. Tatsuya AZUHATA who were always support me for my master's study and research.

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