SEISMIC PERFORMANCE EVALUATION OF A RC BUILDING WITH MASONRY INFILL DESIGNED BY PREVIOUS SEISMIC CODE IN BANGLADESH

Md. Ibnul Warah[1]
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Supervisor:Tatsuya AZUHATA[2*]
Haruhiko SUWADA[2], Toshihide KASHIMA[2**],**
Hideo FUKUI[3]**

ABSTRACT

Bangladesh is in a moderately seismic-active region. Due to the unplanned construction, many buildings have been built without proper seismic consideration. Also, the seismic zone factors in the seismic code were revised in 2020. This revision raised the seismic design force to 1.5 times the previous in some areas. In this situation, it is necessary to check the seismic safety of the existing buildings. This study aims to evaluate the seismic performance of RC frame buildings considering the effect of infill brick masonry designed by the previous code. In Bangladesh, the load-bearing capacity of masonry walls is not considered during structural design. However, for dealing with more severe seismic conditions assumed in the current code, we attempt to include the effects of infills in the seismic performance evaluation. To investigate these effects, we execute earthquake response analyses to three models. One has high-quality masonry infills, and the other has low-quality infills. The third model is the bare frame model. To get seismic responses, we apply the capacity spectrum method and response history analyses. By comparing the earthquake responses for three models, we concluded that high-quality masonry infills could improve the seismic performance of the RC buildings sufficiently so that the existing building may resist even against the seismic forces assumed in the current code.

Keywords: Seismic performance, Masonry infill, Seismic code, Artificial ground motion.

1. INTRODUCTION

Bangladesh is a moderately seismic-active region around the world. For the structural design of mid to high-rise buildings in the city, earthquakes are of vital concern. Masonry infill RC frame structures are widespread throughout Bangladesh, like the other developing countries. In general, infill can be grouped into two different categories: isolated infill and regular infill. Isolated infill is not anchored with the frame of the building. In our country, the masonry infill is isolated from structures. Using infill masonry walls has been prohibited by modern codes of developed countries unless a special technique has been taken to ensure that they can withstand lateral loading. To mitigate expected earthquake damage, developing an effective strategy for changing the current system is also necessary. In our country, the first building code was published in 1993 (act issued in 2006). The building code has been updated recently. The revised code was published in 2020 (and came into effect in February 2021). In the new code, Bangladesh has been divided into four seismic zones. The value seismic zone coefficient has been 1.5 times larger than the previous one. A school building has been analyzed in this study to evaluate the seismic performance of this building considering masonry infill. The model building was designed and constructed before the publication of the updated code. In this study, a comparative analysis of the

[1] Research Engineer, Housing and Building Research Institute (HBRI), Bangladesh.
[2] International Institute of Seismology and Earthquake Engineering, Building Research Institute.
[3] National Graduate Institute for Policy Studies.
* Chief examiner, ** Examiner

building will be performed to understand its behavior, considering the previous and new ones. Moreover, the effect of masonry walls having different strengths will be discussed. This study is therefore of vital importance for the seismic assessment procedure of buildings in Bangladesh.

2. STRUCTURAL TEST DATA AND TARGET BUILDING

Infill brick masonry is used as a partition wall in RC frames almost all over the world and is considered a non-structural Element. But it is observed that this infill masonry has a significant effect, especially in the case of lateral loading. So, it is significantly necessary to know the level of performance of infill masonry during an earthquake. To understand the behavior and failure mechanism of infill brick masonry, laboratory tests on infill frames have been performed in Bangladesh under several projects. Figure 1 shows one example of them. This laboratory test on the Model Infill RC frames against cyclic load was conducted with a test setup which was constructed in Housing and Building Research Institute (HBRI) workshop.

Figure 1. Photograph of specimen to be tested during loading.

The cyclic load was applied by means of a reverse loading hydraulic jack mounted on the reaction frame. At the time of applying cyclic load, the behavior of the test model specimens was measured by means of the Data Acquisition System. Displacement transducers were fitted at selected locations of the frame to measure the deflections. Strain gauges were used for measuring deformations. We use the test data for force-deformation relationship obtained by this test to verify the numerical model for RC frames with masonry infill.

Figure 2 shows the plan and the elevation of the school building. Table 2 shows the general information of it. The building is located in the adjacent city of the capital, Dhaka. The zone co-efficient of this location has been changed due to the revision of the seismic code. Live load and superimposed load at each floor are considered as 12.4 KN/m^2. At the roof, the load is 11.0 KN/m^2. The building is constructed with infill brick masonry in the transverse direction. We suppose that these masonry walls significantly affect the performance of the building.

For the numerical analysis, the target building was modeled in STERA 3D (Saito). By using STERA 3D software (Saito), a model is prepared considering hysteretic behavior corresponding to materials of structure, design parameters, and loading patterns.

Table 1. General information of the target building.

Time of construction	2018
Number of floors	06
Column, C1, C2	300x450 mm & 300x500 mm
Beam, B1, B2	300x375 mm & 300x450 mm
Compressive strength of concrete	20 MPa
Area of each floor	195 sqm
Height of the building	19.2 meter
Seismic zone co-efficient	0.15 (According to previous code, BNBC-2006) 0.28 (According to current code, BNBC-2020)

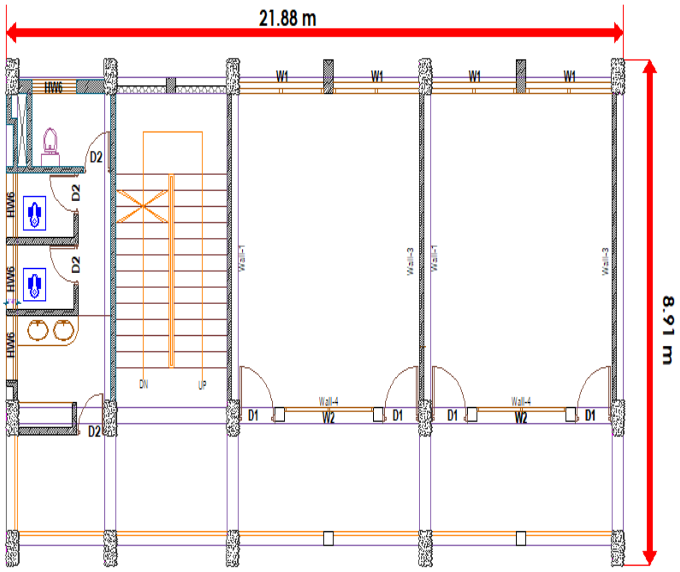

Figure 2. Plan of typical floor

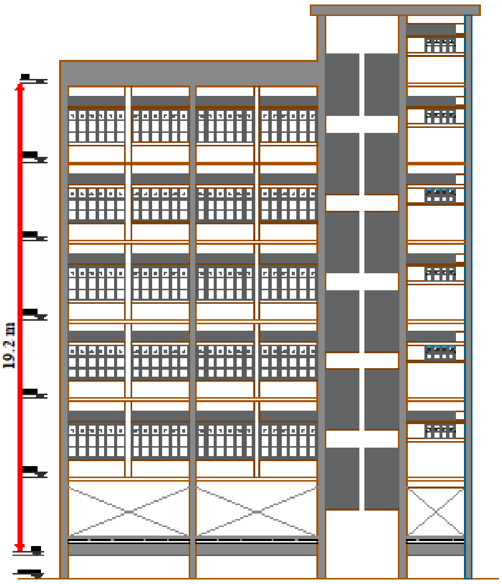

Figure 3. Elevation of building

3. ANALYSIS PROCEDURE AND RESULTS

3.1. Strut model for masonry infill

In this study, we used strut model to evaluate non-linear of masonry infill and defined force-deformation relationship as the poly-linear slip model. The characteristic values, Q_c, Q_y, and Q_u are obtained based on the formulation described in the reference (Paulay and Priestley, 1992). The shear resistance, Q_y, is calculated to be the minimum value between the shear strength by sliding shear failure, V_f, and the shear strength of diagonal compression failure, V_c, that is;
$Q_y = \min (V_f, V_c)$.
The shear displacement at the maximum resistance, γ_y, is obtained as (Madan et al.,1997),

$$\gamma_y = \frac{\varepsilon' m d m}{\cos\theta} \tag{1}$$

where ε'_m is compression strain at the maximum compression stress (ε'_m =0.0018, Hossein and Kabeyasawa, 2004).
Initial elastic stiffness is assumed as (Madan et al., 1997)

$$k_0 = 2Q_y / \gamma_y. \tag{2}$$

The shear resistance and displacement at crack are obtained by,

$$Q_c = \frac{Qy - \alpha k0 \gamma y}{1-\alpha} \tag{3}$$

$$\gamma_c = Q_c / k_0 \tag{4}$$

where α is the stiffness ratio of the second stiffness and assumed to be 0.2.
Shear resistance and displacement at the ultimate stage are assumed as (Hossein & Kabeyasawa, 2004),

$$Q_u = 0.3Q_y \tag{5}$$

$$\gamma_u = 3.5(0.01h_m - \gamma_y) \tag{6}$$

where h_m is the height of masonry wall.
Shear force vs. drift relation of lab tested specimen and numerical analysis in STERA 3D are as follows.

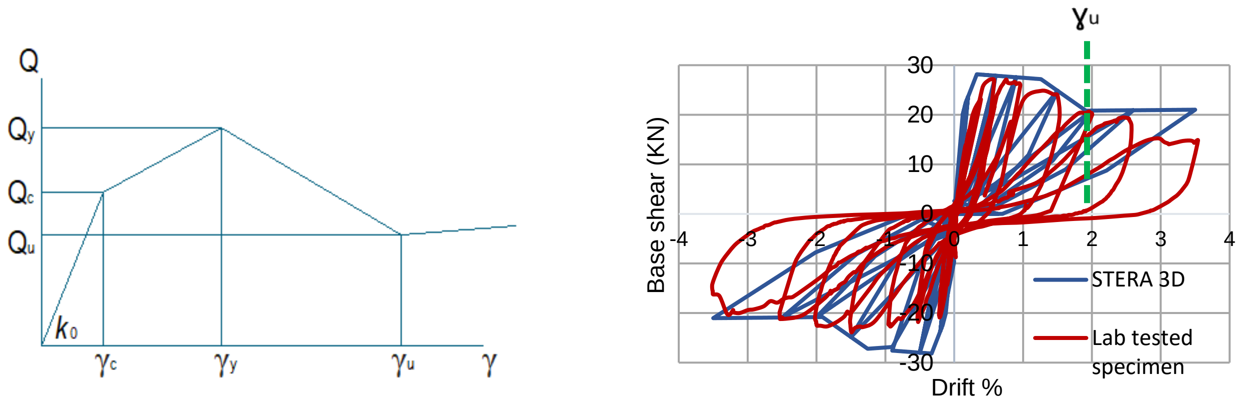

Figure 4. Force-drift relation for laboratory-tested specimen and numerical analysis

3.2. Nonlinear analysis for target building

For the proper understanding of the behavior of the target building with infill, capacity spectrum method and response history analyses are performed in this study. In the capacity spectrum method, the capacity curve and demand spectrum are used for the assessment of building behavior due to the ground motion. An intersection point of the capacity curve and demand spectrum represents the performance point of the structure. The response spectral acceleration and displacement are reduced by the following coefficient,

$$F_h=\frac{1.5}{1+10heq} \tag{7}$$

where h_{eq} is the equivalent damping ratio, $h_{eq}=\frac{1}{5}\,(1-\frac{1}{\sqrt{\mu}})$.

To perform response history analysis in this study, artificial ground motions are applied for previous and new seismic code. Seismic responses are obtained according to two different zone co-efficient of BNBC- 2006 and BNBC-2020.

3.3. Effect of material property

To investigate effects of masonry infills, three kinds of frame structure are considered.

i. High quality infill (f_{cb}=14Mpa and f_m=10 Mpa)
ii. Low quality infill (f_{cb}= 4 Mpa and f_m= 2 Mpa)
iii. Bare frame

As the target building has solid infill along transverse direction, static nonlinear pushover and response history analysis are performed along the transverse direction.

3.4. Result of capacity spectrum method

Non-linear pushover analysis is performed to determine the displacement changing behavior in this study. In the right-sided figure demonstrates the maximum story drift of each floor by the capacity method following the current seismic code.

In figure 6, the capacity curves of three frames intersect the demand spectra of the damped hysteresis system. This graph is constructed according to the updated seismic code.

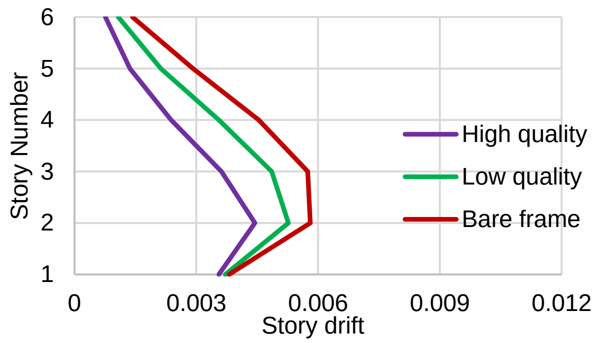

Figure 5. Maximum story drift by CSM

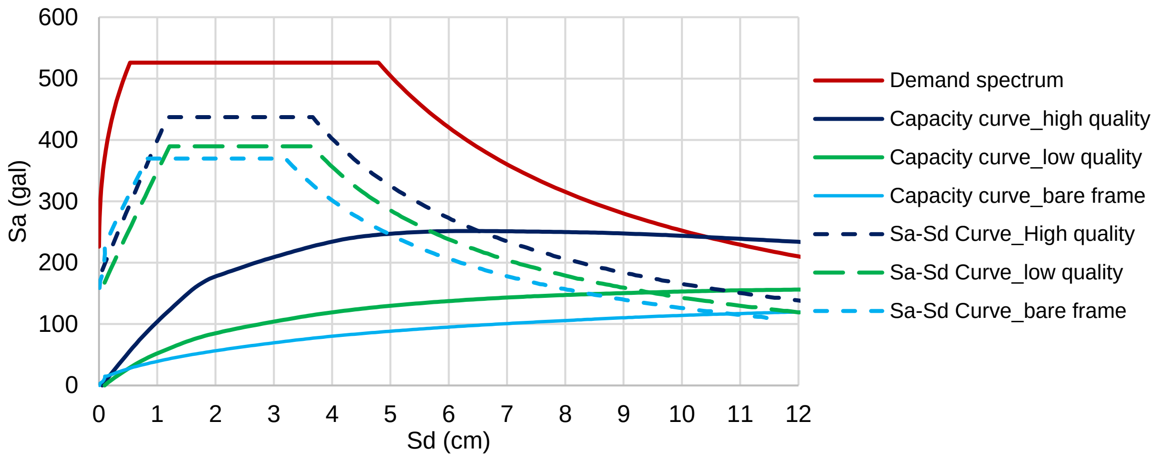

Figure 6. Capacity curve vs. demand spectra for current code

3.5. Result of response history analysis

After conducting response history analysis in this study, the following graph can be obtained for high-quality, low-quality, and bare frame structure.

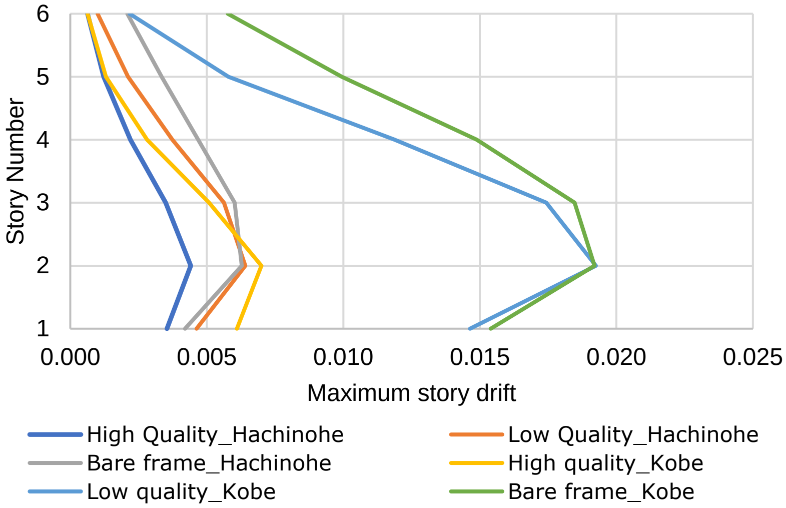

Figure 7. Maximum story drift for response history analysis for current code

4. DISCUSSION

From the result of the capacity spectrum method and response history analysis, it is obtained that seismic responses of the high-quality infill model are the smallest. This result shows that high-quality infill can reduce the seismic response of the structure.

The following figures are for the comparative damage aspect of RC building with high-quality infill model and the bare frame model due to response history analysis for Kobe phase. In the figures, U (ductility factor) > 5 indicates severe damage, and U < 5 indicates moderate damage. After applying the Kobe phase, the columns do not yield for high-quality masonry infill, although Masonry walls at levels 2 and 3 are severely damaged. It is found that the structure with high-quality masonry infill may not collapse even considering the revised seismic code. But masonry infill may damage severely. In the case of bare frame, some of the columns damage severely, which will result in the collapse of the building.

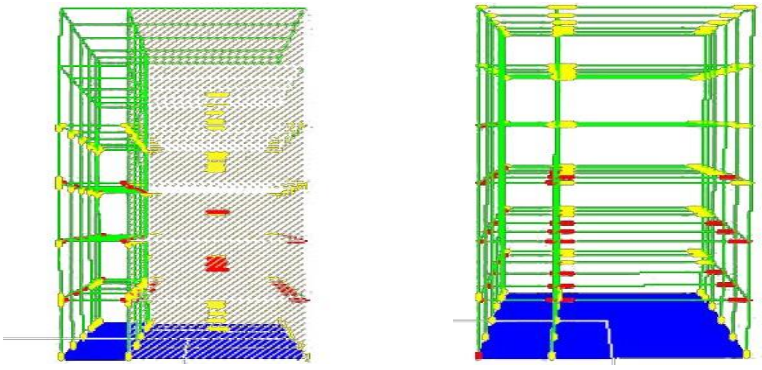

Figure 8. Comparison of damage aspect for high-quality infill and bare frame

5. CONCLUSIONS

- To investigate seismic performance of existing buildings designed by the previous seismic code, one typical school building was analyzed, considering the effects of masonry infills in it.
- A numerical model for shear-story drift relation of RC frames infilled masonry was verified by using an existing laboratory test result. According to this model, deformation capacity can be estimated larger than about 2 % of the story drift angle. However, shear strength gradually decreases after about 1 % of story drift angle.
- Seismic response analysis results showed that seismic deformation responses of the target school building with high-quality masonry infills did not exceed the corresponding limits even against earthquake ground motions assumed in the current design code.
- Columns surrounding masonry infill were not damaged seriously for the target structure with high-quality infills. The damage possibility of these columns should be checked for other buildings if the relatively high deformation capacity of masonry infills is counted like this case.

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