Evaluation of building characteristics and seismic capacity of existing RC Buildings in Bangladesh

Keywords
Seismic evaluation RC buildings
Masonry infill Buildings characteristics

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1. Introduction:

Developing countries such as Bangladesh, have a huge stock of seismically vulnerable existing buildings. Most of them are masonry infilled RC buildings. In order to conduct seismic capacity improvement, it is required to know the basic characteristics and seismic capacity of these existing buildings.

The objectives of this study are to understand the characteristics and seismic capacity of existing RC buildings. In this study, 10 (ten) existing RC buildings, located in Bangladesh, are considered as a case study.

2. The overview of the existing RC buildings

A total of ten RC buildings, constructed and maintained by the Public Works Department (PWD) of Bangladesh are considered as a case study. These buildings are located at severe seismic zone at Sylhet city where the expected PGA is about 0.36g as per Bangladesh National Building Code 2020 [1] in Bangladesh. The buildings are 4 (four) to 6 (six) storied as shown in Figure 1(a). Figure 1(b) shows that 70% of them are residential. The design strength of materials is shown in Table 1. However, the masonry infill compressive strength (f_m) is assumed 10 MPa in this study.

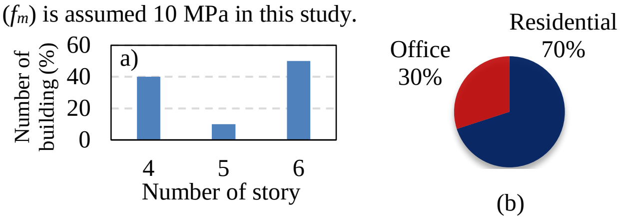

Figure 1: Building characteristics: (a) Story number, (b) Occupancy

Table 1: Material properties according to design documents

Concrete compressive strength, F_c	25 MPa
Steel yield strength, f_y	400 MPa

2.1 Basic characteristics of evaluated buildings

As for the basic characteristics, the column area ratio (the ratio between total column area and total floor area) and masonry infill area ratio (the ratio between total masonry infill area and total floor area) are evaluated for these 10 (ten) buildings. These are important parameters that can affect the seismic capacity as studied previously by [2]. The column area ratio and masonry ratio are compared with other buildings in another city (Dhaka) using a larger buildings' database analyzed in the past study by [2]. Figure 2(a) shows the column area ratio is about 1.5 times higher than that of the other buildings database. A possible reason behind this is that these investigated buildings are public buildings (governmental buildings) designed by PWD, and its design regulations are followed better than private buildings. Another reason is thought that the buildings are located in the higher seismic zone than the zone of the buildings in the past study [2]. Figure 2(b) shows the masonry infill ratio is slightly higher for the evaluated buildings. The column and masonry infill area ratios are investigated based on the occupancy categories is shown in Figures 3(a) and (b). It is observed that the masonry infill ratio is higher in residential buildings than the office buildings. The reason for higher masonry infill ratio is thought to be residential building has more infill wall as a partition wall than office building which are designed to accommodate larger open spaces. As for the column area ratio there was no large variation between residential and office buildings.

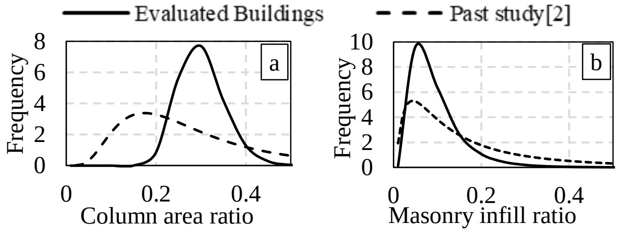

Figure 2: Comparison of distribution between evaluated buildings and past study [2]

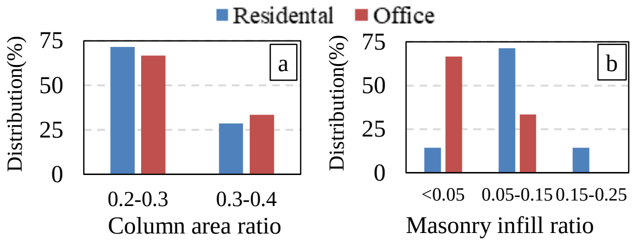

Figure 3: Distribution: a) Column area ratio b) Masonry infill ratio

3. Seismic evaluation of the investigated buildings

The seismic evaluation is conducted by the first level and second level evaluation method for two cases: i) bare frame and ii) considering masonry infill frame. Masonry infill is considered as structural member when the solid masonry infill is confined by surrounding RC columns and the infill panel opening area is less than 40% of the infill panel area.

3.1 First level evaluation

The first level evaluation is conducted by the Japanese seismic evaluation standard [3] for bare frame cases. While considering the masonry infill, the following parameters are considered based on past study [4]: the average shear strength of masonry infill is considered as 0.4 MPa, the ductility index (F) is considered as unity.

The seismic index (I_{S1}) along the longitudinal and transverse direction is shown in Figure 4. For the case of considering masonry infill, an increase of seismic capacity in the transverse direction is about 50% while in the longitudinal direction is about 30% as the amount of masonry infill is higher in the transverse direction.

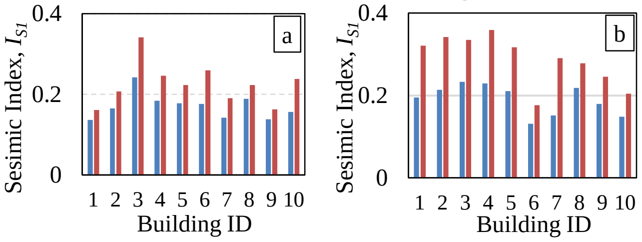

Figure 4: Comparison of I_{S1}: a) longitudinal b) transverse direction

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3.2 Second level evaluation

The second level for bare frame case is conducted by CNCRP manual [5] and, the strength index (*C*) and ductility index (*F*) are evaluated accordingly. On the other hand, the strength index (*C*) and ductility index (*F*) are evaluated considering masonry infill based on the past study [4, 6]. The relationship of strength index (*C*) and ductility index (*F*) are presented in Figure 5 for both the bare frame and considering masonry infill. In most cases, masonry infill increases both strength index (*C*) and ductility index (*F*) as shown in Figure 5 (a). However, in some cases, masonry infill increases the strength index (*C*) but decrease ductility index (*F*) as shown in Figure 5 (b). The reason is that the relative strength of surrounding RC columns compared with the masonry infill is lower (weak frame and strong infill). Hence, the expected failure is sliding-diagonal cracking failure which is thought to have a lower ductility of 1.27 rather than that of diagonal compression failure (for the case of relatively strong RC frame and weak masonry infill) which is assumed to have a higher ductility of F= 1.75 [6].

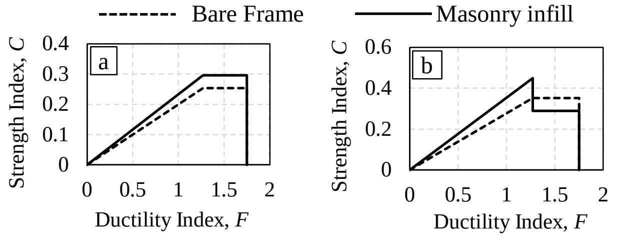

Figure 5: Relationship of Strength Index (*C*) and Ductility Index (*F*)

3.3 Comparison of Bare frame and with masonry infill

Figures 6(a) and 6(b) show the seismic index (I_{S2}) for the bare frame and with masonry infill in both longitudinal and transverse directions respectively. In most of the cases the seismic capacity is increased significantly considering masonry infill except in a few cases due to reduction of ductility as explained in the previous section. It is observed that the seismic capacity is improved with masonry infill about 10% to 25% comparing with a bare frame only and ignoring masonry infill. Figure 7 (a) and (b) show that the seismic capacity improvement in the transverse direction is much higher than that in the longitudinal direction. It is due to the effect of that commonly there are higher amount of masonry infill in the transverse direction. A comparison of Figure 4 and 6 shows that the I_{S2} is about 2.0 times higher than I_{S1} due to increase both the strength and ductility.

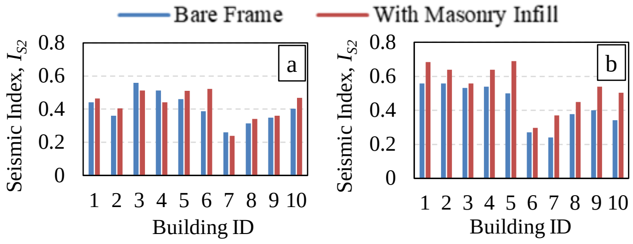

Figure 6: Comparison of I_{S2}: a) longitudinal, b) transverse direction

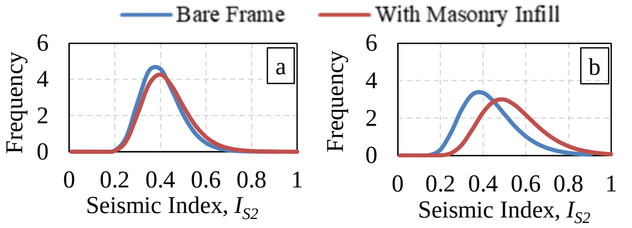

Figure 7: Distribution of I_{S2}: a) longitudinal, b) transverse direction

3.4 Comparison of seismic capacity based on occupancy category

Seismic capacity is evaluated based on occupancy categories as shown in Figures 8 (a) and (b). It is observed that the effect of masonry infill on seismic improvement of office buildings is higher than that of residential buildings. This is due to the relative strength of surrounding RC columns compared with the masonry infill is higher which results diagonal compression failure. In this case, masonry infill increases both the strength and the ductility. However, this seismic capacity trend is very useful information for planning of future seismic strengthening. It is noted that further building survey and investigation are required to clearly understand the general trend.

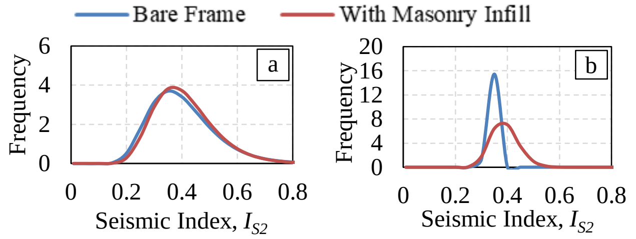

Figure 8: Comparison of I_{S2}: a) Residential, b) Office building

4. Conclusions

This study investigated the characteristics and seismic capacity of existing RC buildings in Bangladesh for a case study of ten buildings. The following conclusions have been made from this study:

- It has been found that the column area ratio of the investigated buildings is about 1.5 times higher compared with the other buildings based on the past study [2]. The masonry infill ratio shows a similar tendency for all buildings and the masonry infill ratio is higher in residential buildings than the office buildings.
- Masonry infill improves the seismic capacity 30% to 50 % in the first level evaluation and 10% to 25% in the second level evaluation. Second level evaluation shows around 2.0 times higher seismic capacity compared with First level evaluation.
- The improvement of seismic capacity due to masonry infill of office building is relatively higher compared with the residential building even though the masonry infill wall area ratio is lower. Because the larger column size of office building results higher confinement of masonry infill compared to residential building.

It should be noted that the results of this study is based on a case study of 10 (ten) buildings, therefore a large number of building survey and investigation are required for final conclusions.

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