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Seismic assessment of existing RC buildings with masonry infill in Bangladesh
Part 2: Evaluation of the Effect of Masonry Infill on Seismic Capacity of Building

Keywords
Seismic evaluation RC building
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○ Debasish Sen*1 Md. Shafiul Islam*1
Hamood Alwashali*1 Yuta Torihata*1
Masaki Maeda *2

1. Introduction:

This study intends to investigate the effect of masonry infill on the seismic capacity of some existing RC buildings of Bangladesh. Seismic evaluation has been conducted for existing RC buildings considering both bare frame and masonry infilled frame by Japanese evaluation standard [1] and contribution of masonry infill was taken into account with F-index proposed in Part 1 of this study. To facilitate this study, six existing RC buildings of Bangladesh have been surveyed to get actual configuration of masonry infill of those buildings.

2. Survey of existing Buildings:

As a case study, six buildings, built and maintained by Public Works Department of Bangladesh, were surveyed to produce as-built drawing with the intension of understanding the distribution of masonry wall in typical buildings of Bangladesh. Basic information of the surveyed buildings is presented in Table 1. Some surveyed buildings are shown in Figure 1. In general, surveyed buildings have two types of masonry infill, i.e. exterior (250mm thick) and interior (125mm thick), made of burnt clay brick as shown in Figure 2(a) and 2(b). All exterior or boundary walls have big opening as window. Commonly, most of the solid walls were found in the short direction of building. Partition walls in long direction and all boundary walls of different floors have mid-height window and high window opening, as shown in Figure 3. The configuration of masonry walls is also changed floor by floor. In general, ground floor contains more open space than other typical floors.

3. Seismic Evaluation:

Seismic capacity (1st and 2nd level evaluation) is investigated considering two cases: (*i*) bare frame and (*ii*) masonry infilled frame. The following assumptions are considered to select masonry walls having influences on structural response: (a) masonry walls having no confinement by adjacent columns or with door adjacent to the columns have not been considered for seismic evaluation and (b) masonry walls having mid panel opening, however less than 40% of panel area, have been considered for the seismic evaluation. The seismic index (I_S), in both first and second level evaluation, has been calculated using Eq. (1), following the determination of basic seismic index (E_o), irregularity index (S_D), and time index (T).

$$I_S = E_O.S_D.T \qquad \text{Eq. (1)}$$

Table 1: Basic information of surveyed buildings

Building ID	Construction year	No of story	Floor area (sqm)	Building usage
Building-1	1968	5	890	Office
Building-2	2006	6	190	Residential
Building-3	1998	2	275	Office
Building-4	1986	4	245	Residential
Building-5	2005	6	120	Residential
Building-6	1988	6	510	Office


Building-1 Building-2 Building-3 Building-4

Figure 1: Photograph of surveyed buildings

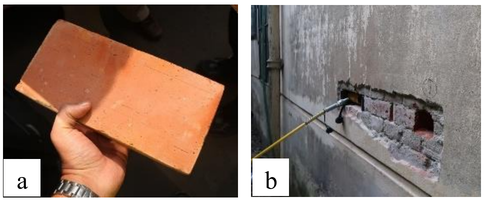

Figure 2: (a) Burnt clay brick and (b) Masonry infill wall in Bangladesh

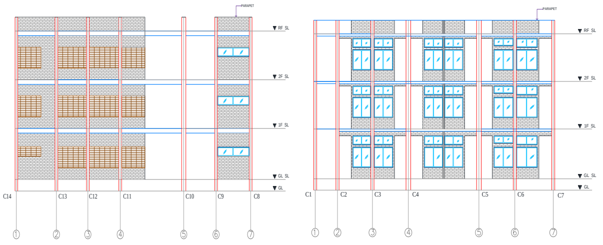
(a) (b)

Figure 3: (a) Interior and (b) Exterior frame of Building-4

3.1 First Level Evaluation:

First level evaluation of bare frame has been adopted directly from Japanese seismic evaluation standard [1] using the basic seismic index (E_o), as mentioned in Eq. (2) where, n and i represents number of story and concerned story level respectively. Seismic basic index (E_o) has been computed from Eq. (3) with the following assumptions: (a) the average shear strength (τ_{inf}) of masonry infill has been assumed conservatively 0.2 MPa, (b) the ductility index (F) has been assumed to be unity, and (c) the strength factor (α) for RC columns is of unity. The wall index ($C_{masonry}$) has been calculated using Eq. (4), where A_{inf} and W are the cross sectional area of masonry wall and weight of the building, respectively.

$$E_o = \left({}^{n+1}/_{n+i}\right)\ C_c.F \qquad \text{Eq. (2)}$$

$$E_o = \left({}^{n+1}/_{n+i}\right)\ \left(C_{masonry} + \alpha C_c\right).F \qquad \text{Eq. (3)}$$

$$C_w = \left({}^{\tau_{inf}.A_{inf}}/_{W}\right) \qquad \text{Eq. (4)}$$

Table 2 shows the first level seismic index (I_S) of bare frame and masonry infilled frame in both long and short direction. The inclusion of masonry infill always improves the seismic capacity of building. However, buildings show more capacity enhancement in short direction, as shown in Figure 4(a), which can be attributed to the presence of more solid masonry walls in that direction as discussed in earlier section.

Table 2: 1st level seismic index of surveyed buildings

Building ID	Bare frame		Masonry infilled frame	
	I_{SL}	I_{SS}	I_{SL}	I_{SS}
Building-1	0.07	0.10	0.09	0.13
Building-2	0.18	0.20	0.21	0.27
Building-3	0.43	0.56	0.47	0.66
Building-4	0.20	0.21	0.23	0.27
Building-5	0.23	0.38	0.23	0.45
Building-6	0.19	0.20	0.20	0.22

I_{SL} = seismic index in long direction and I_{SS} = seismic index in short direction

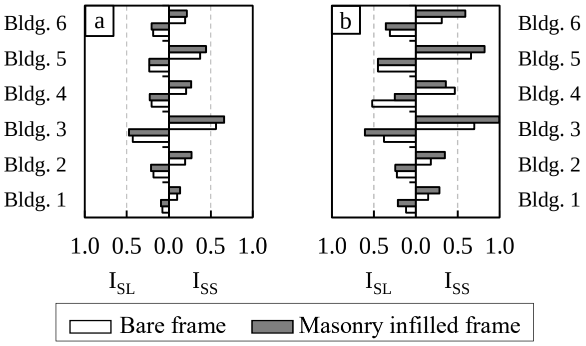

Figure 4: (a) 1st and (b) 2nd level seismic index of the buildings

3.2 Second Level Evaluation:

Second level evaluation of bare frame structure has been performed as per Japanese seismic evaluation standard [1], which has already been adopted in Bangladesh [7] without considering masonry infill. In this study, following procedure has been adopted for second level evaluation to take account the contribution of masonry in terms of strength and ductility. The wall strength index ($C_{masonry}$) for masonry has been determined from Eq. (4). The shear strength of the masonry wall has been determined following the Eq. (5) [4], where masonry prism strength (f_{inf}) has been assumed as 8MPa. The evaluation of ductility index (F) is elaborately discussed in the Part 1 of this study.

$$\tau_{inf} = 0.05.f_{inf} \qquad \text{Eq. (5)}$$

Figure 5 shows the relationship between strength index (C) and ductility index (F) of the surveyed buildings in the direction having lowest seismic capacity. The seismic index (I_S) has been considered at the point of first failure of structural element assuming poor redistribution of loads among columns. The second level evaluation results of all buildings considering bare frame and infilled frame are presented in Table 3. The seismic indices in long and short direction considering both bare frame and infilled frame are displayed graphically in Figure 4(b). It is apparent from the Figure 4(b) that for all surveyed buildings, except Building- 4, the capacity enhancement in both long and short direction is of a higher order than that of in the first level evaluation, which indicates more beneficial effect of masonry on the lateral capacity of building. However, seismic evaluation of Building-4 shows the detrimental effect of masonry on the lateral capacity of building. This can be attributed to the changed hinge location of RC column in presence of masonry wall compared to bare frame, which leads to early shear failure of column, which results lower seismic capacity.

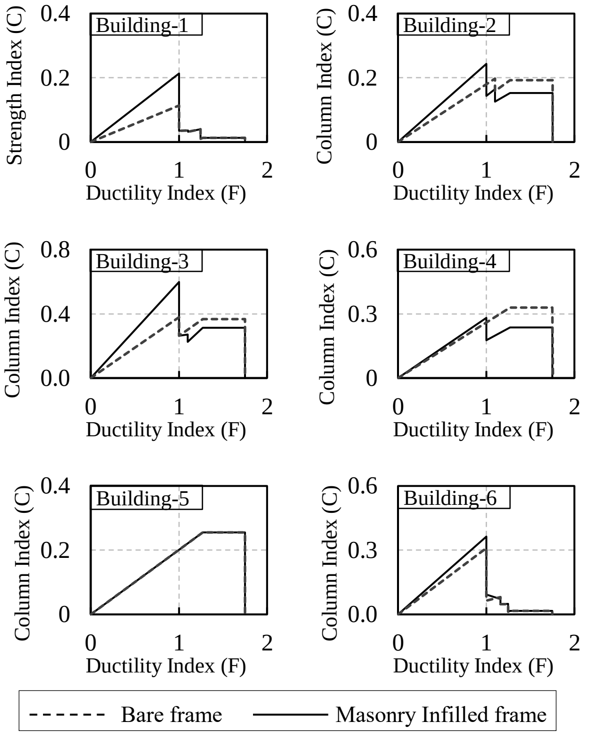

Figure 5: Strength – Ductility relation of surveyed buildings

Table 3: 2nd level seismic index of surveyed buildings

Building ID	Bare frame		Masonry infilled frame	
	I_{SL}	I_{SS}	I_{SL}	I_{SS}
Building-1	0.11	0.15	0.21	0.28
Building-2	0.23	0.18	0.24	0.35
Building-3	0.38	0.70	0.61	0.99
Building-4	0.52	0.46	0.25	0.36
Building-5	0.45	0.66	0.45	0.82
Building-6	0.31	0.31	0.36	0.59

I_{SL} = seismic index in long direction and I_{SS} = seismic index in short direction

4. Conclusions:

The first and second level evaluation of six existing buildings of Bangladesh are presented in this study. The second level screening showed more conservative results as it includes sectional analysis and hinge locations of columns.

References: Please see in Part 4.

1*東北大学大学院　　　　大学院生　（工学）
2*東北大学大学院研究科　教授・博士（工学）
1*Graduate School of Engineering，Graduate student, Tohoku Univ.
2* Professor, Graduate School of Engineering, Tohoku University，Dr..Eng