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## Out-of-Plane Performance Evaluation of Brick Masonry Infill Wall Using Shaking Table Test

### Part 1 Experimental program

Infill wall	Lateral resistance	Member	○PRADHAN Sujan <sup>1</sup>	Member	YOON Rokhyun <sup>3</sup>	Member	CHOI Ho <sup>5</sup>
Nonstructural element	Out-of-Plane	Member	D G José Tomás <sup>1</sup>	Member	SANADA Yasushi <sup>4</sup>	Member	JIN Kiwoong <sup>6</sup>
Shaking Table		Member	HATA Ryuki <sup>2</sup>				

#### 1. Introduction

Brick masonry wall is widely used as infill in RC buildings even in the countries with high seismicity because of its low cost of construction and availability. Although the infill wall is considered as a nonstructural element, previous studies<sup>[1,2]</sup> show that it also affects the seismic performance of the whole building. However, those studies focus on the contribution of infill wall considering only the in-plane direction as it provides the load path for transferring the seismic forces. In contrast, seismic forces in both in-plane and out-of-plane directions act on the infill walls during an earthquake. If the infill wall is not strong enough, out-of-plane collapse occurs and changes its contribution to the seismic performance of the building which also causes significant danger to life safety.

This shows that it is necessary to estimate the out-of-plane resistance of the infill wall to predict its impact on the seismic performance of RC buildings with infill walls more accurately. Hence, this study was performed to experimentally investigate the out-of-plane behavior and to propose an analytical model to estimate the out-of-plane resistance of brick walls.

#### 2. Experimental program

##### 2.1 Specimen and material properties

A full-scale single wythe specimen representing the brick masonry infill wall in Bangladesh was prepared. The specimen possessed 28 layers of burnt bricks with approximate dimensions of 2000 × 900 × 100 mm in height, length and thickness, respectively, as shown in Fig. 1. Bricks were soaked enough in water, air-dried and the wall was constructed by

skilled masons with running bond starting with the mortar (joint mortar) at the base. On the first day, the wall was constructed until the 14<sup>th</sup> layer and overall construction was finished on the following day. The joint mortar having an approximate thickness of 10 mm was prepared by hand mixing with 1 to 6 by a volumetric ratio of cement to sand (i.e 1:6 mortar), which is common practice for brick wall construction in Bangladesh.

A steel frame was assembled and the specimen was constructed on it to provide confinement to the specimen assuming existence of the surrounding structural frame and also to provide lifting support for transporting the specimen onto the shaking table. However, for the pilot test described herein, a vertical gap of approximately 20 mm was kept between the specimen and the top steel plate (TSP) (Fig. 1 b) to avoid the development of axial force on the specimen due to the vertical confinement by the steel frame. On the other hand, 1:1 mortar was used to fill the horizontal gaps between the specimen and the L-shaped angles at both top and bottom ends, to prevent the horizontal slip of the specimen on/at the bottom/top steel plates during the experiment, as shown in Fig. 1 b). Moreover, Teflon sheets (have negligible friction) between 1:1 mortar and top L-shaped angles on both sides were inserted as shown in Fig. 1 b) to prevent vertical friction, hence a roller condition with freedom in the vertical direction was created at the top end and a fixed support at the bottom end. Fig. 2 shows the complete test setup on the shaking table.

Compressive strength tests were conducted over several bricks and the cylindrical mortar samples used for the specimen

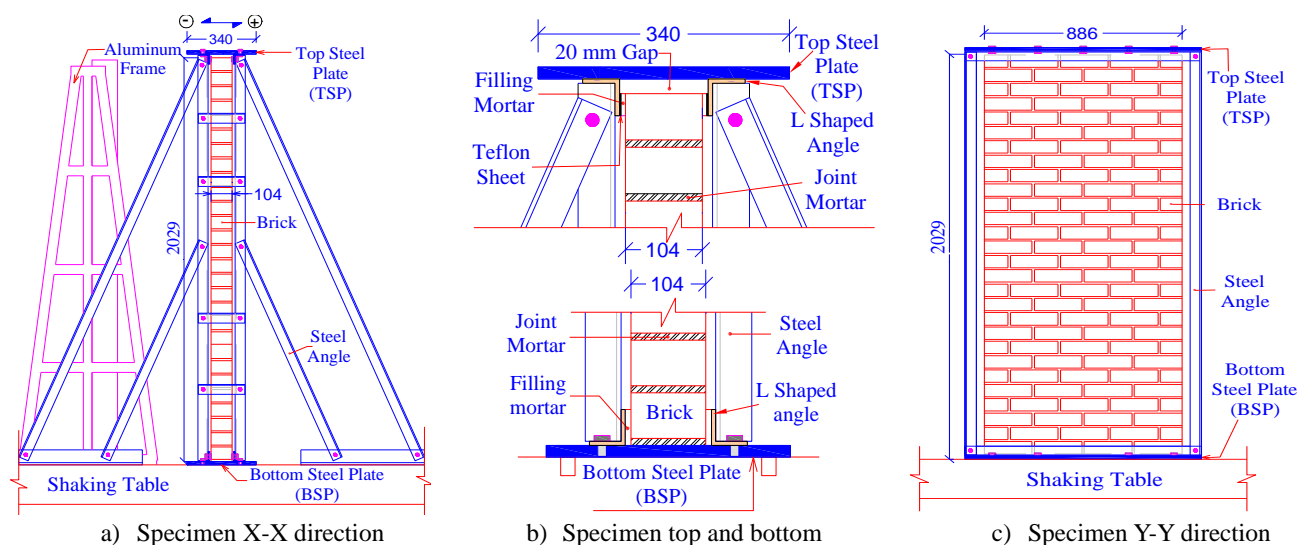


Fig. 1 Specimen details (Unit = mm)

construction. The average values of the elastic/secant moduli and compressive strengths from the tests are shown in **Table 1** where the compressive strength was evaluated by dividing the maximum load by the gross cross-sectional area of the respective test sample. In **Table 1** elastic modulus was evaluated for 1:1 filling mortar as per Japan Industrial Standards [3], whereas, secant modulus, the slope of the line joining the zero value to the highest value of strain, was evaluated for bricks and the 1:6 joint mortar since the stress-strain relationship was almost linear up to the maximum strain value. Moreover, to evaluate the flexural strength of the brick wall with 1:6 joint mortar, five prism specimens with 7-layer bricks were constructed, which failed under self-weight, indicating a value of flexural strength equivalent to  $\sigma_t = 0.012$  MPa at most.

**Table 1** Average mechanical properties of materials

Description	Average value (MPa)	
	Compressive strength	Elastic/Secant modulus
1:1 filling mortar	41.29	23,406
1:6 joint mortar	1.02	2,644
Brick	15.32	1,740

## 2.2 Measurement and loading

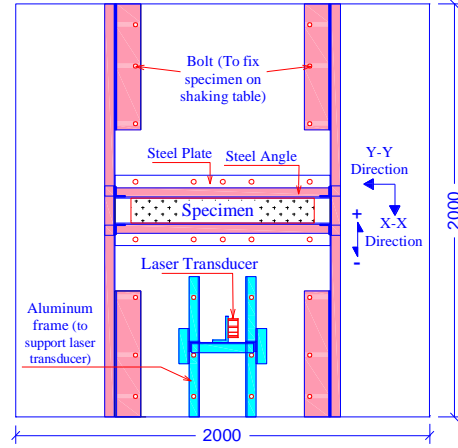
The experiment was conducted at Meiji University, Japan by using the 2 × 2 meter shaking table, as shown in **Fig. 2**. It had a maximum earthquake acceleration of 890 gal and 570 gal in the X-X and Y-Y directions, respectively, with a restricted weight of 1,000 kg. To measure displacement and acceleration of the specimen at different height during the test, six laser transducers and accelerometers (2A to 7A) were installed, as shown in **Fig. 3**. In addition, two accelerometers were fixed at the top of the specimen (1A) and transducer supporter (10A) as well as, two accelerometers (8A (for the X-X direction) and 9A (for the Y-Y direction)) were fixed on the shaking table to monitor the accelerations during the excitation.

A response spectrum was created based on the Bangladesh National Building Code [4], which defined the design spectral acceleration ( $S_a$ ) as:

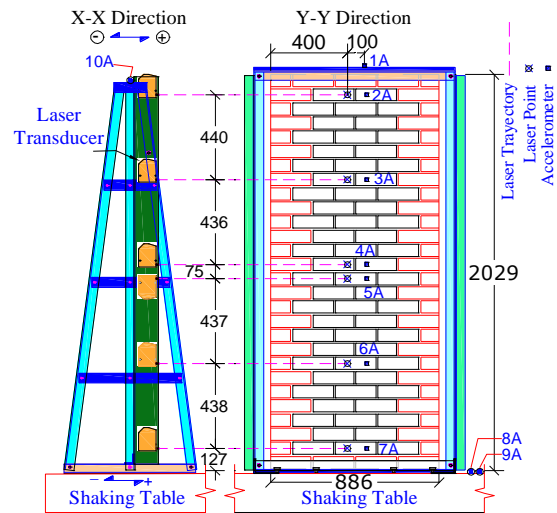
$$S_a = \frac{2ZI}{3R} \times C_s \quad (1)$$

where,  $Z$  is the seismic zone factor ( $Z=0.20$ , Dhaka).  $I$  is the importance factor ( $I=1.00$ , occupancy I or II).  $R$  is the response reduction factor ( $R=1.00$ , elastic).  $C_s$  is the normalized acceleration response spectrum. The assumed soil classification was “SD” and a damping factor was assumed at 5%. **Figure 4** shows an artificial seismic wave which was created by using the

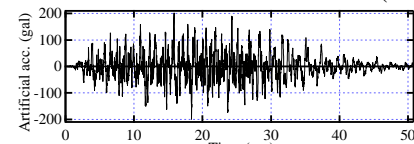
method suggested by Osaki [5] assuming an earthquake magnitude of 8. The maximum acceleration was approximately 200 gal. In addition, the test was performed under 5 input stages i.e.10% (20 gal), 30% (60 gal), 50% (100 gal), 75% (150 gal), and 100% (200 gal) of the artificial seismic wave.



**Fig. 2** Setup on shaking table (Unit = mm)



**Fig. 3** Laser transducers and accelerometers (Unit = mm)



**Fig. 4** Artificial seismic wave

## 3. Remarks

Shaking table test of a full-scale brick masonry infill wall was planned focusing on the out-of-plane performance. The test results and the proposed analytical model are described in **Part 2**.

## [References]

References are listed in **Part 2**.

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