Specimen, Setup, and Loading Protocol Description

Specimen and Setup Description

A total of 29 identical small-scale physical models of an unreinforced masonry (URM) structure are tested under seismic loading conditions, where every specimen is excited by a different earthquake motion. Ground motion records from actual earthquakes are scaled to similar intensity levels and applied in a single direction (North-South direction, Figure 1). The tested buildings are one-story masonry structures. The geometry of the tested 29 identical URM buildings is inspired by the brick masonry building tested by Candeias et al. [1]. The building had windows on the North and West walls, with the East wall remaining opaque (Figure 2). All three walls have a uniform thickness of t_w = 15mm. The height and length of each masonry block are 12.6mm×19.3mm. Figure 1 depicts a photo of the specimen on the seismic shaker mounted to the ETH beam centrifuge. Figure 2 shows different views of the tested specimens. Notches of controlled geometry simulate mortar joints so that the cracks are forced to propagate through them. The vertical and horizontal notches correspond to head and bed joints, respectively. The vertical notches go through the thickness of the wall, while the horizontal notches go through the entire length of the wall. Notch details were inspired by the results of 1:10 tests on 3D-printed walls by Del Giudice et al. [2] who showed that specimens with such notches emulate well the behavior of real masonry walls when the axial load is low. Figure 3 depicts the adopted horizontal and vertical notch details of the tested masonry building. Bottom footings were also printed together with the specimens. These were used to connect the specimen to the test setup.

The drawings and a 3D model of the 3D printed house geometry are available in the files *BPC_drawing.pdf*, *BPC_drawing.dwg, 3DModel.dwg and 3DModel.stl (*this is a format which can opened using almost all CAD software, including free CAD software, e.g., Microsoft Paint 3D*)* under Input Data.

Centrifuge testing was performed at the ETH Zurich Geotechnical Centrifuge Center, GCC. GCC encompasses a beam centrifuge having an effective diameter of 8.25 m and a maximum capacity of 500 gtons. An earthquake simulator is mounted on the centrifuge and used to simulate one-dimensional seismic loading. Figure 4 depicts the ETH GCC beam centrifuge. Metal plates with oval holes were used to fix the URM building to the shaker and apply lateral pressure to restrain the foundation (Figure 1).

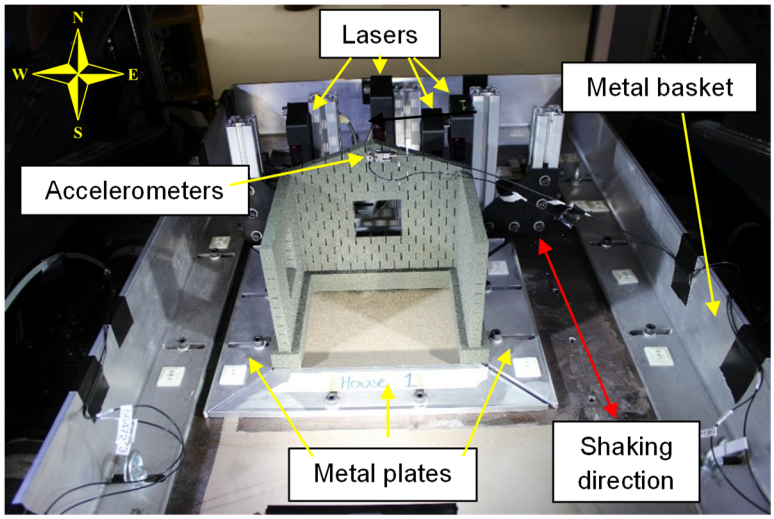
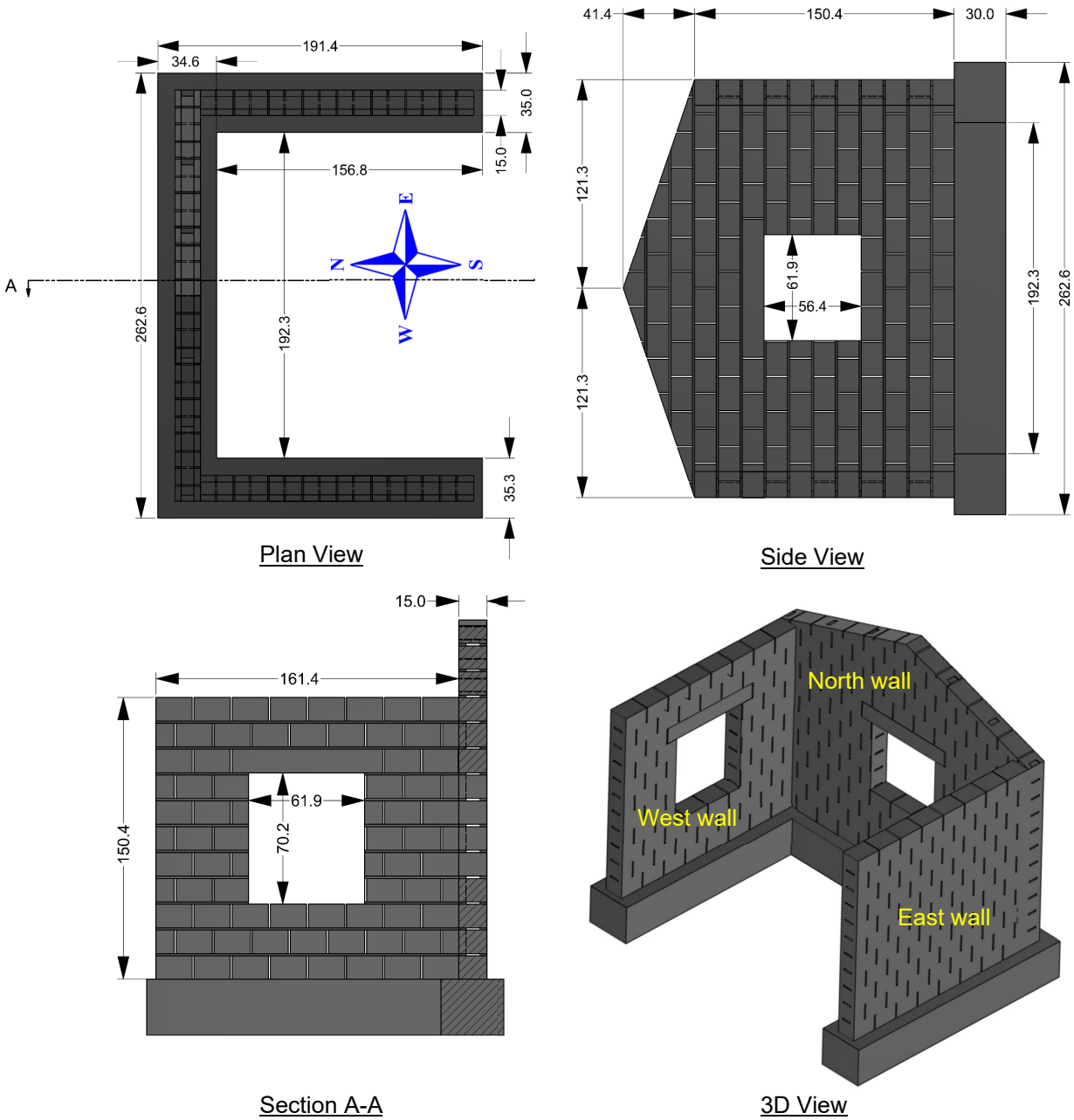


Figure 1. Photo of the specimen on the seismic shaker mounted to the ETH beam centrifuge.



All dimensions are in mm

Figure 2. Geometry of the tested specimens.

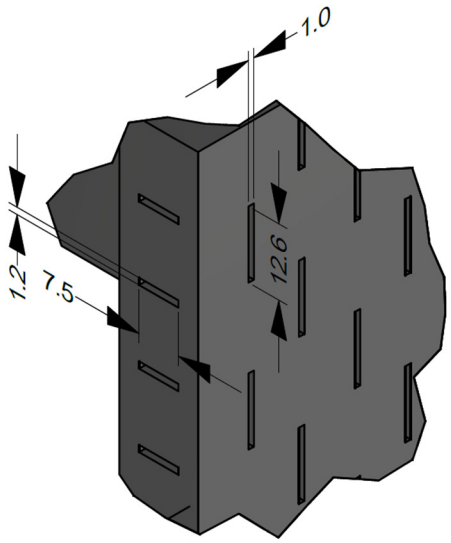
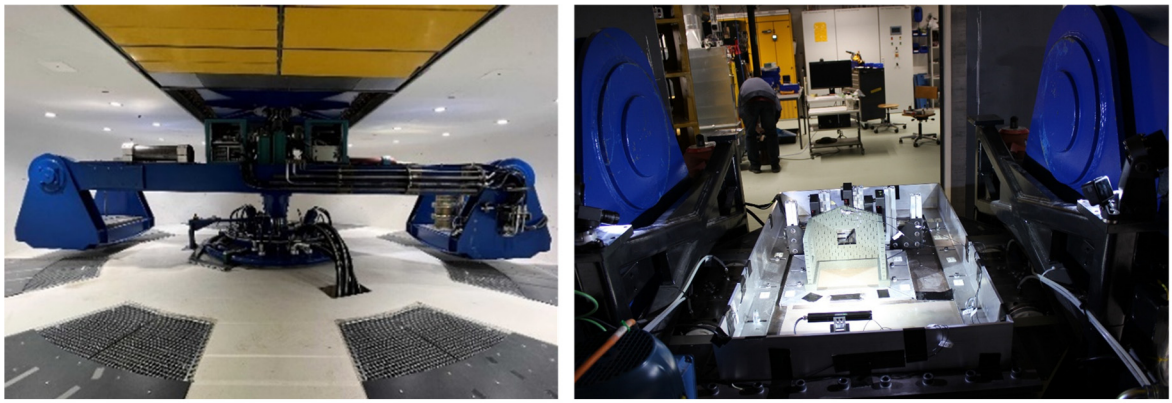


Figure 3. Vertical and horizontal notch details.



(a) (b)

Figure 4. (a) ETH Zurich GCC beam centrifuge and (b) the centrifuge basket showing the URM building specimen.

Testing Protocol and Ground Motions

The loading protocol included 29 ground motions, and one ground motion was applied to each one of the 29 URM building specimens, as listed in Table 1. The ground motion records were selected from the PEER NGA West2 ground motion database [3]. To preserve the similitude of stresses, acceleration and duration of the records were scaled. Since the length scale S_L was equal to 1/15, the time scale was set to $S_T = S_L = 1/15$ (scaled down by 15). The corresponding acceleration scale S_a was equal to 15 (scaled up by 15). The base excitation applied by the shaker was recorded using an accelerometer mounted on top of the shaking table.

The recorded base excitations are provided in *GMinput.zip* under Input Data. Naming of the records is "SpecimenName.txt" where "SpecimenName" is according to the first column in Table 1.

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Table Tests on 29 Masonry Model Structures

Note: 29 specimens were tested, however, the specimen naming includes numbers until 32. House 16, House 25, and House 26 were not tested.

A low-pass Butterworth filter with 32 poles and corner frequency of 250 Hz was applied to the recorded motions. Each text file contains two columns as follows:

Column1: Time in seconds

Column 2: acceleration in g

Table 1. Details of the applied ground motion records and corresponding specimens.

Specimen	PEER File Name	PEER RSN	Earthquake Name	Year	Station Name
House_1	RSN1004_NORTHR_SPV360	1004	Northridge-01	1994	LA - Sepulveda VA Hospital
House_2	RSN1048_NORTHR_STC090	1048	Northridge-01	1994	Northridge - 17645 Saticoy St
House_3	RSN1048_NORTHR_STC180	1048	Northridge-01	1994	Northridge - 17645 Saticoy St
House_4	RSN1063_NORTHR_RRS318	1063	Northridge-01	1994	Rinaldi Receiving Sta
House_5	RSN1086_NORTHR_SYL360	1086	Northridge-01	1994	Sylmar - Olive View Med FF
House_6	RSN1111_KOBE_NIS000	1111	Kobe_ Japan	1995	Nishi-Akashi
House_7	RSN1111_KOBE_NIS090	1111	Kobe_ Japan	1995	Nishi-Akashi
House_8	RSN1244_CHICHI_CHY101-E	1244	Chi-Chi_ Taiwan	1999	CHY101
House_9	RSN125_FRIULI.A_A-TMZ000	125	Friuli_ Italy-01	1976	Tolmezzo
House_10	RSN1602_DUZCE_BOL000	1602	Duzce_ Turkey	1999	Bolu
House_11	RSN1633_MANJIL_ABBAR--L	1633	Manjil_ Iran	1990	Abbar
House_12	RSN169_IMPVALL.H_H-DLT262	169	Imperial Valley-06	1979	Delta
House_13	RSN1787_HECTOR_HEC000	1787	Hector Mine	1999	Hector
House_14	RSN495_NAHANNI_S1010	495	Nahanni_ Canada	1985	Site 1
House_15	RSN495_NAHANNI_S1280	495	Nahanni_ Canada	1985	Site 1
House_17	RSN6888_DARFIELD_CCCCN26W	6888	Darfield_ New Zealand	2010	Christchurch Cathedral College
House_18	RSN6888_DARFIELD_CCCCN64E	6888	Darfield_ New Zealand	2010	Christchurch Cathedral College
House_19	RSN721_SUPER.B_B-ICC000	721	Superstition Hills-02	1987	El Centro Imp. Co. Cent
House_20	RSN723_SUPER.B_B-PTS315	723	Superstition Hills-02	1987	Parachute Test Site
House_21	RSN725_SUPER.B_B-POE270	725	Superstition Hills-02	1987	Poe Road (temp)
House_22	RSN725_SUPER.B_B-POE360	725	Superstition Hills-02	1987	Poe Road (temp)
House_23	RSN752_LOMAP_CAP000	752	Loma Prieta	1989	Capitola
House_24	RSN767_LOMAP_G03000	767	Loma Prieta	1989	Gilroy Array #3
House_27	RSN825_CAPEMEND_CPM000	825	Cape Mendocino	1992	Cape Mendocino
House_28	RSN848_LANDERS_CLW-LN	848	Landers	1992	Coolwater
House_29	RSN953_NORTHR_MUL009	953	Northridge-01	1994	Beverly Hills - 14145 Mulhol
House_30	RSN953_NORTHR_MUL279	953	Northridge-01	1994	Beverly Hills - 14145 Mulhol
House_31	RSN960_NORTHR_LOS000	960	Northridge-01	1994	Canyon Country - W Lost Cany
House_32	RSN960_NORTHR_LOS270	960	Northridge-01	1994	Canyon Country - W Lost Cany

References

1. Candeias, P., et al., *Experimental assessment of the out-of-plane performance of masonry buildings through shaking table tests.* International Journal of Architectural Heritage, 2017. **11**(1): p. 31-58.
2. Del Giudice, L., et al., *Physical modelling of unreinforced masonry walls using a sand-based 3D printer.* Engineering Structures, 2024. **305**: p. 117665.
3. Ancheta, T.D., Darragh, R. B., Stewart, J. P., Seyhan, E., Silva, W. J., Chiou, B. S.-J., Wooddell, K. E., Graves, R. W., Kottke, A. R., Boore, D. M., Kishida, T., and Donahue, J. L., *PEER NGA-West2 Database*. 2013, Pacific Earthquake Engineering Research Center,University of California, Berkeley, CA. p. 134.