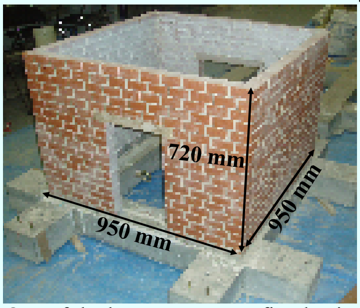
PP-BAND RETROFITTING ASSESSMENT
– SHAKING TABLE EXPERIMENTS (1) –
安価な材料を用いた効果的な耐震補強法の研究
－ＰＰバンドメッシュで補強した組積造建物模型の振動台実験（１）－

Experiment outline

In order to understand the dynamic response of masonry houses with and without PP-band mesh retrofitting and to compare crack patterns, failure behavior, and overall effectiveness of the retrofitting technique, shaking table tests were carried out. These tests were also intended to collect a dataset that will be used in the future to calibrate the numerical model.

Two identical 1:4 scaled models were built using burnt bricks as masonry units and cement, lime and sand (1:8:20) mixture as mortar. This mix was specially designed to obtain mechanical properties similar to those found in masonry houses in developing countries even though the construction materials used were those available in Japan. Both models represented a one-storey box-like dwellings without roof in order to keep the simplicity of the structure for future numerical modeling.

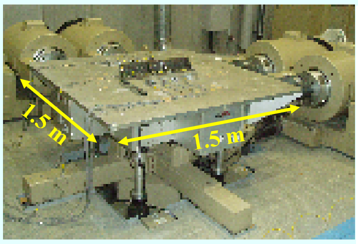


Model geometry (in mm):
Length: 950
Breadth: 950
Height: 720
Wall thickness: 50
Door size: 243 x 485
Window size: 325 x 245

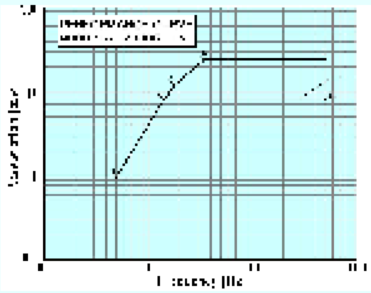
Masonry properties (in MPa):
Diagonal compression strength: 0.08
Direct shear strength: 0.03
Bond strength: 0.05

One of the houses was retrofitted using PP-band meshes following the procedure shown in the box on the right.

Equipment and instrumentation

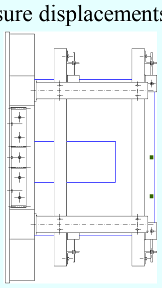


Shaking table performance:
Maximum displacement: ±10cm
Maximum acceleration: ±1.2g
Maximum weight: 2000kg

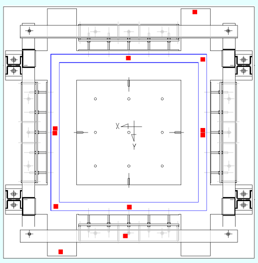


Shaking table performance curve

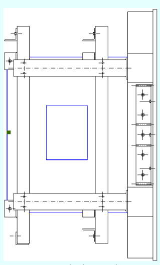
Twelve accelerometers, four with three-dimensional measurement capacity and eight with one-dimensional measurement capacity were installed. Seven lasers, four in N-S direction and three in E-W direction were used to measure displacements.



East side view

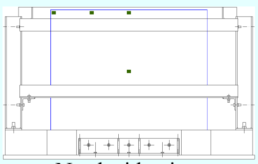


Plan



West side view

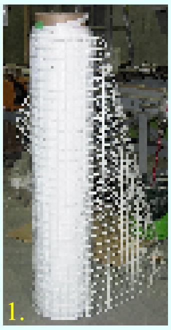
N



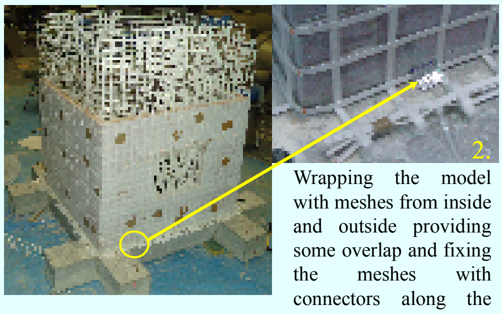
North side view

■ Accelerometers
Capacity: ±2 g
■ Lasers,
Capacity: ± 10 cm

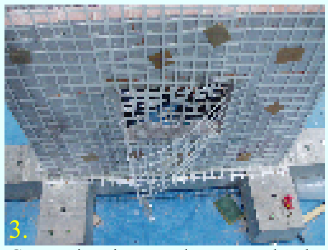
Retrofitting procedure



1. Cutting the PP-band mesh to a convenient size



2. Wrapping the model with meshes from inside and outside providing some overlap and fixing the meshes with connectors along the wall and at the foundation.



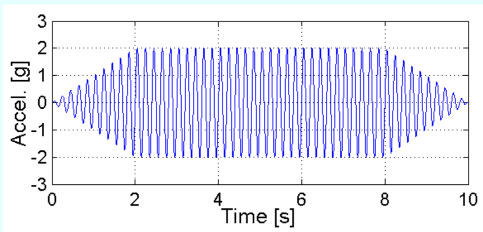
3. Connecting inner and outer meshes by wires and aluminum plates (2cmx2cm) except around the openings.

4. Fixing connectors around the openings after the mesh is cut and overlapped on the other side.

Key point: Installation process is easy and does not require specialized skill!

Loading characteristics

In order to grasp the dynamic behavior of both non-retrofitted and retrofitted houses, sinusoidal waves with frequencies ranging from 2Hz to 35Hz and amplitudes varying from 0.05g to 1.4g were applied. This simple input motion was also considered adequate for later use in the numerical modeling.



The numbers given in the following table show the loading sequence followed for the two tests.

Amplitude	Frequency							
	2Hz	5 Hz	10 Hz	15 Hz	20 Hz	25 Hz	30 Hz	35 Hz
1.4 g		59	58	57				
1.2 g		56	55	54	53			
1.0 g	62	52	51	50	49			
0.8 g	61	47	44	41	38	35	32	29
0.6 g	60	46	43	40	37	34	31	28
0.4 g	48	45	42	39	36	33	30	27
0.2 g	26	25	24	23	22	21	20	19
0.1 g	18	17	16	15	14	13	12	11
0.05 g	10	09	08	07	06	05	04	03
Sweep	01, 02							

■ Loading steps for both non-retrofitted and retrofitted models
■ Loading steps for retrofitted model after non-retrofitted model building collapse

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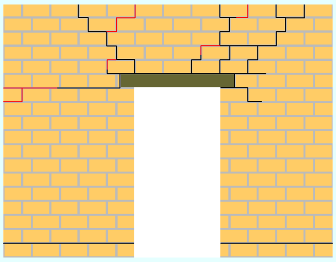
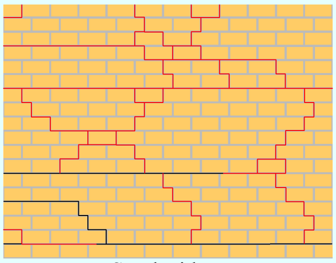
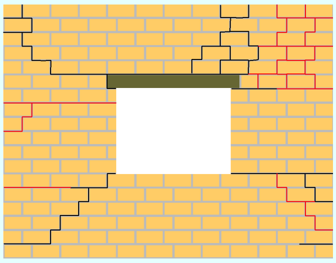
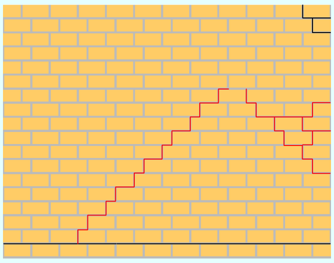
Crack patterns

Non-retrofitted house


East side

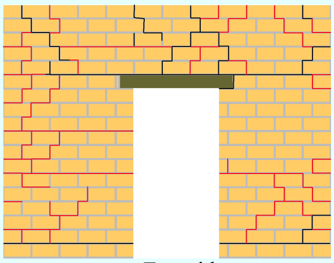

South side

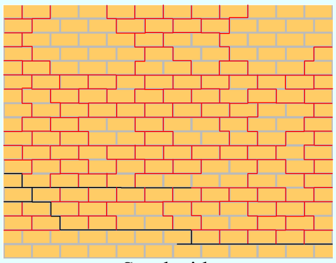

West side

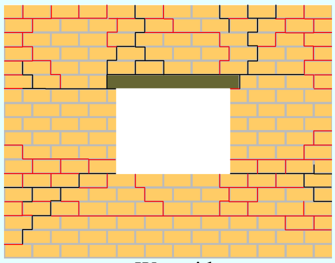

North side

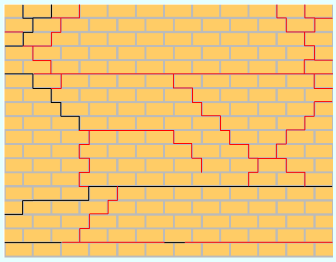
— Cracks observed after the 41st run, the collapse onset (a_{max}: 0.8g, f: 15Hz, d_{max}: 0.9mm)
— Cracks observed after the 46th run (a_{max}: 0.6g, f: 5Hz, d_{max}:6.0mm)

Retrofitted house


East side


South side


West side

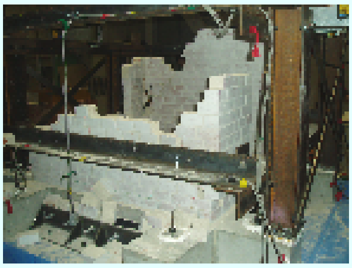

North side

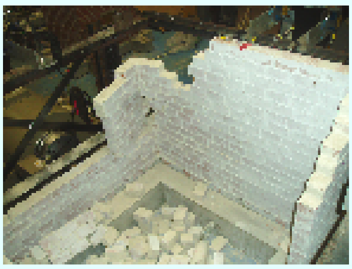
— Cracks observed after the 41th run (a_{max}: 0.8g, f: 15Hz, d_{max}:0.9mm)
— Cracks observed after the 60th run (a_{max}: 0.6g, f: 2Hz, d_{max}: 37.3mm)

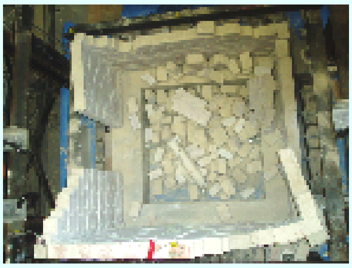
Initial crack patterns for both models were similar. In the non-retrofitted model, cracks widened with each successive run. This finally led to the structure collapse. On the other hand, in the retrofitted model, new cracks appear in each run, thus, extensive cracking was observed. Although the PP-band mesh kept the structure integral during the shaking, it allowed the sliding of the bricks along these cracks. This constituted an important mechanism of energy dissipation.

Failure modes

Non-retrofitted house



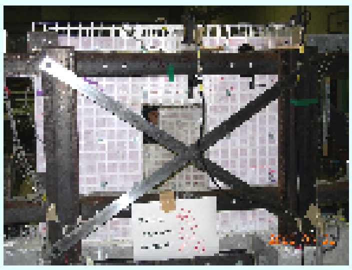


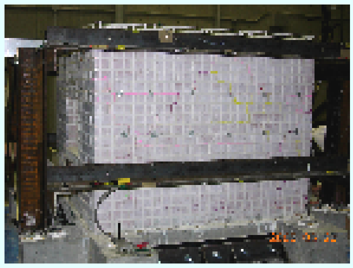


Collapse of non-retrofitted house after the 46th run (a_{max}: 0.6g; f: 5Hz, d_{max}: 6mm)

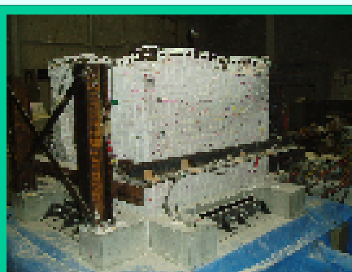
Partial collapse of the non-retrofitted house occurred in the 44th run (a_{max}: 0.8g, f: 10Hz, d_{max}: 2.0mm). The building totally collapsed in the 46th run (a_{max}: 0.6g, f: 5Hz, d_{max}: 6.0mm)

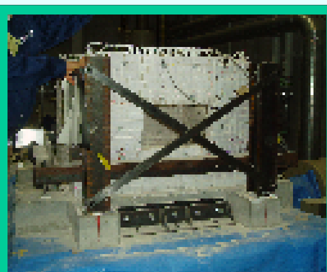
Retrofitted house





Retrofitted house after the 46th run. Although it was slightly more cracked that the non-retrofitted house, it did not collapse.





The retrofitted house was shaken until the 61th run (a_{max}: 0.8g, f: 2Hz, d_{max}: 49.7mm). The structure exhibited remarkable deformations because of the large number of failed mortar joints. Nevertheless, the PP-band mesh provided confinement and held the disintegrated elements together preventing the collapse.

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