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COLLAPSING BEHAVIOR OF SHEAR WALLS PICKED FROM THE OLD WOOD HOUSE

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SUMMARY

The seismic performance of old houses is difficult to be evaluated by the deterioration and degradation. A typical Japanese conventional house was subjected to the survey of durability and the study on the structural performance. The four shear walls with mortar finish on metal lath were picked from the old house. The two shear walls were set on the shaking table, which the seismic wave obtained at JR TAKATORI station in 1995 Hyogo Nambu earthquake was input to. The other two shear walls were tested under the static lateral load and compared with the walls reproduced by virgin components and materials to be the same as the picked walls.
As a result of the shaking table test, most of the mortar finish with metal lath was failed under the seismic wave. About 10 cm shear deformation was left after the test. Then, the same specimen without mortar was shaken by the same seismic wave. As a result, the specimen was collapsed. And, it was discussed that the aging affected on the fracture behavior of the shear wall.

INTRODUCTION

Many of the existing old wooden houses in Japan are not enough strong to resist the strong earthquake. There are several reasons why the required seismic resistant elements by old building code were less than the going code, the seismic consideration of builders was less than the present, the check system of building quality has never established, the old houses often includes the deteriorated or degraded parts of components and joints, and so on. It is necessary for the houses without sufficient seismic performance to be repaired and improved. However, the seismic performance of old houses is difficult to be evaluated by the deterioration and degradation. In this paper, shear walls were picked from a typical old wood house and subjected to the static lateral load test and shaking table tests. A part of results were compared with the results of load tests applied to the reproduced shear walls.

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THE OLD HOUSE WHOSE SHEAR WALLS WERE PICKED

Specifications of the house

A typical old Japanese conventional wood house, as shown in Photo1, was employed to this study. The owner of the wood house was said that the house was built 23 years ago. However, we guessed that the house was built about 40 years ago, depending on the discoloration of components. It had 36.4 and 38.1 m^2 floor area in 1st and 2nd story, (total floor area: 74.5 m^2) respectively, and a plan, as shown Fig. 1. Triangles in Fig. 1 show the location and the direction of wood braces.

Specifications of this house are shown as followings;

- exterior: mortar with wire lath on wood lath,
- interior: plywood with 9 mm thickness,
- wood brace: 45 x 90 mm cross section jointed by 2 nails per an end, and,
- roofing: decorated cement shingles.

Photo 1. The profile of the house whose shear walls were picked up.

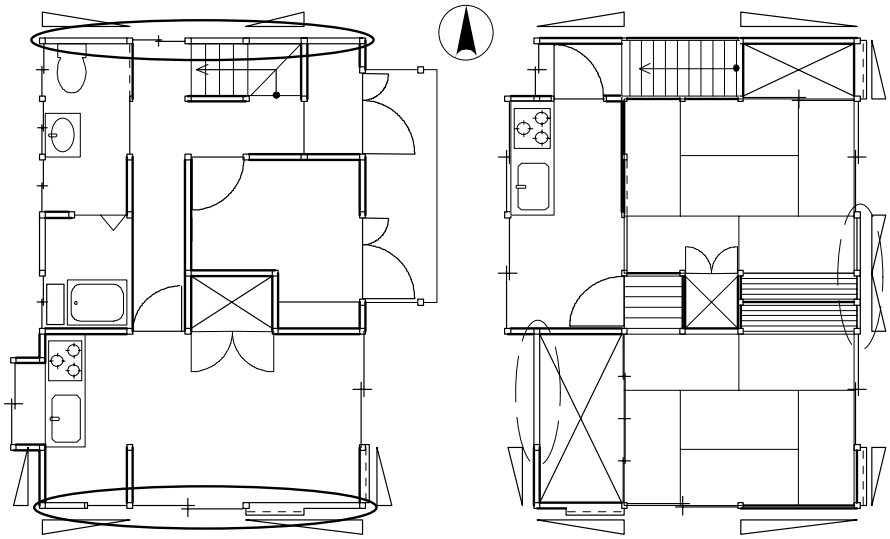

Fig. 1. The plan of the house whose shear walls were picked.

Note: Solid circles show the walls picked up for shaking table test, and dotted circles show were picked up for static load test.

Microtremor of the house

The microtremor was measured. The velocity meters were set on the roof beams and 2nd floor beams parallel to the four perimeters and the center of the building area on the roof beams, the 2nd floor beams, and the earthen floor in the north-south and east-west direction. The spectrum ratios of 2nd floor to 1st floor in the north-south direction were shown in Fig. 2. The natural frequencies in the north-south and east-west direction were 7.7 and 7.4 Hz, respectively. The damping constants obtained by the spectrum ratios measured at the center of the building area in the north-south and east-west direction were 0.050 and 0.069 Hz, respectively. The natural frequencies of typical Japanese conventional wood houses are approximately 5 Hz[1)], so this house was not so deteriorated and degraded.

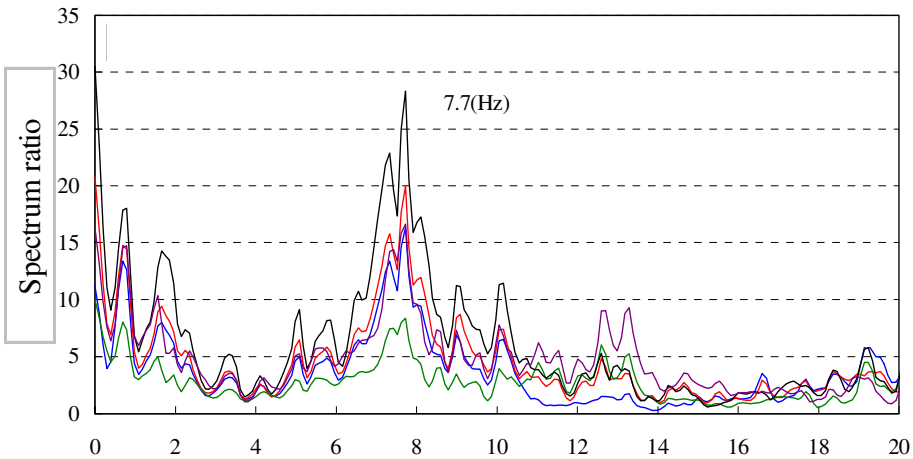

Fig. 2. Spectrum ratios of the microtremor of the house whose shear walls were picked in the north-south direction.

Survey of durability

In order to grasp the effect of the aging to the house, the sills, the bottoms of the columns, and the horizontal angle braces were surveyed whether the parts of those members were decayed or not, by our eyes, and the moisture contents of wood members were measured. As a result, only one decayed member was found. A part of the sill on the east end of the lavatory was decayed. The other decayed members have never been found. The moisture content of the sill was relatively high and more than 20 %. The depth of the pin sunk into wood by the PILODYN® , which is known to be relative to the density of the wood[2)], was measured. The depth of the pin sunk into the decayed portion of the members and those into not decayed portion in the same member were 17 mm and 8 mm, respectively. It was clarified that the part looked like decayed was deteriorated in density or strength of embedment. However, the picked walls subjected to the load tests didn't include the decayed member.

METHODS TO PICK THE SHEAR WALLS FROM THE HOUSE CONSTRUCTION

The walls on the southern and northern perimeter of the 1st floor with 5,005 mm length were decided to be picked for shaking table tests. The 1,820 mm long walls on the eastern and western perimeter of 2nd floor were picked for the static lateral load tests. One of the 1,820 long wall had two wood braces, the other had no brace. The procedures to pick the walls were as followings;

1) Deconstruction of the interior walls, floors, and ceilings surrounding the walls to pick up, as shown in Photo 2(a).
2) Marking the line of cutting on the exterior walls.
3) Cutting the exterior finish, that is mortar with wire lath in this case, parallel to the marked

line with 10 or 15 cm width by grinder, as shown in Photo 2(b). At this time, though wood lath were partly damaged, they were not cut.

4) Cutting the structural members, that is beams, angle beams, stud, and wood lath, except for columns, by using chain saw, so that the space would be 10-15 cm width, as shown in Photo 2(c).
5) Making the two holes at the foundation, as shown in Photo 2(d).
6) Passing two wires through the holes and tensed by the crane
7) Cutting the column by chain saw, as shown in Photo 2(e).
8) Hoisting and laying down the wall by crane as shown Photo 2(f) and (g).
9) Cure of the walls in consideration of the stress in transportation, as shown in Photo 2(h).

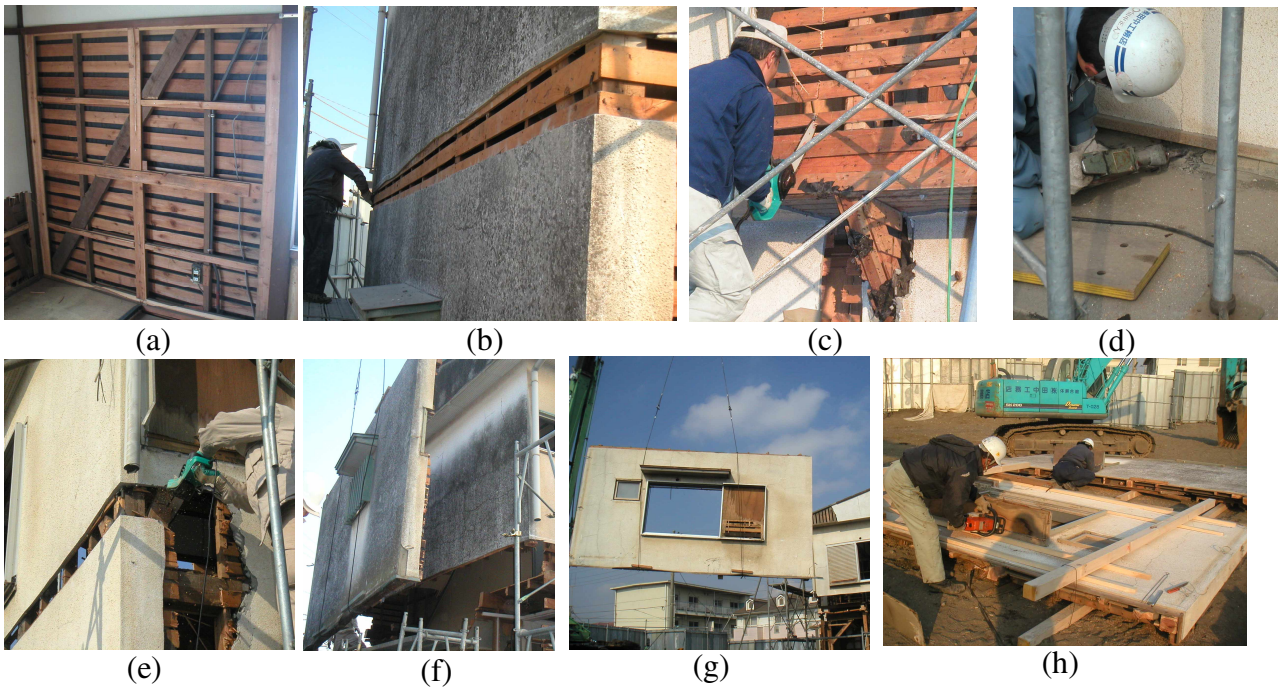

Photo 2. Procedure of the picking the walls from the old house.

STATIC LATERAL LOAD TESTS OF PICKED AND REPRODUCED WALLS

Test Methods

The static lateral load tests were conducted to the picked wall with 1,820 mm length, as shown in Fig. 3. A beam and a sill were added the picked walls and fastened to the top and bottom of them by M16 bolts, respectively. The added sill was fastened on the basement. The lateral load was applied to the added beam. The walls were failed after the load that they had the nominal shear deformation of +/-1/600, +/-1/450, +/-1/300, +/-1/200, +/-1/150, +/-1/100, +/-1/75; +/-1/50 radian was repeated each three time, as shown in Fig. 4. The dead weight of 13.44 kN was loaded on the added beam.

Results of the Picked Walls

The walls had a rocking and failed in the pull-out of the column from the sill, because there were no fastener at the top and bottom of the columns. The finish mortar, wire lath, and wood lath were not damaged significantly. Therefore, the column and the beam and sill were jointed by hold down fasteners (hereinafter referred to as the “HD”), and lateral load tests were conducted again. The load-shear deformation curves of the wall with two braces were compared at the case without HD fasteners and the

case with them and shown in Fig. 5. The maximum load of the wall without the HD fasteners was 7.61 kN, and those of the wall with the HD fasteners was 23.01 kN.

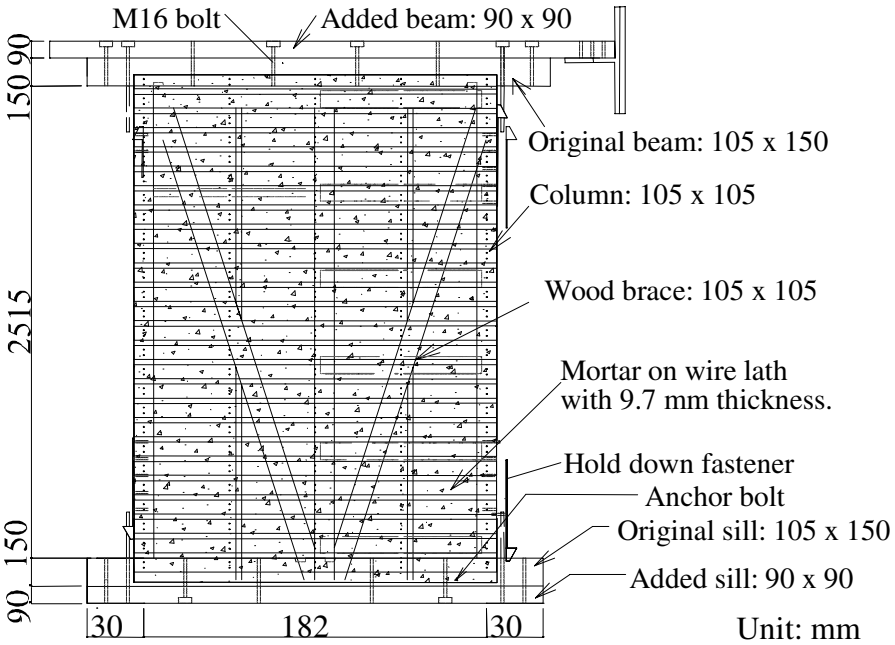

Fig. 3. The schematic diagram of the picked wall with 1,820 length subjected to the static lateral load tests.

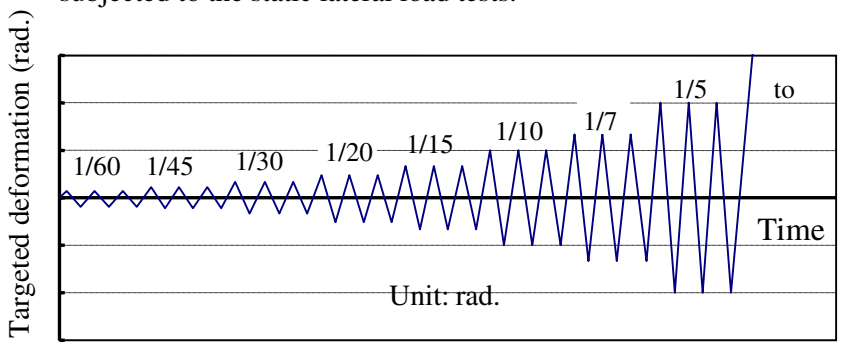

Fig. 4. The loading schedule of static load tests.

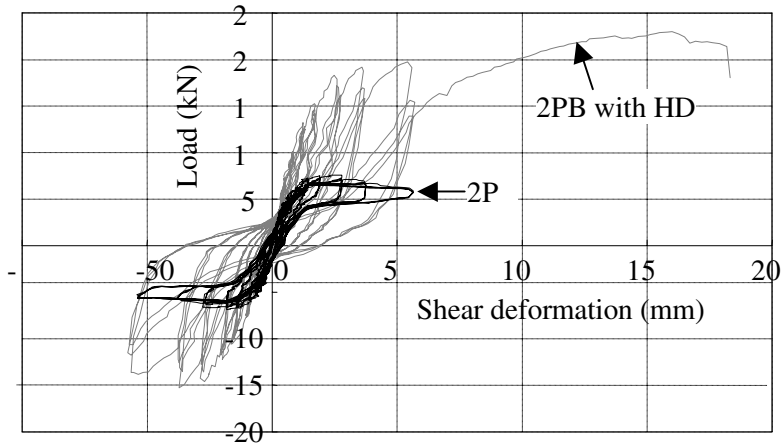

Fig. 5. The load-shear deformation curves of the wall with two braces.

Reproduced Walls

The picked wall with 1,820 mm length was reproduced employing new materials and components. The walls with wood braces and without brace were reproduced each three specimen. The static lateral load tests were conducted to the total six specimens as well as the picked wall. The virgin load path picked from load-shear deformation curves of the reproduced and the picked walls with two braces and HD fasteners were compared and shown in Fig. 6. The maximum loads and the initial stiffness of the picked walls were lower than those of the reproduced walls. The deformation giving the maximum load of the picked wall was larger than those of the reproduced walls. It is not sure about the accuracy of reproducing of the walls, but if the accuracy have been reliable, the maximum loads and the initial stiffness of the picked walls might become to be degraded about 13 % and 35 %, respectively, as shown in Table 1.

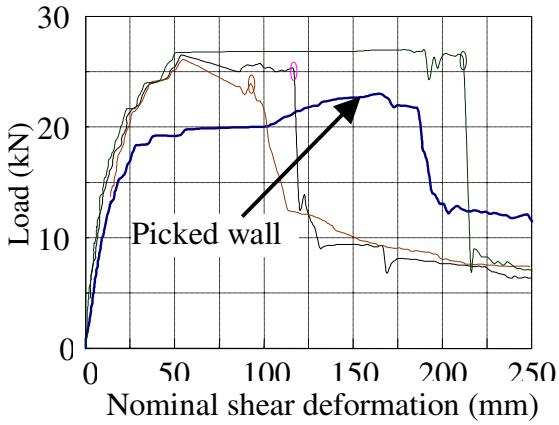

Fig. 6. The load-shear deformation curves of the picked and the reproduced walls with two braces.

Table 1. Results of the lateral load tests for the picked and reproduced walls.

Specimen	Picked / reproduced	Braces	HD fastener	Maximum load (kN)	Initial stiffness (kN/mm)	Ductility factor
2P	picked	none	none	7.32	0.47	8.59
N2P	reproduced	none	none	8.29	1.14	9.20
2PB	picked	2	none	7.62	1.25	10.15
N2PB	reproduced	2	none	9.56	2.35	15.64
2PB-HD	picked	2	4	23.03	0.70	6.16
N2PB-HD	reproduced	2	4	26.51	1.08	6.30
(standard deviation)				(0.368)	(0.100)	(2.41)

SHAKING TABLE TESTS OF PICKED WALLS

Specimen

The picked wall with 5,005 mm length subjected to the shaking table tests. A beam with 105 x 240 mm cross section and a sill with 105 x 105 mm cross section were added each picked wall and fastened to the top and bottom of them by M12 bolts, respectively. The two picked walls were built up on the shaking table to become parallel to each other in the interval about 3.64 m. The two walls were united a diaphragm

and walls perpendicular to the picked walls. The diaphragm was made by doubled 210 dimension lumbers and 24 mm thick plywood. The walls perpendicular to the picked walls were made by braces employing steel rods with 12 mm diameter and shear walls employing 105 x 105 mm columns and 30 x 105 mm studs and 12 mm thick plywood sheathed both sides. The aspect of the assembled specimen was shown in Photo 3. The details of the picked walls, the diaphragm, and the walls perpendicular to the picked walls were shown in Fig. 7.

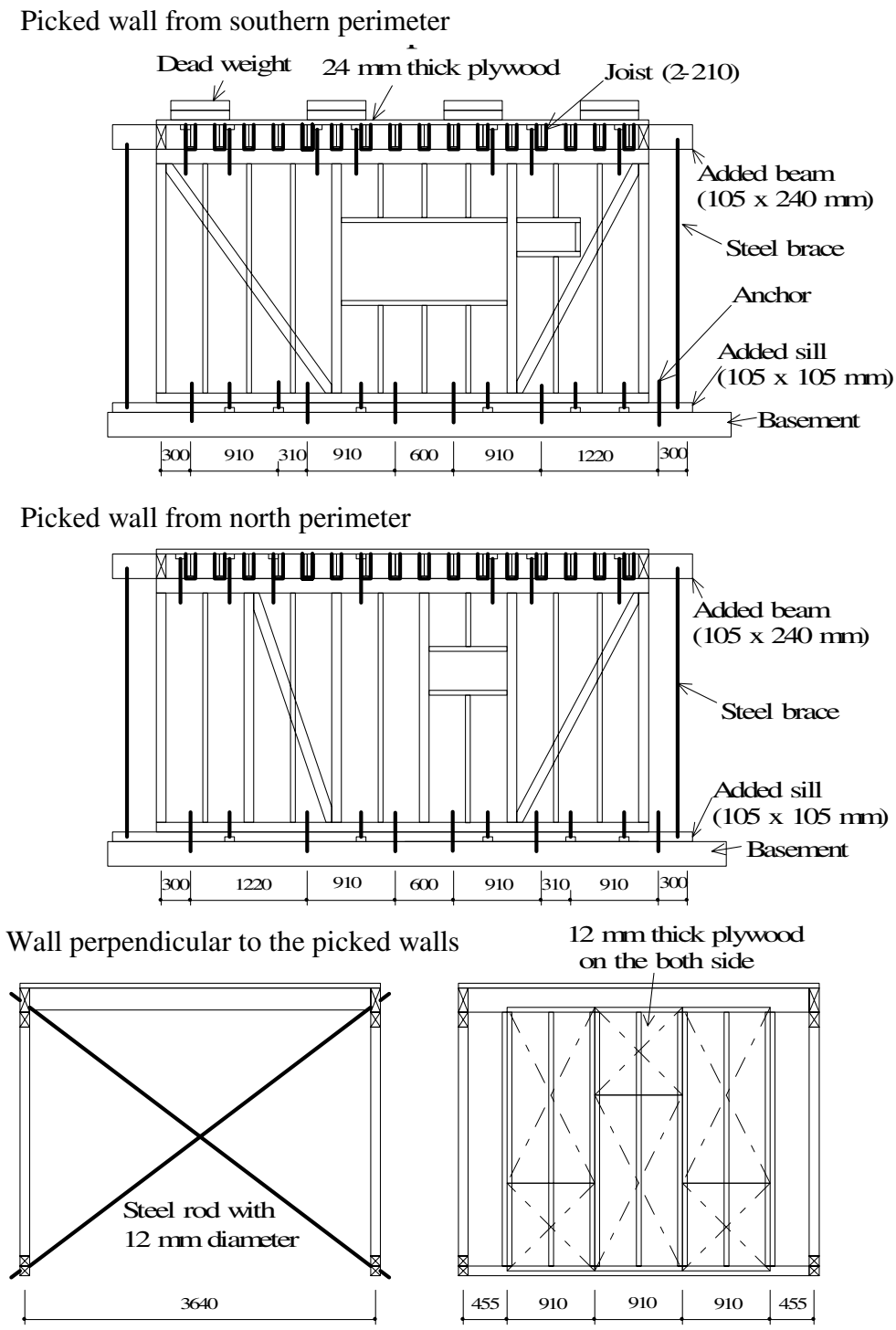

Fig. 7. Details of the picked walls, the diaphragm, and the walls perpendicular to the picked walls.

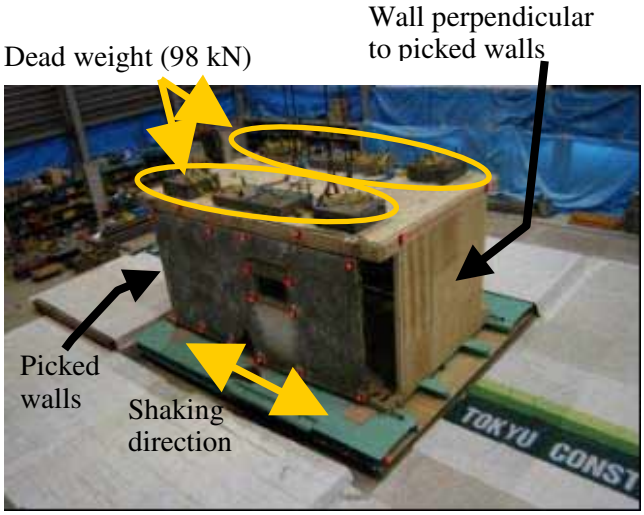

Photo 3. The aspect of the assembled specimen.

Test condition

The specimen was shaken by the ground motion measured at JR Takatori station in 1995 Hyogo-ken Nanbu earthquake. The seismic wave was rotated 40 degree from north to west and input to shaking table, as shown in Fig. 8. The maximum acceleration, displacement, and velocity of the input wave were 741 gal, 50 cm, and 135 cm/s, respectively. As an example, the wave form of the acceleration in the X-axis of the shaking table was shown in Fig.9.

The dead weight was decided as 98 kN. Because, it was estimated that the specimen would be failed by about 4 times of the maximum load of 1,820 mm under static load tests; 23 kN, since the wall length without openings in the specimen was about 7,280 mm. The force of 92 kN corresponds to the product of the dead weight and the weight of diaphragm, and the maximum acceleration of the input seismic wave.

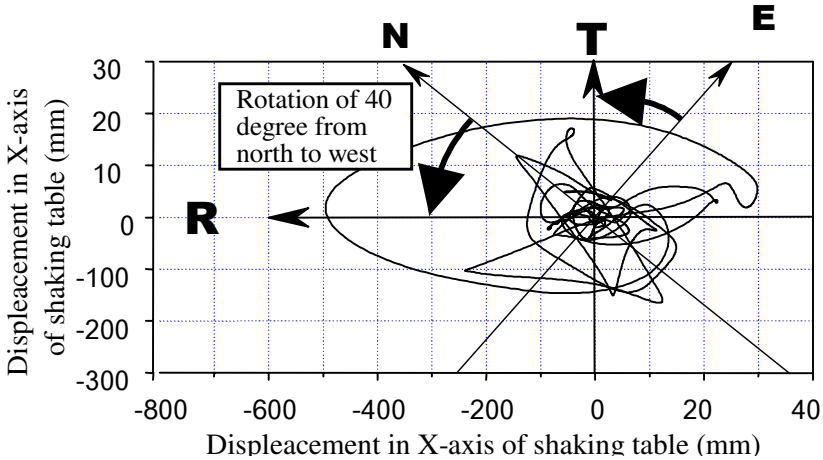

Fig. 8. The Lissajous figures of the input seismic wave.

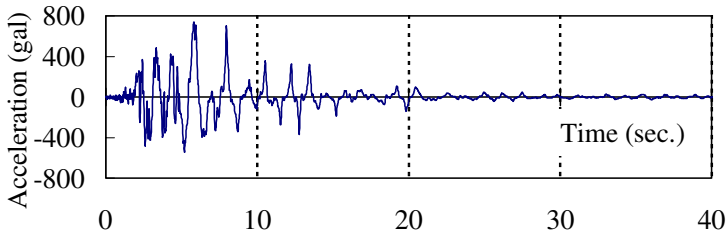

Fig. 9. An example of wave form of the acceleration in the X-axis of the shaking table.

RESULTS OF SHAKING TABLE TESTS

Fracture by the 1st shaking

Shaking table test was conducted to the specimen assemble by the two picked walls, the diaphragm, and the wall perpendicular to the picked walls. The 1st input of the full scale of the JR Takatori seismic wave made the specimen fail. Most of the mortar with wire lath came off the wood lath and fell down, as shown in Photo 4. The maximum relative story displacement was 23.9 cm. The maximum absolute acceleration on the diaphragm was 873 gal. The wood braces didn't buckle, because the brace had been pulled out early and stepped out of the sill. After shaking, the relative story deformation of about 10 cm was left.

Collapse by the 2nd shaking

The mortar with wire lath, which didn't come off and left an the specimen, was prevent from the wood lath. The full scale of the JR Takatori seismic wave was input to the specimen. After the start of shaking, it takes about 10 seconds for the specimen collapse, as sown in Photo 5. The lateral load applied to the specimen was calculated as the product of the dead weight and the weight of the diaphragm, and the acceleration. The load-deformation curves obtained by the 1st and 2nd shaking were shown in Fig. 10. The specimen only with wood lath had very small input load and strength.

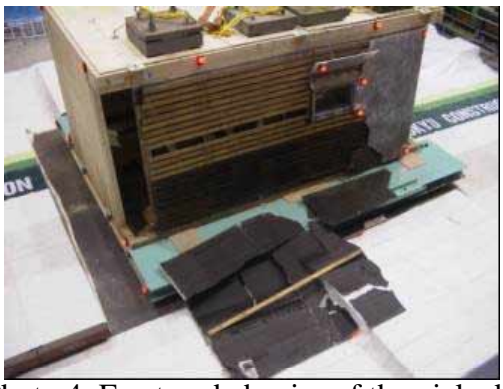

Photo 4. Fracture behavior of the picked shear walls from aged house.

Photo 5. Collapse behaviour of the picked shear walls from aged house.

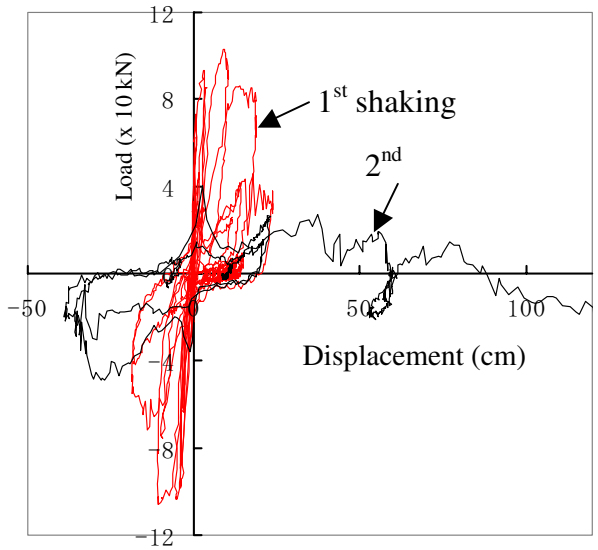

Fig. 10. The load-deformation curves under JR Takatori seismic wave.

CONCLUSIONS

The results of these studies were summarized as follows;

- We could pick the walls from the old house existing really and conduct the static lateral load and the shaking table tests to the walls.
- The wall was failed by the seismic wave, which input the load corresponding to the static shear strength.
- Most of exterior mortar with wire lath came off by the shear deformation of about 1/11 radian, but the wall only with wood lath remains the small restoring force.
- In spite of no decayed components, there is a probability that the strength and stiffness have been degraded.

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