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EXPERIMENTAL AND ANALYTICAL STUDY ON THE SEISMIC PERFORMANCE OF LOAD-BEARING WALLS WITH DIAGONAL WOODEN LATHS AND PLASTER FINISH

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ABSTRACT: This paper reports the results of experimental and analytical investigations into the structural performance of bearing walls with diagonal wooden lath boards and plaster finish, which were frequently used in early modern Japanese wooden buildings. Full-scale tests were conducted on lathboard walls with a width of 50 mm, a clearance of 6 mm and attached to the wall body by nailing, confirming a high bearing capacity of about 6 times the wall magnification equivalent in Japan. Elemental tests on a single lath board were carried out and the results were used to estimate the structural performance of the full-scale wall. An analytical calculation model that takes into account the shear performance and deformation of the nails at the joints was used to estimate the initial stiffness and bearing capacity with good accuracy. It was also quantitatively shown that the plaster finish contributes to the stiffness and bearing capacity increase in the early stages of deformation.

KEYWORDS: *Wooden lath board, Plaster finish, Modern wooden building, Element test*

1 – INTRODUCTION and BACKGROUND

In Japan, Western wooden construction methods were introduced after the *Meiji* Restoration (1868), and various types of wooden buildings were constructed, mixed with traditional techniques. By making it possible to evaluate the structural performance of these construction methods, it will be possible to evaluate their seismic performance for repairs and to consider structural reinforcement methods more appropriately. In this paper, we focus on the walls nailed with "diagonal wooden lath boards" and finished with plaster, which were often used to build walls of Western-style buildings in the late 19th century in Japan. It is believed to have been used as a construction method that expected the horizontal resistance force of diagonal boards as a spontaneous idea by carpenters, especially before the full-fledged introduction of diagonal braces in Japan. However, even today, there is no simple method of estimating the bearing capacity of wooden lath and plaster wall except for full scale experiments despite the the need for the wall in the performance evaluation and reinforcement of modern buildings undergoing repair. Regarding differences in performance depending on the orientation of nailed wood lath boards, there has been research by Karacabeyli and others on board walls without plaster[1], experimental studies on traditional and western style wooden wall in Japanese houses in 1930s by Tanabe et al.[2], and more recent research by Takino et al. on combined use with diagonal braces[3]. However, a clear design policy for analytically evaluating the performance of diagonal wood lath boards has yet to be established.

Based on the background above, the purpose of this study is to propose a simple calculation method for the walls with diagonal wooden laths and plaster, based on full-scale tests and elemental experiments on nail joints of laths.

2 – EXPERIMETAL SPECIMEN AND SETUP

A construction process, diagram of the specimen and the experimental setup are shown in Fig.1 to 5.

Full-scale specimens were modeled after an important cultural property (Former Date County Office, 1883) existing in Tohoku region of Japan: Frame (cedar): 1820*2730 mm, lath board (cedar): 60*12@5mm with two nails (Φ6,L50) at one joint). In the full-scale tests,

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static cyclic loading was applied at the top to measure the shear deformation and load on the wall. The full-scale specimens were subjected to alternating positive and negative forces between 1/450 rad. and 1/15 rad.(Fig.1 to 3)

The shear element test specimen consisted of two lath boards (longest joint spacing length of full-scale test: 933 mm) and support materials (wooden block). The single-shear element tests of the nails and wood lath were carried out under the following conditions. Nails: N50 ordinary steel round nails (φ2.75), Column: 105 mm square cedar (special first-grade lumber), Wooden lath: Cedar (special first-grade lumber), Width: 60 mm / Thickness: 12 mm, Length:Long test specimen: 793 mm, Short test specimen: 250 mm. In the element tests, the one-sided shear performance of each of the two lath plates (four joints) was measured by monotonic shear tests. Elemental experiments were conducted with unidirectional forces of approximately 50 mm until the nail punched out of the lath plate. (Fig. 4 and 5)

Fig. 1 Process of plaster work on diagonal wooden lath (Clockwisefrom top-left figure; base coart, hemp fiber reinforcement, middle coat, finish coat)

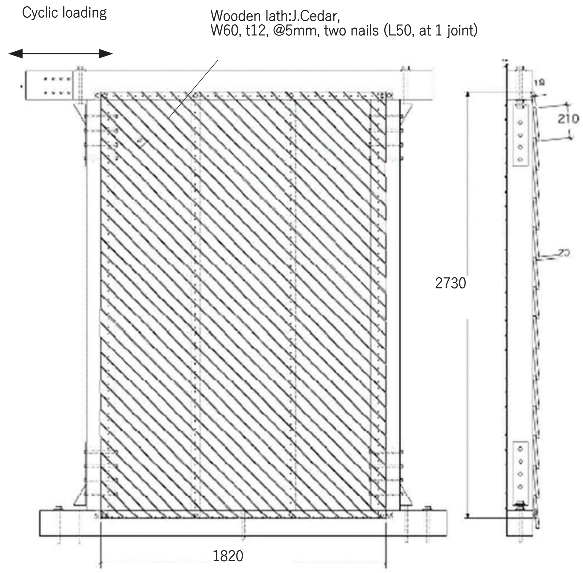

Fig. 2 Full-scale specimen: front side: diagonal wooden lath

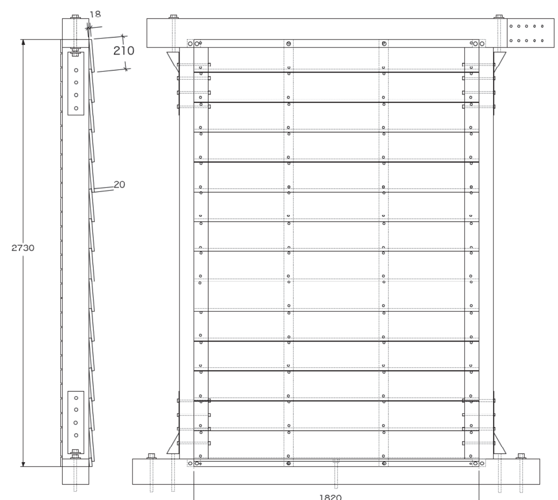

Fig. 3 Full-scale specimen: back side: transverse nailed boards

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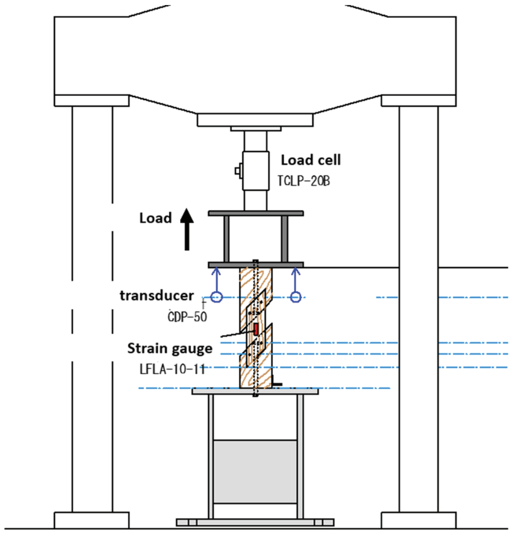

Fig. 4 Set up of element test of lath and nail joint: specimen

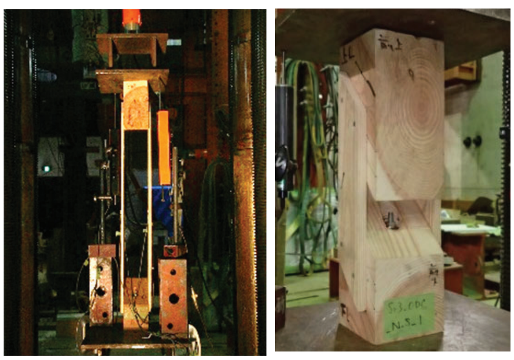

Fig. 5 Specimens of Element test of lath and nail joint: (left):long length specimen, (right):short length specimen

3 – PROPOSED ANALYTICAL MODEL

The frame numerical analysis was performed assuming that the shear performance of each joint can be represented by a trilinear shear spring with initial stiffness and yield capacity obtained from shear element experiments on wooden laths and nails. The columns, studs, and beams were assumed to be made of elastic timber (Japanese cedar, young modulus: around 9 GPa.), and the joints of the column-and-beam were assumed to be pin joints.(Fig.6)

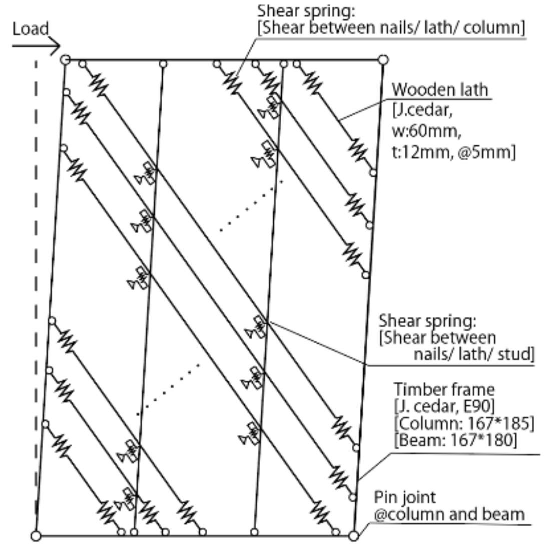

Fig. 6 Proposed analytical model of diagonal wooden lath wall

4 – RESULTS OF FULL SCALE EXPERIMENT, ELEMENTAL TEST AND ANALYSIS

The results of the full-scale tests (Fig.7) indicate that the maximum bearing capacity is about 25 kN [about 13.8 kN/m] with and without plaster (about twice that of a mud wall of the same dimensions). The application of plaster had the effect of increasing the initial stiffness and bearing capacity until crack initiation at about 1/450 rad.. In all specimens, the ultimate failure was the punching out of the nails at the joint (Fig.8).

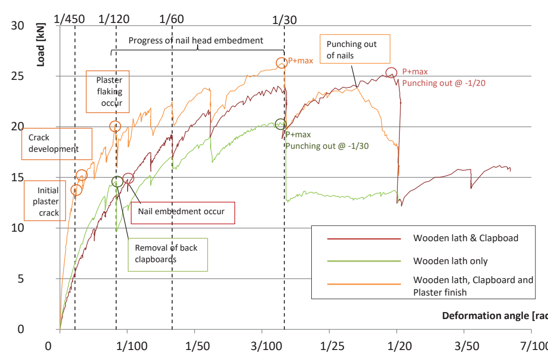

Fig. 7 Load-deformation relationship of full scale tests

Fig. 8 (Clockwise from the top-left figure) Bending deformation of lath at the maximum load (1/30 rad.[Spec.2]), Punching-out failure at 1/20 rad.[spec.2], Lifting at the edge of the plaser finish at 1/150rad.[spec.4], Damage and detachment of the plaster finish at 1/20rad.[Spec.4].

From the elemental experiments, the following points were suggested. In the short wood-lath specimens, the shear force per joint—comprising two nails—reached about 1 kN at the yield load and about 1.5 kN at the maximum load. It appears that, even at large deformations, the effect of bending deformation was not significant. Moreover, when comparing the experimental results with the strength and stiffness values calculated using EYM and Beam-on-elastic-foundation theory, the experimental elastic stiffness was about 80% of the estimated values, while the yield strength was about two to two-and-a-half times the estimated values. Thus, stiffness could be largely predicted, but the experimentally measured load ended up being higher. (Fig.9)

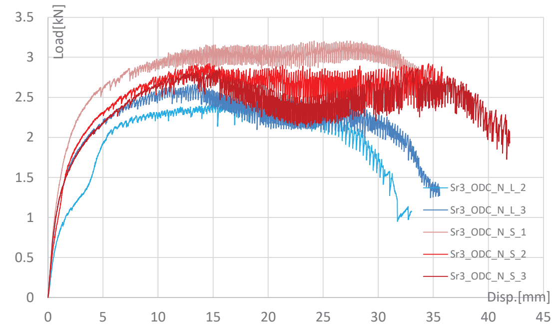

Fig. 9 Load-deformation relationship of elemental tests

The results of the analysis applying the shear performance of the joints (short lath tests results' average value is applied) obtained from the elemental experiments were approximately 1.6 times at the initial stiffness and 0.75 times at the maximum bearing capacity compared to the tests, and although there was some error, the deformation angles at failure were in good agreement (Fig.10).

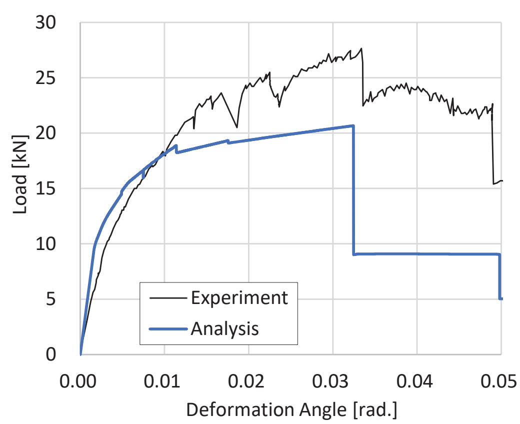

Fig. 10 Comparison between analysis and full scale test

5 – CONCLUSIONS AND RECOMMENDATIONS

The full-scale shear tests, elemental tests, and analytical investigations of diagonal lathboard walls have revealed the following;

(1) shear capacity of the diagonal lath wall [1.82*2.73m] is 25kN/m, which is relatively high among traditional wall construction methods.

(2) The shear capacity of diagonal lath wall can be estimated with about 1.6 times in the initial stiffness and 0.75 times in the maximum load, through

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numerical analysis using the shear capacity of joints obtained by elemental experiments.

(3) The effect of plaster was found to affect the initial stiffnes and bearing capacity at the initial stage of plaster failure and the major resisting element at maximum load was lath-nail joints.

(4) For the appropriate application of the analytical model to actual buildings, boundary conditions of the wall, evaluation of plaster flaking during large deformation, and buckling of the wooden laths are need to be investigated.

6 – REFERENCES

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