A Study on Structural Timber Bearing Wall with Additional Performances

Katsuhiko Kohara[1], Asuka Takahashi[2] and Mitsuo Fukumoto[2]

[1] *Lecturer, Studio of Wooden Structure, Gifu Academy of Forest Science and Culture, Japan*
[2] *Researcher, MOK Structural Design Unit Inc., Japan*
Email: kohara@forest.ac.jp

ABSTRACT :

It aims at expressing the seismic characteristics of the timber bearing wall with additional performances. Recently, our research group developed many timber bearing wall which has seismic performances and other performances. Because a bearing wall in the timber structure is one of essential seismic elements, it is developed for structural performance as a priority issue. But a timber bearing wall has a demand of performance except seismic one, because the timber structure is a sustainable structure. Therefore, we can classify a development of the shear walls under several topics.

1. Added Seismic Performance
   the shear wall with a non-shear board
2. Added Other Performances Except Seismic One
   the shear wall with a performance of a thermal insulation, a fire prevention, a fire-resistant, a sound isolation
3. Considered Environment
   the shear wall with domestic wood, thinned wood, long-span sawed wood, sapwood
   the shear wall used as manure if it will be pulled down
4. Considered Design
   the shear wall considered with concept of light-through, wind-through, space integration
5. Changed Construction
   the shear wall changed for retrofitting
6. Appropriate to Horizontal Diaphragm
   the shear wall used as horizontal diaphragm
7. Combination of the Above Topics

The static loading tests of these shear wall is carried out, and the evaluation of the seismic performances and the energy characteristics of one are calculated.
For the timber structures are able to be continued sustainable, we develop the shear walls thinking that the performances except seismic one is important.

KEYWORDS: Seismic Performance, Timber Bearing Wall, Domestic Timber

1. INTRODUCTION

In Japan, the number of timber structure residences which are built every year is more than 500000. Moreover, the 16 million houses of timber structure residences which have been built before 1981 years are un-suitable rank on present Japanese building code, so these timber houses demand a seismic retrofitting. The load bearing wall which is available for these timber structure residences is being developed in each enterprise and organization.
Because it isn't distinctive of the other load bearing wall by developing only the earthquake-proof performance in such conditions, the load bearing wall which has various characteristics and performance is developed in each enterprise and organization recently.
The purpose in this report classify about these load bearing walls.

2. SEISMIC PERFORMANCES OF TIMBER SHEAR ELEMENT

2.1. Experimental Method for Bearing Wall and Horizontal Diaphragm

An actuator, of which the load is 100 kN and the stroke is 600 mm, was installed as shown in the figure 1 in the beam height, and it went through the loading. The actuator is combined with specimen with a steel stick, of which diameter is 16 mm. The roller which prevented surface outside buckling is installed in the beam two places. A base of column part is fixed by hold-down hardware, and a vertical load-less is taken. The static load for bearing wall is made the plus and minus alternating repetition loading, and the corner of the deformation made the repetition loading of three times with 1/450, 1/300, 1/200, 1/150, 1/100, 1/75 and 1/50 radian the monotonous loading to the destruction after that. The static load for horizontal diaphragm is made the plus and minus alternating repetition loading, and the corner of the deformation made with 1/450, 1/300, 1/200, 1/150, 1/100, 1/75 and 1/50 radian the monotonous loading to the destruction after that.

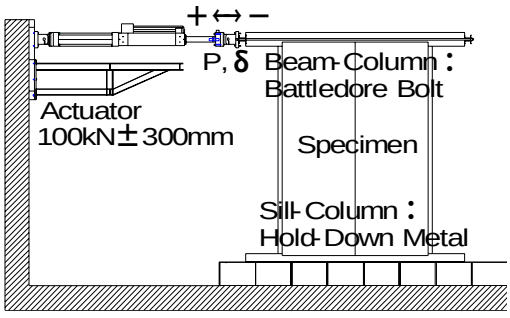


Figure 1 Outline of Static Loading Tests

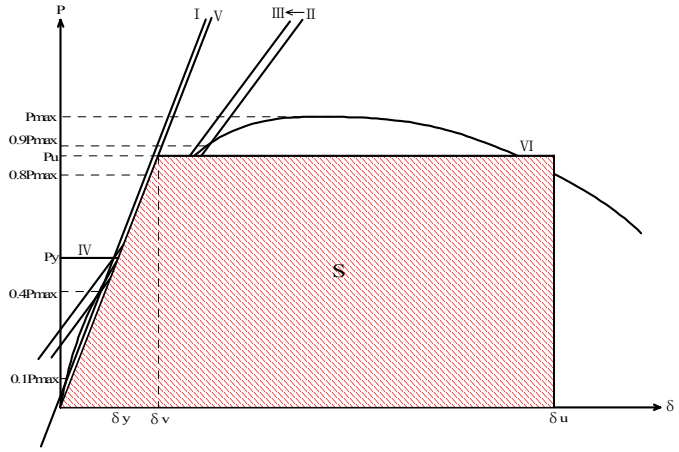


Figure 2 Yielding Proof Stress

2.2. Experimental Method for Bearing Wall and Horizontal Diaphragm

The basic shear proof stress Pa of the joint calculates in the minimum value which was sought at the yielding proof stress, at 2/3 times of the maximum proof stress, at 0.2/Ds times of the ultimate proof stress, at the stress of 1/150rad. or 1/120rad., and has considered the loose of the experimental result. It makes a loose coefficient a coefficient by 50 % of lower limits with 75 % of reliability standards. It calculates the wall magnification n of the connection by the following equation from the permission shear proof stress of wall.

$$n = Pa\ [kN] \times (1/1.96\ [kN]) (1 /L[m]) \quad (1)$$

The loose coefficient is due to the equation below.

$$\text{Loose coefficient} = 1 - (\text{standard deviation} / \text{average}) \times \text{fixed number K} \quad (2)$$

A yielding proof stress is made as following step a) - l).

a) It makes the straight line which links 0.1Pmax and 0.4Pmax on the envelope the I straight line.

b) It makes the straight line which links 0.4Pmax and 0.9Pmax on the envelope the II straight line.

d) It pushes a load in the point of intersection of the I straight line and the III straight line in yielding proof stress Py and it makes the straight line which is parallel to the X axis the IV straight line from this point.

e) It makes the displacement of the point of intersection of the IV straight line and the envelope yielding displacement δy.

f) It makes the starting point and the straight line which links (δy, Py) the V straight line and it makes this the early stage stiffness K.

g) It makes a displacement on the envelope in the 0.8Pmax load decline area after the maximum load finish displacement δu.

h) It makes the area which is surrounded at the envelope, the X axis and in δu S.

i) It makes the straight line which is parallel to the X axis as the area with the trapezoid which is surrounded by

the straight line which is parallel to the V straight line, the X axis, δu and the X axis becomes equal to S the VI straight line.
j) It makes the point of intersection of the V straight line and the VI straight line the finish proof stress Pu of the full bullet plasticity model and it makes a displacement then the yield point displacement δv of the full bullet plasticity model.
k) It makes plastic percentage (the ductility percentage) μ=(δu/δv).
l) Structure characteristic coefficient Ds uses plastic percentage μ and makes Ds=1/√(2μ-1).

3. CLASSIFICATION OF TIMBER SHEAR ELEMENT

3.1.Classification by Opening Rate and Materials

Timber shear elements are classified several points by an opening rate, a material, a structural member or an applicable building. A bearing wall doesn't have usually an opening except by the constructing equipment in Japan. But a timber grid shear wall or a timber portal frame has an opening rate as the concept of light-through, wind-through, and space integration. Recently, a bearing wall is made by timber materials or such other materials as sidings, metals, minerals, or glass fiber reinforced plastics.

3.2. Added Performances for Sustainable

There is a bearing wall with a finishing board added seismic performance. If a non-shear board can be used a shear element, it is not wastefulness with materials. In the opposite side, there is a bearing wall which is added other performances except seismic performance. The performance is a thermal insulation, fire prevention, a fire resistance, or a sound isolation. If a bearing wall has the other performance, it is not wastefulness with materials.
There is a bearing wall considered an environment with a special timber which is used more sustainable than common timber. The special timber is made from domestic woods, thinned woods, sapwoods, or long-span sawed woods. The domestic woods mean that the woods have been produced on a forest in the local area. The thinned woods mean that the woods have been thinned out within a given period of time on an artificial forest. The long-period sawed woods mean that the woods have been thinned out over a given period of time on an artificial forest. And there is a bearing wall with mineral elements which is able to use as manure after the building pulled down
Other bearing wall added performances for sustainable is the followings. There is a bearing wall be changed construction specification for retrofitting from for new building. There is a bearing wall be appropriated to horizontal diaphragm.
The above performances for sustainable are combined usually.

4. SHEAR ELEMENT OF ZERO OPENING RATES

4.1.Shear Element Made from Timber

There are many bearing walls made from timber with zero opening rates. The bearing walls made from domestic woods, thinned woods, or sapwoods with consideration to an environment. The section of these woods is smaller than a section of common sawed woods. Therefore, It is necessary that a newly-devised using of these woods is developed. Therefore, it is necessary that a newly-devised using of these woods is developed with consideration to an environment.
That is less wasteful energy to reduce energy for transport by using some domestic woods and to reuse some scraped thinned woods or sapwoods. These bearing walls are shown in the figure 1. The small-sectioned thinned woods are piled or to glued for making a wall.
The three-layered cross panel bearing walls are shown in the figure 3. The effective wall length ratio of these bearing walls which are different each specification is 3.28 or 6.10 on the experiment and 2.5 of the authorized value by The Ministry of Land, Infrastructure, Transport and Tourism. The three-layered cross panel system of these bearing walls can be applied to horizontal diaphragm. The effective floor magnification is 4.55 on the experiment. These bearing walls and the horizontal diaphragm are developed for fire proof performance. It

is necessary that a system or a material can be applied to several structural elements with consideration to an environment.

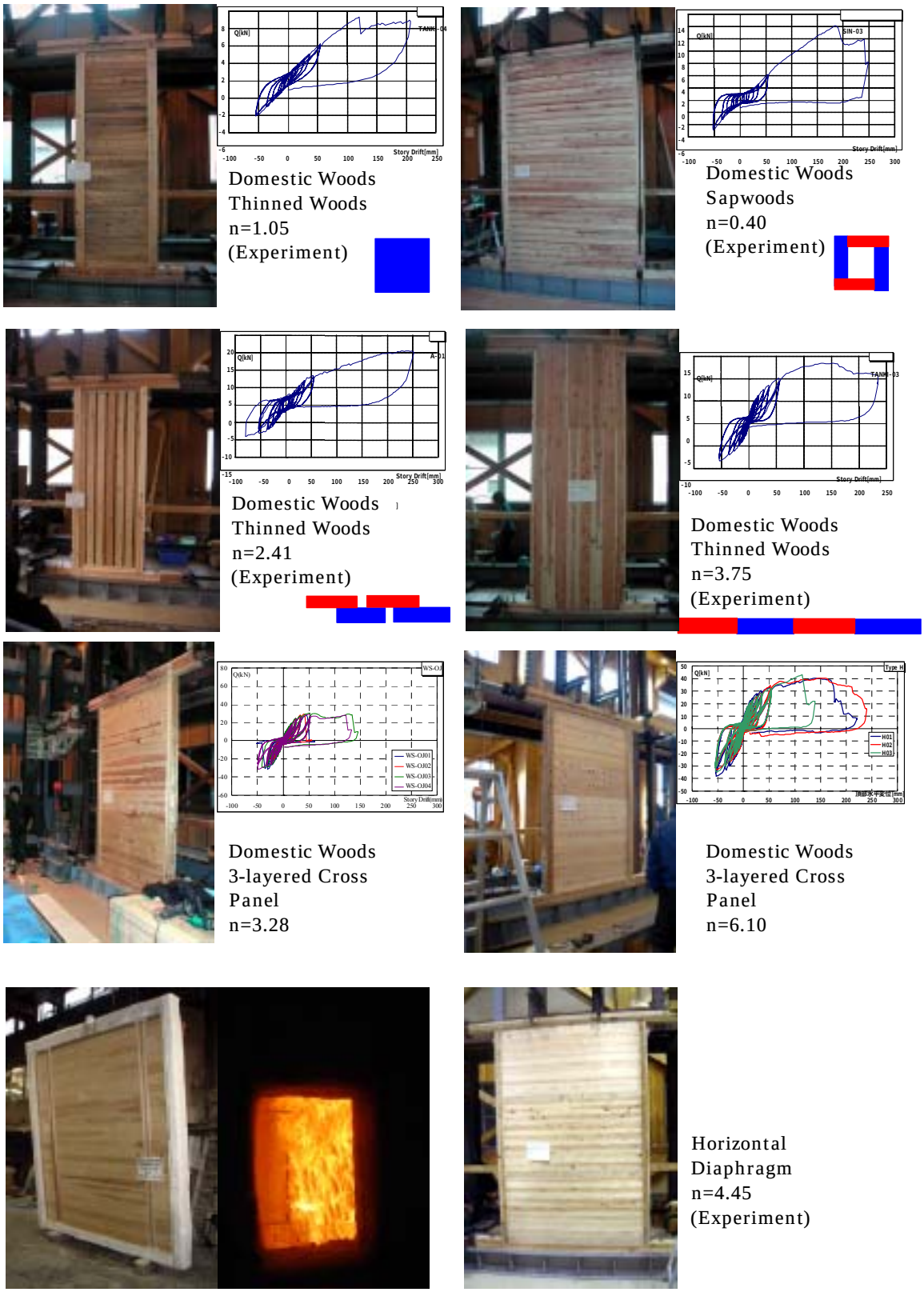


Figure 3 Bearing Wall and Horizontal Diaphragm Made from Timber

4.2.Shear Element Made from Siding Board, Metal Board, or Mineral Board

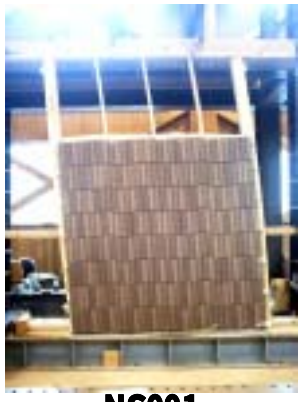
There are many bearing walls made from other material with opening rates. They are shown in the figure 4. Originally, they are used only a finishing material in Japan. Therefore, a seismic performance on the experiment is added the performances of them.

One of them is made from siding boards which have been fire proof performance. The effective wall length ratio of this bearing wall is authorized 2.6 by The Ministry of Land, Infrastructure, Transport and Tourism. And the siding board bearing wall have been developing to be applied a retrofitting with low cost for existent buildings

One of them is made from metal boards which have been fire proof performance and thermal insulation performance. The effective wall length ratio of this bearing wall is authorized 3.2 by The Ministry of Land, Infrastructure, Transport and Tourism.

One of them is made from mineral boards which became to a fertilizer after the building pulled down. The effective wall length ratio of this bearing wall is 4.49 on the experiment.

Siding Board
Fire Proof
n=2.60
(Authorized)



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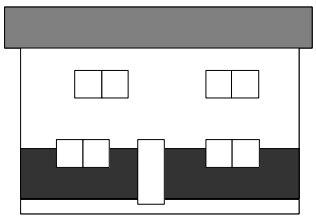
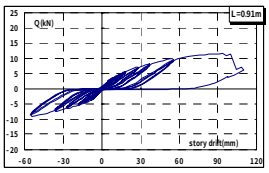


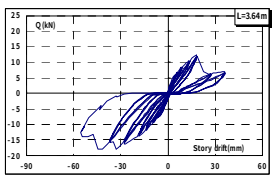
Siding Board
For Retrofitting
n=1.3 - 2.3
(Experiment)

Mineral Board
Fertilizer
n=4.49
(Experiment)

Metal Board
Fire Proof
Thermal Insulation
n=3.20
(Authorised)



Stainless brace
(H=2.73,L=0.91)
n=2.38/m
(Experiment)



Stainless brace
(H=2.73,L=3.64)
n=1.12/m
(Experiment)

Figure 4 Bearing Wall Made from other materials

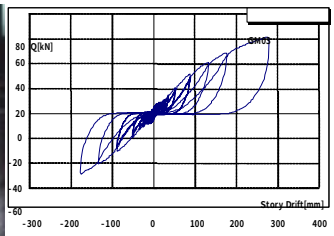
5. SHEAR ELEMENT OF HALF OPENING RATE

5.1. Shear Element Made from Timber

We have developed some bearing walls with half opening rates. The bearing walls have concepts of light-through, wind-through, and space integration. The timber grid shear wall use thinned woods in the part of grid members. Because a timber grid shear wall has originally low stiffness and high strength, it is necessary that the initial stiffness of timber grid shear wall is raise for high seismic performance. Therefore, we make reinforcement for stiffness at the joints of framework or the space between the lattices. The glass boards or the timber blocks are used for stiffness reinforcement at the space between the lattices. The four cotter pins are used for stiffness reinforcement at the all joints of framework. The effective wall length ratio of these bearing walls is 2.37 - 4.91 on the experiment.

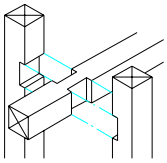
5.2. Shear Element Made from GFRP

In the meanwhile, we have developed a bearing wall applied for a glass fiber reinforced plastic grating with half opening rates. A glass fiber reinforced plastic has high process. The effective wall length ratio of this bearing wall is authorized 2.50 by The Ministry of Land, Infrastructure, Transport and Tourism.



Timber Grid Shear Wall with Glass Board
n=2.37

Timber Grid Shear Wall with Timber Brock
n=4.91
(Experiment)



Timber Grid Shear Wall with 4 Cotter Pins
n=3.32

GFRP Grating
n=2.50
(Authorised)

Figure 5 Bearing Wall of Half Opening Rate

6. SHEAR ELEMENT OF FULL OPENING RATE

6.1. Sear Element Made from Timber

The shear element of full opening rates is a portal frame which is shown in the figure 6. These frames are used domestic woods and the long-period sawed woods which have a large section. In Japan, many timbers become to be able to get from long-period sawed woods with a large section and we have to use them. The

degree of freedom on a planning is high, because the portal frame is available to make a large room without some bearing walls. The effective wall length ratio of this bearing wall is 2.15 – 4.50 of a frame on the experiment.

Portal Frame
n=2.15/Frame
(Experiment)

Portal Frame
with Fixed Foot Base
For Retrofitting
n=3.72/Frame
(Experiment)

Portal Frame
with Hammer Nut - Bolt
n=3.10 - 4.50/Frame

Figure 6 Portal Frame – Shear Element of Full Opening Rate

7. CONCLUSIONS

Many bearing walls are developed to have several performances and several concepts. Mainly concept is consideration of an environment. The bearing walls which have several theme are available for the right member in the right place.

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