A Study on Evaluation of Seismic Performances of Retrofitting with Siding Board for Existing Timber Buildings

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ABSTRACT :

It aims to mention about the various examinations to use an exterior siding material as a retrofitting method of construction of the existent buildings. The retrofitting methods of construction of 2 case are proposed. In the Case 1 method, the siding is changed of the existent wall of the range (about 2.0m) that a part reaches ground floor. In this case, a foothold cost can be reduced. In the Case 2 method, a thickness siding (t= 24 mm) is raised even on the beam. In this case, it works for the improvement in the seismic performance and the fireproof performance. Because a proof stress element and finishing can be included, a restructuring cost can be reduced. And an amount of money assumption is made in the precision which it has in advance in the foundation of the reinforcement part as well because it can be confirmed. Finishing can plan the improvement which sometimes has more than one variation by adding a color pattern in result fine sight as well, too. It can think that execution becomes possible with being here confidently because it is the outside construction. The static loading test is enforced all 26 specimens. In the Case 1, NS001 (width 455 mm, t=18mm) has 2.4 of the wall magnification, NS003 (width 910 mm, 2 sheets-folds of t=12mm) has 3.6, the type (NS010, NS011 and NS013) which drip reinforcement have 3.4 - 4.5. In the Case 2, NS009 (width 910 mm, 2 sheets-folds of t= 12 mm) and NS026 (width 910 mm, t=16mm) have 12.0 of the wall magnification, NS008 (width 455 mm, t=18mm) and NS025 (width 455 mm, t=24mm) have about 4.8 - 5.5. And a narrow house is applied the Case 1 siding in the case study. The case study give to be able to retrofitting of narrow house by siding boards.

KEYWORDS: Seismic Performance, Retrofitting, Siding Board, Bearing Wall

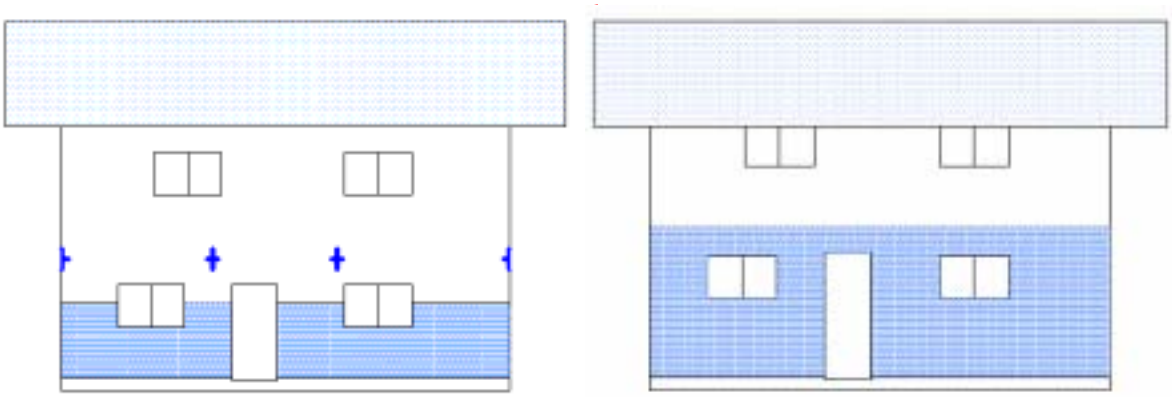
1. INTRODUCTION

In Japan, 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.
Mainly there are many plane materials of ground work in the retrofitting method in case of internal retrofitting. Therefore, the construction steps are the followings; the first step is the removing to existent walls, the second step is the setting to plane materials, and the third step is the refinishing on wall, ceiling and floor. The high restructuring cost is necessary in this case. Such a thing which isn't good in design as well grows easily by the partial improvement. The grasping of the conditions in advance such as foundation and ground sill is difficult in case of internal retrofitting. Because it is difficult that the estimate cost can be assumption in advance, the people are not able to decide on executing the retrofitting. Even when it can be constructed on internal retrofitting, some carpenters may be taken in the room, and the movement of the furniture may be necessary. Therefore the people feel a resistance in mentality.
Because a seismic element and finishing can be included on the retrofitting method which is used an exterior siding board, a restructuring cost can be reduced, and a total cost reduction can be planned. Because the foundation and ground sill of the retrofitting part can be confirmed, an estimate cost can be assumption. The finishing can plan the improvement which has many collar and pattern variations in fine sight. The retrofitting execution becomes possible with living confidently because it is the outside construction.

2. RETROFITTING METHODS

2.1. Outline of Retrofitting Methods

It is a retrofitting method for two cases as shown in the figure 1. The case1 is reinforced by the exchange of a part of the existent wall. The reinforcement part of two meter on first floor level is able to reach by carpenter. This case can reduce a foothold cost. The case2 is reinforced by the exchange of first story part of the existent wall with a special siding which has a thickness of 24mm. This case works for the improvement in the seismic performance and the fireproof performance.



Case1 Foothold-less Reinforcement Cace2 High Standard Reinforcement

Figure 1 Retrofitting Methods

2.2 Outline of Case1's Retrofitting Methods

The outline, the section and the flow chart of case1's retrofitting are shown figure 2 - 4. Firstly, the existent wall is cut a part of about 2m height from first floor level. Secondly, the rust of anchor bolts and hold-down metal and the deterioration of ground sill are checked for necessary to replace new member. Thirdly, the ground works of the building paper, the ceiling and furring strips are set on timber frame. Finally, the siding boards are set on timber frame, and the reinforcement metal fittings are set on the boards.

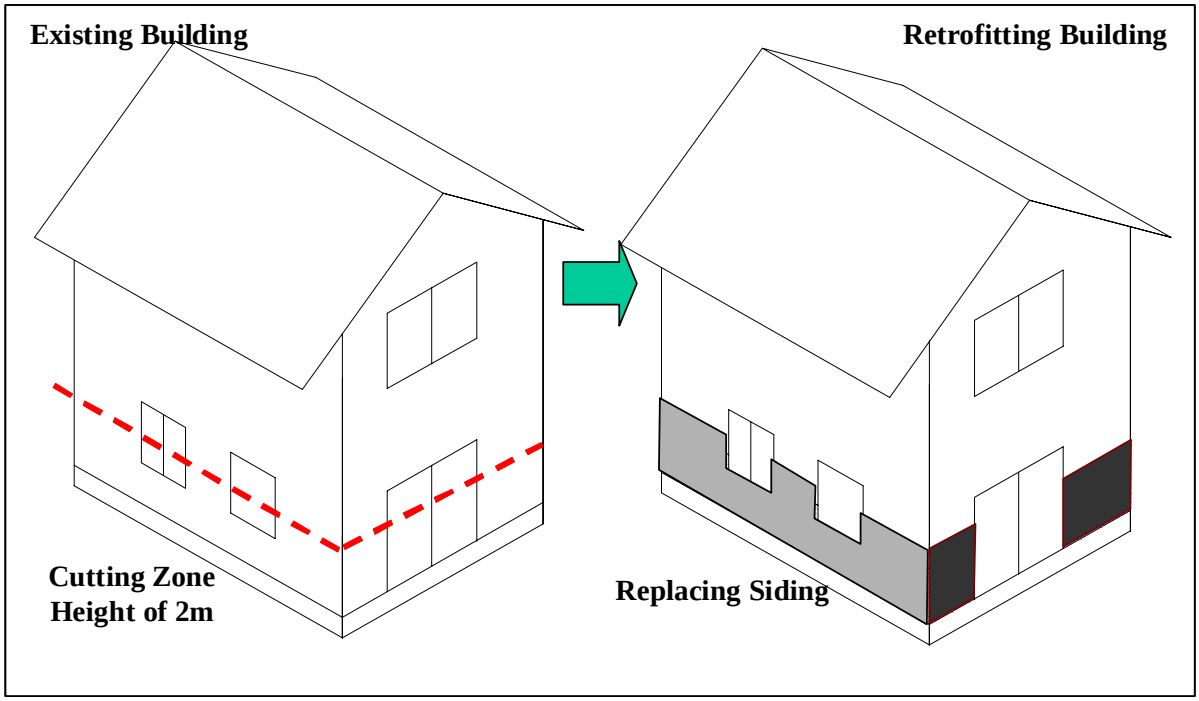


Fig. 2 Outline of Retrofitting Methods in Case1

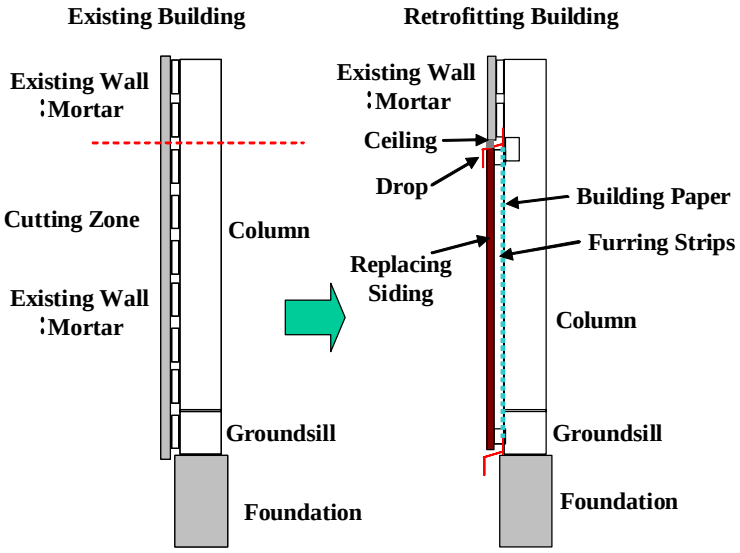


Figure 3 Section of Wall

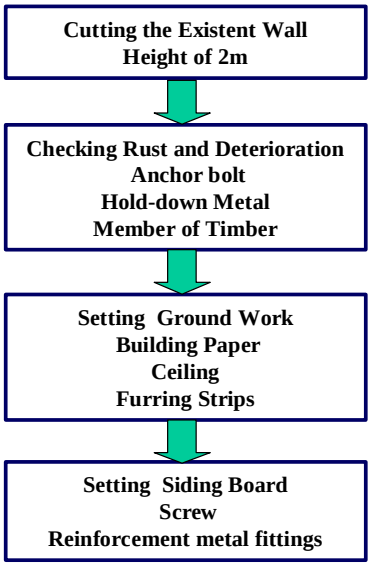


Figure 4 Flow Chart of Retrofitting

2.3 Outline of Case2's Retrofitting Methods

The outline of case2's retrofitting method is basically same on case1, except for the existent wall is cut a part of first story part and the special siding board are used. The thickness of the special siding board is 24mm, and the thickness of normal siding board is 15mm. Fire resistance test in the miniature fire-resisting fireplace was carried out about siding's board as a preliminary examination of the fireproof performance of special siding board on Case2. It could confirm that the special siding board's back-side temperature rise was more slowly than the normal siding board's.

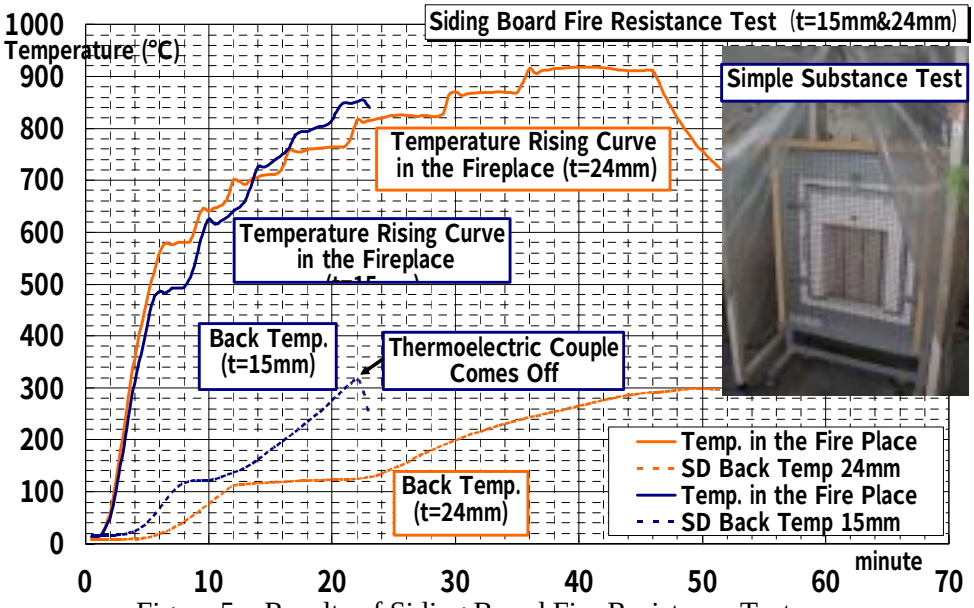


Figure 5 Results of Siding Board Fire Resistance Test

3. STATIC LOADING TESTS

3.1 Specification of Specimens

The static loading tests are executed twenty-six specimens. The Nine specimens of would be mentioned in this report. It is shown about the specifications of each specimen in the table 1. The width of the wall frame

is 1820 mm, and the height is 2730 mm.
The five specimens who are presumed as case1 make the siding on the height of 1800 mm from the ground sill. It is presumed that there is an existent mortars wall and so on for the upper side of this 1800 height. Therefore, it is nothing for this part in these tests, because an assumption of an existent mortar's strength after the deterioration was difficult concerning that durability. Some of the specimens are only used siding boards in type1 - case1. Because the bending destruction of the column in siding top end part is presumed in type2 - case1, the other specimens have the structural drip which is installed in the boundary of the existent mortars and the new siding.
The four specimens who are presumed as case2 make the siding on the top of beam from the ground sill. In this case2, these specimens use the special siding boards.
The thickness of siding boards is 24mm, 18mm, 16mm or two sheets-folds of 12mm. The width of them is 455mm or 910mm. The way to spread is the vertical or the horizontal direction

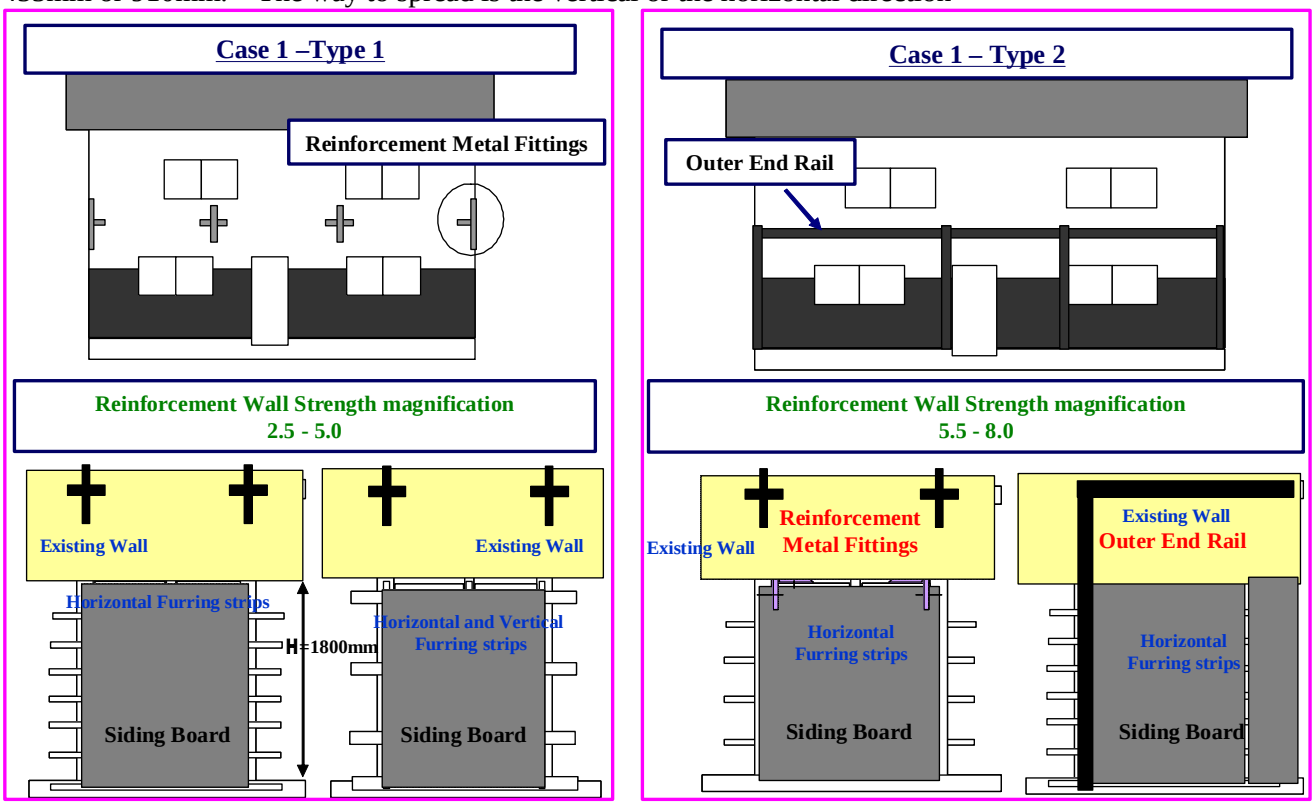


Figure 6 Two-type Retrofitting methods in Case 1

Table 1 Outline of Specimens

NO.		Case	Type	Siding Thickness	Siding Width	Siding Length	Setting Direction	Kind of Siding and Way to Setting	Reinforcement Specifications
1	NS001	1	1	18mm	455mm	1820mm	Vertical	Horizontal Furring Strips @303mm, Coach Screw D=4.5 L=65	---
3	NS003	1	1	12mm x 2	910mm	1820mm	Vertical	Coach Screw D=4.5 L=65, Perimeter@150mm, Inside@200mm	---
8	NS008	2	---	18mm	455mm	1820mm	Horizontal	Setting Siding Board to Top of the Beam Vertical Furring Strip, Coach Screw D=4.5 L=65	---
9	NS009	2	---	12mm x 2	910mm	1820mm	Vertical	Setting Siding Board to Top of the Beam Coach Screw D=4.5 L=65, Perimeter@150mm, Inside@200mm	---
10	NS010	1	2	12mm x 2	455mm	1820mm	Vertical	Coach Screw D=4.5 L=65	C Shape Steel as Drop
11	NS011	1	2	18mm	455mm	1820mm	Vertical	Coach Screw D=4.5 L=65	Triangle Reinforcement Member as Drop
13	NS013	1	2	18mm	455mm	1820mm	Vertical	Coach Screw D=4.5 L=65	Reinforcement Drop
25	NS025	2	---	24mm	455mm	1820mm	Vertical	Setting Siding Board to Top of the Beam Vertical Frring Strip by Plywood @303mm, Coach Screw D=5.0 L=50	---
26	NS026	2	---	16mm	910mm	1820mm	Vertical	Setting Siding Board to Top of the Beam Coach Screw D=5.0 L=50, Perimeter@150mm, Inside@200mm	---

3.2 Way of Static Loading Test

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 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.

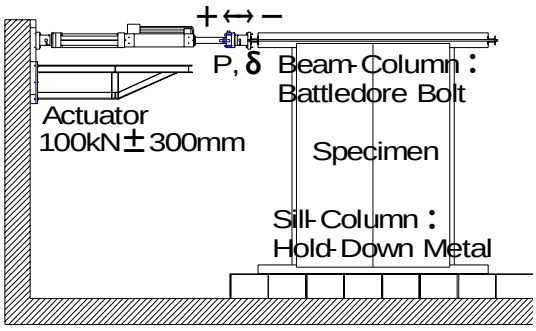


Figure 7 Outline of Static Loading Tests

3.3 Destruction Overview

The destruction overview of the specimen is shown in the figure 8. The destruction overview is the following; the crack of siding board's end part, the chip of siding board, the punching shear of the screw, an opening of siding board to front side, the crack of the column in siding board's top end and furring strips junction, the bending destruction of the stud in siding board's top end part, the bending destruction of the column in siding board's top end furring strips junction, the disconnection of the drip reinforcement hardware.

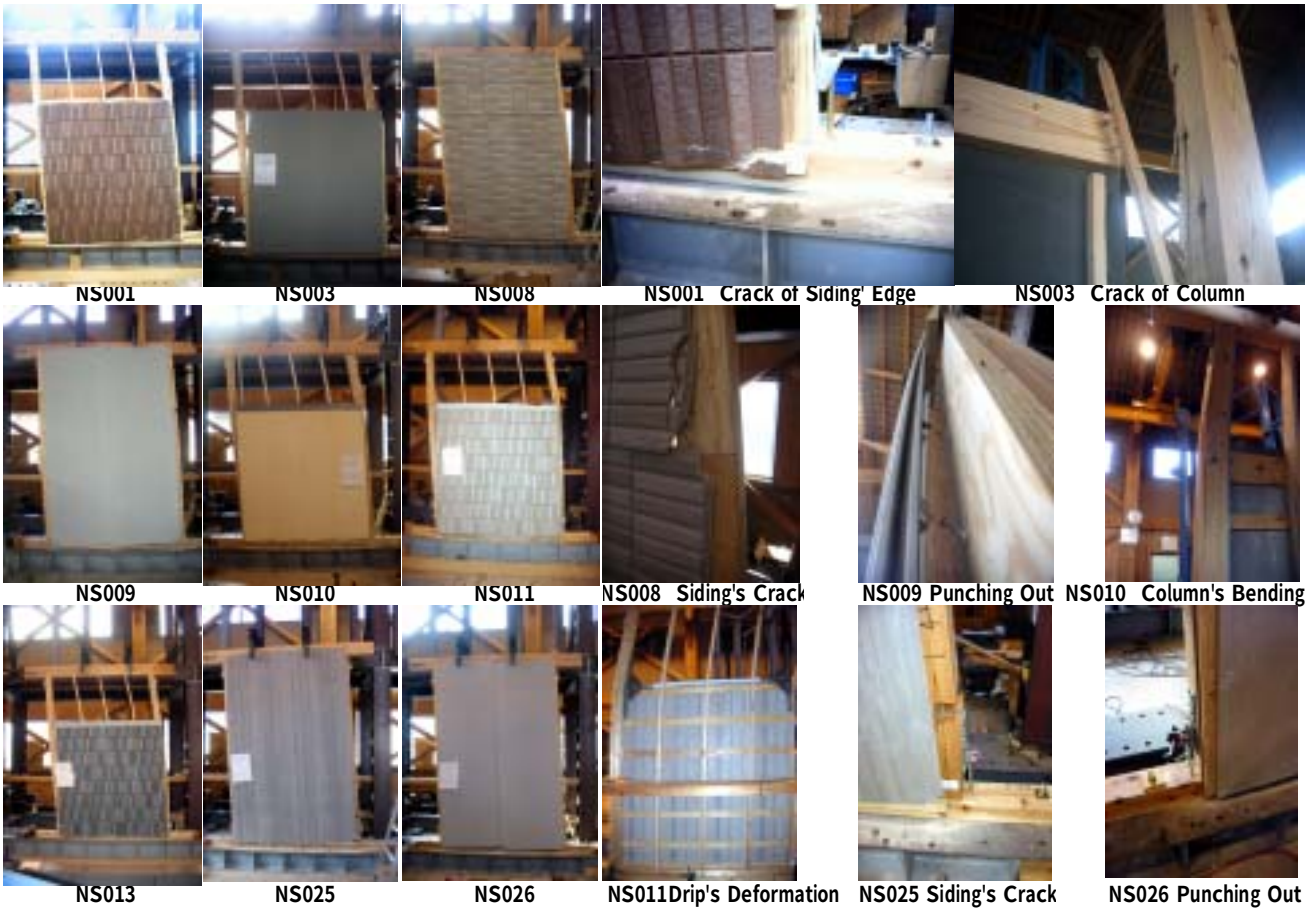


Figure 8 Destruction Overview

3.4 Load –Story Drift Curve

In the type1 - case1, the maximum strength is 11 - 14kN with NS001 specimen (width 455mm, t= 18mm) and NS003 specimen (width 910mm, 2 sheets-folds of t= 12mm).

In the type2 – case1, the maximum strength is 14 - 20kN with NS010, NS011 and NS013 specimens which have drip reinforcement.
In the case2, the maximum strength is more over 40kN with NS009 specimen (width 910mm, two sheets-folds of t= 12mm) and NS026 specimen (width 910mm, t= 16mm). The maximum strength is about 20kN with NS008 specimen (width 455mm, t= 18mm) and NS025 specimen (width 455mm, t= 24mm).

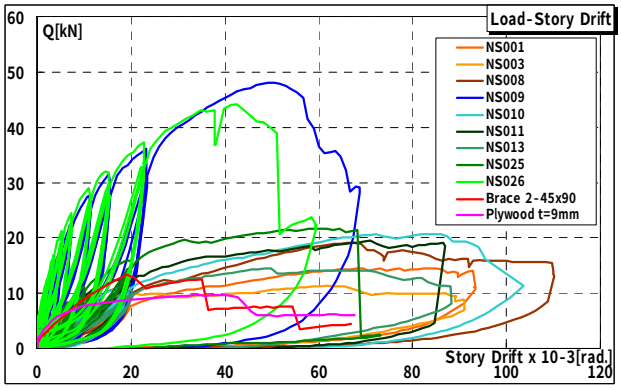


Fig. 9 Load-Story Drift Curves on Each Specimen

3.5 Reinforcement Wall Strength Magnification

The short-term allowable standard strength is estimated from the minimum value of 2/3Pmax, Py, P1/120 or 0.2xPu/Ds. A structure characteristic coefficient, an effective wall strength ratio and a reinforcement wall strength magnification are shown in the table 2. And, the decision factor of the effective wall strength ratio is 0.2xPu/Ds, Py or P1/120. A dispersion coefficient and a decrease coefficient aren't taken into consideration.
In the type1 - case1, the reinforcement wall strength magnification is 2.4 with NS001 specimen (width 455mm, t= 18mm) and 3.6 with NS003 specimen (width 910mm, 2 sheets-folds of t= 12mm).
In the type2 - case1, the reinforcement wall strength magnification is 3.4 - 4.5 with NS010, NS011 and NS013 specimens which have drip reinforcement.

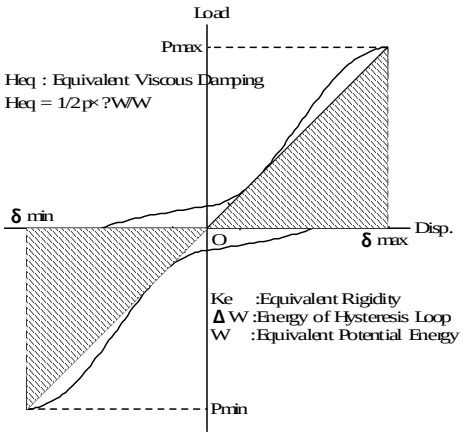
Table 2 Results of Static Loading Tests

	NO.	Reinforcement Wall Strength Magnification	Pmax	2/3Pmax	Py	1/120P	Pu*0.2/Ds	Ds	Effective Wall Length Ratio
1	NS001	2.4	14.4	9.6	7.7	4.7	4.5	0.59	1.3
3	NS003	3.6	11.4	7.6	5.5	6.3	6.7	0.30	1.5
8	NS008	4.8	19.2	12.8	9.0	9.1	8.8	0.34	2.5
9	NS009	12.0	48.1	32.1	25.5	26.3	22.0	0.37	6.2
10	NS010	3.8	20.0	13.4	10.1	7.0	7.1	0.47	2.0
11	NS011	4.5	18.9	12.6	10.9	8.5	8.3	0.40	2.3
13	NS013	3.4	14.5	9.7	8.5	6.2	6.2	0.43	1.7
25	NS025	5.5	21.7	14.5	11.8	9.8	10.0	0.40	2.8
26	NS026	12.1	36.3	24.2	24.8	27.9	22.1	0.36	6.2

In the case2, the reinforcement wall strength magnification is about 12.0 with NS009 specimen (width 910mm, two sheets-folds of t= 12mm) and NS026 specimen (width 910mm, t= 16mm). The reinforcement wall strength magnification is 4.8 - 5.5 with NS008 specimen (width 455mm, t= 18mm) and NS025 specimen (width 455mm, t= 24mm).

3.6 Energy Characteristics

An equivalent viscous damping ratio (Heq) , an equivalent rigidity (Ke) and a hysteresis loop energy (Eh) are shown in the figure 10 - 11. When it exceed 1/100 radian, Heq is about 0.06～0.15.
Ke and Eh with NS009 specimen and NS026 specimen (width 910mm, it is extended to the beam.) are higher than Ke and Eh of the other specimen.



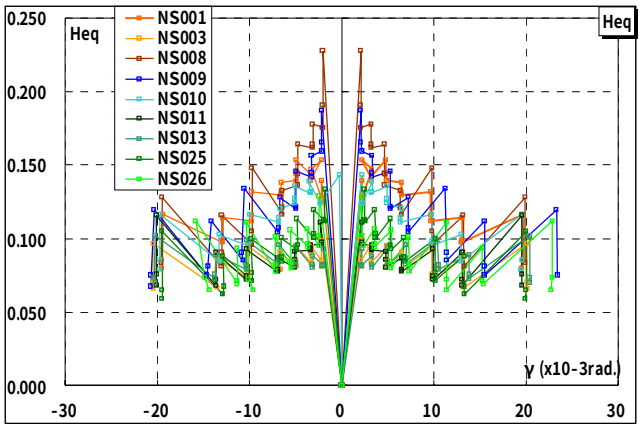


Fig.10 Definition and Experimental Results of Energy Characteristics

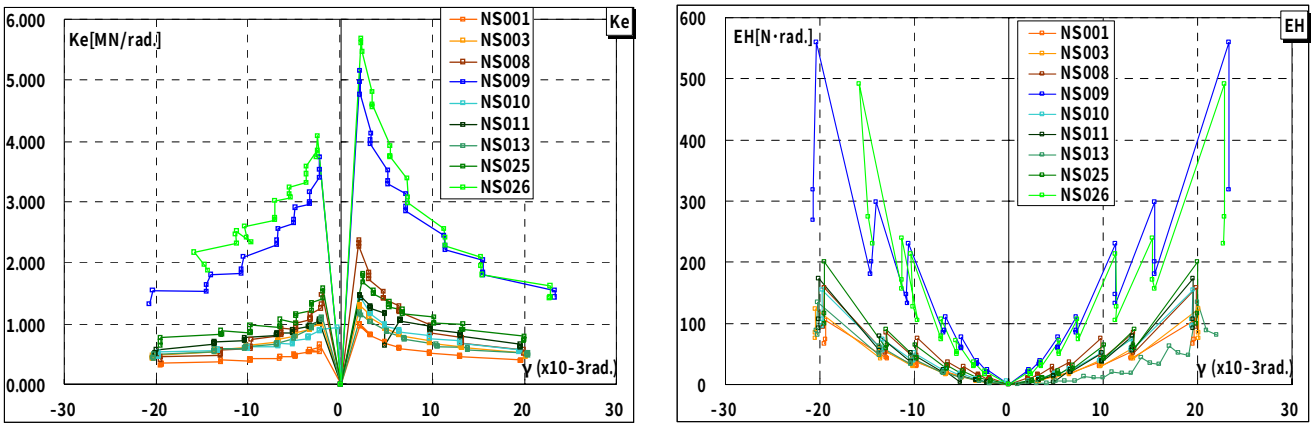


Fig.11 Experimental Results of Energy Characteristics

4. CASE STUDY

In Japan, there are many narrow houses which like a figure 12. The narrow houses are insufficient seismic performance and are lived a low income earner, generally. We have to retrofit these houses with lower cost for the retrofitting. Therefore, a case study of retrofitting for narrow house is executed.

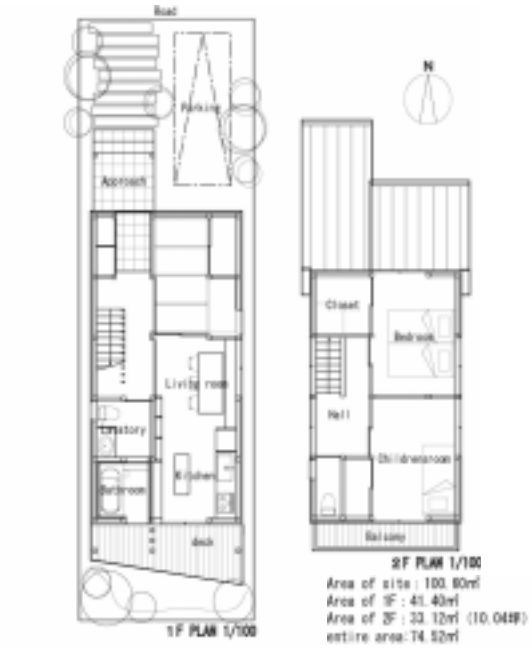
In the real plan, seismic performance is calculated. After that, a retrofitting plan is calculated the seismic performance. It is confirmed that a retrofitting plan has sufficient seismic performance and costs about 8000 dollars.

Before Rertofit

Floor	Direction	Points in evaluation of timber	Judgment
2	NS	0.88	There is a possibility of collapsing.
	EW	0.83	There is a possibility of collapsing.
1	NS	1.03	The possibility of collapsing is high.
	EW	2.19	The possibility of collapsing is low.

After Retrofit

Floor	Direction	Points in evaluation of timber	Judgment
2	NS	0.88	There is a possibility of collapsing.
	EW	0.83	There is a possibility of collapsing.
1	NS	1.03	The possibility of collapsing is low.
	EW	2.19	There is no possibility of collapsing.



■Trial calculation result of cost

Area that reinforcement targeted：38m^2

Part that reinforcement targeted：1F,The lower side of the outside wall

	Item	Amount(m^2)	Unit price(Yen)	Amount of money(Yen)
1	Dismantlement expense	38	\2,000	\76,000
2	Cost of metal for reinforcement	-	\100,000	\100,000
3	Rail	38	\2,500	\114,000
4	Siding	38	\14,000	\532,000
Total amount of money				\803,000

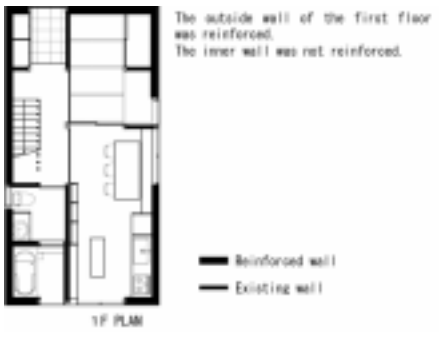


Fig.12 Retrofit for Narrow House

5. CONCLUSIONS

The difference of the width 455mm and 910mm can be confirmed on the structural properties. The effect of the drip reinforcement can be confirmed on the structural properties. The difference of the 1800mm high and the top of beam with siding board can be confirmed on the structural properties. Destruction mode, the one related to the load-displacement and reinforcement wall strength magnification could be confirmed.

ACKNOWLEDGEMENTS

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