A Development of the Damper Device which used High Damping Rubber to Install in Joints for Wooden Houses

Tomoki FURUTA[1], Satoshi KANAMORI[2] and Masato NAKAO[3]

[1] *Manager, Engineering Department, Civil Engineering & Construction Products Division, Bando Chemical Industries, ltd. Hyogo, Japan*
[2] *Damping & Isolation Department. KOKANKYO Engineering Corporation, Kanagawa, Japan*
[3] *Research Associate, Faculty of Engineering, Yokohama National University, Yokohama, Japan*
Email: tomoki.furuta@bando.co.jp, kanamori@gmail.com, mnakao@ynu.ac.jp

ABSTRACT :

The damper device that is used high damping rubber to install in joints for wooden house (It is called the damper device at below) developed by us. The cost of manufacturing the damper devices is low and the mechanism is simple for the wooden house. When making this damper device, the laminated structure which established on a normal joint metal and inserted high damping rubber between the part of the steel plate and making the foundation side fixed settlement, a column revolves by vibration, and when it can be pulled out, high damping rubber transforms a shearing revolution, and oscillation energy is absorbed. In this paper, it is showed the performance evaluation result and the seismic response result of the damper device.

KEYWORDS: Wooden Houses, Construction of Controlled Building, Connecting Metal Material, High Damping Rubber, Framework Structure, Seismic Response Analysis

1. INTRODUCTION

Whenever earthquakes more than seismic intensity around 6 occur, much wooden houses are partially destroyed, and the complete destruction is remarkable which are damaged. But there is the diffusion rate in the very low situation so that existing devices that are a base isolation or a damping control device for wooden house is expensive. And trouble suffers from execution. In addition, by the seismic reinforcement of the existing wood house, the situation that reliability loses by image damaging by the local vicious reform company has it. Therefore, the development of the quakeproof element / part execution trouble is an unnecessary and cheap, have reliability is urgent business.
Therefore we propose the damper device that is used high damping rubber. That is simple form and cheap and, having the amount of reliability for wooden house (Framework structure in particular), in particular the joint of a pillar / the base (a beam). I apply vulcanization adhesion technology to means a damper with high damping rubber of the high durability that we developed for the base isolation rubber of the large-sized structure. In addition, this damper regards it as the shape that is available for seismic reinforcement at the time of the renewal, performance not to mention new time.
By this paper, we confirmed the performance of the damper device experimentally and, for a building used the data for, the maximum reply displacement by the earthquake response analysis.

2. OUTLINE OF THE DAMPER DEVICE

This means the damper device expected a decrement effect by the transformation so that the joint (a pillar, a beam, a pillar and a base) of the structure member transformed it at the time of vibration. In other words when I do it with the laminating structure that put high damping rubber between a part of the steel plate to show it in figure 1 (rubber and the steel plate glue vulcanization together) and did the base side with fix, high damping rubber transforms a shear turn like figure 2 when a pillar turns by vibration and can pull it up and absorbs vibration energy.

In the others, the damper device has many patterns of the forms, and thought about like L character (figure 3.), corresponded to brace (figure 4.), hall down joints (figure 5.), etc.

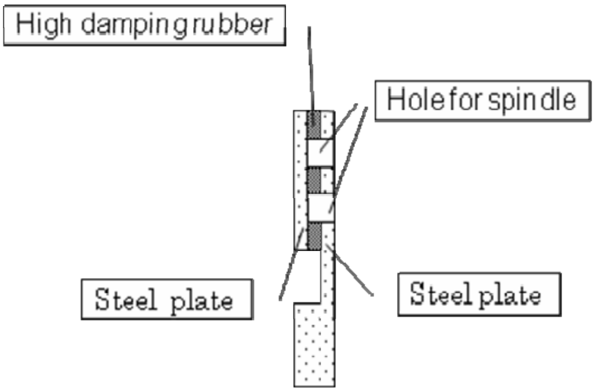


Figure 1. The damper device (T type)

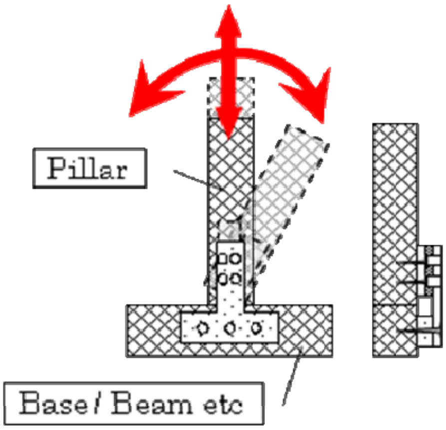


Figure 2. Moving state

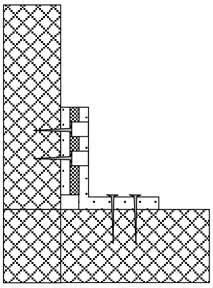


Figure 3. The damper device (L type)

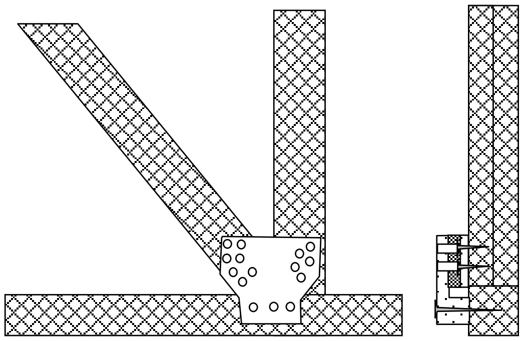


Figure 4. The damper device (Brace type)

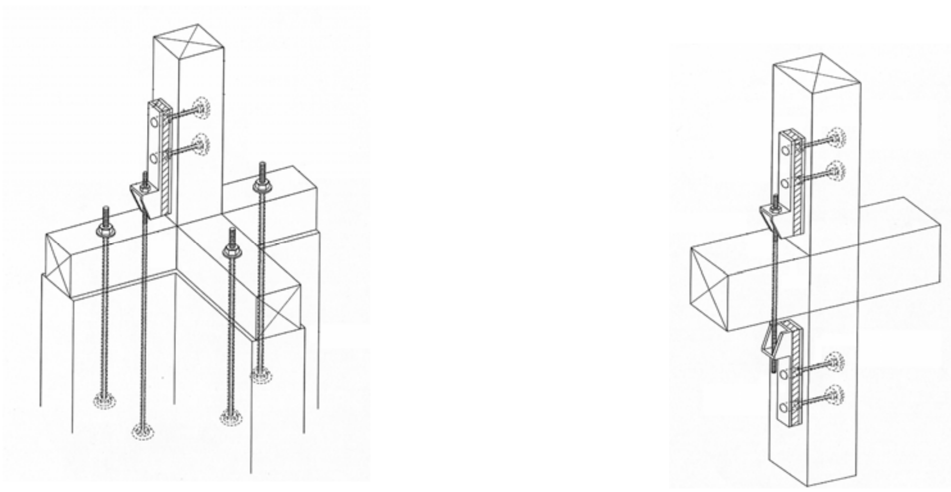


Figure 5. The damper device (Hall dawn type)

3. A BASIC PERFORMANCE TEST

3.1. Test pieces

I show the test piece which identified basic performance test in figure 6. and table 1 each. The damper device which I applied here is usually T type and two kinds of the L-form by a type to install from the top of used joining metal plate. I assumed an examination body only for existing joining hardware a standard and prepared for in total seven examination test piceces which changed four kinds which were in the shape of a rubber department. A basic characteristic of the high damping rubber which I used is just what to show it in table 2. In addition, wood which used this time is usually (class E110), is a cedar. The implication water rate at the time of the examination was an average of 14.7%.

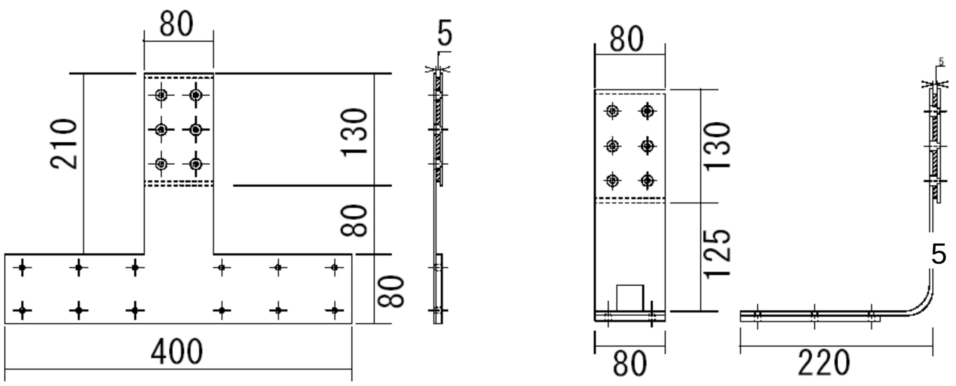


Figure 6. Form of test pieces

Table 1. Test pieces

Test piece No.	Form of steel plate	Form of rubber (mm)	Existing joint metal
No.01	—	—	CP−T／A
No.02	T type	80×80×@5	CP−T／A
No.03	T type	80×80×@16	CP−T／A
No.04	T type	80×120×@5	CP−T／A
No.05	T type	80×120×@16	CP−T／A
No.06	—	—	CP−T／L
No.07	L type	80×120×@5	CP−T／L

Table 2. Specific of high damping rubber

Material	Shear modulus G (N/mm^2)	Equivalent viscous damping factor H_{eq} (%)	The rate of Fracture increase E_b (%)
High damping rubber	0.40	23.9	Over 600

3.2. The way to test

I took out a pillar and the joining part of the base as I showed it in figure 7, and fasten a base to a reaction frame and did loading in a horizontal direction by an actuator. The loading step assumed it pillar member corner (R) =1/450, 1/300, 1/200, 1/150, 1/100, 1/75, 1/50, 1/30, 1/15 and did for each 3 cycles repetition loading. I show the loading situation in photograph 1.

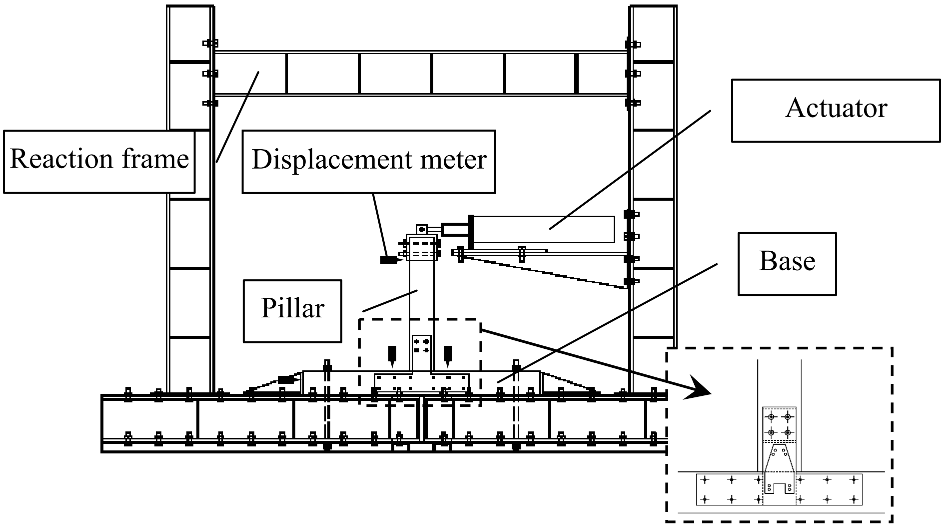
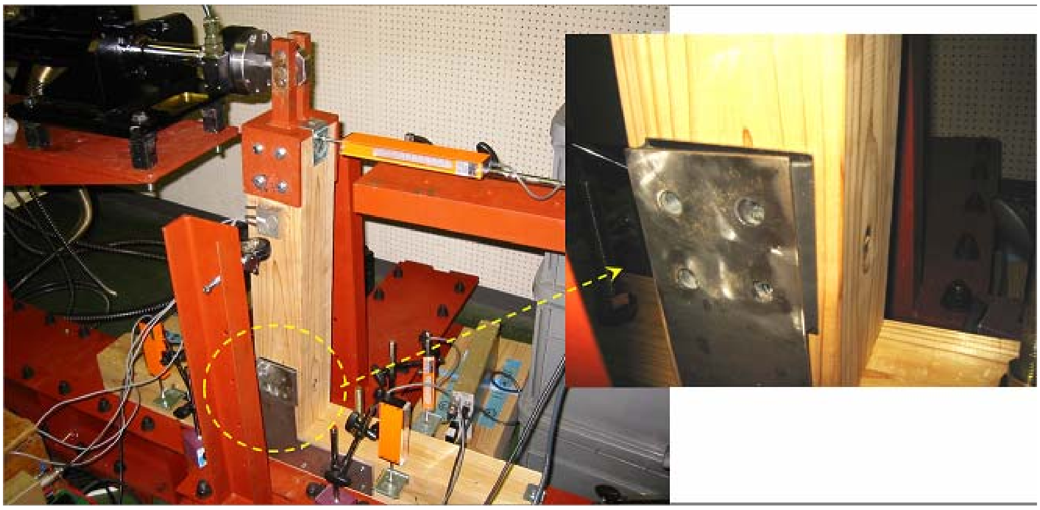


Figure 7. Figure of loading



Picture 1. The loading situation

3.3. Result of the test

I show equivalent hardness (K_{eq}) in the quantity of main displacement and quantity of damping (H_{eq}) in table 3, table 4 in figure 8 with a representative load hysteresis curve each. The hardness compared it with existing joint metal in the case of the T type and could confirm improvement more than an average of 1.45 times. In particular, prepared big at the area of the rubber department No. 04 that thinned thickness was able to confirm improvement of the hardness of 2.33 times on average. As for improvement of the hardness of No. 7 of the same shape-shaped L type compares it with 1.47 times and the T type on average, and No. 04 and a rubber department having been low, fixation degree with the base is low of the dowel depend to get away. I can confirm this tendency in the comparison of No. 01 only for existing joining joint metal and No. 06.

The quantity of damping compared it with existing joining hardware in the case of the T type and was able to confirm improvement more than an average of 1.47 times. I expected that influence of the thickness was bigger than the area of the Rubber Department, but it was not able to confirm the influence by the comparison with No. 04 and No. 05 conspicuously. This is supposed with a thing by the unevenness of the characteristic of the wood that a shear distortion is greatest, and thickness of the rubber was hard to leave influence by the thickness for γ =226% even in the case of an test pieces (No. 02, No. 04s) of @ 5mm. As for the improvement of the quantity of decrement of No. 7 of the same shape-shaped L type compares it with 1.45 times and No. 04 on average, and No. 04 and a rubber department having been low, fixation degree to the base is low like hardness of the dowel depend to get away.

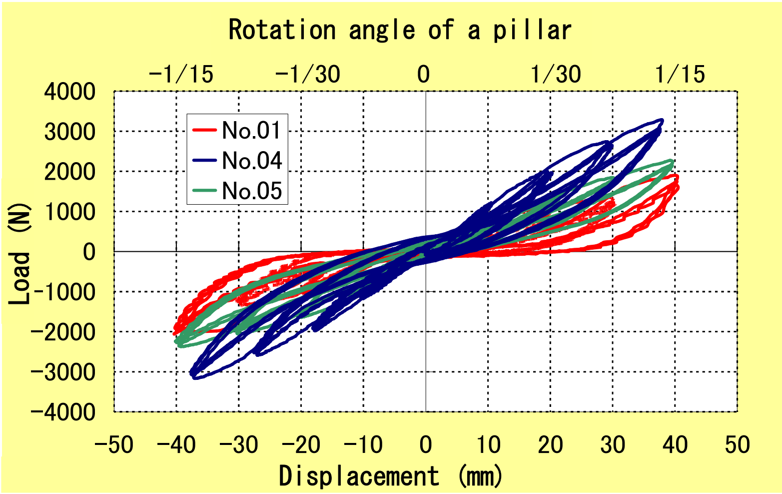


Figure 8. Load hysteresis curve

Table 3. Alteration of equivalent stiffness

Quantity of displacement		Test piece No.											
mm	R	01	02		03		04		05		06	07	
		N/mm	N/mm	02/01	N/mm	03/01	N/mm	04/01	N/mm	05/01	N/mm	N/mm	07/01
1.3	1/450	53.2	106.8	2.01	79.1	1.49	115.8	2.17	109.2	2.05	61.8	84.2	1.36
3.0	1/200	46.6	95.7	2.05	70.9	1.52	121.2	2.60	102.8	2.21	55.4	70.9	1.28
6.0	1/100	42.7	84.3	1.97	71.6	1.67	118.2	2.77	89.1	2.09	48.2	64.6	1.34
12.0	1/50	55.7	79.3	1.42	68.7	1.23	113.3	2.03	75.6	1.36	40.3	62.0	1.54
20.0	1/30	54.7	73.7	1.35	65.9	1.20	103.4	1.89	72.3	1.32	30.8	57.2	1.86
40.0	1/15	50.8	64.2	1.26	52.5	1.03	85.4	1.68	58.2	1.15	24.1	44.5	1.85
Ave.		48.1	84.5	1.65	68.8	1.45	110.7	2.33	85.3	1.80	44.0	63.3	1.47

Table 4. Alteration of amount of the damping

Quantity of displacement		Test piece No.											
mm	R	01	02		03		04		05		06	07	
		%	%	02/01	%	03/01	%	04/01	%	05/01	%	%	07/01
1.3	1/450	21.6	28.3	1.31	3.53	1.64	37.8	1.75	37.8	1.75	17.6	21.8	1.24
3.0	1/200	22.6	28.4	1.26	44.8	1.98	32.3	1.43	31.9	1.41	15.5	21.4	1.38
6.0	1/100	22.6	28.5	1.26	38.6	1.71	31.0	1.37	33.3	1.47	13.5	19.4	1.44
12.0	1/50	19.6	29.4	1.50	29.6	1.51	32.6	1.66	35.1	1.79	12.5	21.9	1.76
20.0	1/30	18.6	34.1	1.83	36.0	1.94	32.1	1.73	32.8	1.77	11.8	19.9	1.68
40.0	1/15	19.3	32.4	1.68	33.6	1.74	33.0	1.71	34.4	1.78	15.1	24.8	1.64
Ave.		21.0	30.5	1.47	37.4	1.78	33.8	1.62	34.3	1.65	14.5	20.9	1.45

4. EARTHQUAKE RESPONSE ANALYSIS

4.1. Object of a wooden house

In comparison with only the existing joint metal, equivalent hardness (K_{eq}) applied an amount of means damping rubber damper of No. 04 of table 1 that 2.33 times, quantity of damping (H_{eq}) identified an effect as a damper as 1.62 times and carried out earthquake response analysis for the building which I showed in a ground plan of figure 9. Here, the object of a wooden house referred to references 1) to intend for the wooden house of the general framework structure.

The specifications of the object building are floor spaces： the first floor 67.49m^2, the second floor 62.93m^2, weight： the first floor 122.0kN, the second floor 228.2kN (including roof load), and gross weight 410.2kN. Floor height： the first floor 2.8m, the second floor (including a roof) 3.9m. A natural frequency： 3.3Hz. The damping fixed number： it is 5.0%. All the quakeproof elements a 1P bracing wall (105mm *45mm), the quantity of obstacle sufficiency rate of the Building Standard Act is satisfied for quantity of necessary obstacle with 123.14% with the first floor XY direction, with 116.48% the second floor XY direction.

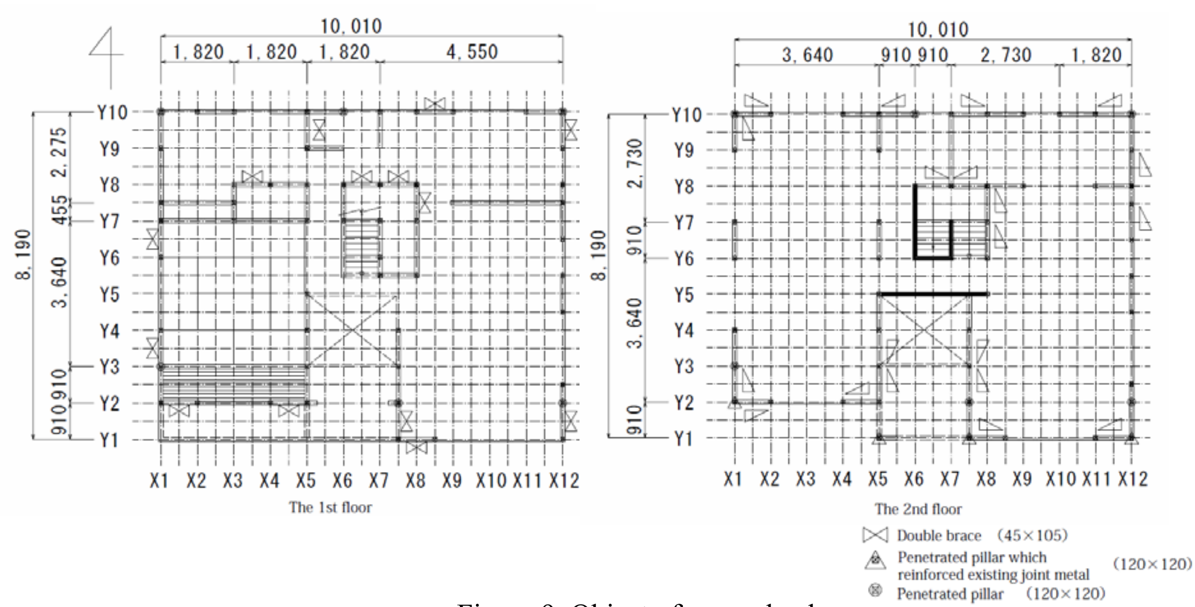


Figure 9. Object of a wooden house

4.2. Earthquake response analysis condition

The power of restitution characteristic of the object building added the horizontal force experiment result of the strut wall of references 2) into account as I showed it in figure 10. In addition, X, Y direction is equal in the stiffness of the object of the wooden house together. In addition, the power of restitution characteristic that I added the damper device to supposed a power of restitution model with origin point type based on the red curve that supposed the case that amount of means damping rubber damper two were able to possess at the brace joint of the 1P piece strut wall (wall magnification 1.0 time) of Oregon pine brace 105mm * 45mm to show it in a light blue curve of figure 11. 0.9kN/mm, the third hardness supposed that the minus number incline after a proof stress at the maximum did not occur, and the primary hardness of this the "bracing wall + the damper device" model set 2.3kN/mm, the second hardness with 0.001kN/mm. The analysis model assumes it two mass point models that assumed each floor a rigid body, the power of restitution model an "amount of bracing wall + the damper device" model the bracing wall (double brace) of each floor. I sprain wall magnification 2.0 times. A wall magnification total (the first floor wall magnification total) of wall magnification 1.0 time is 14.0; the second floor wall magnification total is 7.0).

The method of analysis used earthquake response analysis program "Cygwin" by the direct integral calculus how I used Newmark-β method for in a career at the many mass points system time. The input earthquake wave intended for Building Center of Japan simulation wave bcj-L1 (an original wave), El Centro NS (an original wave), 3 of Kobe NS (an original wave).

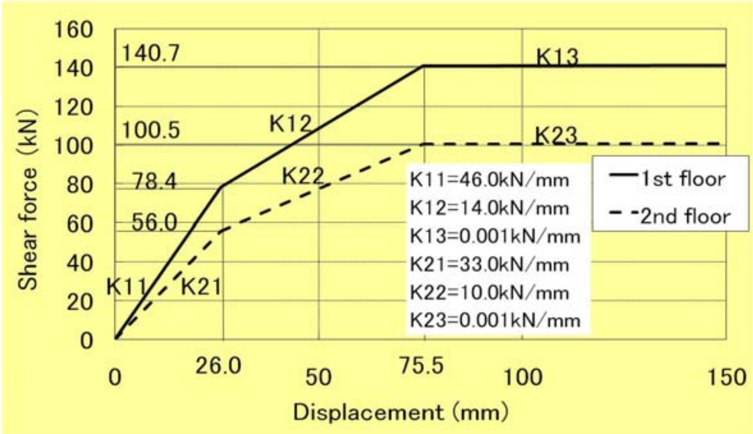


Figure 10. Object of wooden house of restring force model

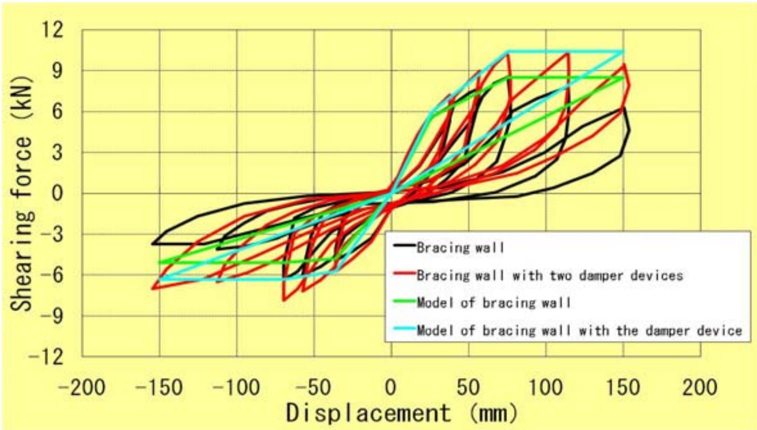


Figure 11. The damper device of restring force model

4.3. Result of Earthquake response analysis

I show a reply result every earthquake wave in table 5 in figure 12 in displacement between each hierarchies by ElCentro NS wave as a masterpiece of the earthquake response analysis result each in a career at the time. I installed the damper device in each bracing wall, and 26.8% were greatest, and, as a result of analysis, as for the reply displacement, it was reduced equivalent hardness 41.1% on average by raising it. Furthermore, as for the greatest reply acceleration, it was reduced 29.8% at 15.0%, a maximum on average by decrement power of the high damping rubber.

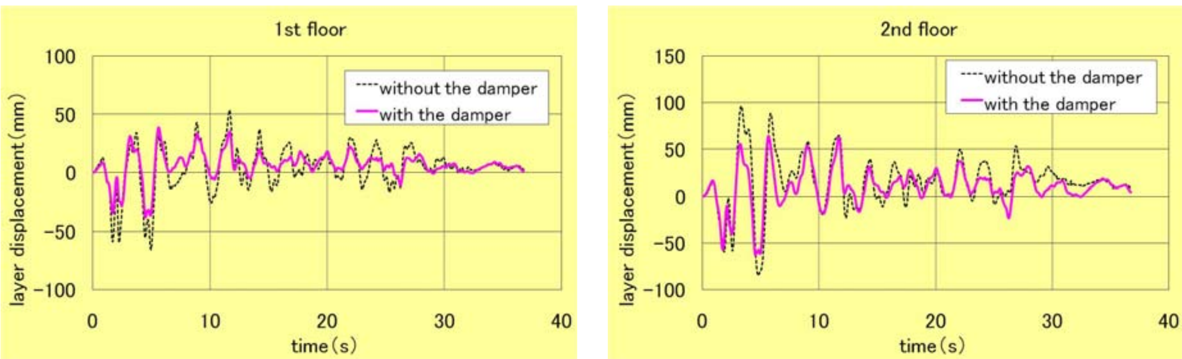


Figure 12. Displacement between each hierarchy by ElCentro NS wave

Table 5. Response result every earthquake wave

		without the damper		with the damper		decrease rate (%)	
		1st floor	2nd floor	1st floor	2nd floor	1st floor	2nd floor
ElCentro NS	Max. of the acceleration(gal)	460.7	431.5	323.2	355.9	70.2%	82.5%
	Max. of the response displacement(mm)	65.8	80.5	38.7	63.4	58.9%	78.7%
	Ratio of the layer displacement(rad)	1/43	1/48	1/72	1/62	-	-
BcjL2	Max. of the acceleration(gal)	269.1	411.4	242.7	393.1	90.2%	95.6%
	Max. of the response displacement(mm)	63.1	100.4	48.8	72.6	77.4%	72.3%
	Ratio of the layer displacement(rad)	1/44	1/39	1/57	1/54	-	-
Kobe NS	Max. of the acceleration(gal)	434.1	843.3	382.9	701.9	88.2%	83.2%
	Max. of the response displacement(mm)	59.1	61.0	46.5	44.6	78.6%	73.1%
	Ratio of the layer displacement(rad)	1/47	1/64	1/60	1/88	-	-

5. CONCLUSION

We were able to confirm that hardness, decrement improved together by adding the damper device to conventional joint metal. And maximum reply displacement, reply acceleration at the maximum confirmed what was reduced together by installing the damper device in the bracing wall by earthquake reply analysis. I pass through a frame experiment, a dynamic experiment and will push forward examination for the commodification in future.

REFERENCES

Sakata, Miyake, Hirano, Kawai, Koshihara, Minowa, Isoda (2006) The performance of the building repaired a quakeproof performance inspection experiment vol.5 , *AIJ Summaries of Technical Papers of Annual Meeting 2006.9*, 377-378

Ono, Okabe, Sakuma, Shimoyashiki (2000) The influence of the repetition number of times for horizontal force examination of the bearing wall, *AIJ Summaries of Technical Papers of Annual Meeting 2000.9*, 279-280,