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EXPERIMENTAL STUDY ON BEHAVIOR OF WOODEN FRAMES WITH BEARING WALLS SUBJECTED TO HORIZONTAL LOAD

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SUMMARY

This paper describes an experiment and its results using two-storied frames of Japanese conventional type wooden dwelling houses with bearing walls subjected to horizontal loads. The effects of layout of let-in braces and application of finishes on behavior of the frame are discussed.

INTRODUCTION

Japanese wooden dwelling houses have their origin in traditional wooden buildings, and their vertical frames consist of beams and columns. The frames have let-in braces and/or are sheathed with boards to form bearing walls. The bearing capacity of such a wall is estimated based on racking tests using an unit wall. However, the behavior of the walls placed in a frame differs from the behavior of the unit wall. Besides, the behavior of a frame with finishes is different from the bare frame.

This paper presents experimental results on the behavior of two-storied frames with bearing walls subjected to horizontal loads.

EXPERIMENT

Two sets of two-storied wooden frame with bearing walls, A and B, were constructed for the experiment as shown in Fig.1. The dimensions of the frames are 4.5m in width and 5.0m in height. The frames allow some openings. The section of a column is 10.3cm x 10.3cm. The section of a braces is 10.3cm x 3.5cm. The joints of members are fastened with nails or metal plates. The bare frame was tested at the first stage of the experiment. The sheathing members and finishes were applied one by one according to the experimental stages.

The two specimens are different with each other in the following details.
Specimen A : All columns are separated by the second floor beams. Two beams, that is, the horizontal members at the second floor level and at the roof level, are continuous ones without joint from the left end to the right end. The braces are applied as shown in the figure. The face side (Outer Side) is finished with lath-mortar. The back side (Inner Side) is sheathed with gypsum boards.

Specimen B : The frame of the specimen B is more realistic than that of the specimen A, that is, the frame of the specimen B has such construction as often observed in the actual wooden dwelling houses. The column at the left end is continuous column, that is, the column is one unit without joint from the base to the top of the frame. On the other hand, the beams have a joint at the left hand side bay. The braces are applied as shown in the figure. The face side is sheathed with cemented chip hard boards and the back side is sheathed with gypsum lath boards according to the experimental stages.

The set up of the experiment is shown in Fig.2. The horizontal loads were applied at the two points, that is, at the top of the frame and at the second floor. A special lever mechanism was devised to give approximately same amount of drift to the first story and the second story as shown in the figure. The vertical load to simulate the effect of floor load was applied by suspended weights. The average weight along the frame is about 100kg/m at the second floor beam level as well as at the roof beam level.

As mentioned above, both specimens,A and B, were applied with finishes as the stage of the experiment proceeded. The stages are listed in Table 1.

The reversible horizontal loads were applied to the specimens by a hydraulic jack. The loading schedule is as follows. The maximum amplitude of story drift of 1/500 radian was given in the first cycle of the test. The maximum amplitude in the successive cycle was multiplied by $\sqrt{2}$ until it reached the amplitude of 1/120 radian, in which the damages of the frames and finishes are rather small and the stiffness and strength of them could be recovered by re-fastening the nails. The maximum amplitude at the last stage of the experiment in each specimens was limited by the capacity of the jack, and reached about 1/30 radian. The displacements of each points of the frames and finishes were measured by electronic transducers.

RESULTS OF TESTS AND DISCUSSIONS

The deformation of the two bare frames, A and B, is shown in Fig.3. The two frames have same amount of bearing walls (braces), but the deformed shape and the distribution of horizontal loads of them is different from each other.

The relationships between the shear force and the interstory displacement (story drift) at each stages of the two specimens, A and B, are shown in Fig.4. The shear resistances at the story drift of 1/500 radian as well as at that of 1/120 radian are listed in Table 2. The maximum shear resistances at the final stage are also included in the table. The shear resistance at the story drift of 1/500 radian could be regarded as a representative of the initial stiffness. The shear resistance at the story drift of 1/120 radian is considered to be a basis to determine the allowable shear strength of bearing walls in the seismic design method of wooden dwelling houses in Japan.

The initial stiffness and the shear resistance at the story drift of 1/120 radian are increased by application of sheathing members such as wooden lath, gypsum boards and gypsum lath boards. They are increased remarkably in the last stage of the experiment, in which the specimen A was finished with mortar and the specimen B was sheathed with cemented chip hard boards. The initial stiffness in the specimen A is increased by more than ten times after application of mortar compared with the original bare frame. The shear resistance at the story drift of 1/120 radian is increased by five to seven times, but the resistance is approaching the maximum value with small margin. Both the initial stiffness and the shear resistance at the story drift of 1/120 radian in the specimen B is increased by about three times after application of cemented chip hard boards compared with the original bare frame, and the resistance could be increased by two times until it reaches the maximum value. This fact suggests that the cemented chip hard boards give larger ductility to the frame than the mortar finish.

The residual displacement ratios, which are defined as the ratio of residual displacement after unloading from maximum displacement divided by the maximum displacement, in each cycle of loading in every stage of the experiment are shown in Fig.5. The ratios range from 20% to 50%.

The equivalent damping factors, which are defined based on the hysteretic energy dissipation in one cycle divided by the equivalent stiffness of the cycle, are shown in Fig.6. The ratios range from 10% to 20%.

CONCLUSION

The following facts were found in this experimental research.

1. The deformation of the frames is influenced by the construction of frame work including the application angle of the braces.
2. The frame sheathed with gypsum boards and finished with mortar are stiffened by more than ten times, and strengthened by about six times of the bare frame.
3. The frame sheathed with gypsum lath boards and applied with cemented chip hard boards are stiffened and strengthened by about three times of the bare frame.
4. The frame sheathed with cemented chip hard boards is more ductile than the frame finished with mortar.
5. Residual displacements after unloading are 20 to 50% of the maximum displacement.
6. Equivalent damping factors range from 10 to 20%.

ACKNOWLEDGMENT

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REFERENCES

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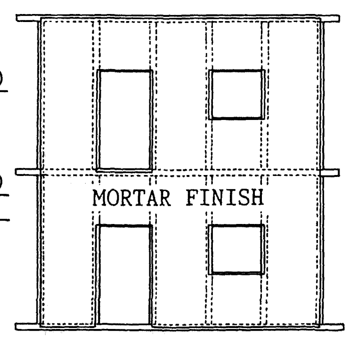
TABLE 1 CONSTRUCTION OF SPECIMENS IN EXPERIMENTAL STAGES

	SPECIMEN A		SPECIMEN B	
STAGE	Outer Side	Inner Side	Outer Side	Inner side
1	Bare Frame (BO) (Brace Only)		Bare Frame (BO) (Brace Only)	
2	Wooden Lath (WL)			Gypsum Lath Board (LB)
3		Gypsum Board (GB)	—	
4	Mortar finish (MF)		Cemented Chip Hard Board(CB)	

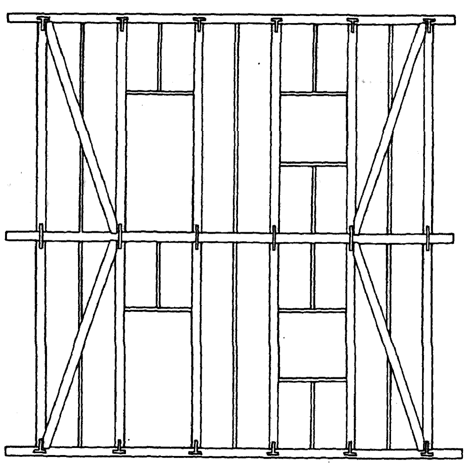
TABLE 2 TEST RESULTS

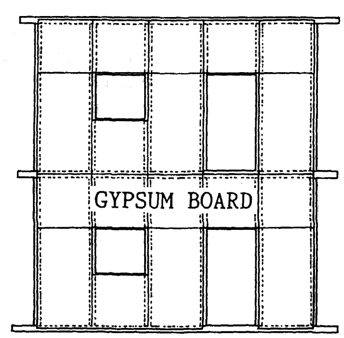
SPECIMEN A		BRACE ONLY		WOOD LATH		GYPSUM BOARD		MORTAR FINISH	
		1F	2F	1F	2F	1F	2F	1F	2F
P500	+	100	100	152	145	330	242	1255	1232
(kg)	-	114	97	155	135	327	295	1295	1102
	AVERAGE	107	99	154	140	329	269	1275	1167
		(1.00)	(1.00)	(1.44)	(1.41)	(3.07)	(2.72)	(11.92)	(11.79)
P120	+	296	290	412	395	689	812	1490	2052
(kg)	-	341	270	380	362	756	913	1870	1975
	AVERAGE	319	280	396	379	723	863	1680	2014
	RATIO	(1.00)	(1.00)	(1.24)	(1.35)	(2.27)	(3.08)	(5.27)	(7.19)
Pmax		-	-	-	-	-	-	2190	2192

SPECIMEN B		BRACE ONLY		LATH BOARD		CEMENTED CHIP HARD BOARD	
		1F	2F	1F	2F	1F	2F
P500	+	197	147	321	250	482	435
(kg)	-	182	112	271	252	468	432
	AVERAGE	190	130	296	251	475	434
	RATIO	(1.00)	(1.00)	(1.56)	(1.93)	(2.50)	(3.34)
P120	+	397	302	640	547	1233	920
(kg)	-	373	207	566	562	1202	935
	AVERAGE	385	255	603	555	1218	928
	RATIO	(1.00)	(1.00)	(1.57)	(2.18)	(3.16)	(3.64)
Pmax	+	-	-	-	-	>2200	>2000



FACE SIDE





BACK SIDE

FIG.1(a) SPECIMEN A

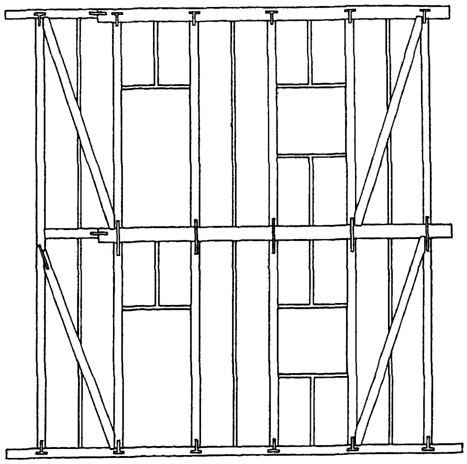
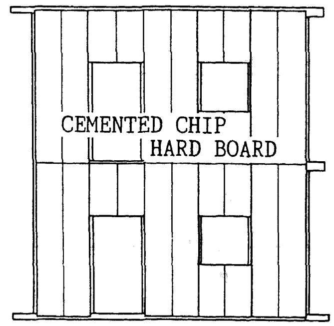
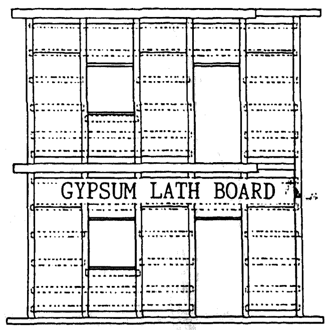


FIG.1(b) SPECIMEN B



FACE SIDE



BACK SIDE

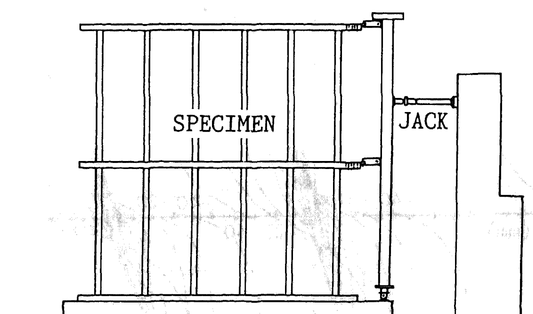
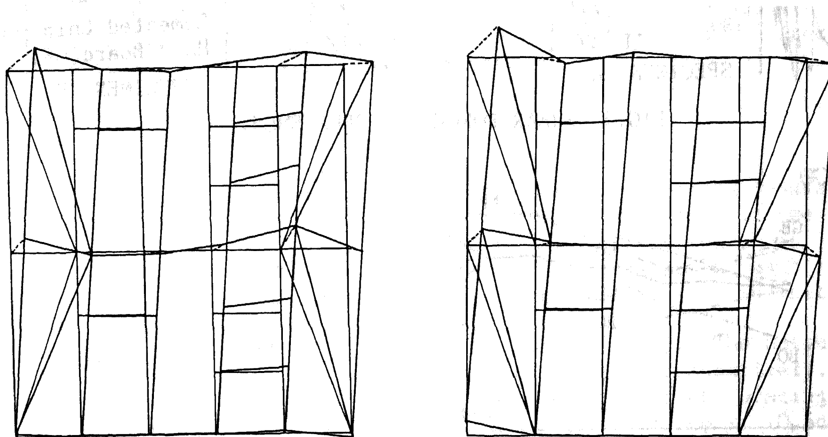


FIG.2 SET UP OF THE TEST



SPECIMEN A

SPECIMEN B

FIG.3 DEFORMATION OF THE FRAME

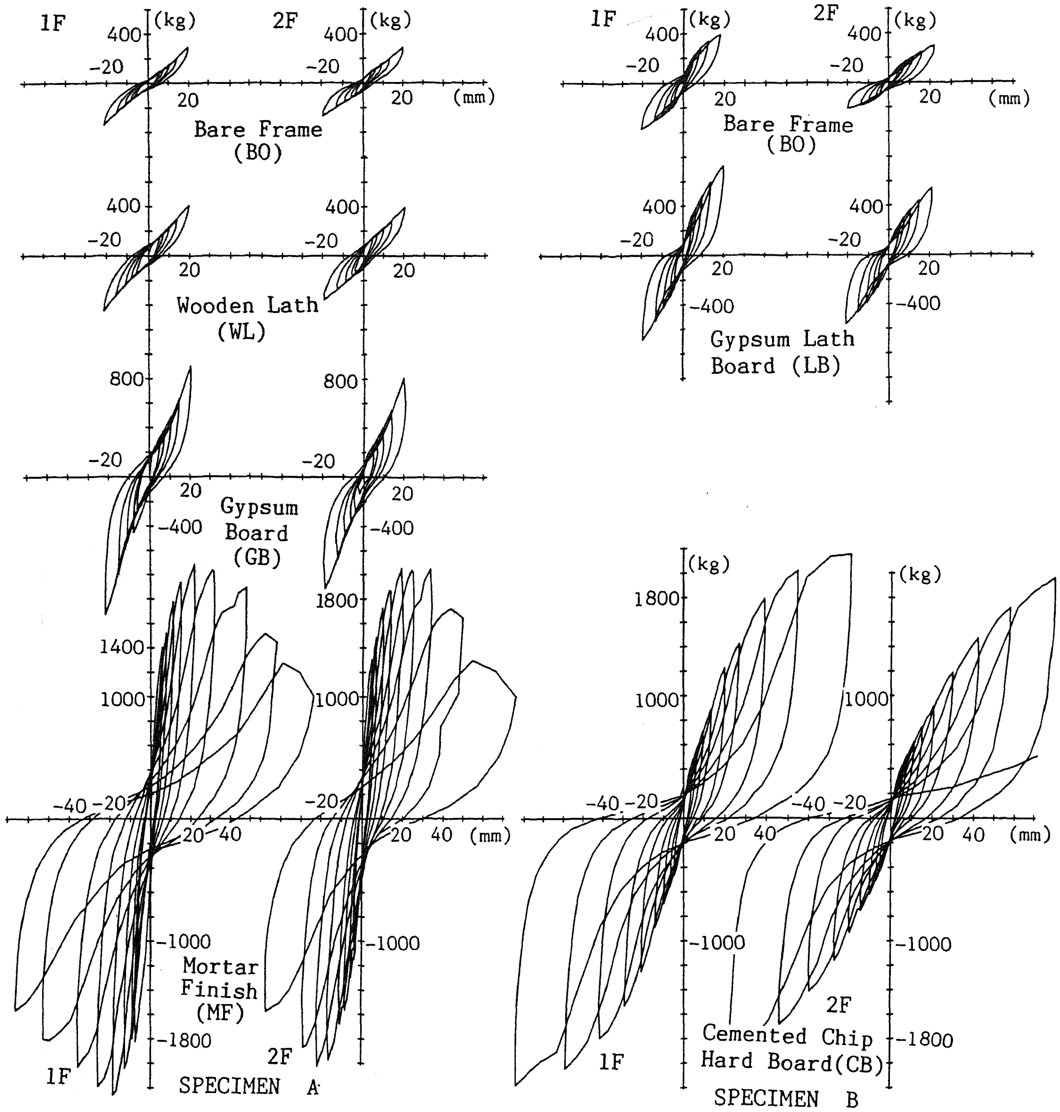


FIG.4 SHEAR FORCE - DISPLACEMENT CURVES

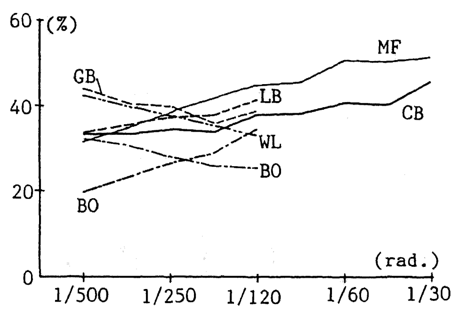


FIG.5 RESIDUAL DISPLACEMENT RATIOS

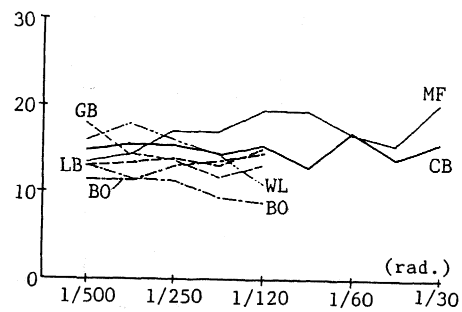


FIG.6 EQUIVALENT DAMPING FACTORS