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A STUDY ON DYNAMIC STRENGTH OF TIMBER STRUCTURE

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SUMMARY

The Building Standard Law was amended because of the 1995 Hyogo-Ken Nanbu Earthquake caused a great many and severe damages to the wooden houses. And the dynamic conception was introduced also in timber structure. But the dynamic conception is not included in the structural design of wooden house. And so this report is a study on the dynamic effect of timber structure by the full-scale shaking table test and dynamic loading test of shear wall.
By the experimental result of nailed plywood shear wall, Velocity-dependence of stiffness was identified. The stiffness ratio of a dynamic loading test to a static loading test was about 1.5 times at a maximum. Since Velocity-dependence of stiffness was elastic range comparatively, evaluation method was proposed using response spectrum method. As a result of considered correlation about the experimental result of shaking table test and evaluation method using experimental result of dynamic loading test, the possibility of the appraisal method of dynamic effect was found out using the velocity-dependence of stiffness and the response spectrum method.

INTRODUCTION

The 1995 Hyogo-Ken Nanbu Earthquake caused a great many and severe damages to the wooden houses (Houseing damages by the earthquake were about 90,000 complete collapses and were about 10,000 half collapses). And the dynamic conception was introduced also in timber structure. But the dynamic conception is not included in the structural design of wooden house. And so, Emphasis has been put to research in consideration of the dynamic phenomenon. Then, the way to evaluate a dynamic effect quantitatively using an experiment result (dynamic loading test of nailed fastener, dynamic loading test of nailed plywood shear wall and full-scale shaking table test) was examined.

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1. DYNAMIC LOADING TEST OF SHEAR WALL

1.1 Experimental Purpose

The main organization for a wooden house to resist against a disaster, such as an earthquake, is the nailed plywood shear wall. Also, in the present method, it is thought that the nailed plywood shear wall has borne 2/3 of seismic force, and it is holding an importance in testing the dynamic effect of a wooden house. Therefore, the dynamic loading test of the nailed plywood shear wall was carried out and the existence of a dynamic effect was tested. The experiment result adopted for the main subject is based on a dynamic loading test of the nailed plywood shear wall.

1.2 Outline of Dynamic Loading Test

Loading tests of a nailed plywood shear wall was carried out 4 times in total. Since there were few examination objects, loading speed was arranged to two, 0.1kine and 25kine. (Since then, the experiment of speed 25kine is called dynamic experiment, and the experiment of speed 0.1kine is called static experiment.) The static experiment followed 0.1kine speed of the grade which is not influenced of inertia power as a standard. The way of loading test object is to connect the beam and actuator, and gave displacement compulsorily to the top part. The examination object is shown in Fig.1.1. (See the document 1. for details of an experiment)

Table.1 Outline of Experimental Plan

Name	DYNAMIC-25	STATIC-01
Loading Speed	25kine (Dynamic Loading Test)	0.1kine (Static Loading Test)
Loading Method	Reversed Cyclic Loading (Sine Wave : Number of Times is 3)	Reversed Cyclic Loading (Sine Wave : Number of Times is 3)
The Number of Test Piece	2 (Size : 1820mm×2730mm)	2 (Size : 1820mm×2730mm)
Target of Story Drift Angle	1/600rad, 1/450rad, 1/300rad, 1/200rad, 1/150rad	1/600rad, 1/450rad, 1/300rad, 1/200rad, 1/150rad
	1/100rad, 1/60rad, 1/30rad, 1/20rad, 1/15rad	1/100rad, 1/60rad, 1/30rad, 1/20rad, 1/15rad

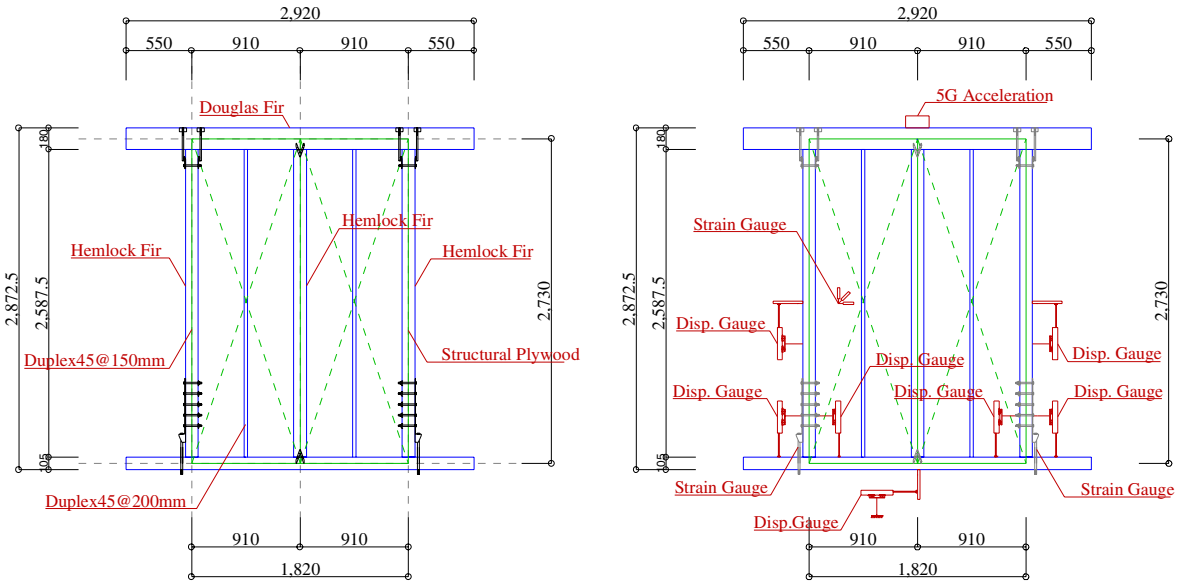

Fig.1.1 Plan of Test Piece and Measurement Plan

1.2 Experimental Result

The ratio of stiffness which is by loading speed of the nailed plywood shear wall is shown in Fig.1.2. The relation of maximum value between 1st story displacement and the slip displacement of nailed fastener which is shown in Fig.1.3, is the plot of the experimental value (shown in CH.10 of Fig.1.1) and the theoretical value which is caluculated by the balance of moment. The relation between the slip displacement of nailed fastener and displacement speed of nailed fastener is shown in Fig.1.4 and Fig.1.5. The theoretical value and the experimental value of slip displacement of nailed fastener are nearly equal to 1/60 radian of story drift angle, and elastic action can be confirmed (Fig.1.3). The difference of drift due to loading speed is hardly found to the end, and the velocity-dependence of stiffness is confirmed to nearby 1/60 radian, and when the rigid ratios of a static experiment and a dynamic experiment are the 1.0 neighborhoods (Fig.1.2).

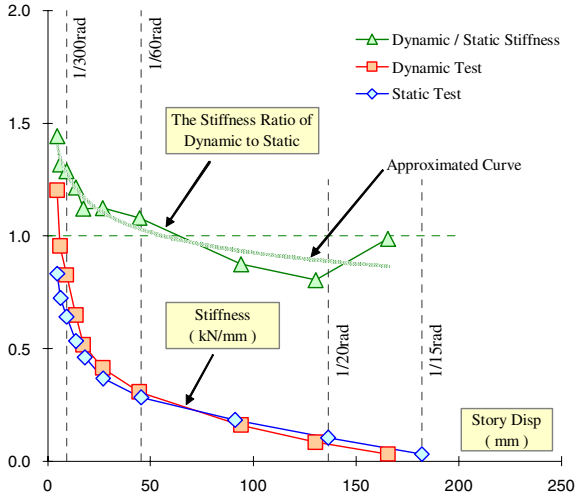

Fig. 1.2 The Stiffness Ratio of Dynamic Test to Static Test

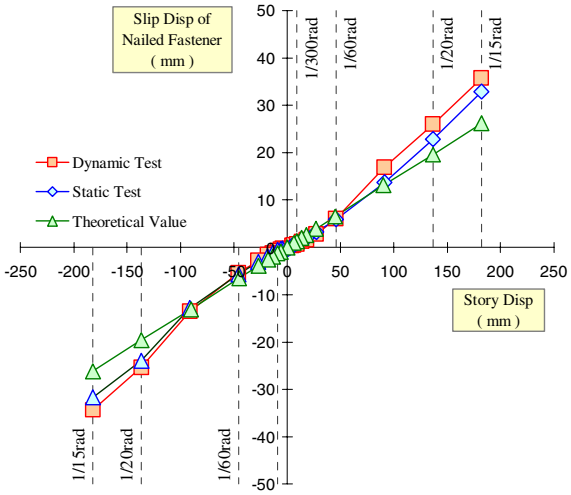

Fig. 1.3 RelationShip of Slip Disp of Nailed Fastener and Story Disp

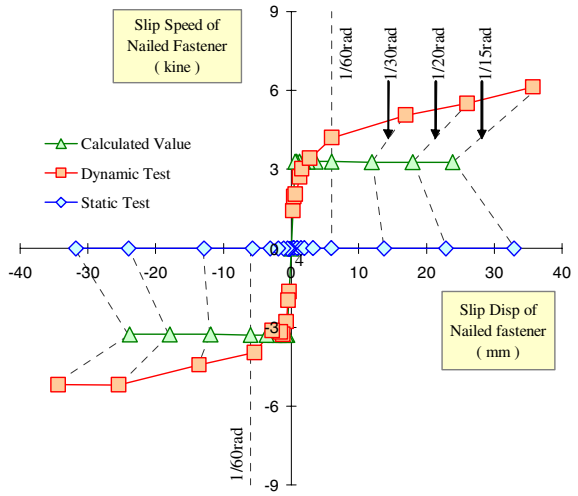

Fig. 1.4 Relationship of Slip Speed and Slip Disp

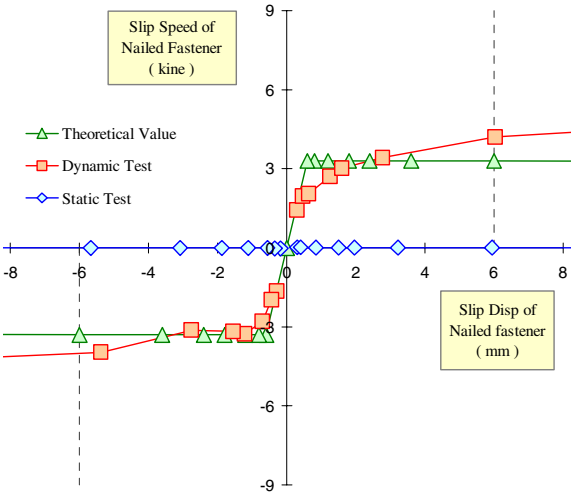

Fig. 1.5 Relationship of Slip Speed and Slip Disp

1.3 Conclusion

The velocity-dependence of stiffness by loading speed was checked in this experiment before 1/60radian of story drift angle. The strength in 1/60 radian of story drift angle was about 80 percent of maximum strength. So 1/60 radian of story drift angle was defined as displacement of damage limit.

The dynamic effect which has been checked before displacement of damage limit from being comparatively elastic range was examined using response spectrum method (Fig.1.6 and Fig.1.7). The flow of an appraisal method is shown below.

(1) Asking displacement response spectrum of seismic wave, and asking cross point of the response displacement and displacement of damage limit. In other word, natural frequency before this cross point is meaning to expect dynamic effect.

(2) Response speed which is using natural frequency asked from displacement response spectrum is asked from velocity response spectrum.

(3) Based on the response speed, dynamic effect is got to know from stiffness-ratio of a dynamic loading test and static loading test.

If the appraisal method of a dynamic effect is summarized response displacement becomes more than displacement of damage limit, since the dependence by rigid speed becomes small and a dynamic effect cannot be expected rather than the result of dynamic loading test, displacement of damage limit or less following becomes important. In short, the dynamic effect about a short cycle which is natural frequency of the response displacement and displacement of damage limit is expectable. And it can ask for evaluation of a quantitive dynamic effect using the relation of the rigid ratio of the response speed, dynamic loading test, and static experiment which can be found from a speed response spectrum.

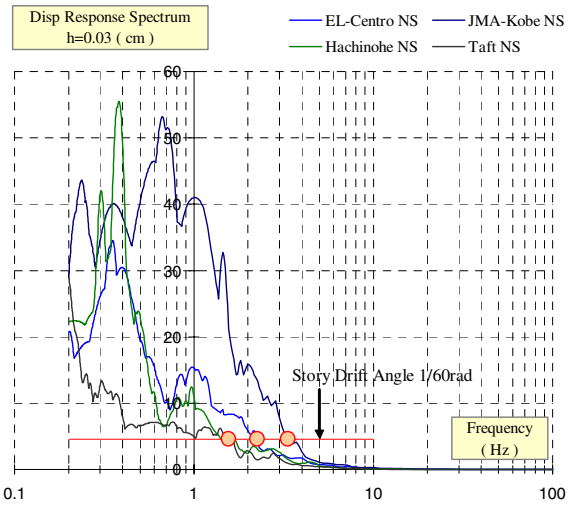

Fig. 1.6 Disp Response Spectrum

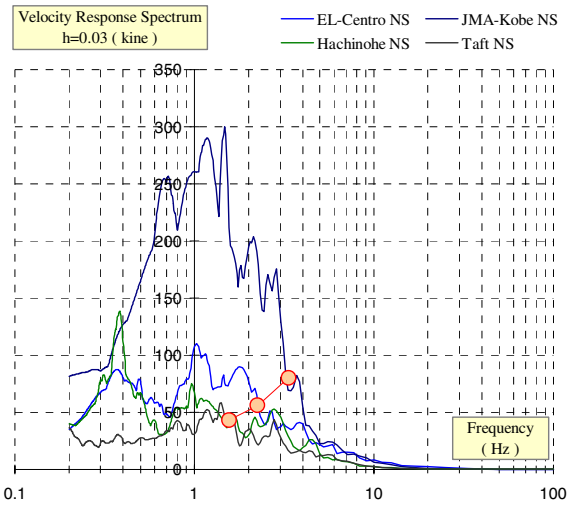

Fig. 1.7 Velocity Response Spectrum

2. FULL-SCALE SHAKING TABLE TEST OF WOODEN HOUSE

2.1 Experimental Purpose

Velocity-dependence of stiffness which was confirmed by the dynamic loading test was carried two loading speed. Dynamic loading test of nailed plywood shear wall gave displacement compulsorily. However, the actual response by the earthquake was not known. And so, Full-scale shaking table test was carried out. And, this chapter also examined the evaluation method of dynamic effect which is proposed by dynamic loading test of nailed shear wall.

2.2 Outline of Full-Scale Shaking table test

There are two examination objects, frame structure and wall frame structure. Both frame structure and wall frame structure is the almost same structure specification. Inputted seismic wave to examination objects was observed at Japan Meteorological Agency in Kobe City (See the document 2. and document 3. for the details of an experiment).

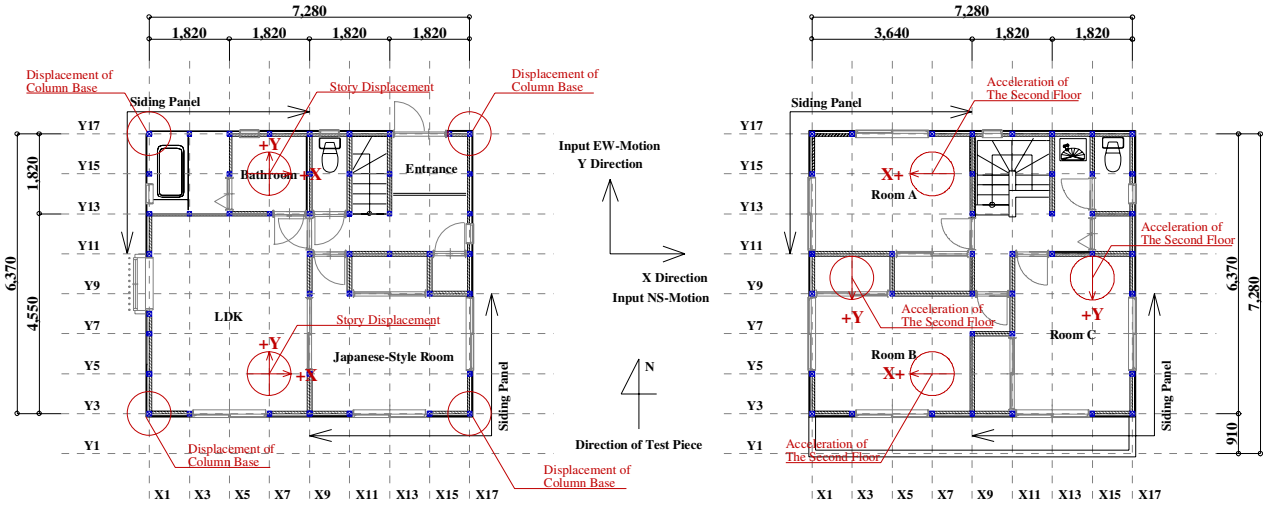

Fig. 2.1 Plan of Frame Structural House

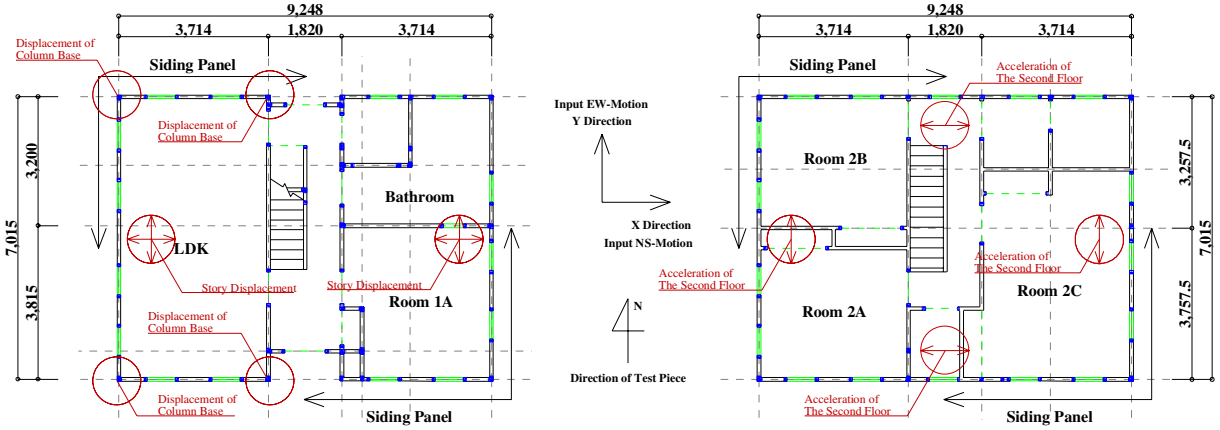

Fig. 2.2 Plan of Wall Frame Structural House

2.3 Conclusion

The Fig.2.3 and Table2 is examined the experiment result (relation of the maximum story speed and story displacement) about dynamic effect in examination object X-direction. In both the frame structure and the wall frame structure, story displacement which is the result of shaking table test by the JMA-Kobe wave was under displacement of damage limit. And the experimental objects were shown the high seismic performance. So, the result of full-scale shaking table test can expect dynamic effect.

The relation between maximum story speed and maximum story displacement is equivalent to the relation velocity response spectrum and displacement response spectrum about natural frequency of experimental objects. There is the next relation to velocity response spectrum (Sv) and displacement response spectrum (Sd).

$$Sv = \omega Sd \quad \Leftrightarrow \quad f\ (\text{Natural Frequency}) = Sv / (2\pi \times Sd)$$

The story speed of experimental result by full-scale shaking table test of wall frame structure is 23.36kine which is almost same value of dynamic loading test. It can be predicted that the stiffness ratio of a dynamic experiment to a static experiment is about 1.25 times because of natural frequency of experimental object and response frequency of dynamic loading test is almost same value. Dynamic effects completely differ in four areas which is made based on the experimental result of JMA-Kobe 67 percent. On the area 1, dynamic effect is high. On the area 2, dynamic effects become small. Area 3 has a small effect compared with area 1. Area 4 can hardly expect a dynamic effect.

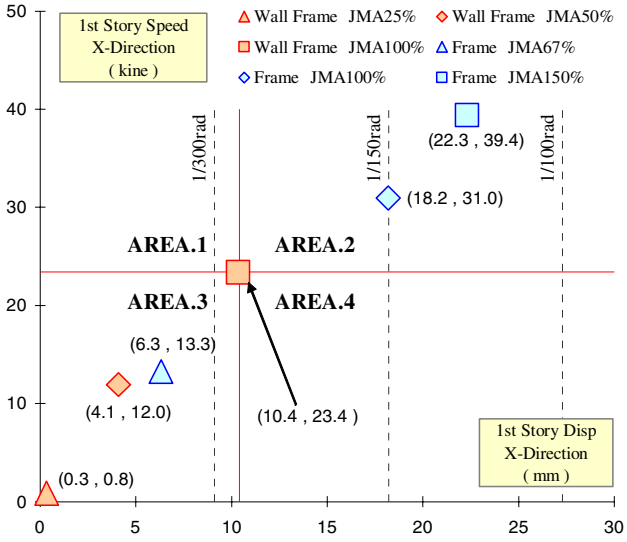

Fig. 2.3 Relationship of Story Speed and Story Disp.

Table.2 Experimental Result

EXPERIMENTAL RESULT OF WALL FRAME STRUCTURE

INPUT SEISMIC WAVE	1st STORY SPEED	1st STORY DISP	FREQUENCY
	kine	mm	Hz
JMA KOBE NS 25%	0.847	0.349	3.86
JMA KOBE NS 50%	11.95	4.091	4.65
JMA KOBE NS 100%	23.36	10.354	3.59

EXPERIMENTAL RESULT OF FRAME STRUCTURE

INPUT SEISMIC WAVE	1st STORY SPEED	1st STORY DISP	FREQUENCY
	kine	mm	Hz
JMA KOBE NS 67%	13.265	6.307	3.35
JMA KOBE NS 100%	30.95	18.188	2.71
JMA KOBE NS 150%	39.385	22.327	2.81

3. CONCLUSION

The dynamic effect of a wooden dwelling house was examined using dynamic loading test and full-scale shaking table test, and the following results were obtained.

(1) The difference of drift due to loading speed is hardly found to the end, and the velocity-dependence of stiffness is confirmed to nearby 1/60 radian, and when the rigid ratios of a static experiment and a dynamic experiment are the 1.0 neighborhoods (Fig.1.2).

(2) The experimental objects were shown the high seismic performance. So, the result of full-scale shaking table test can expect dynamic effect.

(3) As a result of considered correlation about the experimental result of shaking table test and evaluation method using experimental result of dynamic loading test, the possibility of the appraisal method of dynamic effect was found out using the velocity-dependence of stiffness and the response spectrum method.

However, it cannot be said that it experimented in the dynamic experiment of nailed plywood shear wall about the sufficient number of the tests. And so it is necessary to increase the number of examination objects and to raise reliability.

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