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SHAKING TABLE TEST ON INDOOR HUMAN RESPONSE AND EVACUATION ACTION LIMIT IN STRONG GROUND MOTION

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SUMMARY

To clarify the evacuation action limit in the strong ground motion, shaking table test was performed in 2000 and 2002. The input motions were sine waves with totally 96 patterns of actions were tested for 15 (partially for 30) subjects for experiment. The authors asked each subject for his/her feeling at the test for each input. The performance of each subject was recorded by motion capture system and analyzed as three-dimensional motion. Their feelings of difficulty for actions, worriment for shaking, and confusion ratio of their actions were considered.

INTRODUCTION

Structural performance has been usually represented with structural capacity against earthquakes. The capacity has been mainly explained with strength and/or deformation capacity of structural resistance against earthquakes. The authors paid attention with indoor human response and evacuation action in the strong ground motion. The evacuation action does not mean refuge from the building, but means hiding under the table or turning off the kitchen stove, for example. The reason why the authors pay attention the evacuation action was that the safety of human inside the buildings was more important than the safety of the buildings itself. The concept might lead us to the situation that the structural performance could represent with the ease of evacuation action [1].

Noguchi studied on habitability to the motion in floating ocean structures [2], though, there seems no precedential study on action limit for strong ground motion. Therefore, to clarify the evacuation action limit in the strong ground motion, shaking table test was performed. The authors asked each subject to explain his/her feeling after each input. The performance of each subject was recorded by motion capture system and analyzed as three-dimensional motion. Their feelings of difficulty for actions, anxiousness for shaking, and impossibility of actions in future earthquakes by questionnaire survey and unbalanced ratio of their actions that judged from the record of motion capture system were considered in the analysis.

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SHAKING TABLE TEST

The shaking table tests were performed in 2000 and 2002. In 2000, shaking table in the Building Research Institute was used. In the test, necessity of long period input was discovered [3][4], and in 2002, additional shaking table test was performed, using the shaking table at Fujita Corporation [5].

Outline of the test

Shaking table test in 2000 was performed from September 25 to 29 at Building Research Institute, Tsukuba, Japan. Three subjects on one day and totally 15 subjects joined the test. Four subjects were female. Input motions were sine waves, and combinations of the waves are shown in Table 1. The combinations were chosen based on floor response of various buildings in the strong ground motions. Because of the limit in displacement of shaking table, additional tests were performed on August 26, 29, September 11, 19 and 20, 2002 at Technology Center, Fujita Corporation, Atsugi, Japan. Total number of subjects were 15. Three subjects were female. Combinations of input sine waves are shown in Table 1. Therefore, totally 30 subjects (7 of them were female) joined in the test.

Table 1. List of input vibrations.

Frequency (Hz)	0.3	0.6	1.0	2.5	5.0
Velocity (m/s)	0.265**	0.265	0.159	0.064*	0.032*
	0.398**	0.398	0.318	0.127*	0.064*
	0.531**	0.531**	0.478**	0.318	0.159*
	0.663**	0.663**	0.637**	0.624	0.312*
	0.796**	0.796**	0.796		0.477*

*: in 2000 only, **: in 2002 only

Each subject wore protectors for head, elbows and knees. Then they put markers for motion capture system on head, chest, belly, elbows, knees and toes. One scene of the shaking table test in 2002 is shown in Figure 1. The authors tested two kinds of evacuation actions, i.e., standing up and walking. The authors tested two directions for input, i.e., front and rear, and right and left motions. Therefore, totally 56 patterns of actions for the test in 2000 and 68 patterns of actions for the test in 2002 were tested.

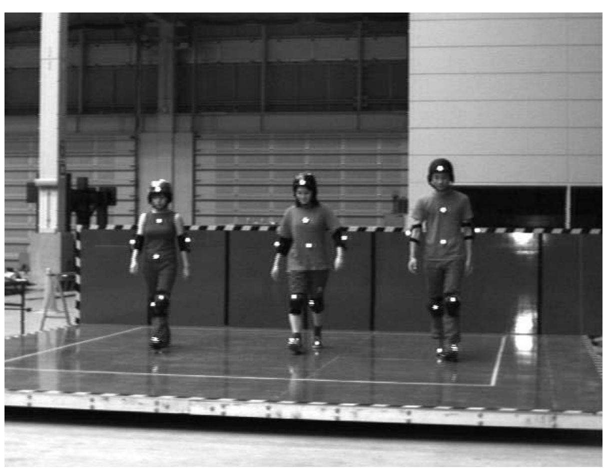

Figure 1. One scene of front and rear shaking test.

The authors asked subjects to answer the questionnaire shown in Table 2 after each input motion. Each action was recorded by motion capture system using equipments shown in Figure 2 and analyzed later.

Table 2. Questionnaire list (Standing up test)

A. How did you feel about difficulty in action?	
0. No difficulty for standing up.	1. There was slight difficulty but I could.
2. There was difficulty but I could.	3. There was difficulty for standing up.
4. I could not stand up.	
B. How did you feel in the test?	
0. There was no anxiety.	1. I felt anxiety a little.
2. I felt anxiety.	3. I felt rather anxiety.
4. I felt anxiety very much.	
C. What do you think that it is the real earthquake?	
0. I can action.	1. I am not sure whether I can or not.
2. I do not think I can action.	

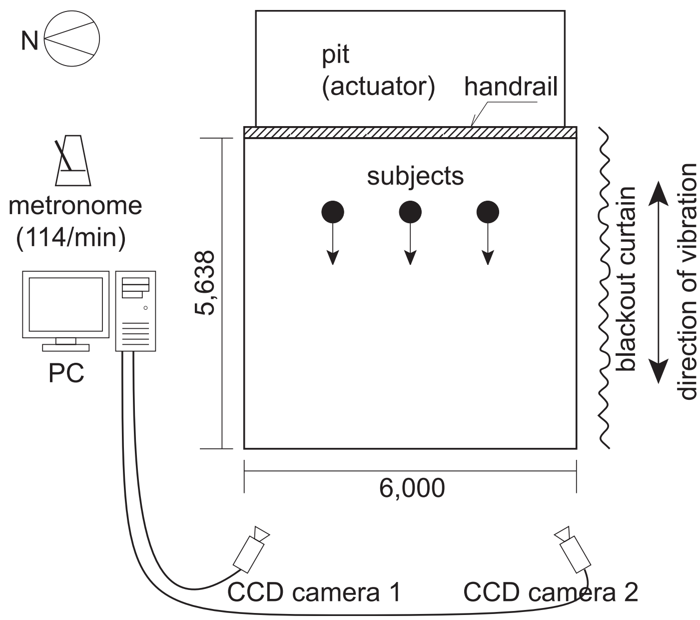

Figure 2. Outline of test equipments.

Analysis method

Results of the questionnaire survey, data of motion capture system, and result of judgment whether each subject unbalanced in the motion or not were considered in the analysis. The judgment whether unbalanced or not has been done by the authors, watching the record of motion capture system.

TEST RESULTS

Result of questionnaires

Examples results of questionnaires are shown in Figures 3, 4 and 5. The values are average in male and female respectively. Relationships between questionnaires are shown in Figure 6. Figure 3 shows subjects felt more difficulties in walking than standing up action. Figure 4 shows that in high frequency motion, i.e., 5.0 Hz, they felt more anxiousness than low frequency motion, in the same velocity. Figure 5 and 6(a) shows that difficulty of action and impossibility in the future earthquake has strong correlation. Figure 6(b) shows that high frequency motion cause strong anxiousness instead of its small difficulty of actions.

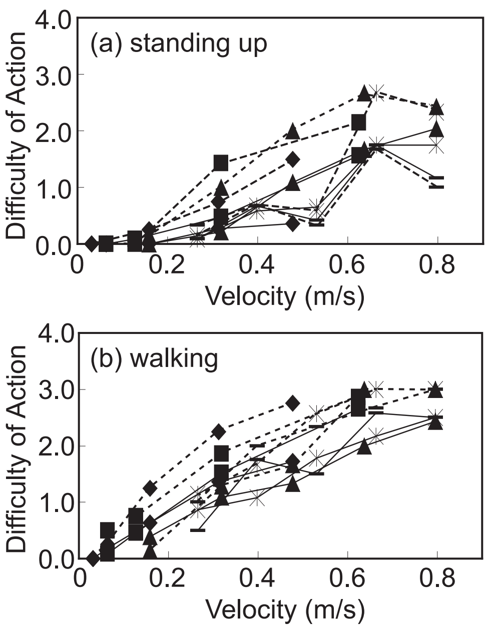

Figure 3. Difficulty of action. (right and left vibration)

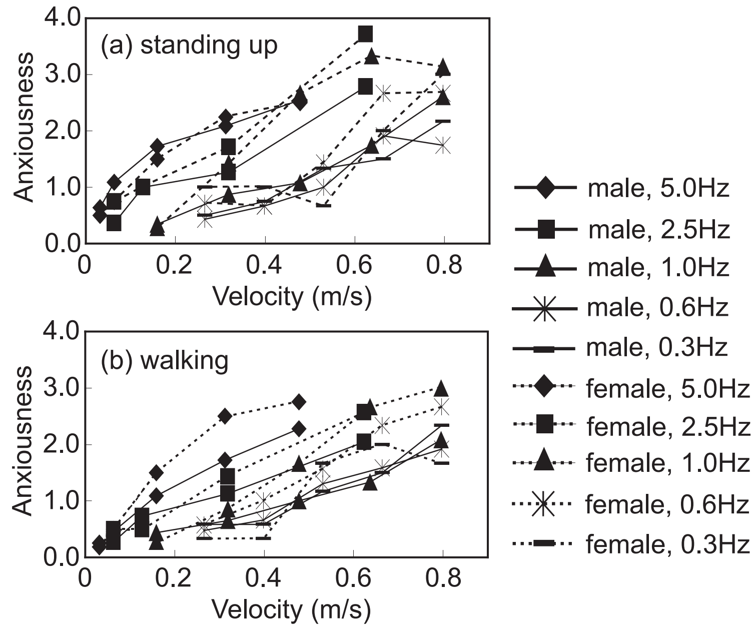

Figure 4. Anxiousness in the motion. (front and rear vibration)

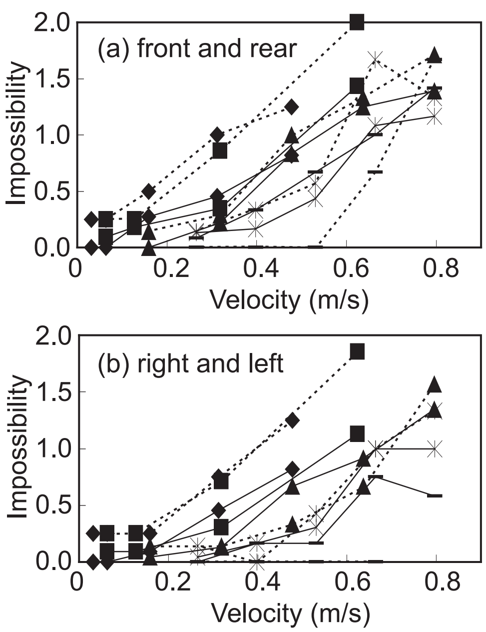

Figure 5. Impossibility of action. (standing up action)

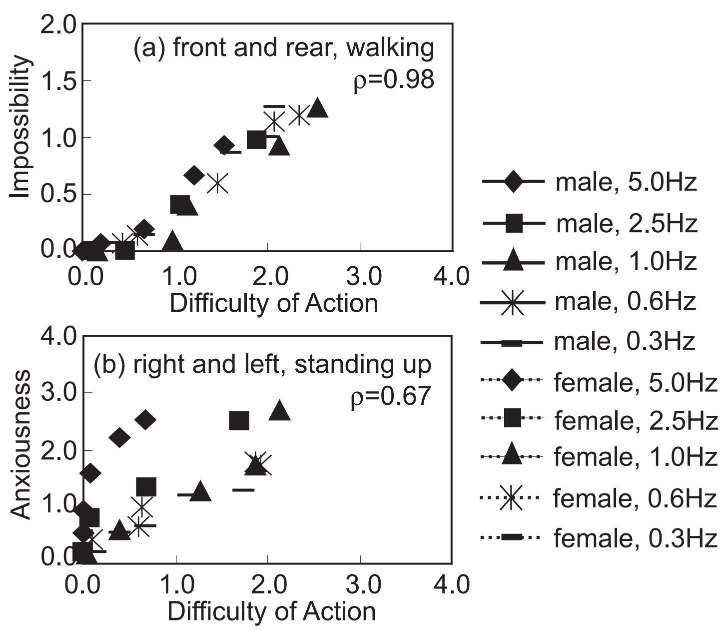

Figure 6. Relationship between questionnaire surveys.

Unbalanced ratio

Figures 7, 8, 9 and 10 shows unbalanced subjects' ratio in male and female respectively. Figure 7 shows unbalanced ratio before standing up action. Unbalanced ratio in right and left motion is higher than front and rear motion. Figure 8 shows unbalanced ratio after standing up action and before and after walking action. Unbalanced ratio in standing is higher in front and rear motion. That is because subjects took stance wide as their shoulder and could resist right and left motion. Figures 9 and 10 shows that unbalanced ratio in moving actions are higher than that of standstill states. In comparison of standing up action and walking action, unbalanced ratio of walking action is higher than standing up action, generally. In walking action, unbalanced ratio in right and left motion is higher than that of front and rear motion.

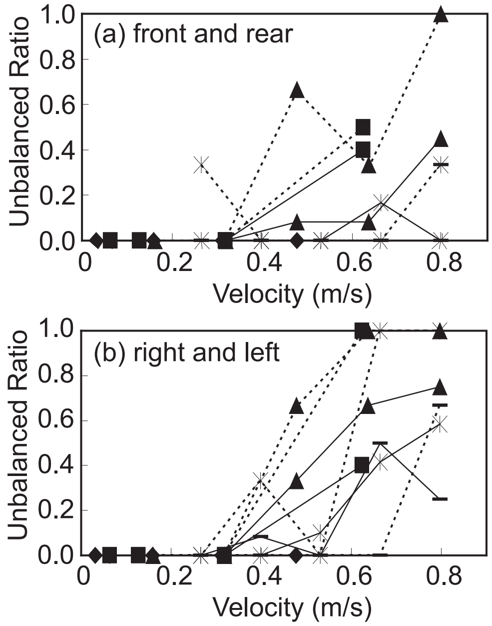

Figure 7. unbalanced ratio in sitting

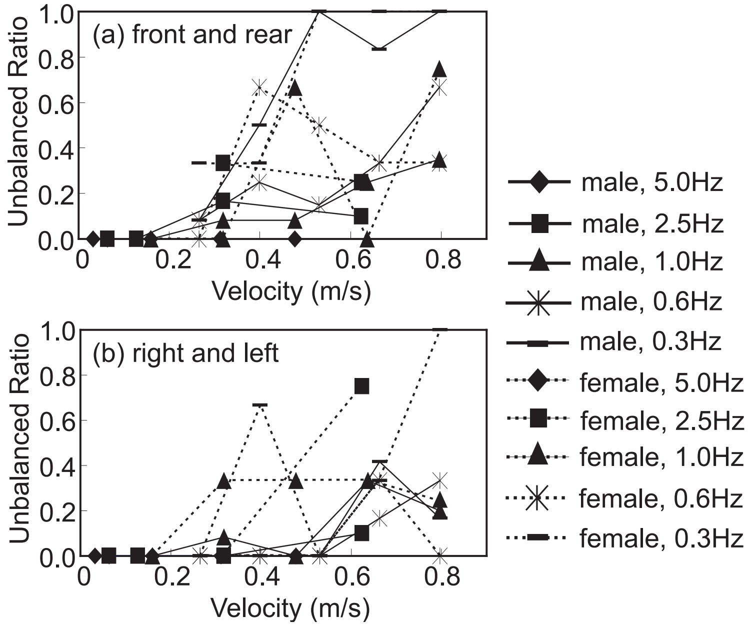

Figure 8. Unbalanced ratio in standing.

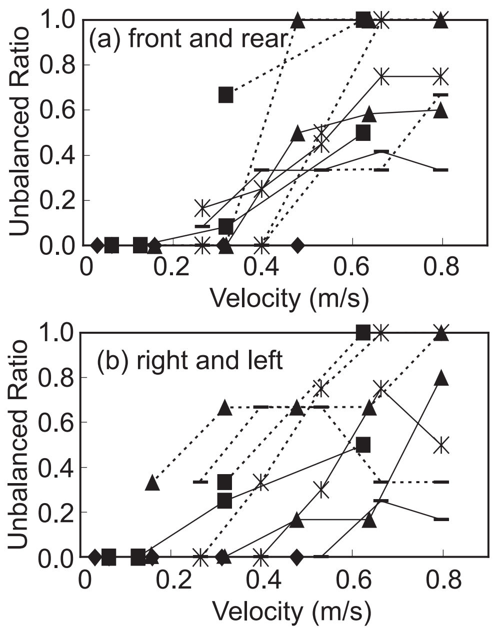

Figure 9. unbalanced ratio in standing up action.

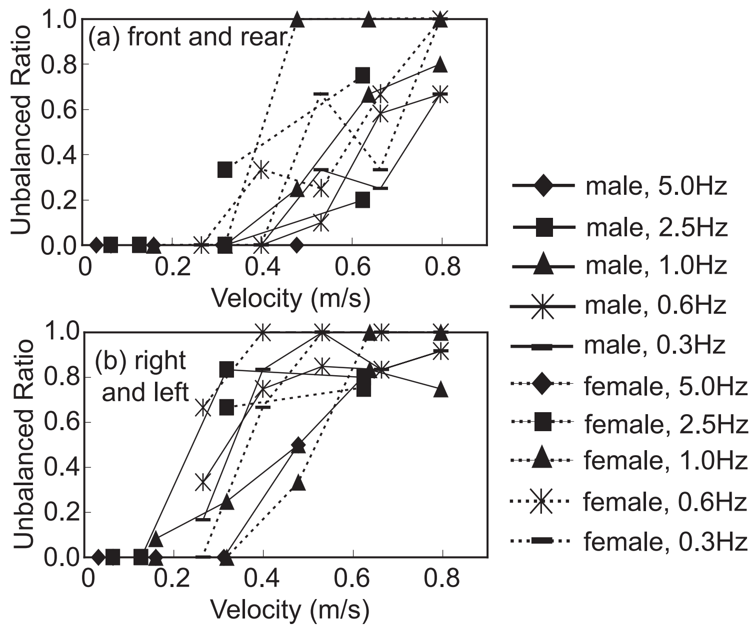

Figure 10. Unbalanced ratio in walking action.

Figure 11 shows relationship between unbalanced ratio and questionnaire survey. The feeling of difficulty in action and unbalanced ratio has strong correlation as shown in Figure 11(a). Figure 11(b) shows that high frequency motion causes strong anxiousness and low frequency motion causes stagger even if anxiousness is small.

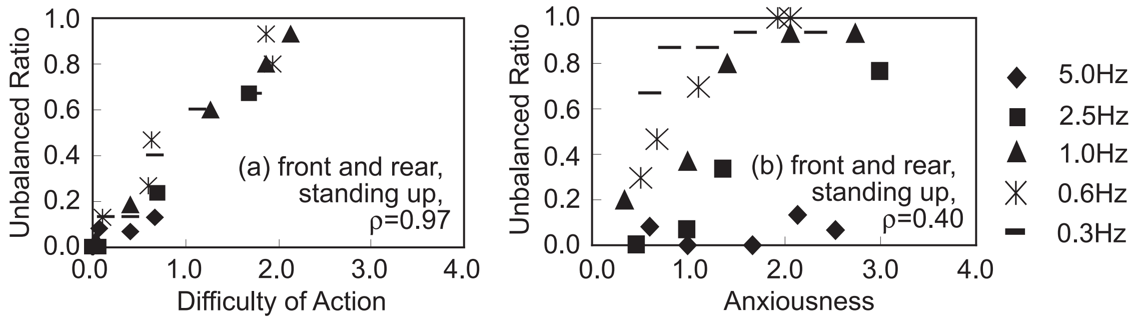

Figure 11. Relationship between unbalanced ratio and questionnaire survey.

Displacement of markers

Figure 12 shows displacement of shaking table and markers on the subjects. Figure 12(a) is an example who did not stagger, and Figure 12(b) is an example who staggered. In this case, subject No.10 (Figure 12(a)) seems to use knee effectively. The authors have not find clear limit value for evacuation limit structural performance, yet, because of limitation of number of subjects. The authors are planning additional test for gathering data of mature number and variety of age in subjects.

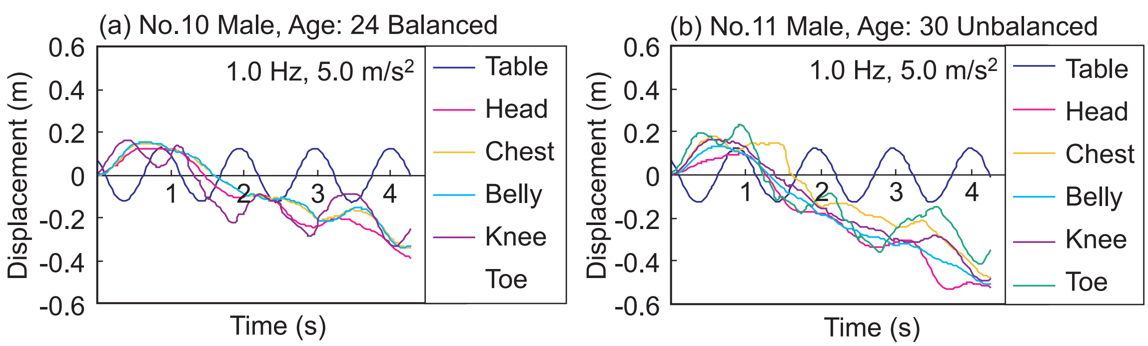

Figure 12. Displacement of markers (right and left motion, walking action)

CONCLUSIONS

Shaking table tests were performed for the sake of making new criterion for structural performance. It could be said that high frequency floor response causes strong anxiousness for indoor people. Low frequency floor response cause stagger for indoor people, but additional tests might be need to clarify its limit value.

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