Evaluation of Floor Vibrations under Influence of Exposure of Large Vibration

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ABSTRACT

Floor micro-vibrations are an important environmental factor in habitability. More recently in Japan, vibration problems are increasing in existing buildings because of the increase in floor vibration amplitude or the shifts of acceptable values of residents caused by changes in surrounding environment, replacement of residents, or usage changes of the buildings. Therefore, it is important to implement effective countermeasures against vibration problems in existing buildings. Although studies on human perception and evaluation of absolute amplitudes have been widely conducted, to the best of our knowledge, human perception and evaluation of differences in floor vibrations before and after implementation of countermeasures have not been studied. In this study, we evaluated the permission levels of test subjects by exposing them to various vibrations. The subjects were exposed to larger vibrations than the permission levels as vibrations before countermeasure, and relatively small vibrations after the countermeasures were implemented. The permission levels for these small vibrations were again evaluated. Depending on whether the test subjects were previously exposed to large vibrations or not, we also studied the differences in the permission levels. The obtained results showed that human perception and evaluation of absolute amplitude varied with test subjects, but was approximately the same for reduced volumes of vibrations.

Keywords: Floor Vibration, Evaluation, Influence of Exposure, Absolute Magnitude, Reduced Volume

1. INTRODUCTION

In Japan, improving building materials and structural systems can extend the life of buildings. Neighboring environments, residents, and building usage is likely to change within the lifespan of the building. These changes cause an increase in floor vibration amplitudes and the shift of acceptable values of residents against vibration amplitude. Therefore, recently, vibration problems are increasing in existing buildings. Effective countermeasures against such vibration problems in existing buildings are important and developing an evaluation method for the effectiveness of countermeasures is necessary.

It is believed that the perception and evaluation of reduced floor vibrations are influenced by the exposure of floor vibrations before the implementation of countermeasures. Although studies on human perception and evaluation of absolute amplitudes have been widely conducted, to the best of our knowledge, human perception and evaluation of differences in floor vibrations before and after implementation of countermeasures have not been studied.

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2. SENSORY EVALUATION TESTS

2.1 Outline

Figure 1 shows the procedures of the sensory evaluation tests, and Table 1 shows the outline of these tests. In TEST I, test subjects were exposed to various levels of vibrations, and permission levels for absolute vibration amplitudes were obtained for all subjects. In TEST II, test subjects were expose to vibration levels that were larger than their permission levels (hereinafter, "reference vibrations"), after which the subjects were exposed to relatively lower levels of vibrations. The permission levels for these smaller vibrations were evaluated for all test subjects. Two cases were used as reference vibrations. For the first case (reference vibration I), the reference vibration was 5 dB larger than the permission levels evaluated for each test subject in TEST I. Thus, reference vibration I varied for each subject. For the second case, the reference vibration was 5 dB higher than the maximum permissible level stated by the subjects (reference vibration II). Reference vibration II was the same for all test subjects. Figure 2 shows the setup for the tests. Every test subject was seated on a chair placed on top of a shaking table and exposed to vibrations.

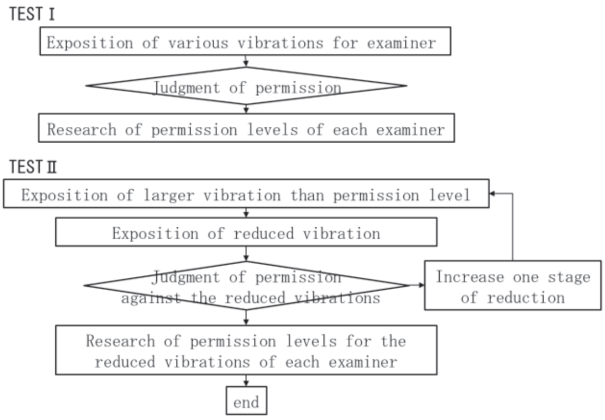


Figure 1 – Procedure of the sensory evaluation test.

Table 1 – Outline of the sensory evaluation tests

	TEST I	TEST II
Questions	Can you permit this vibration if you perceive it when you are working in office?	Can you permit this reduced vibration with the vibration before measure in mind?
Categories to reply evaluation	①permissible ②not permissible	①permissible ②not permissible
Waveform for the test	11 kinds to show in Table 2	
Examiners	9 adult males (age:22 - 52 years old, weight:54 - 98 kg)	
Attitude	Sitting on the chair fixed to the shaking table	

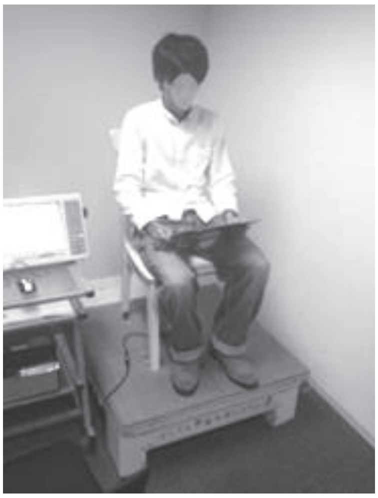


Figure 2 – Setup for the sensory evaluation test.

2.2 Test samples

Eleven waveforms were selected for the test samples with reference to past research (1). Table 2 shows an outline of the test samples. The samples were categorized into three groups: "walking vibration", "traffic vibration," and "continuous vibration". In TEST I, the amplitude of each of the 11 waveforms was separated into 5 vibration levels, from 60 dB to 80 dB, with an interval of 5 dB. The vibration level (VL) is the effective value calculated at 10 ms of the time constant with 0 dB of VL (10 × 10−5 m/s2). In TEST II, samples were reduced in amplitude from the reference vibration by damping. Specifically, the reference vibration was assumed as 0.02 of the damping ratio, and each sample was reduced in 8 stages in the first-order spectrum. Table 3 shows the vibration levels of the samples in TEST I. It also shows the first-order modal damping ratios and reduction magnifications in the first-order spectrum for TEST II. Figure 3 shows example waveforms of the test sample.

Table 2 – Outline of test samples

wave No.	Category	Characteristics	Main dominant frequency (Hz)	Length (s)
1	Walking vibration	Resonance	6.6	8
2		Resonance	7.7	10
3		Resonance	14.0	12
4	Trafic vibration	Fright train	7.6	30
5		Passenger train	7.5, 8.3	15
6		Automobile, continual	7.6	20
7		Automobile, intermittent	7.6	26
8	Continuous vibration	Sine wave	10.0	16
9		Beat wave	14.0	18
10		Aerobics-induced vibration	7.6	20
11		Machinery operation-induced vibration	16.0	16

Table 3 – Vibration levels of the samples in TEST I and the first-order modal damping ratios and reduction magnifications of samples in TEST II.

TEST I	*VLmax* (Time constant : 10ms)		1	2	3	4	5	6		
			60dB	65dB	70dB	75dB	80dB	85dB		
TEST II	Danping ratio	Refference Vibration	1	2	3	4	5	6	7	8
		0.02	0.03	0.04	0.06	0.08	0.12	0.17	0.22	0.30
	Reduction ratio for first order spectrum (0dB=1)	0dB	-3dB	-6dB	-9dB	-12dB	-15dB	-18dB	-21dB	-24dB

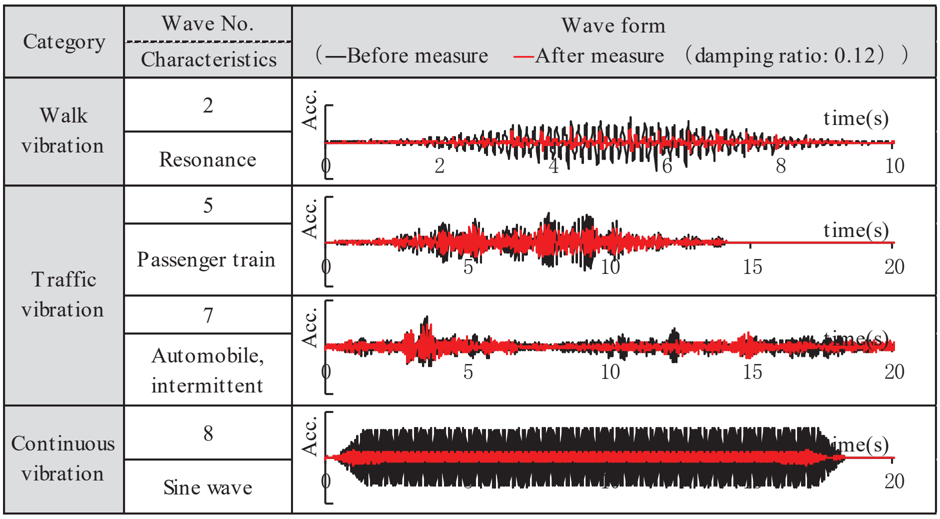


Figure 3 – Examples of test samples

2.3 Physical index

The index "VLT" was set with reference to prior research (1) to represent vibration amplitudes. It was shown that the index expresses human perception of "largeness" and "unpleasantness".

$$VLT = VL\max + 20\log T^{1/4}$$

VL (dB): Vibration level calculated by

$$VL = 20\log\frac{a}{a_0}$$

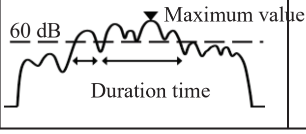
T (s): Duration time at VL being more than reference level

a (m/s^2): R.M.S. value of acceleration added sensitive correction under Japanese Industrial Standards C 1510.

a_0 (m/s^2): Reference value (1.0×10^{-5} m/s^2)

The time constant for calculating root mean squared values was 25 msec. The reference level to calculate T was 60 dB. Table 4 shows the outline of VLT.

Table 4 – Outline of *VLT*

	Consept of the index on the vibration level - time curve	Caluculation method
Maximum value of vibration level plus the duration time		$VLT = VLmax + 20 \cdot \log(T^{1/4})$ *VLmax:* Maximum value of vibration level (dB) *T:* Duration time (s) (Total time when *VL* become more than 60dB. If $T<1$, $T=1$.)

3. RESULTS AND DISCUSSION

3.1 Tests on reference vibration I

Figure 4 shows the results of the test for reference vibration I. The figure shows that the permission levels evaluated in TEST I (hereinafter, "Permission Levels before Measure") were about the same level as those evaluated in TEST II (hereinafter, "Permission Levels after Measure") in terms of their averages and standard deviations. This indicates that the vibration after implementing countermeasures is permitted if the vibration level is reduced to about the permission level before implementing countermeasures. It was also observed that the difference between the Permission Levels and reference vibration I is about –5 dB, which is approximately the same as the difference between Permission Levels before Measure and reference vibration I.

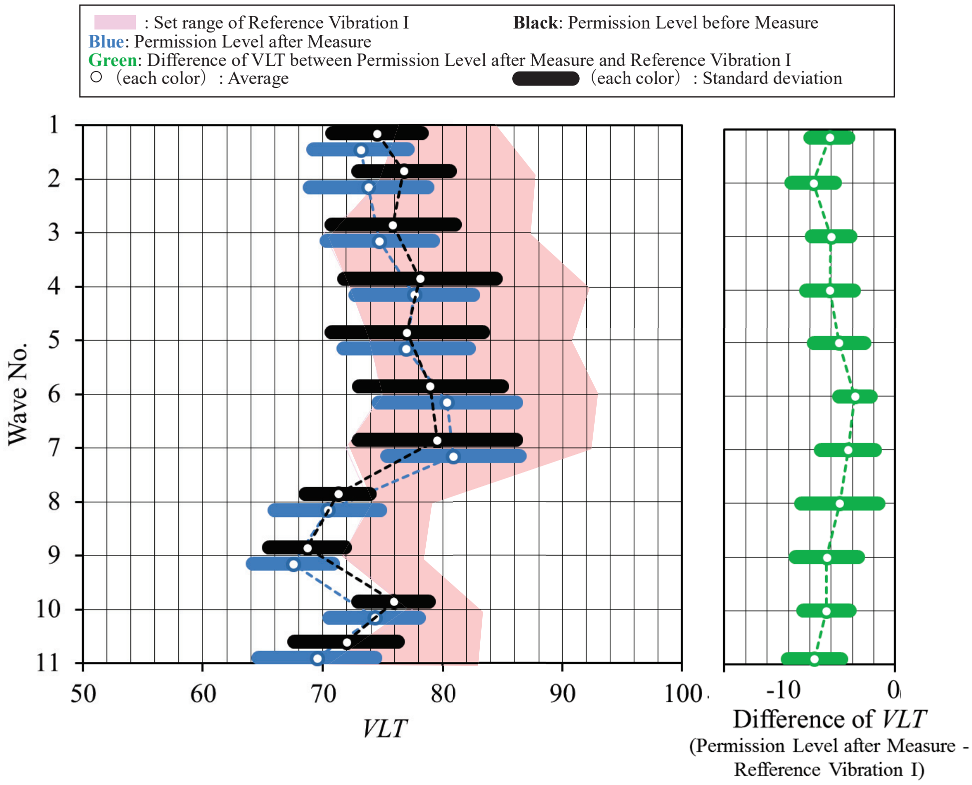


Figure 4 – Result of the test for reference vibration I

3.2 Tests on reference vibration II

Figure 5 shows the results of the tests for reference vibration II. The averages of Permission Level after Measure are to the right side of Permission Level before Measure. This implies that the measured and reduced vibrations were permitted even if the amplitude of vibration was not reduced to Permission Level before Measure. The standard deviations of the difference between Permission

Level after Measure and reference vibration II are clearly smaller than those of the difference between Permission Level after Measure and reference vibration II. The averages of differences between Permission Level after Measure and reference vibration are approximately –8 dB for all waveforms.

Figure 6 shows the cumulative frequency distribution of the permission level against the difference between Permission Level and reference vibration II. The normal distribution shown in Figure 6 was calculated using the averages and standard deviations. From the figure, it was observed that 50% of the permission level reduced by approximately 8 dB and 90 % of the permission level reduced by approximately 12 dB. It was also observed that the cumulative frequency distribution of the test results corresponded closely with the normal distribution, thus it is supposedly possible to estimate an advisability of a vibration measure in advance.

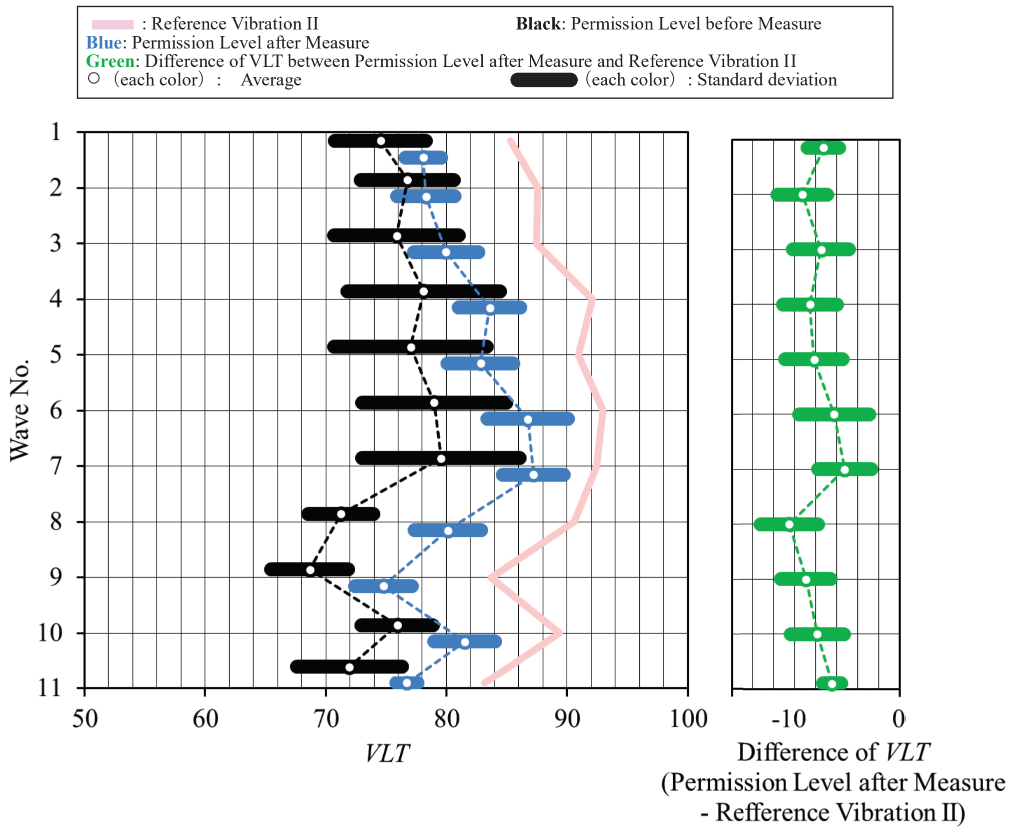


Figure 5 – Result of the test for reference vibration II

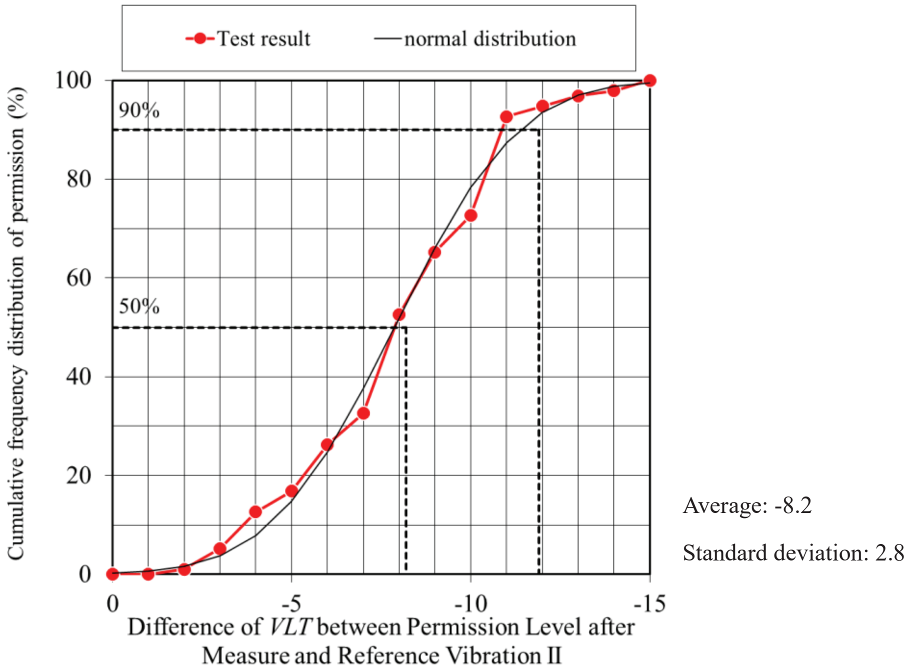


Figure 6 – A cumulative frequency distribution of permission against the difference between Permission Level and reference vibration II

4. CONCLUSIONS

When using countermeasures against floor vibration in an existing building, it is adequate that vibration levels are reduced to permission levels for each inhabitant. However, in cases where vibration levels are rather large before the implementation of countermeasures, it was shown that these levels can be adequately reduced by a certain level, even if the level of reduced vibration is larger than permission level before implementing countermeasures.

Deciding permission levels against the absolute amplitude of vibration varies by the individual. If test subjects have been previously exposed to large vibration levels, individual judgment of permission against reduction level of vibration varies to a lesser extent. For the evaluation of countermeasures against floor vibration in existing buildings, reduction levels from before implementing countermeasures can potentially be a useful index.

REFERENCES

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