EasyChair Preprint

№ 1414

Shaking Table Test on Quantification of Anxiety using Head Mount Display during Strong Motion

Junglin Xu, Satoshi Ishikawa, Toru Takahashi and Takuzo Yamashita

August 24, 2019

Shaking Table Test On Quantification Of Anxiety Using Head Mount Display During Strong Vibration

Jinglin Xu [1], Satoshi Ishikawa [1], Toru Takahashi [2]
Chiba University
1-33, Chiba, 263-8522, Japan
ayfa6114@chiba-u.jp, basketball_center_1020@yahoo.co.jp, takahashi.toru@faculty.chiba-u.jp

Takuzo Yamashita [3]
National Research Institute for Earth Science and Disaster Resilience (NIED)
3-1, Ibaraki, 305-0006, JAPAN
tyamashi@bosai.go.jp

ABSTRACT

Nowadays, more and more people pay attention to the safety and health of human body under strong vibration. Quantifying the level of anxiety under vibration is valuable for clarifying the structural performance needed for human safety and will facilitate the communication between structural designers and clients about comfort. Chiba University has been devoting itself to the study of the anxiety of human-body induced by earthquake vibration since 2000, and has preliminarily obtained a curve to describe the Anxiety quantitatively. It is defined as "Anxiety curve of Human Body under Vibration"(AHV). In this study, a shaking-table test for humans who are wearing a head-mounted display (HMD) was performed to quantify the levels of anxiety during strong vibration. A virtual scene consisting of a living room with several pieces of furniture was simulated using virtual reality (VR). The period, speed, and shape of input vibration were varied for each VR-based situation. The results of the test show that a longer shaking period produced lower levels of anxiety. The results of this study will further advance our understanding about how vibration in a building affects the anxiety of its occupants during strong vibration.

1 INTRODUCTION

When a strong vibration occurs, evaluating the ability to evacuate according to factors such as human anxiety is very important for ensuring human-body safety. In this study, a shaking-table test for humans using a head-mounted display (HMD) was performed to quantify anxiety during strong ground vibration. To evaluate the influence of strong vibration, virtual reality (VR) was used to simulate a living room with a table, sofa, chairs, television, bookshelf, and sideboard during strong vibration. The aim was to assess the difference in the level of anxiety experienced by subjects using a shaking table and an HMD that displayed views of a virtual scene in which the furniture either fell to the side or forward under the vibration.

2 SHAKING-TABLE TEST

The shaking-table test (Fig.1) were performed as early as from Oct, 2000. The recent experiment was operated in Jul 22th, 2019. We conducted experiments on 140 subjects (95% male and 5% female), using a simple vibration table installed in the Building Engineering Laboratory at

Chiba University, Japan. We asked subjects to answer a questionnaire after experiencing multiple vibration that were presented with a virtual scene of falling furniture, displayed under the same vibration conditions. In each experiment, the subject's bioinformatics were measured and the acceleration was measured by accelerometers attached to the shaking table and one subject's head.

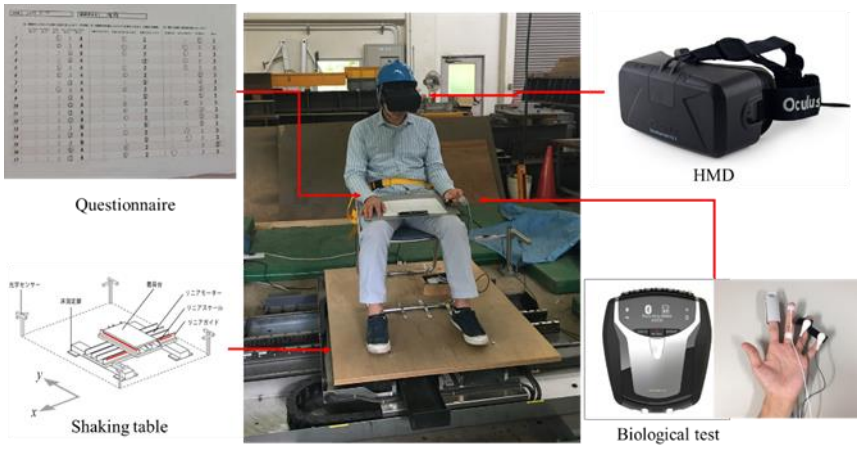

Fig. 1 experimental setup

2.1 HMD

In the experiment, we use HMD (Oculus rift) as the display device. It can block the visual contact between the experimenter and the outside environment during the experiment. It can output the specified sound, image and other information according to the needs of the experiment. while the shaking table operates with the input waves, the display device can simultaneously play the three-dimensional video image, such as the collapse and offset of indoor furniture. It can help us to obtain the most real anxiety data of the subjects.

Fig. 2 Virtual scene in which furniture collapses:
(left) before vibration and (right) after vibration.

2.2 The experiment wave of the vibration

In the test, six vibration periods (0.4, 0.6, 1.0, 2.0, 3.0, and 4.0 s), four levels of input vibration (0.1, 0.15, 0.3, and 0.6 m/s), and five input directions (x-direction, y-direction, O-shape, 8-shape, and ∞-shape) were performed for each viewpoint of the virtual scene. However, some of these inputs were abandoned because of the limitations of the stroke and maximum acceleration of the vibration table. Therefore, each participant was subjected to a total of 142 inputs in this experiment. Vibration was continued for a duration of 12 to 32 s, and the excitation sequence was random to take into account the psychological impact on the subject. The magnitude of the internal change has a significant impact on three indoor conditions: whether the bookshelf falls, the television falls, or the table falls.

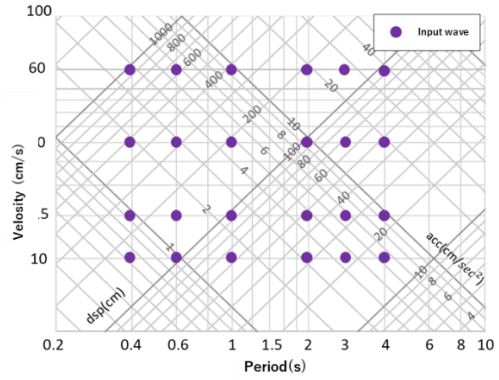

Fig. 3 the experiment wave of the vibration.

2.3 Questionnaire

The subjects were asked to answer a questionnaire after each shaking-table vibration was completed. The questionnaire evaluated three main aspects: the degree of anxiety (on a scale from 0 to 4), ability to take action (on a scale from 0 to 2), and difference between shaking and display. The questions (Partial content) are shown in Table 1.

2.4 Biological test

In order to identify the validity of the anxiety questionnaire, we installed NeXus-10 MarkIIon one hand of the subjects. It consists of blood volume pulse (BVP), electro dermal activity (EDA), temperature (TMP). By comparing the data, some probabilistic errors can be eliminated from the data of the questionnaire.

Table 1 Questionnaire (Partial content)

(A) How did you feel in the shaking table experiments? (Degree of anxiety)	
0. I had no anxiety.	1. I felt a little anxiety.
2. I felt anxiety.	3. I felt some anxiety.
4. I felt a lot of anxiety.	
(B) Do you think you could take action if it were the real earthquake? (Ability to take action)	
0. I can take action.	1. I am not sure whether I can take action or not.
2. I do not think I can take action.	
…	

3 TEST RESULTS

By comparing the effects of three generations of HMD used in the past, it is found that the standard deviation is smaller in the case where HMD is mounted, and the stability of the data is improved.

3.1 Analysis of questionnaire

The results of the questionnaire after each input vibration are presented with the bubble charts (Fig. 4). The X axis is the maximum speed of input wave and the Y axis is the level of anxiety. The size of the bubble is related to the number of subjects who gave the same answer. Finally, a straight line was fitted to the data using the weighted least squares method. In this study, we focus on the degree of anxiety in the questionnaire results.

According to figure 4, the degree of anxiety of type O is relatively high, and It's guessed that it is due to the large eccentricity of type O. On the other hand, the degree of anxiety of type Y is relatively low. It's guessed that the seat is supported in the front and rear directions, part of the body sloshing is eliminated. In the vibration video of HMD, the long edge of furniture is set in the Y direction. so it is not easy for the experimenter to catch the furniture's moving in this direction, which indirectly reduces the occurrence of anxiety.

According to figure 5, Under the same speed of vibration, the shorter the period, the higher the degree of anxiety. In other words, a longer shaking period produced lower levels of anxiety. The author thinks that it is caused by the rising of the acceleration with the shortening of the period. Under the same period of vibration, the faster the speed, the higher the degree of anxiety.

Based on the Figure 6 it is found that the value of anxiety increases with the increase of acceleration. This shows that in addition to speed, acceleration is also an important factor affecting human-body anxiety. When the acceleration exceeded 600 cm/s2, the value of anxiety was close to 4, which indicated that the subjects felt great anxiety.

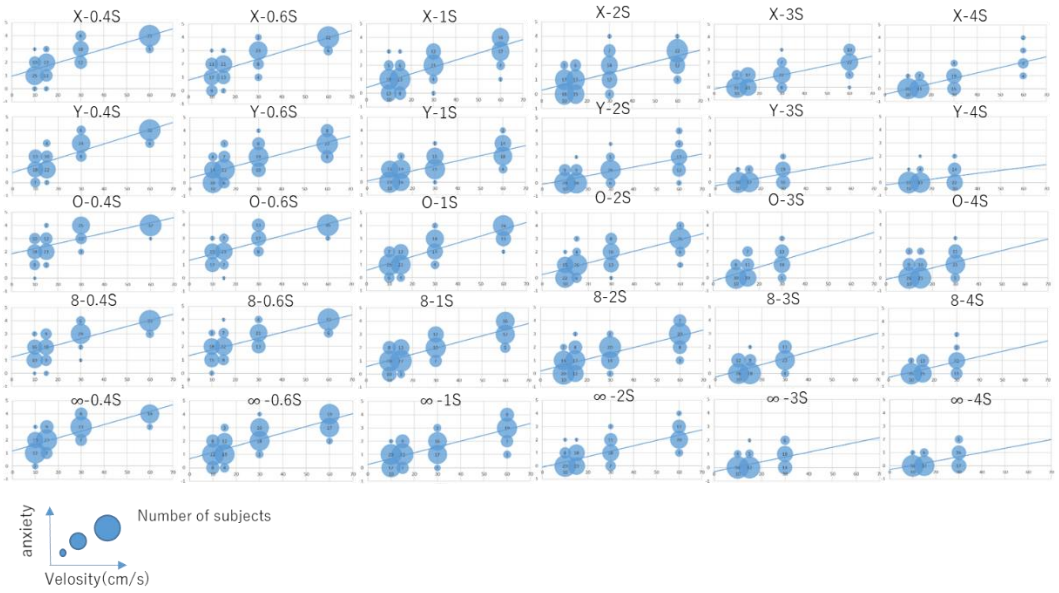

Fig. 4 Bubble charts of anxiety

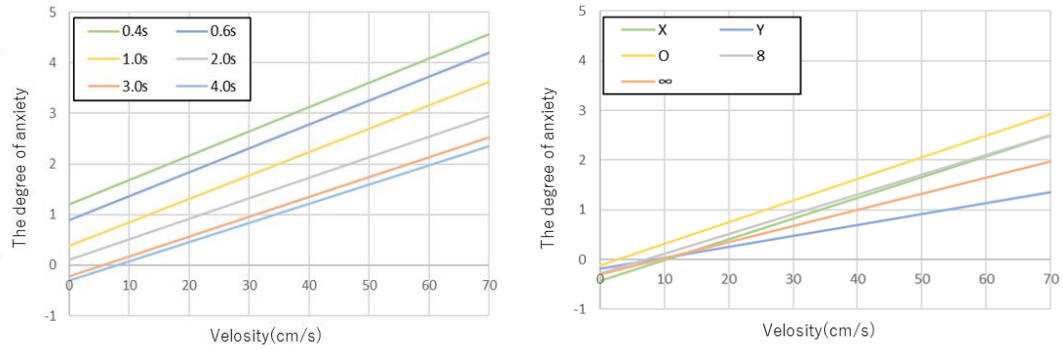

Fig.5 comparison of anxiety line

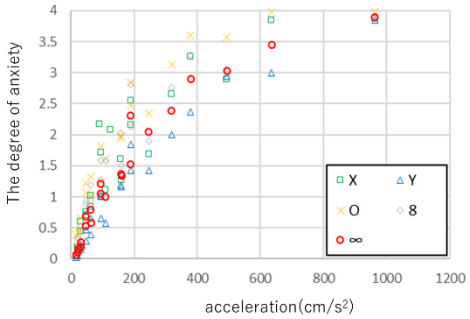

Fig.6 The correlation of anxiety and acceleration

3.2 Analysis of Biological test

In this study, three biological information such as BVP (blood volume pulse), EDA (electro dermal activity), and TMP (temperature: skin temperature) are measured. However, the noise was added to the result of BVP with the strong vibration. Some analytical values were overvalued.

According to Fig.7, It shows that the value of EDA is inversely proportional to the period of vibration. The smaller the period of vibration, the larger the value of EDA. On the other hand, the value of EDA is proportional to the speed of vibration. As the speed increases, the value of EDA increases. Especially when the acceleration of vibration exceeds 200 cm/s2, there is an obvious increase of the value of EDA. Among all the formation of vibration, the increasing trend of O-type is the most obvious.

The reaction value of TMP becomes larger as the speed increases. when the acceleration of vibration exceeds 100 cm/s2, there is an obvious correlation between the acceleration and TMP.

The above analysis of the data is basically consistent with the results of the questionnaire, which proves the validity of the questionnaire.

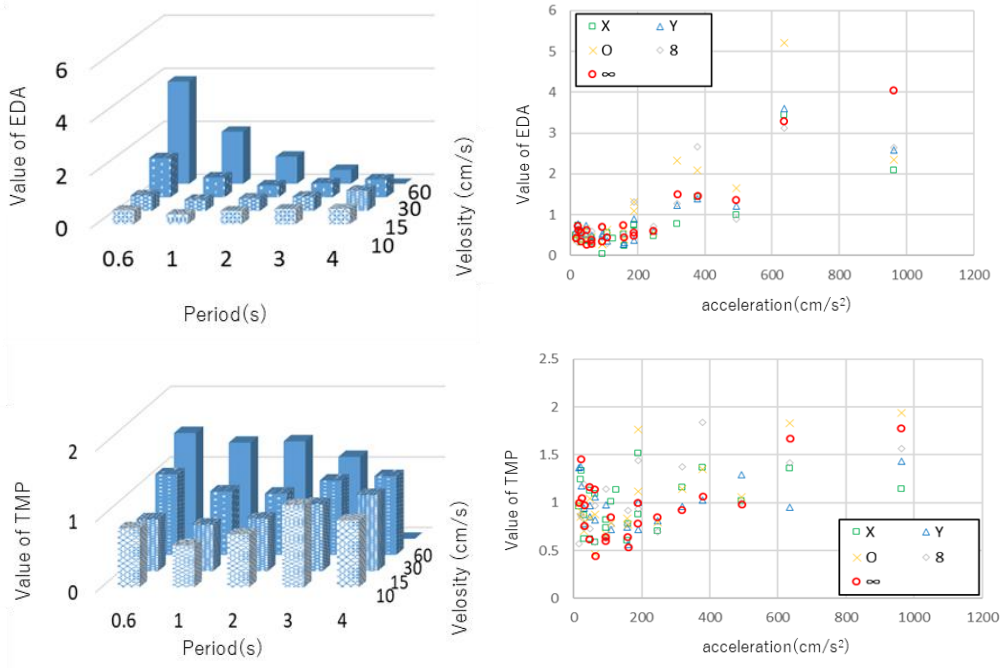

Fig. 7 anxiety analysis of Biological test

3.3 Anxiety curve of Human Body under Vibration (AHV)

Based on the results of the questionnaire and biological test, Fig.8 is produced to evaluate the anxiety of the strong vibration. Firstly, divide bubble graph from each periodic zone, and draw an approximate straight line. Then, an approximate straight line is used to obtain the velocity for each anxiety value. Period of building is plotted on the trapetite diagram on the X-axis and the velocity of vibration is plotted on the Y-axis. It is connected with the same anxiety values. Do it at each vibration type, and a performance evaluation curve was obtained (Fig.8). Connect the lowest point of the evaluation curve in all vibration types and produce the most dangerous AHV curve.

Comparing with each vibration type, it is understood that the degree of anxiety in the O-type is higher than in the Y type. In addition, the slope of AHV is especially larger in the short period side in the region where the speed is from 0 to 40 cm/s. From this fact, it is understood that the rise in the acceleration leads to the rise of the anxiety. On the other hand, the slope of the evaluation curve is smaller in the long period side, and the rise of the velocity affects the rise of the anxiety. Especially, when the speed exceeds 40 cm/s, the slope of the anxiety evaluation curve on the short period side is smaller than the long period side. It shows that the speed of vibration has a great influence on the value of the anxiety than the acceleration of the vibration.

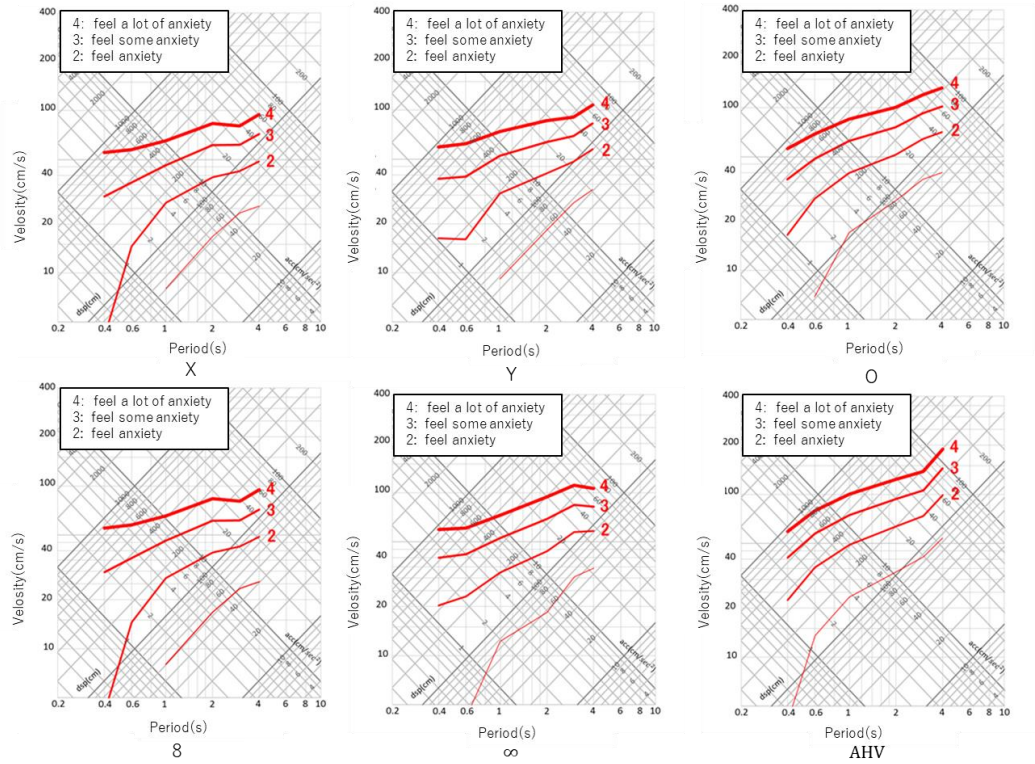

Fig. 8 Anxiety curve of Human Body under Vibration (AHV)

4 CONCLUSION

In this study, we investigated the effect of vibration parameters on human anxiety from questionnaires and biometric test using HMD. As the result, it was found that: the anxiety of human body under vibration is closely related to the formation, speed, acceleration and period of the vibration. It is easier to feel anxiety under the vibration of O type than the vibration of Y type. A longer shaking period produced lower levels of anxiety. It also can be concluded that in the short period of vibration, The greater the speed, the greater the anxiety. In the long period, the greater the acceleration, the greater the anxiety. However, there are still some defects in this experiment. For example, the age and sex ratio of the subjects are still not uniform. The stock of experimental data is still not large

enough. In the next experiments, we will constantly improve the shortcomings in this area to get more accurate expressions about anxiety of human-body under vibration.

REFERENCES

[1] T. Takahashi, T. Suzuki, T. Saito, T. Azuhata, and K. Morita: Shaking Table Test for Indoor Human Response and Evacuation Limit, Joint Proc. 7CUEE & 5ICEE, Tokyo Institute of Technology, Paper No. 17, pp. 187-193, 2010.

[2] T. Takahashi, M. Sadahiro, T. Saito, T. Azuhata, K. Morita, K. Noguchi, and C. Minowa: Shaking Table Test on Indoor Seismic Safety of High-rise Buildings, Part I. Performance Test on BRI Large Stroke Shaking Table. Part II. Movement of Furniture Under Long Period Earthquake Ground Motion, Proc. 14WCEE, Paper IDs: S10-024 and S10-014, 2008.

[3] T. Takahashi, M. Sadahiro, T. Suzuki, T. Saito, T. Azuhata, K. Noguchi, and C. Minowa: Shaking Table Test on Indoor Human Performance Limit in Strong Motion for High-Rise Buildings, Proc. 8th Pacific Conference on Earthquake Engineering, Paper No.131, 2007.

[4] T. Takahashi, A. Mazaki, T. Saito, T. Azuhata, and K. Noguchi: Shaking Table Test on Indoor Human Performance Limit in Strong Motion, Proc. 12JEES, Paper No. 0322, 2006.

[5] T. Takahashi, T. Azuhata, T. Saito, and K. Ohtomo: Structural Performance Considering Human Response Limit During Strong Earthquake, Proc. JCOSSAR2003, JSME, Vol. 5, pp. 825-828, 2003.

[6] T. Takahashi, T. Azuhata, K. Noguchi, D. Kounsana, and Y. Watanabe: Shaking table test on indoor human response and its feeling in strong ground motion, Summaries of Technical Papers of Annual Meeting of the AIJ, B2 pp. 861–864, 2001.

[7] M. Wada, A. Masuzawa, T. Yamashita and T. Takahashi: Experimental Study on Quantification of Anxiety under Strong Motion using Two Dimensional Small Shaking Table, Journal of Structural Engineering, Architectural Institute of Japan, Vol. 64B, pp. 345-350, March 2018.

[8] Yohji Watanabe, Ginga Kimura, Yukiko Nakamura, Toru Takahashi: Experimental study on the quantification of anxiety level during strong earthquake, Part 1 Consideration from the questionnaire results, Architectural Institute of Japan Academic Papers Summary pp. 919-920, 2014.9.

[9] Akira Masuzawa, Yuudai Ohno, Ginga Kimura, Yukiko Nakamura, Toru Takahashi: Experimental study on the quantification of anxiety level during strong earthquake, Part 3 Reproduction of the situation during strong earthquake using HMD, Architectural Institute of Japan Academic Papers Summary pp. 865-866, 2015.9.