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Rattling thresholds of windows and doors by ground vibration *

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This paper reports the rattling thresholds of windows or doors caused by ground vibrations. The frequency characteristics of the threshold curves by vertical and horizontal vibration were measured. The threshold for horizontal vibration is lower than the threshold for vertical vibration. When rattling occurs, the acceleration level of the 3rd and 5th harmonic frequencies increases sharply.

1. INTRODUCTION

Windows or doors are vibrated by low frequency noise and/or ground vibration and complaints occur due to the rattling noise of fittings. Low frequency noises caused by factory activity, running of high-speed trains and highway bridges sometimes rattle windows or doors of neighbourhood houses. Ground vibration together with low frequency noise are also observed around the houses in these cases. To take adequate countermeasures, engineers must identify the main cause of rattling phenomena. It is necessary to know the rattling threshold as a minimum vibration level to cause rattling phenomena by ground vibration and the rattling threshold as a minimum sound pressure level to cause rattling by low frequency noise. Kitamura and others have already reported the rattling threshold of low frequency noise[1].

We measured rattling thresholds of Japanese and European style windows and doors. One window and six doors are chosen as samples. A window and a door with glazing were shaken vertically. Six doors were shaken horizontally in a perpendicular direction to the door surfaces.

2. SAMPLES OF WINDOWS AND DOORS

The samples were selected from windows and doors ordinarily used in Japan as shown in Table I. These are classified as sliding type, or hinged type and with or without glass. The rattling thresholds of all these samples except the small Garasudo due to low frequency noise were published[1].

The Garasudo consists of wooden frames and beams. Five glass panels are held loosely in grooves in the frames and the beams. It slides on a steel rail in a doorframe with two metal wheels. The top is held in a groove of the doorframe.

The Shoji is a Japanese traditional sliding door and consists of a wooden frame and beams with a thin paper pasted to the back of the frames and beams. The top and the bottom are held in the grooves of a doorframe.

The Fusuma resembles the Shoji. Thick paper or thin plywood are pasted on both sides of Fusuma.

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Table I Samples of doors and windows

Sample type	sliding/hinged	with/without glass
Small Garasudo (Japanese style window)	sliding	with glass
Garasudo (Japanese style door)	sliding	with glass
Shoji (Japanese style.Thin paper pasted door)	sliding	without glass
Fusuma (Japanese style. Thick paper pasted door)	sliding	without glass
European style wooden door	sliding	without glass
European style solid wooden door	hinged	without glass
European style wooden door	hinged	with glass

3. RATTLING THRESHOLD DUE TO VERTICAL VIBRATION

A large shaker (EMIC F-1000BD/A) in the Yamanashi Prefectural Industrial Technology Center was used for vertical vibration. The shaker can drive a door with a doorframe and supports. The supports can hold the door vertically (within 1 degree). A normal Garasudo and a small (half sized) Garasudo were chosen as samples. The Garasudo was laid down on the shaker as shown in Fig. 1, because the height of the experimental room is too low to stand it vertically on the shaker. The samples were shaken sinusoidally at 1/3rd octave band centre frequencies from 5Hz to 100Hz. An observer puts his ear at 5-10cm from the sample surface and scans the surface all over to hear rattling noise and records vibration levels at the beginning or the ending of rattling by the ascent or descent method. The experiments were carried out three times by each method. The rattling threshold is calculated from the average of the results. The observer is a man in his twenties who is healthy and has normal hearing. The rattling noise is caused by the collision between the parts of fitting. It was easy for him to detect the rattling phenomenon because the rattling noise suddenly grew and had a characteristic timbre.

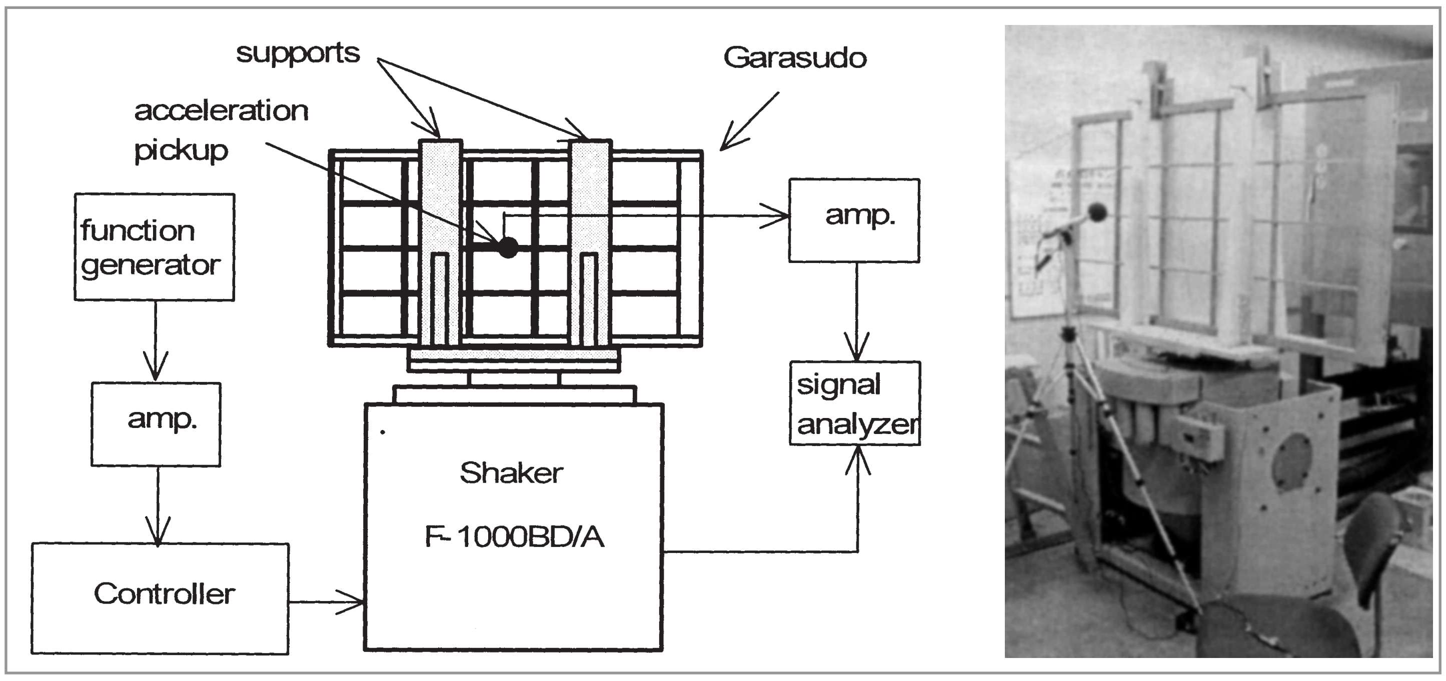

Figure 1. Experimental system for vertical threshold

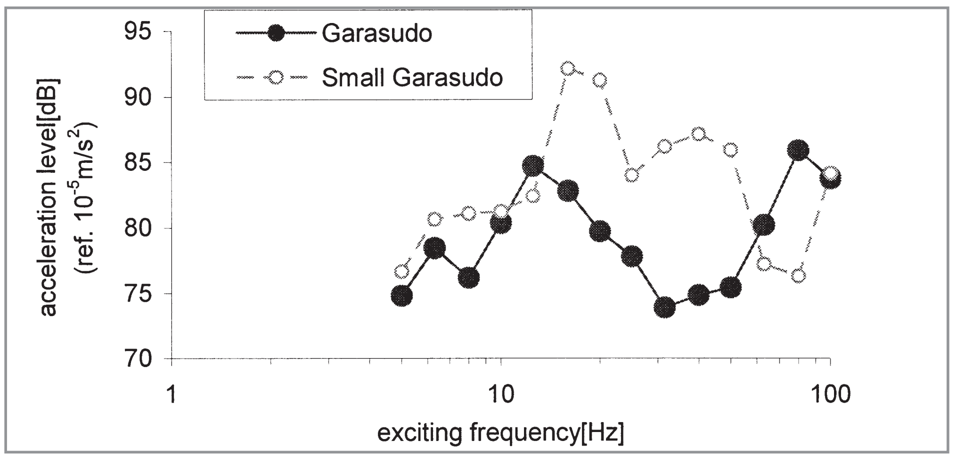

Figure 2. Vertical threshold

Fig.2 shows the rattling thresholds of Garasudo and small Garasudo. The X axis gives the exciting frequency. The Y axis gives the lowest exciting acceleration level (the rattling threshold). In this paper, the reference value of acceleration is 10^{-5}m/s^2 (Japanese reference value) and to convert the value into ISO level (ref. 10^{-6}m/s^2) add 20dB to the level. The low threshold level indicates that the sample is easily rattled at the frequency. In Fig. 2, the thresholds have minima at 31.5 Hz in the Garasudo and at 25 and 80Hz in the small Garasudo. These minima are caused by resonance of the samples. The threshold of the normal Garasudo is lower than that of the small Garasudo at many frequencies.

4. RATTLING THRESHOLD BY HORIZONTAL VIBRATION

The ratting thresholds were measured by a shaker (Akashi ASO-92). The samples with a doorframe were put on a vibration stage as shown in Fig. 3. Four wires were stretched between the top of the frame and the corners of the vibration stage to keep the same acceleration level on the top and the bottom of the sample. The supports between the middle of the doorframe and the corners of the vibration stage fix the doorframe. Three acceleration pickups were put on the top, the centre of sample and the side of vibration state. The pickups sense the acceleration in the perpendicular direction to the surface of the sample.

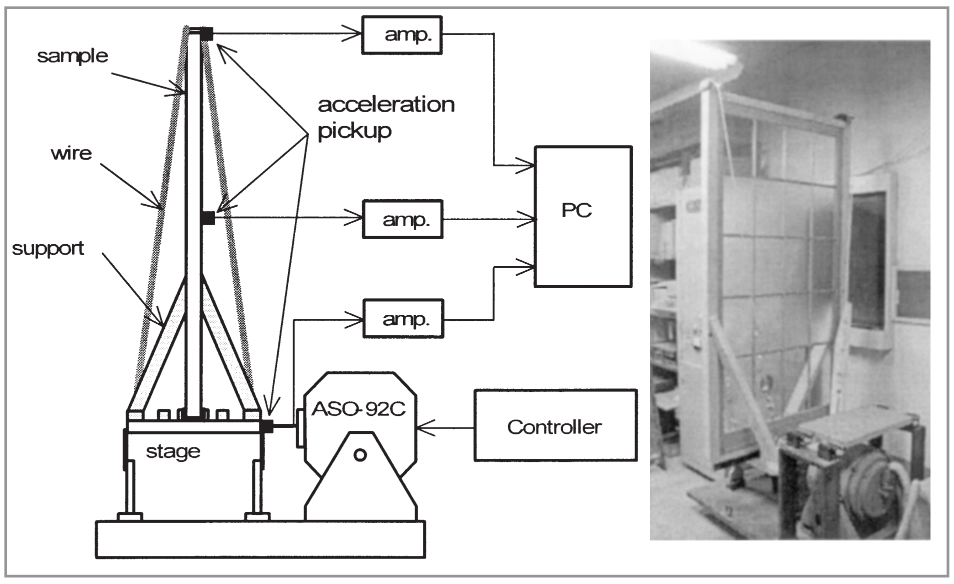

Figure 3. Experimental system to measure horizontal threshold

The rattling thresholds of all the samples for horizontal vibration are shown in Fig. 4. Almost all threshold curves show a tendency to rise with increasing frequency. These curves can be classified into two groups, with glass and without glass. The thresholds with glass are about 10dB lower than without glass. The thresholds of European style doors without glass are higher than the others.

5. VERTICAL VIBRATION VS. HORIZONTAL VIBRATION

Fig. 5 shows all rattling, threshold curves for vertical vibration and for horizontal vibration. The thresholds for horizontal vibration are lower than the thresholds for vertical vibration. That indicates that the horizontal vibration is able to rattle doors more easily than the vertical vibration.

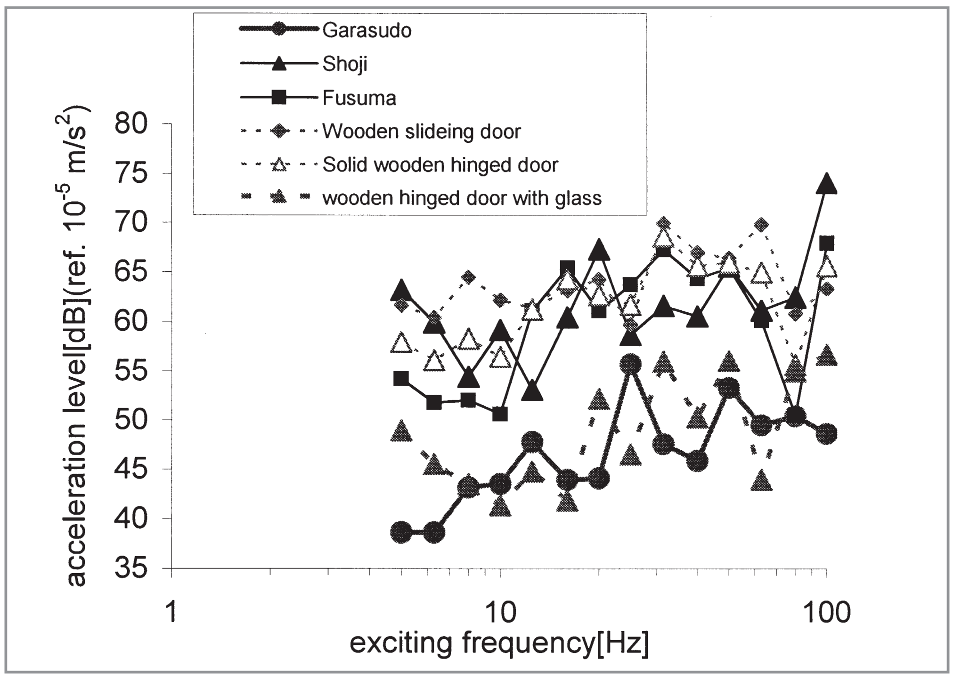

Figure 4. Horizontal threshold

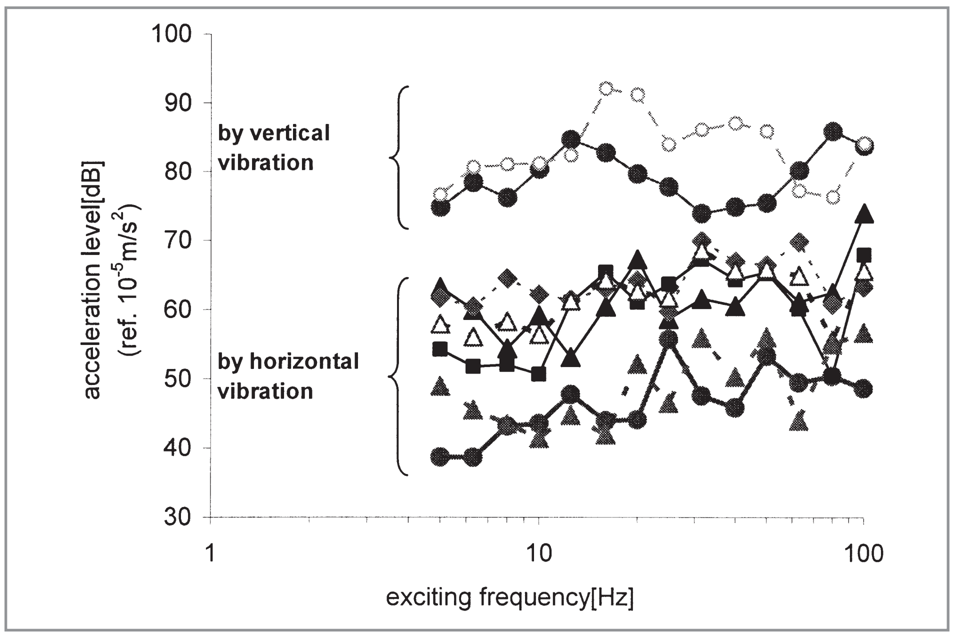

Figure 5. Vertical threshold and horizontal threshold

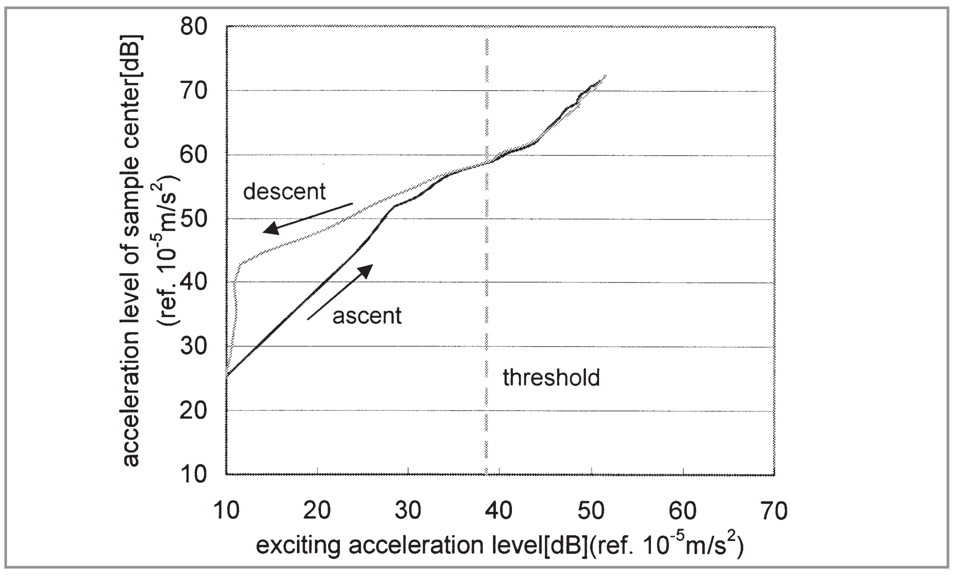

Figure 6. Hysteresis of Garasudo (exciting frequency is 6.3Hz)

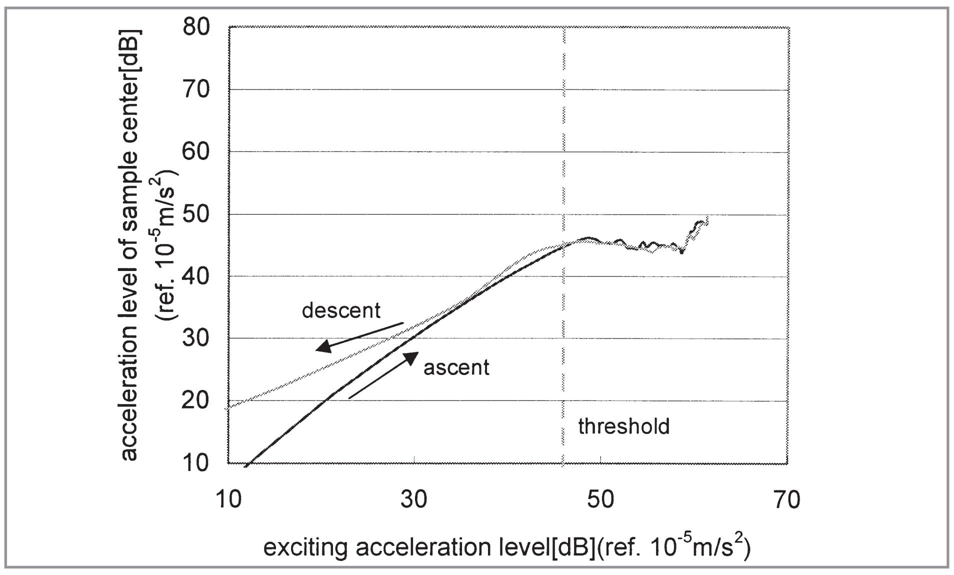

Figure 7. Hysteresis of Garasudo (exciting frequency is 40Hz)

6. HYSTERESIS OF SURFACE ACCELERATION

A hysteresis curve is obtained by plotting the acceleration level of a sample centre according to the exciting level at the ascent or descent method. The hysteresis curves of the Garasudo at 6.3Hz and 40Hz are shown in Fig. 6 and Fig. 7. The vertical broken line means the threshold levels of the frequency. The hysteresis curve of 6.3Hz increases continuously according to the exciting level. However the hysteresis curve of 40Hz is saturated over the threshold level. It means the surface vibration change from a linear phenomenon to a nonlinear phenomenon at the rattling threshold level.

Fig. 8 shows the hysteresis curves analysed by the fundamental, 3rd and 5th frequency of Fig. 6. The curve of the fundamental frequency is roughly linear. The 3rd and the 5th harmonic frequency curves increase sharply around the threshold level. The rattling will be detected more easily by the 3rd or 5th harmonic frequency than the fundamental frequency. Moreover, it is understood that the observer had judged correctly the rattling phenomenon in measurements of rattling thresholds.

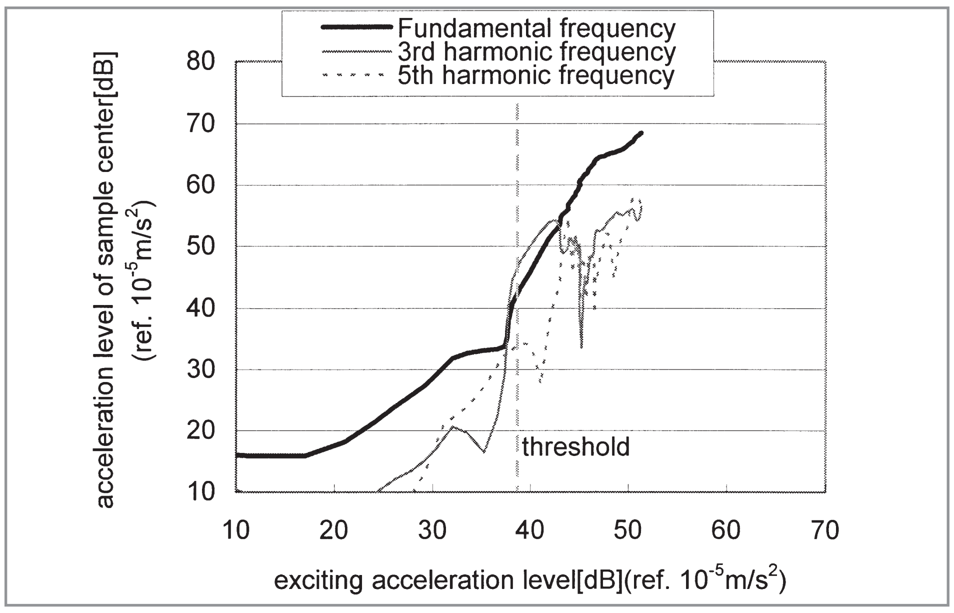

Figure 8. Hysteresis of Garasudo (exciting frequency is 6.3Hz, ascent method)

7. CONCLUSION

The rattling thresholds of Japanese and European style windows and doors by ground vibration were measured. The rattling thresholds tend to increase according to the exciting frequency. The threshold is a minimum at the resonance frequency of the window or door. The threshold of doors with glass is about 10dB lower than without glass. The threshold for horizontal vibration is about 35dB lower than the threshold of vertical vibration. Engineers must consider horizontal vibrations when planning countermeasures. The acceleration levels of doors at the 3rd and the 5th harmonic frequencies increase sharply when the rattling phenomenon begins.

REFERENCE

1. Toshiya Kitamura, Jun-ichi Takano, Yosuke Imura and Shinji Yamada, Threshold of Rattling of Windows and Doors by Low Frequency Noise, *Journal of Low Frequency Noise, Vibration and Active Control*, pp. 141-149, Vol. 19, No. 3, 2000.

IF EYES, WHY NOT EARS?

A new survey has revealed that eight out of ten people in the UK have never had their hearing tested, compared to just one in ten who have never had an eye examination. The poll of 4,000 people conducted by David Ormerod Hearing Centres found that three quarters of people over the ages of 50 have never had a hearing test despite the fact that 40% of people in this age group will have some degree of hearing loss. The survey coincides with the launch of Hearing Clearer Awareness Month, January 2007, which has been established to encourage people to get regular hearing tests - it is estimated that one in seven people in the UK has hearing loss and the average waiting time for a hearing test on the NHS is 47 weeks. It also found that two thirds of people have a friend or relative that they believe has undiagnosed hearing loss, whilst 27% know two or more people who they think could benefit from a hearing aid. Half admitted they find it frustrating speaking to someone with hearing loss, whilst 41% are worried about losing their hearing, 80% would support a national hearing test screening programme.