Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

Effect of resilient channel and floating floor on floor impact sound insulation of wood-frame construction

Atsuo Hiramitsu (1), Tomohito Hirota (2), Manabu Tanaka (3) and Hiroshi Sato (4)

(1) Building Research Institute, 1 Tachihara, Tsukuba, Ibaraki, JAPAN
(2) Hokkaido Northern Regional Building Research Institute, 1-20 1jo 3chome, midorigaoka-higashi, Asahikawa, Hokkaido, JAPAN
(3) General Building Research Corporation of Japan, 5-8-1 Fujishirodai, Suita, Osaka, JAPAN
(4) National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba, Ibaraki, JAPAN

PACS: 43.40.Kd

ABSTRACT

The acoustic environment performance, especially floor impact sound insulation performance, is one of the important performances in the apartment houses. The heavy-weight floor impact sound becomes the problem more often than the light-weight floor impact sound in Japan. Moreover, the floor impact sound insulation performance of the wood-frame constructions is low compared with that of the concrete constructions. Therefore, we have studied the floor impact sound insulation performance of the wood-frame constructions. The floor impact sound insulation performance depends on specification of separation floor. This paper presents the effect of resilient channel and floating floor (dry double system floor) on floor impact sound insulation performance. The resilient cannels are little used for the wooden constructions and the floating floors are usually used for concrete constructions in Japan. The specifications with the resilient channels which were effective for the floor impact sound insulation were investigated. Furthermore, the reductions of transmitted impact sound of the floating floors were measured in accordance with ISO 140-11 [1] or JIS A 1440-1 [2] and -2 [3]. The reference floors are standardized lightweight floors (wooden constructions) in ISO 140-11 and concrete construction floors in JIS A 1440-1 and -2. Measured results indicate that the floating floors are effective in improving the floor impact sound insulation in the wood-frame constructions.

INTRODUCTION

It is often that an acoustic performance becomes the serious problem in Japanese apartment houses. There are many kind of noise source in the apartment houses, but the most serious issue is the floor impact sound. The floor impact sound is the noise heard in the room below caused by a human being movement or something falling. The floor impact sound has two types. One is the heavy-weight floor impact sound caused by jumping or walking. The other is the light-weight floor impact sound caused by dropping something.

Naturally enough, the wooden constructions usually have inferior performance of acoustical environments, in particular the floor impact sound insulation, to the concrete constructions. We have investigated the floor section with high performance of floor impact sound insulation for wood-frame construction. [4][5][6][7]

Bradley and Birta studied the effective stiffness of various common forms of resilient channels in the past paper [8]. However, the knowledge about the resilient channels was little because the resilient cannels are little used in Japan. The floating floors (dry double system floor) are the floor coverings that contained air layers. The floating floor is the most popular floor covering used in Japanese concrete construction, but it is rarely used in wooden construction apartment houses. In this paper, effects of resilient channels and floating floor on floor impact sound insulation are investigated for the wood-frame construction.

The facilities for measurements were three types; a wood-frame model building, a box frame-type reinforced concrete construction laboratory and a wood-frame construction laboratory. The separation floors with resilient channels or floating floors were constructed in each facility and the floor impact sound insulation were measured. Moreover, the reduction of transmitted impact sound of florting floor was measured.

EXPERIMENT – CASE A

Method

In CASE A, the floor impact sound insulation was measured in a wood-frame model building. The model building was four-floor fire-resistant building. The dimensions of room were 2,730 mm x 3,640 mm. Separation floor A-00 that had the standard fire-resistant specifications, was reference floor. Figure 1 shows the section view of A-00.

Table 1 shows the summary of the section specification of separation floor in CASE A. Separation floor A-01, A-02 and A-03 were the same as A-00 but with the floating floor in place of the composite finish flooring used in A-00. The floating floors are the floor coverings that contained air layers. Supporting legs with rubber vibration isolators supported the particle board, the wooden flooring etc. These floors are superior because the space facilitates the installation of plumbing facilities and the adjustable legs obviate the need for barriers such as steps to cover changes in level. Under the influence of air spring and propagation vibration the heavy-weight floor impact sound insulation performance is worse than with a concrete bare floor. The floating floors are the most popular floor covering used in Japanese concrete construction apartment houses. However, it is rarely used in wooden construction apartment houses. Floating floors A and B were commercially available for the concrete apartment houses and floating floor C was a trial product.

The floor impact sound insulation was measured in conformity with the requirements of JIS A 1418-2 [9] and JIS A 1418-1 [10]. The standard impact sources were set each five impact points and the floor impact sound pressure levels were measured in the sound-receiving rooms. The impact sources for measurement of heavy-weight floor impact sound were a car-tire source (defined in JIS A 1418-2) and a rubber ball source (defined in JIS A 1418-2 and ISO 140-11). The impact source for measurement of light-weight floor impact sound was a tapping machine (defined in JIS A 1418-1 and ISO 140-6 [11]).

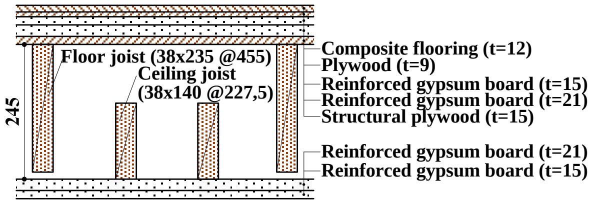

Figure 1. Sectional view of reference floor: A-00

Table 1. Section specification of separation floor in CASE A

Separation Floor	Specifications
A-00	Fire-resistant specifications + compote flooring (Reference floor)
A-01	Fire-resistant specifications + Floating floor A
A-02	Fire-resistant specifications + Floating floor B
A-03	Fire-resistant specifications + Floating floor C

Results

Figure 2 shows the differences in the floor impact sound pressure level relative to that of separation floor A-00 (i.e. reference floor in CASE A). A positive value in Figure 2 indicates that the room has higher floor impact sound insulation performance than the reference floor.

In separation floors A-02 and A-03, the heavy-weight floor impact sound insulation was improved by about 10 dB in 63 Hz octave band compared with A-00. Separation floor A-01 showed little difference in the heavy-weight floor impact sound insulation compared with A-00 in the case of the car-tire source. However, the floating floor successfully improved the heavy-weight floor impact sound insulation by about 3 dB in the 63 Hz octave band in the rubber ball source.

Separation floor A-01, A-02 and A-03 which had floating floor, showed improved the light-weight floor impact sound insulation compared with A-00. As was the case for the heavy-weight floor impact sound insulation, separation floor A-02 gave the highest light-weight floor impact sound insulation performance.

From the above results, we concluded that the floating floors are effective for the heavy-weight and light-weight floor impact sound insulation in wood-frame constructions.

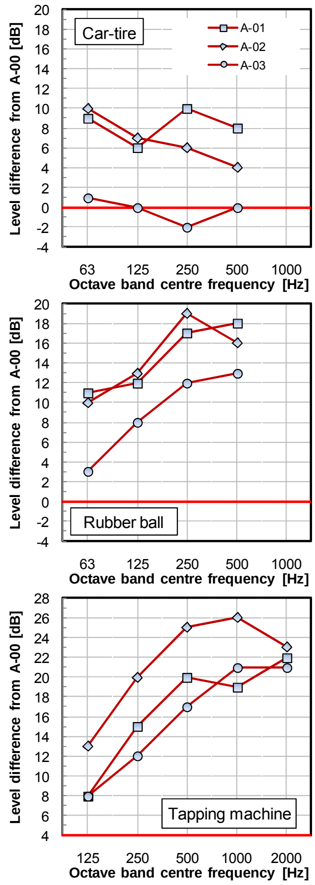

Figure 2. Level differences in floor impact sound levels of CASE A

EXPERIMENT – CASE B AND C

Method

In CASE B and CASE C, the floor impact sound insulation was measured in a laboratory which was made of a box frame-type reinforced concrete construction. The laboratory has the opening in the second floor. The dimensions of the opening are 3,754 mm x 2,844 mm. As for the floor impact sound, the influence of the sound from a ceiling is the highest, so it was executed the specimen only for floors in the opening.

Separation floor B-00 and C-00 were reference floors. Figure 3 shows the section view of B-00 and Figure 4 shows the section view of C-00. Separation floor B-00 had “direct ceiling (ceiling attached to floor joists)”. Separation floor C-00 had “independent ceiling (ceiling attached to ceiling joists and independent from floor joists)”. The direct ceiling and the independent ceiling are adopted the separation floor for the wood-frame constructions. [4]

Table 2 shows the summary of the section specification of separation floor in CASE B and CASE C. Separation floor B-01 was B-00 with the resilient channels, separation floor B-02 was B-01 with the furring strips and separation floor B-03 was B-02 with extra ceiling board. Separation floor C-01 was C-00 with the resilient channels, separation floor C-02 was C-01 with the furring strips and separation floor C-03 and C-04 had the floating floors in substitution for surface plywood of C-00. The resilient channels are used a lot in North America etc., but they are hardly used in Japan. They are called “SR bar” in Japan.

The floor impact sound insulation was measured as the same of CASE A.

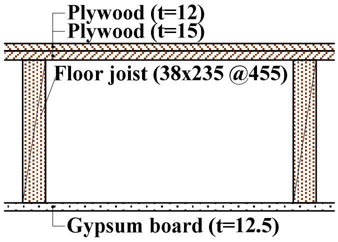

Figure 3. Sectional view of reference floor: B-00

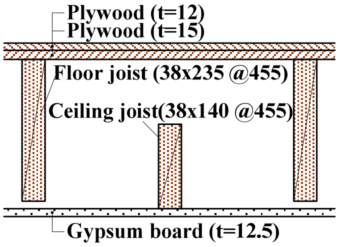

Figure 4. Sectional view of reference floor: C-00

Table 2. Section specification of separation floor in CASE B and CASE C

Separation Floor	Specifications
B-00	PW12 + PW15 + FJ + GB12.5 (Reference floor)
B-01	PW12 + PW15 + FJ + SR + GB12.5
B-02	PW12 + PW15 + FJ + Furring strips + SR + GB12.5
B-03	PW12 + PW15 + FJ + Furring strips + SR + GB12.5 + GB15
C-00	PW12 + PW15 + FJ + CJ + GB12.5 (Reference floor)
C-01	PW12 + PW15 + FJ + CJ + SR + GB12.5
C-02	PW12 + PW15 + FJ + CJ + Furring strips + SR + GB12.5
C-03	Floating floor D + PW15 + FJ + CJ + GB12.5
C-04	Floating floor E + PW15 + FJ + CJ + GB12.5

Note; PW: Plywood, GB: Gypsum board, SR: Resilient channel, FJ: Floor joist, CJ: Ceiling joist

Results

Figure 5 shows the differences in the floor impact sound pressure level relative to that of separation floor B-00 (i.e. reference floor in CASE B). There was little difference in the heavy-weight floor impact sound level between B-00, B-01 and B-02 in 63 Hz octave band. At the same time, B-01 and B-02 showed an increase in performance when compared with B-00 at 125 Hz octave band or higher frequency bands. B-03, which had extra board in the ceiling, showed improvement of the heavy-weight and light-weight floor impact sound insulation.

Figure 6 shows the differences in the floor impact sound pressure level relative to that of separation floor C-00 (i.e. reference floor in CASE C). There was little difference in the floor impact sound insulation performance between C-00 and C-00 with resilient channels unlike the specimen which had the direct ceiling. This is presumably because the rigidity of the independent ceiling is lower than the direct ceiling. This suggests that it was important to consider the stiffness and the vibration characteristic of the independent ceiling. The impact sound insulation performance of separation floor C-03 and C-04, which had the floating floor in substitution for surface plywood of C-00, were improved compared with C-00.

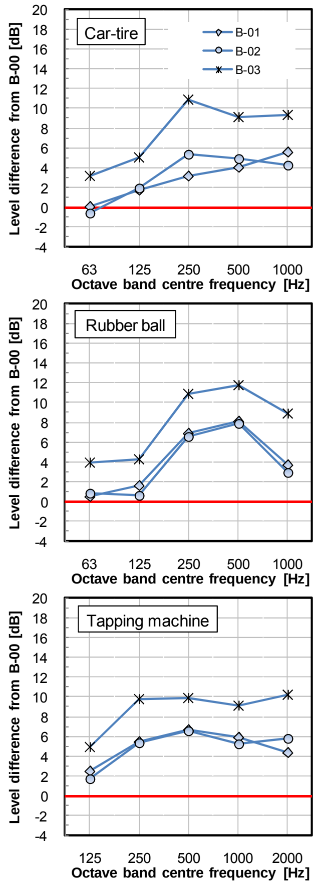

Figure 5. Level differences in floor impact sound levels of CASE B

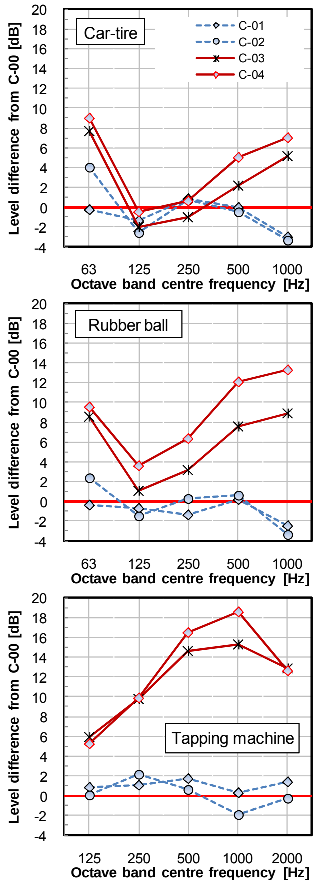

Figure 6. Level differences in floor impact sound levels of CASE C

From above results, the double layer ceiling board is effective for the floor impact sound insulation in direct ceiling. Therefore, it was confirmed that the floating floors had an effect on the heavy-weight and light-weight floor impact sound insulation performance.

EXPERIMENT – CASE D

Method

In CASE D, the floor impact sound insulation was measured in a laboratory which was made of a wood-frame construction. The dimensions of room were 2,730 mm x 2,730 mm. Separation floor D-00 was reference floor in CASE D. Figure 7 shows the section view of D-00. Separation floor D-00 was almost same as B-00.

Table 3 shows the summary of the section specification of separation floor in CASE D. Separation floor D-01 was D-00 with the resilient channels, separation floor D-02 was D-01 with the extra ceiling board and separation floor D-03 was D-02 with the extra ceiling board.

The floor impact sound insulation was measured as the same of CASE A.

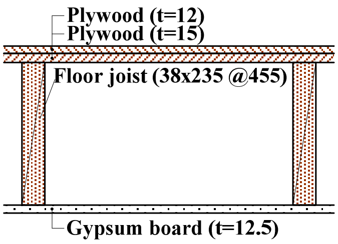

Figure 7. Sectional view of reference floor: D-00

Table 3. Section specification of separation floor in CASE D

Separation Floor	Specifications
D-00	PW12 + PW15 + FJ + GB12.5 (Reference floor)
D-01	PW12 + PW15 + FJ + SR + GB12.5
D-02	PW12 + PW15 + FJ + SR + GB12.5+ GB12.5
D-03	PW12 + PW15 + FJ + SR + GB12.5 + GB12.5 + GB12.5

Note; PW: Plywood, GB: Gypsum board, SR: Resilient channel, FJ: Floor joist

Results

Figure 8 shows the differences in the floor impact sound pressure level relative to that of separation floor D-00 (i.e. reference floor in CASE D).

There was little difference in the heavy-weight floor impact sound insulation performance in 63 Hz octave. band between C-00 and C-01 with resilient channels as reference floor A-01. Most of the heavy-weight floor impact sound pressure level difference of separation floor D-01 was the same as separation floor D-02, and an effect of the layer ceiling board was appeared. The value of the effect in 63 Hz octave band was 3 or 4 dB the case of double layer ceiling board, 5 or 6 dB in the case of triple layer ceiling board.

In the effect for the light-weight floor sound insulation, the extra ceiling board was effective in increasing. However, the value of the effect in 1000 Hz octave band or higher frequency band of separation floor D-01, which had single layer ceiling board, were almost 0 dB.

From above results, the double layer ceiling board is effective for the floor impact sound insulation in direct ceiling with resilient channels.

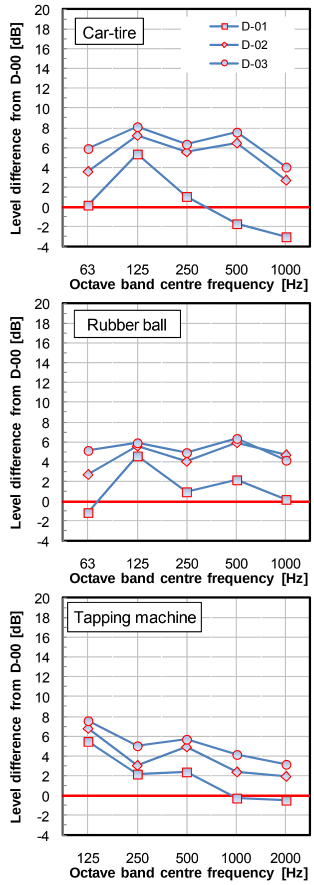

Figure 8. Level differences in floor impact sound levels of CASE D

DISCUSSIONS

Effect of resilient channels and floating floor on floor impact sound insulation

The measurement results of CASE A, CASE B, CASE C and CASE D were gathered to consider the effect of the resilient channels and the floating floor. Figure 9 describe level differences in floor impact sound levels of separation floor with the resilient channels and Figure 10 describes level differences in floor impact sound levels of separation floor with the floating floor.

With the separation floor which used the independent ceiling, there were few effects on the heavy-weight and the light-weight floor impact sound insulation. With the separation floor which used the direct ceiling, the effect of the floor impact sound insulation appeared by adding the board of the ceiling. The maximum value in 63 Hz octave band was approximate 6dB.

With the separation floor which used the floating floor, there were the effects on the heavy-weight and the light-weight floor impact sound insulation. Although there was an exception, the value of effect of the heavy-weight floor impact sound insulation was quite approximate 10dB.

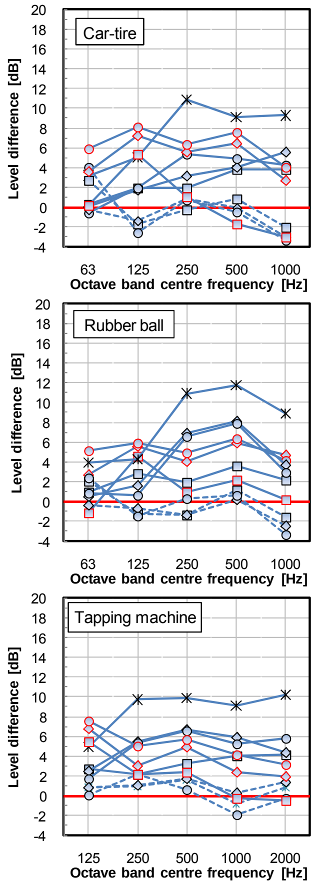

Figure 9. Level differences in floor impact sound levels of specimen with the resilient channels

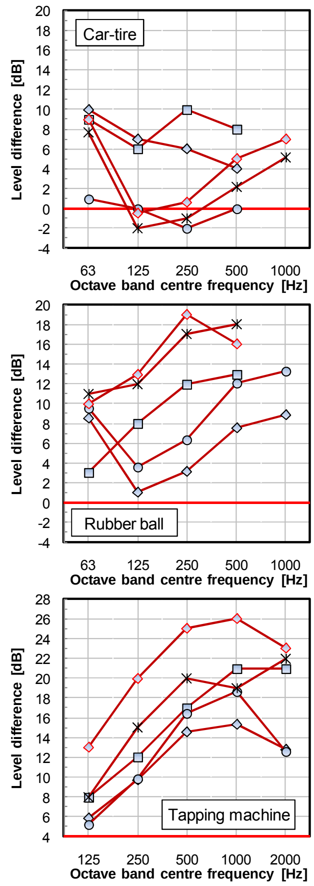

Figure 10. Level differences in floor impact sound levels of specimen with the floating floor

Reduction of transmitted floor impact sound of the floating floor

The reduction of transmitted floor impact sound of the floating floor was measured to consider the effect of the floating floor. The reduction of transmitted floor impact sound was measured in conformity with the requirements of JIS A 1440-2, JIS A 1440-1 and ISO 140-11.

Figure 11 shows the reduction of transmitted floor impact sound level (ΔL) of the floating floor D. The reference floors were the wood-frame slab (C-00) and the reinforced concrete slab (thickness of 200 mm). This concrete slab is a part of a laboratory of a box frame-type reinforced concrete construction, defined in JIS A 1440-2 and JIS A 1440-1. The reduction of transmitted heavy-weight floor impact sound level in 125 Hz octave band or higher frequency bands was almost accorded, but it was different in 63 Hz octave band. The reduction of transmitted light-weight floor impact sound level in 500 Hz octave band or less, but it was different in 1000 Hz and 2000 Hz octave bands. This is reason that they were difference the impedance of slabs and the influence of air spring in the floating floor.

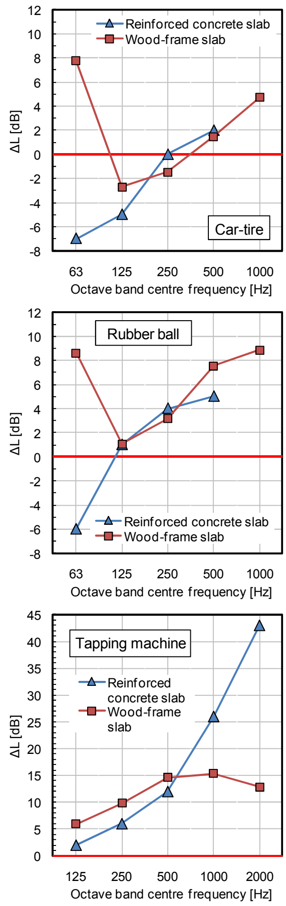

Figure 11. Reduction of transmitted floor impact sound of floating floor D

CONCLUSIONS

In this paper, we studied about effect of resilient channels and floating floor on floor impact sound insulation of wood-frame construction. In the case of separation floor which used the independent ceiling, there were few the effects on the heavy-weight and the light-weight floor impact sound insulation. In the case of separation floor which used the direct ceiling, the effect of the floor impact sound insulation appeared by adding the board of the ceiling. Furthermore, the separation floor which used the floating floor, there were the effects on the heavy-weight and the light-weight floor impact sound insulation for the wood-frame construction.

ACKNOULEDGMENTS

This research was supported by Japan 2x4 Home Builders Association and Council of Forest Industries Canada (COFI).

REFERENCES

1 ISO 140-11: Acoustics - Measurement of sound insulation in buildings and of building elements - Part 11: Laboratory measurements of the reduction of transmitted impact sound by floor coverings on lightweight reference floors (2005) 1 JIS A 1440-1:2007: Acoustics - Laboratory measurements of the reduction of transmitted impact sound by floor coverings on a solid standard floor - Part 1: Method using standard light impact source (2007)

2 JIS A 1440-1:2007: Acoustics - Laboratory measurements of the reduction of transmitted impact sound by floor coverings on a solid standard floor - Part 1: Method using standard light impact source (2007)

3 JIS A 1440-2:2007: Acoustics - Laboratory measurements of the reduction of transmitted impact sound by floor coverings on a solid standard floor - Part 2: Method using standard heavy impact sources (2007)

4 T.Hirota, H.Suzuki, M.Tanaka, A.Hiramitsu and H.Sato, "The Actual Conditions of the floor Impact Sound Insulation by the Questionnaire to Wood-Frame Construction Housing in Japan", *inter-noise 2009*, Ottawa, Canada, In CD-ROM (2009)

5 J.Ryu, H.Sato, A.Hiramitsu, M.Tanaka, T.Hirota and K.Kurakata, "Subjective Rating of Floor Impact Sounds in Wood-Frame Construction", *inter-noise 2009*, Ottawa, Canada, In CD-ROM (2009)

6 A.Hiramitsu, T.Hirota, M.Tanaka and H.Sato, "Development of Floors in Wood-Frame Construction to Improve the Floor Impact Sound Insulation", *inter-noise 2009*, Ottawa, Canada, In CD-ROM (2009)

7 M.Tanaka, T.Hirota, A.Hiramitsu and H.Sato, "Performance for Floor Impact Sound Insulation of Wood-Frame Construction Housing in Japan", *inter-noise 2009*, Ottawa, Canada, In CD-ROM (2009)

8 J.S.Bradley and J.A.Birta, "A simple model of the sound insulation of gypsum board on resilient supports", *Noise Control Eng. J.* **49**(5), pp.216-223 (2001)

9 JIS A 1418-2:2000: Acoustics - Measurement of floor impact sound insulation of buildings - Part 2: Method using standard heavy impact sources (2000)

10 JIS A 1418-1:2000: Acoustics - Measurement of floor impact sound insulation of buildings - Part 1: Method using standard light impact source (2000)

11 ISO 140-6: Acoustics - Measurement of sound insulation in buildings and of building elements - Part 6: Laboratory measurements of impact sound insulation of floors (1998)