Effectiveness of the rubber ball compared to the tapping machine as the impact source to measure the impact sound insulation properties

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ABSTRACT

ISO 16283-2: 2015(E) describes how a standardised tapping machine and a rubber ball are used as impact sources to determine floor impact sound insulation. These standard impact sources do not exactly replicate all the possible types of real floor impacts. According to the ISO 16283-2: 2015(E), the tapping machine is effective to asses a variety of light, hard impacts such as footsteps from walkers wearing hard-heeled footwear, while the rubber ball is more effective to assess heavy, soft impacts such as from walkers in bare feet or children jumping. However, only the standard tapping machine approach is used to measure the impact sound insulation properties of building floors in Australia. This paper explores the effectiveness of the rubber ball compared to the tapping machine as the impact source. In this study, the floor impact sound pressure levels were measured in the receiving room with different types of impact sources; standard tapping machine, rubber ball, human walking, running and jumping on different types of floors; timber, tile, vinyl and hybrid. The results show that rubber ball more closely replicates the impact sounds produced by the human activities such as from walking, jumping and running. Moreover, it is evident that when the building floor is a tile floor, a tapping machine produces higher sound pressure levels at higher frequencies than either hard-heeled or heavy/soft impacts.

1 INTRODUCTION

Apartment housing has become more popular in Australia in recent years. However, floor impact noise complaints have become a contentious issue. These floor impact noises are mainly caused by human activities such as walking, running and jumping on the floor. This causes discomfort to the residents living in the downstairs unit and has become a major cause of conflicts between neighbours. The quality of the floor impact insulation material and the ceiling underneath the floor are crucial in minimising the noise levels in downstairs units.

According to the International Organisation of Standardization (ISO), the weighted standard impact sound pressure level (L'nT,w) is used to measure the floor impact sound insulation rating and the lower the L'nT,w the better the floor impact sound insulation rating. The Building Code of Australia (BCA) states that when a floor is tested on site, the floor must have an L'nT,w not more than 62. However, many apartment buildings have their own Body Corporate By-Laws, which defines the floor impact insulation rating that needs to be achieved when floors are replaced or altered. ISO 16283-2: 2015(E) and ISO 717-2: 2013(E) describe how a standardized tapping machine and the rubber ball are used as impact sources to determine floor impact sound insulation ratings. This paper explores the effectiveness of the rubber ball compared to the tapping machine as the impact source.

2 EQUIPMENT

ISO 16283-2: 2015(E) describes two impact sources; the tapping machine and the rubber ball to determine the impact sound insulation rating. However, these standard impact sources do not exactly replicate all the possible types of real floor impacts. According to the ISO 16283-2: 2015(E), the tapping machine is effective to assess a variety of light, hard impacts such as footsteps from walkers wearing hard-heeled footwear, while the rubber ball is more effective to assess heavy, soft impacts such as from walkers in bare feet or children jumping.

2.1 Standard Tapping Machine

The standard tapping machine (see Figure 1 (a)) has five hammers placed in a line; and mass of each hammer being 500 ± 12 g. The centre-to-centre distance between two adjacent hammers is 100 ± 3 mm. Each hammer falls freely from a height of 40 mm to strike the floor to be tested. The standard tapping machine is a self-driven machine and the time between impact and lift of the hammer is less than 80 ms. The mean time between successive impacts is 100 ± 20 ms. In this study, we used a standard Look Line tapping machine EM50 (serial number TM.14031).

2.2 Rubber Ball

ISO 16283-2: 2015(E) states that the impact sound shall be generated by dropping the rubber ball vertically in a free fall from a height of 100 ± 1 cm measured from the bottom of the rubber ball to the surface of the floor under test. However, as stated in the ISO 16283-2: 2015(E), the rubber ball needs to be a hollow ball of 180 mm in diameter with 30 mm wall thickness. Moreover, the effective mass of the rubber ball has to be 2.5 ± 0.1 kg with the coefficient of restitution of 0.8 ± 0.1. In this study we manufactured a rubber ball (see Figure 1 (b)) consistent with the ISO 16283-2: 2015(E). The characteristics of the rubber ball were tested at the University of Auckland and it was found that the rubber ball complies with the requirements stated in ISO 16283-2: 2015(E) (see Figure 2).

(a) (b)

Figure1: Impact sources; (a) the standard tapping machine and (b) the rubber ball

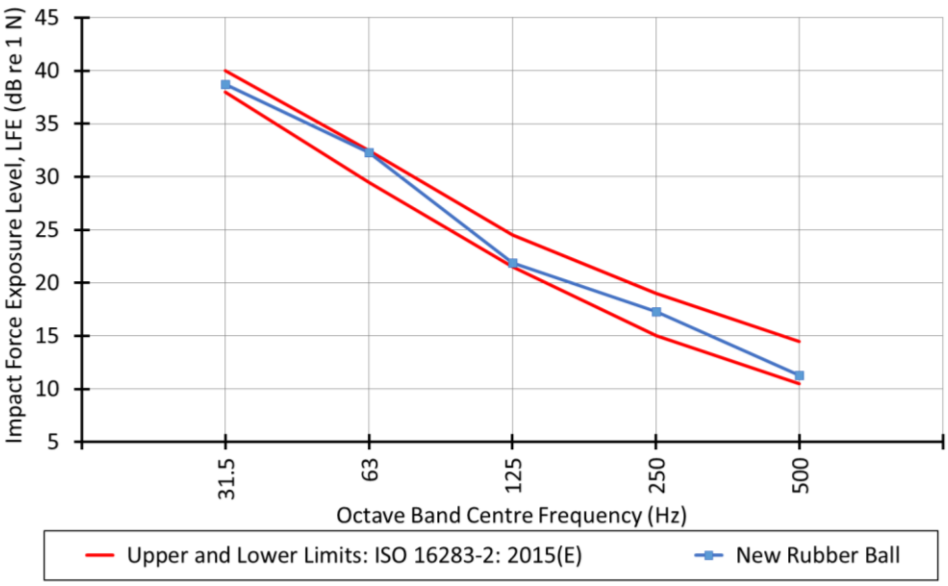

Figure 2: Laboratory test results of the newly developed rubber ball

3 CASE STUDIES AND METHODOLOGY

3.1 Testing On A Bare Concrete Slab

A bare concrete slab was tested in a closed living area of an apartment with a Look Line tapping machine. The measurements were conducted with a calibrated Norsonics 140 Sound level meter (serial number 1403252) in the closed living area of the apartment directly beneath. The bare concrete slab under test was tapped in four different positions with the receiving space's sound measurements averaged over a 30 second period per test position. The rubber ball was also used to test the same bare concrete slab and the rubber ball was released four times from a 1m height. The rubber ball was caught after one bounce, i.e. it was not allowed to bounce multiple times to rest. The sound measurements were taken in the same lower room and the Leq measurements were averaged over a 10 second period per release. Finally, an average male person weighing 75kg, jumped from about 240mm height and the sound measurements were recorded in a similar manner as for the rubber ball release.

Table 1: Descriptions of rooms: Testing on the bare concrete slab

	Source Room	Receiving Room
Floor	Bare concrete slab	Bare concrete slab
Walls	Plasterboard	Plasterboard
Ceiling	13mm Plasterboard ceiling with 100mm air gap	13mm Plasterboard ceiling with 100mm air gap
Slab	200mm	200 mm
Volume	-	139 m^3
Finish	Not Furnished	Not Furnished

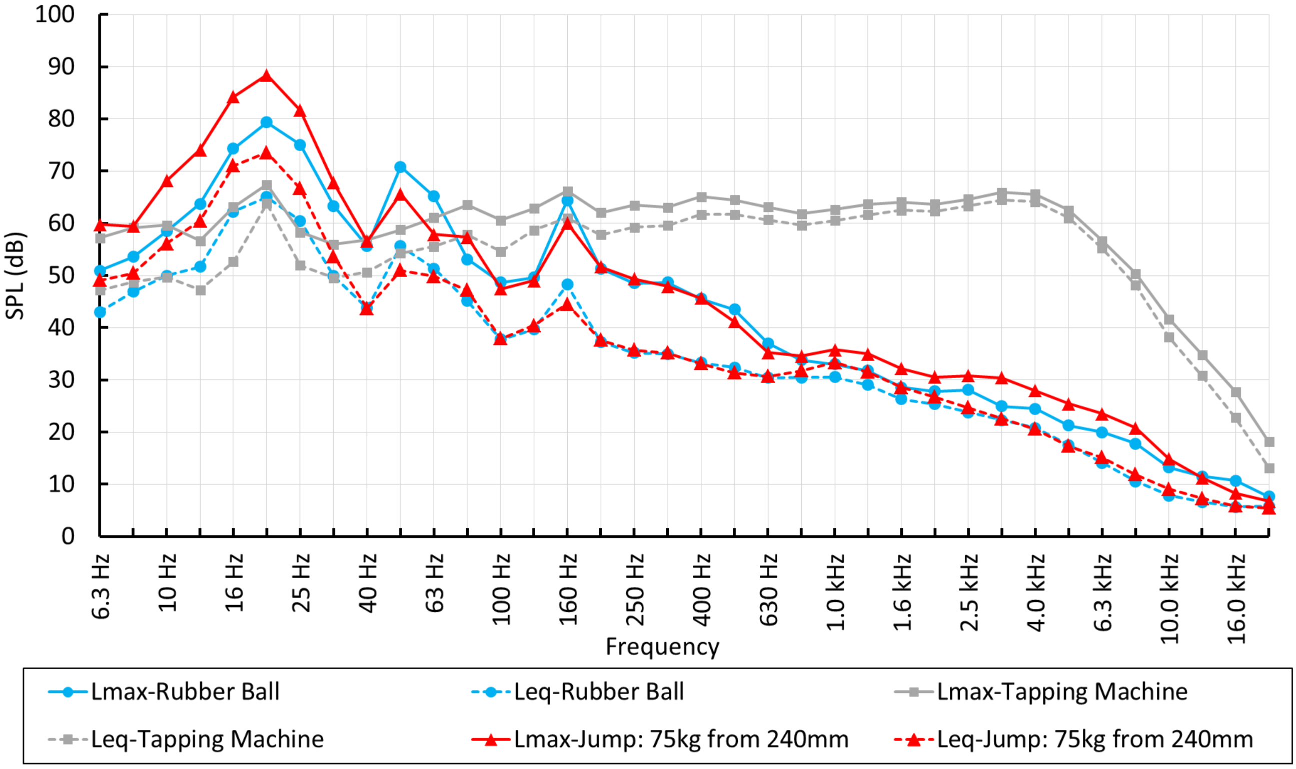

Figure 3: Comparison of the floor impact noise levels generated from different impact sources (the standard tapping machine and the rubber ball) with the human jump on a bare concrete slab

As can be seen in the Figure 3, the Sound Pressure Levels (SPLs) generated by the standard tapping machine are significantly higher when compared to the rubber ball, especially for the frequencies greater than 250 Hz. However, when the SPLs generated from the standard tapping machine and from the rubber ball are compared with the SPLs generated from the human jump, the rubber ball more closely replicate the human jump. Therefore, as can be seen in the Figure 3, tapping machine produces higher SPLs at higher frequencies, which does not represent the frequency spectra generated from human activities.

3.2 Testing on a tile floor

Similar to the testing on the bare concrete slab a finished tile floor installed on a 9mm acoustic underlay in a closed living room was tested with the standard tapping machine and with the rubber ball. In this study, the floor impact sound pressure levels were measured in the closed receiving room with different types of human activities, human walking with flat shoes, human walking with high heels, running and jumping from a 240mm height on the tile floor.

As can be seen in Figure 4, a human jump generates the highest impact noise levels in terms of both Leq and Lmax. However, the floor impact noise generated by the rubber ball results in a similar spectrum and sound pressure level as the human jump. In this case also, SPLs generated by the tapping machine are significantly higher at higher frequencies and are unrepresentative of the SPL generated by the human activities.

Table 2: Descriptions of rooms: Testing on the tile floor

	Source Room	Receiving Room
Floor	Tile	Timber/Carpet
Walls	Plasterboard	Plasterboard
Ceiling	Exposed concrete slab	Plasterboard ceiling
Slab	Not known	Not known
Volume	-	128 m^3
Finish	Fully Furnished	Fully Furnished

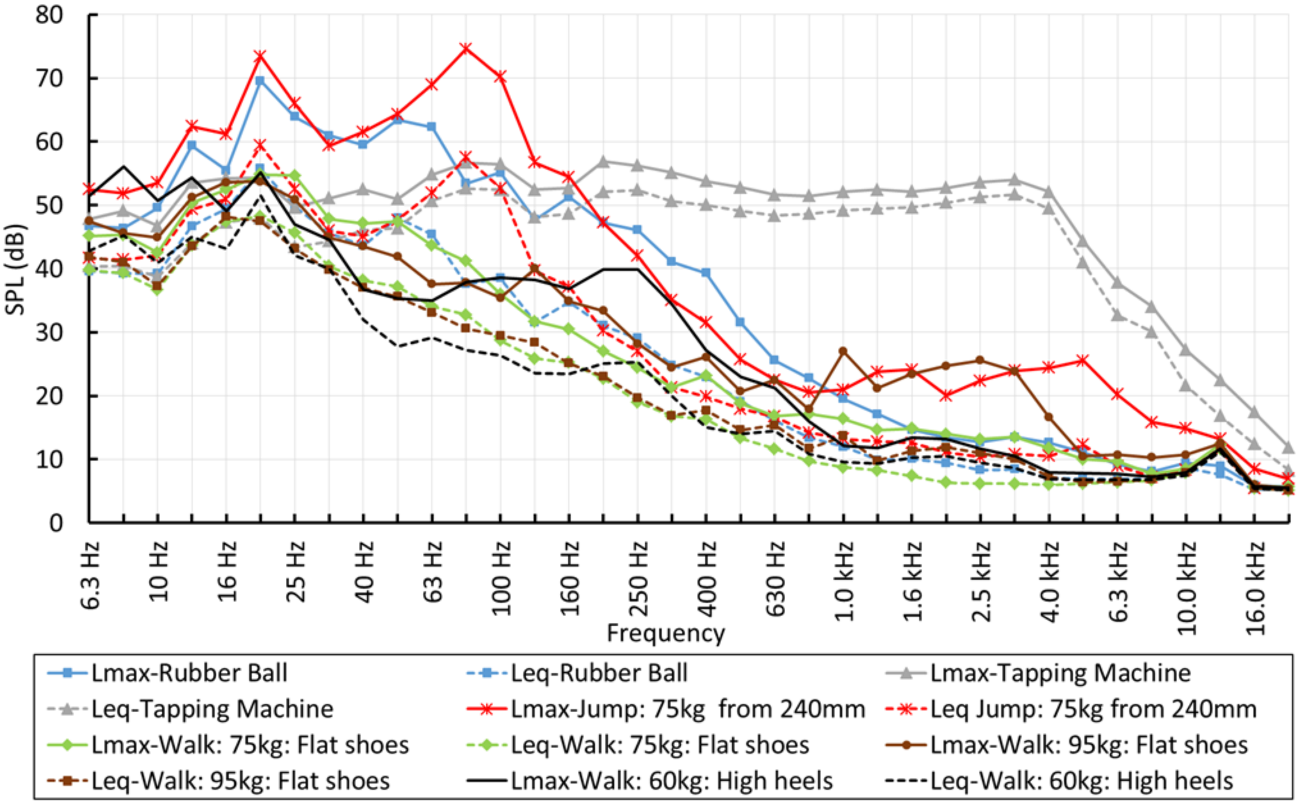

Figure 4: Comparison of the floor impact noise levels generated from different impact sources (the standard tapping machine and the rubber ball) with the human activities on a tile floor

3.3 Testing On A Timber Floor

A finished timber floor was tested for floor impact insulation performances using the standard tapping machine and the rubber ball. Measurements of human activities such as running and jumping on the floor were also performed on the same timber floor. The measurements were conducted from the apartment beneath and were compared with each other. As can be seen in Figure 5, SPLs generated from the human activities closely follow the SPLs generated by the standard tapping machine and the rubber ball.

Table 3: Descriptions of rooms: Testing on the timber floor

	Source Room	Receiving Room
Floor	Timber	Bare concrete slab
Walls	Plasterboard	Plasterboard
Ceiling	10mm Plasterboard ceiling with R3 insulation	10mm Plasterboard ceiling with R3 insulation
Slab	180-200mm	180-200mm
Volume	-	126 m^3
Finish	Not Furnished	Not Furnished

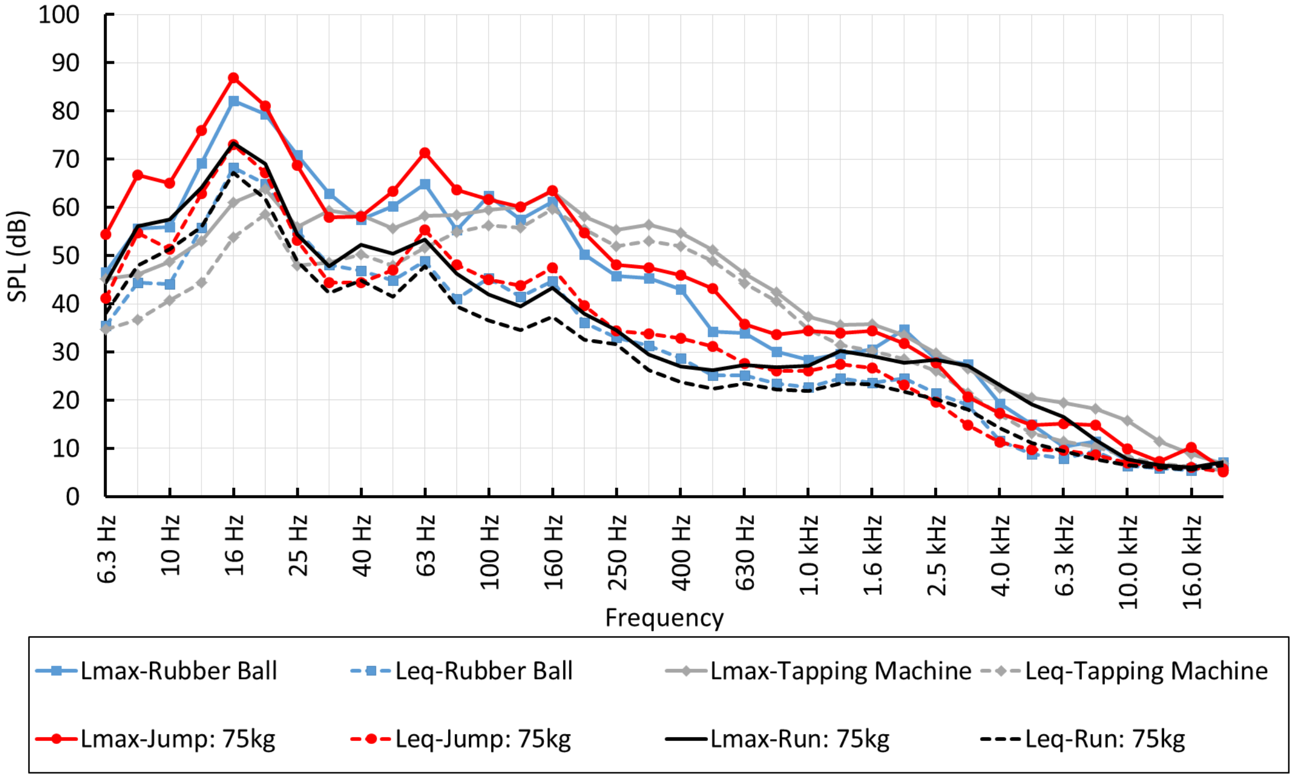

Figure 5: Comparison of the floor impact noise levels generated from different impact sources (the standard tapping machine and the rubber ball) with the human activities on a timber floor

4 EVALUATION OF THE FLOOR IMPACT INSULATION PERFORMANCE

According to ISO 16283-2: 2015(E) and ISO 717-2: 2013, the measurements in the receiving room must be made in one-third octave bands between 100 and 3.15 kHz. The field test results are expressed as weighted standardized impact sound pressure levels L'nT,w. The values obtained from the methodologies of ISO 16283-2: 2015(E) are compared with reference values for each one-third octave band frequencies measured between 100Hz and 3.15 kHz. The reference curve is shifted up and down until the sum of the unfavourable deviations, measured levels higher than the reference levels, is not more than 32dB.

In order to evaluate floor impact insulation properties, the standard tapping machine and the rubber ball were used as impact sources on a glued timber flooring samples with and without an underlay. As can be seen in Figure 6, the SPLs generated from the standard tapping machine on the timber floor without underlay is noticeably higher than that on the timber floor with underlay. However, when the testing was done using the rubber ball, there was no significant difference between SPLs. As described in the ISO 16283-2:2015 and ISO 717-2: 2013 L′nT,w values were calculated for the floors under test

Table 4: Descriptions of rooms: Testing on the glued timber flooring samples

	Source Room	Receiving Room
Floor	Timber flooring samples with and without underlay	Bare concrete slab
Walls	Plasterboard	Plasterboard
Ceiling	13mm Plasterboard ceiling with 100mm air gap	13mm Plasterboard ceiling with 100mm air gap
Slab	200mm	200 mm
Volume	-	139 m^3
Finish	Not Furnished	Not Furnished

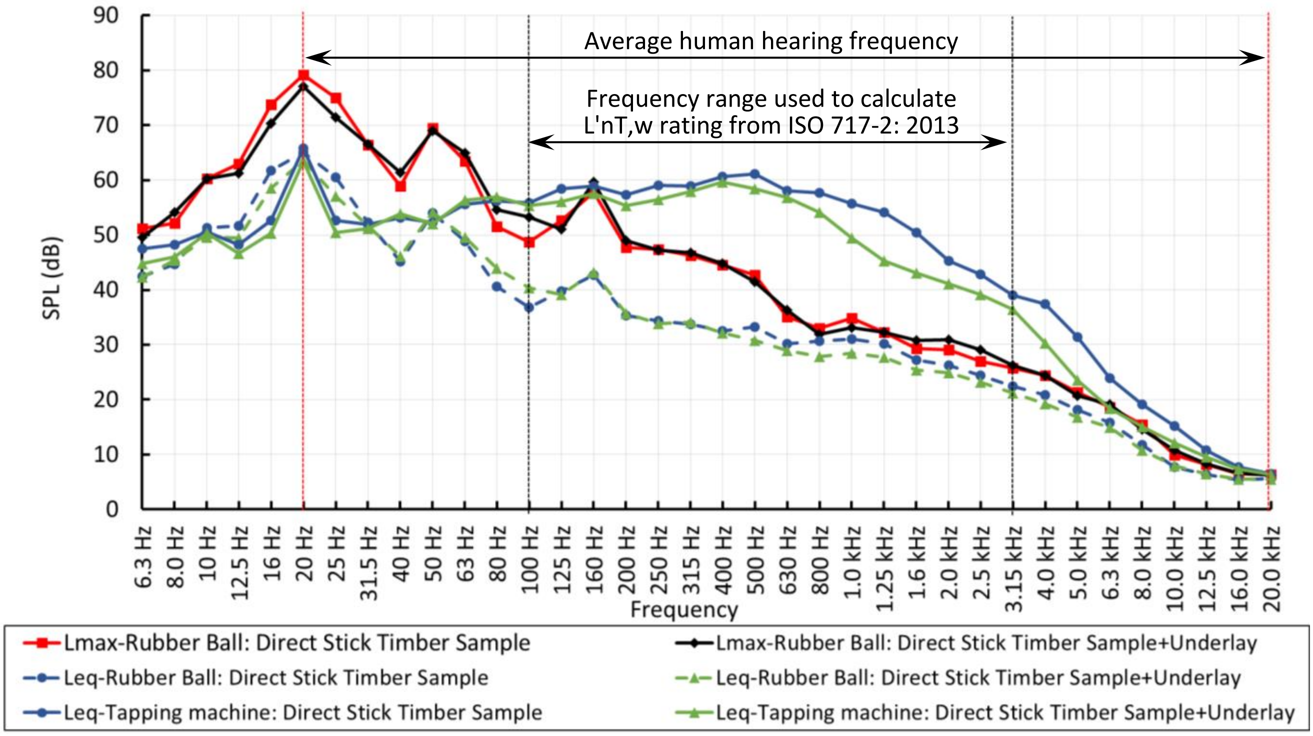

Figure 6: Comparison of the floor impact noise levels generated from different impact sources (the standard tapping machine and the rubber ball) on a timber floor with and without underlay

Table 5: L'nT,w values of timber floor with and without underlay

Test System	L′nT,w
Direct stick timber sample – Standard tapping machine	53
Direct stick timber sample – Rubber ball (with Leq)	29
Direct stick timber sample – Rubber ball (with Lmax)	40
Direct stick timber sample with Underlay – Standard tapping machine	50
Direct stick timber sample with Underlay – Rubber ball (with Leq)	29
Direct stick timber sample with Underlay – Rubber ball (with Lmax)	41

As can be seen in Table 5, when the test was done using the standard tapping machine, the L′nT,w value reduced from 53 to 50 when the underlay is used. However, when the rubber ball was used there is no change in L′nT,w value when the calculations are done using Leq. However, as can be seen in Table 5, L′nT,w increases from 40 to 41 when the calculations are done using Lmax. Therefore, it can be concluded that the underlay does little for heavy impact noises (jumping/rubber ball) as this primarily controlled by floor structure design and receiving room modes. The L'nT,w rating from ISO 717-2: 2013 only looks at frequencies between 100 Hz and 31.5 kHz. In the case of the rubber ball (i.e. the types of source that commonly cause annoyance in the real world) all the action happens in the frequency below 100 Hz. Therefore a single number L'nT,w rating is an inadequate method of assessing real-world impact noise regardless of the impact source chosen.

5 CONCLUSION

The results show that rubber ball more closely replicates the impact sounds produced by the human activities such as from walking, jumping and running. Moreover, it is evident that when the building floor is a tile floor, a tapping machine produces higher sound pressure levels at higher frequencies than either hard-heeled or heavy/soft impacts. However, rubber ball does not make a continuous noise and the measurements need to be very accurate with no disturbing noises when the SPLs are recorded. Moreover, when the rubber ball is used as the impact source, there should be one person to release and catch the rubber ball and another one to do the measurements, whereas a single person can do the measurements and operate the tapping machine with the remote controller. At present, calculation procedures for a single number quantity do not currently exist in an ISO Standards to evaluate the floor impact insulation properties, when the rubber ball is used as the impact source. The ISO 717-2: 2013 only looks at frequencies between 100 Hz and 3.15 kHz to assess the floor impact noises with a single number L′nT,w rating. However, the human ear is responsive to frequencies from about 20 Hz to 20 kHz and most of the common human activities produce frequency below 100 Hz. Therefore a single number L′nT,w rating is an inadequate method of assessing real-world impact noises Therefore, further studies must be done on how to develop an adequate method of assessing real-world impact noises and how to use the rubber ball as an impact source to evaluate the floor impact insulation properties.

ACKNOWLEDGEMENTS

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