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CORRELATION OF IMPACT ISOLATION TEST RESULTS USING STANDARD TAPPING MACHINE AND HEAVY/SOFT IMPACT SOURCE

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Abstract

Currently the use of a standard tapping machine is the primary method for measuring the impact sound of floors and the reduction of transmitted impact sound by floor coverings. The tapping machine is made of five small metal hammers striking the floor with successive impacts to create a noise which is measured from the floor below. The resultant weighted normalised and standardised impact sound pressure levels are determined for the performance of the floor. An alternative method in IS0 140-11 is the Drop Ball Test which is used to determine the A-weighted average fast maximum level, $L_{AF\ max}$ of a flooring system. It involves the dropping of a standardised ball weighing 2.7kg from a height of 1m onto a floor and measuring the noise level below. It is generally acknowledged that the Drop Ball Test is quicker, simpler and less costly to conduct than the Standard Tapping Machine test. The investigation undertaken has identified a correlation between the $L_{n,Tw}$, $L_{n,Tw}$ + C_I values and the $L_{AF\ max}$. The relationship is dependent on factors such as floor surface coverings, ceiling type, construction, insulation and floor thickness. Hence this phenomenon can be utilised to replace the Standard Tapping Machine Test with the Drop Ball Test in the determination of a floor's impact sound insulation rating.

1. INTRODUCTION

In today's ever expanding cities as residencies live in multi-storey residential buildings in pursuit of more living space, noise issues such as floor impact noise transmission is a growing concern. Footsteps, doors closing, shifting furniture items and objects dropping onto hard floor surfaces can all create impact noise which can easily transmit to the floor below, so the impact isolation rating of a flooring system is of great importance in ensuring comfort for the buildings occupants. Currently the primary method of determining the impact isolation rating of a floor, the standardised tapping machine test, is a time-consuming process. A simpler, quicker method of rating floor impact isolation performances is possible, utilising a heavy soft impact source. This paper offers a correlation between these two methods, which may provide a substitute for the tapping machine test with a quicker, easier alternative.

2. BUILDING CODE OF AUSTRALIA REQUIREMENTS

Part F5 of the Building Code of Australia refers to sound transmission and insulation. Its functional statement states "a part of a building that separates sole-occupancy units, or separates a sole-occupancy unit from a common space or a part of another classification within the building is to be constructed to prevent undue sound transmission"[2].

The performance requirements of floors are stipulated in FP5 of the BCA. They apply to Class 2 and 3 buildings and Class 9c aged care buildings. Sections FP5.1 and FP5.2 refer to floors and walls respectively.

Section FP5.1 states the following:

"Floors separating –

a) sole-occupancy units: or
b) sole-occupancy units from a plant room, lift shaft, stairway, public corridor, public lobby, or the like, or a part of a different classification,

must provide insulation against the transmission of airborne and impact generated sound sufficient to prevent illness or loss of amenity to the occupants"[2].

Compliance with FP5.1 is verified when it is measured in-situ that the separating floor has –

a) airborne: a weighted standardized level difference with spectrum adaptation term **($D_{nT,w}$ + C_{tr}) not less than 45** when determined under AS/NZS 1276.1 or ISO 717.1; and
b) impact: a weighted standardized impact sound pressure level with spectrum adaptation term **($L_{nT,w}$ + C_I) not more than 62** when determined under AS/ISO 717.2.

3. ISO STANDARDS

ISO 140 specifies methods for measuring the acoustic properties of floor coverings from the viewpoint of reducing impact sound transmission. One test method described in ISO 140-07 uses the standard tapping machine to simulate impact sources like human footsteps with hard sole shoes. In addition, a method using a heavy/soft impact source is introduced in Annexe E of ISO 140-11 as informative information for the assessment of impact sound insulation of a floor covering against impact sources with significant components at low frequencies, such as human footsteps or children jumping.

4. IMPACT ISOLATION TESTS

In accordance with the ISO standards, the nomenclature for floor systems is a weighted standardised impact sound pressure level with spectrum adaptation term ($L_{nT,w}$ + C_I). This can be determined using a standard tapping machine as described in ISO 140-07. The $L_{nT,w}$ + C_I value is based on a sliding scale, the smaller the value the better the performance. For example, a bare concrete slab may achieve an in-situ performance of $L_{nT,w}$ + C_I of 60, whereas the addition of carpet may reduce its rating to 40.

An alternative to the $L_{nT,w}$ + C_I value, the A-weighted impact sound pressure level, L_{AFmax} maybe utilised for determining the noise impact isolation rating of a floor. This value is derived by dropping a heavy, soft impact source, such as a rubber ball, onto a floor and measuring the transmitted impact noise as described in Annex F of ISO 140-11.

The impact rating method using the tapping machine, or 'tapping test' is much more rigorous and requires more time, effort and equipment than the impact rating method using the ball, or 'drop ball test'. A correlation between the results of these two procedures would prove useful in minimising time and effort in rating a flooring system.

4.1 Tapping Machine Test

The tapping test is used to determine the weighted standardized impact sound pressure level $L_{nT,w}$ plus an adaptation term, C_I, introduced to account for peaks at low frequencies seen in different flooring surfaces.

To determine the weighted standardised impact sound pressure level of a flooring system using the tapping test two vertically adjacent rooms are used, the upper one being designated the "source room" and the lower one the "receiving room".

4.1.1 Equipment

3 pieces of equipment are required to carry out an ISO standard floor impact test;

1. A tapping machine which complies the specification of the ISO 140-6/7.

2. A sound level meter in the receiver room.

3. A speaker and amplifier for measuring the reverberation time in the receiver room.

4.1.2 Procedure

The tapping machine is placed on the floor of the source room and switched on. The noise levels in the receiver room are measured for 30 seconds at a minimum of 5 locations in accordance to ISO 140-7. The tapping machine is then switched off and the background noise level is also measured at these locations.

The ISO Standard requires measurements at 4 different tapping machine locations in accordance with ISO 140-7 on the Source room floor, making the total number of noise measurements in the Receiver room so far to be 4 x 5 = 20 plus 5 background noise measurements, totalling 25.

After the tapping machine measurements are completed a speaker and amplifier are set up in the receiver room to measure the room's reverberation time. That's an additional 5 measurements, making a minimum of 30 measurements in the receiver room, 20 measurements with the tapping machine running, 5 background noise measurement and 5 reverberation time measures.

This entire process generally takes 1.5 to 2 hours to complete, including equipment setup and measurements in receiver room. The results of the 30 measurements are later used to compute single-value impact rating numbers $L_{nT,w}$ and C_I. The formulae and reference curve for calculating $L_{nT,w}$ and C_I are in the ISO Standard 717 Part 2.

4.2 Drop Ball Test

The drop ball test is a method used to measure the acoustic properties of floor coverings from the viewpoint of reducing impact sounds generated by such heavy and soft impacts as human footsteps or children jumping. Again, two vertically adjacent rooms are used, the upper one being designated the "source room" and the lower one the "receiving room".

4.2.1 Equipment

2 pieces of equipment are required to carry out an ISO standard the drop ball test.

1. A heavy/soft impact source for the measurements of impact sound pressure level. A standard rubber ball or tire can be used, provided it meets the specifications laid out in Annex F of ISO 140-11. A rubber sports training ball was used with the following characteristics:
    - shape and size: hollow ball with 180 mm in diameter with 30 mm thickness (see Figure 1);
    - effective mass: (2.5 ± 0.1) kg;
    - coefficient of recovery: 0.8 ± 0.1.

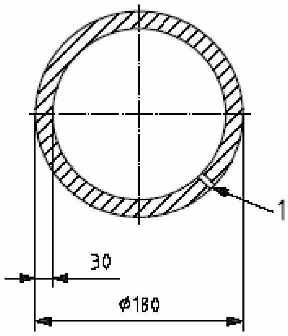


Figure 1. ISO Standard Impact Source

2. A sound level meter in the receiver room.

4.2.2 Procedure

The impact sound is generated by dropping the ball from a height of 100 cm above the surface of the floor covering. The excitation by the heavy/soft impact source is made at four or more different positions on the floor under test. One of these positions should be above the floor and one position should be at the centre point of the floor[3].

For each excitation position, the maximum sound pressure level is measured at a minimum of four different microphone positions from the receiver room. These are to be distributed within the maximum permitted space throughout the room, spaced uniformly in accordance to Annex F of ISO 140-11[3]. The impact sound pressure level is then calculated by arithmetically averaging the values obtained above for all excitation positions.

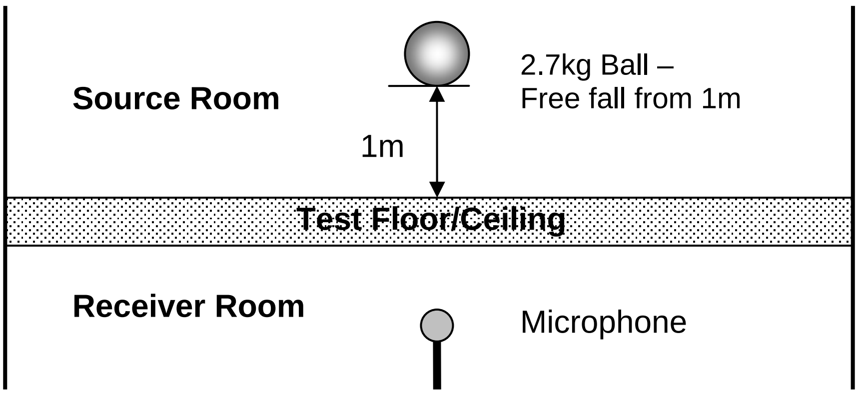


Figure 2. Setup Procedure of Drop Ball Test

5. ANALYSIS

Initially a hypothesis was established; is there a correlation between the L_{AFmax} to the $L_{nT,w}$+ C_I, and hence providing a direct equation linking the drop ball test to the tapping test. It soon became evident, though, that some variables would be required to correlate the two. For example, an extravagantly insulated flooring system, with carpeting, a suspended ceiling using resilient mounts and insulation with an overall acoustic performance of L_{AFmax} 50dB compared to a bare concrete slab with the same performance of L_{AFmax} 50dB would not produce in practice the same $L_{nT,w}$+ C_I value. This is due to the different sound characteristics produced by each test.

The tapping test produces a high frequency continuous tapping noise due to the hard but light metal hammers used to tap the floor below in quick succession. On a solid surface, especially tiles or masonry, the high frequency end of the noise curve is prominent, as shown in Figure 3. This high frequency noise is much more easily damped out with noise control measures such as insulation batts and softer floor surface coverings like carpet.

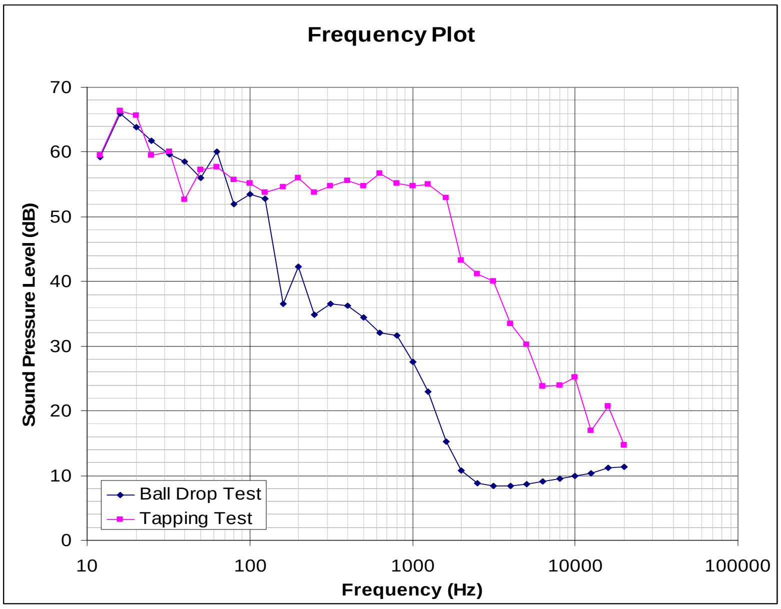


Figure 3. Impact Noise Spectrum of Standard Tapping Machine & Drop Ball

The drop ball test, on the other hand, produces a much duller, low end instantaneous thud. Low frequency noise, which travels further through solid structures such as walls and floors, is much more difficult to damp out and requires more specific noise control measures such as resiliently mounted ceilings to insulate against and acoustic underlays under hard floor surfaces.

Hence, two floors which perform similarly in the drop ball test may give distinctly different results in the tapping machine test as a floor better insulated against high frequency noise transmission would not have as large an advantage in the ball test.

As a collective group of data the data set gave no indication of trends or relationships between the two impact rating methods. The collaborated data needed to be categorised according to their properties which would affect their impact isolation ratings. Several such properties were floor surface coverings, types of mountings used in the ceiling cavities below, type of, if any, insulation in the ceiling cavity, concrete slab thickness and depth of ceiling plenum. Within these categories more meaningful and concise relationships between the $L_{nT,w}$ + C_I and $L_{AF,max}$ could be traced.

The amount of data was limited, however, due to the time and effort required to perform both tests on similar floor coverings and the accessibility to certain flooring and ceiling systems, which limited the depth to which the correlation could be drawn.

6. RESULTS

An immediate pattern did emerge with the grouping of data into different types of floor surface coverings, shown in Figure 4.

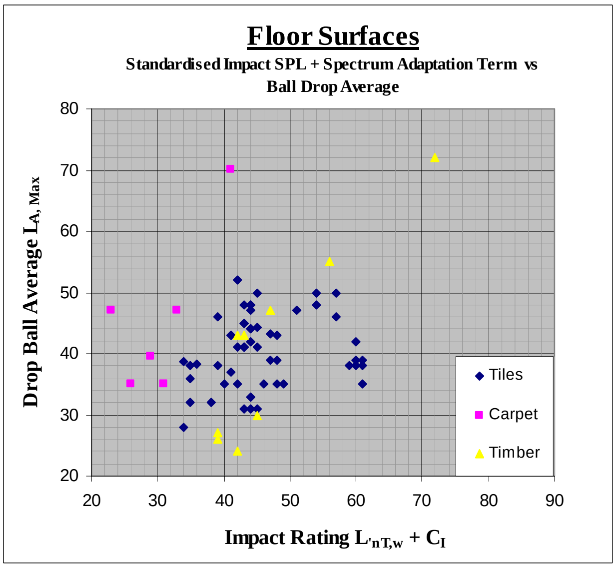


Figure 4. Data Categorisation into Floor Surface Types

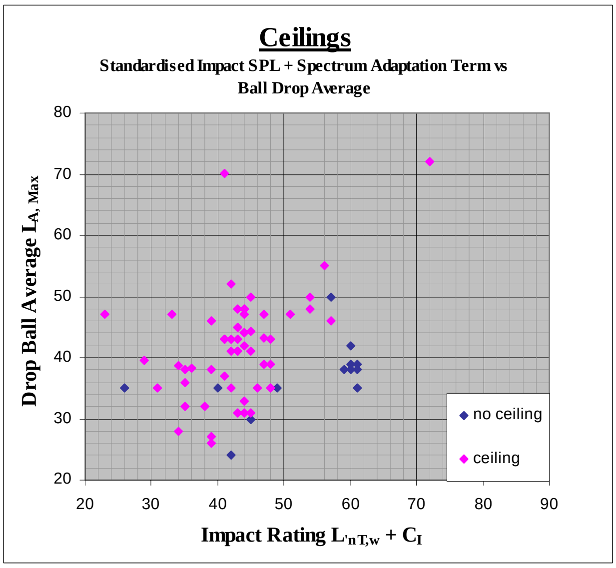
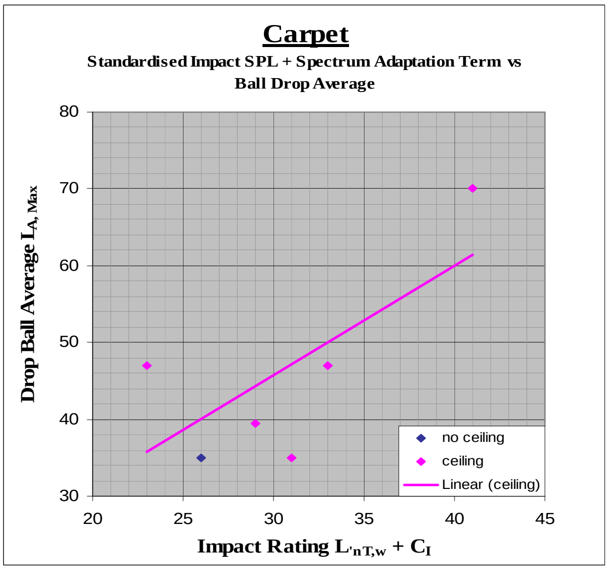


Figure 5. Data Categorisation into Ceiling Presence

Another factor which clearly did influence the impact isolation rating of the floors was the presence or absence of a suspended ceiling in the receiver room, illustrated in Figure 5. With the limited dataset available a simple with suspended ceiling or without separation was all that was possible without dissecting the data into too smaller groups and losing recognition of any possible trends.



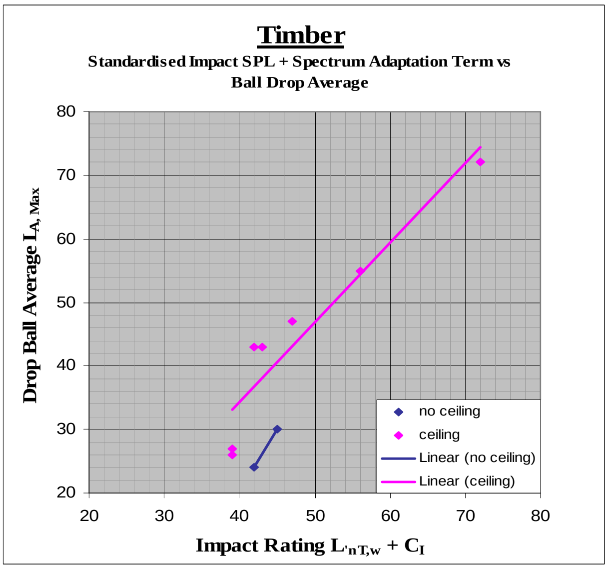
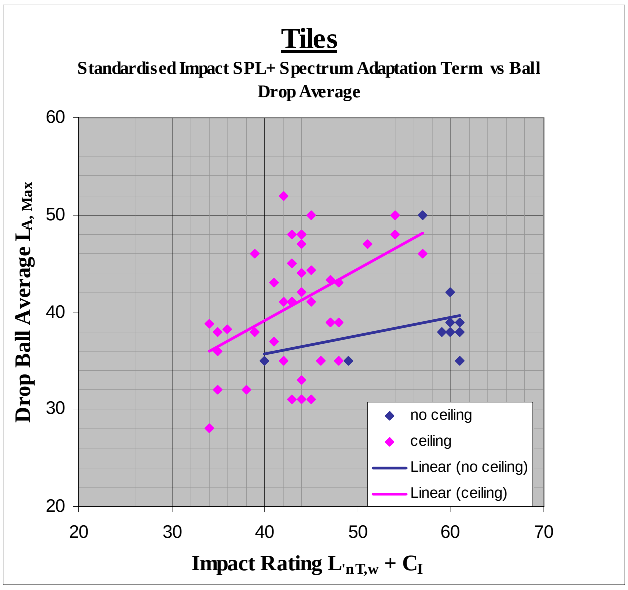


Figure 6. $L_{AF,max}$ & $L_{nT,w} + C_I$ Relationship between (a) Carpeted (b) Timber and (c) Tiled Floor Surfaces



Separating the data into floor surface types then grouping into those with a suspended ceiling and those without revealed linear trends in the data, shown in Figure 6(a), 6(b) & 6(c).

7. DISCUSSION

There was preconceived notion that the type of mounting on which the ceiling below suspended would be a significant parameter in determining the flooring system's impact isolating rating. The reasoning behind this was that the impact noise transmitted from the source room to the receiver room would primarily be transmitted through the solid members of the floor and ceiling construction, for instance, through the hard floor surface, then the concrete slab, then via the ceiling mountings which radiate throughout the ceiling cavity. Theoretically, using resilient mountings instead of standard fixings should isolate the concrete slab and minimise transmission of structure-borne impact noise, improving the impact noise isolation rating significantly. In reality, though, ceilings that used resilient mountings were indistinguishable from those without, as seen in Figure 7.

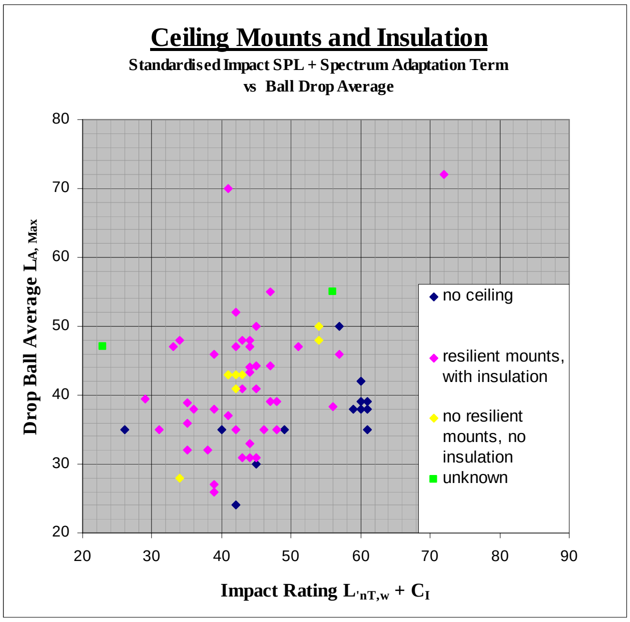


Figure 7. Data Catergorisation into Ceiling Mounting and Insulation

Factors such as depth of ceiling plenum, concrete slab thickness and ceiling cavity insulation gave very weak correlations, with general trends recognizable but distinct relationships impossible to deduce.

With more data points, a more concise and accurate analysis of the effect of each property parameters has on the floor impact isolation rating could be obtained, and therefore the previously abovementioned factors may be introduced into the analysis.

8. RELATIONSHIP EQUATIONS

Flooring Systems with a suspended ceiling below:

Tiles: $$L_{nT,w} + C_I = (L_{AF,max} - 18.03) \times 1.89 \quad (1)$$

$$R^2 = 0.2 \quad (2)$$

Carpet: $$L_{nT,w} + C_I = (L_{AF,max} - 3.02) \times 0.7 \quad (3)$$

$$R^2 = 0.48 \quad (4)$$

Timber: $$L_{nT,w} + C_I = (L_{AF,max} + 15.77) \times 0.8 \quad (5)$$

$$R^2 = 0.89 \quad (6)$$

Flooring Systems without a suspended ceiling below:

Tiles: $$L_{nT,w} + C_I = (L_{AF,max} - 26.862) \times 3.41 \quad (7)$$

$$R^2 = 0.1448 \quad (8)$$

9. CONCLUSIONS

The equations in this paper offer a quicker approximation for determining a floor impact isolation rating through utilisation of the Ball Drop Test. The accuracy of these equations are will only increase as research continues, as a larger dataset will provide a more comprehensive guide to the relationship linking the L_{AFmax} to the $L_{nT,w} + C_I$.

REFERENCES

[1] "*ISO 140-7:1998(E) Acoustics – Measurement of sound insulation of buildings and of building elements-Part 7: Field Measurements of Impact Sound Insulation of Floors*" International Standards Board, 1998

[2] "*Guide to the BCA 2007 Building Code of Australia*", Australian Building Codes Board, Canberra, Australia, 2007.

[3] "*ISO 140-11:2005(E) Acoustics – Measurement of sound insulation of buildings and of building elements-Part 11: Laboratory measurements of the reduction of transmitted impact sound by floor coverings on lightweight reference floors*" International Standards Board, 2005