MEASUREMENT OF THE IMPACT SOUND INSULATION OF WALLS

Davy, John Laurence

CSIRO Manufacturing and Infrastructure Technology
PO Box 56, Highett, Victoria 3190, Australia. Email: John.Davy@csiro.au

and

Department of Applied Physics, RMIT University
GPO Box 2476V, Melbourne, Victoria 3001, Australia. Email: John.Davy@rmit.edu.au

1. INTRODUCTION

The current version of the Building Code of Australia\(^1\) (BCA) regulates the impact sound insulation of walls separating a bathroom, sanitary compartment, laundry or kitchen in one sole occupancy unit from a habitable room (other than a kitchen) in an adjoining unit. A wall satisfies the impact insulation requirement, if it is one of three deemed-to-satisfy walls, has two or more separate leaves without rigid mechanical connection except at their periphery, or is identical with a prototype that is no less resistant to the transmission of impact sound when tested in accordance with Specification F5.5 of the BCA\(^1\) than one of the three deemed-to-satisfy walls. The impact insulation is measured in eighteen third octave bands. Specification F5.5 does not specify any single number rating to be used to determine if the prototype wall’s impact sound insulation is better than one of the deemed-to-satisfy walls. This has caused endless argument in the acoustical community. Does the prototype wall have to be better at all eighteen third octave band frequencies? The impact sound insulation spectra of the three deemed-to-satisfy walls are known to be different. Which deemed-to-satisfy wall should one compare against? Most laboratories have only tested one of the deemed-to-satisfy walls. The most commonly tested deemed-to-satisfy wall has an airborne sound insulation of only \(R_w\) equals 47, rather than the required \(R_w\) equal to at least 50. The need to test at least one deemed-to-satisfy wall adds significantly to the cost of testing a prototype wall.

The test method uses a horizontal steel plate, which has to be held in contact with the test wall along its long edge. An ISO standard tapping machine is operated on the steel plate. The steel plate is usually held in contact with the test wall by supporting it with two sloping legs and leaning it against the steel wall. If the plate exerts only a normal impact force on the wall, the normal impact force is a function of the angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts. This angle is not specified. The proposed revision of the acoustical provisions\(^3\) of the BCA\(^1\) specifies a maximum value of \(L'_{nT,w}\) of 60 dB for a field verification method of impact sound insulation. It also specifies the test method more closely including an angle. This paper will describe the revised wall impact sound insulation test and present laboratory results on the three deemed-to-satisfy walls.
CSIRO tried to obtain funding for a round robin on the wall impact sound insulation measurement method in the BCA in February 1993. CSIRO did not receive any funding for the proposed round robin research project because the state governments refused to match federal funding and because four research projects (mainly fire related) had already been approved in principle in advance of any money becoming available. Without funding, CSIRO was eventually able to obtain normalized impact sound insulation spectra for the first of the deemed-to-satisfy walls from four laboratories. The NAL and CSIRO Highett spectra were in rough agreement. The CSIRO North Ryde old chamber spectrum was significantly higher than the Highett and NAL spectra. The RMIT spectrum was in rough agreement with the Highett and NAL spectra at low frequencies, but crossed over to the old North Ryde spectrum at high frequencies.

A little detective work revealed the following sequence of events. CSIRO North Ryde developed the test and built the first plate rig. Amtek had a Sydney acoustical consultant perform some tests using a plate rig that they had built. Amtek then had Highett perform some tests using the same plate rig. Highett copied the Amtek plate rig. RMIT copied the Highett plate rig. NAL copied the RMIT plate rig. Unfortunately, Amtek had not copied the North Ryde plate rig, and the North Ryde plate rig has an angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts which is different from all the other rigs. Recent measurements in the new North Ryde chambers using the Highett plate rig have agreed with the previous Highett and NAL measurements. Measurements on the same wall showed that the North Ryde plate rig produces higher sound levels, but a similar spectrum shape. RMIT have discovered and removed high frequency flanking between their two acoustical chambers. This flanking is believed to explain the high frequency difference between the RMIT spectrum and the NAL and Highett spectra. Thus, until the plate rig and the test method are more closely specified, it is not possible to specify a single number rating limit for wall impact sound insulation.

The wall impact insulation test requires an expensive standard tapping machine of which there are relatively few available in Australia. NAL and CSR have been experimenting with single impacts from rods, balls and hammers swinging under gravity so that an impact sound insulation test could be conducted cheaply in the field. A firm of Sydney acoustical consultants has designed and constructed a horizontal tapping machine, which uses springs instead of gravity. A paper has been published in the Applied Acoustics learned journal by Taiwanese researchers\(^5\) on using hard and soft ball pendulums for testing the impact sound insulation of walls. RMIT has also conducted research on single impacts for testing the sound insulation of walls.

### 3. THE CURRENT DEEMED TO SATISFY WALLS FOR IMPACT SOUND

The following wall constructions are deemed to satisfy the impact sound insulation requirements in the current version of the Building Code of Australia\(^1\) (BCA).

Deemed 1. Cavity brickwork-
Two leaves 90 mm brick masonry with-
(i) all joints filled with solid mortar; and
(ii) an air space not less than 40 mm between the leaves; and
(iii) the leaves connected only by ties in accordance with AS 3700.

Deemed 2. Single leaf brickwork-
110 mm thick brick masonry with-
(i) each face rendered 13 mm thick; and
(ii) 50 mm x 12 mm thick timber battens at not more than 610 mm centres fixed to each
face but not recessed into the render; and
(iii) one layer of 12 mm thick softboard nailed to the battens; and
(iv) 6 mm thick medium density hardboard adhesive-fixed to the softboard.

Deemed 3. Concrete blockwork-
190 mm thick concrete block masonry with-
(i) each face of the blocks fitted with 50 mm x 50 mm timber battens, spaced at not more
than 610 mm centres, screw-fixed into resilient plugs with rubber inserts; and
(ii) the space between the battens completely filled with mineral or glass wool blanket or
batts not less than 50 mm thick; and
(iii) the outer face of the battens finished with plasterboard not less than 10 mm thick or
other material with a mass per unit area not less than 7.3 kg/m².

4. LABORATORY RESULTS FOR DEEMED TO SATISFY WALLS

Figure 1. Normalised impact sound pressure levels for the deemed to satisfy cavity brickwork
wall measured in different laboratories.
Figure 2. Normalised impact sound pressure levels for the deemed to satisfy single leaf brickwork wall measured with different frames.

Figure 3. Normalised impact sound pressure levels for the deemed to satisfy concrete blockwork wall measured in different laboratories.
Figure 1 shows the normalised impact sound pressure levels for the first of the walls deemed to satisfy the impact sound insulation requirements in the current BCA\(^1\). NAL is the National Acoustics Laboratories at Chatswood in Sydney. NROld is the now demolished CSIRO acoustics chambers at North Ryde in Sydney. NRNew is the new CSIRO acoustics chambers at North Ryde in Sydney. For the CSIRO North Ryde acoustical chambers, a suffix of NR denotes that the North Ryde frame was used, while a suffix of HT denotes that a copy of the Highett frame was used. Highett is the CSIRO acoustical chambers at Highett in Melbourne. RMIT is the Royal Melbourne Institute of Technology acoustical chambers in the central business district of Melbourne. Results for the other two deemed to satisfy walls are shown in figures 2 and 3.

The weighted normalized impact sound pressure \(L_{n,w}^4\) and the Impact Insulation Class IIC\(^6\) are single number ratings which are determined by fitting the same reference curve to the normalised impact sound pressure levels, for the 16 one third octave bands from 100 to 3150 Hz, by moving the reference curve in 1 dB steps. The sum of the positive deviations above the fitted reference curve must be as close as possible to, but less than or equal to 32 dB. For IIC no individual positive deviation above the fitted reference curve can be greater than 8 dB. \(L_{n,w}\) is the value of the fitted reference curve at 500 Hz. IIC is equal to 110 minus the value of the fitted reference curve at 500 Hz. Thus the better the impact sound insulation, the smaller the value of \(L_{n,w}\) and the larger the value of IIC. For \(L_{n,w}\) the values and calculations are rounded to the nearest 0.1 dB while for IIC the values and calculations are rounded to the nearest 1 dB. \(L_{n,w} + C_1^4\) is the decibel value of the energy summation of the normalised impact sound pressure levels in the 16 one third octave bands from 100 to 3150 Hz minus 15 dB. \(C_1^4\) is obtained by subtracting \(L_{n,w}\) from \(L_{n,w} + C_1^4\). A dash is added to \(L_{n,w}\) if the measurements are field measurements which may include significant flanking transmission. A “T” is added to the subscript if the values are normalised to 0.5 s reverberation times rather than 10 m\(^2\) of sound absorption. These single number ratings are shown in tables 1 to 3.

<table>
<thead>
<tr>
<th>Deemed 1</th>
<th>(L_{n,w})</th>
<th>(C_1)</th>
<th>(L_{n,w} + C_1^4)</th>
<th>IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAL</td>
<td>57</td>
<td>-2</td>
<td>55</td>
<td>53</td>
</tr>
<tr>
<td>NROldNR</td>
<td>66</td>
<td>-3</td>
<td>63</td>
<td>44</td>
</tr>
<tr>
<td>NRNewNR</td>
<td>66</td>
<td>-1</td>
<td>65</td>
<td>44</td>
</tr>
<tr>
<td>NRNewHT</td>
<td>58</td>
<td>-1</td>
<td>57</td>
<td>52</td>
</tr>
<tr>
<td>Highett</td>
<td>58</td>
<td>-2</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>RMIT</td>
<td>61</td>
<td>-5</td>
<td>56</td>
<td>44</td>
</tr>
</tbody>
</table>

**Table 1.** Single number impact sound insulation ratings for the deemed to satisfy cavity brickwork wall measured in different laboratories.

<table>
<thead>
<tr>
<th>Deemed 2</th>
<th>(L_{n,w})</th>
<th>(C_1)</th>
<th>(L_{n,w} + C_1^4)</th>
<th>IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRNewNR</td>
<td>51</td>
<td>-3</td>
<td>48</td>
<td>59</td>
</tr>
<tr>
<td>NRNewHT</td>
<td>44</td>
<td>-3</td>
<td>41</td>
<td>66</td>
</tr>
</tbody>
</table>

**Table 2.** Single number impact sound insulation ratings for the deemed to satisfy single leaf brickwork wall measured with different frames.
Table 3. Single number impact sound insulation ratings for the deemed to satisfy concrete blockwork wall measured in different laboratories.

5. OTHER WALLS

Mark Debevc\(^7\) has supplied data on a number of other wall constructions which were measured at RMIT. The constructions are as follows.

Wall 1. Staggered timber stud system - 2 layers 13 mm fire-rated plasterboard each side of 70 x 45 mm staggered timber studs at 600 mm centres each side of 90 x 45 mm timber plates - perimeter sealed. Nominal surface density of 42 kg/m\(^2\).

Wall 2. This is the deemed 3 wall. Nominal surface density 192 kg/m\(^2\).

Wall 3. Timber stud system - 2 layers 13 mm fire-rated plasterboard each side of 90 x 45 mm timber studs at 600 mm centres - 50 mm thick fibreglass cavity insulation - sheets nail attached - joints staggered - perimeter sealed. Nominal surface density 42 kg/m\(^2\).

Wall 4. Resilient timber stud system - 2 layers 13 mm fire-rated plasterboard each side of 90 x 45 mm timber studs at 600 mm centres - resilient channel fixed at 600 mm centres to one face of framing only - plasterboard fixed to resilient channel - 50 mm fibreglass insulation - sheets nail/screw attached - joints staggered - perimeter sealed. Nominal surface density 42 kg/m\(^2\).

Wall 5. This is the deemed 1 wall with 13 mm of cement render on both sides.

These results are shown in figure 4 and table 4.

Table 4. Single number impact sound insulation ratings for other walls measured at RMIT.

6. TEST METHOD

The test method in the current Building Code of Australia\(^6\) is the following comparison test with one of the three deemed to satisfy walls.

(a) The wall constructions to be compared must be tested in accordance with AS 1191\(^8\).
(b) A horizontal steel platform 510 mm x 460 mm x 10 mm thick must be placed with one long edge in continuous and direct contact with the wall to be tested on the side of the wall on which the impact sound is to be generated.
(c) A tapping machine complying with ISO 140/6-1998 (E) must be mounted centrally on the steel platform.

(d) The sound transmission through the wall must be determined in accordance with AS 1191 except that the tapping machine as mounted on the steel platform must be used as the source of sound.

(e) The impact sound pressure levels measured in the receiving room must be converted into normalised levels using a reference equivalent absorption area of 10 m².

![Other walls](image)

**Figure 4.** Normalised impact sound pressure levels for other walls measured at RMIT.

The above test method was removed as a laboratory test from the sound insulation regulatory impact statement issued in February 2002, and replaced with a field verification test. It has been re-instated as an absolute laboratory test in the draft sound insulation provisions directions report released at the end of June 2002, with the following changes. The phrase "to be compared" has been deleted from clause (a). The following additional clause (f) has been added.

(f) A single figure rating (L_{n,w}) must be calculated in accordance with ISO 717-2.

The sound insulation regulatory impact statement issued in February 2002 introduced the following modification of the wall impact sound test as a field verification method.

The method is based on ISO 140-7 (Field Measurement for Impact Insulation of Floor) adapted for walls as follows:

(a) The equipment must comply with annex A of ISO 140.7.
(b) The standard tapping machine must be mounted on a horizontal steel platform 510 x 460 x 10 mm thick with legs that slope at 60° to the floor so that half the force imposed on the plate is transferred to the wall via the long edge of the plate.

(c) The test procedure and evaluation must be in accordance with Clause 5 of ISO 140.711.

(d) Expression of results must be in accordance with Clause 7 of ISO 140.711.

(e) The impact sound levels measured in the receiving room must be normalised using a reference equivalent absorption area (A) of 10 m².

(f) The test report must be in accordance with Clause 8 of ISO 140.711.

(g) A single figure rating \( L_{nT,w} \) must be calculated in accordance with ISO 717-24.

In response to this proposed field verification test, the author wrote to the Australian Building Codes Board, supplying most of the information in the first half of this paper. The author also pointed out that the first of the deemed to satisfy walls in Table 5.5 of the current version of the BCA would only satisfy the proposed wall impact requirement, if the angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts was increased or if the specified maximum value of \( L_{nT,w} \) was increased.

The levels produced by the North Ryde frame are higher because the angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts is smaller. The RMIT measurements at high frequencies on the first of the deemed to satisfy walls are greater than those of the other laboratories. It is suspected that this was due to flanking transmission that has now been removed.

The angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts for the North Ryde is 55.6°. The angle between the floor and the plane containing the line of the feet of the legs and the line of the tapping machine impacts for the Highett frame is in the range of 78.9° to 79.5°. With the North Ryde frame, the old North Ryde chambers gave \( L_{n,w} \) of 66 and the new North Ryde chambers gave \( L_{n,w} \) of 66 for the first of the deemed to satisfy walls in Table 5.5 of the current version of the BCA. This exceeds the proposed limit of 60 with a frame whose angle of 55.6° is slightly less than the 60° specified. The Highett frame which has a much greater angle of 79° has given \( L_{n,w} \) values of 57, 58, 58, and 61 for the first of the deemed to satisfy walls in Table 5.5 of the current version of the BCA when measured in four different laboratories. The 61 value is believed to be due to flanking transmission in the RMIT chambers which has now been removed. Thus this wall would satisfy the maximum value of \( L_{n,w} \) equals 60 if the specified angle was changed to 79°.

The author strongly recommended that one of the two existing angles, namely 79° or 55.6° be specify. This means that some of the existing measurement data will be able to be used. The 55.6° angle has the advantage that it produces louder signals and according to Prem Narang less variability. However the author recommended the adoption of the 79° angle because RMIT, NAL, CSIRO Highett and CSIRO North Ryde have all made a number of measurements with the 79° frame. Only CSIRO North Ryde have made measurements with the 55.6° frame. Another reason for recommending the 79° frame was that it will stay in place on its rubber feet under the action of the tapping machine. The 55.6° frame needs heavy weights to stop its feet from slipping. The consultants are unhappy about having to carry a frame as well as the tapping machine up stairs in a partially completed building. They will be even unhappier if they also have to carry heavy weights to stop the tapping machine frame...
from moving. The current North Ryde 55.6° frame has a 25 mm flange along the edge in contact with the wall. Thus technically it does not satisfy the current or proposed measurement methods. This flange would need to be included if the 55.6° frame was adopted.

There is no justification for leaving out the laboratory wall impact test, unless the field verification wall impact test is also left out. The author strongly recommended that the laboratory wall impact test be reinstated.

According to the author’s calculations, the force transferred to the wall by an impact frame with an angle of 60° is 1 divided by the square root of three times the impact force rather than half the impact force as stated in FV5.1.3(b) of the proposed acoustics changes to the BCA.

The ABCB issued a revised test with clauses (b), (c) and (g) modified as follows.

(b) The standard tapping machine must be mounted on a horizontal steel platform 510 x 460 x 10 mm thick and 1--1.5 m above the floor with legs that form an angle of 79° to the floor so that a component of the tapping force is imposed on wall via the long edge of the plate.

(c) The test procedure and evaluation must be in accordance with Clause 5 of ISO 140.7 except that -
   (i) for framed and sheeted walls - the wall must be impacted at least 3 times midway between adjacent studs and no closer than 150 mm to a noggin, the first stud no closer than 1 m from a side wall and at least 3 times on the stud closest to the centre of the wall; and
   (ii) for other walls - the wall shall be impacted in at least 3 evenly distributed positions; and
   (iii) a continuously interpolating moving microphone must be used for at least 30 seconds for each tapping position.

(g) A single figure rating (L'nT,w) must be calculated in accordance with ISO 717-2 and the highest value of L'nT,w shall be adopted as the rating for the wall.

The author recommended that rather than take the noisiest level, the results should be averaged in the energy domain since this would reduce the experimental uncertainty. Paragraph (e) requires normalisation to 10 square metres of absorption. This gives L'n and L'n,w. To obtain L'nT and L'nT,w requires normalisation to a reverberation time of 0.5 second.

The word interpolating needs to be removed from paragraph (e) as it is technically incorrect in this situation. Paragraph (e) should allow the use of a minimum of four fixed microphone positions at least 0.7 metres apart and specify a minimum moving microphone traverse length of 4.2 metres.

The author was disappointed to discover that in the draft sound insulation directions report released at the end of June 2002, the original rather than the revised field verification test had been included. He was pleased that a laboratory wall impact sound test had been included, but disappointed that it was the modification of the existing test, which has been given above, rather than a version of the revised field test.

The author wrote to the ABCB saying that he was shocked to discover that Specification FV5.1 still contained the 60° leg angle. He also pointed out that the reference to normalising
to 10 square meters of absorption must be removed if the intention is to use \( L'_{nT,w} \), since \( L'_{nT,w} \) is normalised to 0.5 second reverberation time not to 10 square metres of absorption. The author was pleased that the laboratory test Specification F5.5 Impact Sound - Test had been re-inserted, but pointed out that it needs to include an angle of 79° and should probably refer to ISO 140 Part 6\(^9\) rather than AS 1191\(^8\) for consistency.

7. CONCLUSIONS

It is necessary to specify the design of the wall impact frame since this affects the impacts that the wall receives. A corrected version of the revised field verification test for wall impact sound insulation testing should be adopted for both laboratory testing and field verification.

8. ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of Peter Alway, Jack Bramwell, Ken Cook, Peter Dale, Mark Debevc, Prem Narang and Matthew Patterson.

REFERENCES