Impact Sound Insulation of Building Partitions: Its Measurement and Inherent Difficulties*

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ABSTRACT: Part F5 of the Building Code of Australia 1990 contains performance requirements in relation to the resistance of building partitions to the transmission of impact sounds. The Code specifies the method required under laboratory conditions. The construction is deemed-to-satisfy if it is no less resistant to impact sound than one of three specified walls. Measurements have been carried out on a number of commercial partitions. Great difficulties are experienced so far as details/requirements are concerned, and even more in the interpretation of results. In this paper these difficulties are pointed out, with suggestions for modification of the Code and possible adoption of a means of the expression of results by a single number. Some alarming errors in measured values due to unexpected flanking paths have been detected. Accordingly it has been decided to eliminate the reporting of actual measured values of impact insulation.

1. INTRODUCTION

One of the basic objectives stated by the Building Code of Australia [1] is to "...ensure that acceptable standards of amenity are maintained for the benefit of the community". On the aspects of noise transmission and insulation, Part F5 sets out specifications for the sound insulation offered by partitions, and outlines the method of measurement of impact insulation.

The original purpose of this paper was to present the results and comments given in two papers of the Australian Acoustical Society in Brisbane in November 1996. Paper 1 was confined to measurement of impact insulation with the Code in mind while Paper 2 discussed shortcomings of the Code both in measurement and interpretation. In view of the many Code shortcomings, and some alarming discoveries, this paper will not present measurement results for fear of creating wrong impressions for measuring laboratories desirous of commercially testing partitions in conformity with the Code.

This paper examines measurement procedures for commercial partitions and shows why current procedures are quite unworkable. The interpretation of results poses a far greater problem especially due to the doubtful validity of measured quantities. The question of a possible single-value rating for impact insulation is discussed and questions are posed on the likely benefit to the occupants of an adjoining room.

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2. MEASUREMENT OF IMPACT

2.1 Measuring facilities

In order to measure the airborne sound transmission loss and impact insulation of partitions, Code specification F5.5 requires a measuring facility which complies with AS 1191 [2]. The facilities for the study described in this paper comprise two pentagonal-plan reverberation rooms each of volume 110-120 m^3 and includes an aperture for a sample of 10.69 m^2. This suite satisfies all requirements of AS 1191 which include the testing to ensure that the sound transmitted by any path other than through the partition shall be negligible compared with that through the partition. Valid measurements are possible in one-third octave bands of centre frequency 100 to 5000 Hz. Even though precision is compromised, the measurements may be extended down to centre frequency 50 Hz.

2.2 Application to impact insulation measurements

In following the Code, a horizontal steel platform is placed with one long edge in contact with the source-room side of the test wall. To generate the impacts a tapping machine complying with ISO140/VI-1978 [3] is mounted on the platform. The impact sound pressure levels resulting in the receiving room are measured, in particular at four microphone positions each for a period of 128 seconds. These are then normalised using a reference equivalent absorption area, A_0 of 10 m^2

$$L_{nf} = L_{pf} - 10\log_{10}(A_0/A_f) \quad (1)$$

where L_{nf} is the normalised sound pressure level in dB at centre frequency f, A_f is the receiving room equivalent absorption area in square metres at centre frequency f, given by

$$A_f = 0.16V/T_{60,f} \quad (2)$$

where V is the receiving room volume in cubic metres and $T_{60,f}$ is the reverberation time in seconds at centre frequency f.

Because of anomalous behaviour detected and discussed later in this paper the actual results of measurement are not presented. However some actual results of measurement of impact insulation by Debevc [4] are available.

2.3 Test of equivalence of results

Table F5.5 of the Code sets out construction details of three walls which have been deemed to possess impact insulating properties which are suitable for dividing walls. The results of measurement of a sample partition are to be compared with those of one of the Table F5.5 walls. The sample partition is deemed to satisfy the Code only if its impact insulation is at least as high as that of one of the standard walls.

2.4 Measurement-procedure shortcomings of Code

At first glance it may appear a particular measuring laboratory need only take comparative measurements of a sample partition and a Table F5.5 partition, though the means of comparison is not stipulated. It is nevertheless important that measurement results are to some extent comparable between measuring laboratories. This will only be feasible if the method of measurement is laid down with some rigidity, not the currently-worded version of the Code. Some of the measurement-method features which may greatly influence the results are as follows:

(a) Location of the impacting of the sample

- (i) In the vertical direction, the distance between the bottom of sample and the source-room floor for the steel platform will vary between measuring laboratories
- (ii) In the horizontal direction, the number of locations for the impacting plate has not been stated so the minimum number must be specified. For the results in this paper the number was chosen as four.

What is of greater significance is the influence on the resulting impact levels due to studs in a cavity wall construction. An average effect will not be obtained unless the impacting plate locations chosen comprise some over the studs and some between the studs.

(b) Nature of the impact – the impact on the sample caused by the tapping machine is in fact not a direct one (in contrast with that used for testing floors). It is an indirect one via the 510 × 10 mm horizontal steel edge of the platform. Should this edge not be a strictly continuous one then the imparted impact energy will not always be constant. In real partitions it may be very difficult for the installer to achieve a perfectly plane surface over each and every region of edge contact.

(c) Precision in equivalent absorption area of the receiving room – A_f in eqn.(1) is required in the normalising of measured sound pressure levels. To enable some valid comparison of results between measuring laboratories the precision in terms say of the 95% confidence interval should be prescribed. (In measurements for this paper, between 100 and 5000 Hz, four microphone positions are used. This number is increased when investigations are carried out down to 50 Hz.)

(d) Frequency range – the Code fails to state the appropriate frequency range. Such a choice will be influenced by the intended destination of results, particularly if there is a desire/intention to derive a single-value for a partition.

2.5 Possible alternative measurement method

The original method of using a tapping machine to investigate floors to simulate footstep noise is not relevant in the study of the effect of common single impacts on walls. It is even less relevant if impacts on a wall are not direct ones but via a plate as required by the Code. For real walls it would be more appropriate to produce single impacts and then to measure the direct energy transmitted to the receiving room. This anomaly is pointed out by Craik [5], Schultz [6], Tanaka et al [7]; this latter work recommends use of a rubber ball and is applicable to a Japanese standard [8]. In practice, generally the disturbance to the amenity of an occupant of a room is due to single impacts caused for instance by closing doors and use of sinks attached to an adjoining wall. Two alternatives that have been investigated are:

Impulse by a falling rod. A polycarbonate rod 30mm diameter length 375mm and mass 0.335kg is attached to a horizontal reference plate by two sisal strings each of length 280mm. The rod is released and completes one-quarter revolution before impacting the sample wall (horizontally). On rebounding the rod is prevented from further action.

As with work with the tapping machine, four locations for the impact by the rod are chosen at the same height above the base of the sample as the tapping method plate. The measurement of the effect of impact in the adjoining room is by measurement of peak sound pressure levels. In this case however the microphone is located in the receiving room direct field at a distance of 535mm from the sample surface and behind the point of impact. Note that for this method the sound pressure levels in each one-third octave band of centre frequency between 50 and 5000 Hz are not normalised.

The advantage of this method is that it becomes possible to standardise it completely. The impacting rod details, the method of impacting and the technique of measurement of the effect in the adjoining room may all be specified.

A similar-type method employed by Craik [5] uses a simple plastic-headed hammer to produce single impacts on walls In work reported by Tanaka et al [7] a special rubber ball is the impact source and is used to drop onto a floor. It would seem reasonable that such a ball could be used as a source in preference to the polycarbonate rod earlier described because its design has been optimised.

Impacts due to running water. A garden tap is fixed to the sample wall on the source room side and water is supplied via a 19mm garden hose. The flow rate of approximately 12 litres/minute is regulated and measured. Details are provided by Debevc[4]. This method resembles conditions in practice where plumbing noise impacts an adjoining partition of a building. For this method only one tap location is used. The resulting receiving room sound pressure levels are measured at three locations in the reverberant field and normalised using eqn. (1). The one-third octave band levels are measured in centre frequency range of 100 to 5000 Hz.

2.6 Effects of flanking transmission

In measuring the sound transmission loss, clause 2.7(b) of AS 1191 [2] requires the edge conditions of a test sample to resemble those of an actual installation. Since it is beneficial to incorporate this test with the work on impact insulation the sample remains in the same condition. However when impacts are made on the wall it is probable that some impact energy incident on the wall will in part be transferred to the steel aperture and thence to the wall of the source room. This will in turn exert some influence on the sound pressure levels present in the receiving room. This part-bypass may be prevented by use at the sample perimeter of some isolating material but this then will contravene the requirements in sound transmission loss determination. Some detective work was carried out to see whether this possible flanking exists but is not a detailed study:

(a) *Using tapping machine:* Following normal measures the steel impact plate was moved slightly from contact with the sample and measures repeated. These show that significant energy is entering the receiving room which has not originated solely from the partition; this is more noticeable above 800 Hz.

(b) *Using impact rod:* After normal measures, the polycarbonate rod was moved so that the impact was on a wall of the source room some 3 metres from the sample wall. Measures of non-normalised levels in the receiving room close to the sample partition show that above 160 Hz there were no significant differences from when the rod made contact with the sample wall. This is quite a staggering discovery because it appears to negate any attempt to measure impact insulation of a wall.

Should further investigation reveal that flanking transmission is restricted to the sample perimeter then it effectively means any determination of impact insulation without rigid fixture to the aperture may not later be used to determine airborne sound transmission loss. This coupling of a test sample to surrounding structures is pointed out by Craik[9] who takes special care to see that such coupling errors are minimised.

3. INTERPRETATION OF THE CODE

3.1 Sample performance requirements

In F5.5 of the Code a wall is required to possess a stated single-number rating for airborne sound transmission. However for impact insulation it is required to be no less resistant to the transmission of impact sound than a wall listed in Table F5.5. The shortcomings of the Code are three-fold:

(a) The frequency range of investigation is not stated. Even though airborne transmission deals with a range 100 to 5000 Hz it does not necessarily follow that the appropriate range for impact testing be the same. It is necessary to devise a frequency range after studying the subjective effect on occupants. Current thoughts by ISO suggest an extension of the range down to 50 Hz.

(b) No information is provided of the likely normalised sound pressure levels of each of the Table F5.5 walls when tested by the method of No.3 of Specification F5.5. Nevertheless, this presents no real difficulties, so long as further shortcomings are addressed, since the laboratory is required to compare the results with those for a sample with a Table wall.

(c) Short of any clarification, currently a comparison of two walls means a sample fails the Code if its normalised sound pressure level exceeds that of a Table wall at any centre frequency. This is clearly a ridiculous state of affairs in resolving the practical performance of a given partition.

3.2 Possible single-number value of impact insulation

The above Code shortcomings could be overcome if the impact insulating properties of partitions could be expressed by a single-number value. The essential requirement of such a rating is that it addresses the subjective response of an occupant in the receiving room. This is of course contingent on each of the Table F5.5 walls providing satisfactory impact insulation. Initially, one should review some possible known methods of rating impact insulation.

Impact insulation class, IIC. The means of deriving this rating is set out in ASTM E989 [10]. It is based on use of the tapping machine but in direct contact as distinct from the Code indirect contact method via the steel plate. It is specifically applicable to the comparison of floor assemblies and is not designed to simulate any one type of impact. This is clearly then not suitable or applicable to impact on walls.

Normalised impact sound pressure level, L'_n or standardised impact sound pressure level, L'_{nT}. These values are derived as set out in ISO/DIS 717-2.2 [11] and measured using a tapping machine. However this standard is intended for field and not laboratory measurements and is intended just for floor assemblies. This is therefore an unsatisfactory rating for the Code.

Bodlund's index, I_s The above ratings compare normalised levels with a shifted reference curve whose values vary with frequency from 100 to 3150 Hz. For walls in practice this is considered to be not the most appropriate one because of the different exciting mechanisms impacting the walls. In addition such impacts are commonly single events rather than the repetitive one imposed by a tapping machine. In an attempt to resolve these differences Bodlund [12] studied possible variations in the shape of the reference curve also the frequency range. His work is based on work both on floors and on party walls.

Bodlund derived a modified reference curve to yield a new single-value rating I_s which yields better correlation with his judged subjective ratings of intrusive impact sounds. The important differences for this index are the appropriate frequency range for measurements namely 50 to 1000 Hz, as well as the shape of the curve. Following necessary investigations it might then be beneficial to adopt a single-value rating for impact insulation. It would be necessary also to measure the impact behaviour of the three Table F5.5 walls along with any subjective effects of the intrusive impact noise. This of course still leaves the questions of whether the tapping machine is the most suitable impactor and of the appropriate measures to be made in the receiving room.

When an alternative reference curve rating method has been derived it may require alternative shape and rules depending on the means used to impact a wall. Such means will depend on a building code identifying the most significant type of intrusive impact sounds likely to cause a loss of amenity to occupants of a room.

4. ALTERNATIVE TYPES OF IMPACT SOUND

When the most suitable single-value rating for impact insulation has been established, it now requires a method or methods by means of which a wall may be impacted. It is also necessary to decide on the most appropriate measures in the receiving room. It is felt essential that the method for measuring impact insulation be laboratory-based if it is the intention of the Code to have a sample partition deemed-to-satisfy the performance of a Table F5.5 type. This comparison of partitions will not be possible if field measurements are permitted.

As discussed earlier, possibly the most serious type of intrusive impact noise is due to single events. Accordingly it is more appropriate to use a single-impact source. Such single impacts feature in a Japanese industrial standard [13] even though it is a field method designed for floors. From this standard a working group has been set up, a round robin conducted, and an interim report produced [14]. The basis of the source is a rubber ball to produce a single impact by dropping and the consequent ball design allows standardisation.

In order to utilise the Japanese method as a means of producing a single impact on walls, it would be possible for a suspended ball to describe an arc before striking a partition as discussed in section 2.5 of this paper. By this means the actual impact energy may be specified in terms of the arc travelled and height fallen of the ball.

5. SUBJECTIVE EFFECT IN RECEIVING ROOM

When one first reads the Code, the impression is gained that in terms of impact insulation there is a benchmark of three magical walls which will provide adequate protection for the occupants in an adjoining room from the large range of possible impact noises. All sample partitions are then divided into "pass" or deemed-to-satisfy and "fail" when compared with this benchmark. Unless guidance is provided concerning the method of comparison and the actual measured quantities the whole aim of giving acceptable standards of amenity is doomed to failure. Short of Code guidelines the acceptance or rejection of a partition could well be based largely on the personal opinion of a measuring laboratory together with a few measurements, meaningful or meaningless.

5.1 Which quantity to measure in receiving room?

By including a tapping machine in testing methods it is probable the Code is assuming the use of normalised sound pressure levels in the adjoining room. There are various possible sound levels such as peak level dB, dB(A), dB(C), long-term average dB, dB(A), dB(C), sound exposure levels etc. As pointed out by Akay [15] the human auditory system has difficulty in accurately judging impact noises by just comparing the loudness with steady state levels. This then seems to condemn the Code practice of just measuring normalised sound pressure levels.

Each and all of the above types have appeared in work by various authors over many years. For instance in the investigation of a ratings system for impact noise transmission Bowles has suggested [16] the use of the C-weighting level for large-amplitude responses having dominant low-frequency components. Schultz [6] discusses the various types of level measures and that is likely to achieve a better correlation with the subjective assessment if the impact used is a real-life one. This then appears to support replacement of the tapping machine by some mechanism as discussed in section 2.5 of this paper. Kumagai [17] has investigated various types of single-impact noises and states that influencing parameters are the peak level, decay and rise times of the impact energy. Even though support is given to the measure of peak levels due to impact, the influence of the time-response mechanism appears to add complication to the measurement process.

5.2 Impact noise generation mechanisms

It is necessary to better understand the impact noise generation mechanisms if the most appropriate measurement system is to be chosen. Considerable work has been carried out over a number of years into these mechanisms. However this work has largely been confined to the subjective effect due to sonic booms, aircraft noise, drop-forge operation and not to single impacts on interior building partitions with adjoining rooms. There has been general agreement on the importance for impact noise nature of the energy level the impact rise-time and decay-time. Studies however have concluded that the greatest influencing factor has been the significant variations between the people in matching the loudnesses of two impact sounds.

For the response to impulse noise, Schomer [18] discusses some objective measures though work appears restricted to external sources. A particular quantity discussed is the sound exposure level, SEL where

$$\mathrm{SEL} = 10 \log_{10} [1/p_{ref}^2 t_0^2 \int p^2 (t)\, dt] \qquad (3)$$

where p_{ref} is reference pressure of 20 μPa, t_0 = 1s and $p(t)$ is a time-varying sound pressure, A- or C-weighted. This term has been chosen by the Environmental Protection Agency of USA as a better indicator of annoyance estimates. Schomer concludes that the most appropriate measure is the C-weighted SEL for impulse noises external to the building. In fact its measurement is possible by incorporation in a sound level meter. However it has been pointed out by others that an ordinary sound-level meter does not incorporate an adequate time constant to address the impact rise time. Schultz [6] has suggested instead a measurement of peak impact levels using a time constant of 35 milliseconds. Considerable work has been carried out by Carter [19] on the auditory response to impact noise and its controlling factors, in addition to considerable other studies reported by him. It would be beneficial to develop and further such studies in an attempt to decide on the most appropriate quantity for measurement in the receiving room.

6. CONCLUSIONS

This paper illustrates the enormous problems facing the Australian Building Codes Board in the production of a practical and useful code for the measurement of impact insulation of building partitions. It is considered that the present status of the Code relegates it to the guide classification and not to a Code. Perhaps difficulties have emerged because, to a large extent, the question of impact insulation of walls in a quantitative sense has generally not emerged as a problem in other parts of the world, so that there has not been pressure for International Standards that can be applied.

The Code in its present form is not likely to point those measuring impact insulation in the same direction so naturally they will probably produce significantly different results. The use of the tapping machine has been shown to be inappropriate and it is recommended it be replaced by a more suitable type of single impact. To achieve some degree of uniformity nationally in the results, it is felt advisable to require some stated precision in the measured response in the receiving room from which a confident Code can be derived.

A most serious problem present is that a measurement facility for airborne sound transmission is probably not one suitable for impact insulation determination with the same sample mounting. Any duplication of sample mounting to dismiss flanking would of course complicate the laboratory determination in an economic sense. It is essential that the transfer of impact energy to the receiving room structure via the partition is minimised. Such flanking has been shown to be significant when a partition has been installed primarily to measure airborne sound transmission.

In the event that the difficulties of measurement have been addressed by the inclusion of more stringent operating procedures with achievement goals there remains the problem of interpretation of results. The introduction of a single-value rating of impact insulation would not only be in harmony with the single-value STC for airborne sound transmission but would greatly simplify the question of meeting or not meeting the Code. It has been shown that some ratings are inappropriate for impacts on walls and their relevance can be influenced by the nature of the impact. Before selection of this single-value rating it is necessary to investigate the subjective effect of impact sounds on room occupants. In conjunction with this work the three walls of Code Table F5.5 should be checked to ensure that they satisfy criteria for impact-insulating partitions. It should be a task of such a study to recommend the rating that truly reflects the effect of that type of impact considered to be most intrusive upon room occupants.

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