Impact sound measurements on floors covered with small patches of resilient materials or floating assemblies

Warnock, A. C. C.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20331190
Internal Report (National Research Council of Canada. Institute for Research in Construction); no. IRC-IR-802, 2001-03-01

National Research Council Canada
Conseil national de recherches Canada

NRC · CNRC

Impact Sound Measurements on Floors Covered with Small Patches of Resilient Materials or Floating Assemblies

Warnock, A.C.C.

IRC-IR-802

.

www.nrc.ca/irc/ircpubs

construction

Institute for Research in Construction
Institut de recherche en construction
IRC

Impact sound measurements on floors covered with small patches of resilient materials or floating assemblies.

by A.C.C. Warnock, IRC, NRC Canada

Internal Report IRC-IR-802

January 2000

The work was supported by a consortium that included

Vibro-Acoustics

Kinetics Noise Control

Mason Industries

Dura Undercushions

The Noble Company

Abstract

Resilient materials are commonly placed on top of a hard floor surface to reduce impact sound transmission to rooms below. Examples of such are carpets and vinyl or cork flooring. A raft of material, such as a wood or concrete slab, may also be placed on top of a resilient layer to form a “floating” floor. All of these systems may be referred to collectively as *floor toppings*.

The same floor topping in combination with different base floors provides quite different impact sound insulation ratings, partly because the base floors give different sound insulation and partly because of different interactions with the base floor. Thus it is often impossible to select the most effective floor topping from several that have been tested on different base floor assemblies and only composite impact sound insulation ratings are available.

An ISO test procedure measures the improvement due to a floor topping when it is placed on a concrete slab. The improvement may then be used to estimate the impact sound insulation of floors incorporating concrete slabs. This project confirmed that the ISO procedure works well and that small areas of floor topping specimens can be evaluated without serious error. The measurements showed that these improvements may not be applied to joist floors with lightweight subfloors such as plywood.

Improvement ratings for a number of generic materials are provided in the report.

Résumé

Souvent, on place les matériaux résilients sur un plancher dur afin de réduire les bruits d'impact dans les salles en bas. Des examples sont les tapis , ou les tapis de vinyle ou liège. Aussi, on peut mettre une dalle de béton ou de bois au-dessus d'un matériau résilient et créer une "dalle flottante". Simplement, on peut appeler tous ces systèmes "couvrements de plancher."

Un même couvrement de plancher donne des insonorisatons tout-à-fait différents sur des planchers de base différents. C'est parce que les planchers de base donnent des réductions de bruits différents et que l'interaction entre le couvrement et chaque plancher est différent aussi. Donc, c'est presque impossible à choisir un couvrement de plancher quand on a seulement les resultats d'essai sur des planchers complets.

Il y a une méthode d'essai de l'ISO qui donne l'amélioration due à un couvrement de plancher sur une dalle de béton. On peut utiliser l'amélioration pour estimer l'insorisation des autres planchers qui incorporent une dalle de béton. Ce projet a confirmé que la méthode d'ISO fonctionne bien et qu'on peut utiliser des petits échantillons de couvrement pour lévaluation sans erreurs importantes. Les mesures ont montrés qu'on ne peut pas utiliser les améliorations avec des planchers en solives avec un sous-plancher léger comme le contreplaqué.

On présente dans ce rapport des indices d'amélioration pour plusieurs couvrements typiques.

Introduction

The work described in this report was conducted as part of a project investigating the effectiveness of floor coverings, especially coverings comprising a hard upper layer supported by a resilient layer—a floating floor. The work was supported by a consortium that included

- Vibro-Acoustics
- Kinetics Noise Control
- Mason Industries
- Dura Undercushions
- The Noble Company

The work reported in this document was done to determine whether the ISO procedure for evaluating floor toppings could be adapted for use in North America and whether it could be extended for use on lightweight joist floors. The evaluation of the ISO test method is described in Part 1 of this report.

During the project, impact sound reductions for some generic toppings were obtained. Although primarily obtained using only small specimens, these will have general interest for those wishing to reduce impact sound transmission through floor systems. This work is described in Part 2 of this report.

For convenience and economy, small specimens of material measuring 1.2 x 1.2 m were used for most of the measurements. The effects of doing so are discussed in Appendix A. Normally floor specimens and coverings completely fill the test frame and measure 3.8 x 4.7 m. None of the specimens were glued or cemented to the floor.

Acknowledgement

The measurements in this project were carried out competently, cheerfully and enthusiastically by Jennifer Birta, Brian Fitzpatrick and Keith Lay. The author is grateful for their support.

Background

Resilient materials are commonly placed on top of a hard floor surface to reduce impact sound transmission to rooms below. Examples of such are carpets and vinyl flooring with resilient backing. A raft of material, such as a wood or concrete slab, may also be placed on top of a resilient layer to form a "floating" floor. Floating floors can be even more complex than a raft and a resilient layer. The raft may be supported on resilient pads or springs with sound absorbing material in the cavity between the raft and the floor below. All of these systems may be referred to collectively as *floor toppings*.

The same floor topping in combination with different base floors provides quite different impact sound insulation ratings, partly because the base floors give different sound insulation and partly because of different interactions with the base floor. Thus it is often impossible to select the most effective floor topping from a set that has been tested on different base floor assemblies and only composite impact sound insulation ratings are available.

The most widely used standardized test methods for rating impact sound insulation, ASTM E492[1] and the corresponding ISO 140[2] use a standard tapping machine that has five steel hammers. The 500-g hammers strike the floor at a combined rate of 10 impacts per second. A machine meeting the requirements of the standard is shown in Figure 1. ASTM method E989 [3] describes how to calculate the single-number rating *impact insulation class*, IIC for the ASTM test. The ISO rating systems are described in ISO 717 [4]

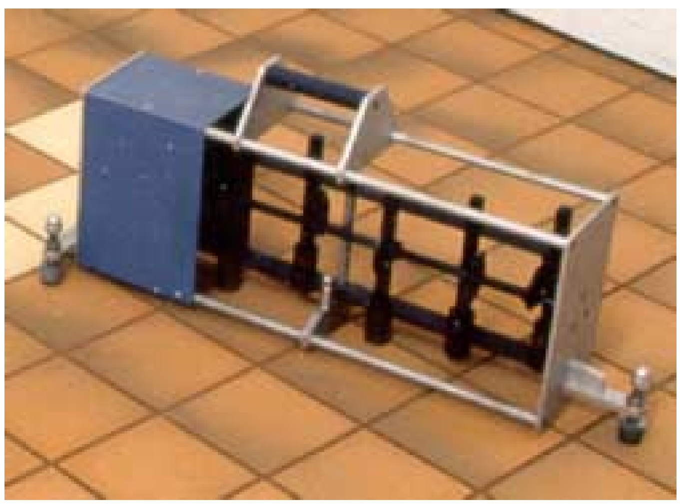

Figure 1: A standard tapping machine for testing according to ASTM E492 and ISO 140.

Results from different laboratories for nominally identical slabs

The range in impact sound insulation data found in different laboratories for *nominally identical* floors tested using the standard tapping machine exacerbates the problem of rating floor toppings. Figure 2 shows normalized impact sound pressure levels (NISPL) for nominal 100 mm thick, normal-weight concrete slabs tested in different laboratories. Figure 3 and Figure 4 show corresponding data for 150 and 200 mm slabs. Given the differences in these figures, it is hardly surprising that the same topping placed on nominally identical slabs in different laboratories may obtain quite different impact sound insulation values.

These figures have disturbing implications about the reproducibility of tests carried out according to E492. If the data truly represent nominally identical specimens, then the reproducibility of the test is very poor. While there are differences in concrete density, these differences are not great enough to account for the differences in NISPL. These data were collected mostly from published literature and do not qualify as a legitimate inter-laboratory comparison. When this report was prepared, no inter-laboratory comparison had been carried out for method E492.

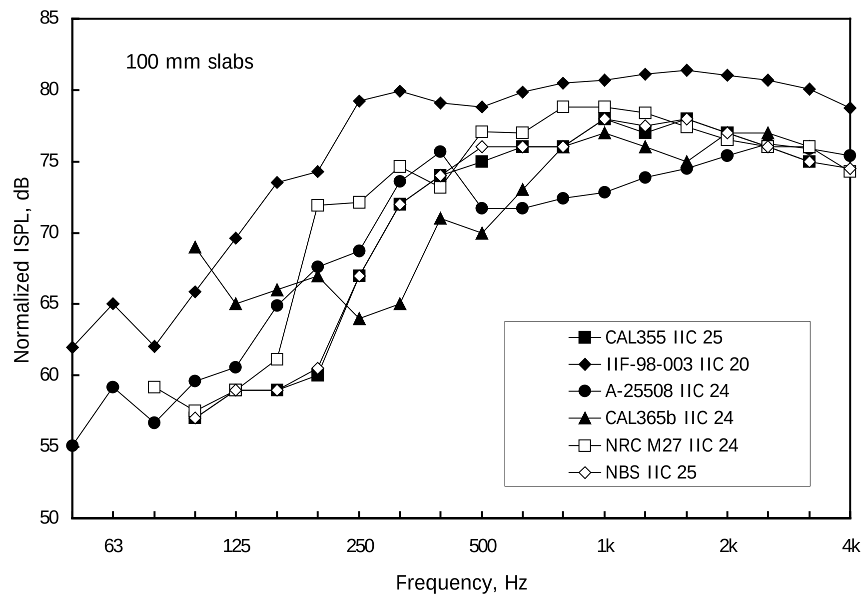

Figure 2: Normalized impact sound pressure levels for 100-mm concrete slabs from different laboratories.

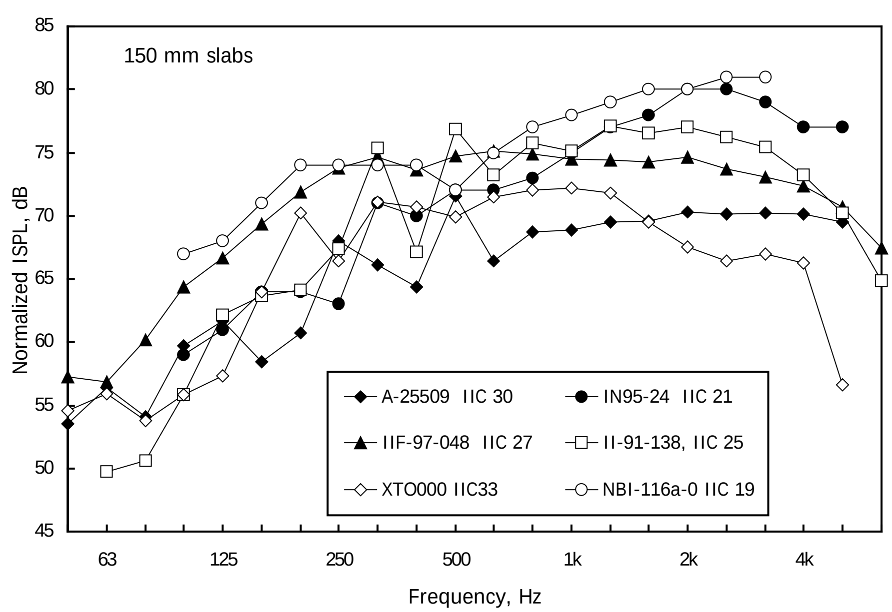

Figure 3: Normalized impact sound pressure levels for 150-mm concrete slabs from different laboratories.

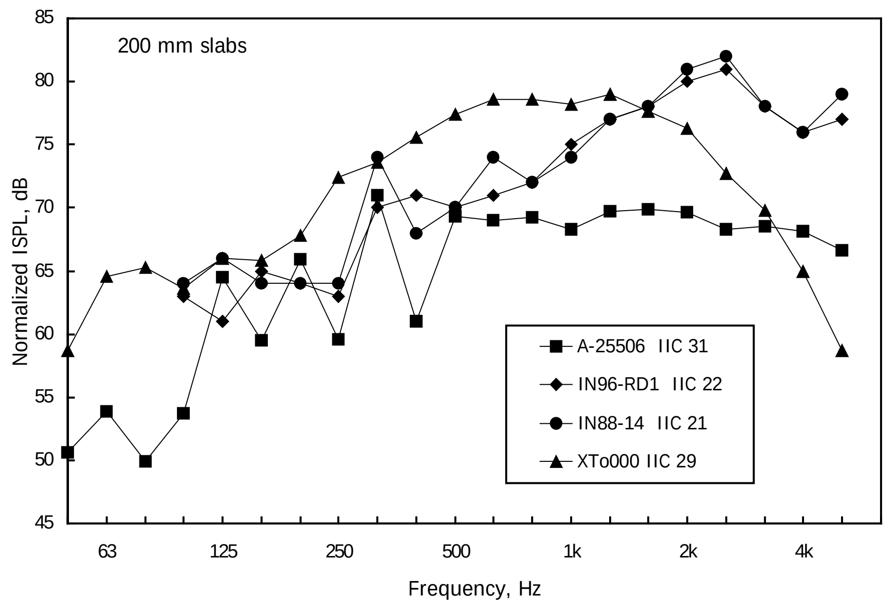

Figure 4: Normalized impact sound pressure levels for 200-mm concrete slabs from different laboratories

ISO test procedure

The problem of evaluating resilient floor toppings has been addressed in ISO 140 part 8[5]. The steps in the test procedure are as follows:

1. Measure the impact sound pressure levels using the standard tapping machine on a bare concrete slab with a thickness in the range 100 to 160 mm.

2. Install the resilient covering or floating floor and measure the impact sound pressure levels again.

3. Calculate the difference between the two results for each one-third-octave band.

4. Add the spectrum of differences to the spectrum of impact sound pressure levels for the idealized concrete slab defined in the standard.

5. Calculate a single-number rating for the combination of the topping and the idealized slab.

6. Report the idealized rating for the combination and the improvement as a change in the single-number rating.

This procedure assumes that the reduction in impact sound pressure level obtained for a floor topping is independent of the laboratory and the floor slab on which the topping was tested.

An extensive investigation of the variables affecting the results from this test procedure is described in reference [6]. The findings in that report alone provide adequate support for the use of the ISO test procedure. The project did not include much information for typical materials and focussed primarily on validating the test procedure. No tests were made on joist assemblies with lightweight sub-floors.

Part 1: Evaluation of ISO 140-8 procedure

The evaluation of the ISO procedure had two main objectives:

- The first was to verify that the ISO procedure using a concrete slab gave satisfactory repeatability for the kinds of toppings being used in North America. If found satisfactory, the intent was to write an ASTM version of the ISO test method.

- The second was to investigate the possibility of applying the ISO procedure on joist floors with lightweight sub-floors.

It is known that the improvement in impact sound insulation obtained for a floor topping placed on top of a concrete slab is not the same for the topping placed on top of a wood joist floor. Since joist floors are very commonly used in North America, an investigation was needed to find how the ISO procedure could be used or extended for them.

Base floors used

Four types of base floor were used for most measurements. These were

- A 100 mm thick concrete slab, 2248 $kg/m^{3,}$ 226 kg/m^2, with a measured IIC of 20.

- A 150 mm thick concrete slab, 2375 kg/m^3, 356 kg/m^2, with a measured IIC of 26.

- OSB/steel joist floor — A steel joist assembly with a 15 mm thick OSB (oriented strandboard) sub-floor. The joists were 16-gauge steel, 203 mm deep and 406 mm o.c. The floor cavity contained 150-mm thick glass fibre batts, and resilient metal channels 610 mm o.c. perpendicular to the joists supported a single layer of 16 mm Type X gypsum board. The measured IIC for this floor was 45. It is referred to as the OSB/steel joist floor in the text.

- Gypsum concrete/truss floor — A wood truss floor with a 38-mm thick layer of gypsum concrete on top of the 16-mm thick plywood sub-floor. The wood trusses were 284 mm deep and 535 mm o.c. There was 89 mm of mineral fibre insulation in the cavity, and resilient metal channels 610 mm o.c. perpendicular to the wood trusses supporting a single layer of 16 mm Type X gypsum board. The measured IIC for this floor was 36. It is referred to as the gypsum concrete/truss floor in the text.

The two concrete slabs (100 and 150 mm thick) are reference specimens maintained by NRC that can be installed as needed in the floor test frame[7]. These two slabs make it easy to test how well the ISO procedure works for concrete floors of different thickness close to the extremes allowed.

Measuring the reduction in impact sound level due to floor toppings is costly and protracted if full-size specimens are used. To minimize costs, most measurements were made using small specimens measuring only 1.2 x 1.2 m. It seems obvious that using a specimen that does not entirely cover the base floor will give results that can not be applied to complete coverings. In fact, ASTM E492 [1] forbids reporting data from such measurements as valid for complete floor coverings. However, measurements using such small specimens ought to at least rank systems correctly and so are satisfactory for experimental or development work. The consequences of using small specimens are discussed in Appendix A of this report.

Resilient materials on concrete slabs

The fundamental assumption of ISO 140-8 is that the reduction in impact sound pressure level should be the same no matter what concrete slab the system or product is tested on. Figure 5 and Figure 6 show the reduction in impact sound pressure level for two small specimens of different materials tested on the 100-mm and the 150-mm slabs. The agreement between slabs is very good. (Details for the rafts and materials mentioned in this part of the report can be found in Part 2.)

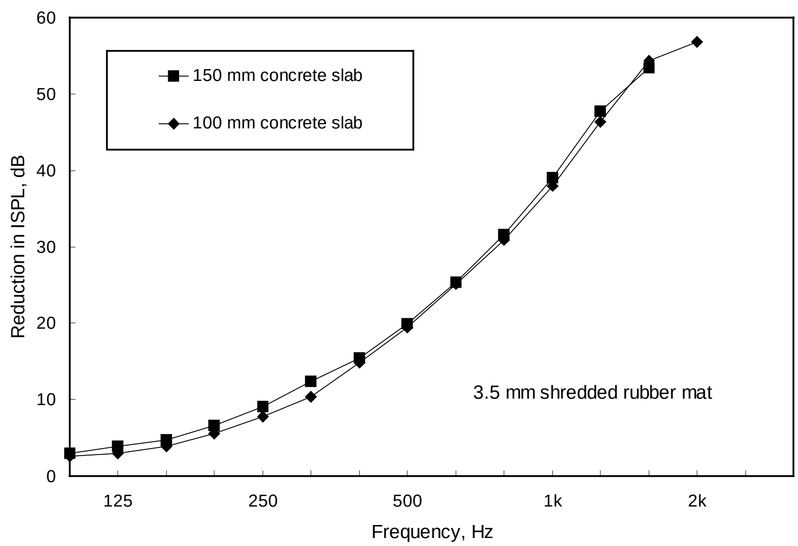

Figure 5: Reduction in impact sound pressure level for 3.5-mm thick shredded rubber mat on two concrete slabs.

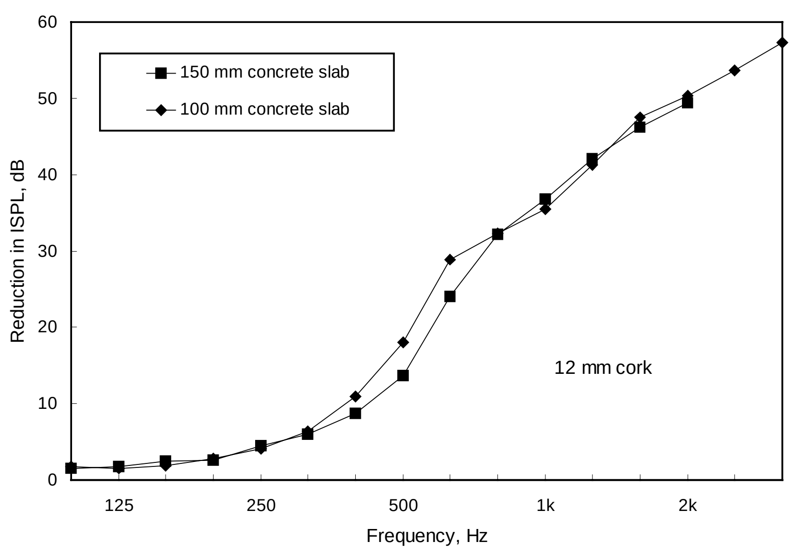

Figure 6: Reduction in impact sound pressure level for 12-mm cork on two concrete slabs.

Raft assemblies on concrete slabs

Figure 7 compares the reduction in impact sound pressure level for a floating assembly on the two concrete slabs. As before, the reductions are practically identical. One interesting point to note in this figure is that the impact sound pressure level actually increases around 160 Hz because of the resonance due to the mass of the floating slab and the compliance of the resilient layer.

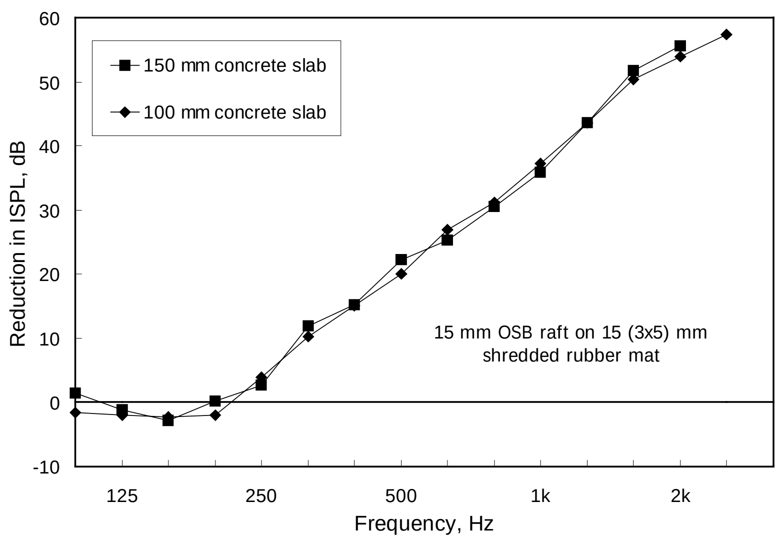

Figure 7: Reduction in impact sound pressure level for 15 mm OSB supported on 15 mm of shredded rubber mat on three different basic floors.

During the project, a ribbed concrete floor with a thickness varying from 75 to 150 mm became available briefly. This floor had a density of 272 kg/m^2 and gave an IIC of 21 when tested bare. Figure 8 shows good agreement for a *full-size* (3.8 x 4.7 m) floating assembly tested on the 150 mm reference concrete slab and on the ribbed slab. For these measurements, the complete wood raft was lifted off one floor as a unit and placed on the other on top of the same resilient material. This figure suggests strongly that the fundamental assumption of ISO 140-8 is valid even when the base concrete slab does not have a uniform thickness.

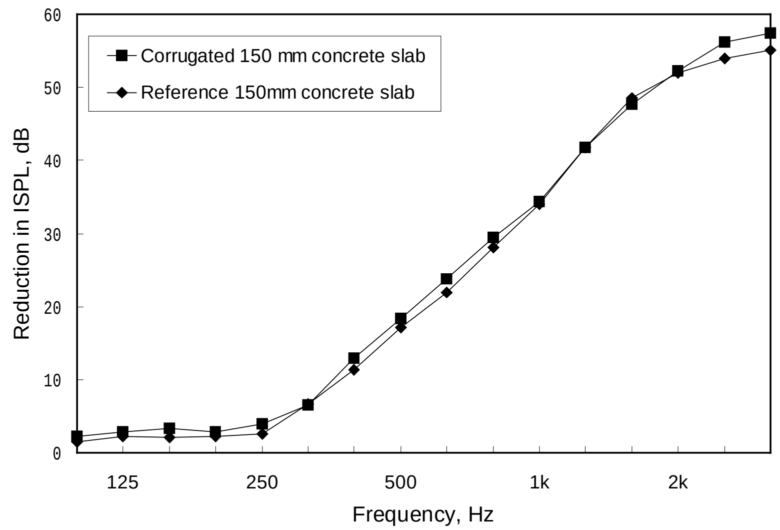

Figure 8: Reduction in impact sound pressure level for 8 mm dense fibre board on top of 5 mm shredded rubber mat tested on the reference 150 mm concrete slab and on a corrugated slab with thickness varying from 80 to 150 mm. Full-size specimens.

Figure 9 shows for all toppings the mean differences ± 1 standard deviation between the results measured on the 150-mm slab and those on the 100-mm concrete slab for each one-third-octave band. This figure supports what has been said already; comparisons between concrete slabs are good. It may appear that the standard deviation in each band is rather large but, as will be seen in the next section, the standard deviation for the single number rating is not so large.

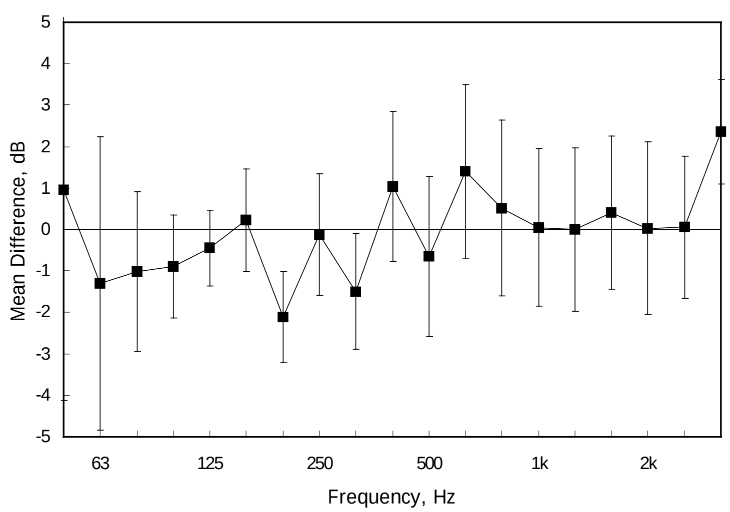

Figure 9: Mean of differences between improvements for all toppings measured on 100-mm slab and on the 150-mm slab.

Single-number ratings

The preceding charts give results in one-third octave bands. The ISO procedure specifies the calculation and presentation of an improvement rating, ΔL, that is the difference between the weighted, single-number rating for the idealized bare floor and the calculated rating for the idealized floor with the topping under test on top. That procedure was followed here but the single number rating calculated was IIC according to ASTM E989 [3]. In the following, this difference is denoted ΔL_A. The difference between the IIC rating for the base floor with the topping and the IIC rating for the base floor with no topping is denoted ΔIIC.

The idealized reference specimen in ISO140-8 has an IIC rating of 28 that is limited by the application of the 8 dB rule in E989 at 3150 Hz. Some of the ratings for the idealized floor in combination with the test assembly are also limited by application of the 8 dB rule. ISO 717-2[4] has no 8 dB rule, consequently, the ISO ΔL will not be numerically equal to ΔL_A. The two ratings must be independently calculated using the measured one-third octave band levels.

Another difference between ISO 717-2 and E989 is that calculations in the former are carried out to one decimal place. In E989, measured levels are required to be rounded to the nearest integer.

Figure 10 compares ΔL_A ratings for several resilient materials alone and in combination with different types of raft on the two concrete slabs. With a few exceptions, the ratings are in good agreement. The mean difference of the 38 values is 0.53 and the standard deviation is 0.95.

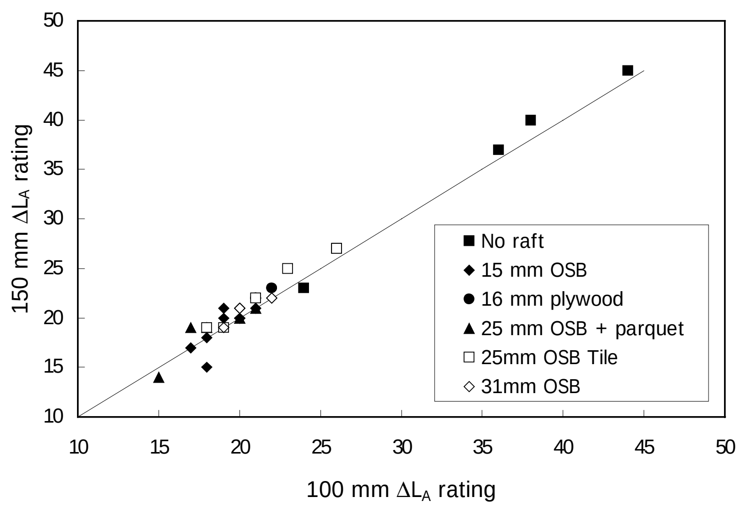

Figure 10: Improvements for specimens on 100 mm and 150 mm slabs. The straight line is a visual reference showing where points would lie if testing on both slabs gave identical ratings.

Summary for concrete slabs

These data support the assumption that the improvement spectrum is independent of the thickness of the concrete slab on which it is measured. Thus, the ISO procedure can be used successfully with resilient materials and lightweight floating floors to rank the toppings. The data from such testing can be used to estimate impact sound pressure levels for other concrete floors where the levels for the bare floor are known.

Resilient materials on joist floors

It would be convenient if the improvement obtained for a topping on a bare concrete slab could be applied to joist assemblies with wood sub-floors or to wood sub-floors with a concrete topping. Doing so, unfortunately, does not give reliable information. Figure 11 and Figure 12 show reductions in impact sound pressure level for two materials on the OSB/steel joist floor, the gypsum concrete/truss floor and on the 100-mm concrete slab.

OSB is more resilient than concrete, so the force pulse generated by the hammer lasts longer, has a lower amplitude and generates less high frequency energy. Resilient layers only add slightly to the high-frequency attenuation. Thus, the reduction in sound pressure level at high frequencies for toppings placed on top of the OSB is much less than it is for concrete.

Gypsum concrete is harder than OSB but not so hard as concrete; it is friable and during testing the surface becomes quite damaged by the repeated hammer blows. It is probable that the powder in the indentations softens the hammer impacts and so reduces the high frequency content. Thus, the improvement at high frequencies is not as great as for the concrete slab.

The friability of the gypsum concrete means that the impact sound pressure levels without a topping will have a significant uncertainty at high frequencies. Obviously friable materials should not be used as reference surfaces with the standard tapping machine. If there were some way to eliminate the powdering of the gypsum concrete without changing its other properties, it is probable that the improvement curve obtained would better match that obtained on the concrete slabs at high frequencies.

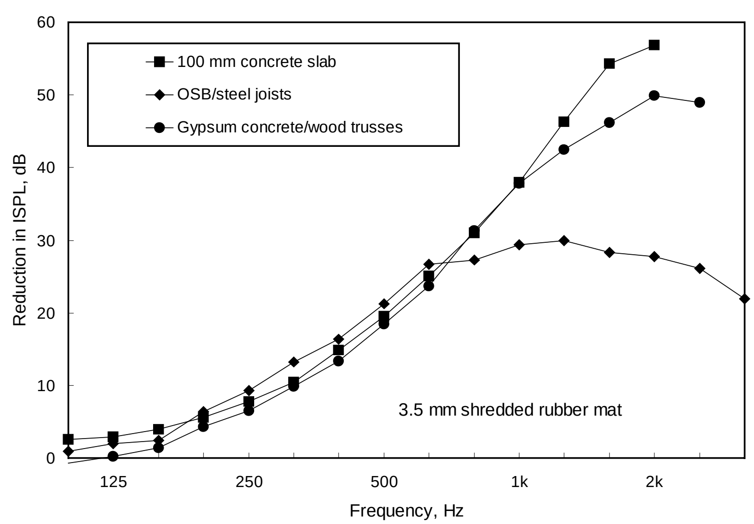

Figure 11: Reduction in impact sound pressure level obtained with 3.5 mm shredded rubber mat on three floors.

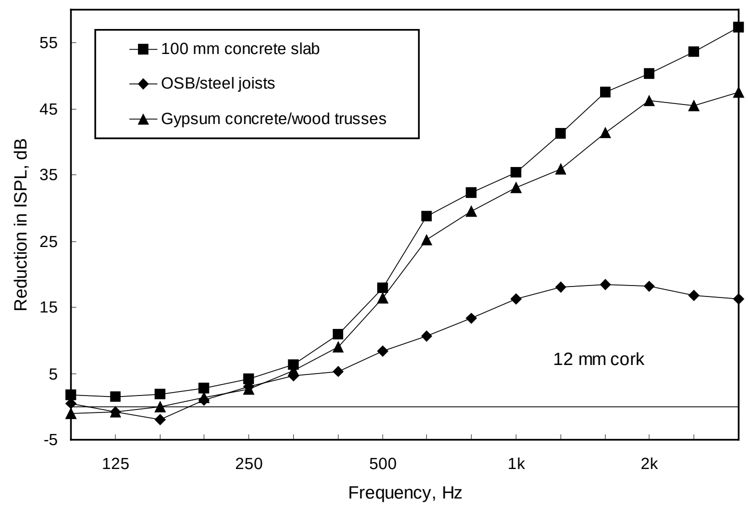

Figure 12: Reduction in impact sound pressure level obtained with 12-mm cork on three floors.

Raft assemblies on OSB/steel joist floor

The improvement spectrum for a 15-mm OSB raft on the OSB/steel joist floor is also quite different from that on the 100-mm slab (Figure 13). As well as giving much smaller reductions at high frequencies, there is a enhanced improvement provided by the topping around 200 Hz. This is probably due to the interaction between the two OSB layers and the resilient layer. The effect of the masses of the sub-floor and of the raft on the position of this enhancement was not thoroughly investigated in this project. As will be seen later, however, changing the mass of the raft did not change the frequency where the enhancement occurred.

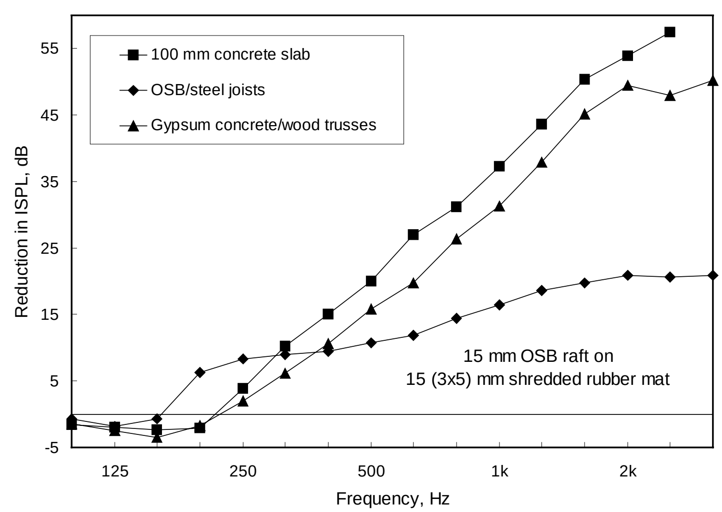

Figure 13: Reduction in impact sound pressure level obtained with a 15 mm OSB raft on 15 mm of shredded rubber mat on three floors.

This chart is typical of the results for all the raft assemblies and makes it quite clear why improvements measured for a topping on a concrete slab do not give accurate predictions when applied to floor systems with light sub-floors.

In Part 2 of this report the data show that the increase in IIC ratings for toppings on the OSB/steel joist floor were all rather small. The IIC for joist floors with lightweight sub-floors is usually determined by the impact sound pressure levels at low frequencies. The graphs presented here show that, for the systems measured, there were no significant improvements in impact sound insulation below about 160 Hz, hence only small improvements in IIC. It may be possible to develop toppings for lightweight floors that would give greater low frequency improvement but that remains to be investigated.

One interesting point in Figure 13 is that the result for the gypsum concrete/truss floor is not too far below that for the concrete slab. Figure 14 compares the ΔL_A ratings on the 100-mm slab and the increase in IIC rating for the gypsum concrete/wood truss floor. Despite the differences noted in the one-third octave band spectra, the ΔL_A rating predicts the ΔIIC rating fairly well; for most points, the predicted IIC values are smaller than those actually measured. Thus, the ΔL_A rating may still be useful for predicting the reduction in impact sound pressure level under joist floors with concrete or gypsum concrete toppings.

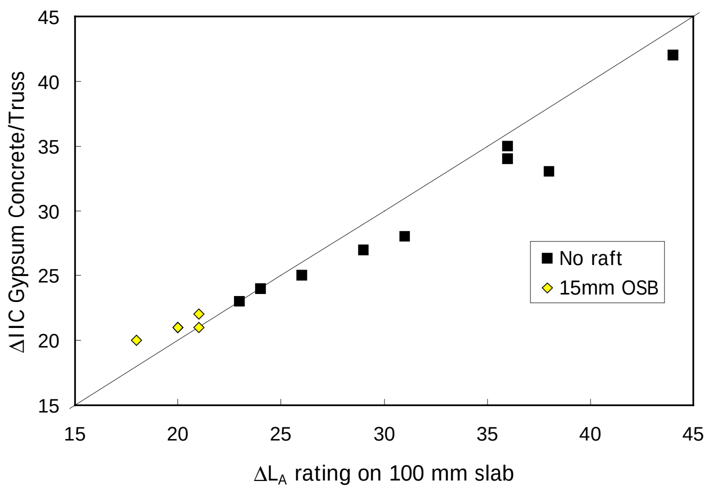

Figure 14: Improvements on 100 mm concrete slab versus change in IIC measured for gypsum concrete on joists.

Conclusions

The data presented above and in reference [6] support the conclusion that the procedures in ISO 140 part 8 can be used to reliably rank floor toppings for use on concrete slabs. The data so obtained can be used to predict the impact sound pressure levels for the combination of the floor topping and a slab if the impact sound pressure levels for the slab alone are known. The improvement spectrum should still be valid if there is a suspended ceiling below the slab.

The data may also be used to predict impact sound pressure levels for joist floors with gypsum concrete toppings with somewhat less precision. Applying the improvement spectra to joist floors with concrete toppings is likely to give agreement as good as that obtained for gypsum concrete, if not better. This remark assumes that the heavier the concrete topping, the more closely the improvement spectrum approaches that measured on a concrete slab.

Further research needs to be done to examine what can be done with joist assemblies having wood sub-floors. There are two aspects to this research. One is to search for systems that will significantly improve impact sound insulation at low frequencies without seriously increasing the floor mass. The other is to develop a reference joist floor that can be used to measure improvement spectra for toppings that may be applied to lightweight joist systems.

Proposed new ASTM test procedure

A new ASTM version of the ISO standard is needed to reduce the confusion surrounding the evaluation of floor toppings in North America. Even if a new standard is initially limited to concrete slabs only; the test data would be more useful than what is commonly available now. Details of the test procedure will not change the conclusions drawn here. Since the IIC rating already exists, it is likely that this is the rating that will be chosen with the result that the ASTM ratings will not agree with the ISO ratings.

Part 2: Improvement in impact sound pressure level for different floor toppings

This part of the report provides measured reductions in impact sound pressure level for different resilient materials in combination with different floating slabs. Many of the materials are non-proprietary and generally available. Consequently, impact sound ratings are not usually available. The intent of this section is to provide some indication of the reduction in impact sound pressure level that might be expected with these systems. The presentation of the measured results is preceded by a short summary of the classical theory relating to elastic floor coverings and floating floor slabs.

Theoretical improvement

Elastic surface layers

A resilient layer, much softer than the surface of the slab on which it lies, changes the shape of the force pulse from a hard impacting object such as the hammer of the standard ISO tapping machine. For the standard hammer the reduction in impact sound level provided by a resilient layer covering a very hard surface begins at a frequency given by

$$\begin{aligned} f_0 &= \frac{1}{2\pi}\sqrt{\frac{A_h E}{m\,h}} \\ &= 5.98\times10^{-3}\sqrt{\frac{E}{h}}\ \mathrm{Hz} \end{aligned} \qquad (1)$$

where

A_h is the striking area of the tapping machine hammer, m^2

E is the dynamic Young's modulus of the covering, N/m

m is the mass of the hammer, kg

h is the thickness of the covering, m [8].

The improvement in impact sound insulation above the frequency f_0 is given approximately by

$$\Delta L(f) = 40\log\left(f / f_0\right)\ \text{dB.} \qquad (2)$$

According to this equation, above the frequency f_0 the impact sound pressure level decreases with a slope of 40 dB per decade in frequency.

Floating floors

Where a hard walking surface is required, the most practical means of obtaining high impact sound insulation is to use a floating floor construction. This type of floor has the additional advantage that it will also improve airborne sound insulation above f_0.

A floating floor consists of a load-distributing slab or raft resting on the structural floor but separated from it by a continuous resilient layer (e.g. mineral wool, glass fiber, foamed plastic or rubber). Instead of a continuous resilient layer, a number of resilient pads may be used. In this case, the cavity between the floating slab and the structural floor is best filled with soft sound absorbing material. Floating slabs may be of concrete (about 30 to 60 mm thick), wooden floorboards or of some other material. In North America, concrete slabs are not common but toppings comprising a resilient layer some 3 to 10 mm thick and a wood topping of some kind are beginning to be popular.

The slab in combination with the resilient layer has a fundamental resonance frequency, f_{sl}, given by

$$f_{sl} = \frac{1}{2\pi}\sqrt{\frac{ns}{M_{sl}}} \ \text{Hz} \qquad (3)$$

where

s is the dynamic stiffness of the elastic mounts, N/m;

n is the number of mounts per unit area (for a continuous layer of material n is 1 and s is the dynamic stiffness per unit area of the material); and

M_{sl} is the mass per unit area of the floating floor, kg [8].

The dynamic stiffness per unit area of a resilient layer consists of the dynamic stiffness per unit area of the material and of that of the enclosed air, which includes the effects of airflow resistivity [9,10,11]. When separate resilient mounts are used, the stiffness of the enclosed air must also be considered [12]. As with other resonant systems, there is usually a *decrease* in sound insulation around the resonance frequency.

If some simplifying assumptions are made, it can be shown that the high frequency approximation for the improvement in impact insulation is

$$\Delta L \approx 10 \log \frac{2.3 M_{sl}{}^2 \omega^3 \eta\, c_L h}{ns^2} \ \text{dB} \qquad (4)$$

where

η is the loss factor in the slab, dimensionless

ω is $2\pi f$, s^{-1}

c_L is the longitudinal wave speed in the slab, m/s, and

h is the thickness of the slab, m [8].

This equation predicts an increase in ΔL of 30 dB/decade in frequency if the loss factor is independent of frequency. It also predicts an increase of 9 dB for each doubling of the slab thickness. For many reasons, the improvements predicted in equation (4) are not always achieved in practice.

Materials used in the measurements

The resilient materials used in this work are listed in Table 1. Some materials were commercial products and are either described in generic terms or identified by “Product” followed by a letter designation. Five different rafts were placed on top of these resilient materials to form floating assemblies. The rafts are listed in Table 2. Some information for other full-size toppings was available from tests being run in other projects. These are described later as necessary. As mentioned in the Introduction, none of the materials were glued or cemented to the floors; they were simply laid on top.

Table 1: Resilient Materials used in the study.

Material	Thickness, mm	Surface Weight, kg/m^2
Shredded rubber mat	3.5	1.3
Shredded rubber mat	5	1.9
Shredded rubber mat	10	3.7
Shredded rubber mat	15	5.6
Sill gasket*	4.6	0.1
Sill gasket	9.2	0.2
Product A (rigid, glass fibre board)	8	1.0
Product B (two outer layers of glass fibre board separated by paper honeycomb core)	16	1.6
Carpet underlay A (quilted)	10	2.8
Carpet underlay B	7	2.2
Sponge underlay	12	0.3
15 lb building paper	0.7	0.5
Cork	6	1.0
Cork	12	2.4
Perforated wood fibre board	19	4.7
Product C (closed-cell, plastic foam)	4	0.1
White Polystyrene bead board	17	0.2

* Sill gasket is a closed-cell, resilient plastic foam used to seal gaps between concrete foundations and the wood frame of a house.

Table 2: 1.2 x 1.2-m rafts used on top of the resilient materials.

Material	Thickness, mm	Surface Weight, kg/m^2
Single layer of OSB	16	9.6
Single layer of plywood	16	6.6
Ceramic tiles adhered to 25 mm OSB	29	32.8
Parquet glued to 25 mm OSB	30	21.0
Double layer of OSB	32	19.5

Improvements due to resilient materials only

As predicted by the theory for resilient materials outlined above, different materials give different improvement spectra when tested on the same slab. Some examples are given in Figure 15. The materials in this figure would not be used alone as floor coverings in normal circumstances and the results serve mainly to illustrate the principles involved.

These measurements were made with small specimens of the material measuring 1.2 x 1.2 m. The effects of using small specimens are discussed in Appendix A.

The dashed line in the figure has a slope of +40 dB/decade and is included only as a visual reference to show how well practical materials follow equation (2).

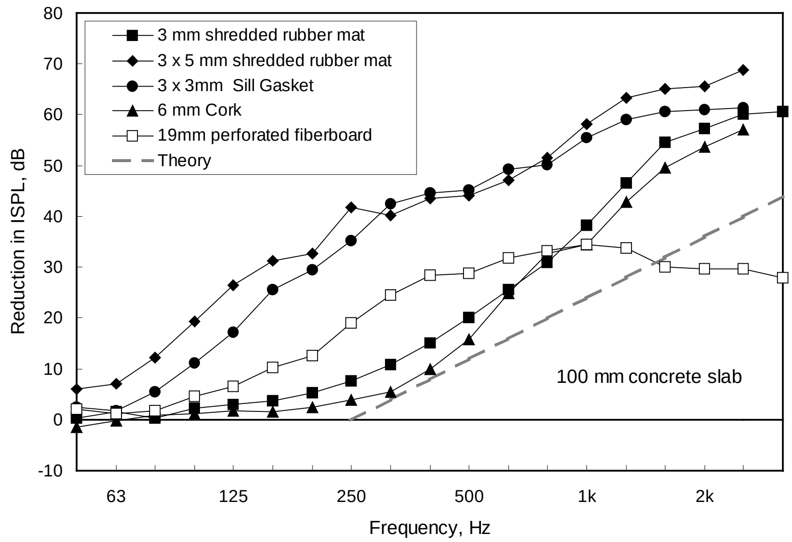

Figure 15: Reduction in impact sound pressure level for different resilient materials placed on top of the 100 mm thick concrete slab.

According to Equation (1), increasing the thickness of a resilient material increases the compliance and decreases the frequency where the improvement in impact sound pressure level begins. This behavior is exhibited by the shredded rubber mat in Figure 16; generally, the thicker the layer the greater the reduction in the impact sound pressure level at any frequency.

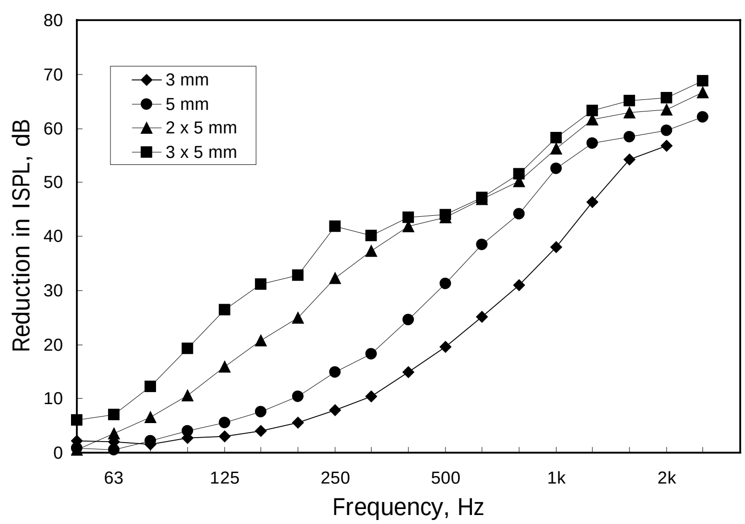

Figure 16: Reduction in impact sound pressure level for four thicknesses of shredded rubber mat on 100-mm concrete slab.

The two thicknesses of cork tested behaved quite differently. In this case, there is no difference in improvement between the 6-mm layer and the 12-mm layer (Figure 17).

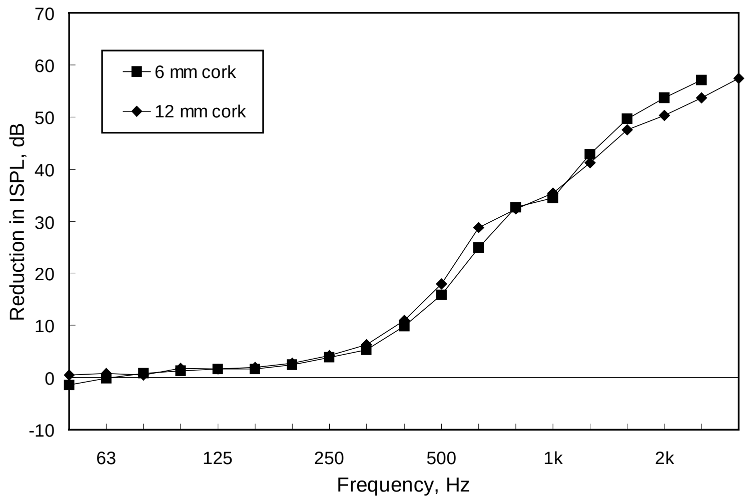

Figure 17: Reduction in impact sound pressure level for two thicknesses of cork on 100-mm concrete slab.

Improvements due to floating slabs

When a floating slab covers the various resilient materials, the variations seen are much less than those with the resilient materials alone. Figure 18 shows the reduction in impact sound pressure level for a number of materials under 15 mm OSB. The range in the data is much less than that in Figure 15. Another point to note is the negative improvement — corresponding to increased sound pressure levels in the receiving room — for some of the materials. Some materials are worse than others in this respect. This is the resonance phenomenon described in the theoretical section dealing with floating floors that begins on page 17. The material factors that influence the depth of the resonance are not known.

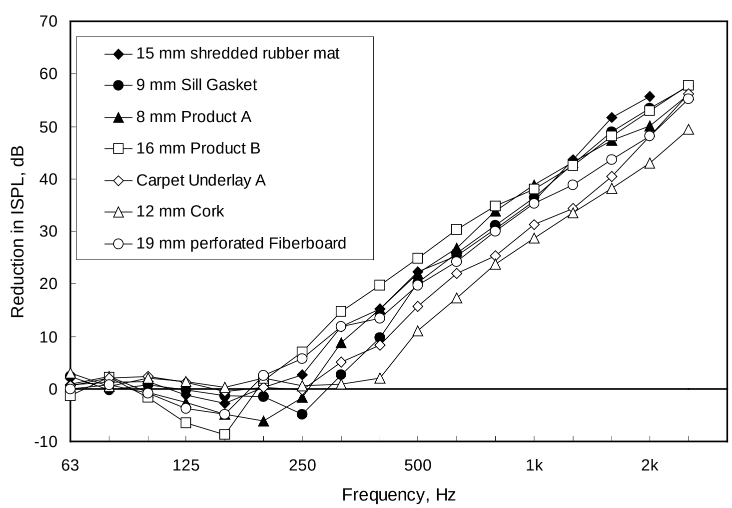

Figure 18: Reduction in impact sound pressure level for different resilient materials under 15 mm OSB placed on the 150 mm thick concrete slab.

Figure 19 compares results for the 15 mm OSB laid directly on the 100 mm slab with results when it was laid on top of cork and shredded rubber mat. The resilient materials give an additional reduction in impact sound pressure level but clearly, the improvement due to the topping is not just due to the resilient material alone. The surface of the OSB is soft enough relative to the concrete to provide significant improvement without the resilient layer. Similar data are shown in Figure 20 for a 25-mm thick layer of OSB with parquet tiles glued to it.

Recall that for these measurements, none of the small specimens were glued or cemented to the floor slab. Thus, any beneficial or detrimental effects of glue or cement were not seen. The improvement curve for the OSB might be quite different if it had been firmly attached to the concrete. As well, normal wood floor finishes are harder than OSB.

In other work, only small differences were found when vinyl flooring was glued or stapled to the OSB sub-floor. In this project, one product was intended to be used under ceramic tile with latex cement. Simply laying ceramic tiles on top of the product gave erroneously high results.

To allow laboratories with re-usable concrete slabs to glue or cement test materials to the slab, it is suggested in reference [6] that a sheet of thin paper be fixed to the slab using wallpaper paste. The paste and paper would have negligible effect on the impact sound pressure levels when the test materials are applied on top but would allow the test materials to be removed easily. Clearly, some additional work is needed to establish the effect of gluing or cementing specimens directly to the base floor.

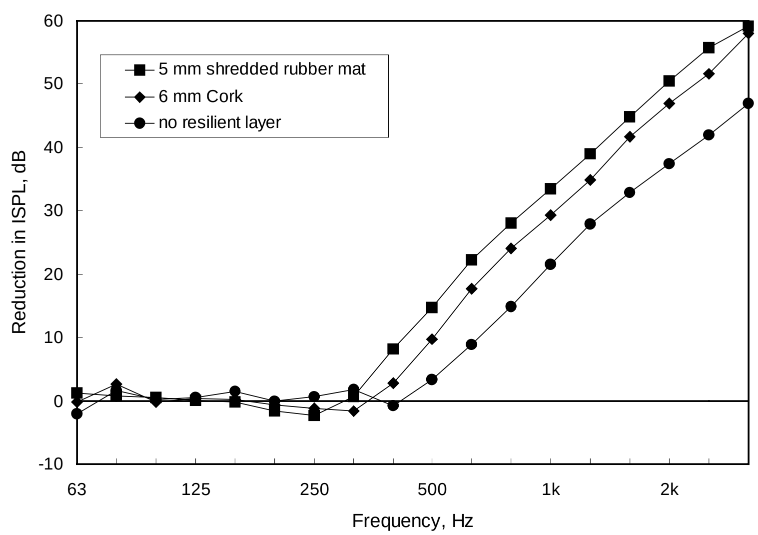

Figure 19: Reduction in impact sound pressure level for 15 mm OSB placed directly on the 100 mm concrete slab and on two resilient materials.

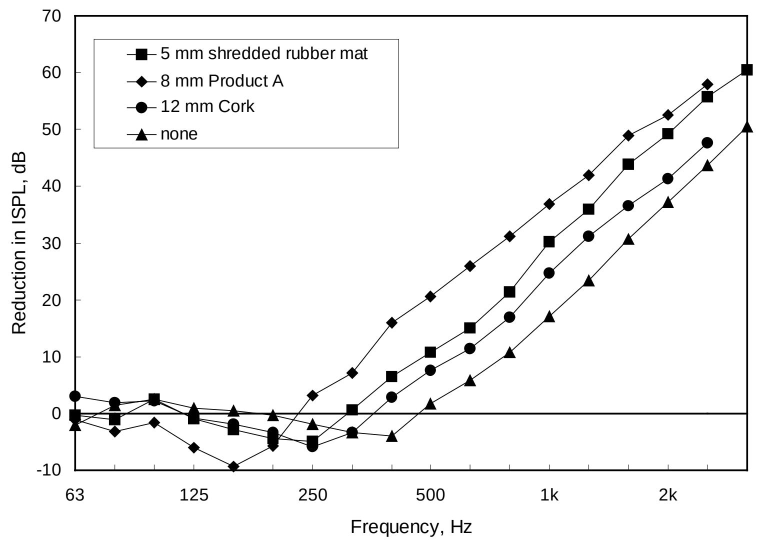

Figure 20: Reduction in impact sound pressure level for a slab comprising parquet tiles glued to 25 mm OSB placed directly on the 100 mm concrete slab and on three resilient materials

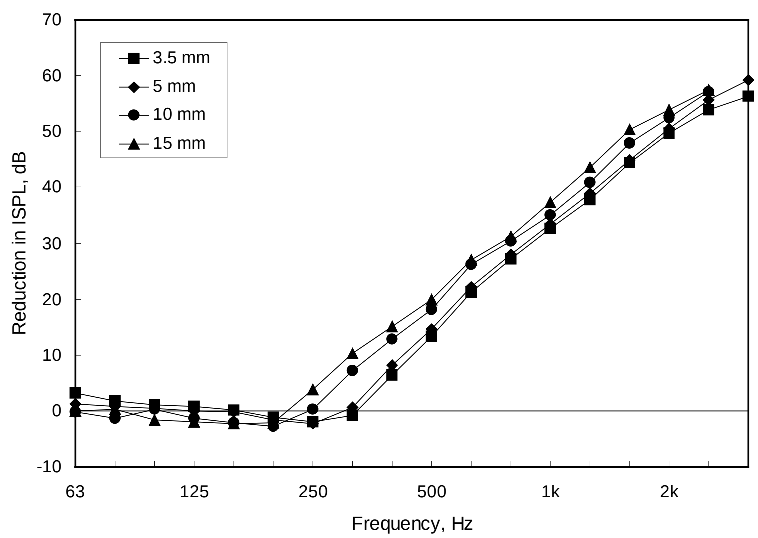

Figure 21: Reduction in impact sound pressure level for four thicknesses of shredded rubber mat under 15 mm OSB placed on the 100 mm concrete slab.

Figure 21 shows the improvement spectra for four thicknesses of shredded rubber mat under a 15-mm thick OSB slab. If this figure is compared with Figure 16, it will be seen that increasing the thickness of the resilient material has a much greater effect on the impact sound pressure level when there is no floating slab.

As seen earlier (Figure 17), when the tapping machine impacted directly on cork, increasing the thickness of the cork layer did not reduce the impact sound pressure level. Figure 22 shows data for three thicknesses of cork under wood rafts. Here again, the thickness of the cork layer makes no significant difference to the impact sound pressure levels. Thus it is reasonable to say that there is not much point in using a thickness greater than 3 mm under a wood raft for this type of cork. (Differences due to the different floating slab used on the 3 mm thickness can be ignored since, as shown in Figure 23, increasing the weight of the floating slab has little effect on the improvement spectrum.)

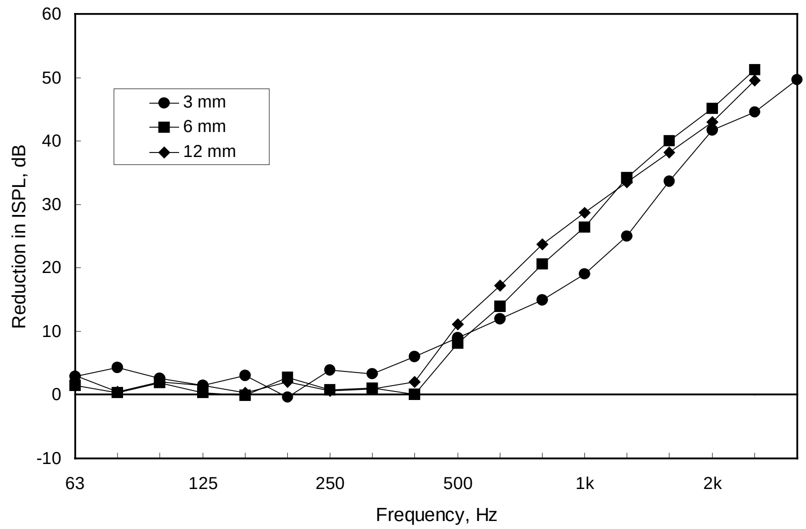

Figure 22: Reduction in impact sound pressure level for three thicknesses of cork under wood slabs. The 6 and 12 mm layers lay under 15 mm OSB, the 3 mm layer was under 8 mm high density fiber board faced with hard plastic.

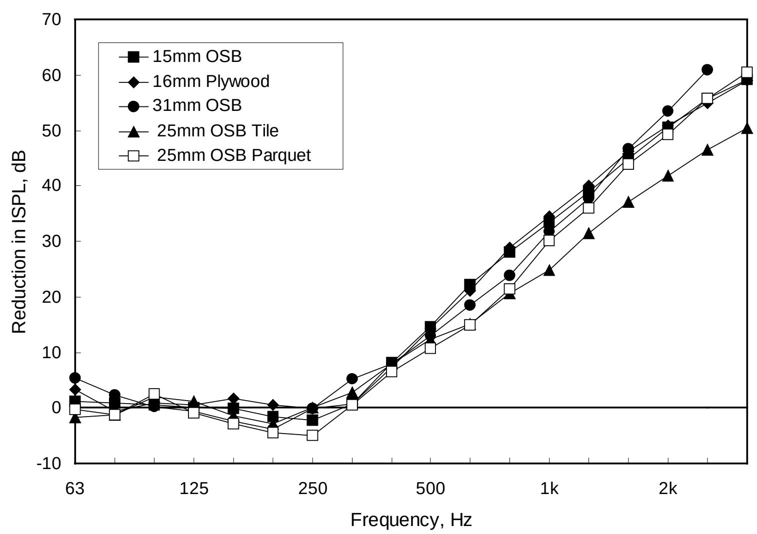

Figure 23: Reduction in impact sound pressure level for five different slabs laid on 5 mm shredded rubber mat on the 100 mm concrete slab.

Improvements due to floating slabs on OSB/steel joist floor

Figure 24 shows results for a number of different materials under 15 mm OSB on top of the OSB/steel joist floor. The enhanced improvement around 200 to 250 Hz mentioned on page 14 is quite evident. When different small slabs are placed on top of 5-mm thick shredded rubber mat, the enhancement is still evident and does not move to a different frequency (Figure 25). The cause of this phenomenon has not been found.

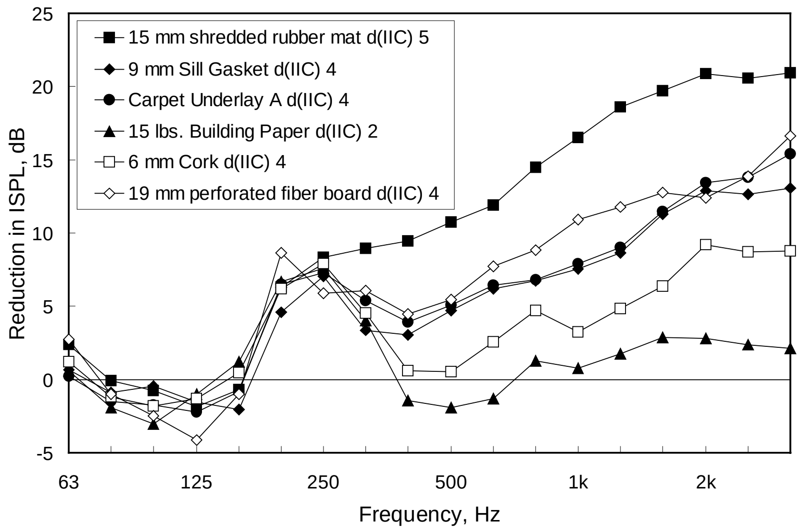

Figure 24: OSB/Steel joist base floor: Various resilient materials tested under a 1.2 x 1.2 m piece of 15 mm thick OSB. d(IIC) is the change in IIC relative to the floor with no topping. d(IIC) is the change in IIC rating relative to the floor without the topping.

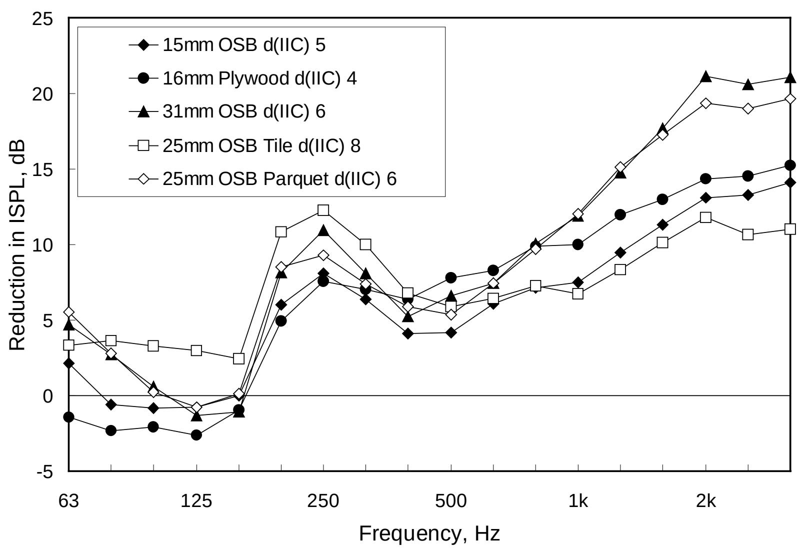

Figure 25: Different slabs on 5 mm shredded rubber mat on OSB/steel joist base floor. d(IIC) is the change in IIC rating relative to the floor without the topping.

Tables of improvement ratings

The tables that follow were included in this report to give some indication of magnitude of the improvements that can be expected from the materials and systems tested. The ratings denoted as ΔL_A were generated by assuming that ASTM will follow the measurement procedure of ISO140-8 but will use the rating system ASTM E989. Thus, ΔL_A is the difference between the IIC ratings for the idealized concrete slab alone and the idealized slab with the topping.

Table 3 shows that there are large differences in among the resilient materials when they are used alone. When used under a raft, the range in ΔL_A is much less. In fact, there is little reason to choose one material over another. (Remember again that these values were obtained using small specimens and may not accurately represent what would be achieved with a full-sized topping.)

No carpet specimen was used in this work, but from other work, the ΔL_A rating for a carpet is about 35. The ΔL_A rating for a carpet and underlay on concrete is about 50. Exact values in each case will depend on the type of the carpet and underlay. These values are included in Table 3 for convenience.

Table 4 shows the differences in measured IIC for the 100 mm concrete slab. Some of the values are significantly larger than the ΔL_A values and the table is only included for interest and comparison with the following tables.

Table 5 shows differences in measured IIC, since it was shown earlier that the ISO test and rating procedure does not work well with joist floors. This table shows that toppings on the OSB/steel joist floor give much smaller improvements than they do on the concrete slabs.

Table 6 also shows differences in measured IIC but for the gypsum concrete/wood truss floor. As pointed out earlier, the improvements for the toppings are only slightly less than those found from testing on the 100 mm slab. Ratings from measurements on slabs give optimistic estimates of what will be achieved on a gypsum concrete/joist floor.

Table 3: Improvement, ΔL_A, calculated according to draft ASTM standard for toppings on concrete slabs.

	Raft type					
Resilient Layer	No raft	15 mm OSB	16 mm Plywood	Parquet on 25 mm OSB	6 mm ceramic tile on 25 mm OSB	31 mm OSB
3.5 mm shredded rubber mat	26	20				
5 mm shredded rubber mat	29	20	21	18	21	20
10 mm shredded rubber mat	36	21				
15 mm shredded rubber mat	44	21		20		
3 mm Sill Gasket	24	20			19	
6 mm Sill Gasket	31	19				
9 mm Sill Gasket	36	18				
6 mm Cork	23	20			18	
12 mm Cork	24	20		17		19
11 mm Carpet Underlay A	38	21	22	21	23	22
Carpet Underlay B	33	19				
11 mm Sponge Underlay		22	22	20	26	22
15 lbs. Building Paper	3	20				
19 mm perforated fiber board	28	19				
Product A (8 mm rigid, glass fibre board)	29	17		15		
Product B (16 mm, two layers of glass fibre board with paper honeycomb core)	30	18				
none		19		17		
Carpet	35					
Carpet with underlay	50					

Table 4: Increase in IIC measured for toppings on concrete slabs.

	Raft type					
Resilient Layer	No raft	15mm OSB	16mm Plywood	Parquet on 25 mm OSB	6 mm ceramic tile on 25 mm OSB	31mm OSB
3.5 mm shredded rubber mat	28	19				
5 mm shredded rubber mat	33	18	20	16	21	21
10 mm shredded rubber mat	45	21				
15 mm shredded rubber mat	53	24		22		
3 mm Sill Gasket		18			17	
6 mm Sill Gasket	39	17				
9 mm Sill Gasket	45	16				
6 mm Cork	25	18			16	
12 mm Cork	25	19		15		16
11 mm Carpet Underlay A	45	20	21	21	25	23
Carpet Underlay B		19				
11 mm Sponge Underlay		24	23	22	30	26
15 lbs. Building Paper	3	20				
19 mm perforated fiber board	28	23				
Product A (8 mm rigid, glass fibre board)	33	19		16		
Product B (16 mm thick, two outer layers of glass fibre board separated by paper honeycomb core)	33	20				
none		19		16		

Table 5: Increase in IIC measured for toppings on OSB/Steel joist floor.

	Raft type					
Resilient Layer	No raft	15 mm OSB	16 mm Plywood	Parquet on 25 mm OSB	6 mm ceramic tile on 25 mm OSB	31 mm OSB
3.5 mm shredded rubber mat	7	4				
5 mm shredded rubber mat	10	5	4	6	8	6
10 mm shredded rubber mat	17	4				
15 mm shredded rubber mat	23	5		7		
3 mm Sill Gasket		4		6	7	
6 mm Sill Gasket	11	4				
9 mm Sill Gasket	16	4				
6 mm Cork		4			5	7
12 mm Cork	4	5		7	6	
11 mm Carpet Underlay A		4	4	7	9	6
Carpet Underlay B		3				
12 mm Sponge Underlay		3	3	5	7	5
15 lbs. Building Paper		2				
19 mm perforated fiber board		4				
Product A (8 mm rigid, glass fibre board)		4		6		
Product B (16 mm thick, two outer layers of glass fibre board separated by paper honeycomb core)		4				

Table 6: Increase in IIC measured for toppings on gypsum concrete/wood truss floor.

Resilient Layer	**No raft**	**15 mm OSB**
3.5 mm shredded rubber mat	25	21
5 mm shredded rubber mat	27	
10 mm shredded rubber mat	34	
15 mm shredded rubber mat	42	22
6 mm sill gasket	28	
9 mm sill gasket	35	20
6 mm Cork	23	21
12 mm Cork	24	21
11 mm Carpet Underlay A	33	21
17 mm expanded polystyrene board		20

Appendix A: Effect of using small specimens

To examine the differences between tests with a full-size specimen and a small specimen, a floating floor assembly resting on a 150 mm thick concrete slab was progressively reduced in size and tested at each stage. The floating slab comprised a 5 mm thick shredded rubber mat covered with a dense particle board 8 mm thick. The floor measured 3.7 x 4.8 m. The density of the particleboard was 890 kg/m^3 and the weight was 7.1 kg/m^2.

The reductions in impact sound pressure level for the full size specimen and smaller toppings measuring 1.2 x 1.2, 1.2 x 2.4 and 3.6 x 2.7 m are shown in Figure 26. Presented in this form, the differences between each configuration appear rather small. In fact, there were no significant changes in either the ISO or the proposed ASTM single number ratings. Examination of the differences among the configurations showed that smaller specimens gave lower reductions at some frequencies; at worst, differences relative to the full size specimen were about 3 dB in some bands. Despite this, the 1.2 x 1.2-m size was chosen for the measurements for economy and convenience.

Figure 27 shows the difference in impact sound pressure level between the complete specimen and a 1.2 x 1.2 m sample for two conditions: one where the edges of the small specimen were covered with tape and one where they were not covered. This figure makes it easier to see the differences between the full size specimen and the 1.2 x 1.2-m specimen. Detailed examination of all the data showed that taping the edges had only a small effect; single number ratings were not affected at all and only a few high frequency bands changed by 1 or 2 dB. In any case, for the experiments described here, tape was not used to simplify changing specimens.

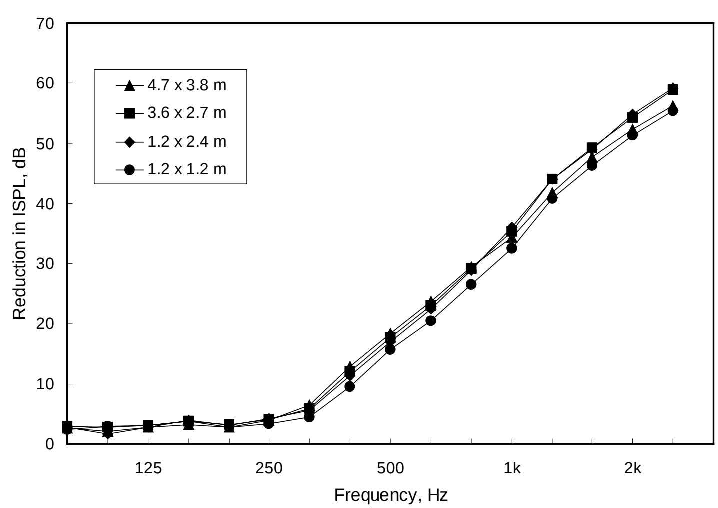

Figure 26: Reduction in impact sound pressure level for three small specimens of different sizes and a full-size specimen.

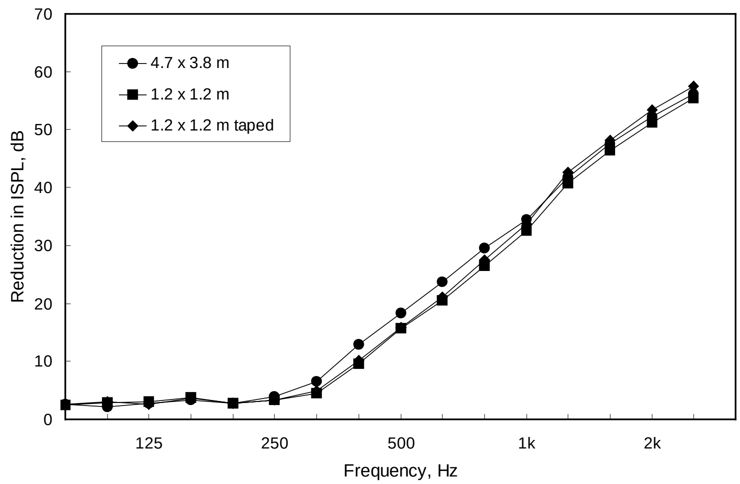

Figure 27: Reductions in impact sound pressure level for taped and untaped 1.2 x 1.2 m specimens compared with full-size results.

Comparison of small specimen results with full scale tests

From other full-scale testing in the NRC laboratory, ISPL reduction curves are available for comparison with the small specimen data presented earlier. Figure 28 shows one comparison for 6-mm cork and Figure 29 is for 5 mm shredded rubber mat. Although the rafts are different in each case, as shown earlier (Figure 23), the mass of the raft does not appear to have as large an effect as predicted by theory. In this figure and the following, a negative value means that the small specimen gave higher impact sound pressure level than the full size specimen and thus made the materials being tested appear worse.

Figure 30 shows a result where a complete floor topping comprising a bed of mortar poured on expanded polystyrene was cut away to leave behind an undisturbed 1.2 x 1.2 m specimen resting on the 150 mm slab.

The agreement in all of these cases is quite good. There seems to be a pattern that using a small specimen underrates the improvement of the topping at low frequencies and overrates it at high frequencies but this is by no means a very clear trend. The data do support the hypothesis that small specimens can be used to rank toppings and for development work.

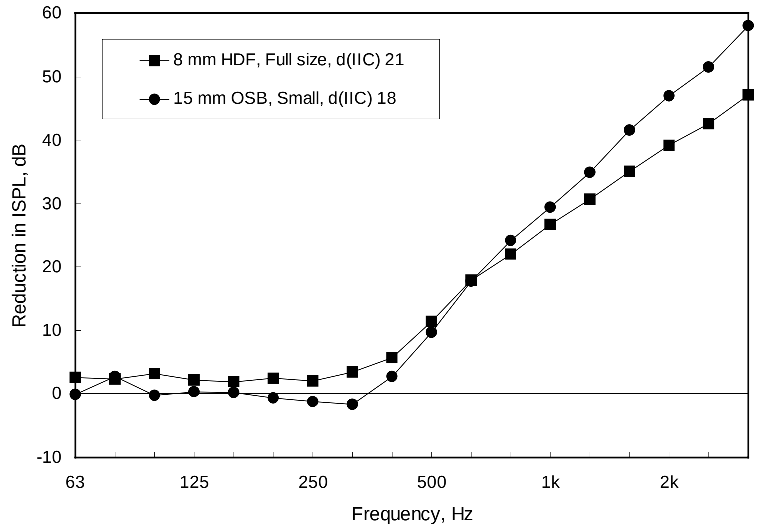

Figure 28: 6 mm cork tested under 8 mm high density fiberboard (full-size) and under 15 mm OSB (small size). d(IIC) is the change in IIC rating relative to the floor without the topping.

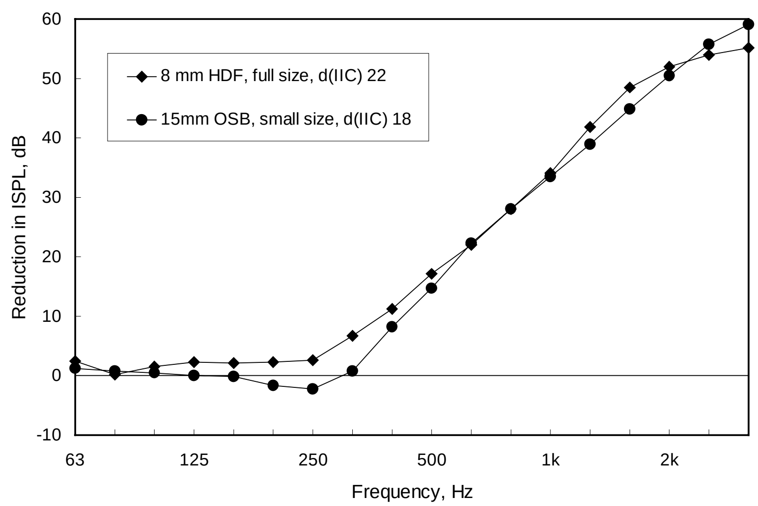

Figure 29: 5 mm shredded rubber mat tested under 8 mm high-density fiberboard (full-size) and under 15 mm OSB (small size). d(IIC) is the change in IIC rating relative to the floor without the topping.

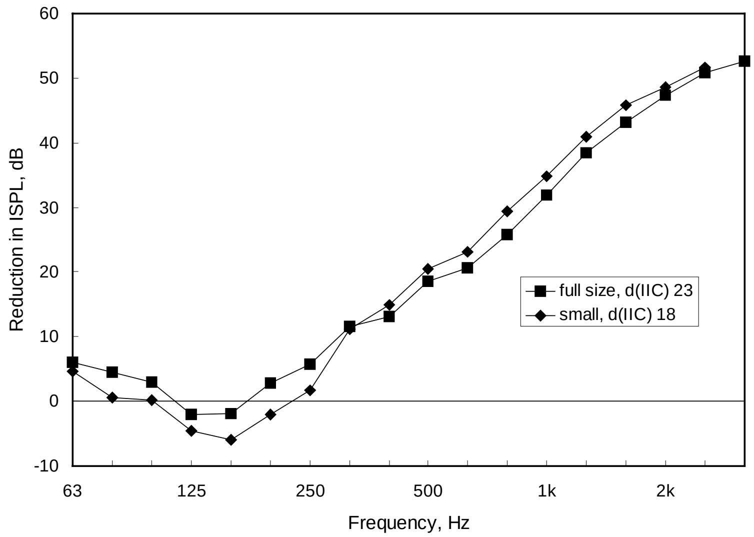

Figure 30: Ceramic tiles on a 25-mm bed of mortar on expanded polystyrene board. d(IIC) is the change in IIC rating relative to the floor without the topping.

References

1 ASTM E492 Standard Test Method for Laboratory Measurement of Impact Sound Transmission through Floor-ceiling Assemblies using the Tapping Machine.

[2] ISO 140-3, Acoustics, Measurement of sound insulation in buildings and of building elements, laboratory measurements of airborne sound insulation of building elements, 1978

[3] ASTM E989 Standard Classification for Determination of Impact Insulation Class (IIC).

[4] ISO 717-2, Acoustics, Rating of sound insulation in buildings and of building elements, Impact sound insulation, 1982.

[5] ISO 140-8, Acoustics, Measurement of sound insulation in buildings and of building elements, Laboratory measurement of the reduction of transmitted impact noise by floor coverings on a standard floor.

[6] K. Bodlund. Laboratory Measurement of the Improvement of Impact Sound Insulation by Floor Coverings on a Standard Floor. Nordtest Project 279-81. Technical Report SP-RAPP 1983:01. Statens Provningsanstalt. Borås. Sweden. 1983

[7] R.E. Halliwell, J.D. Quirt, and A.C.C. Warnock, “Design and Commissioning of a New Floor Sound Transmission Facility”, Proc INCE 93, p995.

[8] Ver, I.L., "Impact Noise Isolation of Composite Floors", J. Acoust. Soc. Am., **50**, p1043, 1971

[9] ASTM Method C522 — Standard Test Method for Airflow Resistance of Acoustical Materials. American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, USA, 19103

[10] ISO 9052-1, Acoustics, Determination of dynamic stiffness, Materials used under floating floors in dwellings, 1989

[11] ISO 9053, Acoustics, Material for acoustical applications, determination of airflow resistance, 1990.

[12] E.E Ungar, “Design of Floated Slabs To Avoid Stiffness of Entrapped Air”, Noise Con. Eng, July-August, **12**, 1975