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THE EFFECTIVE SOUND REDUCTION INDEX OF FACTORY CLADDING PANELS

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1. INTRODUCTION

The Sound Reduction Index (SRI) of a panel is conventionally measured when it forms all or part of the connecting wall between two rooms of a standard transmission suite, according to ISO140 [1]. Each of the rooms is proportionately dimensioned, and the sound field inside them is arranged to be diffuse i.e. sound energy arriving at a point consists of equal amount of energy from every direction. Josse & Lamure [2] have shown that the SRI of a wall measured when it forms part of the connecting wall between two such rooms (i.e. a transmission suite) is dependant on the degree of spatial matching, and the closeness of the natural frequencies of the room and panel modes.

A typical factory space, however, is dis-proportionate i.e. at least one dimension is much greater than the other two, and the sound field does not exhibit this diffuse property. The existence of room modes in the form presented by Josse & Lamure, which for a sufficiently high modal density, is equivalent to a classical diffuse field, does not exist typical factory spaces. In industrial noise prediction methods, therefore, it may be inappropriate to use conventionally measured values of Sound Reduction Index in calculating the noise level transmitted through the factory envelope, because of the non-diffuse nature of the sound field in a typical factory space resulting in the mechanism of acoustic excitation of the walls being different from that occurring in test chambers.

Typical factory/industrial buildings, generally have a shape that is either "duct" like, where the length is much greater than either the height or the width, or "flat", where the length and width are much larger than the height.- In rooms such as this, the sound-field exhibits no reverberant field, but the energy level decays with distance from the source. The change in energy levels with distance from a source is characterised by the quantity Sound Propagation (SP), which is equal to the sound pressure level (SPL) normalised with respect to the sound power level (PWL) of a source, i.e.

$$SP = SPL - PWL \qquad (1)$$

In this paper, an investigation is made into the effect of the non-diffuse nature of the incident field on the effective Sound Reduction Index (SRI_{eff}) of a panel. To ascertain as to whether the SRI_{eff} of a panel is affected by the form of the exciting field, the SRE_{eff} of a number of test panels was measured for a variety of non-diffuse excitation fields. The resultant values of SRE_{eff} for the different fields could then be compared with the sound reduction index measured with a conventional diffuse excitation field.

2. FACTORS AFFECTING THE MEASURED SOUND REDUCTION INDEX OF A PANEL

The sound reduction index of a panel is measured according to ISO140. This standard specifies several requirements that must be met, for the resultant SRI to be "dependable". These requirements include a specification of the minimum volume for the test rooms, and a minimum area for the panel under test However, it has been shown by Kihlmann and Nilsson [3] when the SRI of a panel is measured by different laboratories according to ISO140, the resultant sound reduction indices, can differ by as much as 8 to 10 dB, at frequencies below coincidence, and as much as 5 dB above coincidence. Bhattacharya and Guy [4] also presented results for the SRI of an aluminium panel, when measured at two different facilities. They reported differences of up to 10 dB below coincidence.

In a typical transmission suite, the aperture between the two rooms where the test panel is mounted, has a significant depth (due to room isolation requirements). It has been shown by many authors e.g. Guy & Mulholland[5], that the position of the panel under test has a significant affect on the resultant sound reduction index, below the critical frequency of the panel.

As a result of the above observation it is obvious that in performing an experimental investigation into the effect of different forms of incident field on the SRI of a panel it would be necessary to minimise the effects of room volume, panel area and aperture depth.

3. DETERMINATION OF THE EFFECT OF THE INTERNAL SOUND FIELD ON THE SRI OF A PANEL

To measure the sound reduction index of panels situated on a factory wall in accordance with procedures set out in ISO140, would require the construction of a separate reception room which would need to be attached to the outside of the factory, and be movable to allow measurements at different positions along the factory wall. This would prove cumbersome and it would be difficult to avoid flanking transmission through the points of attachment of the reception room.

Because of the above considerations, it was decided that the intensity method of measuring the SRI of a panel should be employed to avoid the need for a mobile reception room and a scale model would be employed to enable a range of conditions to be rapidly investigated.

3.1 Measurement of SRI by means of sound Intensity.

The measurement of SRI by means of sound intensity is based upon the following relationship:

$$SRI = SPL - IL - 6 \qquad (1)$$

where:

SPL is the mean SPL in the source room
IL is the transmitted intensity level

The 6 dB constant term comes from the relationship between the mean energy in a room and the energy that is incident on the room surfaces.

3.2 The Scale Model

To provide the different forms of non-diffuse source field, it was decided that a room of suitable disproportionality should be constructed, to "model" a typical factory space. By manipulation of the fittings etc., in the room, and by using different positions relative to the source for the test panel, a variety of different non-diffuse incident fields could be created. A scale factor of 10:1 was chosen, because of the limitations of the equipment used, the highest frequency that could be employed was the 20 kHz 3rd-octave.

It was also decided that different panel structures should be tested. To this end, a homogeneous perspex and a quasi-sinusoidally corrugated PVC panel were selected. The corrugated panel was chosen to be tested as well as a homogeneous panel, because many of the parameters that affect the SRI of a structure, appear to affect SRI below the critical frequency of the structure. Structurally orthotropic panels, such as the corrugated panel used in this work, are believed to have two critical frequencies, arising from the increased stiffness in the direction of the corrugations. Typically, the critical frequency for the direction parallel to the corrugations is two orders of magnitude less than the critical frequency perpendicular to the corrugations (because of the increased bending stiffness), with this latter critical frequency being approximately the same as the critical frequency for an uncorrugated panel made from the same material.

In designing the model factory, no attempt was made to accurately model an existing building. the full sized internal dimensions of the factory were chosen to be 7m high, 12m wide, and 55m long The frame of the building was constructed from 50mm x 50mm softwood, with the walls from sheets of 18mm high-density chipboard. The roof section was laid onto the frame, to allow easy access to the space inside the model. Along one of the long sides of the model, three holes were cut, to take the panels to be tested. On either side of the holes, there were rotatable blocks of wood to firmly clamp the test panel into place. Holes were drilled in the roof of the model, a number along the centre line to allow for the measurement of the SP characteristics of the model, and three holes adjacent to each of the panel cutouts in the long wall of the model, to allow for the measurement of the internal SPL required for the calculation of the SRI of the test panels. A schematic diagram of the model factory can be seen in figure (1).

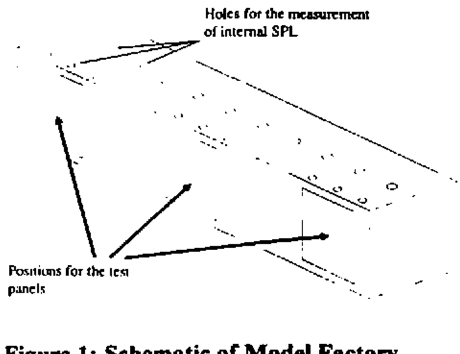


Figure 1: Schematic of Model Factory

For each of the panel positions, dummy panels were constructed out of two layers of 3/4" high-density chipboard. One layer was larger than the cutout, forming a flange, so as to minimise transmission of sound around the edge of the hole. The construction details of each panel can be seen in Figure 2

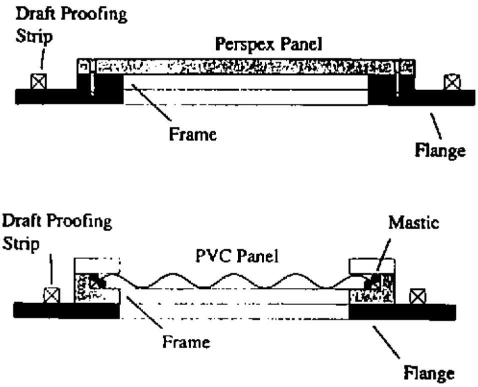


Figure 2: Construction of Test Panels

The homogeneous perspex panel was screwed onto a 3/4" hd chipboard frame, which was glued to a chipboard flange, as for the dummy panels describe above. The corrugated PVC panel could not be screwed down to the mounting frame, so it was laid onto a bead of mastic then wedged into place with another bead of mastic and an outer covering frame constructed from 3/8" plywood. The construction of the flange was as for the homogeneous perspex panel described above. The test panels were mounted in the removable frames, so as to minimise the effect of changing mounting conditions and aperture depths on the resultant sound reduction indices

To vary the sound field inside the model factory for the three different panel positions, it was decided that three different levels of fittings should be modelled. With the source in one corner of the model, opposite the wall containing the test panels, the three levels chosen were:

(1) Completely empty
(2) Full of scatterers
(3) Full of scatterers, with the far-end of the factory from the source made anechoic

The scatterers used were cubes measuring 2.25m x 2.25m x 2.25m full-scale, made of 3/4" high-density chipboard.

To create the normal diffuse excitation field for the test panels, for comparison with the different non-diffuse fields, the end third of the factory containing the source was blanked off with a sheet of 3/4" high-density chip-board, so that a space measuring 18m x 12m x 7m full-scale was created.

With the three panel positions for the three factory field conditions, and the diffuse field condition, a total of ten different excitation fields were tested in this work. With at least five repeats of the measurement for each different source field, a total of at least fifty measurements for each panel were performed.

3.3 The Measurement System
The source used was a cubic arrangements of high-frequency dome tweeters. This was fed with a white noise signal from a Bruel & Kjaer type 1405 noise generator, amplified by a Trio power amplifier. The equipment chosen to measure the internal SPL in the model, was a Bruel & Kjaer 2131 3rd octave real-time analyser, with a 1/2" Bruel & Kjaer 4165 microphone and a type 2619 preamplifier. This analyser allows for measurements in 3rd or whole octaves up to 20kHz, with averaging times selectable from 1/16 to 128 seconds.

The method of measuring intensity that is used in this work, is the two-microphone indirect method. This method of calculating intensity is implemented directly by the Bruel & Kjaer type 2032 dual-channel FFT analyser. The near field scan technique was employed to determine the average intensity over the surface of the panel. The Bruel & Kjaer 2032 FFT analyser produces constant linear bandwidth data .It was necessary that the narrow band intensity spectra be "converted" into 3rd-octave intensity levels, for subsequent use in the calculation of the SRI of the test panel.

4. THE MEASUREMENTS

A typical measurement proceeded as follows:

(1) The internal SPL was measured at six positions, comprising of 3 positions x 2 heights, at a distance of 1m full-scale from the wall, for third octaves from 100Hz to 2kHz full-scale. This distance is greater than the 0.7m specified by ISO140 [6]. From these individual measurements, the mean internal SPL was calculated.

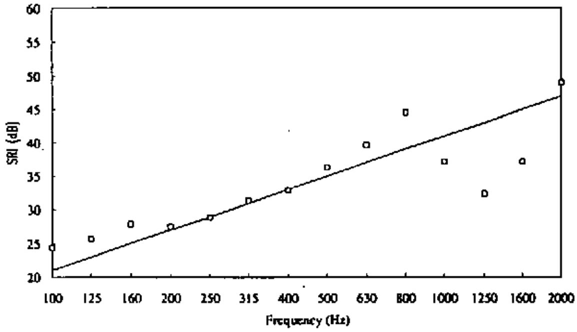
(2) Next the transmitted intensity level was measured, by the scanning method over a square area at a distance of approximately 60 to 100mm from the facade. From the narrow band spectrum, the third-octave intensity level spectrum was calculated.

(3) The internal SPL was measured again, following the same procedure as before.

(4) The sound reduction index was calculated using eq.(3), with the internal SPL taken as the mean of the results of the first and second measurements of SPL.

If the mean SPL measured in step (3) differed from that from step (1) by more than a few tenths of a dB, then the entire measurement was repeated. Generally, however, the two SPL values were identical, (to within 0.1-2 dB, for all frequencies).

As an initial test of the experimental procedure, measurements made on the simple perpex panel were compared with theoretical predictions of sound reduction index. Calculations suggested that the coincidence dip in the measured SRI should occur at approximately 12,500Hz.- As can be seen from figure 3, there is a dip at the scale frequency of 1250 Hz. A comparison of the measured SRI for the diffuse field case, with the theoretical field incidence mass-law sound reduction index, SRI_f is also shown in figure (3).



A comparison of (□) the measured SRI, and (———) the field-incidence mass-law for the homogeneous perspex panel.

Figure 3: Comparison of Measured Data with Theoretical Predictions for Simple Panel

It can be seen that there is good agreement between the measured and theoretical sound reduction index from 200 Hz to 500 Hz. Above 500 Hz, there is an increase in slope of the curve, with a peak of approximately 5 dB above the mass-law curve at 800 Hz, before the coincidence dip is reached. This is probably due to the size of the intensity probe which is significant at scale frequencies. The general agreement between the measured and theoretical sound reduction indices, would support the validity of the measurements, and hence any conclusions that were drawn from them.

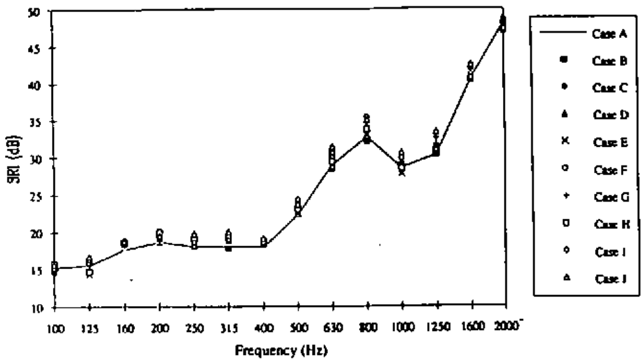


Figure 4: Variation of Measured Sound Reduction Indices of Corrugated Panel

Figure 4 show the mean SRI for each of the ten different source fields, for the corrugated test panel. It can be seen, that the "spread" of the results is not as great as that reported by Kihlmann and Nilsson [3], with maximum deviations of approximately 3dBl. This is probably due to the fact that the mounting of the panels in this work, was identical for each of the different incident field conditions. It has been shown in section 2.1 that the mounting conditions of a panel greatly affect the resultant SRI, as does the presence of an aperture of a significant depth and the position of the panel in the aperture.

Despite the good agreement observed visually between all the measured data, the application of standard statistical tests indicated that there was a significant difference between the sound reduction indices measured with diffuse excitation and non diffuse excitation. This would give rise to the conclusion that the sound reduction index of a panel is dependant on the form of the excitation field. However, it can be seen from Figures an that the non-diffuse field sound reduction indices are approximately equivalent to the diffuse-field sound reduction index for both panels (to within 1 or 2 dB in all cases). This gives rise to the question as to whether they are close enough for practical purposes. ISO140 gives a procedure for testing the "repeatability" of a series of measurements of sound reduction index - that is to say, are the individual sound reduction indices the same for practical purposes.

5. APPLICATION OF ISO140

SO140 [5] specifies the level of precision that should be attainable in measurements of SRI, in terms of a repeatability index, r. This quantity r, is a measure of the "spread" of a number of independent measurements of SRI. The standard states that a reliable measure of the standard deviation s will be obtained if a number of measurements on separate of the same construction are carried out in a number of different laboratories. If the different source field conditions (nine factory + one diffuse) effectively represent different laboratories, then if the results from this pass the repeatability test of the standard, then it can be said that the form of the internal sound field has no appreciable effect on the sound reduction index of a panel.

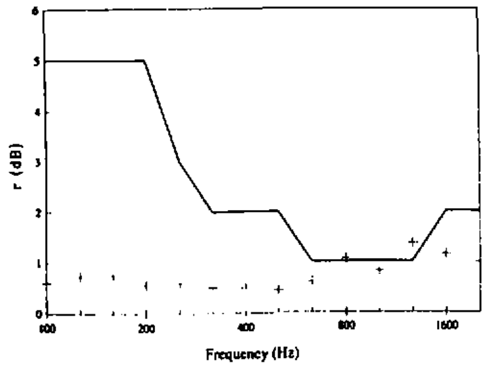


Figure 5: Comparison of Mean SRI's for Each Excitation Case for Corrugated PVC Panel

The repeatability index r, calculated according to ISO140, for the homogeneous perspex panel is shown in figure 5. Also shown, is the maximum repeatability index as defined by ISO140. The results are compared with the ISO140 criterion for the actual frequencies of the measurements, from 100Hz to 2kHz. As can be seen, the repeatability of this work is generally better than the criterion, with the only failure occurring with the homogeneous perspex panel at 800 Hz and 1250 Hz full-scale.

6. CONCLUSION

From the above analysis of the experimental results, it can be concluded that the form of the excitation field has no significant effect on the sound reduction index of a panel. i.e. the non-diffusivity of the field in a typical factory appears not to give rise to a different SRI for a panel over the SRI measured for a normal diffuse field.

The conclusion was based on measurements made with a limited set of internal sound-fields that were all from one room shape. It may be the case that a different conclusion could be drawn with a factory that was of the "flat" type, as opposed to the "duct" type used here.

7. REFERENCES

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