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SOME APPLICATIONS OF SOUND INTENSITY IN BUILDING ACOUSTICS

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1. INTRODUCTION

The sound intensity technique has now been applied for many years in building acoustics. Nordtest has, for example, test methods for sound insulation measurements in the laboratory on doors, windows and small building elements and also for sound power determination of air terminals. In addition the sound intensity technique has been tested intensively for sound insulation applications in the field. Others has used sound intensity for applications on structure borne sound in buildings. ISO TC 43/SC 2 Building acoustics has got its first working group, WG 23, dealing with sound intensity in building acoustics. The subject is sound insulation measurements. There is already an informative annex in ISO 140-5 dealing with sound insulation measurements on windows and other facade elements.

The sound intensity technique has several advantages compared with traditional methods. It is often simpler to use, once you have the right equipment and experience. It also increases the possibility to be able to carry out accurate measurements under difficult environmental conditions. As to sound insulation it has even been shown to be more reliable than traditional methods when measuring on small building elements with good sound insulation.

In the paper examples of both successful and less successful applications of sound intensity will be given. Most examples will be taken from the Nordic countries.

2. SOUND INSULATION MEASUREMENTS

In the Laboratory

Measurement of sound reduction index in the laboratory is one of the most common acoustical measurements. Ideally these measurements are carried out without flanking transmission. On measurements of small building elements, however, it is often difficult to avoid all flanking transmission. Recently ISO, in the revision of the ISO 140 series, has proposed to allow some corrections for flanking transmission. However, even with these corrections many small building elements with high sound insulation will still be difficult to handle. A solution to this problem is the sound intensity technique.

In [1,2] the intensity sound reduction index is defined as

$$R_I = L_1 - L_{In} - 6 + 10\,\lg(\frac{S}{S_m}) \qquad (1)$$

where where L_1 = the time and space averaged sound pressure levels in the source room, L_{In}= the sound intensity level in the direction of the normal to a measurement surface S_m, enveloping the test object in the receiving room and S= the area of the test object.

[1] also introduces the corrected intensity sound reduction index

$$R_{I,c} = L_1 - L_{In} + 10\,\lg(\frac{S}{S_m}) - 6 + 10\,\lg(1 + \frac{S_b \cdot \lambda}{8 \cdot V}) \qquad (2)$$

to use when comparing with traditional measurements according to ISO 140-3.

Compared to (1) the Waterhouse correction

$$C_{Waterhouse} = 10\,\lg(1 + \frac{S_b \cdot \lambda}{8 \cdot V}) \qquad (3)$$

has been added. S_b = the total area of the boundary surfaces of the room, λ = the wavelength, V = the volume of the room. As to how to handle this correction there are different opinions. Although everybody seems to agree that it is applicable in the receiving room the opinion about the source room differs. Here it will be assumed that it is not applicable in the source room because the higher energy density at the boundaries will not in general affect the sound power incident on the test specimen . In [5] an alternative to (3) is proposed

$$C_{Waterhouse} = 10\,\lg(1 + \frac{S_b \cdot \lambda}{8 \cdot V} + \frac{L \cdot \lambda^2}{32\pi \cdot V}) \qquad (4)$$

where L = 4(a + b + c) where a,b and c are the linear dimensions of the receiving room. (4) seems to be a small improvement, especially below 100 Hz, and it should be considered in later revisions of the methods involved.

The Waterhouse correction can't be expected to give the whole truth as it assumes diffuse field conditions in the middle of the room and takes no account of the modal behaviour of the sound field. This is particularly serious as the Waterhouse correction has its major importance at low frequencies where the modal density has its minimum.

The sound intensity is to be measured by scanning a measurement surface at a minimum distance of 0,1 m from the test object. If the test object is mounted in a niche the measurement surface is the niche opening. Two consecutive scans shall be carried out using two different scan patterns. The maximum difference in any single frequency band between these two scans must not exceed 1,0 dB. If the difference is larger than 1,0 dB two new scans with different patterns must be carried out. This procedure is repeated until the requirement is fulfilled.

If the test object is flush mounted the measurement surface is to be box-shaped and the closing of this surface along the boundary becomes critical. It is then often necessary to scan several subareas separately in order to comply with the 1,0 dB requirement.

In order to be able to measure the sound intensity correctly certain requirements on the sound field have to be fulfilled. As it has been shown that the time and space averaged pressure-intensity indicator L_p-L_{In} normally is the most important indicator to evaluate the quality of the measurements the following requirement is used

$$L_p - L_{In} < 10 \text{ dB} \quad (5)$$

assuming the test specimen is not absorbing incoming sound. Although this limit of 10 dB cannot be verified theoretically there are numerous examples that it does work well. When the test specimen is sound absorbing on the receiving side an additional error is introduced. The measured intensity will become too low because the energy coming from the receiving room will only partially be reflected back to the room. In this case the requirement is

$$L_p - L_{In} < 6 \text{ dB} \quad (6)$$

In the Nordtest project two steel "windows", one single and one double metal leaf were circulated for testing in 4 different laboratories with both the traditional ISO 140-3:1995 method and the Nordtest intensity method. The results, [4], are given in figure 1-2. It should be observed that the double window has a very extreme sound insulation.

As to the window with low sound reduction the results show an excellent agreement both for the traditional method and the intensity method. The small differences between the laboratories seem to be the same for both methods. For the best window all laboratories get a 1-3 dB higher R_W with the intensity technique and the reproduceability is considerably better for the intensity method. This probably depends on some flanking transmission. It is difficult to measure with the traditional method on such a good window.

Although the statistical basis is certainly not satisfactory a comparison with the reproduceability requirements of ISO 140-2 has been made by multiplying the standard deviation in each frequency band by 2,8. The result is shown in Figure 5 and it indicates that there is no significant difference between the two methods. Both have problems with the very good "window".

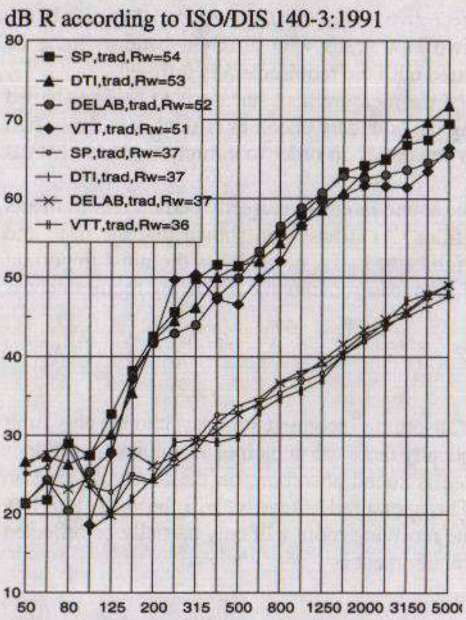

Figure 1 Interlaboratory comparisons according to ISO 140-3 for a single metal leaf window(lower curves) and a double metal leaf window(upper curves).

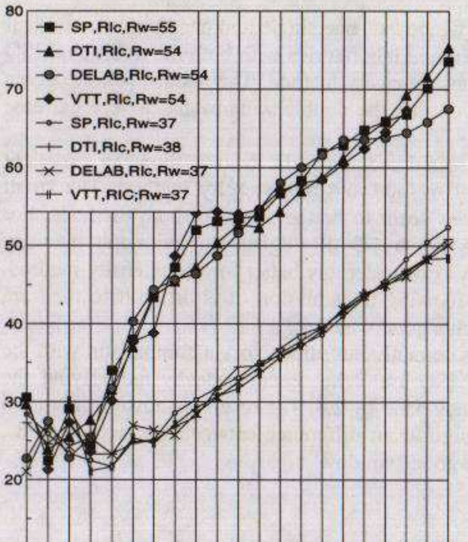

Figure 2 Interlaboratory comparisons with the intensity technique for a single metal leaf window(lower curves) and a double metal leaf window(upper curves).

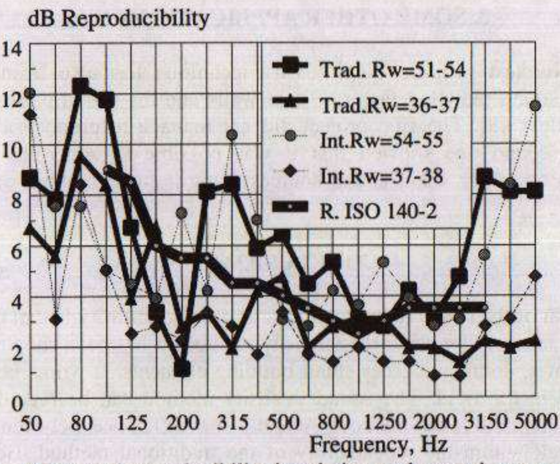

Figure 3 Measured reproducibility in relation to the requirements of ISO 140-2.

In the Field

In [6] a Nordic intercomparison test program for field measurement of sound insulation using different methods is reported. 5 different laboratories measured on the same test objects in the field. The reproducibility is given in figure 4. The results indicate that the intensity method and the traditional method have about the same reproducibility.

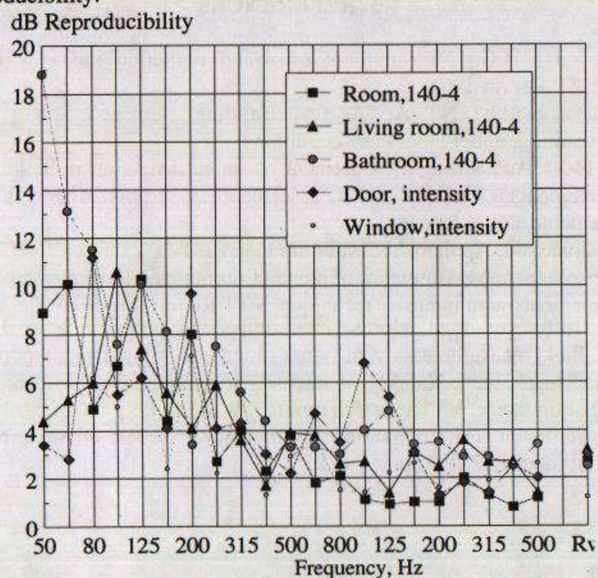

Figure 4 The reproducibility of ISO 140-4 and NT ACOU 084 respectively.

3. SOME OTHER APPLICATIONS

In different Nordtest projects the intensity technique has also been used to determine the sound radiation factor, [7], of walls and the sound power level of ventilation outlets, [8]. The first project did not manage to produce a Nordtest method. The second one showed that it was possible to apply the intensity technique also on rather silent sound sources using a small number of discrete probe positions.

4. CONCLUSIONS

Measurement of the sound reduction index as defined in ISO 140 can be carried out with good accuracy by using the intensity method. It has been shown to work well for windows, doors and other small building elements. It works both in the laboratory and in the field. The sound intensity method can be regarded to be equivalent to the traditional method. Actually the difference between the two methods lie well within the repeatability of the traditional method. Because of flanking transmission problems the intensity method is likely to be more reliable than the traditional method when measuring on building elements with high sound insulation.

The intensity method can also be used in other applications of interest in buildings, for example by determining sound power levels of ventilation outlets. Other applications have been tried with mixed success.

5. REFERENCES

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