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THE CALCULATION OF THE SOUND INSULATION OF DOUBLE PANELS - COMPARISON OF THE EXISTING MODELS

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ABSTRACT

Custom made construction products are nowadays very usual. It is very important to be able to optimize the price, the weight and several other properties of the building product, case by case. The wall may have to be manufactured of several layers, each having its own function e.g. stiffness, appearance, heat isolation or fire isolation. In many cases, sound insulation is also an important parameter to be optimized. To be able to calculate the SRI of multilayer walls, a thorough understanding of double walls is extremely important. There are abundantly references where such calculation models have been introduced, modified or applied. The scope of this work was to compare the most frequently referred models. So far, ten different calculation models have been programmed to PC. The verification of the program code was made by comparing the calculation results to the calculation results presented in the original articles. The wall structures were the same as in the original articles. It was found that the physical parameters were reported inadequately in several original articles. Most of the models were quite narrow in scope. The cavity absorption was modelled with several ways. In certain models the cavity was required to be empty or totally absorbing. Interpanel connections were considered only by a few models. This investigation is very useful for the selection of the correct model when the effect of different physical parameters of a double wall has to be investigated theoretically. In the future, an extensive comparison will be made between the calculated results and the measured results. The correct documentation of the physical parameters of the measured wall is very important to be able to state the validity and the range of applicability of the calculation models.

1 - INTRODUCTION

Custom-made construction products are very popular nowadays. It is important to optimize the price, the weight and several other properties of the building product, case by case. The wall may have to be manufactured of several layers, each having its own function, e.g. stiffness, appearance, heat isolation or fire isolation. In many cases, sound insulation is also an important parameter to be optimized. To be able to calculate the SRI of multilayer walls, a thorough understanding of double walls is important.

There are abundant references where such calculation models have been introduced [1-12], modified or applied in practice [13-14]. So far, only few and limited qualitative comparisons of the models have been presented in the literature. The aim of this study was to partially fill this gap. The ultimate aim of this study is to find the best calculation models for double panels, which can be reliably applied in the product development and practical design of multilayer wall structures.

2 - CALCULATION METHODS AND VERIFICATION

The 13 original models referred to in this study are presented in [1-12]. Model nr 11 included two models. Due to space limitations, there will be no specific introduction to the models.

For practical calculations, all models were programmed into a PC using the Microsoft Visual Basic 3.0 software. The calculations were done in the frequency range 50…5000 Hz, using 1/63-octave resolution. The results are presented in 1/3-octave bands, each containing 21 narrower frequency bands. Most of

the models required numerical integration. The sound incidence angles in the range 0 . . . 78° were used to simulate field sound incidence. The resolution of the angle was 0.25°. Depending on the model, the calculation time (numerical integration) was 2. . .45 seconds using a standard PC (233 MHz).
It was necessary to verify the programming code before the direct comparison of the models. The verification was done by comparing the calculation results obtained by SRICALC to the calculation results presented in the original articles using the same wall structures as documented in the original articles. The verification was found to be successful. The differences between SRICALC and the calculations in the original publications were usually within ±1 dB. Zero difference could not be obtained because the original data points (SRI versus third octave frequency band) were copied from the graphs of the original publications.
The physical parameters used in the original calculations were reported inadequately in most of the articles. Typically, one or two parameters had to be guessed because they were not given at all. In such cases, the verification procedure was laborious.

3 - RESULTS AND DISCUSSION

The total number of different physical quantities used to describe a double panel was 26. Eight parameters were needed for each panel, nine parameters for the cavity and three parameters for the rooms. The integration required three parameters. The general comparison of the calculation models, including the number of different physical parameters for each model, is indicated in Table 1.
The differences between the models are obvious. On average, the range of application is quite limited for all models. There are certainly such differences between the models that make direct comparison difficult. Four important differences between the models were:

- Some models do not permit any cavity absorbents, while other models presume that the cavity is sound-absorbing (α=1).
- Mechanical coupling between the panels (studs) are considered only in three models. Studs can be flexible in one of them.
- Some models can deal only with normal sound incidence, while most models presume that numerical integration takes into account different sound incidence angles. Some models have been fixed for field or random sound incidence to avoid numerical integration.
- Resonant vibration (critical frequency) has not been taken into account by all models.

Calculations were made for two simple wall structures A and B. The calculation results and the measured results are presented in Figs 1 and 2. Such models are not presented in Fig. 1 which do not allow for sound-absorbing cavities. Correspondingly, such models are not presented in Fig. 2 which do not allow for empty cavities.

In spite of this, the results obtained with different models are very different. The scatter is higher when the cavity is empty (wall B). Models 1 and 11 do not consider any other sound incidence angles than $\theta = 0°$. The results are markedly overestimated because the SRI decreases strongly with increasing sound incidence angle.

Reference, model	Year	Interpanel coupling	Cavity absorption	Asymmetric panels allowed	Resonant vibration considered	Sound incidence angle	Nr of calculation parameters
1. Beranek and Work	1949	no	Γ	yes	no	normal	4
2. London	1950	no	no	no	yes	arbitrary	7
3. Mulholland et al.	1967	no	α of panels	no	no	arbitrary	5
4. Cummings and Mulholland	1968	no	α of edges	yes	no	arbitrary	7
5. Crocker and Price	1970	no	α of edges	yes	yes	diffuse	14
6. Donato	1972	no	no	no	yes	arbitrary	9
7. Sharp	1978	rigid	$\alpha = 1$	yes	yes	diffuse	7
8. Ookura and Saito	1978	no	Z	yes	yes	arbitrary	8
9. Heckl	1981	no	stiffness	yes	yes	arbitrary	8
10. Gu and Wang	1983	flexible	$\alpha = 1$	yes	yes	diffuse	8
11. Fahy I	1985	no	Γ	yes	no	normal	8
11. Fahy II	1985	rigid	no	yes	no	diffuse	7
12. Au and Byrne	1987	no	Z, Γ	yes	yes	arbitrary	7

Table 1: General properties of the calculation models; the model of Delany and Bazley [15] was used to calculate the characteristic impedance Z, the absorption coefficient α and the propagation factor Γ of the cavity material.

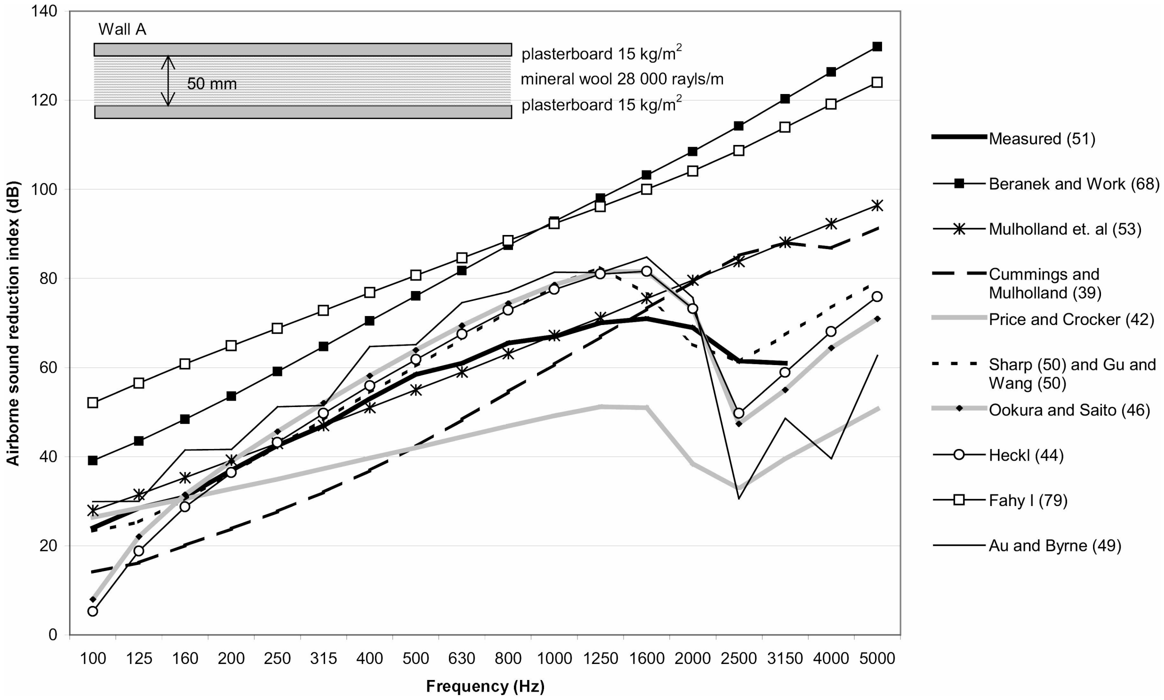

Figure 1: The sound reduction index of wall structure A; the measured result has been obtained from Ref. [12] Figure 17a; the weighted sound reduction index (R_w) is in brackets.

For wall A, the models of Sharp, Heckl, and Ookura and Saito were in reasonable agreement with the measurements. For wall B, the models of Donato, and Price and Crocker were in best agreement with the measured result. In the original publications, the agreement between the measurements and the

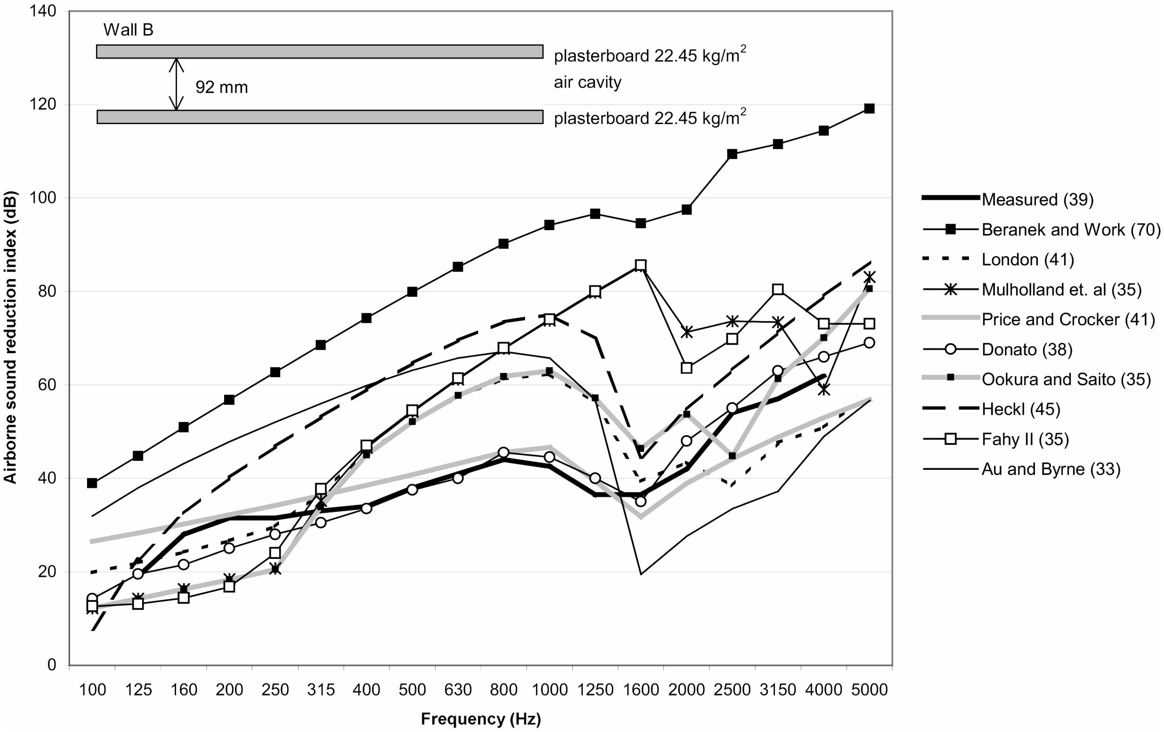

Figure 2: The sound reduction index of wall structure B; the measured result has been obtained from Ref. [9] Figure 4d; the weighted sound reduction index (R_w) is in brackets.

calculations was much better than in Figs. 1 and 2. According to Figs. 1 and 2, the results of the original publications should not be generalized without limitations.

In the future, a more extensive comparison of calculation models will be carried out. There are still some models that have not yet been programmed or verified. The correct documentation of the physical parameters of the measured wall is very important. This was not done with sufficient care in the original papers. The values of the physical quantities (e.g. stiffness, loss factor, absorption coefficient, impedance, flow resistivity) should be based on measurements. Recently, Kang et al. [16] proposed that the distribution of the sound incidence angles is not linear but Gaussian. They used the model of Ref. [11]. The influence of the sound incidence angle is probably very important and it should be considered in later studies. It is also essential to compare the results of different models with measurements that are performed in a single reliable test laboratory where the wall structures and mounting are well documented.

4 - CONCLUSIONS

- So far, 13 different calculation models have been compared with each other. Two simple wall structures were studied. The differences between the models were surprisingly large compared to the view arised by reading the original articles [1-12].
- The range of applicability of all models seems to be quite narrow. There does not seem to be a single model that considers most of the acoustically important properties of a double wall. More work is needed to find appropriate models for different wall structures.

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