Sound Reduction Index and Mode Shapes of Cavity Walls

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Introduction

Last year at DAGA`03 strong evidence was presented for the outstanding performance of asymmetrical cavity walls compared to symmetrical constructions [1], [2].

Asymmetry can be achieved by differences in the length of the wall-leaves, differences in the mass per area m‘ of the leaves and by slits in one leaf. m‘ and slits were subject to **laboratory** measurements by HFT Stuttgart [2] and our laboratory [1].

In the course of the last year we extended our research to **construction sites**. In addition to slits, for which we hold a patent, we focused on buildings with asymmetrical ground-plans (asymmetrical wall lengths). Moreover we now considered the deflection shapes (or mode shapes) too, not just the average transfer-function as before.

Transfer-function across the cavity

We call it a transfer-function “across the cavity”, if one leaf of the cavity wall is stimulated and the response is measured on the other leaf. Due to the separation we have a poor signal there but it is enough, especially with coincident modes, to see changes in the magnitude and the phase relations of the leaves.

Figure 1 shows the transfer-function across the cavity of a 2x17,5cm AAC-wall with 3cm cavity width measured in the laboratory. The symmetry of the test object was broken by cutting one leaf off its frame on the left and right side. This change from rigid bound edges to free moving edges heavily affects the mode shapes, which now no longer fit together. At frequencies below 100Hz the transfer-function across the cavity becomes flatter. The peaks are cut down 5-10dB. At higher frequencies, where there is greater density of the modes and things are more complicated, the dominating higher values are generally lowered, too.

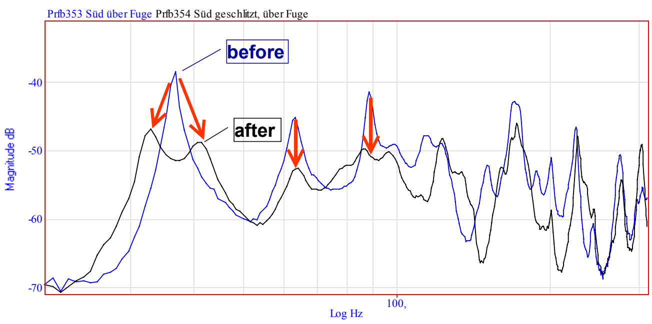

Figure 1 At lower frequencies the improvement in sound reduction can directly be seen in the transfer-function across the cavity.

Figure 2 shows the effect on the sound reduction index. In all 1/3-octave Bands R has increased. R_w moves from 61dB up to 66dB.

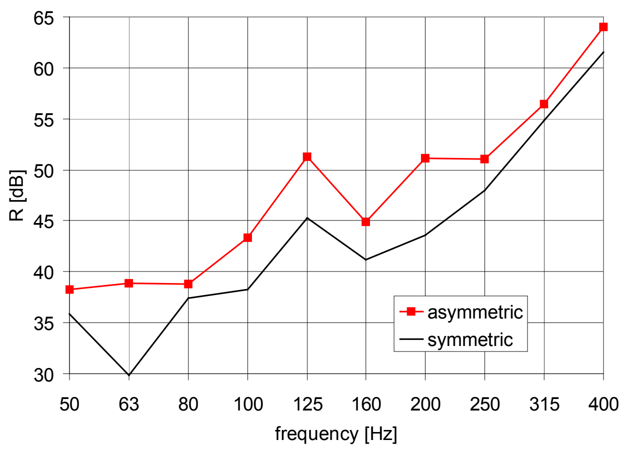

Figure 2 The sound reduction index increases even at higher frequencies, though not easily explained by the transfer-function.

Figure 3 gives a deeper insight. It shows the transfer-function of the **untreated** leaf. Nevertheless we see clear changes at lower frequencies. Only at higher frequencies there are no changes, as one could expect. We conclude that both leaves are coupled at low frequencies and have modes as an entity. However, this does not mean that opposite parts of the leaves move with the same phase and amplitude. On the contrary, at higher frequencies the leaves can be seen as independent.

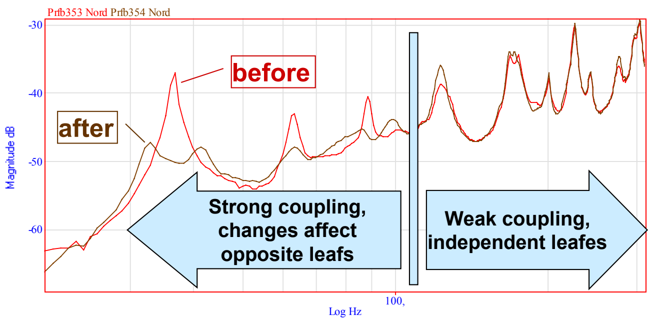

Figure 3 At lower frequencies slits in one wall-leaf affect the transfer-function of the other leaf, although this was not treated.

Asymmetrical ground-plans

Unlike in the laboratory important parameters such as material used and accuracy of work cannot be controlled on a construction site. Fortunately we found two sites (at Pasing and Mammendorf) like the one in Figure 4 with a symmetrical and an asymmetrical cavity wall in the same site. This allows us to make a direct comparison.

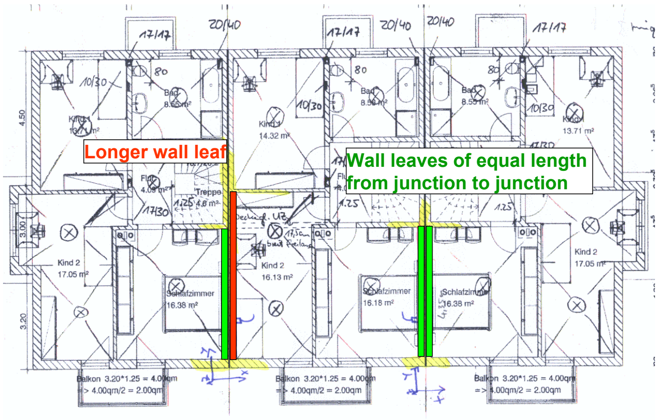

Figure 4 These three semidetached houses provide ideal conditions for the comparison of symmetrical and asymmetrical cavity walls. Despite the wall length, all parameters are equal.

As in the laboratory we found that the transfer-functions of equal leaves are quite the same. We also found that the modes of the longer wall-leaf are detuned. See for example the transfer-function near (1;2)-mode in Figure 5 and the accompanying deflection shape in Figure 6.

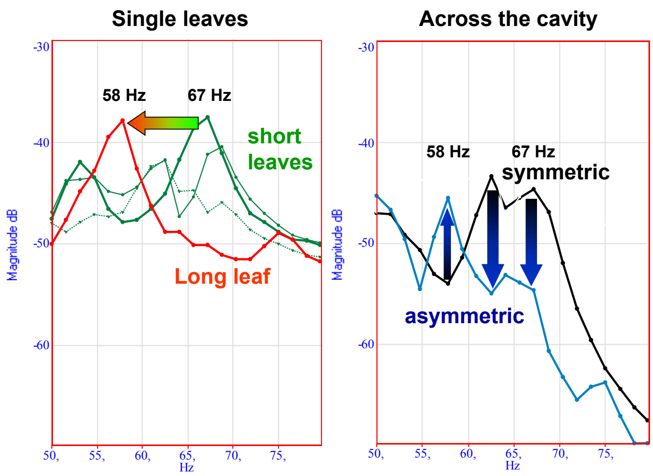

Figure 5 Transfer-functions. Left side: The shorter leaves have their (1;2)-mode at 67Hz, the long one at 58Hz. Right side: The transfer-functions across the cavity show the effect.

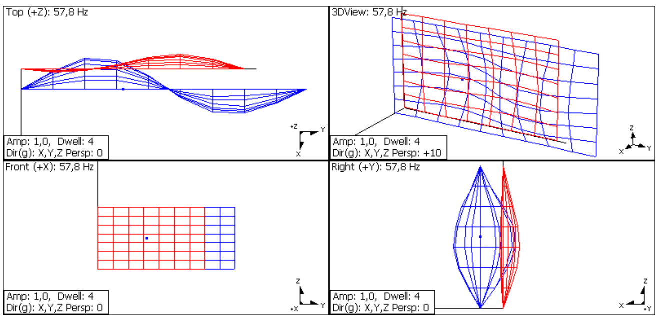

Figure 6 (1;2)-mode of the longer wall-leaf. The short leaf shows forced motion but no eigenmode.

At the Mammendorf site we observed the coincidence of the (n;3)-modes of the shorter leaf with the (n;4)-modes of the longer leaf (see Figure 7). This led to an increased transfer-function compared to the symmetrical case for n=1,2 and 3. One could say that at these certain frequencies (97Hz, 164Hz and 261Hz) the leaves were symmetrical in an acoustic sense.

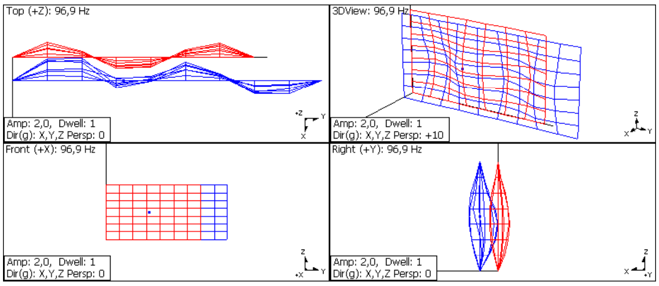

Figure 7 Due to the ratio of the lengths of the leaves the (1;3)-mode of the short leaf (red) and the (1;4)-mode of the long leaf (blue) fit together.

At both sites the weighted sound reduction index R'_w of the asymmetrical wall was 3dB higher than that of the symmetrical wall. Increase or decrease of the sound reduction was not intelligibly correlated to the transfer-functions on all 3rd octave bands. The varying modal properties of the rooms and varying microphone positions might be the reason. In contrast to laboratory measurements these parameters cannot be kept constant at site.

Slits at site

In Elmshorn we gained experience with slits in two pairs of semidetached houses for the first time. The transfer-functions of equal leaves were similar. The transfer-functions of leaves with and without slits were different.

There were no identical houses with symmetrical cavity walls for comparison. Compared to measurements in similar houses two years ago the increase at this first test-site could be 2-3dB. The leaves were joined by a common foundation.

Summary

An overwhelming number of measurements in two laboratories demonstrate the potential of asymmetrical cavity walls. First results obtained at construction sites encourage further research.

The best position and kind of slits have to be determined. The expected increase in sound reduction has to be estimated. Without measurements on identical symmetrical walls more tests are necessary to prove the advantage of asymmetrical cavity walls in the average.

The transfer-function across the cavity and identification of the modes are helpful tools. Room modes might be the missing link between transfer-function and sound reduction.

References

[1] J. Seidel; Direktschalldämmung Zweischaliger Haus-trennwände im Wandprüfstand; conference proceedings Daga'03

[2] J.Scheck, H.-M. Fischer, M. Schneider; Einfluss der Einbaubedingungen auf die Schalldämmung ein- und zweischaliger Massivwände; conference proceedings Daga'03