Influence of Wall Construction on the Acoustical Behaviour of ETHICS

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1 Introduction

External thermal insulation composite systems (ETHICS) are used to improve the heat insulation of the outer walls of buildings. In addition they change the acoustical properties of the walls. Depending on construction (thickness and stiffness of the insulating layer, mass of the plaster coat) the sound insulation can be either increased or reduced [1].

According to the basic acoustical model, which is based on a simple mass-spring-mass system, the improvement of sound insulation by ETHICS doesn't depend on the kind of the supporting wall. In practice, however, this simplification only applies to heavy, massive walls. For light walls consisting of perforated bricks or bricks with low density the interaction between wall and ETHICS can't be neglected. Systematic investigations of the acoustical interaction are so far missing. In the article in hand we present some examples to illustrate the relation between wall construction and the improvement of sound insulation by ETHICS.

2 Construction of ETHICS

ETHICS consist of heat insulating plates (mostly rigid foam polystyrene or mineral fibre), which are fixed onto the outer surface of the wall and covered by a plaster coat. The fixation is performed by adhesive mortar and sometimes additionally by dowels. The thickness of the insulating layer typically ranges from about 80 to 200 mm. An example for the construction of ETHICS is shown in the following picture:

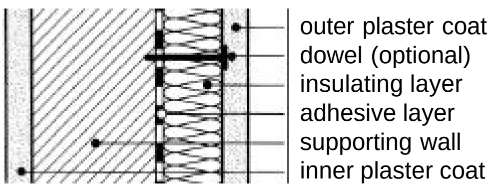

Fig. 1 Construction of ETHICS.

3 Theory

In principle ETHICS can be represented by two rigid masses (plaster coat and wall) which are connected by a spring (insulating layer). Since the mass of the plaster coat is generally much smaller than that of the wall, the frequency of the double leaf resonance f_r is given by

$$f_r = (1/2\pi)\sqrt{s'/m''}\ , \qquad (1)$$

with s' = E/d = dynamic stiffness of the insulating layer,
E = dynamic modulus of elasticity,
d = thickness of the insulating layer,
m'' = mass per unit area of the supporting wall.

In practice the dynamic stiffness of the insulating layer takes values of about $2\,MN/m^3 \le s' \le 50\,MN/m^3$ resulting in a resonance frequency in the range of $50\,Hz \le f_r \le 500\,Hz$ [2]. Depending on f_r the frequency response of the transmission loss contains three characteristic regions:

– For $f \ll f_r$ the transmission loss of the supporting wall remains almost unchanged. The acoustical effect of ETHICS is negligibly small.
– In the range of the resonance frequency $f \cong f_r$ a reduction of transmission loss occurs. The strength of the reduction depends on the damping of the system.
– For $f \gg f_r$ the sound insulation of the supporting wall is improved. The transmission loss increases by 18 dB per octave band compared to 6 dB per octave band without ETHICS.

4 Improvement of sound insulation

The improvement of the sound insulation by ETHICS is defined as

$$\Delta R = R_E - R_s\ , \qquad (2)$$

with R_E = transmission loss of the wall with ETHICS,
R_s = transmission loss of the wall without ETHICS.

The weighted improvement ΔR_w is determined by analogy as difference of the weighted sound reduction indices with and without ETHICS:

$$\Delta R_w = R_{E,w} - R_{s,w}\ . \qquad (3)$$

On condition that ΔR is independent of the construction of the supporting wall the transmission loss of any wall can in principle be determined by

$$R = R_s + \Delta R\ . \qquad (4)$$

In practice, however, the validity of Eq. (4) is restricted, because ΔR in some cases considerably depends on wall construction.

5 Investigated systems

Since systematic investigations were missing we searched for measurements which could provide information on the interaction between ETHICS and supporting wall. From our collection of data we chose two pairs of measurements, where identical ETHICS were combined with different walls. The construction of the systems is described in the following table:

No.	Supporting Wall			ETHICS		
	brick	d [mm]	m'' [kg/m²]	Insu-lation	d [mm]	m'' [kg/m²]
1a	slb	115	215	eps	200	32
1b	slb	240	460	eps	200	31
2a	slb	175	360	mf	80	8
2b	vcb	300	240	mf	80	8

d thickness of supporting wall or insulating layer
m'' mass per unit area of supporting wall or outer plaster coat
slb solid lime-sand brick
vcb vertical coring brick
eps extruded polystyrene
mf mineral fibre

Tab. 1 Construction of the investigated walls.

The main acoustical properties of the walls are specified in Tab. 2:

No.	f_c [Hz]	f_r [Hz]	$R_{s,w}$ [dB]	ΔR_w [dB]
1a	255	80	46	19
1b	125	80	55	13
2a	175	125	52	0
2b	105	125	43	14

f_c critical frequency of supporting wall (calculated)
f_r double leaf resonance frequency
$R_{s,w}$ weighted sound reduction index of supporting wall without ETHICS
ΔR_w improvement of R_w by ETHICS

Tab. 2 Acoustical properties of the investigated walls. The results for f_c are only approximations since they are based on estimated values of the elastic modulus.

6 Results

A typical example for the transmission loss with and without ETHICS is shown in Fig. 2:

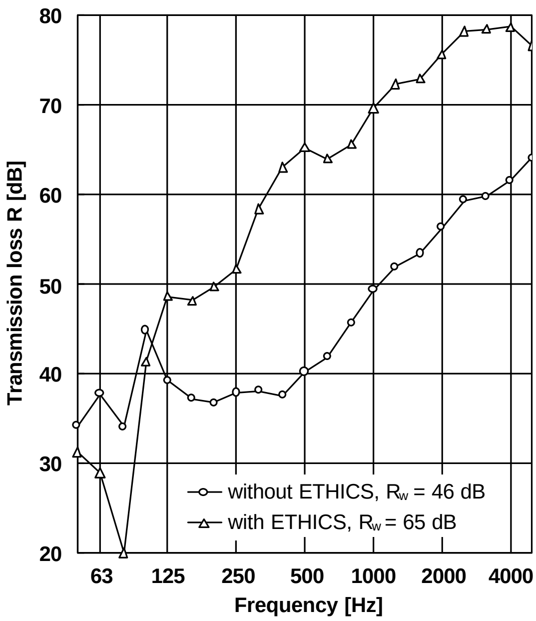

Fig. 2 Transmission loss of wall 1a (see Tab. 2) with and without ETHICS.

According to the results in Tab. 2 the improvement of sound reduction by ETHICS can vary strongly if the supporting wall is changed. Examples for the dependence of the improvement on the construction of the supporting wall are shown in Fig. 3 and 4. The presented data allow the following conclusions:

- The improvement of sound insulation depends on the relation between the critical frequency f_c and the double leaf resonance frequency f_r. For $f_r < f_c$ the influence of the wall construction is only weak (see Fig. 3, f ≤ 315 Hz). Otherwise there are strong differences already at low frequencies (see Fig. 4).
- The differences at high frequencies can not be explained by f_r and f_c .There must be further effects which influence the acoustical properties of ETHICS.
- For light walls with low transmission loss the improvement of sound insulation seems to be stronger.

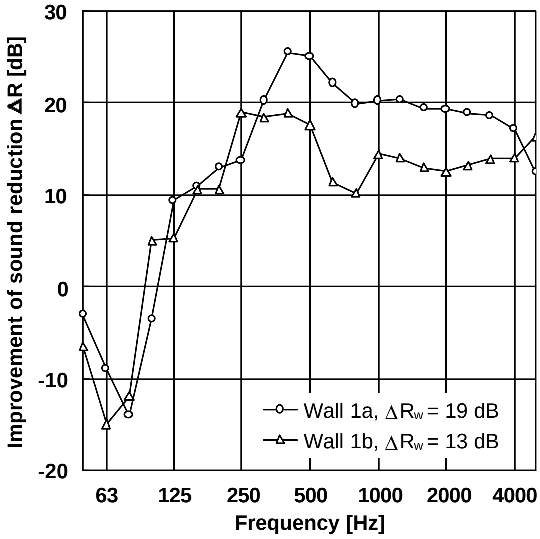

Fig. 3 Improvement of transmission loss by two identical ETHICS attached to different walls (walls 1a and 1b). The construction of the walls can be seen from Tab. 1.

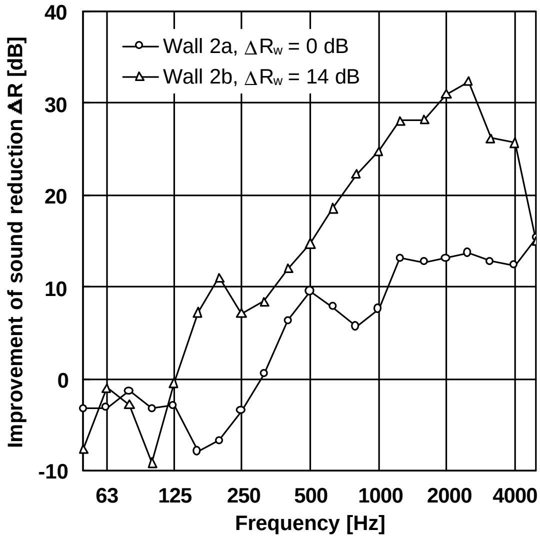

Fig. 4 Improvement of transmission loss by two identical ETHICS attached to different walls (walls 2a and 2b). The construction of the walls can be seen from Tab. 1.

7 Summary

According to the presented examples the improvement of sound insulation by ETHICS can strongly depend on the construction of the supporting wall. Since so far are not enough data available, additional investigations are required to enable a detailed explanation of this effect. Till then the transfer of the improvement to different walls have to be performed very carefully.

8 Literature

[1] Scholl, W.: Schalldämmung mit Wärmedämmverbundsystemen. Bauphysik 21 (1999), no. 1, pp. 20 - 28.

[2] Weber, L., Brandstetter, D., Scholl, W.: Schallschutz bei Wärmedämm-Verbundsystemen. Fortschritte der Akustik - DAGA 2001 (2001), pp. 222 - 223.