Acoustical behaviour of dry wall linings

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Dry wall linings, i.e. the combination of insulation material and a dry sheet such as plasterboard or chipboard are widely used to improve the thermal insulation of outside walls from the inside. In dependence of the acoustical data of the insulation material, e. g. dynamic stiffness, airflow resistivity, and the surface mass of the lining, different results in the acoustical performance are found. Recent investigations on different basic walls and linings together with the preparation of an ISO standard for the measurement of such linings show new connections of the different parameters with regard to the performance of the construction.

1 Introduction

Dry wall linings belong to the classical constructions in building acoustics. In many cases they are the ultima ratio for the improvement of existing building components with weak acoustical performance.

But also in new constructions the principle of dry wall lining is applied to solve acoustical problems, e. g. when installing floating floors, suspended ceilings or external thermal insulation under stucco (ETICS), etc.

In all cases the dry wall lining follows the principle of a mass-spring-mass-system. One mass is represented by either the basic wall, floor or ceiling – the other mass is represented by the lining.

The spring in between is characterized in different ways:

In the case of floating floors, ETICS and inside linings of exterior walls, where a composite system insulation/board is directly glewed on the wall, the characterizing quality is the dynamic stiffness of the mineral wool or plastic foam.

In the case of suspending ceilings and of free standing wall systems the stiffness of the air in the cavity between basic wall/ceiling and lining is characteristic. This air stiffness depends on the distance of the lining from the basic component and the amount of damping inside the cavity. Of course connecting elements can influence the acoustical performance in a negative way but there are enough good solutions on the market to solve this problem.

2 Problem

The Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig and the European Insulation Manufacturers Association (EURIMA) co-operated to study the question how different acoustical linings would act on different solid basic walls for sound insulation purposes. The studies were based on the draft of a new European standard: prEN ISO 140-16: Acoustics - Measurement of sound insulation in buildings and of building elements - Part 16: Laboratory measurement of the sound reduction improvement by acoustical linings [1]. This standard was prepared under the convenorship of PTB. The measurements for this report were carried out by two officially accredited laboratories,

− Fraunhofer-Institut für Bauphysik in Stuttgart (IBP) and Materialprüfanstalt für das Bauwesen an der TU Braunschweig (IBMB).
− The co-ordination of the measurement program and the summarising interpretation were made by PTB.

The following questions were asked:

− Is the performance of linings independent from the basic wall construction? Do we get e. g. the same improvement on a heavy calcium silicate wall as on a lightweight gypsum block wall?
− What are the values of the newly defined single number values according to prEN ISO 140-16?
− Are there big or systematic differences, is the scattering of the improvement values by identical linings on different basic walls different?
− Does the loss factor and with it the sound reduction index of the solid basic walls change when the lining is applied to the wall?
− How close are the results of different laboratories?

Three different basic walls were chosen (a heavyweight, a lightweight and a lightweight with cavities) and three different linings (a stiff one of EPS-plasterboard laminate, a soft one of mineral fibre-plasterboard laminate, and a free-standing one). Each lining was combined with each basic wall. To get some information about the reproducibility of the measurements in different laboratories, the heavyweight solid wall measurements including all lining versions were carried out in both laboratories.

3 Measurement Program

Details of the measurements can be found in the test reports of the laboratories [2,3]. The essential facts follow here:

The following basic walls were chosen for the tests:

1. Basic wall B1
   heavy homogeneous masonry of
   175 mm calcium silicate blocks
   10 mm plaster render
   total surface weight about 350 kg/m²

2. Basic wall B2
   60 mm homogeneous gypsum blocks
   smoothed on both sides
   total surface weight about 60 kg/m²

3. Basic wall B3
   70 mm hollow gypsum blocks
   10 mm plaster render
   total surface weight about 63 kg/m².

The first two basic constructions comply with the basic walls proposed in prEN ISO 140-16 as reference constructions with low coincidence frequency and about 350 kg/m² total surface weight or medium coincidence frequency and 70 kg/m² respectively. The third basic construction was used to investigate the influence of cavities on the performance of the linings and was representative for widely used exterior walls on the French market.

All linings were built up by the same craftsmen to keep differences of construction small. The following linings were tested:

1. Lining L1:
   a system of insulating laminate, directly glued to the basic wall, consisting of
   12,5 mm plasterboard
   50 mm mineral fibre, dynamic stiffness about 9 MN/m²
   Such linings are used in many countries to improve the acoustical performance of existing separating walls between rooms or dwellings but also to improve the thermal performance of exterior walls from inside when increasing flanking transmission shall be avoided.

2. Lining L2:
   a system of insulating laminate, directly glued to the basic wall, consisting of
   12,5 mm plasterboard
   50 mm expanded polystyrene, dynamic stiffness about 70 MN/m²
   This type of lining is widely used in many countries to improve the thermal performance of exterior walls from inside, when outside insulation is forbidden due to architectural reasons (e.g. preservation of monuments). The application of such materials decreases the sound transmission loss between adjacent rooms via flanking transmission.

3. Lining L3:
   a free-standing system on metal studs, consisting of
   2 x 12,5 mm plasterboard (8,5 kg/m²)
   100 mm metal studs, with
   100 mm mineral wool between the studs.
   This type of linings is recently growing in market share for several reasons: in the case of uneven surfaces of the existing walls it is easier to handle than the glewed types, people are more flexible in choosing the type of vapour barrier in special cases. Also pipes, cables and ducts are easier to hide in the lining construction. And – last but not least – as will be shown later, this type of lining gives by far the best acoustical improvement.

Each lining was combined with each basic wall. The measurement program for basic wall B1 was carried out in both laboratories. The measurement program for each basic wall was the following:

− measurement of the sound reduction index of the basic wall acc. to [4, 5]
− measurement of the total loss factor of the basic wall [5, 6]
− measurement of the sound reduction index of the basic wall with lining L1
4 Results

Details can be found in the test reports of the two laboratories. The main results are summarised as follows.

4.1 Improvement by the linings

The airborne sound reduction improvement by the linings on different basic walls is displayed in figures 1 to 3. As far as IBMB-values are significantly lower than values from IBP for equal combinations of linings and basic walls, they seem to be limited by flanking transmission. However, it remains an open question, why at IBP lining L3 yields such different improvement values on basic walls B1 and B3. The differences amount to 10 to 15 dB in a broad frequency range. According to information from IBP the sound reduction index in these cases stays more than 10 dB below the maximum sound reduction index of the test facility for this kind of specimens, so that flanking transmission has no influence in these cases. Also the influence of the loss factor cannot be the reason – in both cases it is of the same order of magnitude.

4.2 Single number values

According to prEN ISO 140-16 numerous single number values are admissible to describe the improvement of the airborne sound reduction by linings. But in all cases one starts with determining the frequency spectrum of the difference of sound reduction of a basic wall with and without lining, the so-called sound reduction improvement index \( \Delta R \).

The 'direct difference of the weighted sound reduction indices' \( \Delta R_{w,\text{direct}} \) is obtained by simply subtracting the weighted sound reduction indices of the basic wall with and without lining:

\[
\Delta R_{w,\text{direct}} = R_{w,\text{with}} - R_{w,\text{without}}
\]

This value is strictly speaking valid only for the special combination, which was tested. A more general
characterisation is obtained when the measured sound reduction improvement of a lining is applied to a standardised "generalised" reference basic wall by calculation, before subtracting the weighted sound reduction indices of that reference wall with and without lining. This is called 'weighted sound reduction improvement index':

$$\Delta R_w = R_w,\text{ref,with} - R_w,\text{ref,without}.$$  

Apart from weighted sound reduction indices, since some time ago there is an alternative characterisation of sound insulation by the A-level differences caused by building elements against certain exciting noises (e.g. pink noise or traffic noise). The A-level differences are expressed as the sum of the weighted sound reduction index of the element plus a so-called spectrum adaptation term acc. to ISO 717-1 [10], e.g.

$$R_w + C_{tr}.$$  

The index 'tr' here means 'traffic' (= traffic noise). The performance of a lining thus can be expressed as the change of the A-level difference of a basic wall, caused by the lining, e.g.

$$\Delta (R_w+C) = (R_w + C)_{\text{with lining}} - (R_w + C)_{\text{without lining}}.$$  

If $R_w$ and $C$ of a specific basic wall with and without lining are directly put into the above term, it will be called the 'direct difference of the A-weighted sound reduction indices'. If $R_w$ and $C$ are calculated for a reference wall with and without lining, the above term will represent an 'A-weighted sound reduction improvement index'. prEN ISO 140-16 offers altogether 3 different basic constructions (on special request of some standard working group members) - two walls and one floor. That means, that - regarding all C-values and all possible frequency ranges - 36 different single number values are admissible to characterise linings. It is recommended here to omit all single number values, which include frequencies below 100 Hz because of increased measurement uncertainties and above 3150 Hz because of no additional information. Secondly single number values referring to the reference floor can be omitted here because of the small difference compared with the heavyweight reference wall. Thus only 9 single number values are left, 3 respectively to characterise the performance of linings on heavy walls, on lightweight walls and directly on the special wall used in the laboratory.

The single number values for all linings are given in tables 1 to 3. The single numbers again reveal that the performance of the linings depends on the type of basic wall (which was not expected) and the type of reference wall (which was expected). The number of measurements is too small to do real statistics. But, when taking results from IBP as a basis (because of the absence of flanking transmission influences), it seems that single number values being based on reference walls scatter much less than single number values based on direct differences. This is an advantage of the reference wall based characteristic values.

### Table 1: Single number values of lining L1 (mineral fibre) on the different basic walls

<table>
<thead>
<tr>
<th>Laboratory:</th>
<th>IBP</th>
<th>IBMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic wall: B1</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Basic wall: B3</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Basic wall: B2</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
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<td>13</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Basic wall: B1</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

### Table 2: Single number values of lining L2 (polystyrene) on the different basic walls

<table>
<thead>
<tr>
<th>Laboratory:</th>
<th>IBP</th>
<th>IBMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic wall: B1</td>
<td>-2</td>
<td>2</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>-2</td>
<td>2</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
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<td>1</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>Basic wall: B3</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Basic wall: B2</td>
<td>-2</td>
<td>6</td>
</tr>
<tr>
<td>Delta (Rw)</td>
<td>-2</td>
<td>6</td>
</tr>
<tr>
<td>Delta (Rw+C)</td>
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</tr>
<tr>
<td>Delta (Rw+Ctr)</td>
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<td>5</td>
</tr>
</tbody>
</table>

### Table 3: Single number values of lining L3 (free standing) on the different basic walls
5 Conclusions

Question: Is the frequency spectrum of the performance of linings – the sound reduction improvement index – independent of the basic walls?

Answer: According to the measurements carried out it seems that the performance is not independent of the basic walls. One reason is that the way of installing the specimens in the test facility according to EN ISO 140-3/prA1 increases the influence of flanking transmission, so that basic walls with high sound reduction can result in lower improvement values for the linings. But there were additional differences found during the measurements, which could not be explained within the frame of this project.

Question: Which results are obtained for the newly defined single number values in prEN ISO 140-16?

Answer: In case of the linings under test improvement values (single number values) were found between -3 and more than +30 dB. Theoretically prEN ISO 140-16 allows the presentation of 36 different single number values, which is not efficient. All values including frequencies below 100 Hz should be omitted for lack of measurement precision. Furthermore direct differences of the sound reduction indices without use of reference basic walls are not recommended, as these values are only valid for the specific wall-lining-combination tested, and show increased scattering when misusing them by applying them to other basic walls. Finally it should be kept in mind, that prognosis of the acoustic performance of linings using 18 third octave or 6 octave band values could be easier and simpler than to chose the right single number value out of a group of 15 to 36, accepting at the same time the increased inaccuracy of single number evaluation methods.

Question: How well do results from different laboratories correspond?

Answer: There was only one basic wall with three different linings, which could be compared in the two laboratories, involved in the project. Because of different boundary conditions in the laboratories different results were obtained. It remains an open question, whether special boundary conditions should be defined for walls with linings, which allow stating the theoretically possible improvement although under conditions less close to practice.

6 Summary

In connection with the new standard prEN ISO 140-16 measurements of the sound reduction improvement of linings applied to massive walls were carried out in two officially approved laboratories in Germany. Three massive basic walls were tested: a heavyweight calcium-silicate masonry, two more lightweight gypsum walls, one of them homogeneous, the other one with cavities. Three different linings were applied to each basic wall: a laminate system with polystyrene, another one with mineral fibre, and a free-standing lining. Measurements on the calcium-silicate masonry were carried out in both laboratories, the other measurements only in one of both labs. For the characterisation of the linings, 15 single number values according to prEN ISO 140-16 were calculated. Single number values based on standardised reference basic walls scatter significantly less than single number values simply representing the differences of weighted sound reduction indices with and without lining of the specific wall in the lab. The third octave band values of the sound reduction improvement was not independent of the basic walls, as was expected. In same cases this could be explained by flanking transmission of the test suites. In all the other cases further clarification is needed. Fixing a lining increases the total loss factor of the basic wall. The additional sound reduction improvement by additional damping amounts to up to 6 dB. Whereas the sound reduction indices of the simultaneously tested calcium-silicate masonry walls agreed nearly perfectly, larger differences occurred after the application of the linings, the reason for which are different boundary conditions in the two laboratories, resulting in different flanking transmission.
References

[3] Test report 2080/5723-DK/br of Materialprüfungsanstalt für das Bauwesen from 17. 5. 2004
[6] PTB measurement guidelines for total loss factor