Influence of Standard Gypsum Board Cladding on Room Acoustic Parameters

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Abstract: The purpose of this research is to investigate the effect of low-absorbent and reflective building materials (gypsum board) on the acoustic parameters of the room, depending on the type and structure of the cladding. Although gypsum board (dry cladding system) is widely used in music schools, concert halls, gyms, recording studios, their sound-absorbing properties are generally under-considered, with the main focus on their sound insulation properties. More than 10 types of boards comply with the EN520 standard; each type of board has its own sound-absorbing parameters and is used in different systems. The essence of this study is to evaluate the influence of EN520 plates on the acoustic parameters of the room: Rt; C80 and RASTI. This study does not cover all types of EN520 boards and possible combinations of their applications. This study compared four different wall-cladding systems—single- and double-layer cladding, with and without the use of stone/glass wool in order to determine acoustic properties compliance to function for sport and teaching room space.

Key words: Gypsum board, RASTI, double-layer cladding.

1. Introduction

Sound absorption properties are divided into eight classes according to EN ISO 11654, ranging from absorptive class A (absorption coefficient > 0.8) to reflective class E (absorption coefficient < 0.1). The sound absorption properties for various gypsum boards configurations were evaluated in the frequency range from 125 Hz to 4,000 Hz. In turn, gypsum boards according to EN520 are mainly divided into the following classes A; D; F; R; I; H (1-3) E. This classification is related to the physical properties of construction—strength, fire safety, surface hardness, water absorption, which in turn resulted in significant differences in slab mass from 7.8 kg/m² to 18 kg/m², as well as the modulus of elasticity range is different namely 2,000 N-3,000 N. In most cases, the evaluation of gypsum board sound absorbing parameters begins and ends with the division into the class of reflective materials, that is, the absorption coefficient < 0.1. Although mentioned above, their weight and modulus of elasticity can vary more than twice. Also, in the technical literature, these boards are not referred to as acoustic or sound absorbing boards but as standard or regular boards according to EN520.

The modulus of elasticity of gypsum boards and the cut-off frequency of the absorption coefficient depend on the number of boards. In practice, two layers of cladding is used to provide sound insulation, fire safety and impact resistance requirements, sound absorption properties of these variants are omitted. This study compares four different wall-cladding systems—single- and double-layer cladding, with and without the use of stone wool in order to determine acoustic properties compliance to function for sport and teaching room space.

2. Methodology

2.1 Room Acoustics Concept

One of the most important parameters of room
The acoustics is reverberation time—$R_t$. This is the time $t$ (S) at which the sound pressure drops by 60 dB. The reverberation time is calculated according to the Sabine equation (1900)

$$R_t = 0.1611 \frac{V}{\alpha S}$$

where: $V$—room volume, m$^3$; $S$—room surface areas, m$^2$; $\alpha$—for these areas, respectively their finishing materials, corresponding sound absorption coefficients [1]. As can be seen from the formula, the reverberation time is inversely proportional to the surface area and directly proportional to the volume of the room. As gypsum boards relatively often make up 30-80% of the surface of the room, even a small absorption < 0.1 is important. Gypsum boards according to EN520 DFH2IR are used in this study, which work as membrane absorbents (all types of panels and linings with or without air absorbent filling). Here, energy conversion occurs due to the resistance of the membrane to rapid bending and the resistance of the interlayer to compression, these absorbents are effective in the low and medium frequency range, but usually not in a very wide band (1-2 octaves, Table 1).

The maximum efficiency cut-off frequency $f_R$ can be expressed as follows:

$$f_R = \frac{60}{\sqrt{Mb}}$$

where $M$ is the mass of the panel surface (i.e. 1 m$^2$) (kg) and $b$ is the air gap between the mounting points (m). The value of the $f_R$-cut-off frequency is important in determining both the sound insulation and the absorption properties of the system. Namely, in the study, the distance $b$ is 600 mm and the plates—Knauf Blue DFH2IR (EN520) are fastened parallel to the frame CD profiles. The E-module is different in the longitudinal and transverse directions for gypsum boards. Only one variant -4,000 N/mm$^2$ is considered in the study.

### 2.2 Measurement Procedure

Investigations of sound absorption properties of cladding system W623 were performed in the reverberation chamber of the factory Radiotehnika, in accordance with the requirements of the standard LVS EN ISO 11654: 1997.

### 2.3 Different Cladding Systems

The 10 m$^2$ sample to be measured in order to ensure maximum compliance with the real construction situation was placed in the corner of the measuring chamber, Image 1. Its structural structure corresponded to the original drawing of the W623, see Fig. 1, but without screw fastening to the main structure. Thus, the measurements simulate a complete real finishing situation with the characteristic elements of the carcass, clamps and cotton wool. The thickness of the layer was 60 mm with 40 mm Rockwool Rooftock wool filling. Cladding panels—Knauf Blue GKFI.

### Table 1  Absorption coefficients for common materials.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>REF</th>
<th>NOTE</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster on lath, deep air space</td>
<td>Dfree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 mm plasterboard on frame, 100 mm cavity, no mineral wool</td>
<td>9</td>
<td></td>
<td>0.20</td>
<td>0.15</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>13 mm plasterboard on frame, 100 mm airspace with mineral wool</td>
<td>9</td>
<td></td>
<td>0.08</td>
<td>0.11</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>2 X 13 mm plasterboard on steel frame, 50 mm mineral wool in cavity, st.</td>
<td>7</td>
<td></td>
<td>0.15</td>
<td>0.01</td>
<td>0.06</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>9.5 mm plasterboard on frame, 100 mm empty cavity</td>
<td>9</td>
<td></td>
<td>0.08</td>
<td>0.11</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>9.5 mm plasterboard on frame, 100 mm cavity filled with mineral wool</td>
<td>9</td>
<td></td>
<td>0.28</td>
<td>0.14</td>
<td>0.09</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>
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Image 1  Sample measured.

Fig. 1  System 1.
- Rockwool Roofrock: 40 mm
- CD profile: 60/27/0.6
- UD shape clamp: 28/27/0.6
- TN25 screw
- Knauf Blue GKFI 1 × 12.5 mm

Fig. 2  System 2.
- Rockwool Roofrock: 40 mm
- CD profile: 60/27/0.6
- UD shape clamp: 28/27/0.6
- TN25 screw
- Knauf Blue GKFI 2 × 12.5 mm
3. Results and Discussion

3.1 Four Different Systems

The results of the four constructive situations (Figs. 1–4) are shown in Fig. 5.

3.2 Proposed and Implemented Applications

As the measurement results show, the W623 cladding system can also perform the functions of low-frequency sound absorber very successfully. To assess the real effect [2], a 3D acoustic computer simulation was performed for a real school class [3] in Riga, initially with an original plastered masonry and concrete finish, but then with a KNAUF W623 finish for walls and ceilings. The original image of the computer model is shown in Image 2 and Image 3.

It is clear that in the initial class finish LBN 016-15 “Building Acoustics” an inappropriate picture is to be seen—reverberation times are excessive 1.08-1.44 sec. (max. 0.6 sec. allowed), but the fast speech transmission index RASTI reaches only 0.53 (min. 0.6 required). The sound clarity of the C80 with an interval of 0.85-2.80 at most frequencies is also inadequate. When finishing class walls with 2 × 12.5 plasterboard finish, and ceiling—with 12.5 mm, which is considered a typical repair/reconstruction solution without the use of special absorbents, the acoustic picture changes significantly: (i) reverberation times decrease to 0.54-1.22 sec., i.e. at low frequencies already meets the requirements of LBN 016-15 [3], (ii) RASTI value improving to 0.56 and (iii) the sound clarity C80 is in the range 1.86-8.56, i.e. meets the requirements of LBN 016-15 in most frequency bands [4].
Fig. 5  Results of 4 different systems. X-axes indicate sound absorption coefficient ($\alpha$). Y-axes indicate frequency response of the measured $\alpha$ values in 1/3 octave bands or frequency (Hz).

- Absorption coefficient, $\alpha$, avg. values in octave bands.
- Frequency (Hz) response of the measured $\alpha$ values (in 1/3 octave bands).
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Image 2  Original image of the computer model.

Image 3  New computer model (plasterboard finish in green).
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Double-clad systems, in turn, are highly recommended for the function of sound reflectors in the premises of various acoustic concert functions, see Image 4.

4. Conclusions

The obtained results show stable values in all 8 octave frequency bands, but further analyses are focused mainly in the direction of the most acoustically significant range namely 125-4,000 Hz. Samples with 12.5 mm ordinary cladding (with and without glass wool) show a significant absorption of low frequency (63-250 Hz) sounds in the range of 0.06-0.14, but significantly lower values of medium-high frequency (500-8,000 Hz) in the range 0.02-0.05. The obtained results correlate well with the results of other research [5] and computer program databases. In practice, in order to meet the requirements of impact resistance, a two-layer plasterboard cladding is used in gyms, which is not acoustically suitable. From the point of view of building acoustics, it is more correct to use a single layer of gypsum board cladding using special boards—according to EN 520 type DF. The two layers of gypsum board cladding are very suitable for acoustic concert halls, because two layers cladding has low absorption, which suit better to function.

References