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The acoustic properties of the lecture hall of the Faculty of Building Services in Cluj-Napoca

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Abstract

The present paper deals with the study of the acoustic properties of the Lecture Hall belonging to the Faculty of Building Services in Cluj-Napoca; the hall is dedicated to both teaching activities and used as a national and international conference venue; complex measures to ameliorate the acoustic features of the hall are also envisaged. After performing the acoustic measurements and processing the data found, it was found out that the reverberation time was not situated in the standard range limits and that several measures to improve the hall acoustics were required. The paper presents several proposals to improve the acoustic properties of the hall and a costs analysis of these solutions. The acoustic properties of the hall were determined in accordance with the Romanian standards that are in full agreement with the European norms.

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Keywords: Acoustic measurement; acoustic comfort; Lecture Hall acoustic; reverberation time; acoustic rehabilitation.

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1. Introduction

The present paper deals with the complex study of the acoustic properties of the Lecture Hall belonging to the Faculty of Building Services in Cluj-Napoca, Romania (Fig.1). The hall is dedicated to both teaching activities and used as a national and international conference venue.

Fig. 1. Faculty of Building Services: (a) Main façade; (b) Lecture Hall viewed from the outside; (c) Lecture Hall viewed from the inside.

The building body where the hall is a part was erected between 2005-2007, when the entire Faculty of Building Services was modernized and renovated. Though relatively new, until now no concern for the acoustic properties was given.

The aim of this paper is to draw attention upon the importance of such investigations that are necessary when erecting halls with high levels of acoustic properties. The acoustic properties of the hall were determined in accordance with the Romanian standards that are in full agreement with the European norms.

The Lecture Hall is rectangular in plane, with a footprint of about 260 m^2, the length of 17.65 m, the width of 15.80 m and a maximum height of 8.10 m. The single floor building body where the hall is situated has a structure made with reinforced concrete frames and filler brick masonry. The ceiling is false, made of gypsum panels where lighting bodies and air conditioning air intakes are situated; the windows are with PVC joinery and heat insulating double glazing. There are 311 seats in the hall where lectures, national and international conferences are held permanently. The entrance to the hall is made from a central lounge connecting the area with other bodies of buildings belonging to the Faculty of Building Services.

2. Evaluation of internal acoustics

2.1. Measurement Equipment

The measurement process involved the observance of the requirements in [1]. For the measurement purpose, a high performance acoustic chain was used, built by Brüel&Kjær Company. The equipment used for acoustic

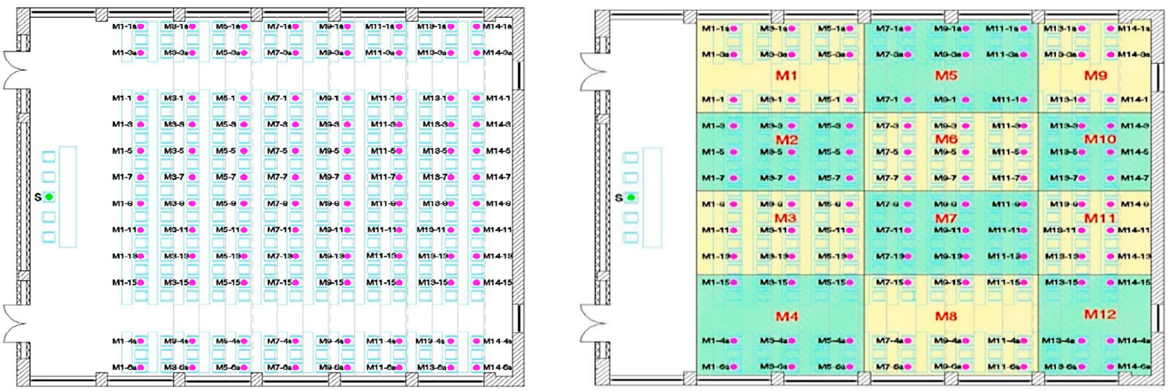
Fig. 2. Images from the acoustic measurements in the Lecture Hall.

measurements includes: the omnidirectional noise source “OmniPower Sound Source type 4292”, mounted on a tripod, 300 W power amplifier “Power Amplifier type 2716”, the microphone and preamplifier set, type 4189, fixed on a tripod of type UA0801, Sound Level Calibrator type 4231, the sound and vibration analyser “PULSE type 3560B”, software “PULSE FFT&CPB Analysis type 7700”, installed on a Dell laptop. Images from the acoustic measurements are given in Fig. 2.

2.2. Establishing the acoustic measurement method

In order to appreciate the acoustic properties of the Lecture Hall, we made use of the reverberation time. The reverberation time is the time interval in which the sound intensity diminishes by 60 dB from the moment in which source emission stops. The measurement of the reverberation time in the hall was performed in the empty hall, without occupants. The omnidirectional power source was placed opposite to the place where the speaker stands. The microphone was fixed in 96 points distributed in the audience area. The sound source was arranged so that it could render actual noise as faithfully as possible, namely in the position of the speaker. The source and microphone positioning in the hall plane can be seen in Fig. 3a.

In order to obtain results as accurately and as close as possible close to actual hall situation as possible results measurements were performed in 96 points. Because of the large number of points and data found, averages in smaller sections were made reaching 12 areas (M1 ÷ M12), which were then used to get a total average, needed to determine the reverberation time (Fig. 3b).



a. b.

Fig. 3. (a) The source and microphone positioning in the chosen points; (b) Separation in 12 areas.

The measurements themselves concerned the positioning of the omnidirectional source and the emission of noise for a time interval of several seconds. In turns, the microphone was placed in all the previously established points, it received the noise emitted by the source and, then, with the help of the analysor and special measurement dedicated analysis software of type Bruel&Kjaer, the reverberation times were recorded along a frequency range contained between 125 and 5000 Hz.

2.3. Data found from acoustic measurements

For computational purposes, only the frequency values of 125, 250, 500, 1000, 2000 and 4000 Hz will be considered, according to [2]. The values found in each of the mentioned frequencies are the values found in the 12 areas, as averages of those areas.

2.4. Defining the admissible range of the reverberation time found by acoustic measurements

According to [2] and norms in force, the ratio between time T_f determined for frequencies 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz and the average hall reverberation time T_m should be framed between certain limits. The average reverberation time of the hall T_m was computed as in the diagram from [2], [4] function on the type of sonorous production and volume. Dependent on the building volume V = 1156.25 m^3 and the line corresponding to the predominant sonorous production, i.e. in this case the teaching activity, included in the field of the conference hall, by interpolation, we found an average reverberation time T_m = 1.146 s. The ratio between the reverberation time T_f and the average reverberation time of the hall T_m is presented in Fig. 4.

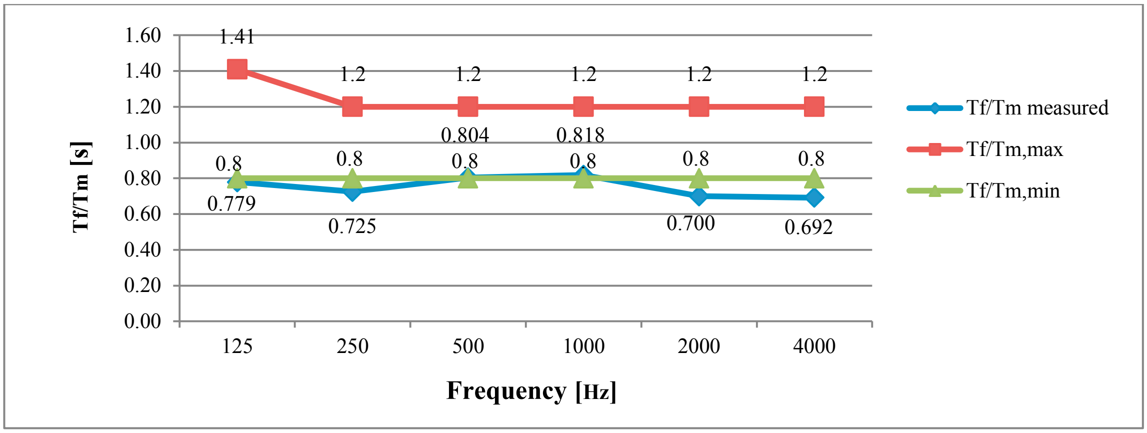


Fig. 4. Comparison of the Tf/Tm ratio to admissible values.

The interpretation of the graph given in Fig. 4 leads to the idea that the values of the Tf/Tm ratio are not included in the admissible range of the reverberation time given in [2], meaning that measures to improve the hall acoustics are necessary to be put to work.

2.5. Determination of the reverberation time with Sabine's formula

At this stage, it was necessary to compute the reverberation time, with the help of Sabine's formula. According to the provisions specified in [3], the reverberation time can be calculated with the relationship:

$$T = \frac{0.163 \cdot V}{A} \quad [\mathrm{s}] \tag{1}$$

where: V is the room volume, in m^3 and A is the equivalent absorption area, in m^2 , calculated with:

$$A = \sum S_i \alpha_i + \sum a_j \quad [\mathrm{m}^2] \tag{2}$$

In the formula (2) S_i represent the interior surfaces of the Lecture Hall with absorption coefficients α_i, while a_j is the unit absorption area of a person or an object. A, in m^2, was calculated taking into account all the interior surfaces of the Lecture Hall (walls, ceiling, flooring, windows, doors, furniture) with their corresponding absorption coefficients α_i,. The reverberation time $T_{f,}$ found for each and every frequency provided in [2] was calculated with the formula (1) and the average reverberation time is T_m=1.146 s, as shown above. The ratio between the computed reverberation time and the average reverberation time is presented in Fig. 5.

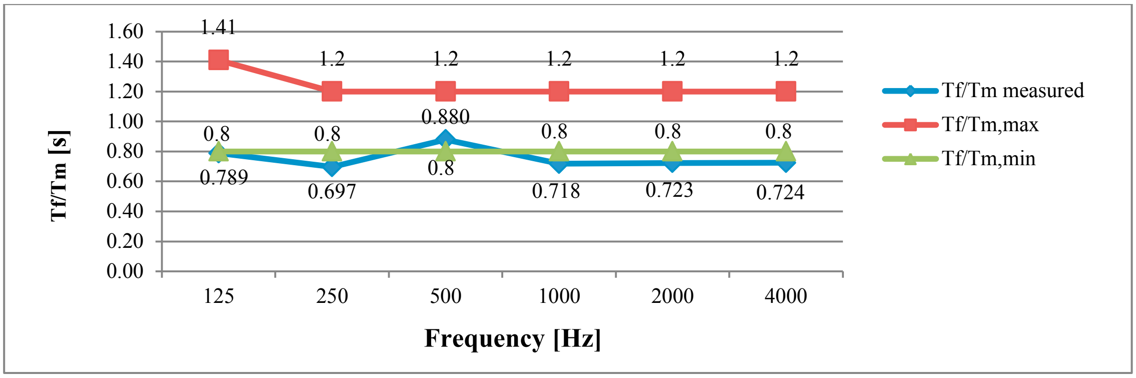


Fig. 5. Comparison of the Tf/Tm ratio to admissible values.

Fig. 5 highlights the fact that the values of the Tf/Tm ratio do not include in the admissible range of the reverberation time given in [2]. Comparing the magnitudes reached with the two methods, it was found that the results presented close values.

3. Proposing solutions to improve the acoustic comfort in the hall

Following the results reached by acoustic measurements and by computation, one can notice that is compulsorily necessary to improve the acoustic comfort of the hall. For this aim, three constructive solutions are proposed. According to [2], it is necessary to check also the situation when the room is 50% full and 100% full.

3.1. Positioning sound absorbing Ecophon tiles + sound absorbing AMF panels

The first suggested solution is the following: the false ceiling of plastered gypsum will be replaced with sound absorbing Ecophon Master Rigid Dp gamma tiles, and AMF panels will be mounted on a surface of 34 m^2 on the backwall of the Lecture Hall (Fig. 6).

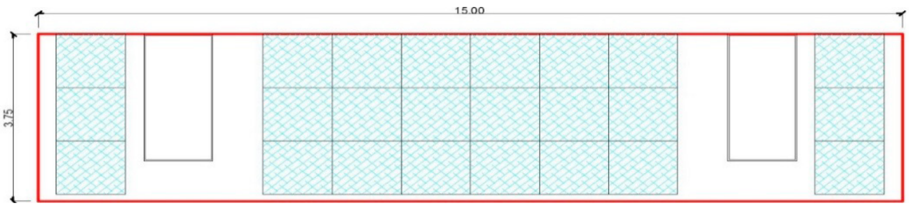


Fig. 6. Positioning AMF Line Modern panels on the backwall of the hall.

The sound absorbing Ecophon Master Rigid Dp gamma tiles are produced from high density glass fibre wool. The α_i absorption coefficients at various frequencies were taken from product catalogues [5]. Among the advantages of using such panels one can enumerate: accessibility (plates can be dismounted), easiness in cleaning, good light reflection, good operation in high humidity conditions, resistance to fire according to norms in force, easy mounting. The dimensions of the plates are 600x600x20 mm, and the surface covered by the panels is 278 m^2. The sound absorbing AMF Line Modern [6] are panels made from mineral wool stretched in a metal frame which is covered by wool, too. This provides high acoustic performances, increased resistance to fire, easiness in mounting and a modern design appearance. The sizes of the panels are 1200x1200mm, with the aluminium frame of 43 mm. The Tf/Tm ratio values for this solution range in the limits of [2] (Fig. 7). This solution was also verified for the case of the 50% and 100% occupied Lecture Hall and it was found out that in these cases Tf/Tm ratios range also in the limits of [2].

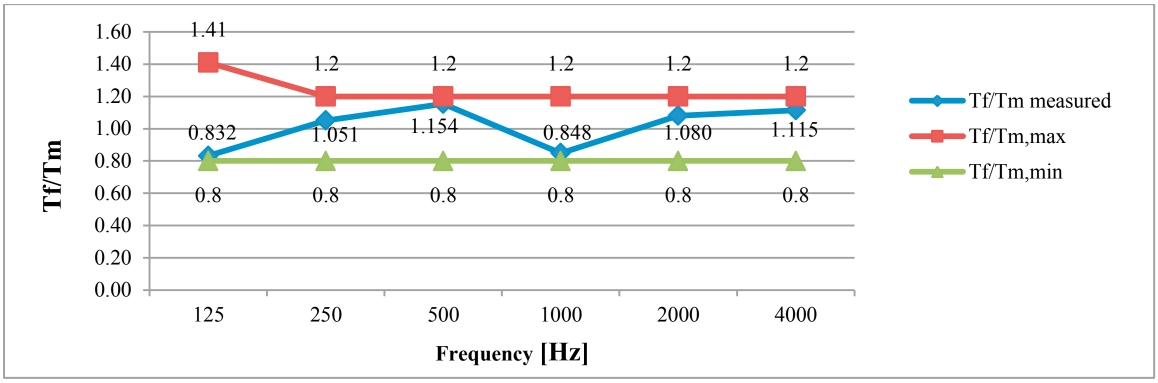


Fig. 7. Comparison of the Tf/Tm ratio to admissible values for the Lecture Hall without the public present.

3.2. Positioning sound absorbing Ecophon tiles + sound absorbing Gyptone Quattro 20 tiles

The second constructive solution consists in replacing the ceiling with sound absorbing Ecophon Master Rigid Dp plates on a surface of 150 m^2 and sound absorbing Gyptone Quattro 20 tiles on a surface of 128 m^2 .Gyptone Quattro 20 are grid ceiling tiles, made of plastered gypsum, with perforations, mixed with acoustic tissue that provide excellent acoustic properties. The tiles are proper for all kinds of standard visible structures. The dimensions of the tiles are 600x600x10 mm, the α_i absorption coefficients at various frequencies were taken from the product catalogue [7]. They will be laid on a surface of 138 m^2 of the total ceiling surface of 278 m^2, the remaining 140 m^2 being replaced with sound absorbing Ecophon tiles (Fig. 8).

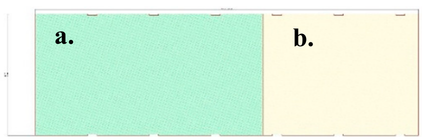


Fig. 8. Positioning the tiles on the ceiling: a – Ecophon Master Rigid Dp tiles; b –Gyptone Quattro 20 tiles.

It was found out that Tf/Tm ratio values made for the Lecture Hall without the public present (Fig. 9) and for the cases of the 50% and 100% occupied Lecture Hall range within the limits provided by [2].

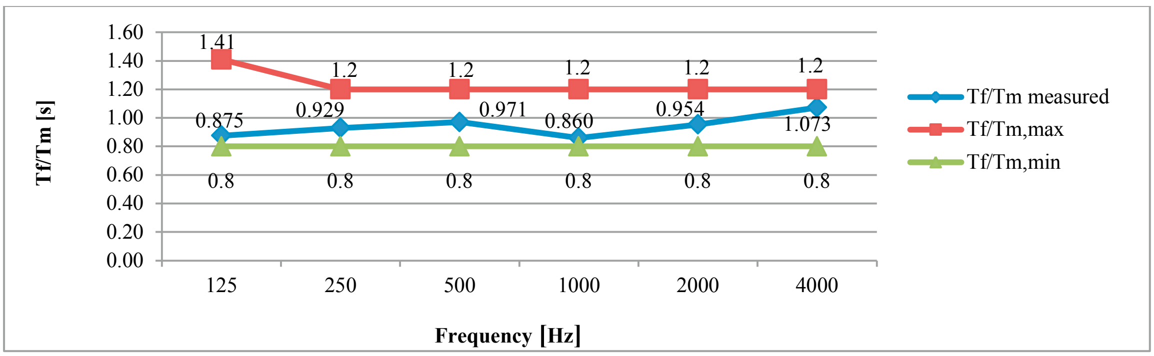


Fig. 9. Comparison of the Tf/Tm ratio to admissible value for the Lecture Hall without the public present.

3.3. Positioning sound absorbing Gyptone Xtensive Line 8 tiles + sound absorbing Vicoustic panels

The third solution proposed consists in the following: The false ceiling of gypsum boards will be replaced by sound absorbing plates Gyptone Xtensive Line 8; on the wall behind the hall sound absorbing panels of type Vicoustic Waveline BC Absorbtion VB will be laid on a surface of 40 m^2. The sound absorbing tiles Gyptone Xtensive Line 8 [8] contribute to the room appearance, its acoustics and improve air quality. The dimensions of a plate are: 300x1200x10 mm. The dimensions of the panels are 600x600x135 mm. The panels will be mounted on the back wall of the hall on a surface of 40 m^2 as shown in Fig. 10.

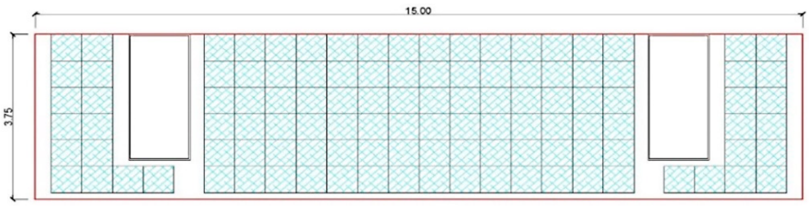


Fig. 10. Positioning the Vicoustic panels on the back wall of the hall.

The Tf/Tm ratio values for this solution range in the limits of [2] (Fig. 11). This solution was also verified for the case of the 50% and 100% occupied Lecture Hall and it was found out that in these cases Tf/Tm ratios range also in the limits of [2].

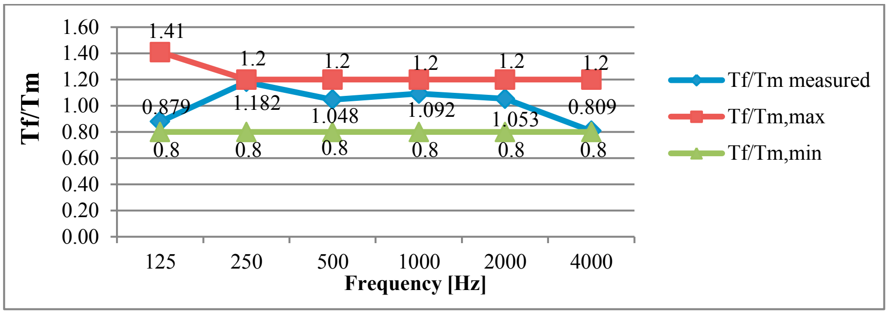


Fig. 11. Comparison of the Tf/Tm ratio to admissible value for the Lecture Hall without the public present.

4. Investment costs analysis

The costs of the investment solutions proposed to improve the acoustic comfort of the Lecture Hall, considering the materials used and the labour costs are shown in Fig. 12. They are as follows: 18758 Euro for the solution presented at 3.1, 10930 Euro for the solution presented at 3.2 and 17229 Euro for the solution presented at 3.3.

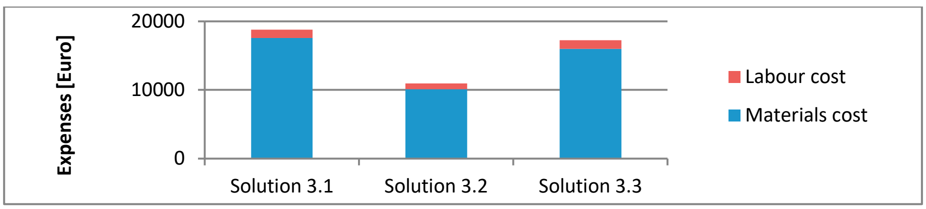


Fig. 12. Comparison of costs for the 3 proposed solutions.

5. Conclusions

Public audition rooms defined by proper acoustics in the context of natural sound propagation have been and still are a topic of discussion and research for the people working in this field. Except for rooms where the sound field is obtained by electrical-acoustic methods, the audition quality of the rooms can be improved only by a proper acoustic design relative to room geometry and sound treatment.

The present paper shows the study made relative to the acoustic behaviour of the Lecture Hall of the Faculty of Building Services. Making measurements with high performance Brüel&Kjær equipment and computing the values with Sabine's formula, it was found out that the hall reverberation time is not included in the admissible limits established by standards and norms in force and that an optimization of the acoustic comfort was required. Consequently, 3 solutions to improve the hall acoustics were proposed, a comparison of the investment costs was made and it was found that the best solution would be the one presented at point 3.2.

The materials proposed are innovative, with higher level acoustic and appearance properties. After implementing the acoustic treatments, the reverberation time was computed again, an improvement of the properties and the inclusion in the range of admissible limits mentioned in [2] was found.

The knowledge and in-depth study of buildings' acoustics, a sound design tailored for each specific case from the very beginning of the erection of a building and the implementation of acoustic treatment to ameliorate the acoustic comfort are basic requirements to be applied to existing buildings.

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