An Approach to Improve Acoustic performance in Multipurpose Halls

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Abstract: This paper demonstrates a method to improve acoustic performance of multipurpose halls which are noisy and have echoes when used by many people particularly children. The objective is to provide more insights into acoustic design and assessment as part of a functional and pleasant interior. The motivation for this work is a project for a major private school to assess a hall used for different activities, such as a play area, music and theater. The hall becomes noisy and has high echo level when used by children. Measurements presented in this paper include reverberation time and background noise, sound reflection surfaces and volume of the hall. These measurements are taken before and after the implementation of acoustic solutions. Results are used to assess reverberant field in the hall and evaluation of acoustic performance after intervention.

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Keywords: Multi-purpose hall acoustic; background noise; reverberation time; noise absorbers

1. Introduction

Multi-purpose halls have various uses, for example, gallery, exhibition, theatre and musical performances. Acoustic design has important role in the interior quality and functionality of a multi-use hall and has a great effect on user comfort and satisfaction. User comfort depends on several factors including light, indoor environment quality and acoustics, but acoustic comfort is of particular importance where the major use is based on user interaction and communication (Nagy *at el*, 2008).

Smooth surface materials such as plaster, marble and glass are usually acoustically reflecting. Absence of proper acoustic treatment will produce a reverberant environment. In case of inappropriate shape of the hall, reflecting surfaces may cause distinct echoes. This becomes evident when large number of people uses a hall, as in school halls where the noise level is high (Hammad, 2000).

Main acoustic design objectives in multi-purpose halls include moderate reverberation times selected according to the volume of the hall; diffusers to help avoiding focusing and flutter echo with consideration to the number of users. A carefully chosen reverberation time with little variation and low frequency is a first step towards acoustic comfort (Fuchs, *at el*, 2001).

Acoustic comfort of multi-purpose halls can be accomplished using suitable sound absorbers. Sound absorption is one of the noise control methods, commonly; multi-layer sound absorbers are applied to absorb broad band noise (Fuchs, 2001).

High and mid frequency absorption materials include carpets, hanging ceilings, curtains, furniture, whilst low frequencies down to 63Hz require deeper absorbers. In order to overcome the depth of low frequency absorbers a compact and thin absorber is recommended (Mahmoud and Abd-elbasseer 2011, Abd AL-Rahman, *at el* 2012).

Absorption boards such as gypsum board, timber or metal panels comes in different sizes and can be mounted on walls. Since the sound absorbers can be made of almost any material, such as wood, acrylic, glass, metal, plastic foil or timber they can fit into any interior design concept. Pleasant interior design of multi-purpose halls combined with acoustic comfort can be accomplished with suitable fibreless absorbers (Drotleff and Zhou, 2001). Background external noise need to be considered and treatment using proper sound observers for the building envelope (Abdelazeez and Hammad, 1991).

An acoustic assessment for a multiuse hall at a major private school in Jordan is presented in this paper.

2. Acoustic measurements in the multipurpose hall

The acoustic measurements performed at a multipurpose hall of the private school include reverberation time and background noise (Hammad, 1990). The hall is manly used as assembly and play space and in some occasions as a music and acting theatre for children.

Acoustic assessment of multi-use hall comes in three stages:

The first stage assesses the real aural conditions in the multipurpose hall. A field measurement of reverberation time and background noise is conducted in the hall; the results are compared with recommended criteria by ISO 354: 2003 Standards (ISO, 2003) and ASTM standards (ASTM C-423).

The second stage is design and recommendation of acoustic treatments including implementation details and specifications to match reverberation time with standards.

The third stage describes results after applying the recommended acoustic treatments in stage two. The final stage is taking measurements after the application of acoustic treatments and evaluation of reverberation time and NB.

The roof of the hall is made of concrete and drop beams; walls have smooth cement plaster with no sound absorption materials on the surface. The hall's dimensions are 20x15m² and 7m height, there are many windows and doors in the hall (Figure 1) and (Figure 2). Teachers and children using the hall describe the aural conditions as a noisy, particularly when used by many children as a playing area. The intelligibility inside the hall was poor when used for speech or music (Figure 3).

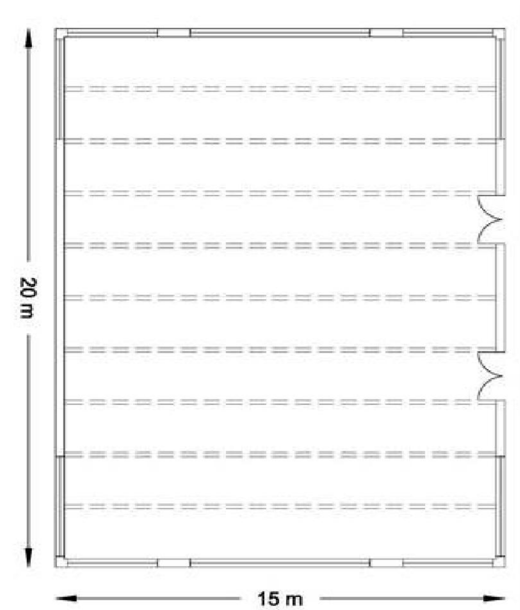


Figure 1. Plan of the multi-purpose hall

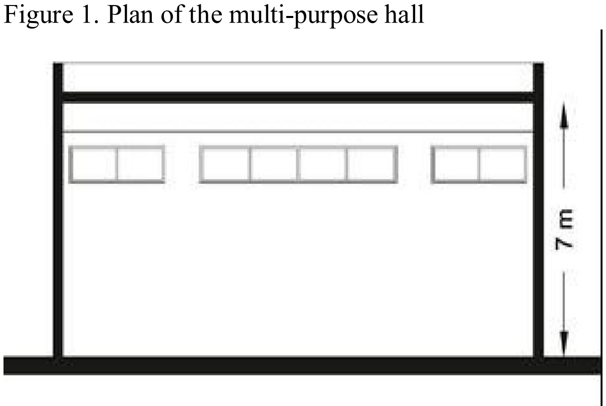


Figure 2. Section of the multi-purpose hall


Figure 3. The hall before applying acoustic solution

3. Measurement equipment

The reverberation time and back ground noise is measured in the first stage and compare with those recommended in the literatures (Fuchs, *et al*, 2001). The equipments used in the measurements are according to ISO no. 140-4:1989, which are:
- Sound Source B & K type: 4224.
- Microphone B & K type 4165 half inch.
- Acoustic analyzer B&K type 2244.
- Measurement performed between 100-8000 Hz in one third octave band.
- Measurements are conducted in two different positions. The analyzer averaging was three different readings in each position.
- The result is the average of total readings.

Figure 4 presents measured & recommended Rt. of the hall, findings from Figure 4 are:

- The measured reverberation time is high according to recommended values (Fuchs, *et al* 2001).
- In mid frequencies, where speech and music spectra are located, reverberation times are double the maximum of recommended values.
- High reverberant field is a result of reflected surfaces in the hall volume.
- The amount and type of absorption materials will reduce reverberant time to meet recommended standards (Mahmoud, 2011).

The absorption material should be distributed on all surfaces. However, this was not possible as the decorations are distributed on all walls and the owner would not change it (Figure 5). Distribution of absorption materials on walls and ceiling improves sound condition in the hall by reducing resonance between parallel reflecting walls (Fuchs, 2001).

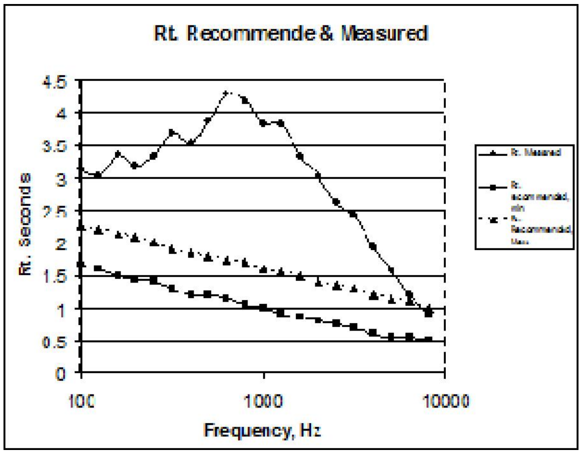


Figure 4. Measured & recommended Rt. of the hall


Figure 5. The hall has many openings on the walls

Measured & recommended background noise of the hall in Figure 6:

- Measured background noise in the hall is performed at about 2.30 pm when the hall is not used by children during working hours;
- generally, the measured background noise in the hall is acceptable compared to recommended background noise in such halls;
- Background noise and reverberation time are main factors affecting intelligibility or clearance of signal in the hall (e.g. music, speech, actress).

The measurements indicate that reverberation field is high compared to standard criteria. The reverberation time is an important factor of the intelligibility of the sound in indoor space. Another two factors are background noise and the signal produced inside the hall, e.g. music, speech, actors voice (Drotleff and Zhou , 2001).

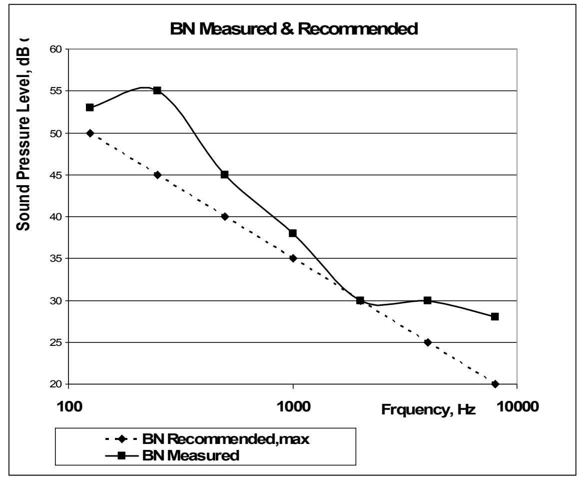


Figure 6. Measured & Recommended Background Noise

The background noise was measured and found to be acceptable according to standards. The factor which affects intelligibility of sound in the hall is reverberation time. Accordingly, reverberation time should be within recommended criteria of the Jordanian Building Codes or international building codes, which are similar in many criteria.

This section describes the acoustic design procedure of the multipurpose hall and the results. Results include suggested solutions to help reduce the reverberant field to meet standard criteria, and required absorption materials.

The reverberation time is measured before and after implementation of acoustic solution and compared with acoustic standards. Aural field is improved to acceptable level when reverberation time is reduced to standard levels. The procedure to accomplish this is as follows:

- Calculating reverberation time in the hall before adding sound absorption material.
- Comparing these calculations with the measured values.
- Recalculation of reverberation time after adding sound absorption material on the ceiling only and comparing it with standards.
- If the calculated and recommended values are close to each other then the absorption material will be added only on the ceiling; if not, another material will be added on part of the walls. Rt. will be recalculated and compared with standards until the values come close to each others.
- Specifications of absorption materials are determined.
- A list of quantities and coast is prepared.
- Suggested sound proof materials and design should be approved by the owner.

4. Calculation of reverberation time

The Measured and recommended reverberation times show that measured Rt. is high comparing to maximum recommended Rt (Figure 7).

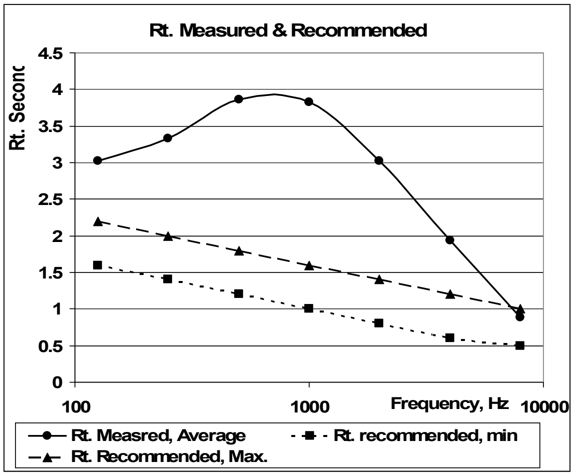


Figure 7. Measured & recommended Rt

The reverberation time Rt. is first calculated using same configuration in the hall as in Table 1, i.e. existing walls, floor and ceiling conditions (Figure 8).

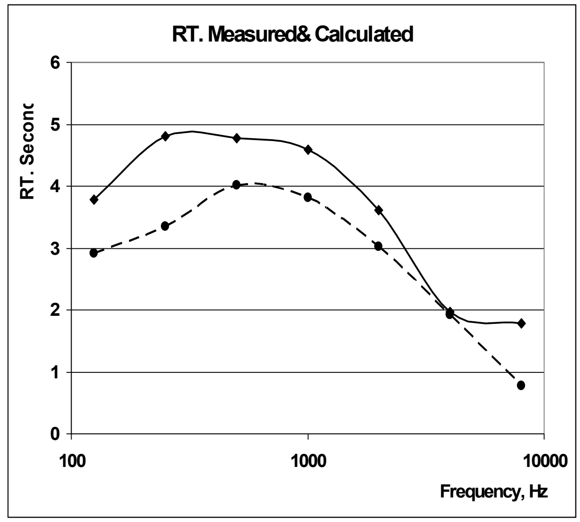


Figure 8. Measured and calculated Rt. for the hall with existing materials (before adding new acoustic materials)

Reverberation time Rt. is calculated after adding sound absorption material to the ceiling. The calculated Rt. is close to recommended values (Figure 9).

Table 1. Measured and calculated Rt.

Frequency, Hz	125	250	500	1000	2000	4000	8000
Rt. Measured	3.12	3.31	3.72	3.83	3.03	1.95	1
Rt. Measured	2.92	3.35	4.01	3.82	3.02	1.92	0.78
Rt. Measured, Average	3.02	3.33	3.865	3.825	3.025	1.94	0.89
Rt. recommended, min	1.6	1.4	1.2	1	0.8	0.6	0.5
Rt. Recommended, Max.	2.2	2	1.8	1.6	1.4	1.2	1

Table 2. Shows Rt. calculation procedure before adding new acoustic materials in the hall

	area	125	250	500	1000	2000	4000	8000
surfaces Floor, solid tiles	21*14 (α)	0.04	0.04	0.08	0.12	0.13	0.12	0.13
Equiv.absorption	Area * α	11.76	11.76	23.52	35.3	38.22	35.28	38.22
Ceiling, paint on cement plaster	21*14 (α)	0.01	0.012	0.015	0.02	0.08	0.085	0.09
Equiv.absorption	Area * α	2.94	3.528	4.41	5.59	23.52	24.99	26.46
Walls, paint on cement plaster	60%*2(21+14)*6.7	0.01 2.814	0.012 3.377	0.015 4.221	0.02 5.35	0.03 8.442	.12 33.768	.13 36.582
Walls, paint on cement plaster & 20% glazing and wood doors	20%*2(21+14)*6.7	0.35 65.66	0.25 46.9	0.18 33.77	0.12 22.5	0.09 16.88	0.35 65.66	0.4 75.04
Total absorption		83.17	65.56	65.92	68.7	87.07	159.698	176.302
volume	21*14*6.7							
Rt.Calculated		3.789	4.807	4.781	4.59	3.62	1.973525	1.78766
Measured Rt.		2.92	3.35	4.01	3.82	3.02	1.92	0.78

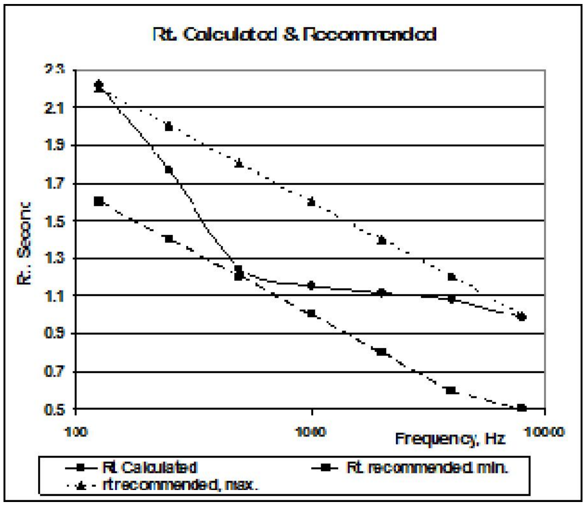


Figure 9. Rt. Calculated & Recommended after adding absorption material on the ceiling only

This means that the amount of absorption material on the ceiling will be sufficient to reduce Rt. to required values. There is a need for absorption material on walls to reduce resonance and to produce good aural conditions. Minimum absorption coefficient of the ceiling to achieve these conditions is shown in table (3).

Table 3. Minimum absorption coefficient of the ceiling

Frequency, Hz	125	250	500	1000	2000	4000	8000
Minimum Absorption coefficient	0.4	0.5	0.8	0.85	0.87	0.9	0.95

The sound absorption material is put in between the drop beams of the ceiling as a false ceiling, which is made of an absorption layer of glass wool of 50 mm thick and covered with a perforated sheet such as plywood (6mm), plastic sheets or aluminium sheet (5mm). Distance between the false ceiling and concrete ceiling is 50 mm (Figure 10).

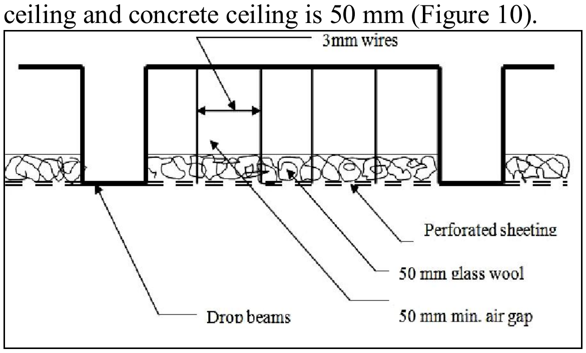


Figure 10. Detail of the false ceiling

It is recommended to add absorption material on walls where it is possible and matches with decorations in the hall. This will reduce resonance and improve acoustic conditions in the hall. Absorption panels size 1m x 1m and 100mm thickness are recommended to cover part of the walls. Detail of wall panel is show in Figure 11.

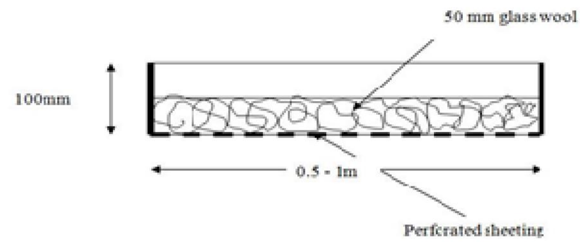


Figure 11. Detail of suggested sound proof sheets to use on the walls

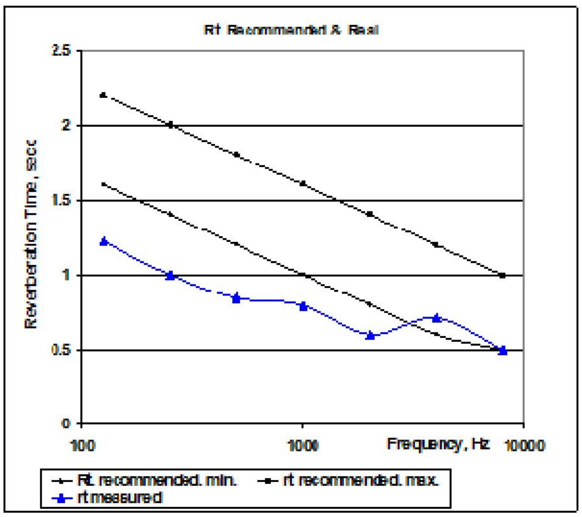
5. Outcomes from the design stage

- Reverberation Time (Rt.) is the most important factor in the intelligibility of the sound in hall.
- Rt. is measured in the hall using suitable equipments and was found high compare to international criteria.
- Rt. is calculated using absorption material fixed on the ceiling only and compare with recommended values.
- It is sufficient to cover the ceiling with an absorption material to reduce the Rt. to the recommended values.
- The amount of absorption is approximately 300 square meters.
- Minimum absorption coefficient of the ceiling should be as given in table (3).

Acoustic treatments on the ceiling and walls are provided with full details and specifications and quantities for implementation as demonstrated in the Bill of quantities.

The third stage is obtaining the final results after applying acoustic treatments as suggested in the design to reduce Rt. and NB to recommended levels by standard codes. Sound proof tiles are used in the false ceiling in between drop beams and on walls. Wall decorations are kept in the existing conditions as required by owner. Installation of acoustic materials in the hall took two weeks. After completion, final measurements are conducted to find whether the acoustic design goal to make Rt. within the standard criteria is established.

6. Final Results



Frequency, Hz	125	250	500	1000	2000	4000	8000
Rt. Calculated	2.2	1.8	1.2	1.15	1.12	1.08	0.98
Rt. Recommended min.	1.6	1.4	1.2	1	0.8	0.6	0.5
Rt recommended max.	2.2	2	1.8	1.6	1.4	1.2	1
Rt measured	1.2	1	0.8	0.79	0.6	0.71	0.5

The calculated reverberation time was produced in stage two, the measured values are presented in Table (5) and Fig.13

Table 5. Estimated & measured Rt. in the hall

Frequency, Hz	125	250	500	1000	2000	4000	8000
Rt. Calculated	2.2	1.8	1.2	1.15	1.12	1.08	0.98
Rt measured	1.2	1	0.8	0.79	0.6	0.71	0.5

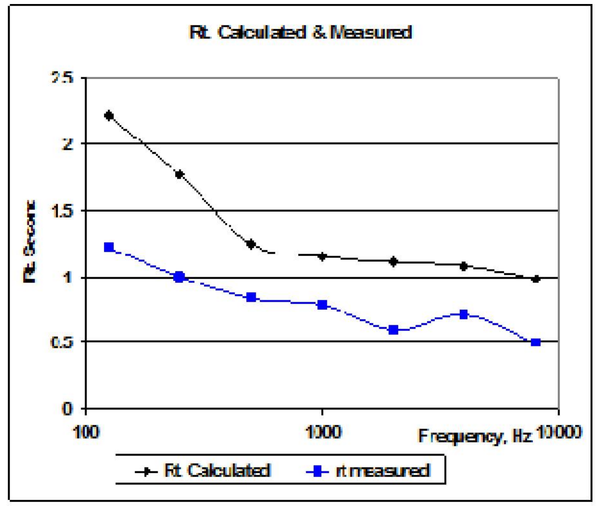


Figure 14. The hall before acoustic treatment

Figure 15. Wall decorations are kept the same after implementation of ceiling and wall sound proof treatment

Figure 16. Sound proof panels on the walls

7. Conclusion

Based on the scientific study and application of acoustic treatments the following can be concluded:

1. Acoustic treatment of walls and ceiling has improved acoustic conditions in the hall as proved by measurements.
2. The final appearance of treatments was attractive and did not cause negative changes to the appearance of the hall.
3. The final reverberation time (Rt) in the hall is within the standard criteria.

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