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Acoustics in Education Zone: Creative Solution to Innovative Learning

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***Abstract*—Acoustic design in educational building helps in making teaching and learning efficient. As it maintains the rustic charm of a particular with its intended use. The most serious problem in room acoustics is excessive reverberation time in the room or noise transfer between the rooms. The paper deals with the problems faced in the classroom acoustics in which it is important to ensure good speech clarity and listening comfort for proper communication in the classroom.**

***Index Terms*—acoustics, classroom acoustics, reverberation, speech clarity, noise.**

I. Introduction

Architectural Acoustics is the branch of science that deals with propagation of sound and its mechanism within a room. In buildings such as schools, pre-schools and other educational buildings, information is shared orally through communication to the listeners so it is important to achieve speech clarity so the student will be able to perceive clearly what the teachers is saying. The major factor for room acoustics is reverberation time (RT), i.e. it is the time required by the reflected sound energy to be absorbed. RT is important because it can how well the person can understand the speech, and also it can change the way music sounds. Longer the reverberation time reduces the clarity of the speech and hence its intelligibility so longer reverberation time is good for concert halls, i.e. for music. The Classroom acoustics demand for good speech intelligibility and low background noise.

II. Objective

To study the effects of poor acoustics in education zones especially in classroom. To analyse the classroom efficiency with or without acoustics of that classroom and to study the reasons why is it important to have acoustics in classroom.

III. Methodology

A. Room Criteria

Room acoustic criteria are the quantities which are to be measured to analyze the acoustical condition of that particular room. Each criteria represents different acoustical property so multiple criteria are used together to determine the acoustical condition of that particular room, as none of them alone could specify and describe the measures correct enough.

These are – (1) Reverberation Time (T60), (2) Early decay time, (3) Speech Transmission Index (STI).

1) Reverberation time: When a sound is emitted from the source, it creates sound pressure level in the surrounding sound field then sound suddenly stops this decreases sound pressure level. The decrease in the sound pressure level to 60dB (one millionth) to the original sound pressure within a certain amount of time, this time is known as reverberation time. This criteria is most commonly used for analysing the acoustical behaviour of the room.

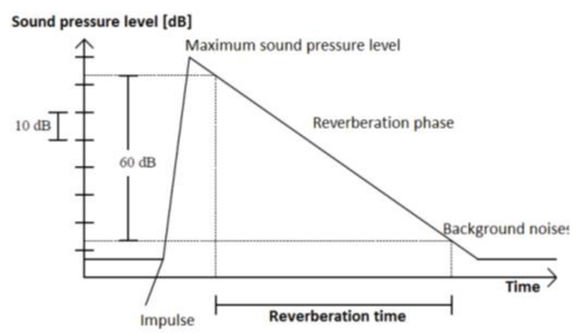

Fig. 1. Definition of the reverberation time

Professor Wallace C. Sabin's reverberation theory explains the nature of growth and decay of sound energy. He derived the relation between the reverberation time, volume and the absorption area of the room.

$$T_{60} = 0.161V/S$$

Where, T_{60} – Reverberation Time

V- Volume of the room

S – Absorption area of the room,

Where $S = \sum \alpha.s$, α is the absorption coefficient and s is the area of corresponding materials.

2) Early Decay Time: Early Decay Time (EDT) is similar to the reverberation time and this is similarly can be identified through the decay curve. The basic difference between EDT and T_{60} is the evaluation time. EDT is directly proportional to the reverberation time. If EDT is low, then the speech clarity is more and reverberation is less and correspondingly if EDT value is high, then the speech is not clear due to much reverberation.

3) Speech Transmission Index: Speech Transmission Index

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(STI) is another measure for speech clarity between the speaker and the listener. STI is the number which represents the speech transmission quality index considering distinctness. The higher the value better the distinctness of the speech.

TABLE I
SPEECH QUALITY CONSIDERING STI-VALUE

STI Value	Quality
0.00-0.35	Bad
0.30-0.45	Poor
0.45-0.60	Fair
0.60-0.75	Good
0.75-1.00	Excellent

B. Measured Space Analysis

A classroom in this context refers to an elementary design school classroom in which these kinds of classrooms are usually arranged in the way that the teacher is mainly talking in the front of the class and students are sitting either in rows separately (i.e. or in small groups. The starting point for an acoustical design in classrooms is a demand for a good speech intelligibility and a low background noise. Noise levels correlate with the reverberation time, thus decreasing reverberation time is also desirable. Noise is the most distracting factor for the speech intelligibility in classrooms. Attenuation of noise and improvement of the speech intelligibility makes contradict for the acoustical treatment of the room. To attenuate noise an

adequate amount of absorbing material should be used but if too large amount of absorbing material is used the speech transmission index will start to decrease especially in the backside of the room due to decreasing speech level. Standard SFS 5907 (SFS 5907:2006 2006) sets target values for the speech transmission index and for the reverberation time in classrooms, which are 0.80 and 0.50 - 0.60 s correspondingly. To achieve these targets at least 30% of the maximum area of ceiling and walls should be covered with absorbing material, which is preferably installed on the ceiling and on the back wall of the room. In addition, to have good STI-values throughout the classroom, the middle part of the ceiling could be covered with more reflective material to allow reflections from the teacher to the rear part of the room, especially in larger rooms (length > 8 m). Low frequency absorbers has also shown to enhance the learning environment by improving the low frequency clarity. For example, the fundamental frequency of a male's voice is normally slightly over 100 Hz and normal acoustic panels absorb rather poorly in that frequency region. The low frequency treatment could be realized with thick low frequency absorbing panels placed above the normal acoustic ceiling around the edges of the room or with different kinds of bass traps. Teacher's voice and speaking skills should also be considered as it changes according to age. To offer a support to the voice of the teacher, a reflecting surface should be placed above the teacher. Also, when the value of strength parameter of the room is high enough, the room amplifies the speech of the teacher. To determine acoustical conditions of the classroom the reverberation time, strength, clarity, speech transmission index, and background noise level should be measured.

The Classroom measured was of typical rectangular shape of 12.5m× 7.5m. Before the acoustical treatment the room contained a large blackboard (3.00 m× 1.23 m) on the back wall, large windows on the both sides of wall. All the walls were made of concrete. On the floor was there were tiles. The classroom contained concrete white painted ceiling. The classroom was measured when it was empty and when it was furnished with drafting tables. There was no extra bass absorber found above the teacher's position. The ceiling has concrete, white painted smooth surface with light and fan fixtures.

C. Result and Analysis

Reverberation times, values of the furnished and the empty classroom before and after (with and without the absorbing wall panel) the acoustical treatment are presented in the Table-2. Reverberation times, background noise levels, strength values, and clarity values of the furnished and empty classroom before and after (with and without the wall panel) the acoustical treatment.

TABLE II
T60 BEFORE AND AFTER USING WALL PANEL BOTH IN THE EMPTY ROOM AS WELL AS FURNISHED ROOM

	No w.p.	w.p.	No w.p.	w.p.
T_{60}	0.57	0.47	0.45	0.38

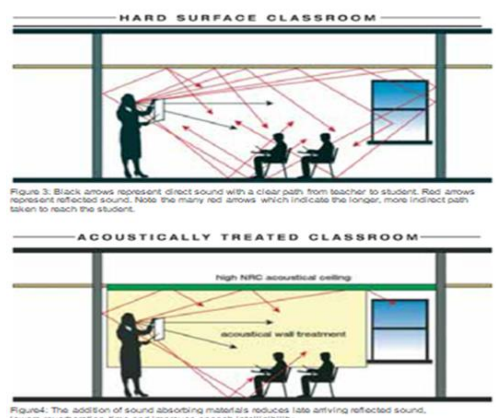

Fig. 2. Ray diagrams of sound waves in classroom

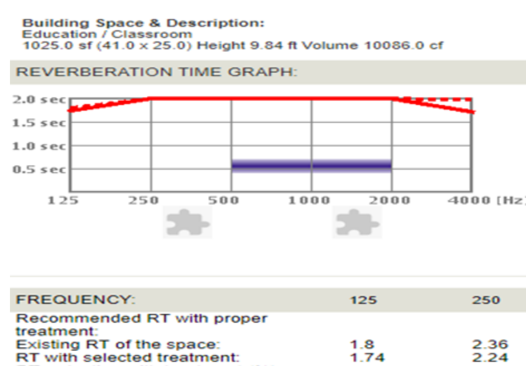

Fig. 3. Reverberation calculation for the measured classroom

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As we can say that there is significant decrease in reverberation time even without using wall panel, this is illustrated in Table-2.

With the ceiling treatment and the wall panel the difference is over 0.4 s. The difference in the reverberation time is only 0.1s with and without use of wall panel. In lower frequency region the values of the reverberation time are nearly the same with or without the wall panel. This is due to the poor absorbing ability of the wall panel in lower frequencies. The reason to this is the used additional bass absorbers above the ceiling. Without the bass absorbers the ceiling's ability to absorb low frequencies would be weaker. However, the effect of the wall panel is much smaller in calculated case than in measured case. Although the calculated values are not exactly the same as the measured values, the calculations could be used to have a rough idea about the magnitude of the reverberation times in the classroom. There is a difference in the measured and the calculated value of reverberation time due to uneven distribution of absorption material. After the acoustical treatment we found the increase in the STI value of about 0.15. The additional wall panel affects mainly to the STI-values in the area near the wall panel increasing them. The change of the STI along the distance is almost constant, thus it is independent from the acoustical treatment.

Reverberation times in octave bands have decreased about 0.2 seconds before the treatment due to the furniture and slightly less after the treatment. The decrease is caused by the scattering effect of the furniture which enhances the absorbing ability of the acoustic ceiling. Before the treatment the above mentioned scattering effect could be seen also from these results. The furnished room have higher STI value than empty room although difference is too small. Also, the strength of the furnished room is about 2 dB smaller than in empty room in all cases and clarity is slightly higher in the furnished room before the treatment and slightly lower in the furnished room after the treatment. The small differences in clarity values correspond to the small differences in STI-values, as both of them represent the clarity or the distinctness of the speech. STI values were in furnished room as compared to empty room. STI recommendation from the same standard is 0.80. Classroom with gypsum ceiling clearly does not meet this recommendation either. The STI value infront of the teacher is 0.69s. After the treatment the reverberation time in empty classroom without the wall panel is 0.57 s, thus it is in the recommended region. The reverberation time is under 0.5s in both the conditions as stated by the standards. STI-values in front of the teacher after the treatment are over 0.8 meeting the recommendation in standard SFS 5907, but in other parts of the classroom the values are under 0.8. Otherwise the acoustical treatment has improved the sound environment of the classroom to the acceptable level but the STI-values in the rear part of the classroom are still too low and this can be increased by the use of air conditioning system.

IV. Conclusion

The acoustical renovation was performed to the classroom and the working environment has improved in the treated spaces and they are now more comfortable to be in than before. As a continuation for the research a subjective part should be performed in the measured space by interviewing the students and the teachers about the sound environment and the acoustics of the, and how it affects to the Class and to know how the class students perform. The classroom had a suspended perforated gypsum ceiling before the treatment, and after the treatment it contained a suspended glass wool ceiling with additional bass absorbers on top of it and a large absorptive wall panel. The sound environment has improved significantly after the acoustical treatment. The reverberation time was shortened greatly, 0.4 s - 0.5 s in every frequency band. Furthermore, the values of speech transmission index were increased by 0.15 everywhere in the room and the values of clarity were increased by over 6 dB. The effect of the additional installed bass absorbers could also be seen from the decreased reverberation times at the low frequency region where the reverberation time has decreased 0.5 s. The installed absorptive wall panel increased the overall absorption area decreasing the reverberation time but also it removed the flutter echo between the side walls. STI-values in the front side were according to the standards but at the backside it was very low. The speech intelligibility could be improved further by muting the air conditioning device, because the reverberation time is already quite low. However, when there will be strength of students then there will be increase in STI values. Wall-to-wall carpet would also reduce the noise from moving chairs and tables. Today's learning environments creates a platform for the student to more interact and communicate so group work, class activity digital performance occur so the acoustics of classroom directly affects the teacher and the students performance.

There are very few options to achieve the existing classroom acoustics through the changes in architectural infrastructure and in HVAC system with great budget. Consequently, the most common and affordable solution is to control reverberation through the addition of sound absorptive materials. To enhance the class performance through acoustics can be done:

- Install a suspended acoustical ceiling in a classroom that does not have one.
- If an acoustical ceiling is already in the room, replace panels that have a low NRC (0.50 or lower) with panels that have a higher NRC (0.70 or higher).
- Use of wall panels, acoustics absorbers, etc.
- Add carpeting.
- We can seal the openings as much we can.
- Add a second pane of glass with an air gap to the windows, if possible, to help block exterior noise.
- Install vibration isolators under HVAC equipment, and silencers in the ductwork. Solutions such as these do not add significantly to the construction cost of a new building. It is when they are included as part of a renovation that additive

costs usually apply.

V. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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