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IMPROVEMENT OF ACOUSTIC COMFORT IN SCHOOL CLASSROOMS OF KERALA

Jolly john[1], B. Premlet. [2], Ashalatha Thampuran[3]

[1]Kerala University, Department of Architecture,
TKM college of Engineering Kollam, Kerala, India
jollyjkollam@gmail.com
[2]TKM College of Engineering, Department of Physics, Kerala University, Kerala, India
Premlet@gmail.com
[3]Kerala University, Department of Architecture, Director of Mohandas College of Engineering
Thiruvananthapuram, India

Abstract: *This paper reports the acoustical quality of school classrooms in Kerala by evaluating the acoustical parameter Reverberation time. Acoustical measurement was made in the unoccupied furnished school classrooms during day time. The RT in normal classrooms exceeded the recommended value stipulated by National and International standards. RT in classroom was experimentally evaluated by installing removable wall panels made by transforming locally available natural materials of plant origin. Three different materials were selected for study viz coir mat, pine mat, bamboo mat. Experiments were also performed by using a combination of pine and coir mat, bamboo and coir mat. The effective change in RT was studied and the noise reduction coefficient of each material was determined. The experiment analysis was made in 1/3rd octave bands for the frequency range 100 Hz to 3000 Hz. The results revealed that the panels made of pine, bamboo and coir mat has good absorption at medium and high frequencies. The experiments proved that the combination of pine mat and coir mat can be efficiently used to reduce RT in classrooms.*

Keywords*: Reverberation time, pine mat, sound absorption coefficient, Noise Reduction coefficient.*

1. INTRODUCTION

Noise pollution in the educational institutions produces multiple problems to teaching – learning process and negatively affects the performance of both teachers and students [1]. Background noise, reverberation time (RT), sound insulation and signal to noise ratio are the important parameters affecting the acoustical comfort in classroom. Good acoustical quality in learning environment by verbal communication inside classrooms demands low noise levels and less reverberation time. Reverberation time is the time taken by a sound to reduce by one millionth of the original intensity (Sabine 1964). High value in reverberation time will reduce the speech intelligibility, as the sound reaching the listener will be subjected to prolonged reflections and sound will have a rolling effect. A preliminary study conducted on the reverberation time in classrooms of warm humid climate in Kerala has been reported by the authors. The study revealed that the RT in normal classrooms exceeded the recommended value stipulated by National and International standards. The acoustical quality inside classroom can be improved by using sound absorbing materials. These materials absorb sound by dissipating the sound energy and also by converting some of the energy into heat energy [2]. Commercially available materials for acoustic treatment are boards and panels which contain conventional synthetic fibrous materials. These materials are not environment friendly. Some of them are harmful to human health when exposed. This issue explores an opportunity to look for alternative natural materials which can be used as effective sound absorbing materials to reduce the RT. Several researches have been conducted to study the use of organic fibers for sound absorbing applications [3]-[5]. In this study RT in classroom was experimentally evaluated by installing removable panels made by transforming locally available natural resources of vegetable origin. These materials are 100% organic and have the advantage that at the end of their life they can be disposed without causing any damage to the environment. It is easy to install and has no harmful effects on human health. Three different materials were selected for this study is coir mat, pine mat (locally known as *thaza paaya*) and bamboo mat (locally known as *panambu*). Experiments were also performed by using a combination of pine and coir mat, bamboo and coir mat.

Coir is extracted from protective husk of the coconut. The husk separated from the nuts, are settled in lagoons up to 10 months. The retted husks are then beaten with wooden mallets manually to produce the golden fiber. The fiber is later spun into yarn on traditional spinning wheels called '*Ratts*' ready for dyeing and weaving. Coir mats of different weaving pattern are available viz. panama weaving, herringbone weaving and boucle weaving [4]. These mats offer a lot of benefits including durability weather resistance and easy maintenance. Many researches has revealed the effectiveness of coir fiber as a sound absorbing material because of which it is being used on a large scale for furnishing floors of stages, stairs, corridors, auditorium and cinema halls

The pine mats are made from leaves taken from sword – shaped thorny screw pine plant (Pandanus family) [6]. The fleshy green plant is peeled into thin strips that are dried in the sun and diagonally plaited to create mats or Thazapaya, which is 100% organic and non-toxic .Mats locally woven are used extensively as floor mats to sleep on.

Bamboo mats are made from bamboo culms. The green skin of the bamboo culms is scraped and the edges are made flat. The culms are then divided into pieces of equal width called *silver*. Each silver is cut into fine strips and then dried manually or mechanically. The strips are the woven into mats of different patterns according to the size of the strips. Bamboo mats woven in herringbone patterns are widely used for aesthetic applications in interiors and for making temporary partitions. The photograph of coir mat, bamboo mat and pine mat is shown in Fig 1.

Though coir, pine, bamboo mats are extensively used in this region, an experimental study on the effectiveness of sound absorption by them has not be studied. This paper mainly aims at a comparative study of the use of coir, bamboo and pine mats as an effective sound absorbing material in reducing the reverberation time and to propose acoustic correction by installing sound absorbing panels in required quantity. The acoustic parameters measured in classroom, for this study are Reverberation Time (T60) which is the RT measured for 60 dB decay.

(a)

(b)

(c)

Fig 1: (a) Coir mat, (b) Bamboo mat (*panambu*), (c) Pine mat. (*Thazapaya)*

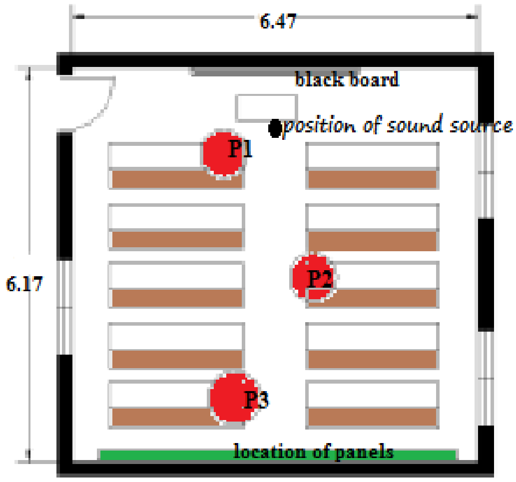
2. METHOD OF STUDY

The reverberation time was initially measured in twelve unoccupied classrooms in a Government higher secondary school located in Kollam district of Kerala State. The volume of all the classrooms was less than 250sqm. The Kerala Education Rule specifies the size of a standard classroom as 6 m x 6 m x 3.7 m for strength of 40 students. Accordingly a classroom which has the measurement close to a standard classroom was chosen for detail investigation and application of acoustical correction.

This classroom situated in the first floor of the school building, measures 6.47 meter x 6.17 meter x 3.92 meters, and has a volume of 156.2 cubic meters. It was furnished with ten wooden desk and bench arranged in two rows to accommodate a total of 40 students. The photograph of the unoccupied classroom is shown in Fig 2a. The classroom walls are made of cement blocks, and painted, floor is of cement concrete finished with cement mortar and roof of reinforced cement concrete.

(a)

Fig 2: (a) unoccupied classroom without any acoustical treatment



(b) Layout of classroom

2.1 Measurement of Reverberation Time

The measurements were taken following the specifications of the ISO 3382 (1997), at one source position and three impulse detection in each room. The RT was taken at three different positions (p1, p2, p3) as shown in the layout in Fig 2b. The equipment used were BK 2250 sound level meter, BK 4292 omnidirectional spherical sound source and a preamplifier [7] connected with laptop pc through interface cable. The photograph of the equipment used for this experimental analysis is shown in Fig 3.

The sound source was placed at teachers position (height 1.5 m), and the microphone was set in three different positions at

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1.1 m height which corresponds to the ear height of an average Indian listener seated on the bench [8]. The measurements were then transferred to the computer using BK Qualifier 7830 software which calculated the mean reverberation time for each frequency. Classrooms were unoccupied and windows were kept open while recording the measurement. All the measurements were carried out on school holidays to minimize the influence of school activities on the acoustic measurements.

(a) (b) (c)

Fig 3: (a) Bruel and kjaer (BK 2250) sound level meter used for measuring Reverberation time. (b) 2734-B power amplifier. (b) 4292-L Omni Power sound source.

2.2 ***Method of acoustic correction***

To evaluate the change in RT in rooms sound absorbing materials are either cladded on walls or suspended from ceilings. In this experiment, mats made of coir, screw- pine and bamboo which are locally available in standard sizes were nailed on custom made aluminum frames. The frames along with the mats fixed on to it were then mounted on strong iron stands placed along the rear wall of the classroom as seen in Fig 4a. Panels were installed in a temporary manner. Care was taken to place the panel as close as possible to the vertical wall to ensure that there is no space in between the wall and the panel. The total area covered by the panel was 6.5 s. q. m which approximately amounts to 25% of the rear wall area and 7.5% of the total wall area. The RT in the classroom was initially measured without any acoustical treatment. The panels made of coir mats were then mounted. The RT was again measured. Experiment was repeated by replacing the coir mat by pine mat, and bamboo mat respectively, keeping the omnidirectional sound source and the receivers in the same positions. Fig 4b shows the photographs of the experimental setup in the classroom.

(a)

(b)

Fig 4: (a) Classroom with panels frames on the rear wall. (b) Experimental set up with coir mat panel mounted on stands

RT in classroom was also measured by using the combination of two materials. The wall area was mounted with pine mat and the 15% of the floor was laid with 10 mm thick coir carpet Fig 5. The experiment was repeated by replacing the pine mat with bamboo mats without removing the coir carpets laid on the floor. The sound source and receivers were placed in the same positions as indicated in the layout.

Fig 5: Classroom with panels mounted on the rear wall and coir mat laid on the floor

It was observed that RT measured in all the classrooms exceeded the values stipulated in the national and international standards.

Table 2: Recommended Reverberation time in classrooms in different countries.

Country	R T (s) (For 500-1000-2000 Hz)	Volume (cubic meter)
Brazil	0.5 - 0.7	270 ≤ V ≤ 600
France	0.4 – 0.8	V ≤ 250
	0.6 – 1.2	V ≥ 250
Germany	0.6 – 1.0	250 ≤ V ≤ 750
	0.6	V ≤ 283
USA	0.7	283 ≤ V ≤566
India [a]	0.75-1.2	0.75-1.2

*Recommendation as per National Building Code-2007

3. RESULT AND DISCUSSION

The area, volume and measured RT in un-occupied classrooms in the school is given in Table 1 and Table 2 shows the recommended reverberation time in different countries. WHO (1999) and ANSI S12.6 (2002) recommends the RT of school classrooms to be 0.6 second for classrooms having volumes less than 283 cubic meter. The Indian National Building Code (NBC 2007) proposes a value of 0.75 second for an occupied class and a higher value of 1.2 second for the empty classroom [11].

Table 1: Area, Volume and Measured Reverberation Time in classroom

Classroom	Area (m^2)	Volume (m^3)	Measured RT in second (T60)
C1	39.92	150.1	1.5
C2	56	208.9	1.58
C3	56.3	211.4	1.88
C4	39.02	152.5	1.64
C5	**39.8**	**156.2**	**1.73**
C6	52.8	205.6	1.13
C7	56.8	222.8	1.7
C8	61.6	226.4	2.34
C9	57.9	228.8	1.56
C10	40.04	134.9	1.55
C11	58.12	190.6	1.39
C12	38.4	125.11	1.36

The high reverberation time in classrooms is attributed to the lack of absorptive materials in the classrooms [8]. The smooth plastered cement walls, ceiling and concrete floors have low sound absorption coefficient (0.02-0.04 at 500 Hz - 2000 Hz) and hence are poor absorbers of sound. The need for acoustical correction, to provide acoustical comfort in classroom is evident. The measured reverberation time in the classroom (C5) before and after installing the different panels made of pine mat, coir mat and bamboo mat at central frequencies of 1/3rd octave bands for the frequency range 100 Hz to 3000 Hz are shown in Table 3. Fig 6 shows the trend of reverberation time (T60), in the classroom before and after installing the wall panels made of coir mat, pine mat and bamboo mat. RT varies as a function of frequencies. High RT of 2.0 second was observed at frequency below 250 Hz in the classroom in all situations. However, the RT reduced significantly at higher frequencies. A comparative study of measured RT in classroom with different panels showed that RT was least when pine mats where installed. Table 3 Also shows the value of measured RT in classroom with absorbing materials used in combination. From Fig 7 it was observed that for a combination of coir mat and pine mat, the RT reduced by 0.31 second and for a combination of bamboo mat and coir mat RT reduced by 0.22 second from the initial measurement at 1000 Hz. Result suggest that absorption coefficient of pine mat is higher than coir mat and bamboo mats.

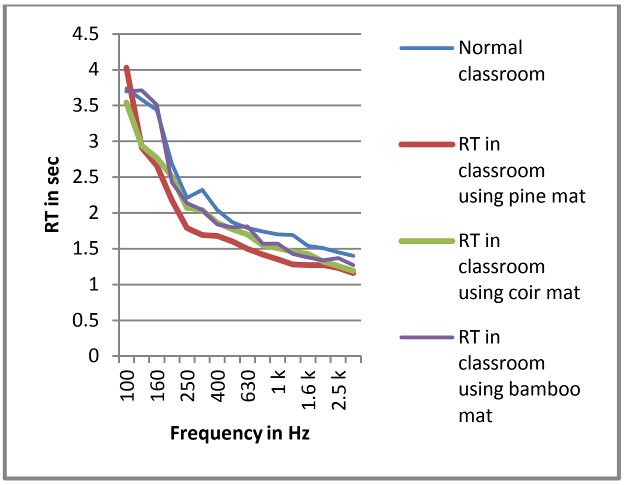

Fig 6: Averaged reverberation time in classroom before and after installing different absorbing panels.

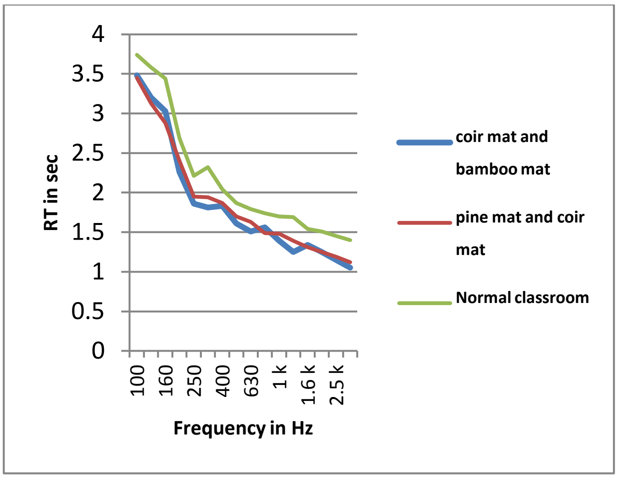

Fig 7: Reverberation time in classroom before and after installing combination of bamboo and pine mat panels, with coir mats on floor.

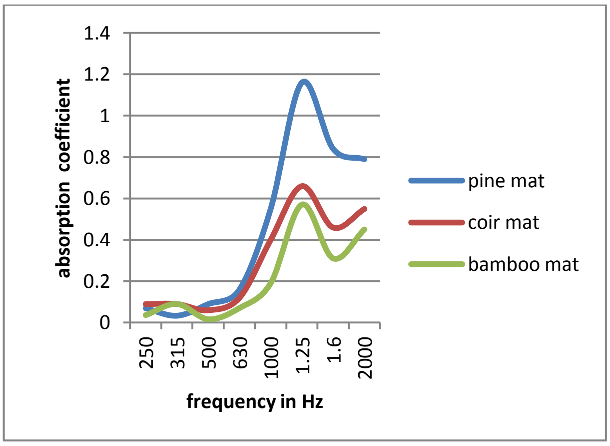

Fig 8: Sound absorption coefficient at different frequencies for pine mat, coir mat, and bamboo mat.

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Table 3: Reverberation Time in classroom before and after installing the panels made of Pine mat, Coir mat, and Bamboo mat.

Frequency *Hertz*	Reverberation Time measured in classroom (T60) second					
	Normal classroom	using pine mat	using coir mat	using bamboo mat	Combination of coir mat and pine mat	Combination of Bamboo mat and coir mat
100	3.74	4.03	3.54	3.7	3.48	3.45
125	3.58	2.91	2.94	3.71	3.2	3.13
160	3.44	2.66	2.77	3.51	3.03	2.88
200	2.69	2.18	2.51	2.43	2.26	2.4
250	2.21	1.79	2.07	2.14	1.86	1.95
315	2.32	1.69	2.04	2.04	1.81	1.94
400	2.04	1.68	1.86	1.84	1.83	1.87
500	1.87	1.6	1.77	1.8	1.61	1.7
630	1.79	1.5	1.7	1.81	1.51	1.63
800	1.74	1.42	1.55	1.57	1.56	1.49
1000	1.7	1.35	1.51	1.57	1.39	1.48
1.25	1.69	1.28	1.46	1.43	1.25	1.39
1.6	1.54	1.27	1.43	1.38	1.34	1.31
2 k	1.51	1.27	1.32	1.34	1.25	1.25
2.5 k	1.45	1.23	1.26	1.37	1.15	1.19
3.15 k	1.4	1.16	1.19	1.27	1.05	1.12

From the experimental study conducted the absorption coefficient of bamboo mat, pine mat and coir mat was determined. Fig 8 shows the sound absorption coefficient of pine mat, coir mat and bamboo mat at central frequencies of $1/3^{rd}$ octave band from 250 Hz to 2000 Hz. It was observed that the sound absorption coefficient of pine mat was higher than sound absorption coefficient of coir and bamboo mats. The value ranged between 0.03 to 0.45 for bamboo mats,0.09 to 0.55 for coir mats, and between 0.42 to 0.79 for pine mats at 250 Hz to 2000 Hz. The noise reduction coefficient is the arithmetic average, rounded off to the nearest multiple 0.05 of the sound absorption coefficients at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz[2]. The NRC values determined for coir, pine, and bamboo mats are 0.30, 0.40, and 0.20 respectively. This result confirms that mats made from these natural materials are good absorbers of medium and high frequency sound. The high absorption of pine mats may be due to the presence of small gaps in the weaving pattern which help in absorbing the high frequency sounds.

4. Conclusion

The classrooms in schools are not acoustically comfortable and they need acoustical corrections. Experimental investigation illustrates that mats made of coir; pine and bamboo have good absorption above 500 Hz. The sound absorption coefficient and NRC of pine mats was found comparatively higher than coir mats and bamboo mats, making it a promising material for the future because it is affordable, locally available and environment friendly than conventional materials. Reduction in reverberation time is an important parameter for improving the speech intelligibility in classrooms. The study proved that the acoustic comfort in classrooms can be enhanced by installing of mats made of vegetable origin, in required quantities. The study on modification of pine mats to improve durability and NRC can be an extension of this study.

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