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Green Building Materials for Acoustics of an Auditorium - A Case Study

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ABSTRACT: *In this paper we report the effectiveness of using coir mats – a green building material as an alternative to the less energy efficient and costly materials for acoustic absorption purposes. The most important parameter of the acoustic performance of an auditorium is the reverberation time(RT) which in turn depends on the sound absorption coefficient of materials layered on the floor, wall and ceiling. The present experimental case study carried out in auditoriums with coir mat fittings reveals that the coir mats are very effective in achieving the desired reverberation time for lecture and music concerts. Studies show a considerable reduction in the RT with the use of coir mats. An attractive feature of coir mats is its low cost, sustainable nature and indoor air quality without compromising the technical feasibility.*

KEY WORDS:*coir mats,reverberation time,absorption coefficient,Noise reduction coefficient*

I. INTRODUCTION

An auditorium is an indispensible one for performing arts,music concerts and various social functions.Acoustic and thermal comforts are the figures of merit of such a building.It has become a necessity to select and utilize the green building materials for constructions. Acoustics deals with the scientific study of sound which includes the effect of reflection, refraction, absorption, diffraction and interference. Absorption coefficient is defined as the fraction of randomly incident sound energy which is absorbed by the surface.The basic parameters of acoustic materials are the impedance and the surface shape. The law of conservation of energy states that energy can neither be created nor destroyed,but it can be changed from one form to another.Absorption converts sound energy into heat energy.It is useful for reducing sound levels within rooms but not between rooms. Each material with which a sound wave interacts absorbs some sound. The most common measurement of that is the absorption coefficient,typically denoted by the Greek letter α.The absorption coefficient is a ratio of absorbed(E_a) to incident sound energy(E_i). The reflection coefficient is a ratio of reflect(E_r) to incident sound energy(E_i).A material with absorption coefficient 0 reflects all sound incident upon it.If a material absorbs all sound incident upon it,its absorption coefficient is 1.In practice,all materials absorb some sound,so this is a theoretical limit[1].Sound absorptive materials are widely used in a variety of situations. Sound absorptive materials exists in many different forms.

Coir and many other natural fibers are now widely used as substitute to synthetic fibers for acoustic absorption purposes because they are renewable,non-abrasive,cheaper,abundant and are environment friendly. Researchers reported that the coconut coir fiber has high potential to be utilized as sound absorbing material [2].Some reported that the absorption of coir fiber can be enhanced by compressing the material [3].The sound absorption coefficient(SAC) and Noise reduction coefficient(NRC) values of different types of weaved coir mats were studied and it reveals that increasing the thickness of mats and by giving latex backing the SAC and NRC of the mats can be improved [4].

The phenomenon of persistence of sound due to multiple reflections from the ceiling,floor,walls and other material objects in an enclosure is called reverberation.Reverberation time (RT) may be defined as the time required from the moment of cessation of sound for the intensity to drop by 60 dB.Research has shown that it is the initial portion of the sound decay curve process which is responsible for our subjective impression of reverberation as the later portion is usually marked by new sounds. For this Early Decay Time (EDT) is used.This is measured in the same way as the normal RT but over only the first 10-15 dB of decay,depending on the work [5,6].

The optimum reverberation time of an auditorium is dependent on the use for which it is designed.The reverberation time of auditorium should be long enough at around 1.5 s to 2.5 s and this time should be longer for low frequency sound and shorter for high frequency sound.

II. TEST MATERIAL AND EXPERIMENTAL TEST PROCED

RT measurements are carried out on Munnar Panchayat auditorium, which is situated at Munnar in Idukki District,Seminar hall and auditorium of Bishop Moor College,Mavelikkara.Both the places are in Kerala.

Equipments used are sound level meter - *Brüel& Kjær* (BK) 2250,sound amplifier - BK 2716 connected with laptop PC through interface cable and sound source - BK 4292,omnidirectional spherical sound source.The Softwares used are Building qualifier- BK 7831 and Utility software- BK 5503. *Type 2250 is the innovative, 4th generation, hand-held analyzer from Brüel& Kjær.*

The photographs of the equipments used for this experimental analysis is shown in fig.a,fig.b and fig.c

(a) (b) (c)

(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.

Taking 3 Auditoriums as the object of study the following procedures are carried out.

1.Comparitive study of Reverberation time of an Auditorium with coir mat fittings as sound absorbing materials and without the sound absorbers.

2.Measurement of reverberation time for two halls (BMC seminar hall&auditorium) with coir mat fitting.

RT Measurement made on Munnar Auditorium

- Calculation of Reverberation Time of empty hall using Sabine's formula.
- Measurement of Reverberation Time of the hall with ceiling replaced by PVC false ceiling
- Measurement of Reverberation Time of the hall with coir mat fittings on floor and walls and also PVC false ceiling using B&K 2250 SPL metre.

The Procedure is:

1.Computed the area of the cement plastered area and multiplied it with the absorption coefficient value for concrete.Measure the area of windows,doors,and ventillation and multiply each with their absorption coefficient.The total absorption coefficient value is used to calculate the Reverberation time of the hall using Sabine's formula given by RT=0.16V/A,where V is the volume of the room and A is the effective "total absorption" area.The "total absorption" area is calculated as the sum of all surface areas in the room,each multiplied by its respective absorption coefficient for a particular frequency.Reverberation time calculated is 5.7328s,which is very high.This makes the hall unfit for speech or music.

2.Replace the ceiling with PVC .Measure the area of the ceiling and calculate the total absorption.Then the total absorption of the remaining portion is calculated.Use Sabine's formula to calculate the reverberation time.In this case the Reverberation time calculated is 3.6693s,which is less than that of first case.

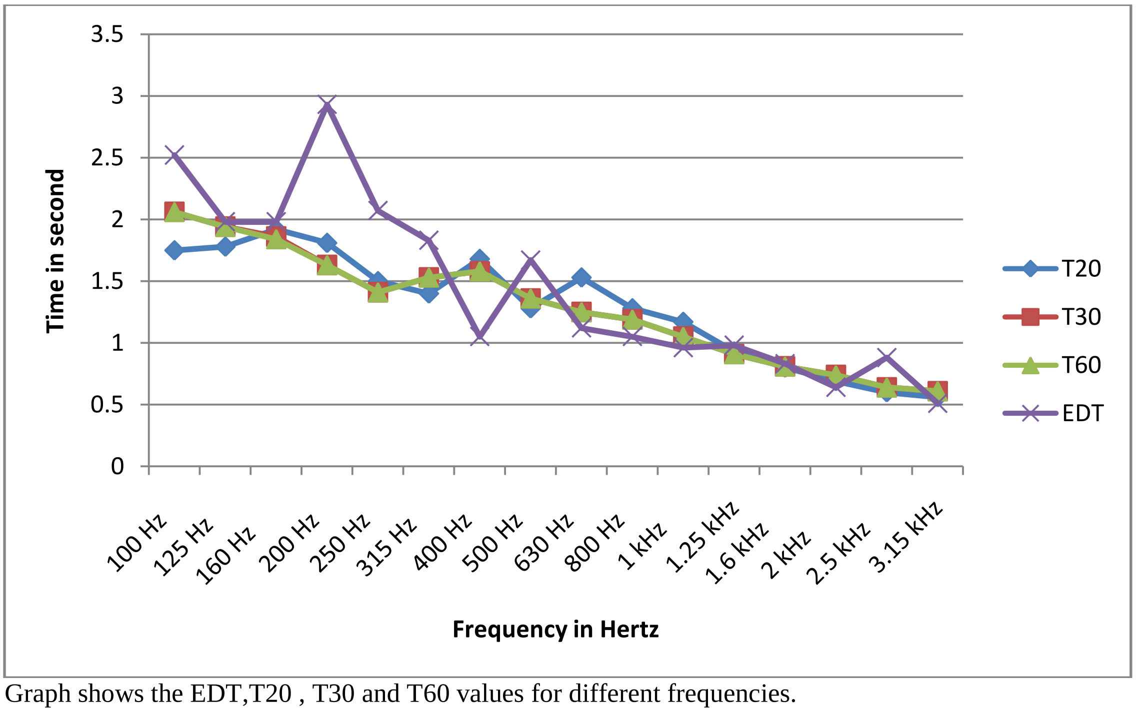
3.The walls and the floor of the hall is then covered with with coir mats.The sound source was placed at the stage of the auditorium and the microphone was set in three different positions.Reverberation time inside the hall is then measured using SPL metre at different positions.the measurements were then transferred to the computer using BK qualifier 7831 software which calculate the mean RT for each frequency.

Reverberation Time-Munnar Auditorium

`Boucle weaved mats are used on the walls and floor.T20,T30,T60(RT) and EDT values for different positions are shown in Table 1,Table 2 and Table 3.

Table 1: EDT,T20 , T30 and T60(RT) values for different frequencies.-position-1

Frequency	T20	T30	T60	EDT
100 Hz	1.75	2.06	2.06	2.52
125 Hz	1.78	1.94	1.94	1.98
160 Hz	1.92	1.86	1.84	1.98
200 Hz	1.81	1.63	1.63	2.93
250 Hz	1.5	1.41	1.41	2.07
315 Hz	1.4	1.53	1.53	1.83
400 Hz	1.68	1.58	1.58	1.05
500 Hz	1.28	1.36	1.36	1.67
630 Hz	1.53	1.25	1.25	1.12
800 Hz	1.28	1.19	1.19	1.05
1 kHz	1.17	1.05	1.05	0.96
1.25 kHz	0.93	0.91	0.91	0.98
1.6 kHz	0.8	0.81	0.81	0.83
2 kHz	0.69	0.74	0.74	0.64
2.5 kHz	0.6	0.64	0.64	0.88
3.15 kHz	0.56	0.61	0.61	0.51



Graph shows the EDT,T20 , T30 and T60 values for different frequencies.

X-axis:**Frequency in Hertz**
Y-axis: **Time in second**

Munnar Auditorium-Reverberation time-pos-2

Table 2: EDT,T20,T30 and T60(RT) values for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	1.81	1.65	1.65	1.89
125 Hz	1.64	1.71	1.71	1.81
160 Hz	1.44	1.67	1.67	1.87
200 Hz	1.6	1.83	1.83	2.86
250 Hz	1.57	1.38	1.38	3.57
315 Hz	1.3	1.29	1.29	1.33
400 Hz	1.52	1.56	1.56	1.56

500 Hz	1.5	1.45	1.45	1.92
630 Hz	1.19	1.25	1.25	1.21
800 Hz	1.15	1.26	1.26	1.4
1 kHz	0.94	1.00	1.00	1.21
1.25 kHz	0.98	0.94	0.94	1.02
1.6 kHz	0.91	0.84	0.84	0.83
2 kHz	0.73	0.75	0.75	0.76
2.5 kHz	0.67	0.68	0.68	0.64
3.15 kHz	0.55	0.59	0.59	0.65

Munnar Auditorium-Reverberation time-pos-3

Table 3:EDT,T20,T30 and T60(RT) for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	1.97	1.95	1.95	1.76
125 Hz	1.63	1.6	1.6	1.63
160 Hz	1.73	1.87	1.87	2.81
200 Hz	1.31	1.77	1.77	1.95
250 Hz	1.49	1.49	1.49	1.75
315 Hz	1.46	1.45	1.45	2.21
400 Hz	1.05	1.45	1.45	1.85
500 Hz	1.54	1.4	1.4	1.27
630 Hz	1.36	1.37	1.37	1.24
800 Hz	1.13	1.17	1.17	1.41
1 kHz	1.19	1.09	1.09	0.81
1.25 kHz	1.04	0.99	0.99	1.06
1.6 kHz	0.92	0.85	0.85	0.8
2 kHz	0.75	0.74	0.74	0.84
2.5 kHz	0.68	0.73	0.73	0.65
3.15 kHz	0.63	0.63	0.63	0.57

High RT of coir mats was observed at low frequencies and RT is reduced significantly at higher frequenciesThe values corresponding to 3 different locations leads to a convergent value.Hence we restrict the measurements corresponding to few positions.

Reverberation time of BMC-seminar hall

Panama weaved mats are used on the walls and floor of this hall.T20,T30,T60 and EDT values for different positions are shown in Table 4,Table 5 and Table 6.

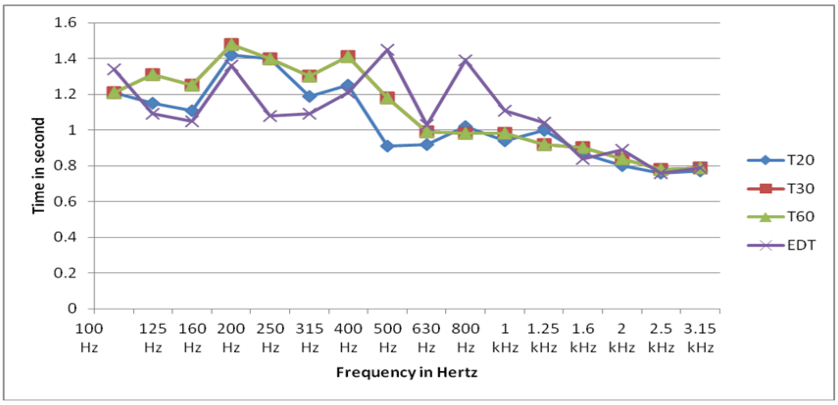
Table 4: EDT,T20,T30,T60(RT) values for different frequencies –position 1

Frequency	T20	T30	T60	EDT
100 Hz	0.97	1.22	1.22	1.75
125 Hz	1.3	1.19	1.19	1.65
160 Hz	1.58	1.31	1.31	2.23
200 Hz	1.94	1.66	1.66	1.36
250 Hz	1.31	1.25	1.25	1.34
315 Hz	1.33	1.32	1.32	1.43
400 Hz	1.14	1.21	1.21	1.49
500 Hz	1.07	1.12	1.12	0.75
630 Hz	1.04	1.01	1.01	0.64
800 Hz	0.98	1.04	1.04	1.21
1 kHz	0.98	1.04	1.04	0.88
1.25 kHz	0.96	0.95	0.95	1.05
1.6 kHz	1.03	0.91	0.91	0.78
2 kHz	0.94	0.91	0.91	0.73
2.5 kHz	0.87	0.86	0.86	0.71
3.15 kHz	0.78	0.82	0.82	0.83

Reverberation Time-BMC seminar hall-position 2

Table5:T20,T30,T60(RT) and EDT values for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	1.21	1.21	1.21	1.34
125 Hz	1.15	1.31	1.31	1.09
160 Hz	1.11	1.25	1.25	1.05
200 Hz	1.42	1.48	1.48	1.36
250 Hz	1.40	1.40	1.40	1.08
315 Hz	1.19	1.30	1.30	1.09
400 Hz	1.25	1.41	1.41	1.21
500 Hz	0.91	1.18	1.18	1.45
630 Hz	0.92	0.99	0.99	1.03
800 Hz	1.02	0.98	0.98	1.39
1 kHz	0.94	0.98	0.98	1.11
1.25 kHz	1.00	0.92	0.92	1.04
1.6 kHz	0.87	0.90	0.90	0.84
2 kHz	0.8	0.84	0.84	0.89
2.5 kHz	0.76	0.78	0.78	0.76
3.15 kHz	0.77	0.79	0.79	0.79



X-axis:Frequency in Hertz
Y-axis:Time in second

Reverberation time –BMC seminar hall- position 3

Table 6:T20,T30,T60 (RT)and EDT values for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	1.28	1.25	1.25	0.84
125 Hz	1.3	1.18	1.18	1.14
160 Hz	0.99	1.26	1.26	1.7
200 Hz	1.68	1.80	1.80	0.9
250 Hz	1.73	1.61	1.61	1.44
315 Hz	1.5	1.42	1.42	2.06
400 Hz	1.37	1.47	1.47	1.46
500 Hz	1.13	1.23	1.23	0.84
630 Hz	0.96	1.00	1.00	0.91
800 Hz	1.05	1.02	1.02	1.03
1 kHz	1.05	1.01	1.01	1.01
1.25 kHz	0.98	0.97	0.97	1.22
1.6 kHz	0.94	0.92	0.92	0.83
2 kHz	0.94	0.89	0.89	0.76
2.5 kHz	0.83	0.83	0.83	0.81
3.15 kHz	0.76	0.78	0.78	0.67

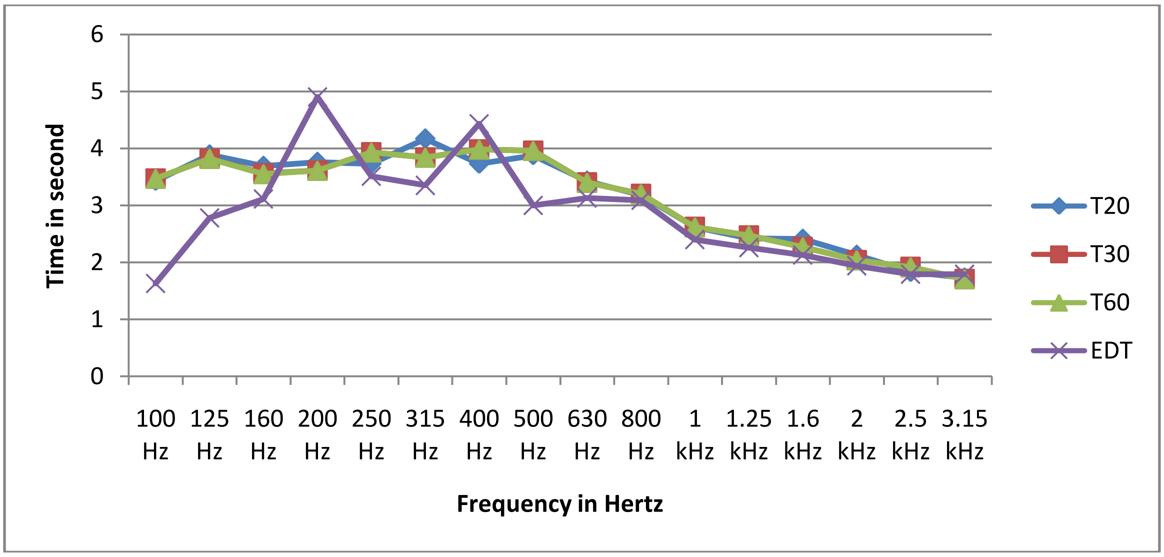
High RT of coir mats was observed at low frequencies and RT is reduced significantly at higher frequencies

RT-BMC auditorium

Boucle weaved mats are used on floor and panama weaved mats are used on the wall.T20,T30,T60 and EDT values for different positions are shown in the Table 7,Table 8 and Table 9.

Table 7:T20,T30,T60(RT) and EDT values for different frequencies –position 1

Frequency	T20	T30	T60	EDT
100 Hz	3.43	3.47	3.47	1.63
125 Hz	3.89	3.82	3.82	2.78
160 Hz	3.69	3.56	3.55	3.11
200 Hz	3.76	3.61	3.61	4.9
250 Hz	3.73	3.93	3.93	3.51
315 Hz	4.17	3.84	3.84	3.35
400 Hz	3.73	3.98	3.98	4.43
500 Hz	3.88	3.96	3.96	3
630 Hz	3.43	3.40	3.40	3.13
800 Hz	3.18	3.20	3.20	3.09
1 kHz	2.62	2.62	2.62	2.4
1.25 kHz	2.42	2.47	2.47	2.26
1.6 kHz	2.41	2.27	2.27	2.13
2 kHz	2.13	2.04	2.04	1.94
2.5 kHz	1.83	1.92	1.92	1.79
3.15 kHz	1.73	1.71	1.71	1.79



X-axis:Frequency in Hertz
Y-axis:Time in second

BMC auditorium-position-2

Table 8:T20,T30,T60(RT) and EDT values for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	3.87	3.75	3.75	4.1
125 Hz	3.39	3.55	3.55	4.4
160 Hz	3.81	3.86	3.86	2.23
200 Hz	4.06	4.06	4.06	5.33
250 Hz	3.95	3.94	3.94	3.19
315 Hz	3.5	3.74	3.74	6.13
400 Hz	3.98	3.82	3.82	4.43
500 Hz	3.72	3.77	3.77	3.88
630 Hz	3.56	3.50	3.50	3.97
800 Hz	2.97	3.13	3.13	3.2
1 kHz	2.64	2.77	2.77	2.85
1.25 kHz	2.47	2.47	2.47	2.17
1.6 kHz	2.37	2.34	2.34	2.21
2 kHz	1.96	2.03	2.03	2.05
2.5 kHz	1.93	1.90	1.90	2.08
3.15 kHz	1.7	1.74	1.74	1.74

BMC auditorium-position-3

Table 9: T20,T30,T60(RT) and EDT values for different frequencies

Frequency	T20	T30	T60	EDT
100 Hz	3.62	3.62	3.62	2.6
125 Hz	4.55	4.12	4.12	2.41
160 Hz	3.7	3.74	3.74	2.61
200 Hz	3.65	3.65	3.65	4.67
250 Hz	3.94	4.16	4.16	4.78
315 Hz	3.71	3.71	3.71	4.68
400 Hz	3.87	3.58	3.58	4.27
500 Hz	3.91	3.96	3.96	5.49
630 Hz	3.55	3.78	3.77	3.75
800 Hz	3.31	3.38	3.38	2.69
1 kHz	2.7	2.89	2.89	2.79
1.25 kHz	2.37	2.61	2.61	2.84
1.6 kHz	2.24	2.37	2.37	2.26
2 kHz	2.04	2.15	2.15	1.85
2.5 kHz	1.93	1.93	1.93	1.88
3.15 kHz	1.75	1.71	1.71	1.9

III. RESULTS AND DISCUSSION

From the above results it is clear that in case-I(Munnar auditorium) Reverberation time calculated for empty hall is very high.This make the hall unfit for speech or music.Reverberation time calculated shows a considerable decrease than the first case when PVC ceiling is used.But when coir mats are fitted to walls and floor, reverberation time measured is very much reduced which shows the effectiveness of coir mats as sound absorbing material.In case-2 (BMC seminar hall)the RT measurement shows that the coir mats as sound absorber makes the hall fit for music and speech.In the case of BMC auditorium large variation in the measured value is caused by incomplete proportion of furnishing the hall with mat.only small portion of the hall is covered with mat.So study suggests that much more areas of wall and floor should be treated acoustically.

IV. CONCLUSION

For Munnar Panchayat Auditorium ,the Reverberation time calculated for the auditorium hall with cement plastered roof,floor and walls is very high.This makes the hall unfit for speech or music. when PVC ceiling is applied the reverberation time calculated is reduced a bit. But when the floor and walls of the hall is covered with coir mats reverberation time measured is very much reduced,making the hall fit for music and speech. For BMC seminar hall the walls are covered with coir mats and this makes the hall fit for music and speech.For BMC auditorium by deliberately choosing the type of mat and area we can design the hall to be of desired RT for comfortable conveyance of speech and other articulation.Coir is a unique natural fiber with diverse applications.Coir is a very good sound absorbing material which is highly economic and ecofriendly.

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