Journal of Pure Applied and Industrial Physics, *Vol. 5(1), 19-24, January 2015* *ISSN 0976-5727 (Print)*
(An International Research Journal), *www.physics-journal.org* *ISSN 2319-8133 (Online*

Study and Measurement of Sound Absorption Coefficient of Materials

Neetu Bargoti[1] and A. K. Srivastava[2]

[1]Research Scholar,
Dr. C. V. Raman University, Kota, Bilaspur, INDIA.
[2]Professor and Head,
Department of Physics,
Dr. C. V. Raman University Kota, Bilaspur., INDIA.

(Received on: January 12, 2015)

ABSTRACT

In this paper an attempt has been made to study the measurement of sound absorption co-efficient of material. A numerical value of reverberation time RT and Strength G has been obtained which is useful for any architect as well as researchers.

Keywords: absorption coefficient, absorption, RT, G, measurement.

INTRODUCTION

Acoustics is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids and solids including vibrations, sound, ultrasound and infrasound. The science of acoustics spreads across so many facets of our society – music, medicine, architecture, industrial production, warfare and more. Art, craft, science, and technology have provoked one another to advance the whole, as in many other fields of knowledge. Lindsay's 'wheel of Acoustics' in a well accepted overview of the various fields in acoustics[1.] Sound absorption coefficient of materials play key role in any architectural buildings. It has been seen in all architecture of India such as: Indus vally civilization, Mughal Era, Akshardham temple, Ajanta caves, Budhists and Jaina Architecture, Ellora cave archicture, virupaksha temple, Taz-mahal, Jama Maszid etc. ; absorption coefficient was kept in mind. Absorption coefficient materials vary at the different frequency. Absorption of sound by materials is due to the porosity, compressibility and elasticity. The materials absorb sound when the sound waves are dissipated into heat by friction in the narrow pores. Some of the materials are compressible, such as hair felt, carpets etc. some absorb sound by vibrating, as is probably the case with thin glass, wood, and suspended plaster ceilings.

THEORETICAL CONSIDERATION

The sound absorption coefficient of a surface is defined as the ratio of the sound energy absorb by the surface to that falling on it. The open window is a perfect absorber because it reflects no sound at all. Hence the absorption coefficient of open window is 1. In big halls, the reverberation time can be minimized to the optimum value by increasing absorption of sound. The absorption can be increase by taking the following steps:

(i) The ventilators and window are kept open.
(ii) Acoustical tilles may be provided.
(iii) The floor is covered with carpets and tapestries.
(iv) Heavy curtains are hung.
(v) The walls and ceiling are lined with absorbent material such as flet, celotex, fiber board, glass wool, rock wool, mineral wool etc.

There are many acoustical variables when music is involved[2]. The following parameters are used in our research. Some are the same as in the music, some are related, (C_{50} instead of C_{80}) and some are for speech intelligibility only and not found in music, frequency, speech transmission index (STI)[3,4] S/N and NR- curves, diffusion coefficient, absorption coefficient, sound pressure level (SPL) strength G, and reverberation time (RT)[5] play key role in such type of research.
The equation for the reverberation time used in this paper is Sabine's,

$$RT = \frac{0.16v}{\alpha s} \quad (1)$$

Where v is the volume of the room and S is the total surface. The value of α denotes the mean value of all absorptions in a room. The equation for the strength G is given as devoted by Barron[7],

$$G = 31 + 101log\left(\frac{Q}{4\pi r^2} + \frac{exp^{(-0.04r/RT)}}{\alpha s}\right) \quad (2)$$

The directivity of the source in denoted by Q, the source receiver distance by r. Equation (1) is less complicated than the sound, since it does not depend on r. This is confirmed by many results from measurements: RT is fairly constant through a room which may well have contributed to its popularity in legal standards. At first sight equation (2) is not so useful in the respect since it depends on Q, r and RT. However, it can be shown that for one specific distance (the mean free path: r=4v/s) equation (2) can be converted into,

$$G = 31 + 101log\left(\frac{4(1-\alpha}{\alpha s}\right) \quad (3)$$

Equation (1) and (3) may be used backwards to calculate α from measurements of RT and G respectively. Of course these values are theoretically the same. A chart of absorption coefficient of material has been shown at different frequency level:

Absorption coefficients of common building materials and finishes

Floor materials	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
carpet	0.01	0.02	0.06	0.15	0.25	0.45
Concrete (unpainted, rough finish)	0.01	0.02	0.04	0.06	0.08	0.1
Concrete (sealed or painted)	0.01	0.01	0.02	0.02	0.02	0.02
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02
Vinyl tile or linoleum on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07
Wood flooring on joists	0.15	0.11	0.1	0.07	0.06	0.07
Seating materials	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
Benches (wooden, empty)	0.1	0.09	0.08	0.08	0.08	0.08
Benches (wooden, 2/3 occupied)	0.37	0.4	0.47	0.53	0.56	0.53
Benches (wooden, fully occupied)	0.5	0.56	0.66	0.76	0.8	0.76
Benches (cushioned seats and backs, empty)	0.32	0.4	0.42	0.44	0.43	0.48
Benches (cushioned seats and backs, 2/3 occupied)	0.44	0.56	0.65	0.72	0.72	0.67
Benches (cushioned seats and backs, fully occupied)	0.5	0.64	0.76	0.86	0.86	0.76
Theater seats (wood, empty)	0.03	0.04	0.05	0.07	0.08	0.08
Theater seats (wood, 2/3 occupied)	0.34	0.21	0.28	0.53	0.56	0.53
Theater seats (wood, fully occupied)	0.5	0.3	0.4	0.76	0.8	0.76
Seats (fabric-upholsterd, empty)	0.49	0.66	0.8	0.88	0.82	0.7
Seats (fabric-upholsterd, fully occupied)	0.6	0.74	0.88	0.96	0.93	0.85
Reflective wall materials	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
Brick (natural)	0.03	0.03	0.03	0.04	0.05	0.07
Brick (painted)	0.01	0.01	0.02	0.02	0.02	0.03
Concrete block (coarse)	0.36	0.44	0.31	0.29	0.39	0.25
Concrete block (painted)	0.1	0.05	0.06	0.07	0.09	0.08
Concrete (poured, rough finish, unpainted)	0.01	0.02	0.04	0.06	0.08	0.1
Doors (solid wood panels)	0.1	0.07	0.05	0.04	0.04	0.04
Glass (1/4" plate, large pane)	0.18	0.06	0.04	0.03	0.02	0.02
Glass (small pane)	0.04	0.04	0.03	0.03	0.02	0.02
Plasterboard (12mm (1/2") paneling on studs)	0.29	0.1	0.06	0.05	0.04	0.04
Plaster (gypsum or lime, on masonry)	0.01	0.02	0.02	0.03	0.04	0.05

Plaster (gypsum or lime, on wood lath)	0.14	0.1	0.06	0.05	0.04	0.04
Plywood (3mm(1/8") paneling over 31.7mm(1-1/4") airspace)	0.15	0.25	0.12	0.08	0.08	0.08
Plywood (3mm(1/8") paneling over 57.1mm(2-1/4") airspace)	0.28	0.2	0.1	0.1	0.08	0.08
Plywood (5mm(3/16") paneling over 50mm(2") airspace)	0.38	0.24	0.17	0.1	0.08	0.05
Plywood (5mm(3/16") panel, 25mm(1") fiberglass in 50mm(2") airspace)	0.42	0.36	0.19	0.1	0.08	0.05
Plywood (6mm(1/4") paneling, airspace, light bracing)	0.3	0.25	0.15	0.1	0.1	0.1
Plywood (10mm(3/8") paneling, airspace, light bracing)	0.28	0.22	0.17	0.09	0.1	0.11
Plywood (19mm(3/4") paneling, airspace, light bracing)	0.2	0.18	0.15	0.12	0.1	0.1
Absorptive wall materials	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
Drapery (10 oz/yd2, 340 g/m2, flat against wall)	0.04	0.05	0.11	0.18	0.3	0.35
Drapery (14 oz/yd2, 476 g/m2, flat against wall)	0.05	0.07	0.13	0.22	0.32	0.35
Drapery (18 oz/yd2, 612 g/m2, flat against wall)	0.05	0.12	0.35	0.48	0.38	0.36
Drapery (14 oz/yd2, 476 g/m2, pleated 50%)	0.07	0.31	0.49	0.75	0.7	0.6
Drapery (18 oz/yd2, 612 g/m2, pleated 50%)	0.14	0.35	0.53	0.75	0.7	0.6
Fiberglass board (25mm(1") thick)	0.06	0.2	0.65	0.9	0.95	0.98
Fiberglass board (50mm(2") thick)	0.18	0.76	0.99	0.99	0.99	0.99
Fiberglass board (75mm(3") thick)	0.53	0.99	0.99	0.99	0.99	0.99
Fiberglass board (100mm(4") thick)	0.99	0.99	0.99	0.99	0.99	0.97
Open brick pattern over 75mm(3") fiberglass	0.4	0.65	0.85	0.75	0.65	0.6
Pageboard over 25mm(1") fiberglass board	0.08	0.32	0.99	0.76	0.34	0.12
Pageboard over 50mm(2") fiberglass board	0.26	0.97	0.99	0.66	0.34	0.14
Pageboard over 75mm(3") fiberglass board	0.49	0.99	0.99	0.69	0.37	0.15
Performated metal (13% open, over 50mm(2") fiberglass)	0.25	0.64	0.99	0.97	0.88	0.92

Ceiling material	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
Plasterboard (12mm(1/2") in suspended ceiling grid)	0.15	0.11	0.04	0.04	0.07	0.08
Underlay in perforated metal panels (25mm(1") batts)	0.51	0.78	0.57	0.77	0.9	0.79
Metal deck (perforated channels,25mm(1") batts)	0.19	0.69	0.99	0.88	0.52	0.27
Metal deck (perforated channels, 75mm(3") batts)	0.73	0.99	0.99	0.89	0.52	0.31
Plaster (gypsum or lime, on masonary)	0.01	0.02	0.02	0.03	0.04	0.05
Plaster (gypsum or lime, rough finish or timber lath)	0.14	0.1	0.06	0.05	0.04	0.04
Sprayed cellulose fiber (16mm(5/8") on solid backing)	0.05	0.16	0.44	0.79	0.9	0.91
Sprayed cellulose fiber (25mm(1") on solid backing)	0.08	0.29	0.75	0.98	0.93	0.76
Sprayed cellulose fiber (25mm(1") on timber lath)	0.47	0.9	1.1	1.03	1.05	1.03
Sprayed cellulose fiber (32mm(1-1/4") on solid backing)	0.1	0.3	0.73	0.92	0.98	0.98
Sprayed cellulose fiber (75mm(3") on solid backing)	0.7	0.95	1	0.85	0.85	0.9
Wood tongue-and-groove roof decking	0.24	0.19	0.14	0.08	0.13	0.1
Miscellaneous surface material	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
People-adults (per 1/10 person)	0.25	0.35	0.42	0.46	0.5	0.5
People-high school students (per 1/10 person)	0.22	0.3	0.38	0.42	0.45	0.45
People-elementary students (per 1/10 person)	0.18	0.23	0.28	0.32	0.35	0.35
Ventilating grilles	0.3	0.4	0.5	0.5	0.5	0.4
Water or ice surface	0.008	0.008	0.013	0.015	0.02	0.025

CONCLUSIONS

The paper is focused on the acoustic analysis and measurement of absorption coefficient. A very large number of research were provided to establish an accurate measurement. Reverberation time RT and Strength G have been explained comprehensively. At last also a relation in between strength G and absorption coefficient have been obtained.

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