

STUDY OF ACOUSTIC PROBLEM IN SDPS WOMEN’S COLLEGE CLASSROOMS AND ITS VIABLE SOLUTIONS

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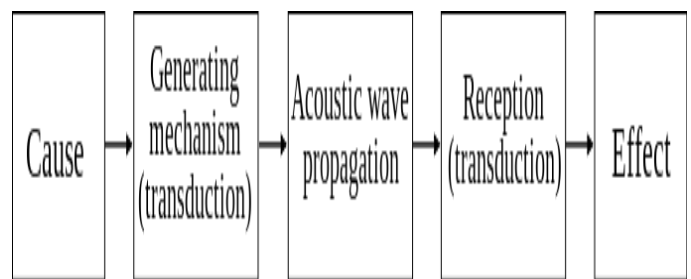
Abstract - Past investigations demonstrate that the acoustical environment of a classroom is a critical factor in the academic, psycho educational and psychosocial achievement of students. This project studies several acoustical variables, such as noise, reverberation, and speaker-listener distance, which can deleteriously affect speech perception in classrooms. Moreover, appropriate acoustical criteria and ways to improve listening conditions in classroom are suggested for students in educational settings. The work involved acoustical modeling of the classroom in 1:20 scale to study ways that can enhance the listening facilities. As a result of measures and observations in “healthy” and “poor” acoustical environments, practical recommendations were proposed for improving the acoustical environment in classrooms. The primary research for these recommendations consisted of recording acoustical measurements of reverberation time in actual classrooms consisting of different strength of students and then measuring reverberation time in classroom consisting of suggested recommendations one by one. The efficiency of these recommendations along with the cost considerations was studied. Finally, few viable solutions are found out to improve the classroom acoustics. Further, calculations verified that the recommended solutions were successful in reducing the reverberation time and improving the classroom acoustics.

Key Words: Acoustical environment, viable solutions, reverberation time.

1. INTRODUCTION:

Acoustics is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. A scientist who works in the field of **acoustics** is an acoustician while someone working in the field of acoustics technology may be called an acoustical engineer. The application of acoustics can be seen in almost all aspects of modern society with the most obvious being the audio and noise control industries, in designing of auditoriums, conference halls etc. The word "acoustic" is derived from the Greek word *ακουστικός (akoustikos)*, meaning "of or for hearing, ready to hear" and that from *ἀκουστός (akoustos)*, "heard, audible". The Latin synonym is "sonic", after which the term sonics used to be a synonym for acoustics and later a branch of acoustics. Frequencies above and below the

audible range are called "ultrasonic" and "infrasonic", respectively. The study of acoustics revolves around the generation, propagation and reception of mechanical waves and vibrations.



The steps shown in the above diagram can be found in any acoustical event or process. There are many kinds of cause, both natural and volitional. There are many kinds of transduction process that convert energy from some other form into sonic energy, producing a sound wave.

1.1 FUNDAMENTALS OF SOUND AND ACOUSTICS:

Technically, sound is air pressure fluctuations resulting in audible vibrations. These vibrations travel in wave patterns away from the sound’s source, and the waves are characterized by their frequency, wavelength, and amplitude. When a sound-wave contacts a surface, for example a wall in a closed room, the energy and direction of the sound is altered. These alterations are perceived as sound reflections and reverberations, which can affect auditory perceptions. The human auditory system is less sensitive to extremely low (below 500 Hz; e.g., mechanical or automotive rumbling) and high (above 8000 Hz; e.g., light fixture buzzing, mechanical ringing) frequencies. Low frequency noise tends to have the detrimental effect of masking speech, particularly consonants. Individuals with hearing loss are particularly susceptible to the masking effects of loud low frequency noise.

The various important definitions related to acoustics are as follows:

- Pitch and Frequency.
- Wave length.

- Amplitude.
- Reverberation time.

1.2 FACTORS AFFECTING ACOUSTICAL DESIGN:

- VOLUME.
- SHAPE.
- SOUND ABSORPTION.
- SITE SELECTION.

1.3 PROBLEM STATEMENT

• **Effect of bad acoustics:**

If the acoustic of a classroom is good then it will be very beneficial for everyone. The benefits can be studied under 2 heads-

- Effect on students
- Effect on teachers

• **EFFECT ON STUDENTS**

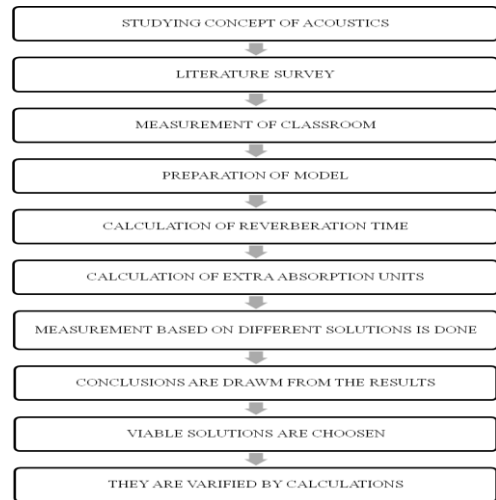
- ✓ Poor acoustics of classroom causes temporary illnesses causing mild hearing loss (e.g., middle ear infections).
- ✓ Students with learning, attention, or reading deficits are more adversely affected by poor acoustic conditions than the average student.
- ✓ Students speaking English as a second language (ESL) require significantly better acoustic conditions to hear the teacher than others.
- ✓ Hearing-impaired students require a significantly better acoustic environment to adequately hear than the average student.

• **EFFECT ON TEACHERS**

- ✓ Loud or reverberant classrooms may cause teachers to raise their voices, leading to increased teacher stress and fatigue.
- ✓ Teachers speaking in noisy classrooms may be at risk for voice impairment.
- ✓ If students cannot hear properly, it leads to repeating which ultimately causes waste of time.

2. METHODOLOGY:

2.1 METHODOLOGY FLOW CHART:



2.2 PROPOSED METHOD:

The methodology for studying the acoustic problem in classrooms of SDPS WOMEN'S COLLEGE building and finding its viable solution is as follows:

- 1) Studying and understanding the basic concepts of acoustics, its fundamentals, various aspects and various terms associated with it.
- 2) Intensive study of the literature associated with acoustics, various research papers, articles etc. and then drawing concepts from them.
- 3) Taking precise measurement of our classroom (A block- first floor) and various components of it. The following measurements were taken:
 - ✓ Dimension of room (length, breadth and height)
 - ✓ Dimensions of door
 - ✓ Position of door
 - ✓ Dimensions of windows
 - ✓ Height of window sill above ground level
 - ✓ Height of stage
 - ✓ Number and position of benches
 - ✓ Area of plaster
 - ✓ Area of flooring
 - ✓ Volume of room; etc
- 4) A model is drawn of the existing classroom with a scale of 1:20.
- 5) Calculation of reverberation time of the classroom is done considering the strength of class as a variable. For this Sabin's formula is used.

4 cases of the class strength are drawn which are as follows:

- ✓ 0 student (worst case)
- ✓ 20 students (usual minimum strength)
- ✓ 40 students (usual class strength)
- ✓ 66 students (maximum class strength)

- 6) Now an optimum reverberation time of say 1.2 seconds is chosen which is required for good acoustics of classroom. For this reverberation time, number of extra absorption units is calculated. Also coefficient of absorption for the absorption unit is calculated.
- 7) Now windows at various positions in the model are provided and the provision is made so that a set of calculations can be done taking each position of window. Similarly, ventilators are also provided on the side walls of the model.
- 8) For every different position of windows and ventilators, sound intensity reaching at the end of classroom is measured using software.
- 9) From the results of the sound intensity reaching the last bench due to different position of windows and from the calculation of extra absorption units, various conclusions can be drawn to improve the room acoustics by decreasing the reverberation time and hence increasing the speech intelligibility.
- 10) Among the suggested solutions, the viable ones are taken out and reverberation time of the room after providing the solution is calculated for each solution. It is noticed that it comes in the range of good acoustics. And hence the conclusion is made that the acoustics of room can be improved on following the suggested measures.

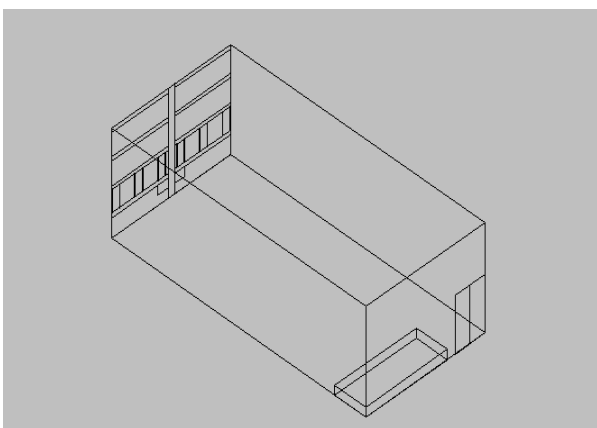


Fig. 2.1

Plan of classroom

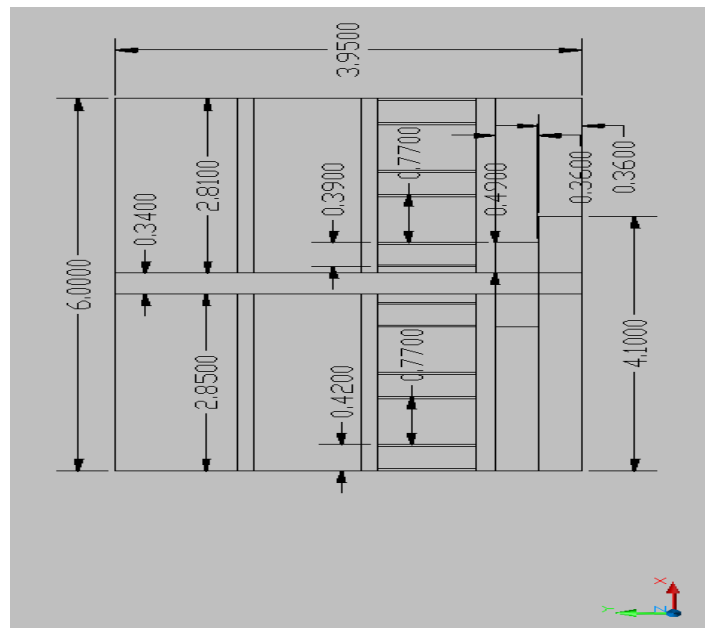


Fig.2.2

Section of classroom

2.3 PROBLEM FORMULATION:

On carrying out the measurement of the classroom and various components within it, the following values are obtained. The various parameters of existing class rooms are as follows:

- Length= 12.8 m
- Breadth= 6 m
- Height= 3.95m
- Position of window= bottom
- Height of window sill above G.L. = 0.94 m
- Approximate occupancy= 40 (maximum 66)
- Area of plaster= 148.52 m²
- Area of flooring= 78.6 m²

Now we need to calculate the number of absorbing units and the time of reverberation when there is:

- 1) No student
- 2) 20 students
- 3) 40 students
- 4) 66 students

The absorption coefficient for various surface and its absorption units is tabulated as follows:

Table-2.1
Calculation of absorption units of various surfaces of classroom

SURFACE	AREA OR NO.	ABSORPTION COEFFICIENT Per m ² or per no.	ABSORPTION UNITS In m ² -sabins
Plaster	148.52 m ²	0.02	2.97
Flooring	76.8 m ²	0.03	2.3
Benches	40 no.	0.02	0.8
			total 6.07

Now, absorption power of an adult = 0.46 m²-sabins

Hence, the net increase in absorption power of room due to presence of one person is obtained by deducting absorption power of seat from that person.

So, net increase in absorption power per person

$$= 0.46 - 0.02$$

$$= 0.44$$

The absorption units of classroom with different strength of students will be as follows:

Table-2.2

Variation of absorption units with strength

STRENGTH	ABSORPTION UNIT WHEN CLASS IS EMPTY	ABSORPTION UNITS OF AUDIENCE	TOTAL ABSORPTION UNITS In m ² -sabins
Nil	6.07	-	6.07
20	6.07	8.8	14.87
40	6.07	17.6	23.67
66	6.07	29.04	35.11

Now, volume of class = 12.8 x 6 x 3.95

$$= 303.36 \text{ m}^3$$

The time of reverberation for different strength of students can be worked out by applying Sabine's equation:

$$T = 0.16 V / A$$

➤ For no students:

$$T = 0.16 \times 303.36 / 6.07$$

$$= 8 \text{ seconds}$$

➤ For 20 students:

$$T = 0.16 \times 303.36 / 14.87$$

$$= 3.26 \text{ seconds}$$

➤ For 40 students:

$$T = 0.16 \times 303.36 / 23.67$$

$$= 3.05 \text{ seconds}$$

➤ For 66 students:

$$T = 0.16 \times 303.36 / 35.11$$

$$= 1.38 \text{ seconds}$$

Thus we see that the reverberation time of the classroom is very long. Hence the classroom comes under the category of "bad acoustics".

Usually the strength of class is about 40 students. So absorption units required so as to get reverberation time of 1.2 seconds when strength of students is 40 is given by:

$$T = 0.16 V / A$$

$$1.2 = 0.16 \times 303.36 / A$$

From here, $A = 40.45 \text{ m}^2$

But, absorption power of the room when the strength is 40 students is 23.67 m²-sabins.

So, extra absorption units required = 40.45 - 23.67

$$= 16.78 \text{ m}^2\text{-sabins}$$

Coefficient of absorbing material if the absorbing material is fixed on the opposite long walls:

Area of opposite long walls = 2 x 12.8 x 3.95

$$= 101.12 \text{ m}^2$$

$$\mu = 16.78 / 101.12$$

$$= 0.2$$

2.4 MODIFICATIONS THAT IMPROVE CLASSROOM ACOUSTICS:

2.4.1 GENERAL MODIFICATIONS:

Noise and reverberation degrade the acoustic signal and adversely affect comprehension of spoken language. Reducing classroom noise and reverberation helps all

children and the teacher enjoy a more pleasant listening, learning, and teaching experience. A quieter class environment also improves student and teacher motivation and morale. Certain materials in the classroom environments can absorb sounds and decrease the effects of noise and reverberation on speech perception. Sound and noise control in the classroom environment is both a science and an art. To improve the acoustics of our classroom following general modifications are needed to be done:

- External Modifications
- Modification of Ceilings
- Modification of Floors
- Modification of Windows
- Modification of Seating and Furniture Arrangement
- Modification of Doors
- Modification of Walls

The following absorbent materials are used in the room to make the room acoustically good:

- Hairfelt.
- Acoustic Plaster
- Acoustical tiles.
- Strawboards.
- Pulp boards.
- Compressed fibreboard.
- Compressed wood particle board.
- Perforated plywood.

The above mentioned solutions are very efficient in making the room acoustically good, but these are not feasible due to following reasons:

- ✓ Classrooms are already constructed. So it will be viable to suggest a solution which does not require change in basic design of class.
- ✓ The suggested solution should be economically feasible. As correcting the acoustics of whole college will require the same solution to be applied to about 100 rooms. So cost will be an important factor to decide the solution.

- ✓ The solution which is provided should be such that it can be easily executed and should not cause any inconvenience to students while studying.

2.4.2 VIABLE SOLUTIONS:

Without adding absorbent material, the time of reverberation varied from 8 seconds to 1.38 seconds for no strength to full strength condition. These times are too long for good acoustics. But the solutions suggested above are not viable. So few of the viable solutions to make the acoustics of room good, is discussed below.

- **WINDOWS (VENTILATORS) AT THE TOP OF THE ROOM**

Let the windows be provided at the height of 2.3 m above floor level. Let the height of window be 1.5 m.

Thus, area of window = 9 m²

For windows, $\mu = 0.5$

Thus, absorption units = 9 x 0.5

$$= 4.5 \text{ m}^2\text{-sabins}$$

Thus total absorption units when there are 40 students = 23.67 + 4.5

$$= 28.17 \text{ m}^2\text{-sabins}$$

Now, $t = 0.16 V/A$

$$= 0.16 \times 303.36 / 28.17$$

$$= 1.7 \text{ seconds. (Good acoustics)}$$

- **VENTILATORS ON ONE OF THE SIDE WALLS:**

Let the ventilators be provided for the length of 8m and height 0.5m.

For ventilators, $\mu = 0.1$

$$A = 4 \text{ m}^2$$

Thus absorption units = 0.4 m²- sabins

Thus total absorption units = 23.67 + 0.4

$$= 24.07 \text{ sabins}$$

$T = 0.16 V/A$

$$= 0.16 \times 303.36 / 24.07$$

$$= 2 \text{ seconds (Good acoustics)}$$

• **ROUGH CAST PLASTER ON WALLS**

$$\text{Area of plaster} = (12.8 \times 3.95 \times 2) + ((6 \times .95) - (2 \times 2.1))$$

$$= 120.72 \text{ m}^2$$

$$\mu = 0.15$$

$$\text{Absorption units} = 120.72 \times 0.15$$

$$= 18.11 \text{ m}^2\text{-sabins}$$

$$\text{Total absorption units} = 23.67 + 18.11$$

$$= 41.78 \text{ m}^2\text{-sabins}$$

$$\text{Therefore, } T = 0.16 \times 303.36 / 41.78$$

$$= 1.16 \text{ seconds (excellent acoustics)}$$

• **GLASED WINDOW HAVING 2 LAYERED GLASSES:**

$$A = (6 \times 1.15) = 6.9 \text{ m}^2$$

$$\mu = 0.36$$

$$\text{Absorption units} = 2.48 \text{ m}^2\text{-sabins}$$

$$\text{Total absorption units} = 23.67 + 2.48$$

$$= 26.15 \text{ m}^2\text{-sabins}$$

$$\text{Therefore, } T = 0.16 \times 303.36 / 26.15$$

$$= 1.8 \text{ seconds. (good acoustics)}$$

3. CONCLUTIONS:

On carrying out the intense study about the acoustical problems and its solutions, we understood that all students are affected by poor classroom acoustics, but it can be a particular problem for student with the following problems:

- hearing loss, including children with a hearing loss in one ear (unilateral hearing loss)
- temporary hearing loss in one or both ears (ear infection or build up of middle ear fluid)
- learning disabilities
- auditory processing disorders
- speakers of another language
- speech and language delay
- attention problems

Poor classroom acoustics can also affect the teacher. It is estimated that teachers use their voices for approximately 60% of their workday. The strain on the voice gets worse when the teacher has to talk louder to overcome poor classroom acoustics. Studies have shown that teachers are 32 times more likely to have voice problems compared to similar occupations.

Creating an environment where good communication can take place should be a goal for any classroom or learning space. Communication breaks down when the classroom acoustics are poor. Reducing noise and reverberation in any space used for learning, such as community buildings, home-based classrooms, and classrooms in places of worship, is important. Thus we carried out intense study about the classroom acoustics and concluded the following:

- The classrooms of SDPS WOMEN'S COLLEGE buildings are not acoustically good. There is a long reverberation time in the classroom which leads to superposition of speech and hence decreases the quality of speech.
- To improve the classroom acoustics, various treatments may be given to it. The type of treatment depends upon the area of absorption and absorption coefficient of the material. From the experiments on model and its verification by calculations, the following measures can be taken to improve classroom acoustics:
 - ✓ Windows should be provided at the height of 2.3m above floor level for optimum acoustics.
 - ✓ Ventilators may be provided in side walls ($\mu=0.1$).
 - ✓ Walls should be covered with rough cast plaster ($\mu=0.15$).
 - ✓ Heavy fold curtains may be provided ($\mu=0.4-0.75$).
 - ✓ Covered seats may be provided ($\mu=0.2$).
 - ✓ Strawboards ($\mu=0.3$), plywood ($\mu=0.17$), compresses wood particle boards ($\mu=0.4$), perforated plywood ($\mu=0.2$) or wood wool boards ($\mu=0.2$) may be used as absorber material on walls.
 - ✓ Double layered glass window may be provided ($\mu=0.36$)
 - ✓ Quilts or mats may be used.
- But the solutions found out are not all feasible. They may prove to be costly or may be difficult to provide as our classroom is already constructed. So few

feasible and viable solutions to improve classroom acoustics may be as follows:

- ✓ Windows may be provided at the top of the classroom i.e. at the height of 2.3m above the floor level.
- ✓ Ventilators may be provided in the side wall.
- ✓ Rough cast plaster may be done on the walls.
- ✓ Normal glasses of the window may be replaced with double layered glass.

3.1 LIMITATION:

There are many suggestions for improving the classroom acoustics and these solutions are very efficient too. But there are few limitations in implementing these solutions. The surface treatment is one of the most effective ways to improve the acoustics. Suitable absorbing surface may be provided in the classroom which can absorb the sound to restrict the reverberation time below 2 seconds. The absorbent may be used such as perforated plywood, straw boards, compressed wood particle boards etc. but these materials come out to be little costly when we keep the view of using them in every classroom of the college. Thus cost has become a limiting factor in use of such efficient absorbing materials. Thus with these limitations in deciding the good acoustic solution of the classroom, we are left with only handful solutions to improve the classroom acoustics in a viable way.

3.2 FUTURE WORK:

The project work of "STUDY OF ACOUSTIC PROBLEM IN SDPS WOMEN'S COLLEGE CLASSROOMS AND SUGGESTING ITS VIABLE SOLUTIONS" is not yet completely finished. This study is performed considering the acoustics of the classroom of the SDPS WOMEN'S COLLEGE building in which the classrooms are perpendicular to the verandah and windows are provided at the opposite side of the door (and green board). The study can be extended further considering variability in buildings. Following areas can be considered for future study:

1. Considering variability of the orientation of the classrooms. i.e. SDPS WOMEN'S COLLEGE building classrooms may also be studied which are present parallel to the verandah and the window lies on the side wall of the green board.
2. Applying other solutions of improving acoustics of classroom in model and calculating their effect too.

Studying the effect of adjacent classroom noise if ventilators are provided.

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