An Experimental Investigation of the Acoustical Characteristics of University Classrooms in the Dense Urban Context of DHAKA, Bangladesh

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Abstract

Hearing is an essential requirement of an individual to perform daily activities whereas hearing impairment is the second commonest form of disability in Bangladesh. However, here education is primarily provided through the medium of verbal instruction. With ever greater emphasis on test scores and teacher accountability, it is also very important to recognize the effects of excessive background noise, reverberation and diffusion both for student learning teacher's healthy voice. Perhaps, giving emphasis on acoustic condition of classrooms an experimental investigation has attained in this study by selecting two different university classrooms of a single building located at the dense urban conurbation like Dhaka. The major differences have lied on their exterior building materials, outdoor noise sources, ventilation systems and interior materials. Only the basic similarities have on their volumes, floor and ceiling materials and students capacity. After describing the position of sources and receivers in the two specimen classrooms, the probable shortcomings have found with their possible causes. Lastly, this study concludes with some suggestions to overcome the unwanted acoustical conditions and also propose a hypothesis for the future subjective tests within this configuration.

Keywords: Background noise, Diffusion, Hearing impairment, Reverberation, Specimen classroom

Introduction

Hearing is an essential requirement of an individual to perform daily activities. But, Hearing impairment is the second commonest form of disability in Bangladesh and is causing economic, social, educational, and vocational problems. Children are the worst affected section of the community in this regard. Many factors including genetic factors, childhood diseases including diseases of the mother during pregnancy and exposure to noise above the threshold level over an extended period of time are responsible for causing hearing impairment [1]. However, education is primarily provided through the medium of verbal instruction. With ever greater emphasis on test scores and teacher accountability it is important to recognize the effects of excessive background noise, reverberation and diffusion on student learning. A common scenario of classroom environment in Bangladesh is rows of desks with a teacher in the front of the classroom, a chalk board (recently white board), and the rustle of energetic young learners and the whir of the ventilation system (mostly ceiling fans or air conditionings). Because of this shared experience most educators and the lay public have a mindset about the presence of noise in the school environment and how good, bad, important, or unimportant it really is [2]. On the contrary, Voice is the primary working tool of teachers, and a good voice is essential for communicating with students. Nowadays, many teachers suffer from voice problems [3]. A recent study reported that around 13% of the active school teachers in southern Sweden self-reported voice
problems [4]. Investigating possible causes for voice disorders from the testimonies of affected teachers, Vilkman [5] points out “bad classroom acoustics” as one of the hazards for voice health. Garcia et al. [6] summarizes the needs of students and teachers regarding the acoustic environment and the most common sources of noise present in classrooms environment in “Fig: 1”.

In this study, two classrooms have chosen from the Department of Architecture, Stamford University Bangladesh. The location of classrooms in the building, type of noise sources, exterior building materials, interior materials and the orientation of these two classrooms have differences to each other. Only the similarities have in their sizes and student capacity. Additionally, the North oriented classroom has fixed glasses on wall with split air conditioning system but the South one has operable sliding windows with no air conditioning within it. However, existence of six ceiling fans is a common feature in both classrooms. After describing the position of sources and receivers in the two different classrooms have chosen for the study, the probable shortcomings have found with their possible causes and later some conditions and hypothesis for the future subjective tests within this configuration are then described.

**Methodology**

The aim of this study is to find out the major acoustical shortcomings along with their causes of the two selected classrooms to attain better sonic environment in near future. The following four objectives have developed to achieve the aim shown in Table-1. “Fig: 2” is showing the consequences of work throughout the study period. CEM DT-8820 environment meter has used for physical survey.

Table 1: Objectives of the study

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Description</th>
<th>Method/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective 01</td>
<td>Understand the importance of sound sonic environment in university classrooms</td>
<td>Literature review</td>
</tr>
<tr>
<td>Objective 02</td>
<td>Search for National and International standards for classroom acoustic</td>
<td>Literature review</td>
</tr>
<tr>
<td>Objective 03</td>
<td>Investigation on the major shortcomings and their relative causes of the case spaces</td>
<td>Case study</td>
</tr>
<tr>
<td>Objective 04</td>
<td>Suggesting most suitable solutions to overcome the shortcomings of the case spaces</td>
<td>Calculations, Literature review and Case study</td>
</tr>
</tbody>
</table>
Literature Review

Classroom acoustics are an important, often neglected, aspect of the learning environment. Up to 60% of classroom activities involve speech between teachers and students or between students, indicating the importance of environments that support clear communication [7]. But speech intelligibility decreases when background noise increases or with long reverberation times. When both background noise and long reverberation times are present, they have a combined effect on both people with and without normal speech, hearing, and language abilities [7]. Designers should focus on controlling background noise levels, reverberation times, and signal-to-noise ratios to improve the acoustic environment of schools [8].

While a 1 decibel (dB (A)) change in sound level is barely noticeable, background noises are perceived as doubling in loudness every 10 dB(A) [9]. Background noise in unoccupied classrooms should not exceed 30-35 dB (A) [10]. Reverberations occur when sound waves strike surfaces (e.g., floors, walls, ceilings) in a room and are reflected back into the space. Reverberation will continue until all the sound waves have been absorbed or have dissipated [11]. Reverberation times (RT) should not exceed 0.6 seconds in general classrooms [7]. Reducing the RT to acceptable limits will help with speech intelligibility, and the added absorption will reduce the overall sound level within the room without adversely affecting the signal-to-noise ratio [7]. Signal-to-noise ratios (SNRs) generally become less favourable for hearing as the distance between the speaker and the student increases, suggesting that different locations within an individual classroom may have different SNRs [11]. SNRs are typically lowest at the back of classrooms or near a noise source (e.g., air conditioning unit) [12]. Students seated in the rear of a classroom may not understand a teacher’s speech to the same extent as one seated at the front of the classroom. SNRs should meet or exceed +15 dB in all locations of a classroom.

Fig: 3: a) Visual analogy of speech sounds smearing together as RT increases [2] and b) Example of a decrease in speech sound level in a classroom [13]
When a teacher speaks at a level of 65 dB(A) (raised voice) in the front of an ordinary classroom with ordinary sound reflections from the surfaces, that level has dropped to nearly 52 dB (A) 6 m out in the classroom, and further away it does not drop much more thanks to reflections (Fig: 3b). “Fig: 3a” is a simplified visual analogy of listening which demonstrates that with effort each of these sentences can be read. Again, greater the effort is put into receiving the message, greater the restriction on the faculties available to process the message. One can clearly imagine the synergistic effects of both excessive S/N and reverberation time on the listening abilities [14].

**Case Study**

**Selection Criteria of Example Case Spaces**

The criteria for site and building selection to determine the typical example of university classrooms were based on the following factors:

- The site should be within the urban boundary and should have characteristics typical of the general urban fabric of Dhaka city.
- The case spaces have external and internal noise sources near their location.
- The case spaces should have variations in their noise sources and opening types.
- The case spaces should be in same sizes and equally occupied by listeners.
- The case spaces should have common floor and ceiling materials within it.

**The Selected Building and its Surroundings**

The building located on road no 6, Dhanmondi, Dhaka which is only 56 feet away from the Mirpur road. Because of its location a numerous no of outdoor noise sources are available like honks from vehicles (buses, cars, trucks etc.), loud sounds from mass gathering and so on. Moreover, there is a car workshop on the south side of the building which is a major noise source for the south oriented classrooms.

**Figure 4: Details of sound generation, propagation and reception of the case unit**

The building has two types of classrooms. The northern classrooms have individual air conditioning system along with six ceiling fans and the southern classrooms have only six ceiling fans for thermal comfort. Both the air conditioners and ceiling fans create background noises during their services. Moreover the generator in basement is also an indoor noise source during load shedding. Students loud gathering on corridors are somewhat disturbing for classroom sonic environment (See “Fig: 4” and “Fig: 5”).
The Two Classrooms

Studio 301 and 303 has picked for this study which are located at the second floor of the building. Studio 303 is nearer to 40 feet wide road on north side and has fixed glass facades on north, east and west sides. The room has a wooden locker of 8'-0"x 7'-0"x 2'-0" and a 16'-0"x4'-0"x1/2" display board (Partex) on southern wall of the room and 27 wooden drafting tables with wooden tools.
On the other hand, studio 301 has furnished with a locker of 21’-0”x7’-0”x2’-0” and a display board of 18’-0”x4’-0”x1/2” and 31 wooden drafting tables with wooden tools for sitting. The room has two sliding glassed windows sized 5’-0”x4.5’ on southern wall only. Both the room have tiles on floor and glossy gypsum panels as false ceiling and rest of the brick walls are plastered with white paints. Additionally, there are two white boards and two cylindrical painted columns existed in each classroom.

Figure 7: Site photos, floor Plan and the blow up plans of the classrooms (showing different indoor noise sources and furniture, fixtures and station points)

Results

Each classroom has five station points for the value readings to compare. There been three types of values on a single station points categorized by sounds without ventilation systems, sounds with ventilation system and receiving signal from the teacher’s desk. All the values have analysed on following three acoustical factors.

Calculation of Background Noise

Bangladesh National Building Code (2006) has suggested that the intrusive noise level should be 35 dBA (NR 25) for the classroom. But according to the survey values both the studio 301 and 303 have Much more noise pressure than the recommendation. For both classrooms the background noise is much high than the standard probably for their location and the major noise sources. But excluding the outdoor noise sources both classrooms have suffered from indoor noise sources. Studio 301 and 303 stand for same noise level during their ventilation systems on where 11.24 dBA and 20.1 dBA increase respectively. So both the rooms need absorbent materials which give better performance against low frequency sounds.

Calculation of Reverberation Time (RT)

The reverberation time should be determined according to their performing activities within the space. Mostly media of language used in these classrooms are Bengali, where English is also delivered. So the reverberation time for these classrooms will be 0.8s-1.5s (Fig: 9) while neglecting
Table 2: Calculation of background noise

<table>
<thead>
<tr>
<th>Room No.</th>
<th>Without ventilation system (dB)</th>
<th>With ventilation system (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>301</td>
<td>62.9</td>
<td>53.8</td>
</tr>
<tr>
<td>303</td>
<td>57.3</td>
<td>48.3</td>
</tr>
</tbody>
</table>

little performance of audio and video playbacks. On this contrary, studio 301 is in better situation than of studio 303 where RT is 3.96s. The calculation has done in empty classroom. The RT will be reduced when human body occupy the space (Average Body Surface Area of Bangladeshi people is 1.47 Sqm and absorbent coefficient α1000 is nearly 0.45).

Fig: 8. Recommended optimum reverberation times for spaces of various uses (Source: Bangladesh National Building Code, 2012)

Calculation of Signal-to-Noise Ratio (SNR)
While background noise and reverberation times are important, signal-to-noise ratios (SNR) may be the most important consideration within a classroom’s acoustical environment. High SNRs are necessary to ensure students and teachers can hear one another. SNR values below +15 dBA make hearing, teaching, and learning more difficult [13]. In general, classroom layouts maintaining short distances (6-8 feet) between the speaker and the student improve classroom SNRs [11]. According to the physical survey values the average background noise for studio 301 and 303 is 53.23 dBA and 68.9 dBA respectively. Because of these high background noise teachers have to deliver their signals on a high level which create stress on their vocal health in case of long speaking. Additionally, Bangladesh National Building Code (2012) has declared that the first row and last row of a classroom’s SNR value should not be less than +6dBA.
Table 3: Calculation of Reverberation Time (RT)

<table>
<thead>
<tr>
<th>Calculation of Reverberation Time (RT) for STUDIO 301</th>
<th>Calculation of Reverberation Time (RT) for STUDIO 303</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfaces</td>
<td>Surfaces</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor</td>
<td>Floor</td>
</tr>
<tr>
<td>Tiles</td>
<td>Tiles</td>
</tr>
<tr>
<td>Wooden Tables + Tools</td>
<td>Wooden Tables + Tools</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Walls</td>
<td>Walls</td>
</tr>
<tr>
<td>North Plainsland Brick wall</td>
<td>North Plainsland Brick wall</td>
</tr>
<tr>
<td>Gypsum Board (1/2&quot;)</td>
<td>Gypsum Board (1/2&quot;)</td>
</tr>
<tr>
<td>Glass Door</td>
<td>Glass Door</td>
</tr>
<tr>
<td>Wooden Cabinet</td>
<td>Wooden Cabinet</td>
</tr>
<tr>
<td>South Plainsland Brick wall</td>
<td>South Plainsland Brick wall</td>
</tr>
<tr>
<td>Glass Window</td>
<td>Glass Window</td>
</tr>
<tr>
<td>Gypsum Board (1/2&quot;)</td>
<td>Gypsum Board (1/2&quot;)</td>
</tr>
<tr>
<td>East Plainsland Brick wall</td>
<td>East Plainsland Brick wall</td>
</tr>
<tr>
<td>Wooden Cabinet</td>
<td>Wooden Cabinet</td>
</tr>
<tr>
<td>Plastered Concrete column</td>
<td>Plastered Concrete column</td>
</tr>
<tr>
<td>West Plainsland Brick wall</td>
<td>West Plainsland Brick wall</td>
</tr>
<tr>
<td>Plastered Concrete column</td>
<td>Plastered Concrete column</td>
</tr>
<tr>
<td>Ceiling</td>
<td>Ceiling</td>
</tr>
<tr>
<td>Suspended glass gypsum</td>
<td>Suspended glass gypsum</td>
</tr>
</tbody>
</table>

|                                                       |                                                       |
|                                                       |                                                       |
| Area         | Ab. Coef | Total ab. | So          | Area         | Ab. Coef | Total ab. | So          |
| (Sqm.)      |          |           |             | (Sqm.)      |          |           |             |
| Floor       | 60.00    | 0.01      | 0.60        | 72.63       | 0.01      | 0.73       |
| Wooden Tables + Tools                                | 27.00      | 0.07      | 1.69        | 28.11       | 0.07      | 1.83       |
| Walls       | 65.52    | 0.02      | 1.31        | 3.36        | 0.02      | 0.07       |
| North Plainsland Brick wall                         | 69.05      | 0.07      | 4.89        | 24.74       | 0.03      | 0.74       |
| Gypsum Board (1/2")                                 | 69.09      | 0.04      | 2.76        | 12.08       | 0.02      | 0.24       |
| Glass Door                                           | 2.28       | 0.12      | 0.27        | 2.28        | 0.12      | 0.27       |
| Wooden Cabinet                                       | 69.19      | 0.02      | 0.34        | 4.92        | 0.07      | 0.34       |
| South Plainsland Brick wall                          | 4.18       | 0.12      | 0.60        | 2.37        | 0.07      | 0.16       |
| Glass Window                                         | 6.99       | 0.04      | 0.27        | 3.16        | 0.05      | 0.15       |
| Gypsum Board (1/2")                                 | 2.88       | 0.02      | 0.66        | 1.15        | 0.02      | 0.23       |
| East Plainsland Brick wall                           | 3.00       | 0.07      | 0.51        | 1.40        | 0.02      | 0.28       |
| Wooden Cabinet                                       | 13.00      | 0.02      | 0.26        | 1.89        | 0.02      | 0.38       |
| Plastered Concrete column                            | 1.19       | 0.02      | 0.35        | 2.47        | 0.02      | 0.49       |
| West Plainsland Brick wall                           | 1.50       | 0.02      | 0.30        | 1.18        | 0.02      | 0.23       |
| Plastered Concrete column                            | 2.97       | 0.02      | 0.60        | 16.73       | 0.03      | 0.50       |
| Ceiling                                              | 69.00      | 0.03      | 2.07        | 72.63       | 0.03      | 2.18       |
|                                                       |                                                       |
| So, RT = 0.16 Vf + A + V = 0.16 x 174.77 / 16.33 = 1.71 s | So, RT = 0.16 Vf + A + V = 0.16 x 190.86 / 7.72 = 3.96 s |
|                                                       |                                                       |
| Total Absorption                                      | 16.33      |                                                       | Total Absorption | 7.72 |

Scenario Regarding Diffusion

According to Bangladesh National Building Code (2012) the recommended sound pressure should not be more than 6dBA in an indoor space. In terms of diffusion the condition of room no 303 is extremely poor to perform as classroom activities. The table 04 shows the signal and receiving situation during ventilation system on in case spaces.

Table 4: Diffusion scenario

<table>
<thead>
<tr>
<th>Room no. with Signal*</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(dBA)</td>
<td>(dBA)</td>
<td>(dBA)</td>
<td>(dBA)</td>
<td>(dBA)</td>
<td>(dBA)</td>
</tr>
<tr>
<td>(g)</td>
<td>82.9</td>
<td>80.8</td>
<td>77.0</td>
<td>80.2</td>
<td>76.8</td>
</tr>
<tr>
<td>301 (82.9)</td>
<td>78.8</td>
<td>77.4</td>
<td>76.2</td>
<td>77.6</td>
<td>75.3</td>
</tr>
</tbody>
</table>

* Male teacher of 33 years old delivered on a frequency range of 950-1050 Hz

Discussion

According to physical survey and their relative result the following modification should be done to improve the present condition of case spaces:

- Use trees, shrubs, earthen banks, and concrete barriers around school buildings to reduce the amount of external noise entering classrooms [11]. Shrubns can be possible to install on west side of studio 303.
- Install pads underneath the school’s supporting structure to reduce structurally-borne background noise [10] which might be possible to incorporate in basement level of the case building.
- Seal gaps in window frames and doorways [12].
- Hang acoustically-treated curtains or draperies in front of windows to reduce the proliferation of external noises in classrooms [10].
- Use additional layers of gypsum or plywood to partition walls and ensure their gap-free construction to increase the STC and reduce interior noise in classrooms [10].
- Install carpeting in classrooms to reduce ambient noises of movement (e.g., movement of chairs and desks, shuffling feet).
- Consider using a suspended acoustical ceiling (full) or acoustical cloud (partial ceiling) to provide sound absorption to reduce interior noise within the room.
- Specify chairs with neoprene chair leg tips to minimize noise from moving chairs in classrooms without carpeting.
- Increase the amount of soft, rough, or porous surfaces (e.g., acoustical paneling, bulletin boards, carpeting, bookcases) and decrease the amount of smooth, hard surfaces (e.g., exposed concrete walls,
glass) to reduce room reverberation times and overall noise levels [10].

- Install acoustical tiling with an absorption coefficient of at least 0.65 to cover hard, sound reflective ceilings [10].

- Install a suspended ceiling of sound-absorbing tile with an NRC of 0.75 or better below the structural ceiling of classrooms with high ceilings to lower reverberation times [12].

The suggestions have complied into “Fig: 9.” for better visual understanding.

Fig: 9. Acoustical solutions for classroom

**Conclusion**

The attempt of this study is a small demonstration of classroom acoustic in the busy urban context of Dhaka, Bangladesh. The effects of speech level and intelligibility are beyond the scope of this study. It is almost impossible to evading the effects of noise levels particularly in the dense context like Dhaka. Thus there remain the ample possibilities for exploring the speaker friendly classroom acoustic for future research. Classroom acoustics truly is a first step toward education for all students.

Together, the voices of the acoustics and hearing industries are needed to champion the case for listening, learning and a better future [8].

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