Achieving Acoustic Comfort in the Architectural Design of a Lecture Hall

Article · October 2018

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International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 2, pp: (161-184), Month: October 2018 - March 2019, Available at: www.researchpublish.com

Achieving Acoustic Comfort in the Architectural Design of a Lecture Hall

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Abstract: **Lectures hall and classroom in Universities are occupied by students and advisors or Instructors for lectures but the acoustic design for these buildings are neglected and student get distracted or cannot clearly hear and pay attention to the lecturers. Acoustic design of these spaces go a long way to affect both the Instructors and students in terms of audibility, communication between the students and instructors or Advisors, comfortability, performance of students in class discussion and in general and so on. From this research, the integration of Acoustic comfort will be achieved through the Architectural design rather than active means and the discussion of both means of achieving Acoustic comfort or Architectural Acoustics is reviewed in the literature review. This research will study possible noise sources and measures or technologies that can be integrated into the architectural design of a lecture hall or classroom to aid acoustic comfort. Some of this noise sources may include HVAC, background noise from outside the lecture space, low sound insulation building materials and so on. The architectural acoustics of a lecture hall or classroom is very important for students to acquire the most knowledge they can and this research will use a case study to analysis the acoustic comfort of the lecture space and propose a suitable design to achieve acoustic comfort within the lecture hall. A software will also be used to estimate the noise level within the selected Case Study to determine the level of noise pollution which will made proposing a suitable design and material selection more feasible. Also this research will discuss the advantages or benefits of acoustics comfort in a lecture hall or classroom.**

Keywords: **Architectural Acoustics, HVAC, Sound Insulation, Acoustic Comfort, Acoustics.**

1. INTRODUCTION

Acoustics is the sound related quality of anything which cuts across various profession and fields of study including Architecture, medicine, Engineering and all science related courses. According to physicians, Hearing is one of the most crucial means of survival in the animal world, and speech is one of the most distinctive characteristics of human development and culture [3]. In Architecture, Acoustics involves promoting or enhancing beneficial sound and suppressing unwanted sound that might be harmful to the occupants. Acoustics in Architecture can be incorporated as part of the Architectural design or as an Active means usually proposed by Acoustics experts or Engineers in a way that it does not affect the aesthetics of the building but sometimes the Architectural acoustics design and active means can both be used in buildings depending on the building function for examples Concert Halls.

Acoustic Comfort is the well-being and feeling of a building or house occupant by suppressing or eliminating intruding noise from the environment or building itself and enhancing speech and quality of music based on the building function to make the building a productive and useful space for an occupant.

According to Research, well designed environment and building with acoustic comfort makes the occupants perform better and be free from unwanted sound diseases or illnesses. In school and office, Learning and working is less stressful and tiring when the unwanted sounds are eliminated and there is better communication and concentration. Harmful sounds or noise affect not just the occupants hearing but the whole body mentally and physically with diseases or illnesses such as headache, displeasure, psychosomatic illnesses, decreased physical and mental performance and so on. Thus, when we are acoustically comfortable, when noise is eliminated and we can clearly hear beneficial sounds, we are more productive, happier and healthy.

The acceptance of any given sound depends on many factors that vary according to the type of building, the type of building function, and the social and cultural habits of the occupants. The quality of beneficial sounds in any given building space is determined by the sources of the sound or noise and quality of the building envelope including:

- Exterior noise (Road traffic, noisy neighbourhood…)
- Interior noise (Loud music, phone and loud conversations…)
- Impact noise (footsteps…)
- Sound vibrations through the structure
- Equipment noise (HVAC systems, ducts and pipes, electrical appliances, elevators…)

The effect of noise on a specific individual depends on many different factors. These include the predictability and familiarity of the sound, the controllability of the sound, personal attitude and sensitivities, information on the contents of the sound, and the necessity for the sound. For instance, we are more likely to tolerate noise from neighbours we like, than those we don't [4].

The benefit of good Architectural Acoustics Design include;

- Productivity: The occupants are more productive and efficient when the unwanted sounds are eliminated or minimised in a space.
- Health: The occupants will be healthy and perform well
- Perception: The occupants will have good perception of surrounding activities in terms of their satisfaction and preference
- Logical thinking: The level of reasoning of the occupants will be high and this will aid individual performance.
- Attention and Alertness: The occupants will be very attentive and alert to surrounding activities
- Motivation: The occupants will be motivated to work and keep to deadlines as unwanted noise cause distraction and discomfort.
- Physiological Effect: The human ear is comprised of three parts: the outer, middle and inner ears, which respectively receive, transmit and detect sound. Sound pressures set the eardrum in vibration and this movement is transmitted to the inner ear, where nerves are stimulated. Thus increasing the nature and level of experienced sounds in a space.

This research is carried out because Acoustic comfort is neglected in lecture halls or classroom at most universities and this acoustic comfort goes a long way to influence students performances both in exams and in class discussions and it also influences the effective communication of lectures and knowledge from advisors and instructors to students.

The aim my research is to analyze and evaluate various sources of noise, level of acoustic comfort in a selected case study lecture hall and then propose an appropriate architectural design to achieve acoustic comfort in a lecture hall or classroom.

2. LITERATURE REVIEW

According to Berendt Raymond D and others, 1967 [1], building noise may be classified according to its origin, as either airborne, structure-borne or a combination of both. Under certain circumstances, airborne noise may produce structure-borne noise which in turn may be reradiated again as airborne noise. Both types of noise cause pressure fluctuations in the surrounding air which are perceived by the ear as sound. Other than by positive identification of a sound, e.g. piano playing and speech or the detection of vibrating floors or rattling windows, the ear cannot easily differentiate between noises of airborne and structure-borne origin.

The transmission of noise from one completely enclosed room to an adjoining room separated by a continuous intervening partition wall may be either direct transmission through that wall or indirect transmission through other walls, ceilings and floors common to both roams or through corridors adjacent to such rooms. This noise transmission by indirect paths is known as "flanking transmission". The chief flanking transmission paths of airborne noise between two adjacent rooms usually involve: common corridors, ventilation grilles, and duct systems, open ceiling plenums which span both rooms, louvered doors and close spacing of windows between roams. Flanking transmission paths of structure-borne noises are far more numerous and much more difficult to trace or detect than those of airborne noises. The detection, cause and correction of structure-borne vibration or noise transmission between adjacent rooms are relatively simple. However, determining the reasons for excessively high noise or vibration levels in rooms far removed from noise sources can be difficult and vexing.

According to BRANZ Bulletin, 2017 [4], the most common sources of noise in a house are:

- externally generated noise from outside the site such as traffic, trains, aeroplanes, neighbours and schools
- externally generated noise from within the site such as wind on the building, rain on the roof, heat pumps and water pumps
- internally generated noise such as loud conversation, washing machines, dishwashers, stereos, televisions and air conditioners
- impact noise through the structure such as footsteps (particularly on stairs) and children playing
- Noise from services such as toilet flushing.

Noise can be airborne (for example, noise from traffic or a television set) or structure-borne (for example, the sound of a door slamming or footsteps from someone upstairs – this is known as impact noise).

Key strategies include: controlling noise at source; increasing distance from the noise source; closing potential sound paths (such as openings in walls facing sources of noise); and using mass, insulation or buffering to block the noise.

Adding sound control features to a building retrospectively can be expensive, so where possible, aim to control sound at its source. For example:

- use quieter appliances
- minimise vibration noise by placing appliances on rubber pads or proprietary anti-vibration mounts
- Install sound-absorbent surfaces in rooms that are potential sources of noise such as laundries, children's playrooms, and rooms where loud music or games may be played.

Where noise cannot be controlled at source:

- increase the distance between the noise and the location where it will be heard – for example, locate the building as far as possible from a noisy street frontage
- use zones to control noise, by grouping noisy or quiet activity spaces together
- don't locate windows or doors towards sources of noise
- avoid direct and flanking sound paths by off-setting doors and windows from noise sources
- provide a buffer space or spaces between quiet and noisy spaces – for example, by locating a wardrobe between bedrooms
- incorporate mass into external walls to block external noise, or use fencing or earth mounding
- use sound-attenuating exterior walls or sound-insulated interior partitions to control noise

According to Berardo Naticchia, Alessandro Carbonari, 2007 [26], the two main types of passive means for improving Sound Transmission Loss (STL) presently utilized are:

- laminated glass technology
- double glazing

Both of them can be useful for reducing noise transmission at high frequencies, in particular, the laminated solution is used to shift the coincidence effect at frequencies higher than the audible range, in fact improving STL values in the range of acoustic waves higher than 1500 Hz, while determining no improvements at lower frequencies.

Presently, two main approaches are known for active control of sound:

- Active noise control (ANC), in which secondary waves interfere destructively with the disturbing noise.

- Active structural acoustic control (ASAC), in which the source of noise is controlled, through the reduction or modification of its vibration field.

Based on the Article written by Blaise Kelly, Danilo Hollosi, Philippe Cousin, Sergio Leal, Branislav Iglár, and Andrea Cavallaro, 2014 [2]. They cited two main Acoustic Sensing Technology for improving Building Energy Efficiency, these include;

- *Audio-based Occupancy Level Estimation for Smart Buildings (S4ECoB*): Current state-of-the-art systems to provide real-time occupancy information, like pre-set occupancy information or presence sensors have energy-saving potentials, but have several drawbacks like insufficient accuracy, installation and maintenance pitfalls, including high costs.

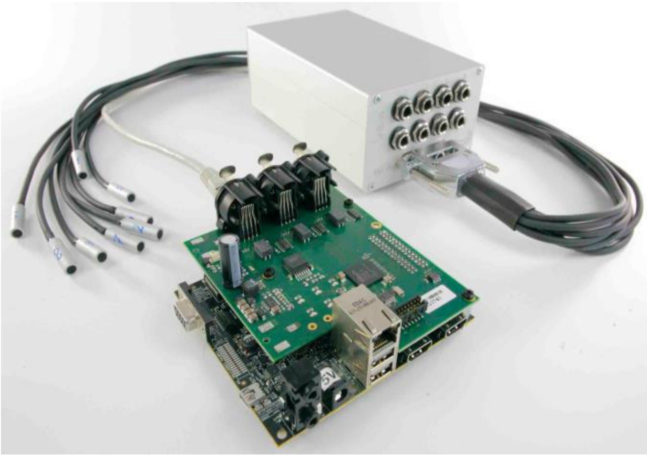

Fig 1: Audio-based Occupancy Level Estimation for Smart Buildings [16]

- *Demonstrators in EAR-IT:* The EAR-IT demonstrator will exhibit intelligent acoustic solutions for indoor environments. EAR-IT research experiments focuses on the use of many basic/cheap Internet-of-Things (IoT) technologies (audio-ready wireless motes that can provide basic acoustic functions, see fig. 2) together with few advanced/costly embedded systems (so called Acoustic Processing Units (APU), capable of performing advanced audio signal processing tasks) as a source of valuable data for smart applications.

Fig 2: Demonstrators in EAR-IT [17]

3. METHODOLOGY

In this research, the central Lecture Hall at Eastern Mediterranean University is selected as a case study which will be analyzed based on the noise sources and Decibel (dB) meter or Noise dosimeter software will be used to estimate sound level heard by projecting equipment sound power data through the surroundings (e.g., floors, ductwork, walls).

According to the study carried out, the existing Central Hall floor plans and site plan will be analyzed based on the General principle of noise control stated above and the sources of noise will be noted to propose a more suitable design for the Central Hall.

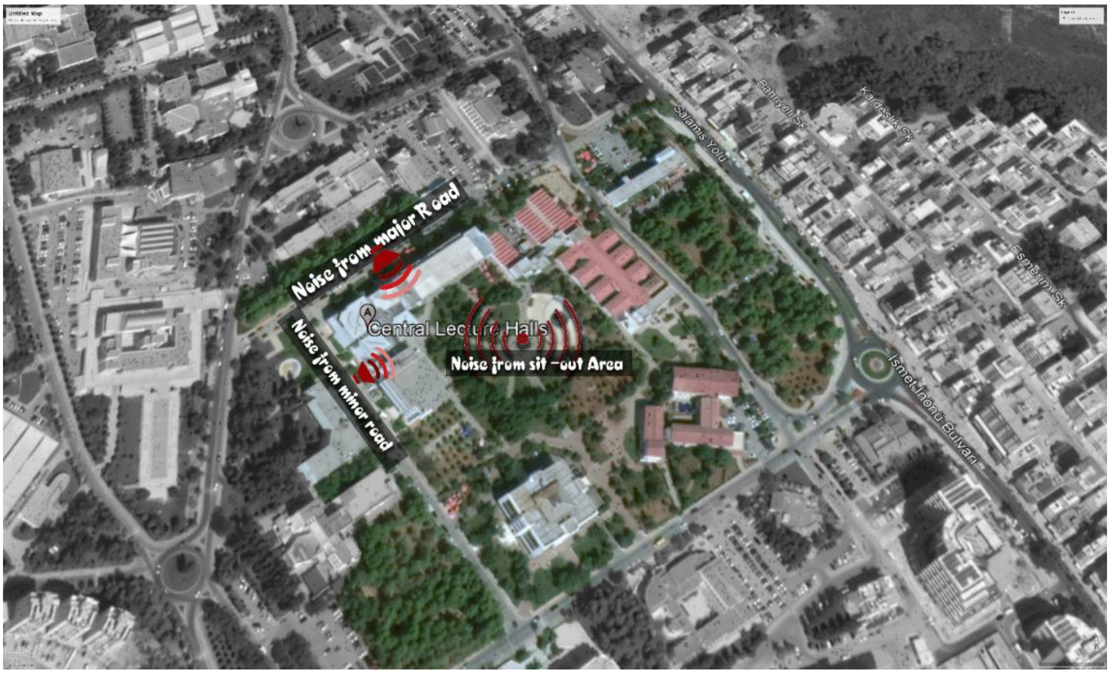

Fig 3: Site Plan of Central Lecture Hall at Eastern Medıterranean Universıty

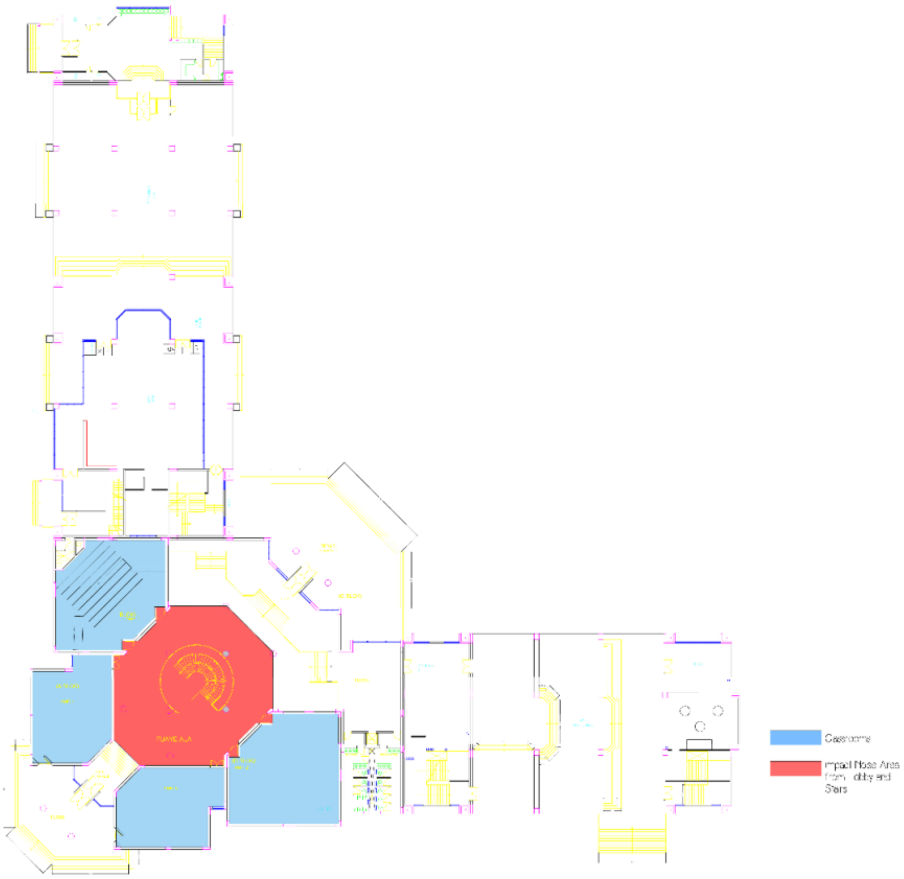

Fig 4: Ground Floor Plan of Central Lecture Hall at Eastern Medıterranean Universıty

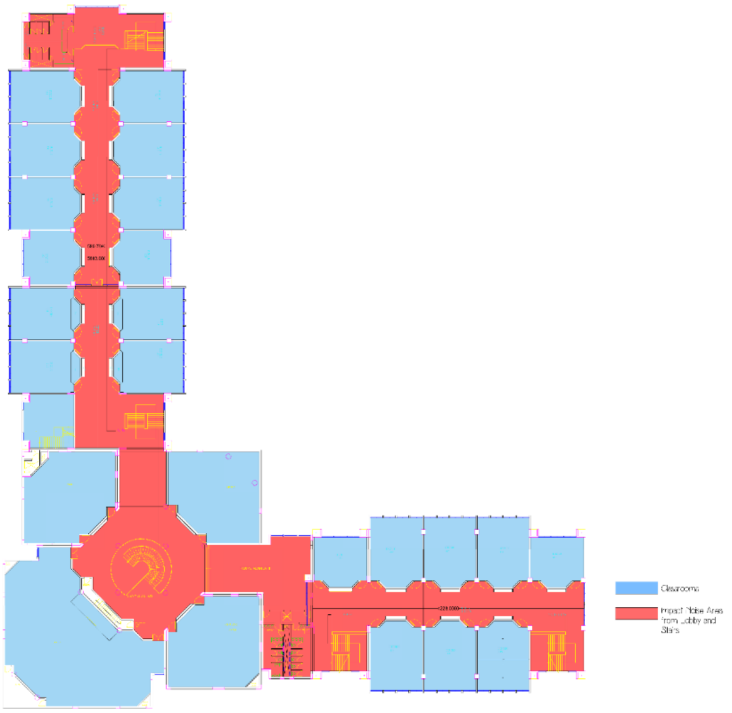

Fig 5: 1st Floor Plan of Central Lecture Hall at Eastern Medıterranean Unıversıty

From the study of the Site Plan and floor plans, the major sources of noise include;

External or Air borne Noise : Noise from surrounding Buildings, Noise from Major Road traffic, Noise from Minor Road and students walking and Noise from CL Square Sit-out

Internal Noise or Structure Borne Noise: Impact Noise from footsteps in the lobby and close-by stairs, Noise from Building elements and Appliances (HVAC systems, Door Slamming), Noise from Loud conservations and Phone calls and Minor noise from Toilet flushing and Hand dryer

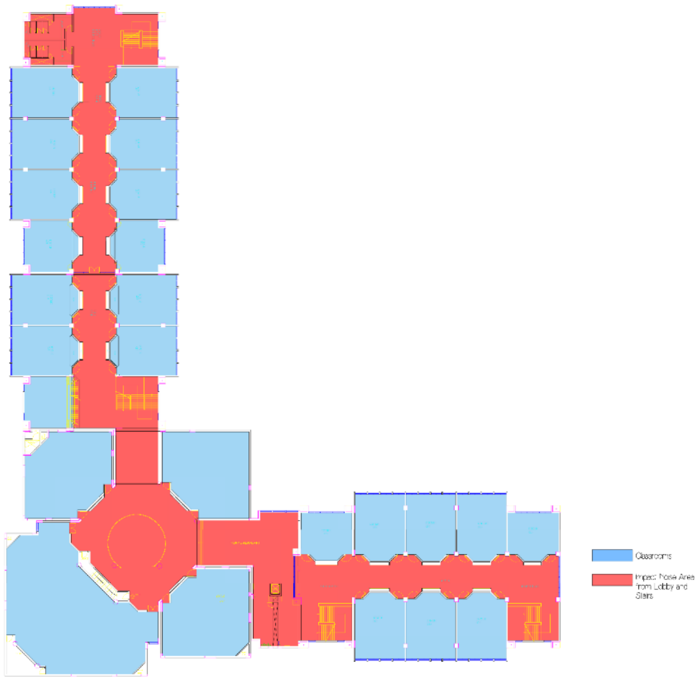

Fig 6: 2ND Floor Plan of Central Lecture Hall at Eastern Medıterranean Unıversıty

From the fig. 3-6, I analyzed the existing Central Lecture Hall building based on the general Principle of noise Control.

International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 6, Issue 2, pp: (161-184), Month: October 2018 - March 2019, Available at: www.researchpublish.com

- Selection of Site: the Selection of the site for the Central lecture hall was based on the school planning and the location of the building is appropriate in that it is located close to the main entrance of the school which is easily accessible by students and instructors but from the Acoustic view, the sources of noise were neglected and there are few natural barriers like trees or existing building to absorb some of the noise or sound from the road and also, it is located along an Hilly road with moderate road traffic (fig. 7 & 8) and noıse (acceleration sound of cars on an hilly road). The Square (CL Square) which is a recreation area has sufficient trees to reduce noise. Thus, the location of the building on the site is satisfactory.

Fig 7: View from Major Road showing the Hilly slope

Fig 8:View from Minor road showing the gentle slope

Fig 10: Exterior view showing lack of Trees for Noise barrier (shaded Area

Fig 11: View from CL square recreation Area

Indicates Classroom Window Area)

- Orientation of Building on Site: The orientation of the building on the site is good and the setbacks as in fig. 12 from the road helps in the noise control.

Fig 12: View showing set-back from Major Road, Main Entrance and Minor Road

- Room and Space Arrangement: The Classroom arrangement and zoning are appropriate, this is because most of the frequently used Classrooms are placed together on the 2nd and 3rd floor and general spaces are located on the ground floor. The only defect is that the few classroom rooms located opposite or beside the stairs are not properly insulated and this is one of the major sources of the internal noise.

Fig 13: Typical CL Classroom sitting Arrangement

- Tenant Placement. This is good because the students learning are placed together in the same floors and this will help students to be motivated to learn more when the see or perceive some level of serious atmosphere just like a library.

- Sound Absorption: There is no sound absorption material in the lobbies or stairs which is very poor acoustically.

- Control of the Noise at the source: The control of noise from noise sources is totally neglected. For example, Inadequate trees to shade the noise from both the major and minor road and lack of sound absorbent materials in the lobbies and stairs.

- Supervision and Pretesting: This is totally absent as the building was not designed with the aim to achieve acoustic comfort.

- Building Equipment: The HVAC systems seem well fixed and air-tight which not does allow noise through duct work. The HVAC exterior component are also in good working condition and does not generate unwanted sound but many of the classroom door as seen in fig 14 does not have anti door slam or hinge and door stopper to avoid door slamming or unwanted sound from door closing.

Fig 14: Classroom Door without anti door slam or Hinge and Door Stopper

- Selecting of Sound Insulating structures: The use of Sound insulating element, structure or Technology is not applied in areas needed. For example, the walls demarcating the classroom from the lobby fig. 16), the classroom close the stairs (fig.15) and the exterior walls facing the road have no sound insulating structures.

Fig 15: Stairs Circulation Image

Fig 16: Image from Lobby for Classroom Access

4. RESULTS AND DISCUSSIONS

The sound level wıthın the Central Lecture hall buıldıng was estimated with **dB METER** usıng NIOSH Sound Standard in a typical Classroom and corrıdor at different frequency weighting.

This is the result of Sound level at a typical Classroom as shown in Fig 13 with no students and with the door closed. The fig. 17 below shows the variation in the noise from both the corridor and outsıde the building. The Classroom used was one along the Major road with windows facing the road as in Fig 10.The Estimation was taken with 'A' frequency weighting which reflects the response of the human ear noise by effectively cutting off the lower and higher frequencies that the average person cannot hear.

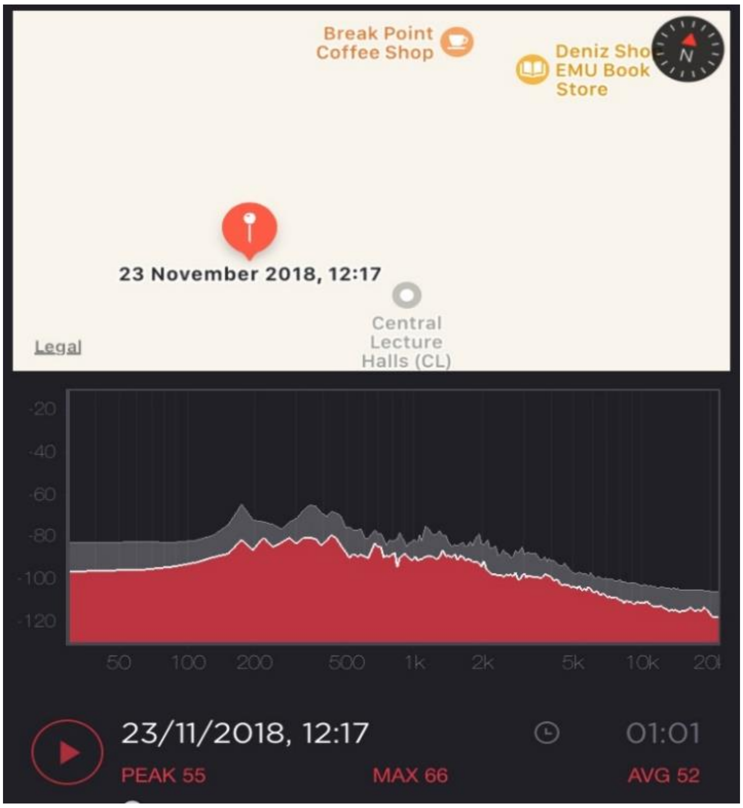

Fig 17: Graphically representation of background Noise estimated within an empty classroom (door Closed

This data shows the Current, Maximum and Average sound measured in decibels at different time within the one minute recorded and it also shows the variation in the levels are dawn in the Graph (fig. 17) based on the variation and level of background sound.

TABLE 1: DATA ANALYSIS OF BACKGROUND NOISE ESTIMATED WITHIN ONE MINUTE TIME RECORDED IN AN EMPTY CLASSROOM WITH THE DOOR CLOSED.

Time	Current (dB-A)	Max (dB-A)	Average (dB-A)	
12:17:17	42	66	42	
12:17:18	50	66	46	
12:17:18	55	66	49	
12:17:19	54	66	50	
12:17:19	52	66	50	
12:17:20	54	66	51	
12:17:20	53	66	51	
12:17:21	53	66	51	
12:17:21	50	66	51	
12:17:22	52	66	51	
12:17:22	53	66	51	
12:17:23	54	66	51	
12:17:23	51	66	51	
12:17:24	52	66	51	
12:17:24	51	66	51	
12:17:25	51	66	51	
12:17:25	53	66	51	
12:17:26	50	66	51	
12:17:26	51	66	51	
12:17:27	53	66	51	
12:17:27	50	66	51	
12:17:28	48	66	51	
12:17:28	51	66	51	
12:17:29	51	66	51	
12:17:29	50	66	51	
12:17:30	52	66	51	
12:17:30	62	66	51	
12:17:31	51	66	51	
12:17:31	51	66	51	
12:17:32	52	66	51	
12:17:32	51	66	51	
12:17:33	51	66	51	
12:17:33	53	66	51	
12:17:34	60	66	51	
12:17:34	51	66	51	
12:17:35	51	66	51	
12:17:35	51	66	51	
12:17:36	51	66	51	
12:17:36	60	66	52	
12:17:37	54	66	52	
12:17:37	55	66	52	
12:17:38	52	66	52	
12:17:38	55	66	52	
12:17:39	53	66	52	
12:17:39	55	66	52	
12:17:40	51	66	52	
12:17:40	54	66	52	
12:17:41	54	66	52	
12:17:41	52	66	52	
12:17:42	53	66	52	

12:17:42	53	66	52	
12:17:43	55	66	52	
12:17:43	52	66	52	
12:17:44	61	66	52	
12:17:44	54	66	52	
12:17:45	49	66	52	
12:17:45	50	66	52	
12:17:46	51	66	52	
12:17:46	55	66	52	
12:17:47	52	66	52	
12:17:47	65	66	52	
12:17:48	60	66	52	
12:17:48	62	66	52	
12:17:49	55	66	53	
12:17:49	51	66	52	
12:17:50	51	66	52	
12:17:50	52	66	52	
12:17:51	50	66	52	
12:17:51	50	66	52	
12:17:52	52	66	52	
12:17:52	51	66	52	
12:17:53	50	66	52	
12:17:53	52	66	52	
12:17:54	53	66	52	
12:17:54	54	66	52	
12:17:55	51	66	52	
12:17:55	50	66	52	
12:17:56	52	66	52	
12:17:56	54	66	52	
12:17:57	53	66	52	
12:17:57	49	66	52	
12:17:58	53	66	52	
12:17:58	54	66	52	
12:17:59	53	66	52	
12:17:59	51	66	52	
12:18:00	49	66	52	
12:18:00	62	66	52	
12:18:01	60	66	52	
12:18:01	60	66	52	
12:18:02	52	66	52	
12:18:02	61	66	53	
12:18:03	54	66	53	
12:18:03	51	66	52	
12:18:04	52	66	52	
12:18:04	52	66	52	
12:18:05	60	66	53	
12:18:05	61	66	53	
12:18:06	54	66	53	
12:18:06	47	66	53	
12:18:07	60	66	53	
12:18:07	50	66	53	
12:18:08	52	66	53	
12:18:08	52	66	53	
12:18:09	50	66	53	

12:18:09	47	66	53	
12:18:10	49	66	52	
12:18:10	48	66	52	
12:18:11	48	66	52	
12:18:11	48	66	52	
12:18:12	47	66	52	
12:18:12	50	66	52	
12:18:13	52	66	52	
12:18:13	50	66	52	
12:18:14	50	66	52	
12:18:14	50	66	52	
12:18:15	51	66	52	
12:18:15	48	66	52	
12:18:16	50	66	52	
12:18:16	51	66	52	
12:18:17	48	66	52	
12:18:17	49	66	52	
12:18:18	55	66	52	
12:18:18	61	66	52	
12:18:19	55	66	52	

This Fig. 18 below shows the sound estimation of the empty Classroom with the door open and it is measured using the 'B' frequency weighting.

Fig 18: Graphically representation of background Noise estimated within an empty classroom (Door open)

The data below gives a download of the variation in the sound level showing the peak, Maximum and Average sound heard in decibels. The 'B' frequency shown in this data gives a mid-range between the 'A' which reflects the human ear response to noise and 'C' the standard weighting measurement used for peak Sound Pressure level and higher level measurement.

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TABLE 2: DATA ANALYSIS OF BACKGROUND NOISE ESTIMATED WITHIN ONE MINUTE TIME RECORDED IN AN EMPTY CLASSROOM WITH THE DOOR OPEN.

Time	Current (dB-B)	Max (dB-B)	Average (dB-B)
12:18:32	44	66	44
12:18:33	57	66	50
12:18:33	61	66	54
12:18:34	61	66	55
12:18:34	57	66	56
12:18:35	58	66	56
12:18:35	56	66	56
12:18:36	62	66	57
12:18:36	59	66	57
12:18:37	58	66	57
12:18:37	61	66	57
12:18:38	62	66	58
12:18:38	62	66	58
12:18:39	62	66	58
12:18:39	60	66	58
12:18:40	60	66	58
12:18:40	61	66	58
12:18:41	58	66	58
12:18:41	60	66	58
12:18:42	59	66	58
12:18:42	59	66	58
12:18:43	57	66	58
12:18:43	59	66	58
12:18:44	58	66	58
12:18:44	59	66	58
12:18:45	57	66	58
12:18:45	62	66	58
12:18:46	61	66	58
12:18:46	58	66	58
12:18:47	59	66	58
12:18:47	58	66	58
12:18:48	59	66	58
12:18:48	62	66	58
12:18:49	61	66	59
12:18:49	57	66	58
12:18:50	63	66	59
12:18:50	60	66	59
12:18:51	59	66	59
12:18:51	59	66	59
12:18:52	57	66	59
12:18:52	56	66	58
12:18:53	55	66	58
12:18:53	62	66	58
12:18:54	58	66	58
12:18:54	56	66	58
12:18:55	58	66	58
12:18:55	61	66	58
12:18:56	63	66	58
12:18:56	59	66	58
12:18:57	60	66	59

12:18:57	61	66	59
12:18:58	60	66	59
12:18:58	57	66	59
12:18:59	56	66	58
12:18:59	60	66	58
12:19:00	61	66	59
12:19:00	62	66	59
12:19:01	57	66	59
12:19:01	58	66	59
12:19:02	58	66	59
12:19:02	57	66	58
12:19:03	58	66	58
12:19:03	56	66	58
12:19:04	58	66	58
12:19:04	55	66	58
12:19:05	56	66	58
12:19:05	55	66	58
12:19:06	52	66	58
12:19:06	53	66	58
12:19:07	55	66	58
12:19:07	52	66	58
12:19:08	52	66	58
12:19:08	57	66	58
12:19:09	53	66	58
12:19:09	56	66	58
12:19:10	56	66	58
12:19:10	55	66	58
12:19:11	57	66	58
12:19:11	58	66	58
12:19:12	55	66	58
12:19:12	55	66	58
12:19:13	56	66	58
12:19:13	57	66	58
12:19:14	59	66	58
12:19:14	58	66	58
12:19:15	55	66	57
12:19:15	57	66	57
12:19:16	58	66	57
12:19:16	56	66	57
12:19:17	55	66	57
12:19:17	60	66	57
12:19:18	58	66	57
12:19:18	57	66	57
12:19:19	60	66	57
12:19:19	59	66	57
12:19:20	59	66	57
12:19:20	56	66	57
12:19:21	60	66	57
12:19:21	59	66	57
12:19:22	55	66	57
12:19:22	61	66	57
12:19:23	56	66	57
12:19:23	58	66	57
12:19:24	62	66	58

12:19:24	59	66	58
12:19:25	56	66	57
12:19:25	53	66	57
12:19:26	53	66	57
12:19:26	52	66	57
12:19:27	60	66	57
12:19:27	53	66	57
12:19:28	53	66	57
12:19:28	57	66	57
12:19:29	59	66	57
12:19:29	59	66	57
12:19:30	55	66	57
12:19:30	54	66	57
12:19:31	54	66	57
12:19:31	56	66	57
12:19:32	53	66	57
12:19:32	54	66	57
12:19:33	58	66	57
12:19:33	57	66	57

Finally, the measurement from the corridor taken with heavy traffic to know the average peak at which the noise gets to during schooling hours when students are learning. This fig. 19 shows the graphical representation of the sound measurement within the one minute recorded. The Noise is measured in 'Z' frequency weighting which indicate no frequency weighting

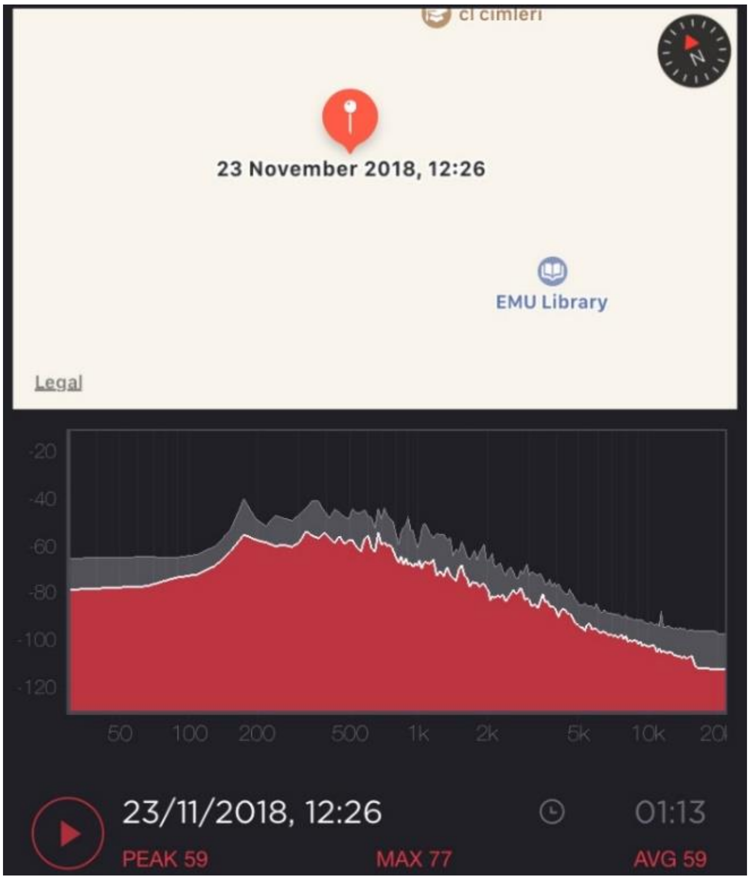

Fig 19: Graphically representation of Noise and sound pressure level estimated at the corridor with Heavy student traffic.

The data is to support the fig 19 above showing the variation in sound level at various time recorded and also indicating the current, Maximum and peak sound level at the various times.

TABLE 3: DATA ANALYSIS OF NOISE LEVEL OR SOUND PRESSURE LEVEL ESTIMATED AT THE CORRIDOR WITH HEAVY STUDENT TRAFFIC

Time	Current (dB-Z)	Max (dB-Z)	Average (dB-Z)
12:26:50	58	77	58
12:26:50	61	77	59
12:26:51	60	77	59
12:26:51	60	77	59
12:26:52	66	77	61
12:26:52	67	77	62
12:26:53	70	77	63
12:26:53	63	77	63
12:26:54	62	77	63
12:26:54	71	77	63
12:26:55	67	77	64
12:26:55	69	77	64
12:26:56	66	77	64
12:26:56	67	77	64
12:26:57	65	77	64
12:26:57	60	77	64
12:26:58	63	77	64
12:26:58	64	77	64
12:26:59	59	77	64
12:26:59	70	77	64
12:27:00	70	77	64
12:27:00	68	77	64
12:27:01	65	77	64
12:27:01	65	77	64
12:27:02	63	77	64
12:27:02	63	77	64
12:27:03	62	77	64
12:27:03	62	77	64
12:27:04	63	77	64
12:27:04	60	77	64
12:27:05	63	77	64
12:27:05	61	77	64
12:27:06	62	77	64
12:27:06	60	77	63
12:27:07	61	77	63
12:27:07	63	77	63
12:27:08	64	77	63
12:27:08	65	77	63
12:27:09	62	77	63
12:27:09	65	77	63
12:27:10	63	77	63
12:27:10	67	77	63
12:27:11	65	77	63
12:27:11	63	77	63
12:27:12	61	77	63
12:27:12	60	77	63
12:27:13	63	77	63
12:27:13	61	77	63
12:27:14	61	77	63
12:27:14	64	77	63

12:27:15	62	77	63
12:27:15	61	77	63
12:27:16	61	77	63
12:27:16	61	77	63
12:27:17	63	77	63
12:27:17	60	77	63
12:27:18	60	77	63
12:27:18	60	77	63
12:27:19	58	77	63
12:27:19	55	77	63
12:27:20	56	77	62
12:27:20	61	77	62
12:27:21	63	77	62
12:27:21	59	77	62
12:27:22	60	77	62
12:27:22	60	77	62
12:27:23	62	77	62
12:27:23	60	77	62
12:27:24	59	77	62
12:27:24	60	77	62
12:27:25	57	77	62
12:27:25	58	77	62
12:27:26	58	77	62
12:27:26	59	77	62
12:27:27	57	77	62
12:27:27	58	77	62
12:27:28	55	77	62
12:27:28	58	77	62
12:27:29	56	77	62
12:27:29	63	77	62
12:27:30	56	77	61
12:27:30	54	77	61
12:27:31	55	77	61
12:27:31	55	77	61
12:27:32	54	77	61
12:27:32	53	77	61
12:27:33	55	77	61
12:27:33	59	77	61
12:27:34	60	77	61
12:27:34	59	77	61
12:27:35	56	77	61
12:27:35	59	77	61
12:27:36	57	77	61
12:27:36	58	77	61
12:27:37	59	77	61
12:27:37	58	77	61
12:27:38	56	77	61
12:27:38	56	77	61
12:27:39	57	77	61
12:27:39	55	77	60
12:27:40	59	77	60
12:27:40	57	77	60
12:27:41	56	77	60
12:27:41	57	77	60

12:27:42	58	77	60
12:27:42	56	77	60
12:27:43	58	77	60
12:27:43	57	77	60
12:27:44	55	77	60
12:27:44	59	77	60
12:27:45	59	77	60
12:27:45	58	77	60
12:27:46	58	77	60
12:27:46	59	77	60
12:27:47	59	77	60
12:27:47	56	77	60
12:27:48	56	77	60
12:27:48	54	77	60
12:27:49	58	77	60
12:27:49	57	77	60
12:27:50	56	77	60
12:27:50	57	77	60
12:27:51	60	77	60
12:27:51	59	77	60
12:27:52	61	77	60
12:27:52	58	77	60
12:27:53	56	77	60
12:27:53	55	77	60
12:27:54	56	77	60
12:27:54	60	77	60
12:27:55	57	77	60
12:27:55	58	77	60
12:27:56	57	77	60
12:27:56	59	77	60
12:27:57	59	77	60
12:27:57	58	77	60
12:27:58	60	77	60
12:27:58	62	77	60
12:27:59	58	77	60
12:27:59	59	77	60
12:28:00	55	77	60
12:28:00	58	77	59
12:28:01	58	77	59
12:28:01	57	77	59
12:28:02	58	77	59
12:28:02	61	77	59
12:28:03	58	77	59
12:28:03	56	77	59
12:28:04	59	77	59

From the result above, the Noise level entering the Classroom is quite high enough to distract a student learning and the sit-out extending all the way to the set back from the Major road creates a lot of noise which must be blocked from entering the Classroom.

Looking at the plans in Fig. 4, 5 and 6, the design is good enough and the location of the building even though it is just Satisfactory but it is justifiable based on the university Planning and North Cyprus building Regulation. The only defect is the choice of materials and finishes and I will propose a more acoustical pleasing approach to the area needed.

The walls, ceiling and floor finishes and material can be adjusted right from the design stage to achieve acoustic comfort if the building location is justifiable as stated earlier. The following are materials suitable to use for the ceiling, walls and floor to cancel the noise at the source or give acoustic comfort.

For the Classroom ceiling;

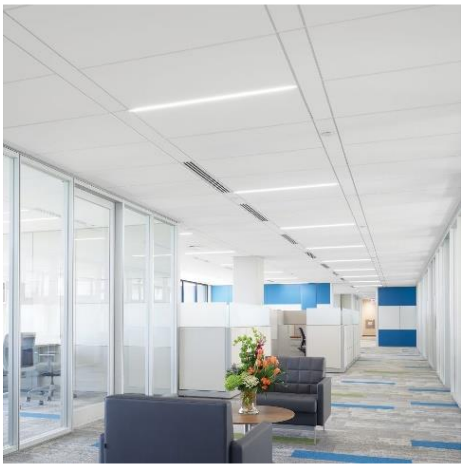

Fig 20: Calla High CAC

This is a Ceiling material from Armstrong with acoustic comfort qualities and the features include;

TABLE 4: TECHNICAL SPECIFICATION OF CALLA HIGH CAC

Sound Absorption (NRC)	0.80
Sound Blocking (CAC)	40
Articulation Class (AC)	170
Light Reflectance	86%
Sag/Humidity Resistance	HumiGuard Plus
Fire Performance	Class A
Durability	Soil Resistance, Impact Resistance, Scratch Resistance, Wash

For the Classroom walls;

Fig 21: OPTIMA walls

TABLE 5: TECHNICAL SPECIFICATION OF OPTIMA WALL

NRC Rating A Mounting	0.80
NRC Rating D-20 Mounting	0.90
Recycled Content	71%
Materials	Fiberglass, PVC
Surface Finish	Painted
Fire Performance	Class A (UL)

Corridor finishes and Materials

For Corridor Ceiling;

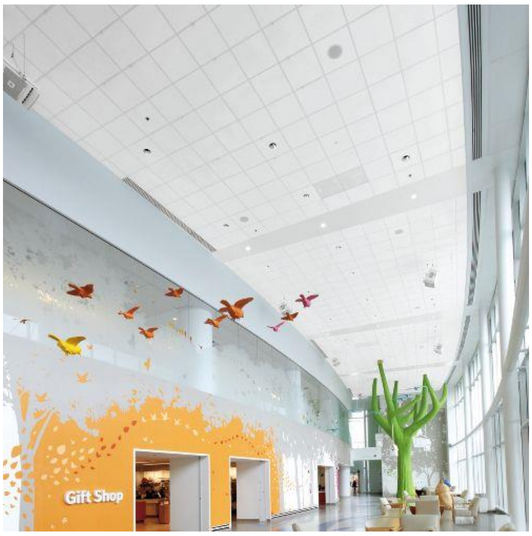

Fig 22: OPTIMA Lay-In and Tegular

TABLE 6: TECHNICAL SPECIFICATION OF OPTIMA LAY-IN AND TEGULAR

Sound Absorption (NRC)	**Up to 1.00**
Sound Blocking (CAC)	26
Articulation Class (AC)	Up to 200
NRC Rating A Mounting	0.80
NRC Rating D-20 Mounting	0.90
Light Reflectance	90%
Recycled Content	Up to 71%
Sag/Humidity Resistance	HumiGuard Plus
Fire Performance	Class A, Class A (UL)
Durability	Soil Resistance, Impact Resistance, Scratch Resistance, Washability

For Corridor walls

Fig 23: SOUNDSOAK 60 - FR-701

TABLE 7: TECHNICAL SPECIFICATION OF SOUNDSOAK 60 - FR-701

NRC Rating A Mounting	**0.65**
NRC Rating D-20 Mounting	0.75
Recycled Content	68%
Materials	Metal, Mineral Fiber, PVC, Wood
Surface Finish	Painted, Ultra-violet clear semi-gloss coating, Woven fabric
Fire Performance	25 or less

For corridor Floor;

Fig 24: Sarlon Acoustic Vinyl

This is a floor Material from FORBO floor system to achieve acoustic comfort by reducing or eliminating the impact sound cause by footstep.

TABLE 8: TECHNICAL SPECIFICATION OF SARLON ACOUSTIC VINYL

Total thickness	EN-ISO 24346	2.6 mm	3.4 mm
Wear layer thickness	EN-ISO 24340	0.70 mm	0.67 mm
Total weight	EN-ISO 23997	2,700 g/m2	2,900 g/m2
Impact sound reduction	EN-ISO 717-2	ΔLw = 15 dB	ΔLw = 19 dB
In-room impact noise	NF S 31-074	Ln,e,w < 65 dB, Class A	Ln,e,w < 65 dB, Class A
Sound absorption	EN-ISO 354 EN-ISO 11654	αw = • } 0,05	αw = • } 0,05
Residual indentation (Typical value) *Requirement*	EN-ISO 24343-1	~0.05 mm *≤ 0,20 mm*	~0.08 mm *≤ 0,20 mm*
Slip resistance	DIN 51130	R9	R9
Abrasion resistance	EN 660-2	T	T
Specifications Commercial use Light industrial use	 EN-ISO 10874 EN-ISO 10874	EN 651 34 42	EN 651 34 42

In conclusion, these materials have been tested and used in various university especially in US which aided achieving acoustic comfort and adding this materials to the choice of material list at the design and construction stage will create a more Acoustical Architectural design for the Central Lecture Hall. Also, the good use of Natural barriers will be very effective when added to the materials above.

Shady Trees and sufficient set back along the Major and Minor road will reduce noise from the roads which is a major source of noise especially when cars are accelerating the hilly roads and the Shady trees if planted will serve as a good shade for the sit-out along the setback instead of the umbrella used presently.

Sound insulation walls should be used both for the exterior walls and interior partition walls of classrooms close to stairs as this will help to lose some level of noise transmitted through Air-borne noise source and structure borne noise source

Finally the windows and door should be air tight and shut whenever there is a class and the doors should have anti Slam hinges and door stopper to avoid noise from slamming/closing of door and for automatic closing of opened doors. During this period the Air conditioning equipment can be used for Heating, ventilation and air conditioning in the Classroom Space.

5. CONCLUSION

The design for acoustic comfort should be implemented at the design stage up to construction to precisely utilize the available Nature and adequate selection of Materials, equipment and finishes to be used. The Eastern Mediterranean University is well planned and from the result above the average Noise level within can be controlled from the sources just by proper selection of materials and good use of trees. The major and minor road is not frequently busy because it is not a road accessing any of the school gates and a bit far from the main school gate and once the lecturers and students have packed their cars, they properly don’t move around the road till the break time. Also, the only inevitable noise are from students Loud conservation, Phone calls and impact noise of students walking both around the building and internally within the corridor and this can easily be controlled with selection of good acoustical material as cited above to provide a healthy and acoustically comfortable environment for student to learn and participate effectively in class.

Active means can also be implemented in a case where the General principle, Natural barriers and material choice is not sufficient enough to subside or cancel excess noise but this should be the last result because these are not architectural solutions to achieve Acoustic comfort.

Active Noise Control (ANC) or Active structural acoustic control (ASAC) is more expensive to install and maintain than the Architectural approach with is why as Architects we should not depend solely on mechanical solutions as our purpose is to solve problems through Architectural designs not create more and also design cost effective and energy efficient buildings

According to NIOSH sound level Standard 85 dB(A) of prolonged exposure becomes hazardous to the human health but looking at the result in Fig. 17 of the typical Empty classroom with the door shut; the noise level are low and less harmful to the human health. Based on the NIOSH Standard, 52 dB which is the average sound level measured in fig 17 is classified as “**Quite Home”** which indicates that the noise level is quite enough to live in and be comfortable on a general basis of human comfort.

Finally, Acoustic comfort is very important in every space and every type of building even in auditorium when music concert are hosted because sound is very powerful and can either inspire you to want more or annoy you by causing discomfort. Sound has a way of affecting the brain, mind and soul positively or negatively so Architect must design for occupants to feel at home rather than causing discomfort which hinders the function of the space. This is why Acoustic Comfort should be one of the necessities when designing a building so as to achieve a very functional and effective space or building.

REFERENCES

[1] Berendt. Raymond D.; And Others. A Guide to Airborne. Impact and Structure Borne Noise Control in Multifamily Dwellings 1967. 4-1, 2, 3: 5 1-10

[2] Blaise Kelly, Danilo Hollosi, Philippe Cousin, Sergio Leal, Branislav Iglár, Andrea Cavallaro. Application of Acoustic Sensing Technology for improving Building Energy Efficiency 2014. 662

[3] Wikipedia.com 2018

[4] Saint-Gobain designs. Acoustic Comfort 2018. https://multicomfort.saint-gobain.com/comforts-and-solutions/acoustic-comfort

[5] BRANZ bulletin. Controlling Noise through design and Layout. http://www.level.org.nz/passive-design/controlling-noise/ 2017

[6] S. Monteiro da Silva, M. Guedes de Almeida. Thermal and Acoustic Comfort in buildings 2010.1-10

[7] Gail S. Brager. Benefits of Improving Occupant Comfort and Well-being in Buildings. 182, 183, 184

[8] GSA Public Buildings Service. Sound Matters; How to achieve acoustic comfort in the contemporary office.

[9] EATON. Designing for Intelligibility & Energy Efficiency 2012- 2013

[10] Wave Motion. Noise Control in Architecture 2012. 1-14

[11] Good friend, L.S., "Noise in the Community "Noise Control, Vol.4, No. 2, (March 195b), pp. 22-28.

[12] Seelbach, Jr., H., and Oran, F.M., "What to Do about Cooling-Tower Noise", Sound, Vol. 2, No. 5, (September-October 1963), pp.32-41.

[13] Mikeska, E.E., "Noise in the Modern Home", Noise Control, Vol. 4, No. 3, (May 1958), pp. 38-41.

[14] Veneklasen, P.S., "City Noise – Los Angeles", Noise Control Vol. 2, No. 4, (July 1956), pp. 14-19.

[15] Callaway, D.B., "Spectra and Loudnesses of Modern Automobile Horns", The Journal of the Acoustical Society of America, Vol. 23, No.1, (January 1951), pp.55-58.

[16] Harris, Cyril M. Noise Control in Buildings: A Practical Guide for Architects and Engineers. New York: McGraw-Hill, 1993.

[17] EU FP7 Project S4ECoB - Sounds for Energy Control of Buildings (ID 284628). Online: http://www.s4ecob.eu/.

[18] EU FP7 Project EAR-IT - Experimenting Acoustics in Real environment using Innovative Test-beds. (ID 318381). Online: http://www.ear-it.eu/.

[19] ZHANG, H., ARENS, E.A., KIM, D., BUCHBERGER, E., BAUMAN, F.S. and HUIZENGA, C., 2010. Comfort, perceived air quality, and work performance in a low-power task–ambient conditioning system. Building and Environment, 45(1), pp.29

[20] Cavanaugh, W.J., G.C. Tocci, J.A. Wilkes. Architectural Acoustics: Principles and Practice. 2nd Ed. New York: Wiley, 2009.

[21] Egan, M.D., Architectural Acoustics. Fort Lauderdale: J. Ross Publishing, 2007; originally New York: McGraw Hill 1988.

[22] GSA PBS P-100 Acoustic Standards

[23] Northwood, T.D., "Sound Insulation and, the Apartment Dweller", the Journal of the Acoustical Society of America, Vol. 36, No. 4, (April 1964), pp. 725-728.

[24] Parkin, P.H., and Humphreys, H.R., Acoustics, Noise and Buildings, (New York: Frederick A. Praeger, 1958).

[25] IMAGINE: EC PROJECT FUNDED Improved methods for assessment of the Generic Impact of Noise in the Environment, Technical Report WP 1.1: Source modelling of road vehicles, 2003.

[26] M. De Grassi, B. Naticchia and A. Carbonari. Design And Development Of an Active Controlled Window With High Sound Transmission Loss 2007.

[27] Berardo Naticchia, Alessandro Carbonari. Feasibility analysis of an active technology to improve acoustic comfort in buildings 2006. pp 2785, 2786

[28] Oral GK, Yener AK, Bayazit NT. Building envelope design with the objective to ensure thermal, visual and acoustic comfort conditions. Building and Environment 2004; 39:281–7.

[29] Kruger EL, Zannin PHT. Acoustic, thermal and luminous comfort in classrooms. Building and Environment 2004; 39:1055–63.

[30] Fuller CR, Elliott SJ, Nelson PA. Active Control of Vibration. 2nd Ed. San Diego-London-Boston-New York: Academic Press; 1997.

[31] Bullmore AJ, Nelson PA, Curtis ARD, Elliot SJ. The active minimization of harmonic enclosed sound fields, Part II: a computer simulation. Journal of Sound and Vibration 1987; 117(1):15–33.

[32] Harris CM. Handbook of Acoustical Measurements and Noise Control. 3rd Ed. New York: McGraw-Hill; 1984.

[33] Fahy F. Sound and structural vibration: radiation, transmission and response. London, San Diego, New York, Berkeley, Boston, Sydne, —Tokyo, Toronto: Academic Press; 1985.

[34] Beranek, L.L. *Noise Reduction*. New York: Wiley, 1960.

[35] Institute of Noise Control Engineering of the USA, www.inceusa.org

[36] International Organization for Standardization. ISO 12913-1:2014 Acoustics Soundscape - Part 1: Definition and conceptual framework. Geneve: ISO; 2014

[37] Ballas JA. Common factors in the identification of an assortment of brief everyday sounds. Journal of Experimental Psychology; 1993. 19, p. 250-267.

[38] Yu CJ, Kang J. Science of The Total Environment, Soundscape in the sustainable living environment: A cross-cultural comparison between the UK and Taiwan; 1 June 2014. p. 482-483 p.501-509

[39] Johansson A, Hammer P, Nilsson E.. Prediction of Subjective Response from Objective Measurements Applied to Walking Sound. Acta Acustica united with Acustica; 2004. 90, p.161-170.

[40] CEN, European Standard EN 12354-1: Building Acoustics – Estimation of Acoustic performance of buildings from the performance of elements – Airborne sound insulation between rooms, Belgium 2002.

[41] CEN, European Standard EN 12354-2: Building Acoustics – Estimation of Acoustic performance of buildings from the performance of elements – Impact sound insulation between rooms, Belgium 2002.