MEASUREMENT AND EVALUATION OF THE REVERBERATION TIME FOR CLASSROOMS IN UTEM

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I declare that this thesis entitled "*Measurement and Evaluation of Reverberation Time for Classrooms in UTEM* " is the result of my own research except as cited in the references.

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ABSTRACT

Reverberation time is important in achieving the standard speech intelligibility during lectures in UTeM's classroom. Basically, RT_{60} means the time for a sound to decay 60 dB. The decaying of sound will be affected by the materials used in the classroom, the noise level background and the size of the classroom itself. The reverberation time must not exceed the ANSI S12.60-2002 standard which is 0.6 or 0.7 second depending on the classroom sizes. In order to achieve this standard, calculation and measurement need to be done on a selection of UTeM's classroom and will be compared to the standard. The measurements will based on the ASTM E336-97 testing standard in order to get accurate results. As a conclusion to this project, the reverberation time for UTeM's classroom does not achieve the ANSI S12.60-2002 standard.

ABSTRAK

Masa gema adalah penting dalam usaha mencapai piawaian kebolehupayaan mendengar syarahan di dalam bilik kuliah di UTeM. Secara amnya, RT60 bermaksud masa yg diambil untuk menurunkan frekuensi bunyi sebanyak 60 desibel (dB). Penurunan ini juga disebabkan oleh jenis bahan yang digunakan di dalam bilik kuliah, tahap kebisingan latarbelakang, dan juga saiz bilik kuliah tersebut. Masa gema haruslah tidak melebihi masa yang telah ditetapkan oleh piawaian antarabangsa ANSI S12.60-2002 iaitu 0.6 saat untuk kelas bersaiz kecil dan 0.7 untuk kelas bersaiz sederhana. Bagi mencapai tahap piawaian ini, pengiraan dan pengukuran hendaklah dibuat di bilik kuliah yang telah dipilih dan akan dibandingkan dengan tahap piawaian ANSI S12.60-2002. Proses pengukuran akan dijalankan mengikut piawaian ASTM E336-97 dalam mencapai keputusan yang lebih jitu. Sebagai kesimpulan kepada projek ini, didapati bahawa masa gema bagi bilik kuliah di UTeM tidak menepati piawaian antarabangsa ANSI S12.60-2002.

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TABLE OF CONTENTS

DECLARATION	i
ABSTRACT	ii
ABSTRAK	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	v
LIST OF TABLE	viii
LIST OF FIGURE	ix

CHAPTER 1: INTRODUCTION

1.1	Project Introduction	1
1.2	Problem Statement	2
1.3	Project Objective	3
1.4	Project Scope	3
1.5	Report Structure	4
1.6	Gantt Chart	5

CHAPTER 2: LITERATURE REVIEW

2.1	Reverberation Time	7
	2.1.1 Rationale for 60 db Reverberation Time	9
	2.2 Speech Intelligibility	10
2.3	A-weighted Curve	12
2.4	Background Noise Level	13
2.5	Sound Propagation	14
	2.5.1 Direct Sound	14
	2.5.2 Reflection	14
	2.5.3 Diffraction	14
2.6	The Sabine Equation	16
2.7	Absorption Coefficient	17
2.8	ANSI S12.60-2002	19

CHAPTER 3: RESEARCH METHODOLOGY

3.1	Selecting Measurement Location	21
3.2	Reverberation Time by Calculation	23
3.3	Reverberation Time by Measurement	24
3.4	Experimental Setup	25
	3.4.1 Omni directional Calibrated Microphone	26
	3.4.2 Signal Conditioning	27
	3.4.2.1 Pre-Amp	27
	3.4.2.2 Analog-to-Digital Converter (ADC)	28
	3.4.3 Data Acquisition System (DAQ)	29
	3.4.4 Audacity Procedures	30

3.4.5 Experiment Procedure 31

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Experiments Results 33
4.1.1 BK6 Results 33
4.1.2 BK10 Results 36
4.2 Calculation Results 42
4.2.1 BK6 Calculation 42
4.2.2 BK10 Calculation 43
4.3 Discussion 45
4.3.1 Problems Encountered 46
4.3.2 Implication of the Result 47
4.3.3 Recommendation 47

CHAPTER 5: CONCLUSION 48

REFERENCES 49

LIST OF TABLE

TABLE	TITLE	PAGE
1	Absorption Coefficient of Materials	12
2	Maximum A-weighted steady background noise levels and maximum reverberation times in unoccupied, furnished learning spaces	18
3	Recommended approximate heights	21
4	Interpolation Data for First Position in BK6	33
5	Interpolation Data for Second Position in BK6	34
6	Interpolation Data for Third Position in BK6	35
7	Interpolation Data for Fourth Position in BK6	36
8	Interpolation Data for First Position in BK10	38
9	Interpolation Data for Second Position in BK10	39
10	Interpolation Data for First Position in BK10	40
11	Interpolation Data for Fourth Position in BK10	41
12	Comparison Data between Measured, Calculated and ANSI S12.60-2002	44

LIST OF FIGURE

FIGURE	TITLE	PAGE
1	Sound Propagation	8
2	Relative Sound Level vs Time	10
3	SPL of Speech at 1 m	15
4	A-,B-,C- Weighting Functions	16
5	Experiment Setup Diagram	24
6	A sample of Omni Directional Microphone	25
7	A Sample of Pre-Amp	26
8	Sampling Rates	27
9	A sample of DAQ Device	28
10	Classroom Setup for BK6	31
11	Classroom Setup for BK10	31
12	Measured Data for First Position in BK6	33
13	Measured Data for Second Position in BK6	34
14	Measured Data for Third Position in BK6	35
15	Measured Data for Fourth Position in BK6	36
16	Measured Data for First Position in BK10	37
17	Measured Data for Second Position in BK10	38
18	Measured Data for Third Position in BK10	39
19	Measured Data for Fourth Position in BK10	40

CHAPTER1

INTRODUCTION

1.1 Project Introduction

Good acoustical qualities are essential in classrooms and other learning spaces in which speech communication is an important part of the learning process. Excessive background noise or reverberation in such spaces interferes with speech communication and thus presents an acoustical barrier to learning. With good classroom acoustics, learning is easier, deeper, more sustained, and less fatiguing. Teaching should be more effective and less stressful with good acoustical characteristics in a classroom. There can be more verbal interaction and less repetition between teacher and students when spoken words are clearly understood.

1.2 Problem Statement

Primarily, classrooms instruction is presented through the teacher's speech or through video or tape recordings. According to the Signal to Noise Ratio (S/N), normal people will have +6dB S/N which mean the speech signal must be 6dB louder than the background disturbance in other for it to be understand. One way to improve the teaching and learning in class is that to increase the volume of the teacher's voice over the background noise.

American Speech-Language-Hearing Association (ASHA) recommends that the teacher's voice should be 15dB above the background noise in a classroom. From previous reports that have been studied, the actual range of S/N in a classroom is +5dB to +7dB. Unfortunately, the background noise, teacher's location and reverberation could vary the range from -20dB to +5db. This poor listening environment due to S/N ratios could effect the student's concentration.

In order to achieve the S/N classroom standard, the reverberation time needs to be measured. Background disturbance could lead to students loosing their attention while learning. This will effect their exam grades thus will not create a high quality of UTEM's graduates. As a university that has a high potential in making big names, the standards of reverberation time in UTEM's classrooms should be taken seriously.

1.3 Project Objective

The objective of this project is to measure the reverberation time for classrooms in UTEM whether it achieves the standard reverberation time for classrooms specified by ANSI S12.60-2002. The quality of teaching and learning in classrooms is important in order to achieve the UTEM's vision which is to be one of the world's leading innovative and creative technical universities. Besides that, the purpose of this project is to suggest improvements that need to be made to the classrooms.

1.4 Project Scope

Initially, the problem statement of this project is determined which is to achieve the standard speech intelligibility during lectures in UTEM's classrooms. For that, research and some studies about basic acoustics generally and reverberation time especially need to be done. Previous works done will be taken as guideline in doing this project. Measurements will be taken by setting up experiments in classrooms using basic method of measuring the reverberation time. Software such as Audacity will be used in doing the measurement and evaluation. Finally, suggestions in improving the classroom reverberation time according to ANSI S12.60-2002 standard will be made.

1.5 Report Structure

Chapter 1 covers the project objective and scope thoroughly. This includes the problem statements of the project on why does this project need to be carried out. The flow process of making this report is also explained in this chapter with the help of a gantt chart.

Chapter 2 elaborates more about the basic terms of acoustics such as definitions and other theory. This chapter will also explain in details about reverberation time definition, terms for reverberation time that need to be considered, ANSI S12.60-2002 standard and the formulas used in calculating reverberation time.

Chapter 3 presents the method in calculating and measuring the reverberation time, previous measurement method and the measurement equipments that will be used in this project.

Chapter 4 will provide the experiment findings, calculation and comparison between the measurements that have been done and ANSI S12.60-2002 standard. Also in this chapter, discussions have been made on problems encountered and recommendations in improving the reverberation time.

Chapter 5 is the overall conclusion of the project done which is to measure reverberation time in UTeM's classroom.

1.6 Gantt Chart

PSM 1 (July 2007 - September 2007)

ACTIVITIES	WEEK															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TITLE SELECTION	■															
TITLE CONFIRMATION		■	■													
OBJECTIVES & SCOPE				■	■											
PROBLEM STATEMENT				■	■											
LITERATURE REVIEW				■	■	■	■	■	■	■						
METHODOLOGY							■	■	■							
CONCLUSIONS										■						
SUBMIT DRAFT REPORT											■					
SUBMIT FULL REPORT												■				
PRESENTATION																■

PSM 2 (January 2008 – March 2008)

ACTIVITIES	WEEK															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LITERATURE REVIEW	■	■	■	■												
MEASUREMENT				■	■	■										
RESULT							■	■								
ANALYSIS									■	■						
DISCUSSION									■	■						
CONCLUSIONS											■					
SUBMIT DRAFT REPORT												■				
SUBMIT FULL REPORT													■			
PRESENTATION																■

CHAPTER 2

LITERATURE REVIEW

This chapter will provide the sound definition, the sounds characteristics, reverberation time and the international standards for reverberation time.

2.1 Sound Propagation

As sound spreads out in an enclosures, it meets obstacles: floor, ceiling, partitions (partial-height screens), light fixtures, furniture, etc. These obstacles change the path of the sound. When designing an open-plan room to block sound, designers must consider all of these paths. Figure 1 illustrates the possibility of sound propagates.

2.1.1 Direct Sound

Sound propagates outward in spheres. It spreads best when the line of sight is clear. Placing partitions between source and receiver blocks direct propagation paths.

2.1.2 Reflection

When propagating sound meets a barrier, some of the sound energy is reflected off the barrier (like light reflection). Sound waves can reflect off multiple surfaces, traveling all around the room. However, with each reflection the sound is attenuated because some energy is absorbed into each surface. Some surfaces are more sound reflective than others. Sound absorbent surfaces can reduce reflected sounds in the room.

2.1.3 Diffraction

Sound waves are able to bend over and around obstacles. However, the sound level attenuates as the sound waves bend. As the sharpness of the angle increases, the attenuation increases. For this reason, high, wide barriers block diffracted sound better than low, narrow barriers.

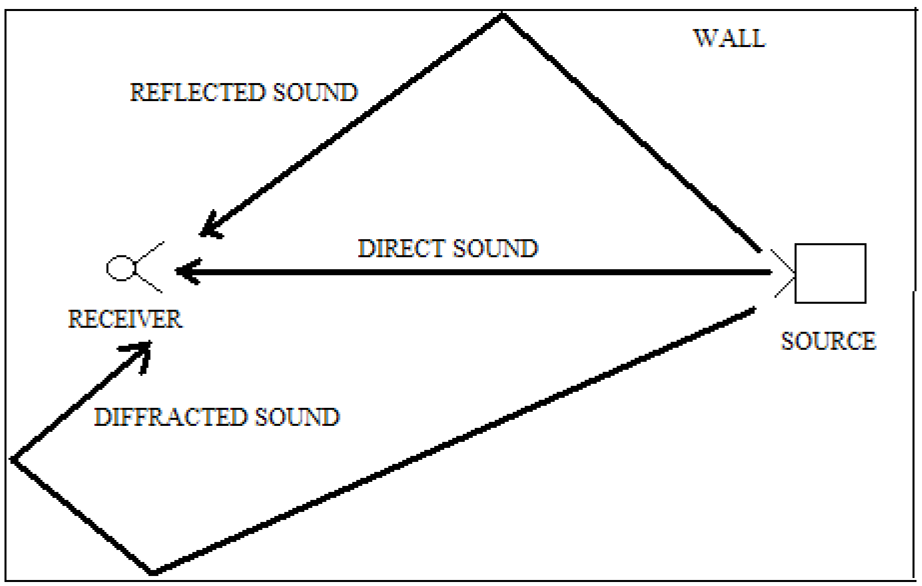

Figure 1: Sound Propagation

(Source: eng-upm.edu.my (2004))

2.2 Reverberation Time

Reverberation time is the time required for a sound in a room to decay by 60 dB (called RT_{60}). Reverberation time is defined for wide band signals. When talking about the decay of an individual frequency, the term decay time is used.

In the late 19th century, Wallace Clement Sabine started experiments at Harvard University to investigate the impact of absorption on the reverberation time (M. D. Egan, 1998). Using a portable wind chest and organ pipes as a sound source, a stopwatch and a clean pair of ears he measured the time from interruption of the source to inaudibility (roughly 60 dB). This time varies directly with the dimensions of room but inversely as the absorption present.

The best reverberation time for a space in which music is played depends on the size of the room and the type of music. Rooms for speech require a shorter reverberation time than for music. A longer reverberation time can make it difficult to understand speech. If the reverberation time from one syllable over laps the next syllable, it may make it difficult to identify the word "Cat", "Cab", and "Cap" may all sound very similar. If on the other hand the reverberation time is too short, tonal balance and loudness may suffer. Reverberation effects are often used in studios to "smooth" sounds; the effect is commonly used on vocals to help remove inconsistencies in pitch.

Basic factors that affect a room's reverberation time include the size and shape of the enclosure as well as the materials used in the construction of the room. Every object placed within the enclosure can also affect this reverberation time, including people and their belongings.

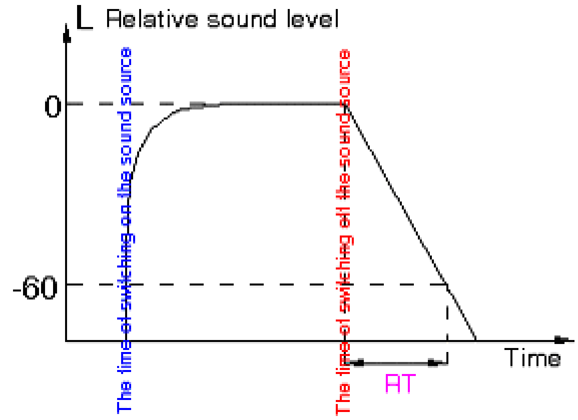

Figure 2: Relative Sound Level vs Time

(Source: Roomacoustics.com (2005))

2.2.1 The Sabine Equation

Sabine's reverberation equation was developed in the late 1890s in an empirical fashion. He established a relationship between the RT_{60} of a room, its volume, and its total absorption (S. Bistafa and J. Bradly,2000). This is given by the equation:

$$RT_{60} = \frac{c \cdot V}{\Sigma Sa} \tag{1}$$

Where:

c = a mathematical constant measuring 0.161

V = the volume of the room in m^3

S = total surface area of room in m^2

a = the average absorption coefficient of room surfaces

Sa = the total absorption in Sabine

It is worth noting that the total absorption in Sabine (and hence reverberation time) generally changes depending on frequency (dependent on which is defined by the acoustic properties of the space), and that the equation does not take into account room shape or dimensions, nor losses from the sound travelling through the air (important in larger spaces). In general most rooms absorb less in the lower frequencies, causing a longer decay time.

2.2.2 Absorption Coefficient

The absorption coefficient of a material is a number between 0 and 1 which indicates the proportion of sound which is absorbed by the surface compared to the proportion which is reflected back into the room. A large, fully open window would offer no reflection as any sound reaching it would pass straight out and no sound would be reflected. This would have an absorption coefficient of 1. Conversely, a thick, smooth painted concrete ceiling would be the acoustic equivalent of a mirror, and would have an absorption coefficient very close to 0 (E. Sala and V. Viljanen, (1995).

The effective absorbing area is a factor in determining the reverberation time of a room. The absorption coefficient of a surface typically changes with frequency, so the reverberation time is likewise frequency dependent. A table of absorption coefficients can be used in calculations of reverberation time with the Sabine Equation.

Table 1: Absorption Coefficient of Materials

(Source: hyperphysics.gsu.edu (2005))

	Sound Absorption Coefficients at frequency					
Nature of Surface	125	250	500	1000	2000	4000
Acoustic tile, rigid mount	0.2	0.4	0.7	0.8	0.6	0.4
Acoustic tile, suspended	0.5	0.7	0.6	0.7	0.7	0.5
Acoustical plaster	0.1	0.2	0.5	0.6	0.7	0.7
Ordinary plaster, on lath	0.2	0.15	0.1	0.05	0.04	0.05
Gypsum wallboard, 1/2" on studs	0.3	0.1	0.05	0.04	0.07	0.1
Plywood sheet, 1/4" on studs	0.6	0.3	0.1	0.1	0.1	0.1
Concrete block, unpainted	0.4	0.4	0.3	0.3	0.4	0.3
Concrete block, painted	0.1	0.05	0.06	0.07	0.1	0.1
Concrete, poured	0.01	0.01	0.02	0.02	0.02	0.03
Brick	0.03	0.03	0.03	0.04	0.05	0.07
Vinyl tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Heavy carpet on concrete	0.02	0.06	0.15	0.4	0.6	0.6
Heavy carpet on felt backing	0.1	0.3	0.4	0.5	0.6	0.7
Platform floor, wooden	0.4	0.3	0.2	0.2	0.15	0.1
Ordinary window glass	0.3	0.2	0.2	0.1	0.07	0.04
Heavy plate glass	0.2	0.06	0.04	0.03	0.02	0.02
Draperies, medium velour	0.07	0.3	0.5	0.7	0.7	0.6
Upholstered seating, unoccupied	0.2	0.4	0.6	0.7	0.6	0.6
Upholstered seating, occupied	0.4	0.6	0.8	0.9	0.9	0.9
Wood seating, unoccupied	0.02	0.03	0.03	0.06	0.06	0.05
Wooden pews, occupied	0.4	0.4	0.7	0.7	0.8	0.7

2.2.3 Rationale for 60 dB Reverberation Time

The reverberation time is perceived as the time for the sound to die away after the sound source ceases, but that of course depends upon the intensity of the sound. To have a reproducible parameter to characterize an auditorium which is independent of the intensity of the test sound, it is necessary to define a standard reverberation time in terms of the drop in intensity from the original level, i.e., to define it in terms of relative intensity (D. J. MacKenzie, 1999).

Intensive and continuous learning of social, intellectual, and communication skills occurs throughout childhood. A wide range of educational research studies has shown that learning is predicated on the ability to communicate with spoken language, and that language input and language proficiency form the bases for most cognitive skills.

Additionally, other research has shown that perception of spoken language provides the foundation for the ability to read and write. Communication with spoken language is essential to most classroom learning activities. Typically, as much as 60% of these activities involve students listening to and participating in spoken communications with the teacher and other students (C. V. Pavlovic, 1987). The central role of spoken language in classroom learning underscores the need for a clear communication channel accessible to all students and teachers.