Faculty of Mechanical Engineering

STUDY ON IMPROVING THE ACOUSTICS PERFORMANCE OF MASJID SAYYIDINA ABU BAKAR UTeM

Dg Hafizah Binti Kassim

Master of Science in Mechanical Engineering

2016

STUDY ON IMPROVING
THE ACOUSTICS PERFORMANCE OF
MASJID SAYYIDINA ABU BAKAR UTeM

DG HAFIZAH BINTI KASSIM

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled "Study on improving the acoustics performance of Masjid Sayyidina Abu Bakar UTeM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	: ....
Name	: ....
Date	: ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering

Signature	: ....
Supervisor Name	: ....
Date	: ....

DEDICATION

"To my parents, families and friends"

ABSTRACT

It has been known that the 'acoustics design' in most of mosques around the world is often neglected in the early design stage of the building. As a consequence, acoustics performance inside mosques is usually poor. The case includes the Sayyidina Abu Bakar Mosque in UTeM where poor speech intelligibility is experienced during congregation. The main objectives of this work are to investigate the root cause of the acoustic problem and to propose acoustic treatment to improve the acoustic quality inside the mosque. The latter is conducted through computer simulation. The measurement found that the mosque has considerably high reverberation time (RT60) at frequency below 1 kHz with the highest RT60 of 5.56 s at 500 Hz. The RT60 calculated from simulation is validated with this measured results and from the simulation, other acoustics parameters namely early decay time, clarity, definition and sound transmission index also indicate poor acoustic quality. This is due to the large volume of the mosque, and walls and ceiling mostly consist of reflective surfaces which cause late reflections of sound. These reflections, especially from the inclined roof, contribute to the high RT60 around the front area of the *minbar*. From simulation, the acoustic treatment using mineral wool absorber with a thickness of 25 mm installed on the inclined roof can reduce the RT60 to 3.25 s at 500 Hz. A Helmholtz resonator-like absorber to counter the problem at low frequency is also simulated using micro-perforated panel (MPP). This is also proposed to give a green absorber compared to the conventional synthetic absorber from fibrous absorber. It is found that installation of MPP on the inclined roof, can give better reduction of RT60 to 2.57 s at 500 Hz. Doubling the MPP separated with air gap is also found to further lower the RT60 to 2.32 s at 500 Hz. Dome shape effect has also been simulated to compare the pyramidal and spherical domes. The former is found to be the identical dome shape of mosques in Malacca, Malaysia. The study reveals that the pyramidal dome provides better acoustics performance compared to that of the spherical dome.

ABSTRAK

Reka bentuk akustik di sebahagian besar masjid-masjid di seluruh dunia sering diabaikan pada peringkat awal reka bentuk. Akibatnya, prestasi akustik di dalam masjid menjadi lemah. Kes ini termasuk Masjid Sayyidina Abu Bakar UTeM dimana kejelasan suara lemah semasa berjemaah. Objektif utama kajian ini adalah untuk menyiasat punca kepada masalah akustik dan mencadangkan penambah baikkan untuk meningkatkan kualiti akustik dalam masjid. Seterusnya simulasi komputer dijalankan. Pengukuran awal mendapati bahawa masjid mempunyai masa gemaan tinggi (RT60) pada frekuensi di bawah 1 kHz dengan RT60 tertinggi ialah 5.56 s pada 500 Hz. Nilai RT60 daripada simulasi disahkan dengan perbandingan nilai pengukuran awal dan pengukuran simulasi, parameter akustik lain iaitu pereputan awal, kejelasan, definisi dan indeks penghantaran bunyi juga menunjukkan kualiti akustik yang lemah. Ini adalah disebabkan oleh jumlah isipadu masjid yang besar, serta permukaan dinding dan siling yang kebanyakannya terdiri daripada permukaan reflektif yang menyebabkan pantulan bunyi yang lambat. Pantulan terutama dari bumbung cenderung menyumbang kepada RT60 yang tinggi sekitar kawasan hadapan minbar. Daripada simulasi, penambah baik menggunakan bulu mineral dengan ketebalan 25 mm dipasang pada bumbung condong boleh menurunkan RT60 kepada 3.25 s pada 500 Hz. Panel berlubang mikro (MPP) yang menyerupai penyerap Helmholtz resonator juga disimulasi bagi mengatasi masalah pada frequensi rendah. Ia juga dicadangkan untuk dijadikan penyerap mesra alam berbanding penyerap sintetik konvensional daripada penyerap fiber. Didapati bahawa pemasangan MPP di atas bumbung condong, boleh memberi pengurangan RT60 yang lebih baik iaitu kepada 2.57 s pada 500 Hz. Menggandakan bilangan MPP yang dipisahkan dengan ruang udara juga didapati dapat menurunkan lagi RT60 kepada 2.32 s pada 500 Hz. Kesan bentuk kubah juga telah disimulasi untuk membandingkan bentuk kubah piramid dan kubah bulat. Kubah piramid merupakan bentuk yang biasa digunakan pada masjid di Melaka, Malaysia. Kajian ini mendedahkan bahawa kubah piramid memberikan prestasi akustik yang lebih baik berbanding dengan kubah bulat.

ACKNOWLEDGEMENTS

In the name of Allah, The Beneficent, The Merciful

With boundless love and appreciation, I would like to express my sincere appreciation to my supervisor, Assoc. Prof. Dr. Azma Putra. His constant guidance, supervision and encouragement throughout the years, without which this study would not have been possible. Also to my second supervisor, Dr. Nor Salim bin Muhammad.

I would like to acknowledge the staff and technician of Universiti Teknikal Malaysia Melaka (UTeM) and Universiti Kebangsaan Malaysia (UKM) who help me directly or indirectly throughout the research.

I would also like to thank my parents, Kassim Bin Mohamad and Piah Binti Bakrin, my sister Khairunisa Binti Kassim and also my families for their patient and continuous motivation during my studies. To Ijan and Fina who have stayed strong for those ups and downs. My friends, Kina, Kak Emi, Faz, Fara, Ika, colleagues in the Vibro-Acoustic research group and those involved in this study, thank you for all your unwavering support and ideas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AI	**A**rticulation **I**ndex
CATT	**C**omputer **A**ided **T**heater **T**echnique
CHARISMA	**C**onservation of the **A**coustical **H**eritage by the **R**evival and **I**dentification of the **S**inan's **M**osque **A**coustics
BN	**B**ackgound **N**oise
C50	**C**larity
dB	**D**eci**b**el
DMPP	**D**ouble leaf **M**icro **P**erforated **P**anel
D50, **D**	**D**efinition
EDT	**E**arly **D**ecay **T**ime
Hz	**H**ertz
IACF	**I**nter **A**ural **C**ross-correlation **F**unction
IEC	**I**nternational **E**lectrotechnical **C**ommission
ISO	**I**nternational **S**tandard **O**rganization
kHz	**k**ilo **H**ertz
LF	**L**ateral **F**raction
MPP	**M**icro-**P**erforated **P**anel
ms	**m**ili second
MTF	**M**odulation **T**ransfer **F**unction
NC	**N**oise **C**riterion

RASTI	**RA**pid **S**peech **T**ransmission **I**ndex
RT	**R**everberation **T**ime
SII	**S**peech **I**ntelligibilty **I**ndex
SPL	**S**ound **P**ressure **L**evel
SRS	**S**ound **R**einforcement **S**ystem
STI	**S**peech **T**ransmission **I**ndex

LIST OF SYMBOLS

A	Total area of absorption in the room in m^2
S	Area
c	Speed of sound (343 m/s^{-1})
D	Distance of panel form rigid wall / air gap
d_0	Hole diameter
ft	Feet
f_m	Modulation frequency
f_0	Resonant frequency
H	Dome height
h	impulse response
$-j$	Imaginary unit = $\sqrt{-1}$
l	length
L	Left ear
L	Distance of MPP form rigid wall
$\mathrm{L_{SN}}$	Signal to noise level
$\mathrm{L_{SN_{app}}}$	Apparent signal to noise level
$\overline{\mathrm{L_{SN_{app}}}}$	Average apparent signal to noise ratio in dB
M	Mass per unit area of the MPP
m	Modulation reduction factor
$\mathrm{P_L}$	Sound pressure arrive at left ear

P_R	Sound pressure arrive at right ear
R	Right ear
R	Sound pressure reflection coefficient
r	Radius
S_T	Total surface area of the room
t	Thickness of panel
t_s	Center time
V	Volume
v_a	Viscosity of the air (1.8×10^{-5} Ns/m^2)
W_i	Weighting for octave bands
w	Height of wall
Z_D	Specific acoustic impedance of the air gap
Z_0	Hole impedance
$Z_{0,R}$	Hole impedance, real part
$Z_{0,I}$	Hole impedance, imaginary part
Z_{tot}	Total impedance
$\bar{\alpha}$	Average absorption coefficient
α	Sound absorption coefficient
θ	Angle
γ	Sound decay rate in dB/s
τ	Perforation ratio
ρ	Density of the air (1.2 kgm^{-3})
ω	Angular frequency

σ Interval of impulse response measured at left and right ear