



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



شبكة المعلومات الجامعية

التوثيق الالكتروني والميكرو فيلم



شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الإلكتروني والميكرو فيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
على هذه الأفلام قد أعدت دون أية تغييرات



يجب أن

تحفظ هذه الأفلام بعيدا عن الغبار

في درجة حرارة من 15-25 مئوية ورطوبة نسبية من 20-40%

To be Kept away from Dust in Dry Cool place of
15-25- c and relative humidity 20-40%



Faculty of Engineering
Architectural Department
Postgraduate Studies

Acoustical Environment Assessment In Enclosures

**Developing A New Parameter Among Speech Intelligibility, Shape
And Volume Using Digital Simulation**

**Thesis Submitted In Partial Fulfillment For The Requirements Of
The Degree Of Ph.D. In Architecture.**

By

AHMED ALI EL-KHATEEB

Assistant Lecturer In The Architectural Department
Ain Shams University

UNDER THE SUPERVISION OF

PROF. Dr. MORAD ABDAL-KADER

Prof. of Architecture and Environmental Control
Ain Shams University

DR. WAHID Z. IBRAHIM
Lecturer of Architecture

DR. GALAL ABADA
Lecturer of Architecture

-2002-

0111

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

Acknowledgment

My first deepest gratitude has to be to "ALLAH" [AL_ALEIY AL_QADEER], Who has given me the strength, the discernment and the perseverance that I needed to do this research.

I would like to express my thanks and appreciation to all my teachers and supervisors, who have given me the trust and donated much of their time and effort to keep this work going. My thanks go to:

- **PROF. Dr. MORAD ABDAL-KADER**, for his valuable guidance, motivating encouragement and resourceful feedback.
- **DR. WAHID Z. IBRAHIM**, for his advice and prompt criticism. He was a stimulus and led me forward.

In an alphabetical order, very special thanks go to all those people who gave me the time and support to complete my task. On the top is my beloved *Mother* whose prayers have always been the strongest leading support.

- | | | |
|----|-----------|--------------------------------|
| 1 | PROF. DR. | ABDEL QAWEE SHOKREE. |
| 2 | ENG. | AMR HELALEE. |
| 3 | ENG. | AYMAN EL-KHATEEB |
| 4 | DR. | BENGT-INGE L. DALENBÄCK |
| 5 | MR. | CLAUS L. CHRISTENSEN. |
| 6 | DR. | ESSR'AA EL-KHATEEB. |
| 7 | PROF. DR. | HEINRICH KUTTRUFF |
| 8 | PROF. DR. | HELMUT A. MÜLLER. |
| 9 | DR. | INGOLF BORK |
| 10 | PROF. DR. | JENS HOLGER RINDEL. |
| 11 | PROF. DR. | JOHN S. BRADLEY. |
| 12 | DR. | MANSOUR EL-BARDISI. |
| 13 | PROF. DR. | MICHAEL BARRON. |
| 14 | PROF. DR. | MICHAEL VORLÄNDER |
| 15 | DR. | QUINSAN CIAO. |
| 16 | PROF. DR. | Y. LAM. |

Finally, I would like to express my thanks and appreciation to MRS. SAWSAN A. MILAD the TOEFL Preparation Courses Advisor in the American University In Cairo (AUC) for her effort in editing the context.



To my *Mother*
Father

Family

And the memory of my teacher, Prof. Dr. *Hassan Hosny*



"I have observed that there isn't a man writes a book in his day, then, he says in the next:

- *If this is changed it will be better, and*
- *If this is increased, this will be preferable, and*
- *If this gives the precedes it will be the best, and*
- *If this left out it will be more beautiful.*

These are one of the greatest lessons, and it is the evidence on the possession of the insufficiency on the whole of the human".

El_Emad El_Asfahanee.

لقد رايت أنه لا يكتب إنسان كتابا في يومه، إلا قال في غده: لو غير هذا لكان أحسن، ولو زيد هذا لكان يستحسن، ولو قدم هذا لكان أفضل، ولو ترك هذا لكان أجمل، وهذا من أعظم العبر، وهو دليل على استيلاء النقص على جملة البشر".
العماد الأصفهاني.

Copyright © 2002. Ahmed Ali El-khateeb

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the prior written permission from the Author.

CONTENTS

ABSTRACT

PREFACE

PART I

THE PROBLEM, ITS DEFINITION AND APPROACH

1.1	Language of Space	5
1.2	Acoustics in Auditoriums	7
1.2.1	Acoustical Requirements	8
1.2.1.1	Adequate Loudness	8
1.2.1.2	Diffused Sound Field	10
1.2.1.3	Controlled Reverberation	12
1.2.1.4	Elimination of Defects	13
A	Echoes	13
B	Sound Concentration	13
C	Sound Shadowing	13
D	Distortions	14
F	Room Resonance	14
F	Multiple Decay Rates	14
1.2.1.5	Controlled Background Noise Levels	14
1.2.2	Acoustic Indicators	15
1.2.2.1	Monophonic Indicators	18
1.2.2.2	Binaural Indicators	18
1.2.2.3	Directional Indicators	18
1.2.3	Phase of the Acoustical Design	18
1.3	On this Research	20
1.3.1	Problem Definition	20
1.3.2	The Importance	22
1.3.2.1	Palestine Auditorium	23
1.3.2.2	The Complex: <i>A/B, C/D</i>	25
1.3.2.3	The Other Auditoria	27
1.3.3	Objectives	30
1.3.4	The Methodology	31
1.3.5	On the Specified Area	32
1.4	Form and Acoustics- Literature Review	33
1.5	Conclusion	40

2.1	historical background	45
2.2	Architectural Review	49
2.2.1	Human Body: Heart of Design Process	50
2.2.2	Room type	52
2.2.3	Design Criteria for Audience Area	53
2.2.3.1	Raw Spacing /Tread <i>T</i>	53

	Subject	P
	2.2.3.2 Sightlines	55
	2.2.3.3 Angle of vision of spectator	57
	2.2.3.4 Orientation of seated spectator	58
	2.2.3.5 Angle of encounter	58
2.2.4	Efficiency	58
	2.2.4.1 Audience Area	59
2.2.5	Design Criteria for Performing Area	59
	2.2.5.1 Performing Area	59
	2.2.5.2 Screen projection	59
2.2.6	Safety regulations and legal criteria	60
2.3	Acoustical Review	62
2.3.1	Sound	62
	2.3.1.1 On the Medium	62
	2.3.1.2 On the Source	62
	A Human Vocal Tract	62
	B Speech Components	64
	C Objective Aspects of Speech:	65
	D Subjective Aspects of Speech:	69
	2.3.1.3 On the Receiver	69
	A Human Hearing Tract	69
	B Objective Aspects of Hearing	71
	C Subjective Aspects of Hearing	74
2.3.2	Design Criteria for Speech Rooms	76
2.3.3	Acoustical Defects in Speech Auditoriums	77
	2.3.3.1 Bad Localization	77
	2.3.3.2 Excessive sound pressure level	78
2.3.4	Speech Intelligibility Indicators – Review	79
	2.3.4.1 Subjective Based Tests	79
	2.3.4.2 Objective Based Tests	80
	A Reverberation Time RT	80
	B Clarity C_{50} and C_{80}	82
	C Definition D_{50}	83
	D Centre Time T_s	84
	E Articulation Loss of Consonants AL_{cons}	85
	F Articulation Index AI	86
	G Speech Transmission Index STI	87
2.3.5	Relation Between Speech Intelligibility Indicators	89
2.3.6	More Difficulties	90
2.4	Conclusion	91

CHAPTER THREE

ANALYSIS METHODOLOGY, TOOLS AND SETUPS

3.1	Introduction	94
3.2	Methodology	94
3.2.1	Wave Model	95
	3.2.1.1 Theory	95
	A Normal Modes of Vibration	96
	B Effect of Non-rigid Walls	104

	Subject	P
	C Finite Element Analysis Theory in Wave Model	106
	D Difficulties and Drawbacks in Wave Model	108
3.2.2	Geometrical model	106
3.2.2.1	Theory	106
	A Application and its Limits	106
	B Types of Geometrical Acoustics	107
	C Geometrical Model Problems	117
	D Which Type?	120
3.2.3	Energy Model	121
3.2.3.1	Theory	121
	A Application	122
	B Problems with the Energy Model	122
3.2.4	Physical Models	122
3.2.5	Conclusion	124
3.3	Tools	125
3.3.1	Modeling Sound Behavior in a Room	126
3.3.1.1	Zones	127
3.3.2	Acoustical Computer Simulation – General Features	129
3.3.2.1	Analysis Sequence	130
3.3.2.2	Output Parameters	131
3.3.3	Acoustical Computer Simulation – Review	131
3.3.3.1	<i>CATT[®] Acoustic v7.2</i>	131
	A General features	134
3.3.3.2	<i>CAESAR</i>	134
3.3.3.3	<i>EASE[®] v.3.0</i>	135
	A Program components	136
3.3.3.4	<i>ODEON[®] v.4.2</i>	138
	A <i>ODEON[®] v.5</i>	139
3.3.3.5	<i>Ramsetc II[®]</i>	140
3.3.3.6	<i>RAYSOFT[®]</i>	142
	A General features	143
3.3.4	Reasons for Using ODEON	144
3.4	Setups	145
3.4.1	Geometrical Setups	145
3.4.1.1	Shapes Determination	145
3.4.1.2	Room Dimensions, Areas and Volume	145
3.4.1.3	Constants and Variables	147
3.4.1.4	Normalized Average Distance	147
3.4.2	Acoustical Setups	150
3.4.2.1	Input Setups	150
	A Number of Faces	150
	B Finishing Materials	150
	C Receivers	150
	D Source	151
3.4.2.2	Calculation Setups	151
	A Noise Criterion NC	151

	Subject	P
	B Air Absorption	152
3.4.2.3	Source-Receiver Relationship	152
	A Minimum source-receiver distance d_{min}	153
	B Distribution of Receivers	153
	C The Minimum Number of Receivers	153
	D Height of Receivers	153
	E Height of Source	153
	F Symmetrical Rooms	154
3.4.2.4	At. ced Setups	154
3.4.3	Conclusion	154

PART II ANALYSIS II. APPROACH

II.1	Introduction	161
II.2	On the involved parameters	161
II.2.1	Reverberation Time RT	162
II.2.2	Sound Pressure Level SPL	162
II.2.3	Speech Transmission Index STI	164
II.2.4	Centre Time T_s	164
II.2.5	Mean Free Path MFP	165
II.2.6	Reasons for Choosing these Parameters	166
II.3	Notes on the Sound fields	167
II.4	Difficulties	170
II.4.1	Problem Definitions - [What We Get]:	170
II.4.1.1	ODEON [®] v4.2 Output	171
II.4.1.2	Behavior of Sound Waves in Enclosures	172
II.4.2	Solving the Problems [what we need]	173
II.4.2.1	Developing a New Polar Grid	173
II.4.2.2	Adapted Parameters	176

CHAPTER FOUR PHASE I INVESTIGATING SHAPE EFFECT

4.1	introduction	181
4.2	shape and acoustics -- review	182
4.2.1	Parallel Walls	183
4.2.2	Perpendicular Walls	184
4.2.3	Obtuse Angle	185
4.2.4	Acute Angle	186
4.3	Methodology	187
4.3.1	Shapes Matrix	187
4.4	Acoustical Fields Within a Room	189
4.4.1	Isosceles Triangular Family	189
4.4.1.1	Acoustical Aspects	189
4.4.1.2	Boundary conditions	191
4.4.1.3	Geometrical Aspects	192
4.4.1.4	Acoustical Fields in Isosceles Triangular Rooms	193