

**INVESTIGATION OF THE BUILDING PERFORMANCE
WITH REFERENCE TO GLAZING PROPERTIES
APPLICATION TO THE NEW PASSENGER TERMINAL
BUILDING AT THE BANDARANAYAKE
INTERNATIONAL AIRPORT, SRI LANKA**

H.M.Senevirathna



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk (08/8611)

Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

May 2013

**INVESTIGATION OF THE BUILDING PERFORMANCE
WITH REFERENCE TO GLAZING PROPERTIES
APPLICATION TO THE NEW PASSENGER TERMINAL
BUILDING AT THE BANDARANAYAKE
INTERNATIONAL AIRPORT, SRI LANKA**

Herath Mudiyansele Senevirathna



University of Moratuwa, Sri Lanka.
(0878611)
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Thesis submitted in partial fulfillment of the requirements for the degree Master of
Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

May 2013

DECLARATION OF THE CANDIDATE AND SUPERVISOR

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Date:

The above candidate has carried out research for the Masters under my supervision.

Signature of the supervisor:

Date

ABSTRACT

This study is aimed to investigate the energy and thermal performances of the airport passenger terminal buildings in Sri Lanka that use different glazing alternatives. In this regard, one of the passenger terminal buildings at the Bandaranaike International Airport (BIA) was selected as the reference case.

Different glazing materials commercially available both in the local and overseas market were compared with a common glass material used in Sri Lanka as the base case to investigate the energy use and the thermal comfort conditions in the building. The computer software tool, DEROB-LTH (version 99.02) was used to evaluate the cooling energy use and thermal environment condition of the building. The cooling energy use was evaluated in terms of hourly, daily and monthly basis and the interior climate was evaluated in terms of the operative temperature.

The simulation results have shown a positive conclusion towards the feasibility of using double glazing units with advanced solar-control coatings and it further showed that the common glazing material used in the Sri Lankan building industry; the single-clear glazing is not feasible in terms of energy cost and indoor thermal performances. The study also supports that a single-pane heat-absorbing type solar-control configuration can give comparatively moderate results; better results than that for the single-clear glazing type in local climatic conditions.

Finally, an economic/cost-benefit analysis was performed in order to investigate the economic viability of applying the best performing, highly expensive, advanced solar-control glazing over the reference case; ordinary single-clear glazing, and it was found that this glazing is highly cost effective and worth paying for any orientation. However, it is noted that the initial capital cost of these advanced solar-control glass materials as well as the popularisation of this technology in the local scenario was identified as the major barrier for the development of this technology in Sri Lanka.

ACKNOWLEDGEMENT

I would like to express my deep gratitude to Professor. Rahula Anura Attalage, the Deputy Vice Chancellor of the University who is also my research supervisor, for his patient guidance, enthusiastic encouragement and valuable and constructive suggestions during the planning and development of this research work, without whom this thesis wouldn't be never successful. His willingness to give his most valuable time so generously is very much appreciated. The dissertation can only be completed smoothly with their constructive advice and valuable assistance.

My grateful appreciation goes to Dr. Thusitha Sugathapala, the then course coordinator of the M.Eng degree program in energy technology, for selecting me to follow this program and his constructive suggestions during the entire period of the degree program.

I would also like to thank Dr. Himan Punchihewa, Senior Lecturer, for his insightful comments, guidance and advice in keeping my progress on schedule. Without his kind assistance, the progress of this dissertation could not be smooth and effective.

My grateful thanks are also extended to Mr. Gayan Sirimanna, Lecturer of the department of mechanical engineering and Mr.S.D.L.Sendanayake of the same department for their kind support during my research work.

In addition, acknowledgement is given to all my colleagues of this degree program for various supports during the entire degree program.

My special appreciation is also offered to Mr.Indika Fernando & Mr.Nilantha Kanameewela at Airport & Aviation Services (Sri Lanka) Limited for their kind support during the construction of this thesis.

Last but not least, I extend my thanks to my family and friends who provided endless support and encouragement to me all the time.

TABLE OF CONTENTS

Declaration of the candidate and supervisor	i
Abstract	ii
Acknowledgement	iii
Table of Content	iv
List of Figures	vii
List of Tables	x
List of Appendices	xi
1. Introduction	01
1.1 Background	01
1.1.1 Overview of energy use at passenger terminal buildings	02
1.1.2 Energy saving potential at passenger terminal buildings	03
1.1.3 Aspects of sustainable energy	06
1.1 Problem statement	06
1.3 Aim and objectives	07
1.3.1 Aim	07
1.3.2 Objectives	07
1.4 Outline of the Thesis	08
2. Literature survey	09
2.1 History of the Bandaranaike International Airport (BIA)	09
2.2 Description of the passenger building	09
2.3 The BIA development project	12
2.4 Passenger occupation behaviour of BIA	13
2.4 Passenger carrying capacity of aircrafts	16
2.6 Sun path for Katunayake	17

3.	Glazing heat transfer theory	18
3.1	Introduction	18
3.2	Glazing heat transfer	18
3.2.1	Aspects of heat transfer	18
3.2.2	Solar energy transmittance	19
3.2.2.1	The solar spectrum	19
3.2.2.2	Angular dependant properties of solar energy transmittance	21
3.2.3	Characteristics of glazing properties	22
3.2.3.1	Reflectance, Absorptance and Transmittance	22
3.2.3.2	Solar Heat Gain Coefficient (SHGC)	22
3.2.3.3	Shading Coefficient (SC)	23
3.3	Glazing types	24
3.3.1	Coated glass	24
3.3.1.1	Reflective glass	24
3.3.1.2	Low-emissivity coated glass	25
3.3.2	Homogeneous glass	26
3.3.2.1	Clear glass	26
3.3.2.2	Heat-absorbing or tinted glass	26
3.4	Benefits of daylighting	28
3.4.1	Effects of natural light on building occupants	28
3.4.2	Effects of natural light on building energy consumption	29
4.	Methodology	31
4.1	Introduction	31
4.2	The simulation software	31
4.3	The simulated lounge	32
4.3.1	Geometry of the simulated lounge	32
4.3.2	Description of building elements	34
4.3.3	Surface properties	37
4.4	Internal loads	38
4.5	Control set point for indoor air temperature	40
4.6	Climatic data at BIA, Katunayake	41



4.7	Types of glazing	42
5.	Results and Discussion	45
5.1	Introduction	45
5.2	Energy use	45
5.2.1	Hourly energy use	45
5.2.1.1	Hourly cooling load on minimum temperature day	46
5.2.1.2	Daily total cooling load on the minimum temperature day	52
5.2.1.3	Hourly cooling load on maximum temperature day	54
5.2.1.4	Daily total cooling load on the maximum temperature day	60
5.2.2	Daily energy use	62
5.2.3	Monthly energy use	66
5.3	Indoor Climate	76
5.3.1	Transmission of solar radiation through glazing	76
5.3.2	Indoor temperatures	81
5.3.2.1	Hourly fluctuations of indoor temperature on maximum temperature day	81
5.4	Economic analysis of glazing products	88
6.	Conclusions	91
6.1	Introduction	91
6.2	Conclusion from the hourly fluctuations analysis	91
6.3	Conclusion from the daily energy use analysis	93
6.4	Conclusion from the monthly energy use analysis	93
6.5	Conclusion from the hourly temperature fluctuations analysis	96
6.6	Conclusion from the economic analysis of glazing products	97
7.	Recommendation for future work	98
	Reference list	
	Appendix	



LIST OF FIGURES

	Page	
Figure 2.1	Linear type passenger building	09
Figure 2.2	Pier or finger type passenger building	10
Figure 2.3	Aerial view of the Bandaranaike International Airport	12
Figure 2.4	Weekly schedule of departure & arrival flight movements	13
Figure 2.5	Weekly schedule of departure flight movements	15
Figure 2.6	Sun path diagram for the pier building at BIA, katunayake	17
Figure 3.1	Solar spectrum and the sensitivity of the human eye	19
Figure 3.2	The angle dependence of transmittance, reflectance and absorptance of clear float glazing for incidence angle θ	21
Figure 3.3	Transmittance for ordinary clear float and some types of low-e coatings	25
Figure 3.4	Spectral transmittance of 6mm thick heat-absorbing glass with various iron oxide contents for incidence radiation at normal radiation	27
Figure 4.1	3-Dimensional view of the simulating lounge	33
Figure 4.2	Simulated lounge as drawn by DEROB-LTH software	34
Figure 4.3	Psychrometric chart giving modified comfort zones	40
Figure 5.1	Monthly average outdoor temperature ($^{\circ}\text{C}$), 2011	46
Figure 5.2	Global solar radiation on a horizontal surface (W/m^2) on 17 th December, 2011	47
Figure 5.3	Outdoor temperature ($^{\circ}\text{C}$) on 17 th December, 2011	47
Figure 5.4	Relative humidity on 17 th December, 2011	48
Figure 5.5	Primary transmission of solar radiation (kWh) through glass type A on 17 th December, 2011	49
Figure 5.6	Daily total of primary transmission of solar radiation (kWh) on 17 th December, 2011	49
Figure 5.7	Hourly cooling demand of lounge#8 at South-East 17 th December, 2011	51
Figure 5.8	Hourly cooling demand of lounge#12 at North-West	51

Figure 5.9	Daily total cooling demand on 17 th December, 2011 for two orientations	52
Figure 5.10	Global solar radiation on a horizontal surface (W/m ²) on 2 nd June, 2011	54
Figure 5.11	Outdoor temperature (°C) on 2 nd June, 2011	55
Figure 5.12	Relative humidity on 2 nd June, 2011	55
Figure 5.13	Primary transmission of solar radiation (kWh) through glass type A on 2 nd June, 2011	56
Figure 5.14	Primary transmission of solar radiation (kWh) on 2 nd June, 2011	57
Figure 5.15	Hourly cooling demand of lounge#8 at South-East on 2 nd June, 2011	58
Figure 5.16	Hourly cooling demand of lounge#12 at North-West on 2 nd June, 2011	59
Figure 5.17	Daily total cooling demand on 2 nd June, 2011 for two orientations	60
Figure 5.18	Daily average outdoor temperature (°C) for March, June & December, 2011	62
Figure 5.19	Daily Global solar radiation on horizontal surface (kWh/m ² day) for March, June & December, 2011	63
Figure 5.20	Daily cooling demand for glasses at South-East façade for March	64
Figure 5.21	Daily cooling demand for glasses at North-West façade for March	64
Figure 5.22	Monthly cooling demand (kWh/m ² month), South-East façade for March	66
Figure 5.23	Monthly cooling demand (kWh/m ² month), North-West façade for March	67
Figure 5.24	Monthly cooling demand (kWh/m ² month), South-East façade for June	67
Figure 5.25	Monthly cooling demand (kWh/m ² month), N-W facade	68



Figure 5.26	Monthly cooling demand (kWh/m ² month), South-East façade for December	68
Figure 5.27	Monthly cooling demand (kWh/m ² month), North-West façade for December	69
Figure 5.28	Monthly cooling demand for all glasses, all months for South-East orientation	74
Figure 5.29	Monthly cooling demand for all glasses, all months for North-West orientation	75
Figure 5.30	The primary transmission of solar radiation (kWh/m ² month) through each glazing at South-East orientation for March, June and December	76
Figure 5.31	The primary transmission of solar radiation (kWh/m ² month) through each glazing at North-West orientation for March, June and December	77
Figure 5.32	Hourly glass inner surface temperature (°C) for SE orientation on 02 nd June	81
Figure 5.33	Hourly operative temperature (°C) for SE orientation on 02 nd June	82
Figure 5.34	Max.Min. and average values of glass operative temp (°C) for SE orientation on 02 nd June	84
Figure 5.35	Max.Min. and average values of glass operative temp (°C) for SE orientation on 02 nd June	85



University of Moratuwa, Sri Lanka.
 Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF TABLES

	Page	
Table 2.1	Passenger seating capacity of lounges at pier building	11
Table 2.2	Weekly schedule of hourly departure flight movements	14
Table 2.3	Passenger carrying capacity of different air crafts	16
Table 4.1	Description of the building elements used in Derob-Lth program	36
Table 4.2	Surface properties of building elements of the modeled lounge	37
Table 4.3	Total internal heat gain (W)	39
Table 4.4	Climate data for BIA, Katunayake	42
Table 4.5	Glazing alternatives and their optical properties	44
Table 5.1	Daily total cooling demand on 17 th December	54
Table 5.2	Daily total cooling demand on 2 nd June, 2011 for two orientations	61
Table 5.3	Primary transmission of solar radiation (kWh/m ² month)	73
Table 5.4	Monthly cooling energy use per unit glazing surface area for SE and NW orientations (kWh/m ² month)	73
Table 5.5	Monthly cooling energy use per unit floor area for SE and NW orientations (kWh/m ² month)	74
Table 5.6	The primary transmission of solar radiation (kWh/m ² month) through each glazing for March, June and December	78
Table 5.7	The primary transmission of solar radiation (kWh/m ² month) through each glazing for March, June and December	80
Table 5.8	Maximum, minimum and average values of glass inner surface and operative temperatures (°C) for South-East orientation on 2 nd June	85
Table 5.9	Maximum, minimum and average values of glass inner surface and operative temperatures (°C) for North-West orientation on 2 nd June	87
Table 5.10	The economic analysis of glazing type-F versus type-A	89
Table 6.1	Impact of change in glazing type on cooling energy use	94
Table 6.2	Summary of the impact of change in glazing type on cooling energy use	97

LIST OF APPENDICES

Appendix	Description	Page
Appendix -A	Hourly cooling demands	102
Appendix -B	Daily cooling demands	106
Appendix -C	Glass inner surface temperatures	112
Appendix -D	Indoor operative temperatures	116
Appendix -E	Comparison of indoor temperatures	119
Appendix -F	Daily sunshine hours for the year, 2011	123
Appendix -G	Daily total solar radiation on a horizontal surface	124
Appendix -H	Comparison of monthly cooling demand	121
Appendix -I	Maximum & Minimum outdoor temperatures	127
Appendix -J	Global solar radiation on a horizontal surface	128
Appendix -K	Total day length & sunshine hours for the year, 2011	134
Appendix -L	Solar-spectral transmission & reflectance curves	135



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk