

# **ENERGY CONSCIOUS BUILDINGS FOR SRI LANKA**



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

**A STUDY WITH SPECIAL REFERENCE TO  
EFFICIENT USE OF ENERGY IN LIGHTING**

# ENERGY CONSCIOUS BUILDINGS FOR SRI LANKA

## A STUDY WITH SPECIAL REFERENCE TO EFFICIENT USE OF ENERGY IN LIGHTING

A dissertation presented to the  
Faculty of Architecture

University of Moratuwa



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

nation  $\frac{72 \text{ "96"}{''}}{696.6}$

in M.Sc. Architecture

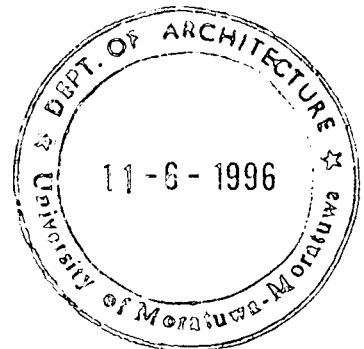
සමස්ත පාඨකරුවන්ගේ සහයකරු  
සමස්ත පාඨකරුවන්ගේ සහයකරු  
සමස්ත පාඨකරුවන්ගේ සහයකරු

66701

4M Thesis  
Coll.

*Shashikala Ranasinghe*

Faculty of Architecture  
University of Moratuwa  
Sri Lanka



1996

## ABSTRACT

Energy is one of the most vital contributions to the sustainable development strategy of Sri Lanka. However, the rising cost of energy generation, the depletion and the unpredictability of the availability of energy resources and the adverse impact of energy generation and its usage on the environment, have been causing much anxiety and great concern from recent times. The entire world has therefore looked up to energy conservation through frugal and efficient use and through the use of alternate renewable energy sources, as a solution to this grave problem. Within this context, buildings have been considered as one of the largest consumers of energy and has therefore been identified as one of the target areas for energy conservation. Statistics have revealed that the proportion of energy consumed for lighting in buildings is much greater than what is consumed individually for providing thermal comfort or other ancillary services. The principle objective in this study is therefore to explore strategies of designing buildings with optimum utilisation of natural light and efficient application of electrical energy for interior lighting.

A number of verification experiments on daylighting were carried out for this task, with different types of scale models of office buildings and windows against a few different external characteristics within the control of the designer. Also, an extensive literary survey on the subject of energy efficient artificial lighting was carried out as related to office lighting. The survey on daylighting clearly revealed that multiple windows which were inclined, high ground reflectivity together with top lighting where necessary contributed to obtain good quality lighting for artificial lighting situations. The literature reviewed would totally eliminate the need for artificial lighting in an absolute minimum in the worst situations. The literature reviewed proved beyond any doubt that task lighting combined with minimum ambient lighting was the most efficient approach to artificial lighting of office spaces. Also, the daylighting data and the artificial lighting information collectively provided clues to the ways in which the two types of interior lighting could be effectively combined as when necessary.

It is quite evident from the total study that artificial lighting is indispensable. It is at least needed as a supplementary light to make any shortfalls in natural lighting or to balance the brightness in an interior when there is an excess of natural light in one part of the space. Therefore, daylight efficient building designs and efficient artificial lighting systems would immensely contribute towards energy conservation, environmental protection and the establishment of a sustainable economic system. Accordingly this study has opened new vistas in to the realms of energy efficient architecture relevant to the Sri Lankan situation.





University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## ACKNOWLEDGEMENTS

A comprehensive discourse on one of the most timely subjects of great importance and relevance to the Sri Lankan energy situation has been concluded.

I consider it my sincere duty towards everyone concerned to acknowledge with a deep sense of gratitude, the whole hearted assistance and encouragement they extended to me to make this endeavour a success.

- Dr. Ranjith Perera, my tutor, for the invaluable contributions and the generous commitment of his precious time and energy. I also greatly admire and value the consistency of keenness displayed by him up to the very end.
- Year Master Dr. Ranjith Dayaratne and Archt. Vidura Sri Nammuni for their encouraging initial guidance.
- Archt. D.P. Chandrasekera for his contribution towards material for the literary survey.
- Mr. Weerasooriya, of the Department of Architecture, for making available the required technical literature.
- Prof. V.K. Samaranayake, Director, Institute of Computer Technology for his whole hearted support in  for the use of computers.
- Mr. J.C. Page, Man  opment Ltd. for his prompt approval for my request to use the roof top of the Majestic City Complex to conduct the experiments, in spite of the current security situation. Mr. Asoka Gunesequera, the Chief Engineer of the complex for his unstained cooperation.
- Mr. Shavindranath Fernando, President Sri Lanka Energy Manager's Association for his kind consent to allow the use of sophisticated photometric equipment owned by SLEMA.
- Ms. Indira Fernando, Mrs. Joan Serpanchy and Mr. Sajith for a wonderful job done on the computers at very short notice.
- The Master Craftsman Mr. R. Prematilleke for an excellent job done in making a unique set of models.
- Finally my family showered me with the much needed power of confidence by being fully involved with the project. My father was the principal driving force, whilst my mother looked after me caringly burning the mid night oil, months on end and my two brothers, giving me all the encouragement and support. I remember all of them with a deep sense of love and gratitude.




# CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	iv
CONTENTS	v
LIST OF FIGURES	vii
LIST OF TABLES	x
LIST OF APPENDICES	xi
INTRODUCTION	
Introduction to the study	2
Problem area and architectural problem	3
Rationale	5
Aims and objectives	6
Scope and limitations	8
Structure of the study	8
CHAPTER ONE - ENERGY EFFICIENCY IN BUILDINGS - A SIGN DETERMINANT	
1.1 Treating energy as a resource	13
1.2 Determination of energy efficiency in buildings	17
CHAPTER TWO - DESIGNING FOR NATURAL LIGHTING	
2.1 Introduction to Natural Light	24
2.1.1 Natural lighting data relevant to Sri Lanka	27
2.1.2 Universally applicable information	33
2.2 Orientation of Buildings	35
2.2.1 Orientation relative to sunpath and sky brightness	35
2.2.2 Orientation relative to the immediate environment	37
2.3 Windows	40
2.3.1 Window sizes, shapes and light distribution	41
2.3.2 Roof windows	46
2.3.3 Glazing materials and their properties	55
2.3.4 Light controlling devices	59
2.3.5 Ventilation	67
2.4 Interior Space design	71
2.4.1 Interior space design relative to flow of light from windows and roof lights	71
2.4.2 Interior space design relative to surface finishes	72
2.4.3 Interior space design relative to usage of space	74

2.5	Introduction to the Experimental Survey	76
2.5.1.	Experiment with openings on Vertical facades (analysis and inferences)	91
2.5.2	Experiment with openings on Horizontal facades (analysis and inferences)	148
2.5.3	General conclusions derived from the experiments	169
2.6	Summary of Recommendations for Energy Efficient Natural Lighting of Office Interiors	172
<b>CHAPTER THREE - DESIGNING FOR ARTIFICIAL LIGHTING</b>		
3.1	Introduction to Artificial Light	187
3.2	Lamps	190
3.2.1	Energy efficient lamps	191
3.3	Luminaires (light fittings)	194
3.3.1	Efficiently designed luminaires	194
3.3.2	Selection of appropriate luminaires	198
3.4	Lighting Design	201
3.4.1	General lighting, localized lighting, general and local lighting	202
3.4.2	System management and operation	204
3.5	Quantitative and Qualitative aspects of Lighting	209
3.5.1	Lighting levels	209
3.5.2	Lighting levels appropriate for Sri Lanka	216
3.6	Surface Finishes	218
3.6.1	Surface reflectance and lighting	218
3.7	Energy Installed Efficacy (EIE) of lighting fixtures per unit area of floor (W/m <sup>2</sup> )	221
3.7.1	Specify Efficacy of lighting fixtures	221
3.8	Summary of Recommendations of Energy Efficient Artificial Lighting of Office Interiors	225
<b>CHAPTER FOUR - CONCLUDING REMARK</b>		
<b>APPENDICES</b>		
	Appendix I - FIGURE AND TABLES	240
	Appendix II - PHOTOGRAPHS	244
<b>REFERENCES</b>		
253		

## LIST OF FIGURES

Figure	Page
1. Annual consumption for lighting in the commercial and the domestic sector	18
2. Percentage of total electricity for lighting in the domestic sector	19
3. Percentage of total electricity for lighting in the commercial sector	19
4. Sun path diagram related to Colombo	28
5a. Apparent paths of the sun as related to Colombo	29
5b. Extreme sun angles over Colombmo	29
6. Sky luminance opposite the sun for Colombo	32
7. Ways of Daylight entering a building	37
8. The changing quality of light throughout the day	39
9. Section of a room for determining the $\bar{H}$ , $\bar{V}$ , $\bar{M}$ aperture proportions	42
10. Daylight penetraion curves when aperture a) facing sun, clear sky; b) overcast sky; c) aperture opposite sun, clear sky.	43
11. Spread of Daylight into the space at different aperture widths	45
12. Spread from top lighting concepts	47
13. Different lighting zones created by different top lighting concepts	48
14. Typical illuminance for clear sky and overcast sky	49
15. Impact on illumination ratios	50
16. Variables used to describe a horizontal aperture	51
17. Direct sunlight's impact on space	52
18. Impact on illumination in a room for varying "well" slopes	53
19. Effect of the base case aperture on a multi floor building	54
20. Variation of transmittance for different incidence on glass	56
21. Maximum transmittance through a 30° angled window	57
22. Nomenclature used for a room with an overhang.	60
23. Impact on Daylight penetration and spread in a room with differnt overhangs	61
24. Light shelf forms and nomenclature	62
25. Impact on Daylight penetration with various light shelves.	63
26. Various light shelf configuration	64
27a. Exterior and interior louver and blind nomenclature	65
27b. Horizontal louver and blind performance at different D ratios	65
27c. Impact on illuminance in a room with full blinds for different blade angles	65
28. Impact on illuminance in a room with varying spacing in the interior louver	66
29. Converting direct rays to diffuse rays of Roof lights	67
30a. Building layouts-parallel arrangements	69
30b. Building layouts-checker board arrangements	69
31. Ventilation caused by stack effect.	69
32. Air flow pattern influenced by vegetation	70
33. The effect of overhangs and shadig devices in the air flow patterns	70
34. Daylight and the effect of surface reflectance	73

35.	Provision of Daylight corridors through proper interior arrangements	75
36a.	Verticle Single-plan elevation and section	81
36b.	Inclined Single-plan elevation and section	81
36c.	Verticle Multiple-plan elevation and section	82
36d.	Inclined Multiple-plan elevation and section	82
37a.	Axonometric view-placing the window	93*
37b.	Axonometric view-placing the shading device	145
38.a.	Roof window opening 2"x20"-plan and section	151
38.b.	Roof window opening 4"x20"-plan and section	153
38.c.	Roof window opening 6"x20"-plan and section	155
39.	Axonometric view-positioning the Roof window	83
40a.	Multi storey Atrium 4"x4" opening-plan and section	158
40b.	Multi storey Atrium 6"x6" opening-plan and section	161
40c.	Multi storey Atrium 8"x8" opening-plan and section	164
41.	Axonometric view-positioning the slab opening	84
42.	Laying out the model	86
43.	Graph for Vertical Single window type-West oriented	93
44.	Graph for Inclined Single window type-West oriented	96
45.	Graph for Verticle Multiple window type-West oriented	99
46.	Graph for Inclined Multiple window type-West oriented	102
47.	Graph for Verticle Single window type-North West oriented.	106
48.	Graph for Inclined Single window type-North West oriented	109
49.	Graph for Verticle Multiple window type-North West oriented	112
50.	Graph for Inclir  University of Moratuwa, Sri Lanka. Vest oriented	115
51a.	Graph for Verti  Electronic Theses & Dissertations ented	119
51b.	Respective Day  www.lib.mrt.ac.lk ited	119
52a.	Graph for Inclined Single window type-North oriented	122
52b.	Respective Daylight Contour diagram-North oriented	122
53a.	Graph for Verticle Multiple window type-North oriented	125
53b.	Respective Daylight Contour diagram-North oriented	125
54a.	Graph for Inclined Multiple window type-North oriented	128
54b.	Respective Daylight Contour diagram-North oriented	128
55.	Graph for Vertical Single window type-North East oriented	132
56.	Graph for Inclined Single window type-North East oriented	135
57.	Graph for Verticle Multiple window type-North East oriented	138
58.	Graph for Inclined Multiple window type-North East oriented	141
59.	Graph for with/without shading device-East oriented	145
60.	Graph for 2"x20", 4"x20" and 6"x20" Roof window-long axis East West direction	150
61.	Graph for 4"x4" slab opening from floor III to ground floor level	158
62.	Graph for 6"x6" slab opening from floor III to ground floor level	161
63.	Graph for 8"x8" slab opening from floor III to ground floor level	164
64.	Obstruction's contribution to interior illumination	174
65.	Further improvement to Inclined window glazing	177
66a.	The effect of shading device to the interior	178
66b.	The effect of shading device to the interior	178
67.	Roof lights as supplementary light	179

\* This figure (37a) also appear in pages 96, 99, 102, 106, 109, 112, 115, 119, 122, 125, 128, 132, 135, 139 and 141



68.	Efficient distribution of light through improved Atrium “well”	181
69	An energy efficient building created through varying window sizes on the facade	182
70.	An energy efficient interior layout	183
71.	Effect of a lighting fixture over a naked lamp	193
72.	Thermal consideration in luminaire	195
73.	Luminous distribution diagram of varying light sources	197
74.	General lighting system	202
75.	Localised lighting system	203
76.	Local + General lighting system	204
77.	Selective switching for energy efficient lighting scheme	205
78.	Effect of illuminance on the performance of varying visual difficulties	210
79.	Mean assessment of quality of lighting	212
80a.	Low reflectance room surfaces	220
80b.	High reflectance room surfaces	220



University of Moratuwa, Sri Lanka.  
 Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)


## LIST OF TABLES

Tables		Page
1.	Different reflection factors for different external surfaces	38
2.	Transmittance properties of different glazing types	58
3.	Average reflection factors for varying materials, finishes and surfaces	73
4.	Luminous efficacy of lamps and Daylight	190
5.	Colour temperature and CRI values of light sources	192
6.	Colour appearance in terms of correlated colour temperature (CCT)	192
7.	Chart on lighting levels for office interiors-British Standards	215
8.	Chart on lighting levels for office interiors-American Standards	215
9.	Typical reflectances for finishing materials	219
10.	Installed efficacy range for uniform lighting installations	222
11.	Calculation of utilization factors	222



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## LIST OF APPENDICES

<b>Appendix I</b>	<b>Page</b>
Figure I      Luminance distribution of design sky	241
Table I      Summary of the illumination climate (at the six stations)	240
Table Ia     Distribution of days according to sky condition (at the six stations)	240
Table II     Brightness factor values at different sky altitudes (at the six stations)	241
Table III    Internally reflected component per unit fenestration and unit window factor (at the six stations)	242
Table IV    Sky component tables	242
Table V    Rivero's sky component tables	243
 <b>Appendix II - Photographs</b>	
1.      Model type A; Verticle Single window type	244
2.      Model type A; Inclined Single window type	244
3.      Model type A; Verticle Multiple window type	245
4.      Model type A; Inclined Multiple window type	245
5.      Model type A; Inclined Multiple window type with shading device	246
6.      Model	246
7a.     Model  University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations	247
7b.     Model <a href="http://www.lib.mrt.ac.lk">www.lib.mrt.ac.lk</a>	247
8.      Model type A; facing West	248
9.      Model type A; facing North West towards obstruction	248
10.     Model type A; facing North	249
11.     Model type A; facing North East towards obstruction	249
12.     Model type A; facing East	250
 Equipment-	
13      Digital luminance meter	250
14.     Digital lux meter (for luminance measurements)	251
15.     Digital lux meter	251
16.     for measuring altitude, azimuth and the magnetic North	252

