

# FEASIBILITY STUDY ON TUBULAR SKYLIGHTS TO BE USED IN SRI LANKAN OFFICE BUILDINGS

B.Y.B.C.P. Kumara

(108919 N)



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

Degree of Master of Science in Building Services Engineering

Department of Electrical Engineering

University of Moratuwa  
Sri Lanka

October 2015

# **FEASIBILITY STUDY ON TUBULAR SKYLIGHTS TO BE USED IN SRI LANKAN OFFICE BUILDINGS**

Bentara Yahathugoda Badalge Charith Prasanga Kumara

(108919 N)



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

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

Department of Electrical Engineering

University of Moratuwa  
Sri Lanka

October 2015

## DECLARATION

“I declare that this is my own work and this dissertation 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 the University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, 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 of the candidate

Date:

(B.Y.B.C.P. Kumara)



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

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

.....  
Signature of the supervisor  
(Dr. Asanka Rodrigo)

Date:

## **ABSTRACT**

Tubular Daylight Guidance technology can deliver natural light in to a space in a building where daylight is limited with an internally mirrored pipe system using the phenomena called total internal reflection. This research has been conducted to identify the potential and feasibility of applying Tubular skylights in a Sri Lankan office building. The research has focused on the existing technologies and evaluated three models of Tubular skylights designed to be used in office applications. Computer simulations have been carried out to evaluate the light outputs of different lighting arrangements made with Tubular skylights. Energy evaluations have been carried out for the cases require artificial lighting to keep constant illuminance levels. Economic evaluations have been carried out with life cycle cost calculations to evaluate the economic feasibility.



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

## ACKNOWLEDGEMENTS

First, I pay my sincere gratitude to Dr. Asanka Rodrigo who encouraged and guided me to conduct this study and on preparation of final dissertation.

I would like to take this opportunity to extend my gratitude to my superiors in the Central Engineering Consultancy Bureau and professionally qualified engineers in the industry who gave their co-operation to conduct my research work successfully.

Finally I would like to thank my parents and my beloved wife who gave me a huge support and a back up to make this research output a success.



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

# TABLE OF CONTENTS

DECLARATION.....	i
ABSTRACT .....	ii
ACKNOWLEDGEMENTS .....	iii
TABLE OF CONTENTS.....	iv
LIST OF FIGURES .....	vi
LIST OF TABLES .....	viii
1 INTRODUCTION.....	1
1.1 Background.....	1
1.2 Research Objectives .....	3
1.3 Scope of Research .....	4
2 LITERATURE REVIEW .....	5
2.1 Invention of the Tubular Sky Light .....	5
2.2 Light Pipes in the Design Process .....	8
2.3 The Research Work That Has Been Carried Out .....	9
2.3.1 Luminous effectiveness of tubular light guides in tropics.....	9
2.3.2 Light-pipe prediction methods.....	11
2.3.3 Tubular light guide evaluation .....	15
2.3.4 An analysis of light-pipe system via full-scale measurements.....	20
2.3.5 Tubular guidance systems for daylight: Achieved and predicted installation performances.....	23
2.3.6 Efficient tubular light guide with two-component glazing with Lambertian diffuser and clear glass.....	25
2.3.7 The costs and benefits of using daylight guidance to light office buildings.....	26
3 PRODUCT REVIEW ON TUBULAR DAYLIGHTING SYSTEMS.....	29
3.1 Systems Produced by Solatube International Inc. (USA) .....	29
3.1.1 Technical Details of “Solatube” .....	29
3.1.2 Price of Solatube .....	39
3.2 Systems Produced by Monodraught Ltd .....	41

3.2.1	Technical details.....	41
3.2.2	Price of Sunpipe .....	48
3.3	Systems Produced by Solarspot International .....	49
3.3.1	Technical Details .....	50
3.4	Systems Produced by VELUX Canada Inc .....	51
3.4.1	Guide lines given by the manufacturer for choosing Sun tunnels.....	52
3.4.2	Price of Sun tunnel .....	53
4	RESEARCH METHODOLOGY .....	55
5	ANALYTICAL FRAMEWORK .....	57
5.1	Method Formation .....	60
5.1.1	Method to perform Light simulation and analysis.....	60
5.1.2	Method to perform Energy evaluation.....	68
5.1.3	Method to perform Economic analysis.....	69
6	CASE STUDY AND COMPUTER SIMULATIONS.....	72
6.1	Building data.....	72
6.1.1	Library room.....	72
6.1.2	Staff room .....	73
6.2	Case 1 – Library room.....	74
6.2.1	Lighting simulation .....	74
6.2.2	Energy evaluation.....	78
6.2.3	Economic Evaluation .....	80
6.2.4	Life cycle payback evaluation.....	82
6.2.5	Lighting up the room to achieve the standard minimum illuminance level	91
6.2.6	Estimating the Energy consumption for artificial backup lighting under overcast sky conditions.....	91
7	DISCUSSION AND CONCLUSIONS.....	96
	REFERENCE LIST.....	99



<b>Appendix 1 – Light output reports from DIALux 4.11 Software.....</b>	<b>101</b>
<b>Appendix 2 – Energy Consumption Evaluations.....</b>	<b>135</b>
<b>Appendix 3 – Cost Estimations.....</b>	<b>141</b>
<b>Appendix 4 – Life Cycle Payback Evaluations.....</b>	<b>151</b>
<b>Appendix 5 – Drawings.....</b>	<b>158</b>

## LIST OF FIGURES

Figure 1-1: A typical Tubular day lighting device.....	3
Figure 2-1: Sectional View of Apparatus.....	7
Figure 2-2: Tube fixed with bolts.....	7
Figure 2-3: Tube fixed with tabs.....	8
Figure 2-4: Cross section of the space.....	10
Figure 2-5: Light distribution on the output of the light guide.....	16
Figure 2-6: Luminous intensity plots.....	17
Figure 2-7: Details of the room and illuminance levels.....	19
Figure 2-8: The seven-sensor layout for the light pipe measurement.....	22
Figure 2-9: Plan view and section of the five measuring points in the corridor.....	22
Figure 3-1: Installation on a pitched roof.....	31
Figure 3-2: Flashing types of “Brighten up series”.....	33
Figure 3-3: Turret extensions.....	33
Figure 3-4: Extension Tubes.....	34
Figure 3-5: Dimmer.....	34
Figure 3-6: Flashing insulator.....	35
Figure 3-7: Light add on kit.....	35



Figure 3-8: Solatube 21-C .....	36
Figure 3-9: Solatube 21-O .....	37
Figure 3-10: Turret Extensions .....	38
Figure 3-11: Shock dome .....	38
Figure 3-12: Security bar .....	39
Figure 3-13: SunPipe System.....	42
Figure 3-14: Horizontal SunPipe .....	42
Figure 3-15: Sunpipe Flashing Types .....	44
Figure 3-16: SunPipe system .....	46
Figure 3-17: Solavent with SunPipe .....	47
Figure 3-18: Solarspot System.....	49
Figure 3-19: Solar Wall Systems .....	50
Figure 3-20: Flexible Sun tunnels.....	51
Figure 3-21: Rigid Sun tunnels.....	51
Figure 5-1: Altitude angle of the sun .....	57
Figure 5-2: Lumen output Vs Solar Altitude angle for TS1 .....	59
Figure 5-3: Lumen output Vs Solar Altitude angle for TS2 .....	59
Figure 5-4: Lumen output Vs Solar Altitude angle for TS3 .....	60
Figure 5-5: Lumen output Vs Time for TS1 .....	64
Figure 5-6: Lumen output Vs Time for TS2 .....	64
Figure 5-7: Lumen output Vs Time for TS3 .....	65
Figure 5-8: TS1 Outputs Vs Time intervals.....	65
Figure 5-9: TS2 Outputs Vs Time intervals.....	66
Figure 5-10: TS3 Outputs Vs Time intervals.....	66
Figure 5-11: Methodology used in the analysis as an algorithm .....	71



Figure 6-1: Average illuminance level variation at 10°,20°,40°, 50° altitudes .....	76
Figure 6-2: Average illuminance level variation at 70°,90°,100°, 150° altitudes .....	77
Figure 6-3: DNI distribution for 10.00 hr over Anuradhapura, Sri Lanka in year 1990 .....	94

## LIST OF TABLES

Table 2-1: Summarised advantages and disadvantages of different light-pipe design methods .....	14
Table 2-2: Indoor illuminance E [lx] on the working plane under the light guide in dependence of the luminance L [cdm <sup>-2</sup> ] of the ceiling diffuser. ....	18
Table 2-4: Breakdown of costs and benefits .....	27
Table 3-1: Brighten Up series models.....	32
Table 3-2: Flashings.....	37
Table 3-3: Solatube Price list.....	40
Table 3-4: Manufacturer Recommendation for size selection .....	43
Table 3-5: Manufacturer Recommendation for Extension Pipe usage .....	43
Table 3-6: Applications of Sun Pipe .....	45
Table 3-7: SunPipe prices as those were available by April 2012.....	48
Table 3-8: Light coverage of Sun tunnels .....	53
Table 3-9: Rigid Sun tunnel Prices .....	54
Table 3-10: Flexible Sun tunnel Prices .....	54
Table 5-1: Tubular Skylight models .....	57
Table 5-2: Lumen outputs of Tubular skylight Models .....	58
Table 5-3: Sun rise - Sunset times in Sri Lanka of the year 2015.....	61
Table 5-4: Tubular skylight lumen outputs from sunrise to sunset on a typical day	63

Table 5-5: Lumen outputs for Tubular skylights in 40 min time intervals .....	67
Table 6-1: Room surface properties of library room .....	72
Table 6-2: Room surface properties of staff room .....	73
Table 6-3: Summary of lighting simulation for current lighting plan for Library room .....	75
Table 6-4 Summary of the energy consumption per day .....	79
Table 6-5 Summarized Cost estimations for Library .....	81
Table 6-6 Summary of the 10 year life cycle payback analysis.....	82
Table 6-7: Summary of the results of 10 year life cycle cost evaluation under the modified assumptions .....	90
Table 6-8: Annual data on DNI over Anuradhapura, Sri Lanka .....	93
Table 6-9: The likely demand for artificial lighting during the 10.00 hr. at various DNI levels .....	94
Table 6-10: The likely demand for artificial lighting due to overcast conditions.....	95



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations

**LIST OF ABBREVIATIONS** [www.mrt.ac.lk](http://www.mrt.ac.lk)

<b>UK</b>	United Kingdom
<b>SLL</b>	Society of Light and Lighting
<b>TDGS</b>	Tubular Daylight Guidance Systems
<b>HLS</b>	Hybrid Daylight/Electric Systems
<b>DGS</b>	Daylight Guidance Systems
<b>ELS</b>	Electric Lighting Systems
<b>HRE</b>	Heat Replacement Effect
<b>EDCS</b>	Effective Daylight Capturing Surface
<b>UV</b>	Ultra Violet
<b>TS1</b>	Tubular Skylight with 250mm diameter
<b>TS2</b>	Tubular Skylight with 350mm diameter
<b>TS3</b>	Tubular Skylight with 525mm diameter
<b>USA</b>	United States of America
<b>CIBSE</b>	Chartered Institution of Building Services Engineers
<b>DNI</b>	Direct Normal Irradiance