

**UNIVERSITI TEKNOLOGI MARA**

**ROOF CONFIGURATIONS FOR  
DAYLIGHT PERFORMANCES IN  
MALAYSIAN ATRIUM BUILDINGS  
UNDER TROPICAL SKY  
CONDITIONS**

**JULITTA BINTI YUNUS**

Thesis submitted in fulfilment  
of the requirements for the degree of  
**Doctor of Philosophy**

**Faculty of Architecture, Planning and Surveying**

August 2017

## AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regarding the conduct of my study and research.

Name of student : Julitta binti Yunus  
Student I.D. No. : 2006654325  
Programmed : Doctor of Philosophy (Built Environment) – AP990  
Faculty : Architecture, Planning and Surveying  
Thesis Title : Roof Configurations For Daylight Performances In  
Malaysian Atrium Buildings Under Tropical Sky  
Conditions

Signature of student : .....  
Date : August 2017

## ABSTRACT

Some crucial elements in the daylighting design of atrium buildings are the shape of the atrium, roof configuration, building orientation, roof transmittance, internal surface reflectivity, and glazing areas. Apart from the various internal design factors, the outdoor sky distribution also has significant impacts on indoor daylighting. Therefore, the aim of this study is to investigate how typical modern construction techniques applied to atrium roofs attenuate daylight transmittance to predict the daylight performance of roof configurations for atrium buildings in Malaysia. An evaluation of the existing atrium roof systems and configurations for atrium buildings in the Klang Valley was conducted. Results show that the most preferred atrium form used for Malaysian buildings is the top-lit and enclosed central rectangular shallow atrium with an average atrium height of 4-storeys. A scaled model of an atrium building was built to emulate the characteristics of a typical atrium with a roof structure for tropical climates. Four models were developed to perform the daylighting performance analyses involving field experiments and computer simulations. The models used different roof fenestration designs and structural truss systems (flat, pitched, pyramidal-gridded and saw-tooth roofs) and were initially tested under real sky conditions to investigate the daylight distribution and illuminance levels on the horizontal surfaces in the atrium building. An internationally accredited Indoor Environmental Solutions Virtual environment (IES-VE) programme, specifically the IESRadiance application software was then used to simulate daylight penetration in the atrium space of the models. This software enabled the researcher to vary the design of various modern roof structures and constructions of the atrium to analyse their effects on daylight distribution patterns. The Daylight Factor/Daylight Ratio on horizontal surfaces under different types of sky conditions at different times of day and different days over a period of one year were obtained. The daylight distribution in the model atrium was consistent with current daylighting theory. Intermediate sky conditions, the predominant sky condition showed a generally linear relationship and good degree of correlation with the overall reduction of daylight levels in the atrium. Results showed that structured roof forms applied to the atrium model reduced daylight levels in the atrium well by 55% with similar patterns of losses for the four roofs studied. Internal roof obstructions created a relatively constant attenuation of daylight compared with the clear unobstructed roof for the four structured roofs. It was found that a high contribution of daylight penetration appeared at the centre nearest to the atrium opening, while the transmittance of the atrium roof structure decreased the illuminance level at the lowest corner by 50%. It was also found that under overcast skies, the illuminance levels greatly decreased at the corner of the atrium floor, especially for the north- and west-facing atrium surfaces for all types of roofs. The flat roof performed well in maintaining the acceptable limit of maximum light utilisation and was more consistent in terms of light distribution across the atrium floor. Meanwhile, complex roof configurations of the pyramidal-gridded atrium type obtained better daylight contribution at approximately 50%. As the most vulnerable one, the pitched roof was found to be less consistent and had poor distribution, especially at low transmittance levels. For a low-rise atrium with a Well Index of up to 1, a top-lit transmittance roof obstruction plays a major role in either limiting, reflecting or splaying daylight away to the corners and works efficiently with 50% or higher solid wall transmittance. The discrepancy of light distribution was increased if measured between the unobstructed atrium well with complex configurations. This work has paved the way for more design strategies using complicated atrium roof fenestration constructions to be analysed with accuracy while combining aesthetics with energy efficiency.

## TABLE OF CONTENTS

	<b>Page</b>
<b>CONFIRMATION BY PANEL OF EXAMINERS</b>	ii
<b>AUTHOR'S DECLARATION</b>	iii
<b>ABSTRACT</b>	iv
<b>ACKNOWLEDGEMENT</b>	v
<b>TABLE OF CONTENTS</b>	vi
<b>LIST OF TABLES</b>	xii
<b>LIST OF FIGURES</b>	xiv
<b>LIST OF PLATES</b>	xxi
<b>LIST OF ABBREVIATIONS</b>	xxiv
<b>CHAPTER ONE: INTRODUCTION</b>	<b>1</b>
1.1 Preamble	1
1.2 Problem Formulation	2
1.2.1 Daylighting in Atrium	3
1.2.2 Malaysian Climate and its Potential	4
1.2.3 Conventional Building Form - Opting For Optimal Strategy Of Atrium Roof For Daylight Performances	5
1.2.4 Daylight Prediction In Atrium	7
1.3 Research Questions	8
1.4 Aim And Objectives	8
1.5 Research Methodology	11
1.6 Significance Of Research	14
1.7 Scope Of Research	14
1.8 Structure Of The Thesis	15
<b>CHAPTER TWO: DAYLIGHTING IN ATRIUM: AN UNDERSTANDING OF THE CONCEPTS</b>	<b>17</b>
2.1 Introduction	17

# CHAPTER ONE

## INTRODUCTION

### 1.1 PREAMBLE

There has been a clear increase of atrium buildings in Malaysia, since the 1990s, especially in the Klang Valley. This design trend is recognised as one of the most popular and environmentally stimulating spaces of today's architecture, as atrium allows daylight in without bringing in the increment weather. When incorporated into many forms of buildings, an atrium can be used for building occupants to relate to outdoor conditions and to admit natural light and some solar heat into the indoor space. Daylighting is a passive solar feature incorporated in the atrium for energy saving. It represents one of the aesthetic values of an atrium and is an essential component of a visually attractive and energy-efficient atrium buildings. The daylighting aspects of the atrium need to be carefully designed to be visually attractive, provide adequate light and as well as to fulfil the energy-efficient building criteria.

An atrium's main feature is the roof. A careful design of the roof fenestration systems will limit glare, mitigate passive solar heating effects, supply adequate daylighting and minimise sunlight. Therefore, atrium roof form and structure are important architectural design elements, where they could influence daylight availability within the space and, in turn, lighting energy consumption. A common feature of most studies was that the atrium roof was left as an open, unobstructed void, which is obviously very different from the conditions existing in the real atrium, which have roof structure to support the glazing (Yunus, Ahmad, & Zain-Ahmed, 2007). This study was embarked based on strongly recommended further analysis of several variations of roof structures and roof glazing and their impacts on the distribution of daylight by prominent daylighting researchers (Calcagni & Paroncini, 2004a; Du & Sharples, 2010b; Ghasemi, Kandar, & Nproozi, 2015; Samant, 2011; Sharples & Lash, 2007; Julitta Yunus, Sabarinah Sheikh Ahmad, & Azni Zain-Ahmed, 2010a) (Calcagni & Paroncini, 2004a; Du & Sharples, 2012b; Felasari, 2003; Sharples & Shea, 1999).