DAYLIGHT PENETRATION IN MALAYSIAN HIGH-RISE OFFICE BUILDINGS

BY

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ABSTRACT

In our natural environment, there is an abundance of daylight. Before the invention of electric lighting, it was a primary source of interior illuminance. However, in today's office buildings, daylight is being underutilized and dependency on artificial lighting is very common. Daylight use can be an energy saving feature of a building by reducing demand for electric lighting. It is very difficult to provide adequate amount of daylight all through a side lit space. Therefore, the knowledge regarding depth of its penetration is important for its proper utilization. This requires detailed daylight analysis. Standard skies are a very important part of this analysis. Recently, sets of fifteen skies have been adopted by the CIE (Commission Internationale de L'eclairage) as standards for the entire globe. These have not yet been incorporated into daylight simulation software. In order to incorporate these standard skies, the study has analysed the depth of daylight and permanent supplementary artificial lighting for interiors (PSALI) in high-rise office under hot-humid climate of Peninsular Malaysia using an alternative method. The study used 'Daylight Coefficient' to perform daylight calculation. 'Waldram Diagram' has been used to calculate the visible sky needed for the daylight coefficient method. Two experiments were conducted to find the upper and lower limits of daylight penetration throughout the year. The lowest levels have been analysed to determine the limiting depth of daylight while the difference between the lowest and highest penetration was considered for PSALI. The research found the depth of daylight was 3 m and 3.5 m from an adjacent window considering the lower limit for daylight of 500 lux and 300 lux, respectively. It also found that the depth of PSALI is different for different orientations. It is greater in the North-East, East, South-East, South-West, West and North-West directions compared to North and South orientations. This is due to the low solar altitude in the morning and afternoon. The research therefore, concludes that these depths may be taken under consideration in the pre-design phase of an office building in order to take maximum advantage of daylight usage in an office interior environment.

ملخص البحث

في محيطنا الطبيعي، توجد كمية هائلة من الإنارة. حيث كانت قبل اختراع الإنارة الكهربائية، مصدر ا للإنارة الداخلية. في المكاتب المعاصرة أصبحت الإنارة مقلصة و متعلقة بالإنارة الإصطناعية التي أصبحت أكثرانتشارا. يعتبراستعمال الإنارة الطبيعية كوسيلة احتياط للحفاظ على الطاقة. إذ يصعب توفيركمية ملائمة من الإنارة الطبيعية في الفضاء. إن لمعرفة مساحة تغطيتها أهمية بالغة لأجل الإستعمال مما يتطلب دراسة تحليلية للإنارة الطبيعية و لمعايير السماء نصيب مهم من هذا التحليل. حاليا توجد مجموعة خمسة عشر سماء إذ تبنتهاالهيئة العالمية للأنارة كمعاييردولية، لكن لم تعتمد في نظام برمجي للإنارة الطبيعية. من أجل اعتماد معايير السماء، قامت هذه الدراسة بتحليل عمق الإنارة الطبيعية الإصطناعية الدائمة في داخل مكاتب البنايات العالية الموجودة تحت رطوبة عالية بجزيرة ماليزيا باستعمال طريقة منتقاة. استعملت الدراسة معامل الإنارة الطبيعية من أجل حساب الإنارة الطبيعية. استعمل مخطط *ولدرام* لحساب قيمة رؤية السماء التي احتيجت في منهجية معامل الإنارة الطبيعية. أجريت عدة تجارب من أجل إيجاد أعلى حد و أقل حد للإنارة الطبيعية المغطاة خلال السنة. حيث أجري تحليل حول أقل المستويات لإيجاد حد عمق الإنارة الطبيعية إذ أن الفارق بين أعلى و أقل تغطية التي اعتبرت في الإنارة الطبيعية الإصطناعية الدائمة في الداخل. وجد البحث عمق الإنارة الطبيعية بين 3م و3.5م من خلال نافذة تعتبر أقل حد للإنارة الطبيعية هو 500لكس و300لكس. ووجد أيضا عمق الإنارة الطبيعية الإصطناعية الدائمة في داخل مختلف ومختلف بإتجاهات مختلفة. فهو عال في جهة شمال أمريكا، غرب،جنوب شرقي، جنوب غربي وشمال غربي مقارنة بالشمال و جنوب التوجيهات. وهذا يعود إلى قلة الشمس صباحا ومساء. لهذا، فالبحث لخص الأعماق التي يجب أن تؤخذ بعين الإعتبارفي مرحلة ماقبل التصميم لبناية مكاتب من أجل أخذ أقصى كمية من الإنارة الطبيعية لإستعمالها في المحيط الداخلي للمكاتب.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Built Environment.

....
Zuraini Denan
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Built Environment.

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(Postgraduate and Research)

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Mansor Ibrahim
Dean,
Kulliyyah of Architecture
and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Abu Nur Mohammad Shahriar

Signature …………………………………… Date ……………………..

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Signature Date

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LIST OF ABBREVIATIONS

CCA	Central Commercial Area
CIE	Commission Internationale de L'eclairage
CIBSE	Chartered Institute of Building Service Engineers
COP	Code of Practice
COPE	Cost Effective Open-plan Office Environment
CPA	Central Planning Area
DBKL	Dewan Bandaraya Kuala Lumpur
IEA	International Energy Agency
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
LBNL	Lawrence Barkley National Laboratory
MSG	Malaysian Sheet Glass Berhad
NRC	National Research Council of Canada
PAL	Permanent Artificial Lighting
PSALI	Permanent Supplementary Artificial Lighting for Interiors
SSLD	Standard Sky Luminance Distribution
SPSS	Statistical Package for Social Sciences
TRY	Test Reference Year

LIST OF SYMBOLS

A	Total room area
av	Luminous extinction
CU	Coefficient of Utilization
$D_{\gamma\alpha}$	Daylight coefficient
D_v/E_v	Diffuse to extraterrestrial illuminance ratio
E_i	Interior illuminance (lux)
E_x	Exterior illuminance (lux)
E_{SE}	Sky components
E_{ERE}	External components
E_{IRE}	Internal components
E_S	Interior illuminance from the direct component of daylight
E_p	Illuminance at a point
E_v	Extraterrestrial horizontal illuminance
G_v	Global horizontal illuminance
K_b	Direct/Beam luminous efficacy
K_d	Diffuse luminous efficacy
K_g	Global luminous efficacy
L	Luminance of the light source
$L_{\gamma\alpha}$	Luminance of the sky element
$L_{\gamma\alpha}$	Luminance of the arbitrary sky element at elevation γ and azimuth α
L_z	Zenith luminance
m	Optical mass
MF	Maintenance factor

NT	Net transmittance
P_v	Direct horizontal illuminance
R	Mean room reflectance
R_{fc}	Reflectance of floor and lower wall surfaces
R_{cw}	Reflectance of ceiling and upper wall surfaces
R_g	Mean ground reflectance
$T_{\gamma\alpha}$	Angular transmittance of window glazing
T	Mean glass transmittance
T_ω	Glass transmittance at incident angle ω
T_v	Turbidity factor
W	Window area
Z	Zenith angle of the sky element
ν	Window azimuth
ω	Solid angle that the light source subtends at a point
θ	Angle with the downward vertical
γ	Altitude angle
ΔE	Fraction of the total illuminance
$\Delta S_{\gamma\alpha}$	Angular size of the sky element at altitude γ and azimuth α
α	Azimuth angles of the vertical plane of the sky element
α_S	Solar meridian
β	Window azimuth angle
θ	Window elevation angle
φ	Gradation function
χ	Scattering angle

Z_s	Zenith angle of the Sun
γ_s	Solar altitude angle

CHAPTER ONE

INTRODUCTION

Daylight is vital for the indoor working environment and hence, it occupies an important consideration in the design of office buildings. In clear sky condition, as much as 80% of the sun's ray reaches the earth surface and heavy cloud cover can reduce this amount to 20%. However, these are average figures and are applicable for the entire globe (Fujinami, 1998). Therefore, in our natural environment there is an abundance of daylight. Before the invention of electric lighting, daylight was a primary source of interior illuminance. Nevertheless, cheap energy cost in some countries of the world, has replaced the use of daylight by artificial light in the office environment.

This study analyses the depth for daylight zone and Permanent Supplementary Artificial Lighting for Interior (PSALI) in high-rise office space under climatic conditions of Malaysia. It intends to provide useful insights into the nature of daylight penetration in office interiors. This chapter introduces the study by providing elaborations on research background. It states the research objectives, scope and research framework.

1.1 Research Background

OVER THE LAST TWENTY YEARS, THERE HAS BEEN A RAPID GROWTH OF OFFICE BUILDINGS IN ALL MAJOR CITIES OF MALAYSIA, ESPECIALLY IN KUALA LUMPUR, WHICH IS THE FEDERAL CAPITAL OF THE COUNTRY. DURING THIS PERIOD, ALTHOUGH A FEW CLIMATE CONSCIOUS

RESEARCHES WERE DONE (ISMAIL, 1996 IN DENAN, 2004), MOST OF THE OFFICE BUILDINGS WERE BUILT WITH LITTLE OR NO REGARD TO THE LOCAL CLIMATIC CONDITIONS, ESPECIALLY DAYLIGHT. ALTHOUGH THE SKYLINE OF KUALA LUMPUR COMPOSES OF A NICE ARRANGEMENT OF HIGH-RISE OFFICE BUILDINGS AS CAN BE SEEN IN FIGURE-1.1, LITTLE CONSIDERATIONS WERE GIVEN TO DESIGN THEM ON THE PRINCIPLE OF ENERGY EFFICIENCY.

FIGURE 1.1: KUALA LUMPUR SKYLINE (SOURCE: THE AUTHOR)

IN AN OFFICE BUILDING, ENERGY CONSUMPTION CAN BE DIVIDED INTO TWO MAIN PARTS – (A) CONSUMPTION OF ENERGY FOR ARTIFICIAL LIGHTING; AND (B) CONSUMPTION OF ENERGY FOR AIR CONDITIONING (RAMATHA, 1994 IN DENAN, 2004). IN ADDITION TO THIS, EXTRA ELECTRIC ENERGY IS CONSUMED FOR COMPUTER USES AND OTHER MACHINERIES, I.E. FOR LIFTS, WATER SUPPLY. THEREFORE, COMBINING DAYLIGHT WITH ARTIFICIAL LIGHT IN OFFICE ENVIRONMENT IS EXPECTED TO HAVE ENERGY SAVING IMPLICATIONS.

Daylight use can be an important energy saving feature of a building by partially replacing electric lighting demand. Studies have shown that as much as 10% of energy consumption in a building can be reduced just by proper window and shading designs (Azni Zain, 2000). It not only can reduce energy usage but also can reduce peak hour power demand for energy. This is due to the fact that the power consumption for other utilities is at their peak corresponding to the time when daylight is most available e.g. during mid-day (Illuminating Engineering Society of North America [IESNA], 1993).

It is a well-known fact that savings due to daylight can be greater than the extra cooling loads that arise due to the additional solar radiation (Department of Standards, 2001). There is no doubt that daylight has energy saving implications, especially in Malaysia because of its tropical climate. The country lacks any major wind flow throughout the year. This reduces the possibility of natural ventilation reducing the cooling loads of a building and leaves daylight as the most practical option for energy savings (Woods, 2004). The use of daylight as a supplement to electric lighting deserves further considerations due to the ever-rising fuel costs that the entire globe is currently experiencing.

1.2 RESEARCH OBJECTIVES

THE MAIN OBJECTIVES OF THE RESEARCH ARE AS FOLLOWS,

I. TO STUDY THE DEPTH OF DAYLIGHT ZONE AND PERMANENT SUPPLEMENTARY ARTIFICIAL LIGHTING FOR INTERIORS (PSALI) IN A GENERALIZED HIGH-RISE OFFICE INTERIOR OF MALAYSIA.

II. TO ESTABLISH ACCEPTABLE DEPTH OF SUCH ZONES FOR THE ENTIRE YEAR BASED ON LIGHTING LEVELS SUITABLE FOR DIFFERENT TYPES OF OFFICE WORKS.

1.3 SCOPE OF THE RESEARCH