HEAT TRANSFER ANALYSIS OF VERTICAL SHADING DEVICE IN OFFICE BUILDINGS IN MALAYSIA USING COMPUTER SIMULATION

BY

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ABSTRACT

The architectural trends of glazed facades have brought more daylighting and transparency into buildings. Large glazed areas bring a large amount of solar radiation, which can be wisely utilized for better environmental building design. However, glazed envelopes can cause excessive heat inside the building, where potential sources of unwanted overheating and glared effects cause indoor discomfort to the building occupants. Therefore, shading devices are designed to prevent excessive solar radiation and to distribute daylight evenly into the interior spaces. Meanwhile, shading devices are based on more of aesthetic value for the building façade. In the design of the shading system, there are a variety of consideration related to the shading type, such as material properties and many more. In order to enhance the daylighting performance, the shading device should play a more efficient role in order to control the heat inside the building. Therefore, a study was conducted on heat gains, particularly for vertical shading device in an office building using computer simulation. The study used 'ECOTECT' software to perform passive heat gains breakdown calculation. 'ECOTECT' has been used to calculate the distribution of daylighting needed for interior spaces in the building. A field measurement was conducted to find out the heat gains in the office building. The temperature was recorded by using data logger. The experiment tested related variables such as the distance between the shading device and the glazing area, as well as materials and thicknesses of the shading device. The data was collected and used to calculate the heat gains in the office building. This data justified the simulation result that compared the heat gains before and after the test variables was conducted. The investigation found that the concrete vertical shading device with 150mm gaps from window had better reduction capacity of heat gains into building. In addition, the analysis also found that with 150mm thicknesses of a vertical shading device has a lower rate of heat transfer whereas, the heat gains in the building was reduced from 31.2W/m^2 to 29.9W/m^2 . This result is compatible with recommended value that is below 50W/m^2 and in accordance to Malaysian Standard 1525:2007. The study, therefore, proposes that these criteria should be taken into consideration in the pre-design phase of an office building in order to apply appropriate shading device in avoiding unnecessary heat transfer into the office building.

خلاصة البحث

وقد أدت الاتجاهات المعمارية التي تعتمد الواجهات الزجاجية إلى دخول مزيد من ضوء النهار والشفافية في المباني. والمساحة الزجاجية الكبيرة تجلب كمية كبيرة من الإشعاع الشمسي، والتي يمكن استخدامها في إنتاج تصميم أفضل للمبنى الصديق للبيئة. وعلى الرغم من ذلك، تسبب المظاريف المزججة الحرارة المفرطة داخل المبنى، حيث أن المصادر المحتملة لارتفاع درجة الحرارة والآثار الساطعة غير المرغوب فيها تسبب عدم الارتياح الداخلي لشاغلي المبنى. ولذلك، فقد تم تصميم أجهزة التظليل لمنع أشعة الشمس المفرطة وتوزيع ضوء النهار بالتساوي في المساحات الداخلية. وفي الوقت نفسه، تقوم وسائل التظليل أساساً على القيمة الجمالية على واجهات المبنى. هناك أمور يجب أخذها بعين الاعتبار في تصميم نظام التظليل، وذلك فيما يتعلق بنوع التظليل، مثل خصائص المواد وغيرها الكثير. ومن أجل تحسين أداء ضوء النهار، ينبغي لجهاز التظليل أن يلعب دورا أكثر فعالية من أجل السيطرة على الحرارة داخل المبنى. ولذلك، أجريت هذه الدراسة على الحرارة المكتسبة، ولا سيما بالنسبة لجهاز التظليل العمودي في مبنى المكاتب، باستخدام برنامج محاكاة الحاسوبي. اعتمدت هذه الدراسة برنامج "ECOTECT" لحساب انهيار الحرارة المكتسبة السلبية. كما استخدم برنامج "ECOTECT" لحساب توزيع ضوء النهار الذي تحتاج إليها المساحات الداخلية في المبنى. وقد أجريت القياسات الميدانية لمعرفة الحرارة المكتسبة في مبنى المكاتب. وسجلت درجات الحرارة باستخدام مسجل بيانات. وقد اختبرت هذه التجربة المتغيرات ذات الصلة مثل المسافة بين جهاز التظليل ومنطقة الزجاج، وكذلك المواد وسمك جهاز التظليل. تم جمع البيانات واستخدامها لحساب الحرارة المكتسبة في مبنى المكاتب. هذه البيانات تبين نتيجة المحاكاة التي تقارن الحرارة المكتسبة قبل وبعد إجراء اختبار المتغيرات. وأثبتت الدراسة أن جهاز التظليل العمودي الثابت الذي يبعد بينه وبين الشباك ب 150 ميليمتر له قدرة أفضل في تخفيض الحرارة المكتسبة إلى المبنى. وبالإضافة إلى ذلك، أثبت التحليل أن جهاز التظليل العمودي بسمك 150 MM ينقل الحرارة نسبة أقل، في حين تم تخفيض الحرارة المكتسبة في المبنى من 31.2 وات لكل كعب مربع إلى 29.9 وات لكل كعب مربع. وهذه النتيجة تتوافق مع القيمة الموصى بها، وهي أن تكون أقل من 250 وات لكل كعب مربع، وفقا للمعيار الماليزي 1525: 2007. لذا، يقترح الباحث أن هذه المعايير ينبغي أن تؤخذ في الاعتبار في مرحلة ما قبل تصميم مبنى المكاتب، وذلك من أجل تطبيق جهاز التظليل المناسب لتجنب نقل غير لازم للحرارة إلى مبنى المكاتب.

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 Building Services of Engineering.

…………………………………..
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 Building Services of Engineering.

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Aliyah Nur Zafirah Sanusi
Examiner

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Rosniza Othman
Head, Department of Architecture

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for the degree of Master of Science in Building Services of Engineering.

…………………………………..
Khairuddin Abdul Rashid
Dean, Kulliyyah of Architecture and Environmental Design

DECLARATION

I hereby declare that this thesis is the result of my own investigation, 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.

Nor Azah binti Arifin

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

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LIST OF ABBREVIATIONS

AAC	Autoclaved Aerated Concrete
CAD	Computer Aided Design
PD	Percentage Difference
RH	Relative Humidity
MS	Malaysian Standard
IES	Integrated Environmental Solutions
SHGF	Shading Gain Factor
SC	Shading Coefficient
CLF	Corrected Load Factor
CLTD	Corrected Load Temperature Difference
CLTDc	Corrected Load Temperature Difference Coefficient
TD	Temperature Difference

LIST OF SYMBOLS

ρ	Density
kg/m^3	Unit of density measurement
k, λ, or κ	Thermal conductivity
Q	Heat
J/kgK	Joule per kilogram Kelvin
W/m^2*K*	Watts per meter square Kelvin
T1	Temperature (earlier)
T2	Temperature (final)
%	Percentage
T	Time
Θ	Temperature
W.m−1.K−1	Watts per metre Kelvin
k	Thermal conductivity
R-value	Resistant
U-value	Conductivity
^{0}*C*	Celsius
m	metre
m^2	Metre square
mm	Millimetre
k/Wm^2	Kilo per watts metre square
^{0}	Degree/angle
K	Kelvin
W/m/0C	Watts per metre Celsius
kWh/m^2	Kilo watts hour per metre square
W	Watts
Cv/Cp	Specific Heat Capacity

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE RESEARCH

The dissertation is on “Heat Transfer Analysis through Vertical Shading Device in Office Building in Malaysia using Computer Simulation." Throughout this chapter, it will describe an overview of the research conducted. This chapter will discuss thoroughly on the following aspects:

1.2 Background of research

1.3 Statement of problem

1.4 Research problems

1.5 Aim and objectives of research

1.6 Research hypothesis

1.7 Scope of research

1.8 Methodology of research

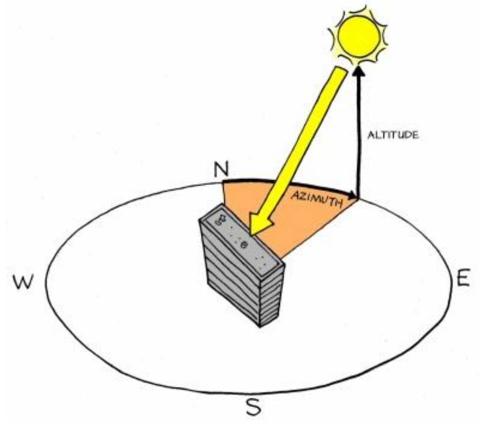
1.9 Significance of research

1.10 Structure of research

1.2 BACKGROUND OF RESEARCH

The climate of Malaysia is driven by its equatorial position, extensive coastlines on tropical seas and monsoonal winds. Malaysia is at latitude 3 degree and one minute north and longitude 101 degree and seven minutes east (time zone GMT+8hrs). Because Malaysia is situated between one and six degrees North latitude, Malaysia has an equatorial climate with uniformly high temperatures, high humidity, relatively light winds, and abundant rainfall throughout the year. The main causes of climatic variation within Malaysia are differences in altitude and the exposure of the coastal lowlands to the alternating southwest and northeast monsoon winds. The southwest monsoon winds blow from April to September and the northeast monsoon winds blow from November to February. Thus, Malaysia has uniformly high temperatures throughout the year. In most areas the average maximum and minimum temperature per month vary less than 2^0C annually. Temperature can range daily between 5^0C to 10^0C near the coast and from 8^0C to 12^0C inland. The relative humidity in Malaysia is high, ranging from 70% to 90%. Humidity varies more throughout the day than it does annually.

The sun's location in the sky is tracked by its horizontal (azimuth) angle and its vertical (altitude) angle. The two angles specify the sun's position in the sky in geographical coordinates as for example; north is taken as 0 degree and horizontal is 0 degree. The azimuth determines the direction in which the shadow will fall on the ground. Solar azimuth is the angle, in a horizontal plane, between true north and the direction of the Sun, measured clockwise from true north. It can have any value from 0^0C to 360^0C. The solar altitude angle determines the length of the shadow cast by a solid object on the ground. Solar altitude is the angle between the sun and the horizon at given latitude. It varied according to the time of the day and according to season. When designing shading device, the geometry of shading device and its relationship to the face of the building produce a number of angles relative to the desired shadow being cast. Thus, when attempting to shade a window, the absolute azimuth and altitude of the Sun are not as important as the horizontal and vertical shadow angles relative to the window plane. This can be calculated for any time if the azimuth and altitude of the Sun are known.



Altitude is the vertical angle the sun makes with the ground plane (0° < alt < 90°).

Azimuth is the horizontal angle between the sun and true north (–180° < azi < 180°, positive in a clockwise direction from north).

Figure 1.1 Solar position

Stereographic sun path diagrams are used to read the solar azimuth and altitude throughout the day and year for a given position on the earth. They can be likened to a photograph of the sky, taken looking straight up towards the zenith, with a 180° fish-eye lens. The paths of the sun at different times of the year can then be projected onto this flattened hemisphere for any location on Earth. The sun’s path varies throughout the year. In the summer the sun is high in the sky, and rises and sets north of east-west in the northern hemisphere (in the southern hemisphere, its south of east-west). It also rises much earlier and sets much later in summer than in winter. In the winter the sun is low in the sky, and rises and sets south of east-west in the northern hemisphere (in the southern hemisphere, its north of east-west). To study more average positions, we can look at the sun’s path on the spring and autumn equinoxes, when the sun rises and sets due east-west. The altitude of the noon sun at the equinox is determined by the latitude of the site. This is why the rule-of-thumb for the optimum angle of solar panels is the latitude of the site. At this angle, the sun's rays are most perpendicular to the panel for most of the year.

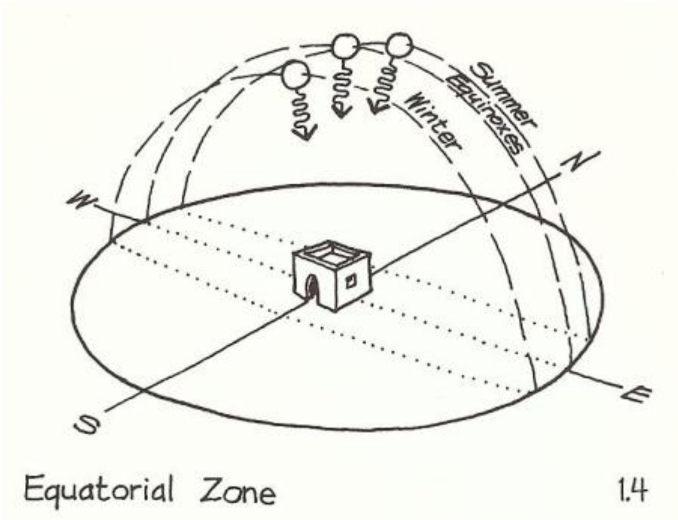


Figure 1.2 The seasonal zones-equatorial zones

There are four important dates to remember when considering sun position:-

Table 1.1 Seasonal variations and important dates

Name	Date		Description
	South Hem.	North Hem.	
Summer Solstice	22 Dec.	22 June	Sun at its highest noon altitude
Autumn Equinox	21 Mar.	21 Sept.	Sun rises due east, sets due west
Winter Solstice	21 June	21 Dec.	Sun at its lowest noon altitude
Spring Equinox	21 Sep.	21 Mar.	Sun rises due east, sets due west

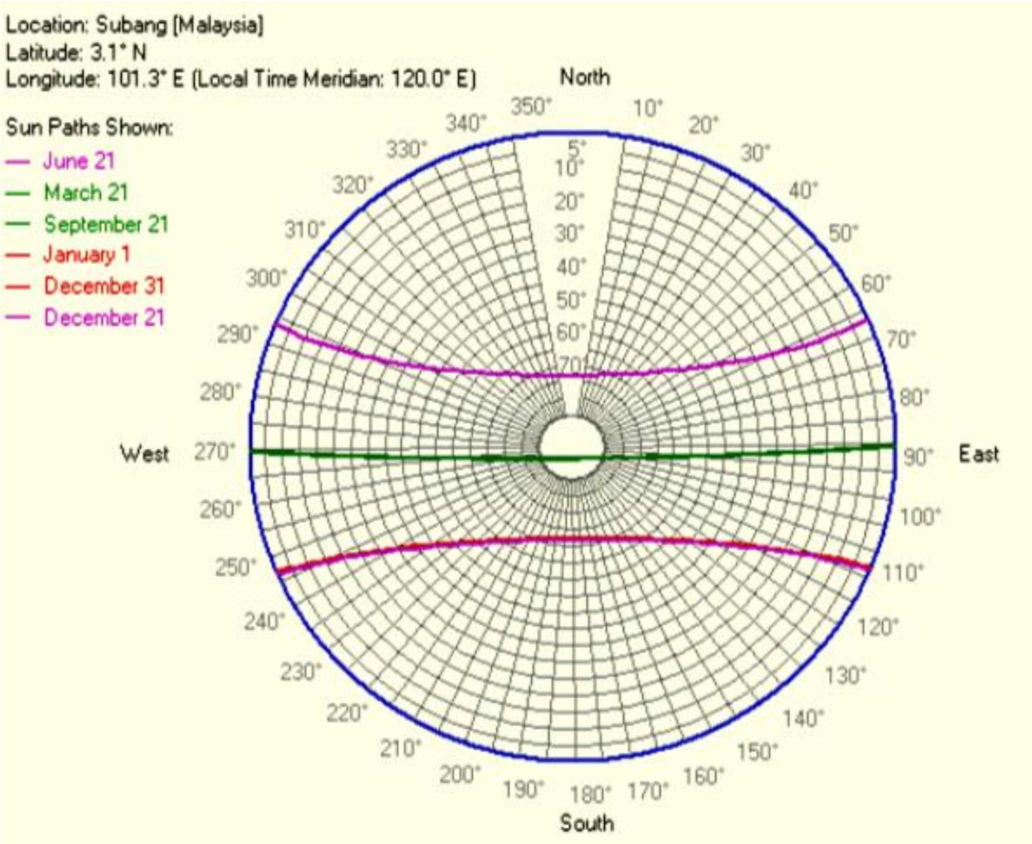


Figure 1.3 Malaysia sun paths diagram at the equatorial zone

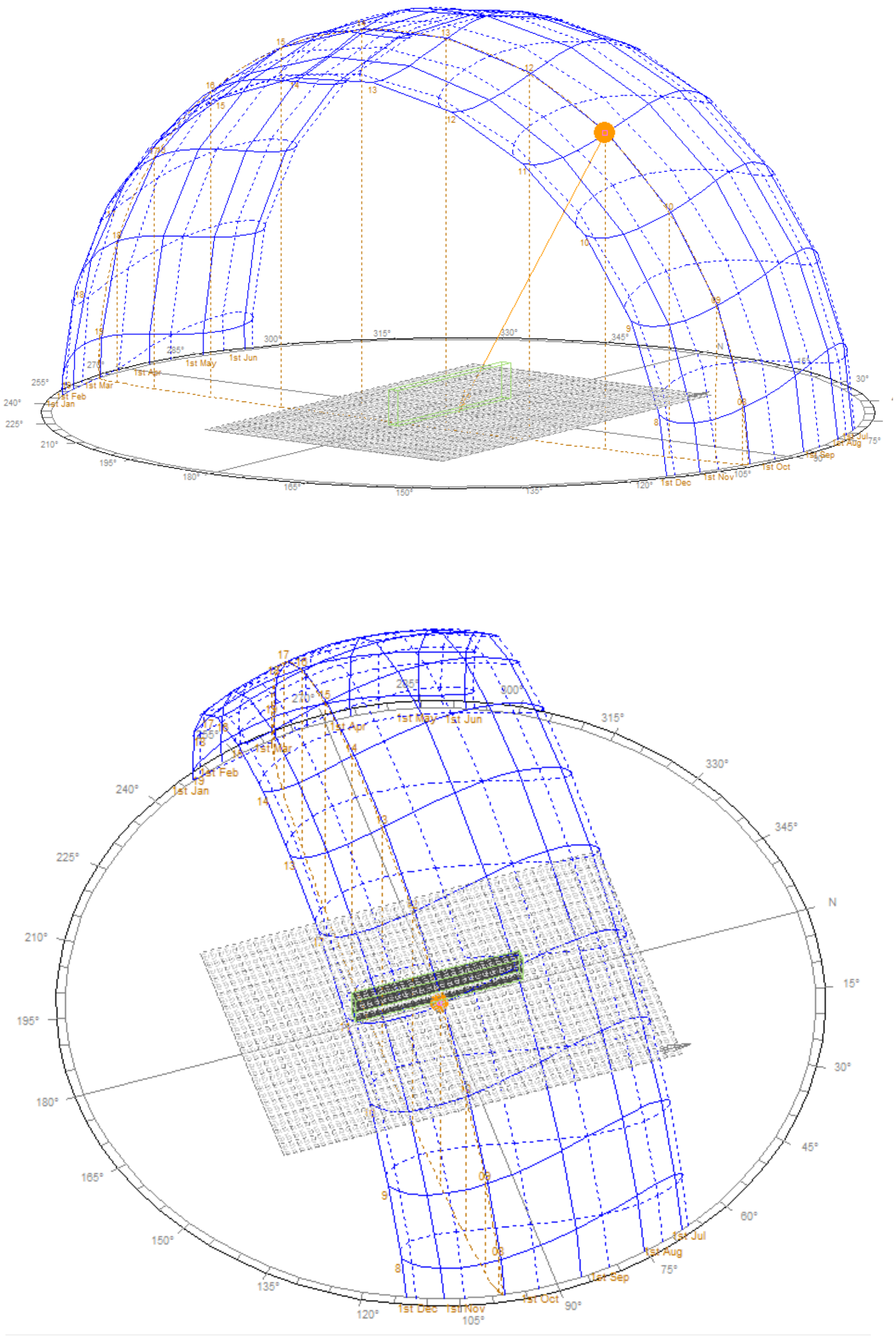


Figure 1.4 3D visualization of the stereographic diagram, showing the position of the sun at the fixed hour of 11 am generated from ECOTECT analysis software

The impact of solar radiation incidence on the east façade in Malaysia is critical from 09:00 – 12:00 hours and 13:00 – 17:00 hours for the west oriented facades. Beyond this limit the building itself give shade as the sun position is behind