THE EFFECT OF SOLAR GEOMETRY ON A WINDOW SHADE FOR ENERGY EFFICIENT DESIGN OF BUILDINGS

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ABSTRACT

This report is based on the effect of solar geometry on a window shade for energy efficient design of building. The objective of this project is investigate the effect of the solar geometry on a window shade of different aspect for energy efficiency purposes and to investigate the effect of using horizontal window shade in reducing solar radiation, thus improving the energy efficiency. It is important to understand the science of solar geometry, it is very important in determining and simulates shadows emitted by solar shades, and directly overhanging horizontal windows to block part of the s radiation will penetrate into the space available in room. Indirectly, the shadow appears to the solar colour varies according to solar geometry, although the movement of the sun relative to the earth's constant. The method that have used in this project is using the C++ Programming to calculate the declination angle and construct diagram to do the sun path. Then, the AWSHADE 3.0 is used to calculate and get the shading degree or beam degree. It was founded, the horizontal shading is suitable to use in highest latitude like Perlis because the radiation arising from the solar movement and the effect caused the solar geometry on the window shades.

ABSTRAK

Laporan ini adalah hasil kajian yang dibuat berkaitan dengan kesan geometri solar di bawah naungan tingkap untuk reka bentuk bangunan yang cekap tenaga. Projek ini adalah untuk menyiasat kesan-kesan geometri solar pada naungan tingkap terhadap perbezaan penggunaan tenaga dan juga menyiasat naugan tingkap yang mendatar terhadap penggurangan tenaga radiasi dan membaiki tenaga effisiensi.Ini adalah penting to memahami sains geometri,juga penting menentukan dan mengkaji baying-bayang solar and naugan tingkap mendatar untuk menghalang solar radiasi menembusi ruang bilik.Kaedah yang digunakan dalam projek ini adalah kaedah dari C++ Programming untuk menentukan sudut matahari dan membuat sun path diagram.Selain itu, AWNSHADE 3.0 juga digunakan untuk pengiraaan dan mendapat sudut naungan tingkap.Berdasarkan keputusan projek,naungan tingkap mendatar adalah sesuai digunakan di latitude yang tinggi seperti di Perlis kerana solar radiasi dari pergerakan solar dan kesan daripada solar geometri terhadap naugan tingkap.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This project gives opportunity to student to apply engineering knowledge that will be one of the most important aspects that an engineering graduate must acquire upon graduation. The only way to learn this practical skill is to have specific engineering problem to solve. One must learn to use all applicable theories in analysis the problem systematically. This project is about to study and stimulate the effect of solar geometry on a window shading of different aspect ratio for efficiency purposes .Then, the amount of the radiation blocked varies with the changing position of the sun and the geometric shape of the shade.

1.2 BACKGROUND

The window shades are an effective measure to block solar through a window coming directly into a window. The window shades gives effect to the energy use in a building and also it can give influence day lighting levels in a room .In addition, the window shades is thus closely connected with energy that used in room or building for heating, cooling and lighting. The amount of the radiation blocked varies with the changing position of the sun and the geometric shape of the shades.

From the solar geometry side, the suns follow an arc rising in the east from the countries in the northern hemisphere and setting in the west. The sun is lower in the sky in winter months and higher in the sky in summer months .Fortunately, the sun is high in the sky so horizontally fixed shading or deeply recessed window will reduce the solar radiation in summer. However, the intensity of solar radiation is less in winter months and generally solar gain is beneficial in winter.

The east facing windows are affected by direct solar radiation from morning to midday. Horizontal shading does not really become effective until after 9.00am.If we see from the west facing window, there are affected by direct solar radiation from afternoon to evening. Horizontal shading may be effective up to 3.00 pm in the afternoon depending on the time of year. From late afternoon to evening, the altitude of the sun is lower allowing solar radiation to enter on a more to horizontal path. The intensity of solar radiation in the summer months at these times is still high. The vertical shading on west facing windows can provide shading from solar gain from afternoon to evening for all months of the year.

Moreover, although this report intends to review most of the important works on solar shading of building, some more studies, mentioned at end of the report, are to be reviewed later. Work connected with calculation programming, window and energy efficiency are also discussed here as they relate indirectly to the problem .As a conclusion ,the review suggest that these future advances will allow climate specific shading strategies.

1.3 PROBLEM STATEMENT

Energy efficiency of a building is highly dependent on the solar geometry, and therefore the solar geometry must be fully understood for any initiative towards improving the energy efficiency of a building. This is especially true for buildings in a hot climatic country like Malaysia, where air-conditioning takes up about 60 to 70 percent of the total energy consumed in a building.

The solar geometry has many special effects on the earth. The movements of the earth with respect to the sun create unique characteristics to the earth. The rotation of the earth within the 24-hour period gives rise to day and night, whereas the revolution of the earth around the sun with the earth polar axis inclined at a certain fixed angle gives rise to the changing day and night hours as well as the seasonal changes, from spring to summer to autumn and winter, and back again to summer.

With both movements combined (rotation and revolution) gives rise to further implications to the earth, particularly the solar radiation. The rate of this solar radiation changes every hour of the day, and every day of the year, based on the solar geometry. The solar radiation in turn, gives rise to thermal behaviour of a building, and for hot-climatic countries like Malaysia, solar radiation is the major contributor to the air-conditioning load of the building or a space.

Using the knowledge and science of solar-geometry, it is useful to simulate the shadows cast by solar shades or window horizontal overhangs to block part of the radiation that would otherwise penetrate into the air-conditioned space. The amount of shadows cast by the solar shades varies according to the solar geometry, albeit the continuous relative movement of the sun with respect to the earth. By blocking part of the radiation, the heat gain into the air-conditioned space can be reduced significantly, and thereby enhancing the energy efficiency of the building. The amount of radiation reduction also depends on the size and geometry of the solar shades.

Hence, a computer programmed is necessary to conduct the simulation using the solar geometry equations well established now.

1.4 OBJECTIVES

To overcome the above issues, some objectives are setup:

i. The objectives are to know the effect of the solar geometry on a window shade of different aspect for energy efficiency purposes.
ii. To study the effect of using horizontal window shade in reducing solar radiation, thus improving the energy efficiency

1.5 SCOPES

This project is focusing on stimulate the effects of solar geometry on a window shade of different aspect ratio for energy efficiency purposes. He work scopes are done based on the following aspect:

i. Study and understanding the solar movement.
ii. Designing a computer programmed to determine the solar position for any locality at any time of the year and any time of the day. Point to note are:
    - Time equation (annual variation of the solar movement)
    - Validity of the equation for North Pole and South Pole
    - Test the programmed for various latitude ,dates and hour
iii. Tabulate the result for various geometric shape of the window shade.

1.6 STRUCTURE OF THESIS

Chapter 1 introduces the overview of the topic. It is continues with the problems statement which related to the study and followed by the objectives, scope of the study, and the structure of the thesis.

Chapter 2 introduces the literature view of the solar geometry where the review showed that It is important to understand the science of solar geometry, it is very important in determining and simulate shadows emitted by solar shades, directly overhanging horizontal windows to block part of the s radiation will penetrate into the space available in room. In directly, the shadow appears to the solar colour varies according to solar geometry, although the movement of the sun relative to the earth's constant.

Chapter 3 reviews about the there are also requires a wide-ranging definition and an overview of the approach that will be used in conducting the research. This chapter is dividing into 3 sections. There are the concept of design, the equation that will used in programming, the software that have being used to do the programming system and the Gantt chart.

Chapter 4 reviews about this chapter describe and explain the results obtained from graph and discuss the method of the calculation that obtained from the research method. This study is a practical project of the field study type. This chapter will discuss more about the solar movement especially about the sunset and sunrise. This chapter will discuss and explain more detail about the sun path in 3 countries. There are Pekan, Perlis and Johor. There have some calculation that used this sun path diagram.

Chapter 5 will conclude the whole topic and conclude based on objective and scope of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The window shade is really useful to measure to block solar radiation through window coming directly into a room. It is important to understand the science of solar geometry, it is very important in determining and simulates shadows emitted by solar shades, and directly overhanging horizontal windows to block part of the s radiation will penetrate into the space available in room.

In directly, the shadow appears to the solar colour varies according to solar geometry, although the movement of the sun relative to the earth's constant. To prevent and reduce the radiation, heat will go through into the space in the room can be significantly reduced, and in so doing, it can improve the energy efficiency of buildings. Total radiation reduction also depends on the size and geometry of solar shades.

2.2 SOLAR GEOMETRY

The shade window status is depend on the angular position of the sun relative to the site, in comparison with the angular position of the angular position of the different obstructions including the horizon line, in the proximity of the site. The sun is evolves in the sky in differently according to the latitude of the side and the time of the year.

This is due to the fact that the north-south axis of the Earth is tilted 23.45 ° from the normal to the ecliptic plane. The main consequence is the changing of seasons and the variation of the day length throughout the year. It is shown in Figure 2.1 the solar geometry

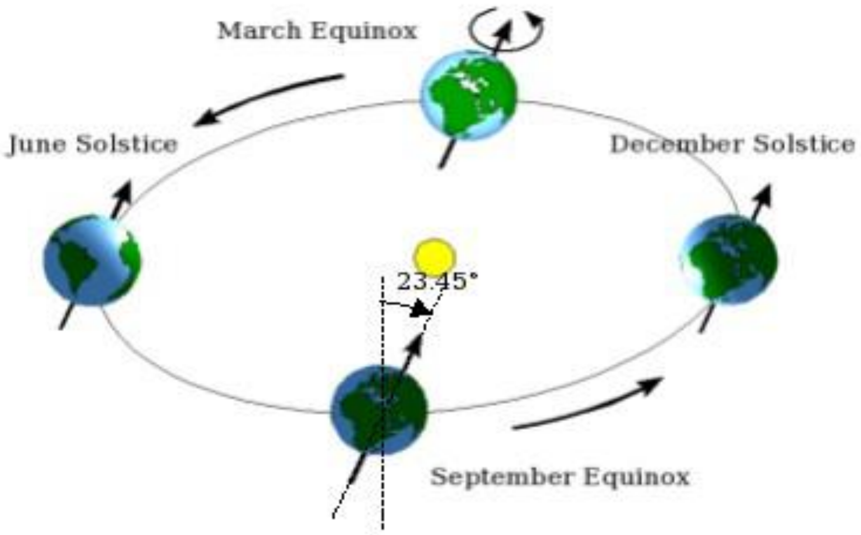

Figure 2.1 The Solar Geometry

The source from N. Baker, A. Fanchiotti, K. Steemers (1993).

At noon

alt = 90 - lat - 23.45 at the winter solstice

alt = 90 - lat + 23.45 at the summer solstice

Where alt is the altitude of the sun in degrees and lat the latitude of the site in degrees. These relations can also be expressed as a function of the zenith angle z and the vertical of the site.

z = lat + 23.45 at the winter solstice

z = lat - 23.45 at the summer solstice

We can also say that at the equinoxes, at noon, z = lat. The difference between the plane of the Sun's path at any day n_{th} day of the year and the plan of the path at the equinoxes is called solar declination, d. This angle varies between -23.45 and +23.45 in a sinusoidal fashion throughout the year.

$\delta = 23.25 \sin[360/365(n+284)]$

Therefore, at any day of the year, the zenith angle z at noon is given by: z = lat - d (expressed in degrees).

For other hours of the day, we need to determine not only the zenith angle of the sun, but also its azimuth from the South direction (which is 0 at noon). The angular movement of the sun in the sky throughout a day is due to the rotation of the. Earth on itself, one round per 24 hours, hence 15° per hour. To determine the position of the Sun we then use the hourly angle w, which increases or decreases of 15° every hour.

w = 15(Ts - 12)

where Ts is the solar time on the site considered. And finally the zenith angle and the azimuth are give by the two relations:

$$\cos z = coz\ lat\ x \cos \omega\ x\ cos\delta + \sin lat\ x \sin \delta$$

$$\sin \varphi = (\cos \delta \text{ x} \sin \omega) / (\sin z)$$

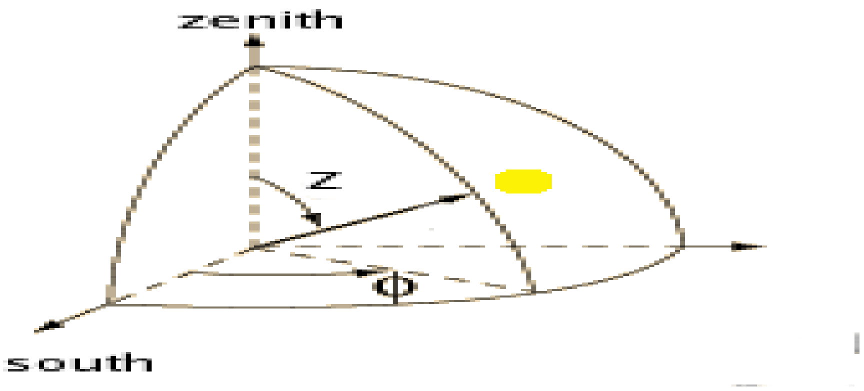

Figure 2.2 the zenith angle

The source from N. Baker, A. Fanchiotti, K. Steemers (1993)

These relations will allow us to determine, for any location at given latitude, the zenith angle and the azimuth .It is shown in Figure 2.2 the zenith angle

2.2.1 SEASON

Seasons are caused by the Earth axis which is tilted by 23.5 degrees with respect to the ecliptic and due to the fact that the axis is always pointed to the same direction. According to the 1998 ASHRAE Handbook of Fundamentals, when the northern axis is pointing to the direction of the Sun, it will be winter in the southern hemisphere and summer in the northern hemisphere.

Northern hemisphere will experience summer because the Sun's ray reached that part of the surface directly and more concentrated hence enabling that area to heat up more quickly. The southern hemisphere will receive the same amount of light ray at a more glancing angle, hence spreading out the light ray therefore is less concentrated and colder. So at this time, In summer the sun is high in the sky so horizontally fixed shading or deeply recessed windows will reduce solar gain and In winter horizontal system will not work.

However the intensity of solar radiation is less in winter months and generally solar gain is beneficial in winter .The converse holds true when the Earth southern axis is pointing towards the Sun. (Figure 1.5). East facing windows are affected by direct solar radiation from morning to midday. Horizontal shading does not really become effective until after 9.00 am

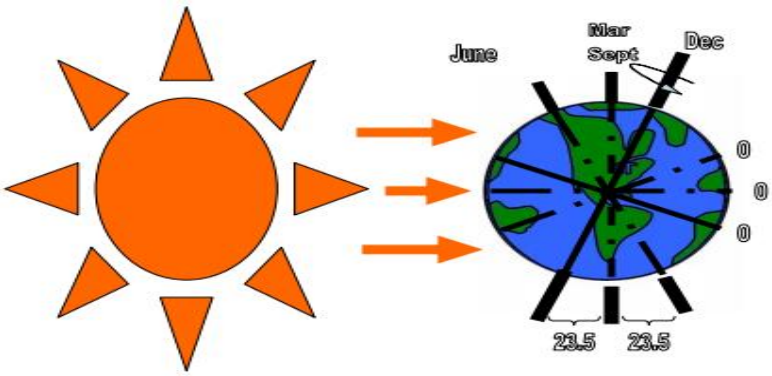

Figure 2.3: Tilt of the earth

Source from Lam, W.M.C. (1986)

By solar geometry, the earth rotates and revolves around the Sun in a 24-hour period, indirectly, it will result in creation of day and night, changing of season, from spring to summer to autumn and winter, and back again for the summer . The summer sun rises higher overhead than the winter sun.

In summer the sun is high in the sky so horizontally fixed shading or deeply recessed windows will reduce solar gain properly sized window overhangs or awnings are an effective option to optimize southerly solar heat gain and shading. They shade windows from the summer sun and, in the winter when the sun is lower in the sky, permit sunlight to pass through the window to warm the interior. Landscaping helps shade south-, east-, or west-facing windows from summer heat gain.

2.2.2 REVOLUTION

It is generally accepted that the earth's complete revolution around the Sun is 365 days. However, to be exact, the number of days the earth takes to revolve around the sunactually depends on whether we are referring to a sidereal year or a tropical (solar) year.A sidereal year is the time taken for the earth to complete exactly one orbit around the Sun.

A sidereal year is then calculated to be 365.2564 solar days. A tropical year is the time interval between two successive vernal equinoxes, which is 365.2422 solar days. The difference between the two is that tropical year takes into consideration precession but the sidereal year does not. Precession is the event where the earth's axis shiftsclockwise in circular motion which then changes the direction when the North Pole ispointing.(Olgyay, A. and Olgyay, V. (1976)).

The difference between the sidereal and the tropical year is 20mins. This difference is negligible in the short run, but in the long run will cause time calculation problems. Thus readjustments to calendars must be made to correct this difference. Hence for simplicity, the average time the earth takes to move around the sun in approximately 365 days. This path that the earth takes to revolve around the sun is called the elliptical path.

2.3 THE SUN AS A HEAT SOURCE

Lastly, the sun is a valuable source of heat energy. Similar to light, the sun’s natural heat may be wanted and unwanted. Countries in the topics do not want excessive heating from the sun like Malaysia where it can gives rise to thermal behavior of a building, and for hot-climatic while higher latitude countries welcome the sun’s warmth during noon .Hence, the amount of heating required depends largely again on the latitude and the function of the building.

Once again, the orientation of the building as well as the structural element used in the design of the building play an active role in controlling the sun’s heat. For example, building with overhangs are able to provide shade during summer month, the sun is unable to reach within the building. However, during the winter months ,the sun is unable to reach within the building .However, during the winter months, the sun is allowed to penetrate through the building enveloped

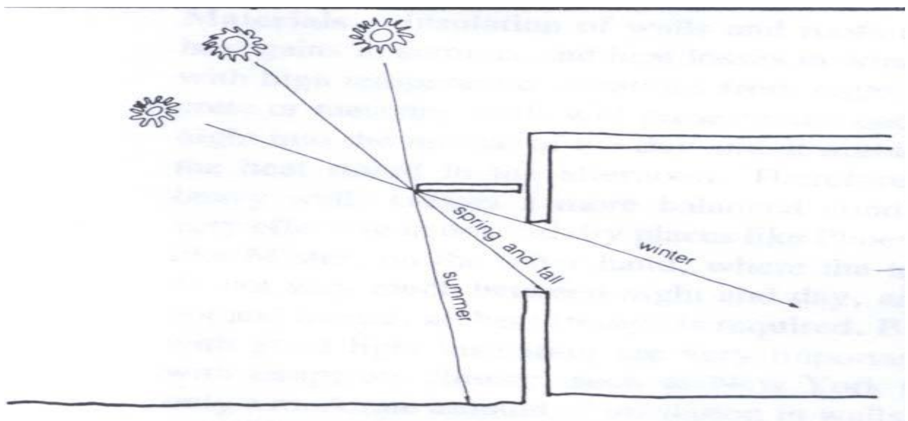

Figure 2.4: Different Angles Of The Sun

Source from Lam, W.M.C. (1986).

2.3.1 PRACTICAL ANALYSIS THE POSITION OF THE SUN.

Having to understand the position of the sun in different angle following the different season and months. It is shown in Figure 2.2.1 the position of the sun

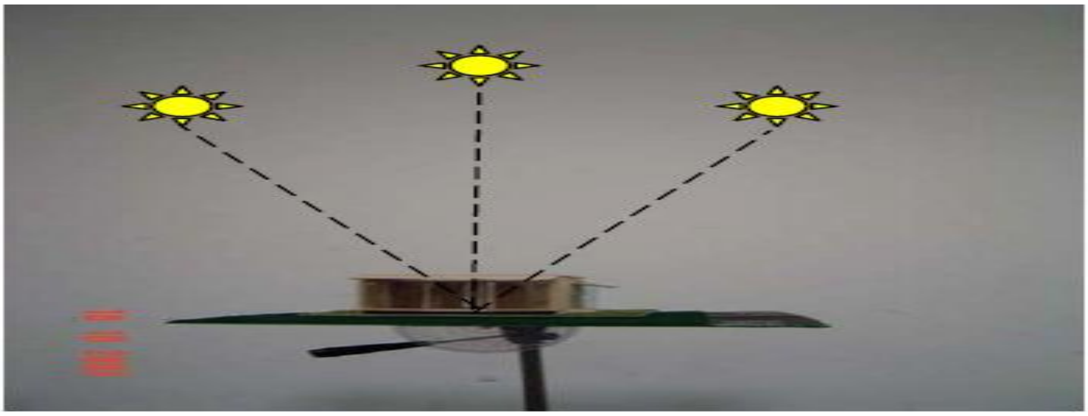

Figure 2.5: The Position Of The Sun

Source from Lam, W.M.C. (1986).

As shown in the figure 2.5.1, the position of the sun will not vary much across the year. From the June solstice to December solstice, the sun remains primary on top (high in the sky), with only slight fluctuation from the zenith position in the equinoxes. In the equatorial region, the temperature fluctuations over the time of the year would not vary much. Unlike the temperate region. there are no seasonal changes in the equatorial region. Hence, the prime concern in the building design would be the ability to keep out the sunlight and heat to reduce the energy.

In June, the people living in the temperate regions are experiencing summer (Northern Hemisphere). The sun is relatively high in the sky. Since it's the summer months, the prime concern will be to block extensive sunlight penetration. This is to reduce the heating effect the sun rays or radiation will have on the building. Achieving this will correspondingly cut down on the energy consumed in artificial cooling.

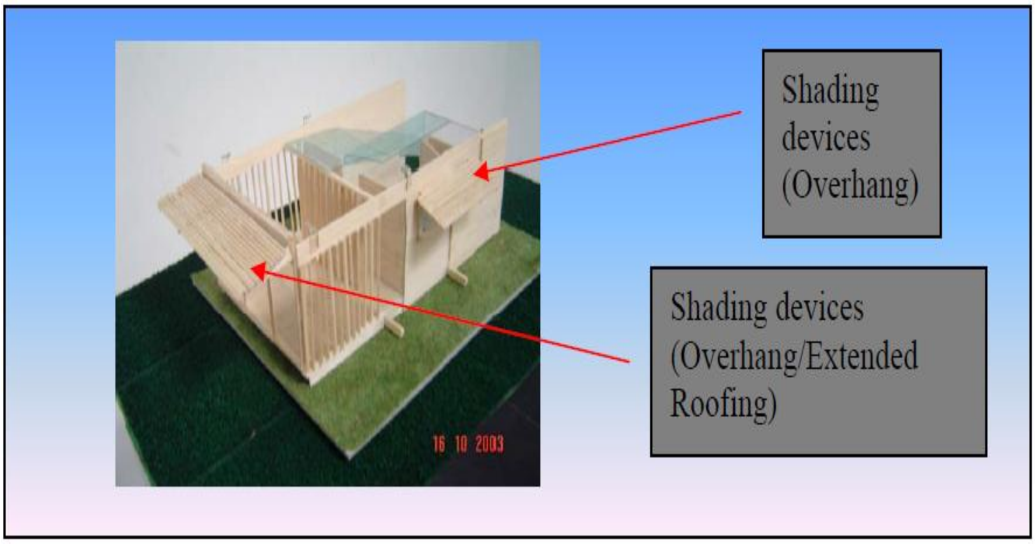

Figure 2.6: Structural Of Shading

Source from Lam, W.M.C. (1986)

In December, it is the winter season in the Northern Hemisphere .The sun is relatively low in the sky .In the winter months; the most consideration in building maintence is heating control. As large sum of energy is consumed to provide for heating, it is therefore logical and wise to tap into the sun's energy. By allowing more sunlight to enter will provide for natural heating that aids in minimizing the cost incurred in heating

2.4 THE SHADOWS CAST BY WINDOW SHADES

Solar altitude and azimuth angle is measured in the direction of the sun and from an observation point, not from the geometry window shade, which will have a particular orientation. Methods are needed to determine the sun's ray's incident on vertical plane, horizontal or intermediate buildings, penetration of sunlight to penetrate through the shade window. (Lam, W.M.C. (1986))

In order to determine the direction of the sun relative to the building, it is useful to changing solar angle into the corner shadows, one for the vertical plane and one for horizontal. Unlike the solar angle, the angle of reflection is measured normal to the surface of the window shade (or surface). They are defined as follows:

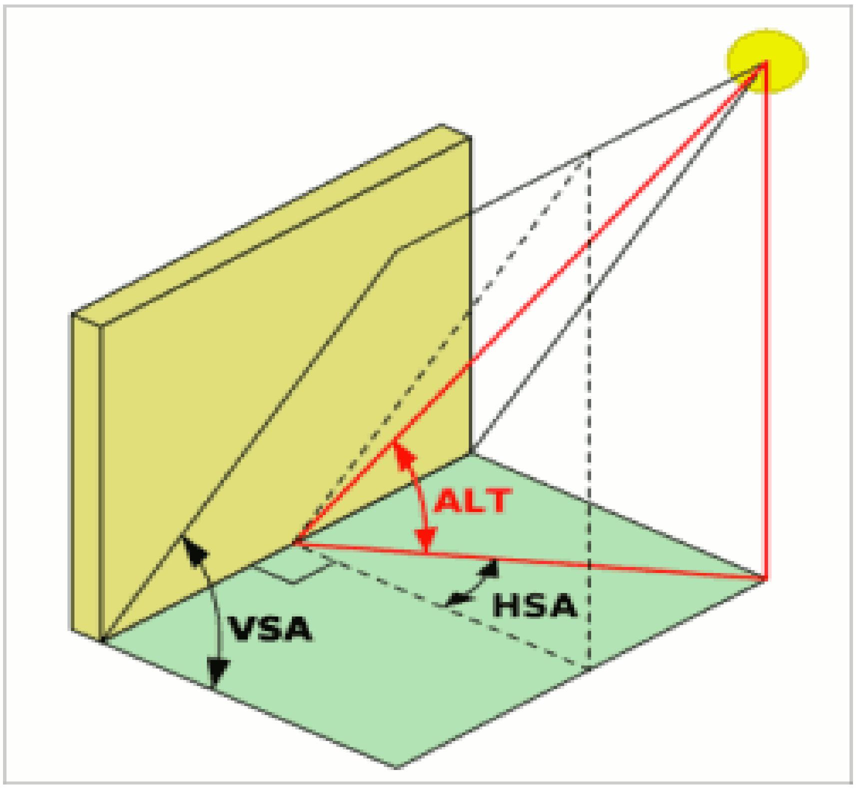

Figure 2.7: Angle Of The Horizontal Shadow Angle (HSA)

Source from The source from N. Baker, A. Fanchiotti, K. Steemers (1993)

The horizontal shadow angle (HSA) is defined as the angular difference between the plan normal to the surface that contains the reference point and the direction of the sun It is shown in Figure 2.30 angle of the horizontal shadow angle (HAS).

$$HSA = (AZ - \boldsymbol{\alpha})$$

From a reference point, the vertical shadow angle (VSA) is defined as the angular difference between the horizontal plane (that contains the reference point) and a plane tilted about the horizontal axis in the plane of the vertical surface that contains both the reference point and the sun

$$\tan VSA = \frac{tanALT}{\cos HSA}$$

2.5 THE RADIATION FLOW

The first is to control the amount of radiation that enters the window at all. The idea is to allow more sunlight to strike the window during cold season of the year. The method consist of putting the shade at the window. Since the mid day summer is at a higher altitude than the mid day winter sun, the shading structure simply allows less sunlight to strike the window in the summer.

At extreme latitudes in either hemisphere the arrangement is not often used. In low latitudes, the idea is to keep the sunlight out all day long. In high latitude once want to let as much sunlight in as possible (ASHRAE Journal (1993)).In Malaysia, solar radiation in turn will affect the thermal behaviour of buildings, and for the warm climate of radiation is a major contributor to the burden of building or room air conditioners.

Actually it is difficult to imagine such as situation, since for the glazing the sun would have to be at the horizon, directly facing the window because of the small amount of solar radiation available at sunrise and sunset In any event, the normal incidence situation in figure 1, the solar gain for a window without the shade at normal incidence is close to that for angle of incidence up to about 50 degrees.

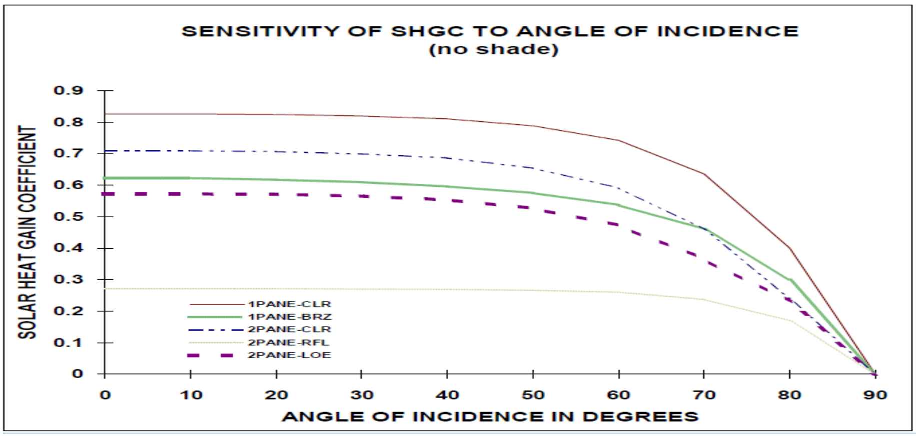

Figure 2.8: Solar Heat Gain Coefficient

Source from R.McCluney and L. Mills, Proc. ASHREA Transactions,Vol. 99,Pt. 2,1993,pp.565-570