Solar Collectors as Shading Devices for Kuala Lumpur, Malaysia

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Abstract: -Lack of understanding of benefits of solar collectors as external shading devices for reducing solar heat gain has led to high energy consumption for cooling and lighting in buildings of hot and humid climate as well as hot and arid climate regions. This paper aims to explore the possibility of using solar collectors as shading devices on walls of building. It also aims to determine the ratio of beam radiation for collectors on vertical surface and inclined surface in Kuala Lumpur, Malaysia. The study presented the important solar collectors that function as external shading devices and presented graphs that can be used in different occasions.

Keywords: Solar panels; Shading; Devices; Malaysia

Nomenclature

δ= Declination angle

n= Day of the year

φ= Latitude

ω_s= Sunset Hour Angle

ß= Tilt angle

γ= Surface azimuth angle

ßi=Collector tracking axis incident angle

θi=Incident angle for surface with slope

y=the height of next row elevates above frontal row

α= Solar altitude angle

ω= Hour angle

θz= Zenith angle

θ= angle of incident

λ= The slope angle of the land surface

R_b =Ratio of beam radiation on collector surface

1. Introduction

Sustainable design and use of renewable energy such as wind, solar, geothermal, wave, biomass etc are regarded as the main remedies of challenges of the millennium [1-4]. Well-planned external shading is the most effective method of reducing solar heat gain [5]. External Shading provides incorporation of day lighting and passive heating [6]. Some external shading devices block the view, while other types do not [7, 8]. External shading is much easier to be integrated into the design of new buildings than to be integrated in retrofitting projects [9]. External shading has major effects on the appearance of buildings, and it must be anchored to buildings structure to resist wind loads.

Each faces of a building require a different shading treatment because sunlight strikes each side from different angles[10]. The south face is best shaded with horizontal shading [11]. East and west faces require shading that blocks sunlight entering at low angles [12]. A north face can be often left un-shaded.

Recently, the designs of windows have become more complex and are flaked with auxiliary devices[13]. The regulation of ventilation, control of light and heat coming into the sheltered space are important topics in energy in buildings. Louvers are used to help to regulate natural ventilation. Meanwhile, outside shutters and blind, inside blinds and curtains help to control light and heat [14].

2. Theory and back ground

A solar collector serves to capture the incident solar energy, convert it into a more suitable form, and provide a means by which the converted energy is transported to the point of usage [15]. A cover system consisting of one or several layers of materials, such as glass, which transmit the solar radiation but do not transmit thermal radiation, is necessary [15]. Thermal conversion is accomplished with any materials that absorbs solar energy and thereby increases its own internal energy. It is also desirable that the absorbing material emit the lowest thermal radiation. Flat black paint is frequently used for the absorber. This internal energy is transported to the point of usage by a heat transferring medium. This is done with a system of tubes (or ducts) and fins. When a working fluid is passed through this system, it is heated by the absorber. The working fluid can then be delivered to the load or storage outside the collector. A passive solar collector converts solar energy into useful heating in a similar manner[16].

2.1 The sun's motion

When viewed from a location on the earth, the sun appears to move in a circular orbit about the earth. Although this view is physically incorrect, it is convenient for purposes of terrestrial solar design, and the results are as accurate as those obtained by assuming correctly that the earth moves about the sun [17].

2.2 Solar altitude angle

Figure 1 shows the he solar altitude angle and azimuth angle. The altitude angle is measured upward from the local horizontal plane to a line between the observer and the sun[18]. The azimuth angle is measured in the horizontal plane between the due-south direction and the projection of the sun-earth line onto the horizontal plane. Azimuth angles have a sign convention, as do other solar angles. The altitude angle depends on three fundamental angles: the solar declination (δ), the latitude (ϕ), and the solar hour angle (ω).

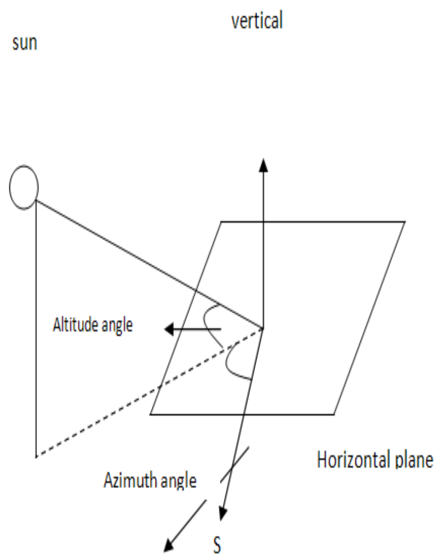

Figure 1 Solar altitude angle and solar azimuth angle

Solar azimuth angle

The solar azimuth angle, which measures the relation of the sun, depends on the same three angles as the solar altitude angle. Equation (1) can be used to calculate the solar azimuth angle:

$$\gamma = \sin^{-1}\left[\frac{\cos\delta * \sin\omega}{\cos\alpha_s}\right] \quad (1)$$

The azimuth angle is greater than 90° for some hours of a day when the length of day is greater than 12hrs. Therefore the equation (1) must also be evaluated for the time of year for which a calculation is being made.

3. Methodology

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Figure 2 Horizontal shelves

4-2 Balconies

Balconies have the same effect as horizontal shelves [20]. They are deep enough to provide significant shading for all directions. They provide major additional value as usable space and as an ambiance feature [21](see Fig 3).

Figure 3 Balconies function as shading device

4-3 Eaves and overhang

Eaves, porches, and over hangs are the buildings accessories that provide effective shading for the floor level directly under the eaves [22]. They merit strong consideration as shading devices, and they can provide major additional value in protecting the wall finish and reducing below-grade moisture problems [22]. Figure (4) shows a typical residential installation, and Figure (5) shows a new type of over hang.

Figure 4 Eaves and porches

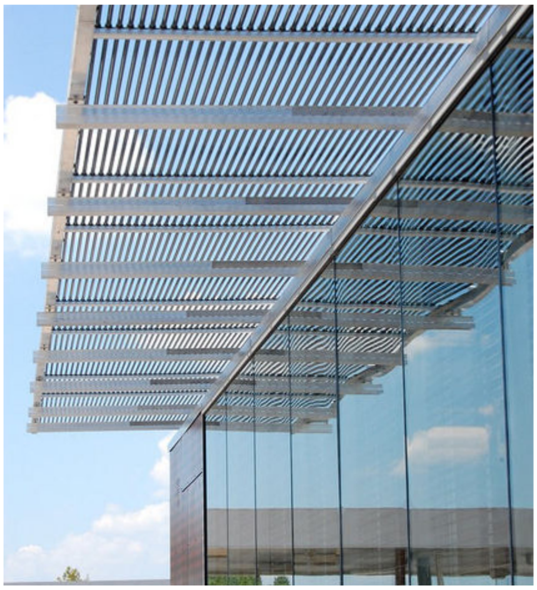

Figure 5 A new types of overhangs

4-4 Fixed louvers.

Fixed louvers are useful for any exposure of buildings, except north [23]. The best orientation for the louver blades depends on the direction that the glazing faces [23]. On the south side,

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the blades should be horizontal. For the north side, louvers are vertical. For other directions, they may be tilted [23]. Louvers can be arranged in a horizontal array, like a shelf (see Figs 6, 7).

Figure 6 Fixed Lovers are very common in developed countries

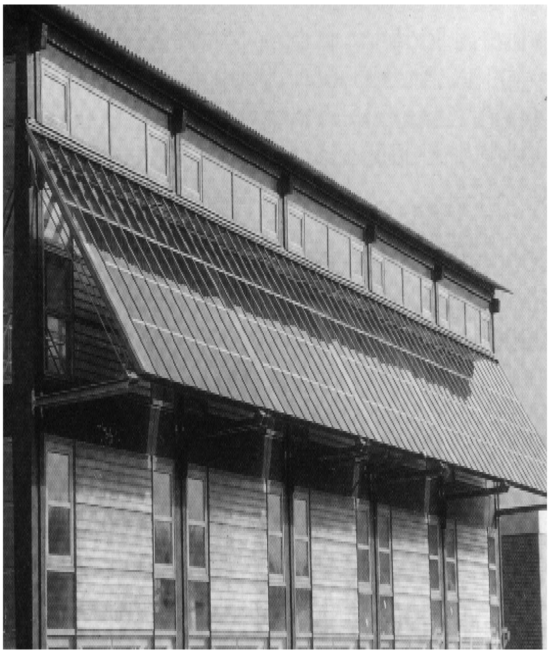

Figure 7 Fixed louvers arranged in horizontal and inclined array

4-5 Vertical fins

Vertical fins are useful for shading north faces from summer sunlight in the early and late times of days[24]. Figure (8) shows a building with fins molded into the wall surface.

Figure 8 Building with fins molded into wall surface

Vertical fins or recessed windows are useful on the north side of buildings to block early morning and late afternoon low sun.

4-6 Awnings

Awnings is shading device that downward over the windows [25]. Figure (9) shows a typical installation. These may be fully effective on south faces, and provide partial shading of windows on east and west faces. A common mistake is making awnings to fit the width of the window. Such awnings are too narrow, allowing an excessive amount of sunlight to enter from the sides.

Figure 9 Awnings installed over the windows

4-7 Influence of the orientation and inclination

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The optimal situation is given when a tracking collector system facing the sun, and the maximal solar radiation are collected. The optimal situation is a complex matter. In the grid connected PV systems, there is no limitation on storage, because the surplus energy can be fed into grids as an infinite "accumulator".

The yearly amount of solar radiance is the most important parameter. A specific surface will receive different solar irradiance in function of their South orientation (Azimuth) and their horizontal inclination. For a vertical façade irradiation it is between 45º East and West. In PV façades the lower irradiation is partially compensated by a higher efficiency due to low PV cell temperature.

4-8 Integration degree

The next concepts of integration techniques, with different integration degrees, can be applied to all solar energy configuration and device.

Independent integration degree

It is a simple and easy method to use for flat roofs and existing buildings. The solar collectors are mounted on a structure which is separated from the building envelope. In this way, solar collectors can be placed on the optimal orientation and inclination. This system is unsightly and expensive.

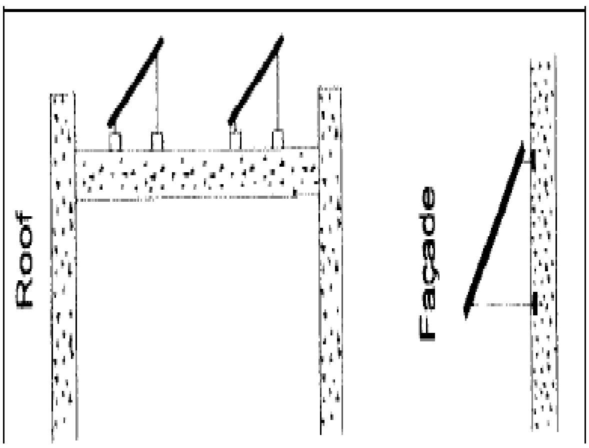

Figure 10 Independent integration degree

Superimposed

Another simple and easy method for existing buildings is superimposed. In this system, the collectors are mounted on a structure of a building envelope and are arranged in parallel. The visual impact of this system on buildings is unsightly.

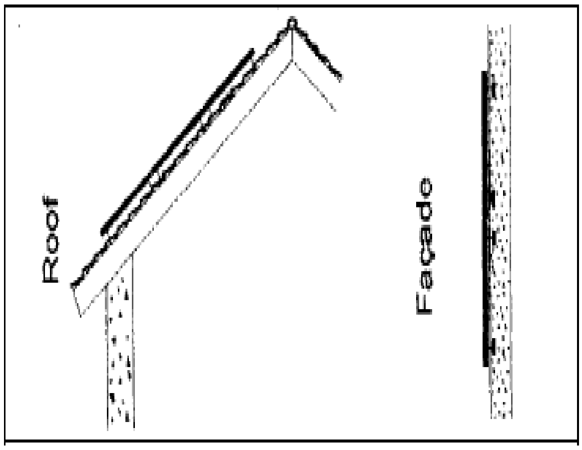

Figure 11 Superimposed

Integrated

In the following cases, the solar collector has an architectural function on the side of energy generation. Constructive elements are then substituted allowing different savings depending on the cost of substituted elements. Most of them are suitable for new buildings. It offers a nice and clean appearance.

Over cladding (cold roof or façades)

An external water-proofed layer made by the solar collector is placed over an opaque layer that ensures the thermal insulation. Solar collector tile is a special technique for roof integration. In solar collector (especially in PV), it is necessary to provide a back ventilation of the modules in order to keep the good cells efficiency. The savings are significant.

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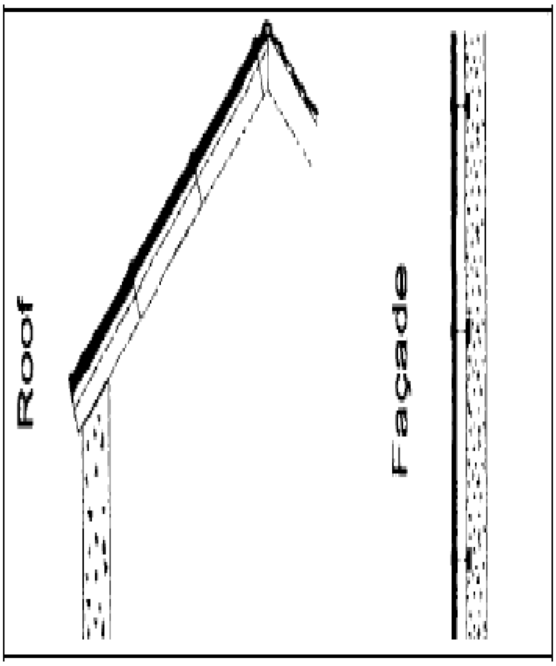

Figure 12: over cladding

Enclosure (hot roof or façades)

This type of collector is the type of collector that is installed in roofs or the facades of buildings. For PV, adapted conventional glazing systems are used (mullion-transom or structural glazing). Also in PV, a double envelope including a ventilated chamber improves the thermal performances and allows capturing warm air for heating purposes. The savings are maximal.

In this part the paper discusses the arrangement of solar collectors when are installed on walls in different sides i.e. towards south, west, north, and east. In this case it is calculated the ratio of beam radiation on the surfaces of the collectors. The slope angle in the case study was vertical angle ($\beta = 90^\circ$) and the other case the slope angle was ($\beta = 10^\circ$). The following diagrams show the difference between each side. The hour angle for this case was taken as ($\omega = -60^\circ$) at 8:00 am.

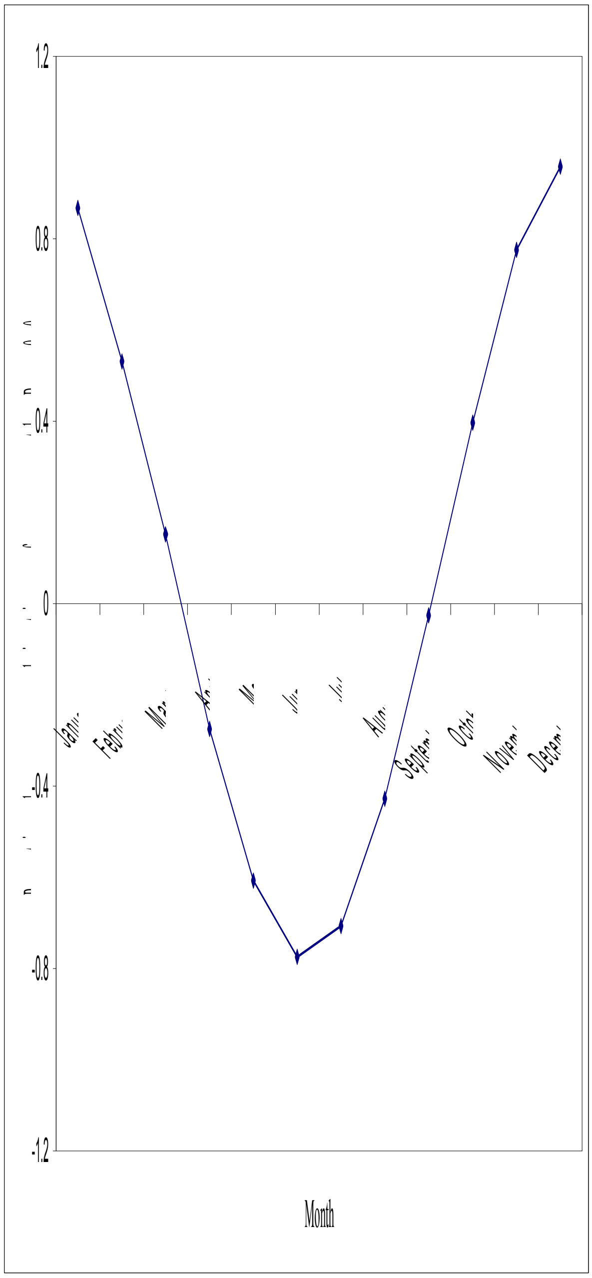

Figure 13 the ratio of beam radiation on the surface toward south side

Table 1 the ratio of beam radiation on vertical surface $\beta = 90^{\circ}$

cos south	cos west	cos North	cos East	cos	R_b south	R_b west	R_b north	R_b east
0.387	-0.81	-0.387	0.807	0.446	0.867713	-1.8161	-0.86771	1.809417
0.252	-0.843	-0.225	0.842	0.474	0.531646	-1.7784	-0.47468	1.776371
0.0753	-0.865	-0.0753	0.865	0.496	0.151815	-1.7439	-0.15181	1.743952
-0.1375	-0.854	0.137	0.854	0.501	-0.27445	-1.7045	0.273453	1.704591
-0.297	-0.819	0.297	0.819	0.489	-0.60736	-1.6748	0.607362	1.674847
-0.371	-0.795	0.371	0.795	0.479	-0.77453	-1.6597	0.77453	1.659708
-0.342	-0.806	0.341	0.806	0.484	-0.70661	-1.6652	0.704545	1.665289
-0.212	-0.841	0.212	0.841	0.497	-0.42656	-1.6921	0.426559	1.692153
-0.0125	-0.865	0.125	0.865	0.501	-0.02495	-1.7265	0.249501	1.726547
0.192	-0.854	-0.192	0.854	0.484	0.396694	-1.7644	-0.39669	1.764463
0.352	-0.818	-0.352	0.818	0.454	0.77533	-1.8017	-0.77533	1.801762

When the solar collector installed on the wall toward south, the ratio of beam radiation is maximum on the surface in December, while in June there is no ratio, because at that time there is no beam radiation fall on the surface, which mean the sun not reach the south side yet.

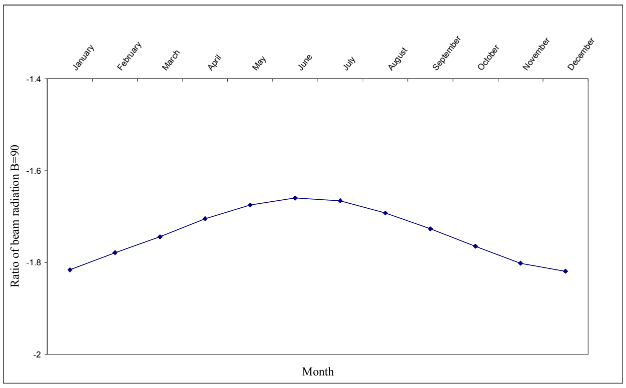

Figure 14 the ratio of beam radiation on the surface toward the west side

In the west side, the beam radiation on the collector surface has negative value. In this case there is no ratio of beam radiation (see Fig14).

In the north side, the ratio of beam radiation changes from positive side in the middle of year to negative in end of year. It happens because there is no beam radiation fall on the surface during that time. In this case the ratio of beam radiation has small value, which means just half of the year has some ratio and the other half does not half ratio of beam radiation on surface of the collector. The curve of ratio of beam radiation during a year and the maximum value in June and decrease till reach to the minimum value in end of the year in December (see Figure 15).

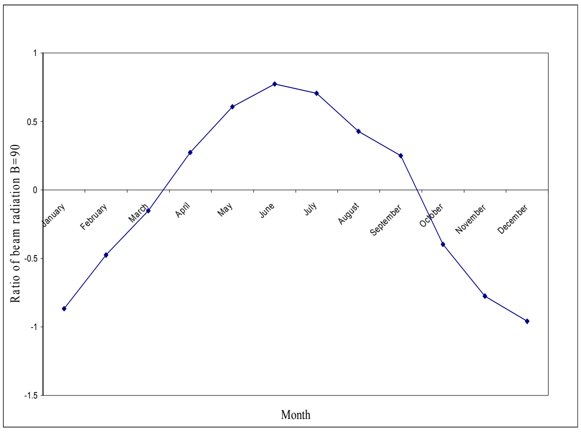

Figure 15 the ratio of beam radiation on the surface toward north side

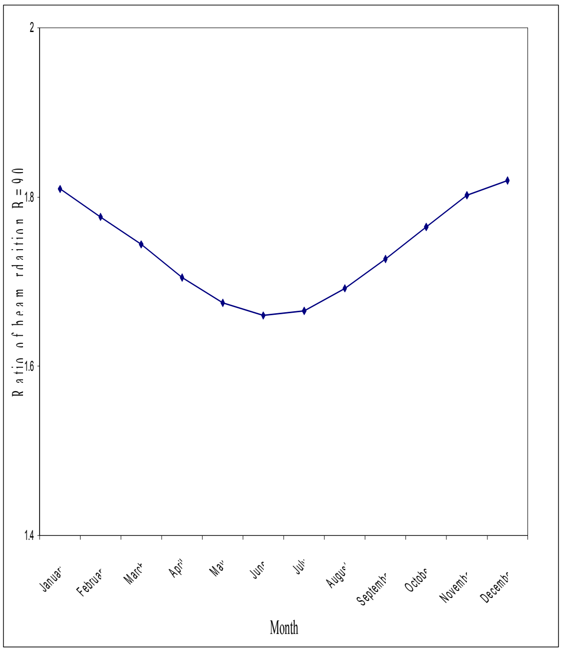

Figure 16 the ratio of beam radiation on the surface toward east side

When the collector installed toward east, the ratio of beam radiation value is maximum in December and decrease gradually till June then increase again. The ratio of beam radiation which falls on the collector surface has the minimum value in the middle of a year and has maximum value in end of year (see Fig 15).Another case that the collector is installed on the wall by slope, the slope angle was taken as ($\beta = 10^{\circ}$). The study calculated the ratio of beam radiation on each side, south, west, north, and east, as we see in figures below, each side has different value. Figure (16) shows the ratio when the collector installed toward south.

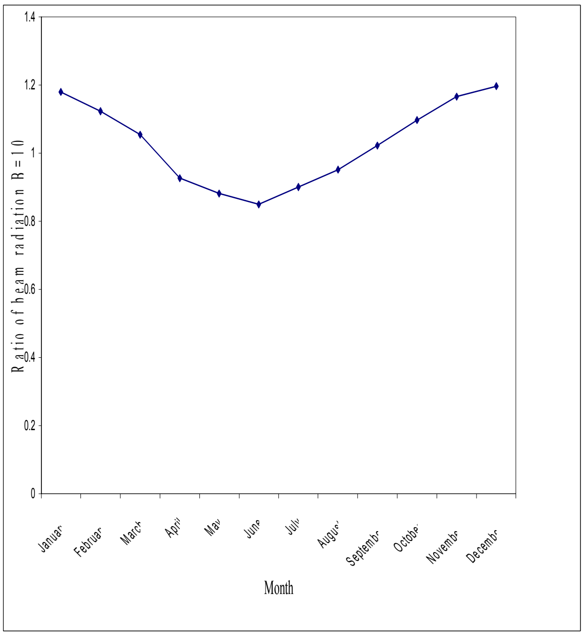

Figure 17 Ratio of beam radiation on the collector toward south side $\beta = 10^{\circ}$

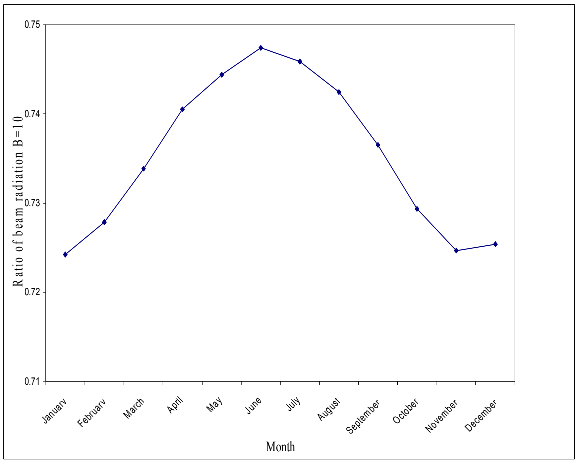

Figure 18 Ratio of beam radiation on the collector toward west $\beta = 10^{\circ}$

Figure (17) shows that the value of beam radiation is less than when collector is in the south, and when the collector is in west side. The maximum were in June (see Figure 19).

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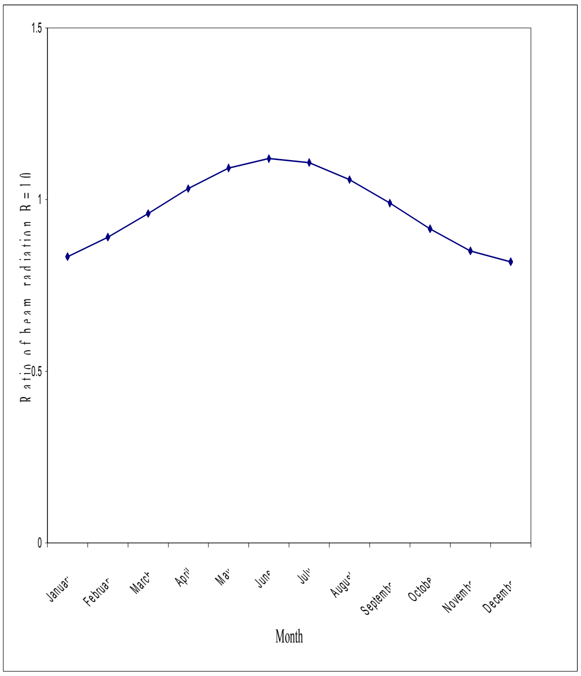

Figure 19 Ratio of beam radiation on the collector toward north $\beta = 10^{\circ}$

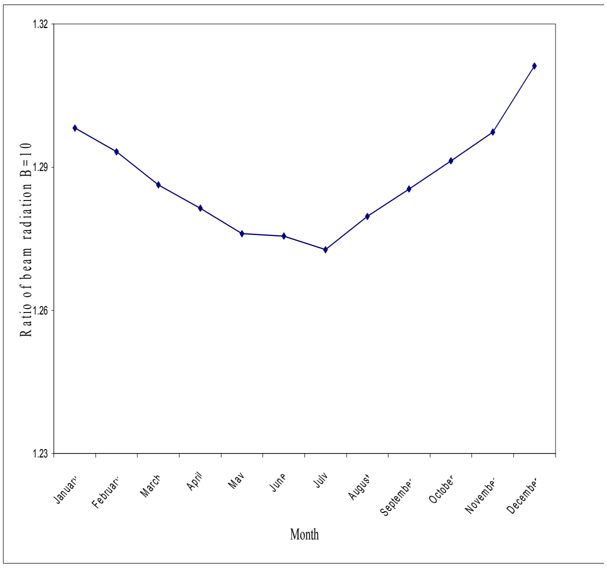

Figure 20 Ratio of beam radiation on the collector toward east $\beta = 10^{\circ}$

Furthermore, when the collector installed in north side of the wall, the ratio of beam radiation is not too much (see Figure 20).

But in the east side the ratio of beam radiation is satisfied (see Fig21). The value of the ratio of beam radiation maximum in December and minimum in July 15th.

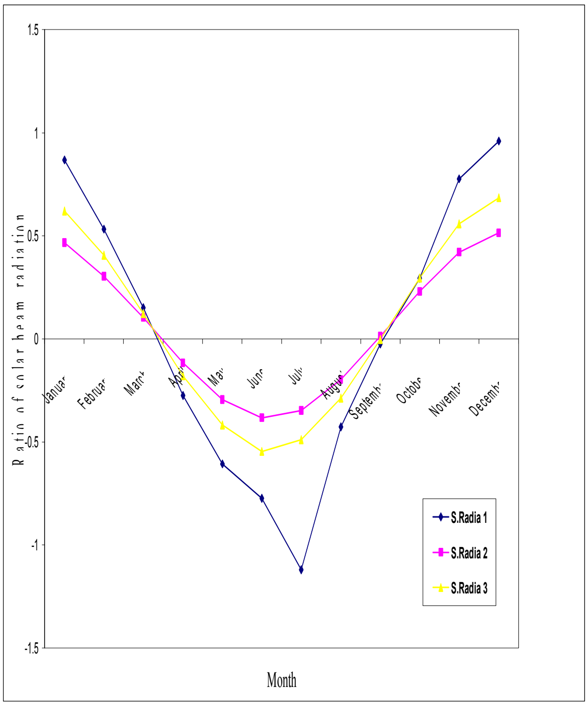

Figure 21 Ratio of beam radiation in different Hour angle toward south $\beta = 90^{\circ}$

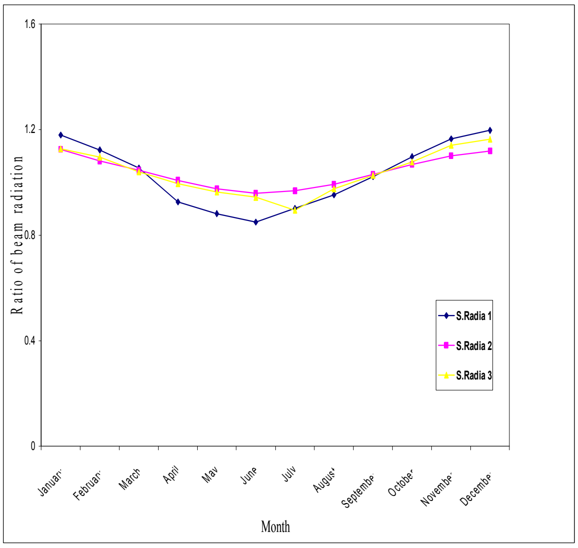

Figure 22 Ratio of beam radiation in different Hour angle toward south $\beta = 10^{\circ}$

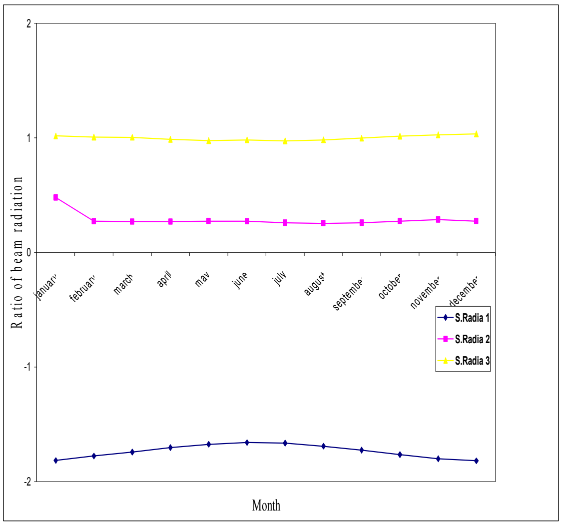

Figure 23 Ratio of beam radiation in different Hour angle toward west $\beta = 90^{\circ}$

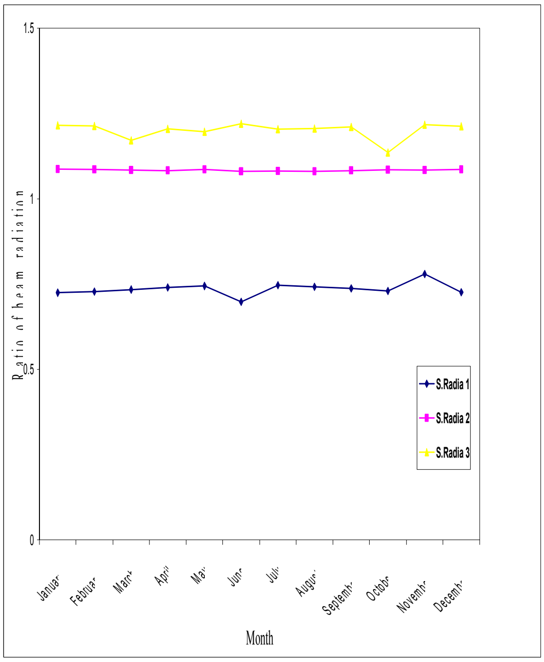

Figure 24 Ratio of beam radiation in different Hour angle toward west $\beta = 10^{\circ}$

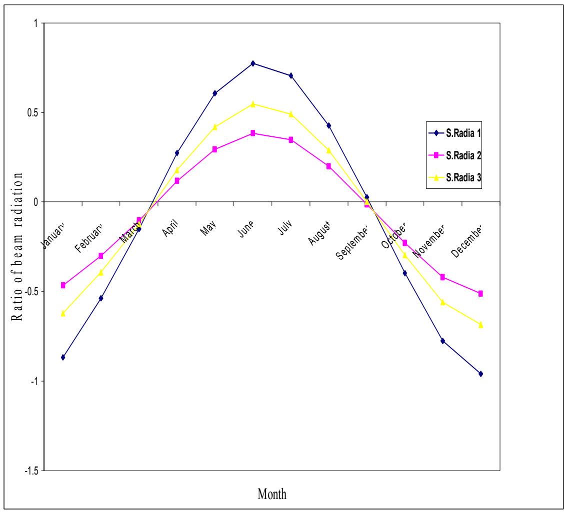

Figure 25 Ratio of beam radiation in different Hour angle toward north $\beta = 90^{\circ}$

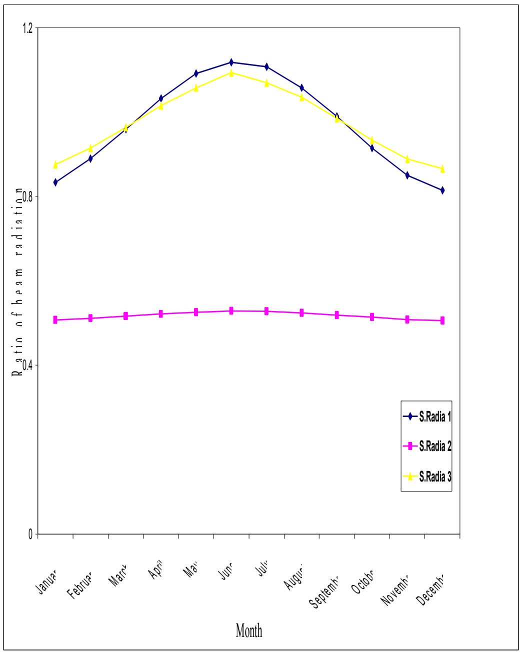

Figure 26 Ratio of beam radiation in different Hour angle toward north $\beta = 10^{\circ}$

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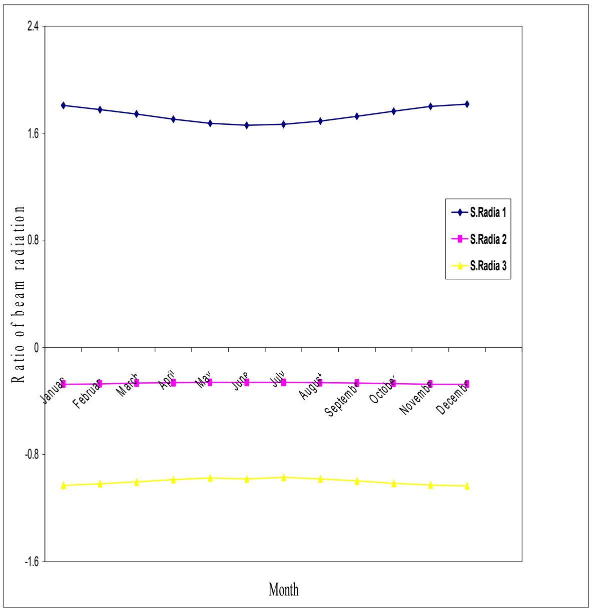

Figure 27 Ratio of beam radiation in different Hour angle toward east $\beta = 90^{\circ}$

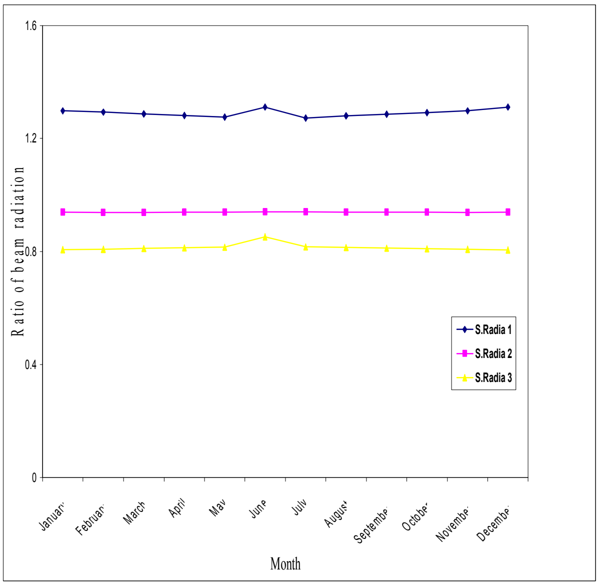

Figure 28 of beam radiation in different Hour angle toward east $\beta = 10^{\circ}$

5. Conclusion

The study concludes that the use of PV panels as a shading device is a good approach to save energy and improve the thermal comfort of occupants in buildings. In Malaysia, there are six common shading building elements that can incorporate solar panels to work more effectively. Those are: horizontal shelves, balconies, eaves, porches, and over hangs, fixed louvers, vertical fins, and awnings. The design of solar panels as shading devises should be based on a thorough calculation for different orientations. Ratio of beam radiation is the main parameter which should be considered in this design.

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