Evaluation of the Horizontal Shading Device Effect on Building Envelopes 
Received Solar Radiation – A Case with Se Orientation in Shiraz

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ABSTRACT
This paper presents the findings on the impact of the horizontal shading device on building envelopes received solar radiation over 1st, 10th and 20th of January and July in a semi arid climatic context in Iran, Shiraz with Latitude 29°33’N. The case study building was a famous shrine with a horizontal shading device toward SE. The solar angle, shadow area, Solar radiation on tilted surface without shading device and with shading device calculations were derived and revealed that the role of orientation and shading device in controlling irradiable or suitable solar radiation in summer and winter was evident. The results showed that the solar altitude angle in July and January were 83.5° and 40.3°. In addition, the shadow area in July was already twice and the entire wall was on shadow in July from 11 to 14 O’clock. The sun coming to the back of building from 14 up to sunset because of SE orientation; therefore, the total radiation on the tilted surface became less than zero at afternoon. The ratio of the total radiation on the tilted surface in July to January was from 47 to 194 fold in different hours. Finally, as the main result, the proportion of not absorbed daily solar radiation on the beneath wall of shading device through existence of shadow in 1st July to January was 370.46 fold and the percentage of it from entire wall solar radiation in July was 67.75% and in January was 30.42%; therefore the main part of solar radiation was absorbed in January and was in shadow in July, as needed to support decreasing energy consumption.

INTRODUCTION

Two main exterior influence factors on the building indoor air condition are wind and temperature [1]. But the solar radiation which is the cause of temperature is the main factor of temperature [2]. Solar energy can be used in term of passive techniques as an auxiliary energy system. Passive solar energy utilization converts solar radiation to heat by means of building structure itself [3]. Passive solar systems have three main functions to assure:

- Solar energy collection through open and glazed areas for indoor space heating, mainly in winter and solar gains reduction (through shading) or ventilation with cooler outdoor air, mainly during summer.
- Energy management or heat distribution [4].

Direct sun can generate the same heat as a single bar radiator over each square meter of a surface. It is a good generator for heating in winter, however in summer conditions, shading can cool up to 90% of this heat. The big problem is that sunlight is a direct source of heat and the radiant heat from the sun passes through glass and is absorbed by building elements and furnishings, which then re-radiate it. Shading is the first step toward natural cooling in building systems. The starting point of cooling building systems is preventing sunlight from entering the building in warm periods. A shade is like putting a hat on a building. Shading must be the first line of defense against excessive heat gain. The highest priority must be placed on the surfaces that receive the most summer heat. Shading of the building and outer spaces can: (1) Reduce summer temperatures; (2) improve thermal comfort; (3) save building energy [5].

While it is well known that shades affect heat gain and loss through windows and thus building energy loads, there is limited information on the actual magnitude and specific behavior of their effects on the building thermal and lighting loads [6]. In light of this, building orientation could improve passive solar utilization and shading affects in a building. Chua et al. [7] presented a study for determining the suitable external shading devices and glazing types in all orientations to improve energy efficiency in residential buildings. Comparing


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results from the model simulations, the most suitable shading device for residential buildings was faced toward the south orientations. Each climate and altitude zone has a best building orientation to reduce energy consumption.

In this regards, present research was conducted to evaluating the horizontal shading device effect on building envelopes received solar radiation for a shrine building with SW orientation in Shiraz (Iran) as a semi arid climate in Latitude 29°33′N. The solar angle, shadow area, solar radiation on tilted surface without shading device and Solar radiation on tilted surface with shading device was calculated.

MATERIAL AND METHOD

Material:
Shiraz is the main city of southern part of Iran, as a semi arid climate with latitude 29°33′N, longitude 052°36′E and elevation 1491m (climate-charts). This city was the most populated one in the mentioned region (1455073 in 2009) (Iran Statistical Center) Also, with the high capacity of the building sector, the buildings energy consumption was about 49.6% (shirazdec.co.). Therefore, Shiraz became a pilot city for the change in energy sector in the southern region of Iran. To know this city better, the climate parameters should be analyzed. One of the main sectors of climate is weather that includes different factors like temperature, radiation, rainfall, humidity, wind. In this part these were separately explained.

A. Temperature: “The concept of temperature describes the degree of heat contained in a body or a fluid medium or some region [8].” Identifying the average, minimum and maximum of local temperature, help the architectures to design below climate (Table 1).

B. Rainfall and humidity: In arid regions, humidity and rainfall have effective role. Low rain and humidity made these places dry; therefore thermal comfort in a building depends on retrieving this Leakage. Here the table is for the amount of rainfall and number of rainy days in Shiraz throughout 2007. Although in all Season Shiraz has the humidity problem, but in summer it is more (world-climates) (Table 1).

C. Wind: Wind can improve human kind sense in hot places. Air movement effects on decreasing temperature. Though, the direction and velocity determine building quality. Shiraz wind speed in December and January was less than other months. This quantity downfall was an advantage, because in cold season wind is low (tititudornceas).

D. Radiation: The sunrise and sunset time shows the day light hour and whatever this amount and the solar radiation were higher, the regional utility of solar energy was improved. Shiraz with a perfect day light (Table 1) and a considerable solar radiation (Table 1) is rich in received solar energy, as in each day of June the amount of average radiation on the horizontal surface was 7.57 kWh/m² (Fars regional Meteorological Organization).

Table 1: the average temperatures in degrees Celsius and the total rainfall in MM (up to 2007) (world-climates) Monthly Averaged Daylight (hours) and Monthly Averaged Radiation Incident On 0-Tilted Surface (kWh/m²/day) in 2009 (Fars regional Meteorological Organization).  

<table>
<thead>
<tr>
<th>Month:</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
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<tr>
<td>Average</td>
<td>5.85</td>
<td>7.95</td>
<td>11.85</td>
<td>16.15</td>
<td>21.9</td>
<td>26.6</td>
<td>28.85</td>
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<td>23.9</td>
<td>18.3</td>
<td>12.15</td>
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<td>12.1</td>
<td>14.7</td>
<td>18.9</td>
<td>23.8</td>
<td>30.6</td>
<td>36.1</td>
<td>37.8</td>
<td>37</td>
<td>33.7</td>
<td>27.8</td>
<td>20.5</td>
<td>14.4</td>
</tr>
<tr>
<td>Min average</td>
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<td>4.8</td>
<td>8.5</td>
<td>13.2</td>
<td>17.1</td>
<td>19.9</td>
<td>18.8</td>
<td>14.1</td>
<td>8.8</td>
<td>3.8</td>
<td>0.5</td>
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<tr>
<td>Total rainfall</td>
<td>79.8</td>
<td>49.8</td>
<td>48.4</td>
<td>30.6</td>
<td>6.6</td>
<td>0.2</td>
<td>1</td>
<td>0.1</td>
<td>0</td>
<td>5.2</td>
<td>20.7</td>
<td>63.2</td>
</tr>
<tr>
<td>Total number of rainy days</td>
<td>6.6</td>
<td>6</td>
<td>3.9</td>
<td>4.2</td>
<td>1.2</td>
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<td>0.2</td>
<td>0.1</td>
<td>0</td>
<td>0.6</td>
<td>2.5</td>
<td>5.5</td>
</tr>
<tr>
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<td>11.1</td>
<td>12</td>
<td>12.8</td>
<td>13.6</td>
<td>13.9</td>
<td>13.8</td>
<td>13.1</td>
<td>12.3</td>
<td>11.5</td>
<td>10.7</td>
<td>10.3</td>
</tr>
<tr>
<td>Diffuse radiation</td>
<td>0.99</td>
<td>1.18</td>
<td>1.6</td>
<td>1.92</td>
<td>1.96</td>
<td>1.93</td>
<td>2.04</td>
<td>1.84</td>
<td>1.49</td>
<td>1.23</td>
<td>1.06</td>
<td>0.92</td>
</tr>
<tr>
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<td>5.56</td>
<td>6.22</td>
<td>6.03</td>
<td>6.29</td>
<td>7.54</td>
<td>8.26</td>
<td>7.34</td>
<td>7.19</td>
<td>7.28</td>
<td>6.65</td>
<td>5.49</td>
<td>5.3</td>
</tr>
<tr>
<td>Tilt 0 radiation</td>
<td>3.47</td>
<td>4.45</td>
<td>5.18</td>
<td>5.95</td>
<td>7.09</td>
<td>7.57</td>
<td>7.05</td>
<td>6.65</td>
<td>5.98</td>
<td>4.88</td>
<td>3.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

In the building selection process some parameters was more effective as the utility of solar radiation, the existence of shadow on the building envelope, a perfect orientation toward south-east (which was the best orientation in Shiraz), the need of outdoor thermal comfort and the huge amount of energy consumption for heating and cooling sectors. Since the research was conducted to evaluate the amount of received solar radiation beneath the envelope with comparison of existence a horizontal shading device shadow or not existence of shadow with direct radiation, one of the buildings with an extended veranda was chosen. The case study had
south east orientation with 61° degree toward east. This building was situated in the center of the ancient city and was one of the important shrines of Iran which was built in 4th century and was renovated and expanded multiple occasions (IGCLO, 1995). The veranda in front of Shahechragh building has 12 m height, 40.2 m length and 5.8 m weight. In addition, the area of the wall back of the veranda is 482.4 m² (Fig. 1).

Fig. 1: The horizontal shading device in front of Shahecheragh (The Technical and Engineering Department of Shahecheragh Shrine).

Method:
A. Solar angles in selected time intervals:
   In solar angle calculation two parameters were important; firstly, the situation of the case study as the altitude and secondly, the time which was selected. In the case study semi arid climate and due to the previous surveys [9] the weather in two periods of year was calm and desirable (spring and autumn), but the hot and dry long days in summer and the cold and almost dry weather in winter was irritating and cooling or heating load was needed, so the survey selected intervals were the first month of winter (January) and the first month of summer (July). For raising the safety coefficient and also the solar specification close proximity in all days of the mentioned months, the January and July 1st, 10th and 20th was chosen in the article process. The solar angles and other parameters of this research were calculated for each hour of the mentioned days from sunrise to sunset.

Fig. 2. Left: \( \gamma_s \) and \( \alpha_s \) [10], Right: Zenith angle, slope, surface azimuth angle, and solar azimuth angle for a tilted surface [11].

The shadow need in the building sector was depended directly to the sun position in winter and summer, so the including altitude (\( \alpha_s \)) and azimuth (\( \gamma_s \)) angles (Fig. 2) was calculated through the following formulas [12]:

\[
\sin \alpha_s = \sin \varphi \sin \delta + \cos \varphi \cos \alpha \cos \delta
\]

\[
\gamma_s = \text{sign}(\omega) \cos^{-1}\left(\frac{\cos \theta_z \sin \varphi - \sin \delta}{\sin \theta_z \cos \varphi}\right)
\]  

(3) [12]
δ = declination = 23.45 \sin (360 \times \left(284 + n \right)/365),

φ = regional latitude = 29.33,

ω = the hour angle = (hour - 12) \times 15; \text{before noon } \omega \text{ is negative and afternoon is positive},

θz = 90 - \alpha_s

and \δ calculated based on different formulas [13].

### B. Shadow area:

The shadow beneath a horizontal shading device could be drawn by the solar angles (αs, DNA, γs) of each moment (Fig. 3) [14]. The auto cad program was used for achieving the shadow area (A,) of the beneath wall of the veranda in the case study plan and elevation and section for the mentioned time intervals. The shadow height was calculated by drawing αs to the shading device edge in section and the shadow edge was computed by drawing γs to the shading device edge in plan (Fig. 3).

![Fig. 3: The shadow area beneath a veranda due to the solar angles](image)

C. Solar radiation on horizontal, vertical and tilted surfaces:

The solar angles and the shadow area without considering the cloudy days was similar in all years, but the solar radiation on the surfaces was completely differs in each year. In this research the solar radiation on horizontal surface was given from Fars regional Meteorological Organization. This organization was provided the data each 10 minutes from 2009 (Table 2). Therefore the 2009 was chosen as the base year.

**Table 2:** Total radiation on horizontal surface in Shiraz (kJ/cm².min) \((R_{horizontal} = 1)\) in 2009 (Fars regional Meteorological Organization).

<table>
<thead>
<tr>
<th>Sunset</th>
<th>PM</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>Noon</th>
<th>AM</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>Sunris</th>
<th>Day</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>0.055</td>
<td>0.485</td>
<td>4.783</td>
<td>11.291</td>
<td>29.933</td>
<td>33.913</td>
<td>16.621</td>
<td>35.351</td>
<td>35.77</td>
<td>-</td>
<td>1.958</td>
<td>1st January</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>285.1</td>
<td>1474</td>
<td>2736.7</td>
<td>4006.4</td>
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<td>5523.4</td>
<td>5093.6</td>
<td>4495.9</td>
<td>3395.2</td>
<td>2402.8</td>
<td>1195</td>
<td>223.3</td>
<td>1st July</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data of Table 2 was the horizontal radiation, but in the research the wall beneath the shading device was vertical and toward SW. The vertical slope of the wall showed that the β was 90º and the surface azimuth angle (γ) was -61º (east angle was negative) (Fig. 2) (for more study refer to: Duffie and Beckman, [11]). Therefore, the solar radiation on vertical surface was determined by Duffie and Beckman [11] Method which was mentioned below.

Firstly, at any point in time, the solar radiation on horizontal surface \((I_o)\) was determined by Equation:

\[
I_o = \frac{\pi \times 1000 \times 10^3 \left(1 + 0.033 \cos \frac{460 \times n}{365}\right) \times \left[ \cos \theta_{z} \cos \delta (\sin \alpha_{s} - \sin \theta_{z}) + \left(\frac{\cos \alpha_{s} - \cos \delta}{\cos \theta_{z}}\right) \sin \theta_{z} \sin \delta \right]}{90 - \alpha_{s}} \tag{3} \tag{11}
\]

\(n\) the day number from 1st of January [11]

\(\alpha_{s1} and \alpha_{s2}\) are for two hour that we need the radiation between them

Next, the hourly average clearness index \((K_{T})\) was defined:

\[
K_T = \frac{I_T}{I_o} \tag{4} \tag{11}
\]
\( I = \) Total solar radiation on a horizontal surface through an hour which was available through the pyranometer measurement by Fars regional Meteorological Organization.

After that, the component of solar radiation which are divided to diffuse, beam and reflected radiation were separately derived (respectively \( I_d, I_b, I_r \) related to \( \rho_g \)). From \( K_T \) the fraction of \( I_d \) to \( I \) was determined:

\[
\begin{align*}
I_d/I &= \left\{ \begin{array}{ll}
1.0 - 0.09k_T & \text{For } k_T \leq 0.22 \\
0.9511 - 0.164k_T + 4.388 k_T^2 - 16.638 k_T^3 + 12.336 k_T^4 & \text{For } 0.22 < k_T \leq 0.80 \\
0.165 & \text{For } k_T > 0.80
\end{array} \right. \\
\end{align*}
\] (5) [11]

In the next step, from \( Id/I \) formula the \( I_b \) could be calculated:

\[ I_b = I_s = I - I_d \] (6) [11]

And by the definition of the \( R \):

\[ R = \frac{I_s}{I} = \frac{I_s}{I} \left( \frac{1 + \cos \beta}{2} \right) + \rho_g \left( \frac{1 - \cos \beta}{2} \right) \] (7) [11]

\[ \cos \theta = \cos \theta z \cos \beta + \sin \theta z \sin \beta \cos (\gamma_s - \gamma) \] (8) [11]

\[ R_b = \frac{\cos \theta}{\cos \theta_i} \] (9) [11]

\( R_b \) = the ratio of beam radiation on the tilted surface to that on a horizontal surface at any time

\( \rho_g \) = Ground reflectance for earth is 0.6 and for snow is 0.7 [11] and the case study was 0.35.

Finally the total radiation on the tilted surface (\( I_T \)), which was the amount of total solar radiation on the wall beneath the shading device in the case study without using any shadow, was obtained:

\[ R = \frac{I_T}{I} \] (10) [11]

\[ I_T = \text{Total radiation on the tilted surface} \]

\[ I = \text{Total radiation on a horizontal surface} \]

**D. Received solar radiation on surface beneath the horizontal shading device:**

The main calculation of this research was evaluating the received solar radiation on the case study when the shading device causes the shadow area on the wall (\( A_s \)). Therefore, the \( A_s \) and \( I_T \) were used to determine the received solar radiation in each hour of the selected time intervals. The \( A_s \) showed the exact moment shadow, therefore the hourly amount was calculated as:

\[ \text{Hourly Shadow } I_T = \text{Hourly } A_s \times \text{Hourly } I_T \] (11)

\[ \text{Hourly } A_s = A_s \times 3600 \]

\( \text{Hourly Shadow } I_T \) was contains of beam, diffuse and reflected radiation and show the whole radiation received to the wall in the not shaded surfaces.

**RESULTS AND DISCUSSION**

**Solar angles (\( \alpha_s, \gamma_s \)):**

The solar angles (\( \alpha_s \) and \( \gamma_s \)) were calculated in Shiraz during 1\(^{st} \), 10\(^{th} \) and 20\(^{th} \) days of January and July (Table 3).

The highest height of solar angle (the more vertical solar radiation) in July was in the 1\(^{st} \) (83.5) and in January in the 20\(^{th} \) (40.3). The difference between the solar altitude angle in summer and winter was more than twice (83.5 and 40.3 respectively) (Table 3 and Fig. 4). As a fact, the solar altitude angle in July was more beneath to vertical line and in winter was nearest to the earth. The azimuth angle comparison showed that the July sunrise amount is less than January and the July sunset amount was more than January (Fig. 4).
In this study, only the shadow of the main shading device in front of building was calculated and analyzed which this amount showed the $A_s$. The $A_s$ had been computed for every hour due to continuous change and was supposed to be fixed in an one hour period (Table 3).

**Fig. 4:** 10th January and July sun chart comparison

**Table 3:** The $\theta_s$ and $\gamma$ (°). Case studies $A_s$ on wall in 1st, 10th and 20th days of January and July (m²) and $I_v$ in 1st January and July (KJ/m²).

<table>
<thead>
<tr>
<th>Month</th>
<th>Day</th>
<th>$\theta_s$</th>
<th>Noon</th>
<th>Afternoon</th>
<th>Sunset</th>
</tr>
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<tr>
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<td>1st</td>
<td>6</td>
<td>0</td>
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<td>13.1</td>
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<tr>
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<td>1st</td>
<td>6</td>
<td>0</td>
<td>116</td>
<td>125</td>
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<td></td>
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<table>
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<th>Month</th>
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<th>Afternoon</th>
<th>Sunset</th>
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</tr>
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<td>10th</td>
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<td>20th</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

**Shadow area ($A_s$):**

In this study, only the shadow of the main shading device in front of building was calculated and analyzed which this amount showed the $A_s$. The $A_s$ had been computed for every hour due to continuous change and was supposed to be fixed in an one hour period (Table 3).
The \( A \) trend in July and January was almost same, but the July shadow was already twice. This fact causes the more effective shadow, as in summer more shadow and cooling needs. From 11 to 14 O’clock, the entire wall was in shadow in July (the \( A \) was 482.4m) and the beam solar radiation was not disturbing the outdoor thermal quality. Opposite that, in January less wall area was in shadow and the beam solar radiation was more available in the considered part of building (Fig. 5). The maximum shadow area in January was 232.57 m\(^2\) in 20\(^{th}\) at noon which was less than the entire wall area. The height of shadow in 1 o’clock was 12 m (the whole height of wall) and in January was 5.63 m which showed the solar absorption in the path of passengers in winter and the shadow in the summer. Therefore, the shadow area under the horizontal device toward South-East was climatic and depends on the cooling and heating needs.

**Solar radiation on tilted surface without shading device \((I_T)\):**

In this case, the \( I_n \) was calculated by formulas and \( I \) was reported by Fars regional Meteorological Organization. But for the purpose of the research the \( I_T \) which was the radiation on the tilted surface of the wall which was oriented toward south-east with 61 degree orientation toward east, was required, and therefore as an essential parameter in formulas, the \( \beta \) value was -61. Also the \( \gamma \) was 90 because the wall was vertical. As a part of calculation and due to the small amount of solar radiation at sunrise and sunset, the \( I_T \) was consumed to be zero in the mentioned time intervals.

The \( \gamma \) value caused less \( I_T \) than \( I \) which indicated that the horizontal surfaces were more effective in summer in arid climates. In 1\(^{st}\) July, the sun came to the back of the building from 14 up to sunset and therefore, the \( I_T \) became less than zero on the supposed surface (Table 3 and Fig. 6). This fact showed one of the best advantages of orientation toward south-east which omit the afternoon non beneficial beam solar radiation absorption (afternoon \( I_T \)) on the vertical surfaces. Besides, the \( I_T \) became less than zero at 9 o’clock in July, due to the solar altitude which was caused the sun position parallel with the shading device (Fig. 6). This sudden drop was happened in January at 11 o’clock, but the \( I_T \) was not under zero (Fig. 6).

**Solar radiation on tilted surface with shading device (Hourly Shadow \( I_T \)):**

Due to calculation of the not absorbed solar radiation on the beneath wall of shading device (Daily Shadow \( I_T \)) through existence of shadow, the 1\(^{st}\) July daily amount was 369490896706 KJ and the January one was
The percentage of Daily Shadow $I_T$ from entire wall $I_T$ was 30.42% which caused more solar radiation absorption (Table 4). Also, the amount of the Not Shaded $I_T$ was calculated and presented in Table 11.

### Table 4: $I_T$ in 1st January and July

<table>
<thead>
<tr>
<th>percent age</th>
<th>1st January</th>
<th>7th July</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Noon</td>
</tr>
<tr>
<td></td>
<td>Shaded I_T</td>
<td>Shaded I_T</td>
</tr>
<tr>
<td>90.42%</td>
<td>9078062.02</td>
<td>9078062.02</td>
</tr>
<tr>
<td>60.00%</td>
<td>3401225.48</td>
<td>3401225.48</td>
</tr>
<tr>
<td>69.58%</td>
<td>2012260.34</td>
<td>2012260.34</td>
</tr>
<tr>
<td>67.35%</td>
<td>3584797.84</td>
<td>3584797.84</td>
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<tr>
<td>67.35%</td>
<td>3584797.84</td>
<td>3584797.84</td>
</tr>
<tr>
<td>52.25%</td>
<td>2012260.34</td>
<td>2012260.34</td>
</tr>
</tbody>
</table>

The maximum rate of Hourly Shadow $I_T$ was in 11 o’clock of 1st July. This result observed the more shadow in noon of summer parallel with cooling need as one of shading device advantages (Table 11). In addition the figure 10 indicated the Hourly Shadow $I_T$ and Hourly Not Shaded $I_T$ of July and January. In July, the both parameters decreased at 11 o’clock and had to some extend opposite trends. But in January the both parameters had decline to zero at 9 o’clock and the trends were same, but the amount of Hourly Not Shaded $I_T$ was higher than the other parameter. In both January and July the Hourly Not Shaded $I_T$ in morning increased and therefore the suitable eastern morning solar radiation was absorbed. And also in July, the afternoon Hourly Shadow $I_T$ was more, so the afternoon western irritable solar radiation was controlled (Fig. 7).

**Fig. 7:** The Hourly Shadow $I_T$ and Hourly Not Shaded $I_T$ of case study in 1st July (right) and January (left)

### Conclusion:

The purpose of present study was the Evaluation of the horizontal shading device effect on building envelopes received solar radiation for a shrine building with SW orientation in Shiraz (Iran) as a semi arid climate in Latitude 29°33’N. The solar angle, shadow area, Solar radiation on tilted surface without shading device and Solar radiation on tilted surface with shading device calculations revealed that the role of orientation and shading device in controlling irritable or suitable solar radiation in summer and winter was evident. Firstly, by calculation solar angles ($\alpha$, $\gamma$), the first climatic parameter became evident; the solar altitude angle in July was more beneath to vertical line and in January was nearest to the earth (83.5° and 40.3° respectively).

Secondly, through shadow area ($A_s$) investigation in July and January, another climatic parameter (summer effective shadow) was shown, because the July shadow was already twice and the entire wall was on shadow in July from 11 to 14 O’clock. Through another climatic parameter (winter solar absorption), the solar absorption in the visitor’s direction was available in winter, because the height of shadow in noon of 1st July was 12 m (the...
whole height of wall) and in January was 5.63 m. the mentioned results caused more thermal comfort using shadow created by horizontal shading device with SE orientation.

Thirdly, Solar radiation on tilted surface without shading device \( (I_T) \) computation indicated that the orientation toward SE was led to coming sun to the back of building from 14 up to sunset and making \( I_T \) less than zero on the supposed surface. This fact as another climatic technique showed one of the best advantages of orientation toward south-east which omit the afternoon non beneficial beam solar radiation absorption (afternoon \( I_T \)) on the vertical surfaces. The need of existence of shadow device in the case study building was appeared by calculating the July \( I_T \) to January \( I_T \) amount which was from 47 to 194 fold in different day hours. The large amount of radiation in summer than winter showed that controlling and omitting this amount of heat from the building surfaces was essential (through the main technique of resent research, shading device).

Finally, as the main result of solar radiation on tilted surface with shading device (Hourly Shadow \( I_T \)), and by calculation of the not absorbed solar radiation on the beneath wall of shading device (Daily Shadow \( I_T \)) through existence of shadow, the 15 July to January daily amount was 37.0.46 fold and The percentage of Daily Shadow \( I_T \) from entire wall \( I_T \) in July was 67.75% and in January was 30.42%; therefore another advantages of shading device with perfect building orientation was obtained; the most irritable heating in summer was omitted from case surface and in winter more solar radiation absorbed by the case surface. In addition, the other advantage of mentioned technique was gained by the maximum rate of Hourly Shadow \( I_T \) in 11 o’clock of 15 July which observed the more shadow in noon of summer parallel with cooling need. Besides, in both January and July, the Hourly Not Shaded \( I_T \) in morning increased and therefore the suitable eastern morning solar radiation was absorbed. And also in July, the afternoon Hourly Shadow \( I_T \) was more, so the afternoon western irritable solar radiation was controlled.

ACKNOWLEDGEMENTS

Support from Islamic Azad University, Science & Research Branch, Tehran, Iran research project entitled “Evaluating the effect of building orientation on vertical shading device performance (Case study: religious building in four different climate in Iran)” is greatly appreciated.

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