Parametric Studies on Solar Performance of Iwan in Traditional Houses in Sulaymaniyah's old Town

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Received: 22/07/2018 / Accepted: 29/09/2018 / Published: 01/04/2019

DOI Link: https://doi.org/10.17656/sjes.10083

Abstract

Iwan, also Eyvan, is strongly associated with the architecture of the Middle East. It has been widely used as a space to serve different purposes in various types of traditional buildings such as mosques, palaces, and houses. This study focuses on the environmental aspects of iwan. The research investigates the effects of changing the exposure degrees of iwan on its insolation within traditional houses in Sulaymaniyah's old town.

Both EnergyPlus and Google SketchUp programs were used to make a 3D model and perform energy simulation analysing for a typical building with iwan in different proportions, similar to what exists in the region. Furthermore, weather data of Sulaymaniyah (latitude 36°) is used in the simulation process.

Several main geometrical variables are affecting the exposure degrees of iwan in Sulaymaniyah:

- Firstly, the length and depth of the space change in different houses whereas the height is almost constant, the same as the building's height, which equals to 3m.
- Secondly, the orientation of the iwan, which is usually facing southeast, south, southwest, and both east and west, considered in the simulations and the results obtained separately for each orientation.

There is no doubt that in hot seasons, shading is preferable. Whereas, in cold seasons, receiving more solar irradiation is desirable. Based on the results, iwan's solar performance improves whenever its width is decreased compared to its depth. In addition, the results show that the iwan's orientation affects significantly on its solar performance, as those facing towards south have better performance, meanwhile, those facing north have it the worst. Furthermore, changing the depth to width ratio for those facing east and west does not seem to affect their solar performance noticeably. Moreover, the results examine to what extend iwan can be used in buildings as a climatic responsive design strategy in Sulaymaniyah.

Keywords: Iwan, Eyvan, Solar performance, Solar incident, Insolation, Exposure degree, Traditional buildings, Sulaymaniyah.

1. Definition and Origin of Iwan

IWAN, "also EYVAN and at times in spoken Arabic LIWAN, a Persian word adopted by the Arabic, Turkish and Kurdish languages and then by western travellers, archaeologists and art historians to refer to certain characteristic features of Near Eastern and especially Islamic architecture" (Donzel, Lewis and Pellat 1997, 287).

Iwan utilized as an element in the architecture of the Sassanian, developed in Mesopotamia, became part of the Islamic and the Middle Eastern architecture when its usage in architecture flourished under the rule of Seljuks in the 10th century (Petersen 1996, 130).

Iwan is commonly linked with the architecture of the Middle East. It is a rectangular hall or space, usually roofed, walled on three sides, while the fourth side is either semi or entirely open through a portico towards a yard (Petersen 1996, 130). Besides, according to references, the word Iwan may refer to "an estrade or of a raised part of a floor" (Donzel, Lewis and Pellat 1997, 287) and (Necipoğlu 1998, 165).

A semi-opened space, iwan, used in buildings for many purposes. It can be considered as a transitional space, linking the garden or yard of a building with the rooms. In addition, it is used as a resting area (Ragette 2003, 57-58). Iwan has climatic roles as well, to offer a shelter by producing shade from summer's strong sun, as a result, the indoor spaces adjusted to the iwan will remain cool (Mahmoudi 2005) and to create a satisfactory microclimate by providing cover against winter's rain, snow and wind (Memarian 2006).

2. Iwan in Sulaymaniyah Architecture

Iwan was commonly used in Sulaymaniyah's architecture, became a fundamental unit of the local architecture of the city, influenced and inspired by the Islamic and Persian architecture. It can be clearly seen within the buildings dating back to mid of the 20th century and earlier, noticeably in the design of most traditional houses of the city's old town (Figure 1).

This transitional space in Sulaymaniyah's traditional houses is typically overlooking a private yard. It works as; a passage, an entryway, linking the rooms behind it to the yard through direct doors or a corridor that opens on the Iwan. Usually, the rooms have windows on the iwan, therefore, a precise design of the Iwan's proportions and orientation will ensure direct solar penetration whenever is desirable into the rooms during the cold season and blocks it in the hot summer period of the year.

3. Literature Review

In general, there are many papers examining Iwan, researchers such as Kakizadeh analysed the spatial fluidity of iwan's space in traditional houses of Bushehr (Kakizadeh 2014). In addition, Peker discussed the symbolic meaning of iwan and its functional role (Peker 1991).

Besides, many other scholars included iwan as one of the vernacular architecture elements and as one of the passive design solutions in their study. These papers include an inspection of Passive Cooling Systems in Iran, which highlights iwan alongside windows, materials, courtyard, wind-catcher and building form as a vernacular climatic design strategy and discuss it, briefly (Moossavi 2011). Moreover, in a published paper, a questionnaire was done by (Leylian, et al. 2010) to analyse the users' thermal comfort satisfaction degree in several residential spaces such as bedrooms, courtyard, living room and iwan.

Further, Foruzanmehr investigates the disappearance of using iwan in new building designs. He considered many features of iwan such as social, cultural and aesthetical aspects by highlighting the pros and cons of the vernacular iwans of Yazd in order to re-incorporate it into our contemporary housing (Foruzanmehr 2015).

However, the sustainable environmental role of iwan has always been a debate. In a research titled (Investigation of the Relationship Between the Climatic Role of Iwan and Rate of Energy Consumption in Traditional Houses of Tabriz), the author states "Iwan was applied only as the symbolic element in the architecture of traditional structures in Tabriz city and its climatic function was rarely considered in designing these structures" (Kalantaria, Singerib and Joursharic 2015). In contrast, results of a study done by Nejadriahi declare the importance of Iwan as one of the sustainable elements in the traditional houses of Iran by "providing more comfort with less energy use" (Nejadriahi 2016). Both the aforementioned papers' results achieved by using the method of Descriptive and Analytic.

On the other hand, using the same methodology of this research paper, through relying on computer analysis simulation, the effect of Iwan on energy consumption in four different climatic regions and for different orientations has been investigated in Iran by Eskandari, Saedvandi and Mahdavinejad which achieved similar results in the term of ideal orientation (Eskandari, Saedvandi and Mahdavinejad 2018).

Above and beyond, the results of a research, which examines the Influence of Iwans on the Thermal Comfort of Talar Rooms in the Traditional Houses, show that the space adjusted with an iwan is 62% more desirable than the same space without the iwan (Shaeri, Yaghoubi and Habibi 2018).

4. Research gap

There is a lack of research studying the solar performances of iwan in the local architecture of Sulaymaniyah; whereas, there are few papers discussing the aforementioned topic in the architecture of other cities within the Middle East. In addition, the effects of the exposure degrees of iwan on its solar incident and its performance in different directions are rarely investigated.

5. Research question

Hence, this investigation seeks to answer the question; to what extent the parametric variables (dimension and orientation) of iwan are related to the incident solar radiation (insolation) and performance of the space itself in the architecture of Sulaymaniyah city?

6. Research Objectives

The main research objectives are:

- To find out the effects of dimensional variables of iwan on the solar incident within the iwan.
- To identify the best and worst orientations in Sulaymaniyah for iwan as a climatic responsive design strategy.
- To examine the effects of iwan's orientation on its sunlight exposure.

7. Case studies

In this research, the iwan of 22 traditional houses investigated; the selected case studies have a history going back to earlier than the 1950s within Sulaymaniyah city centre. The samples include 5 registered houses in the Museum of Sulaimani as cultural Heritage Buildings (HHS 2017).

The collected data from the houses indicates that the analysed iwans are generally located in the middle of the southern front façade, on the first floor. All have a nearly constant height, approximately equals to 3.0m. Whilst, the ratio measurement of depth to width (D:W) ranges from 1:1 to 1:2, as shown in the table below:

8. Methodology

By using Google SketchUp and Euclid extension, a three-dimensional prototype model has been created for an iwan with the same parameters collected from the examination of Sulaymaniyah's traditional iwan samples above. The roof height of the prototype model has been fixed to 3.0m. In addition, the depth of the space has been set to 4.0m as an average of the collected data (Figure 2). Then after, a building simulation analysis made for the typical 3D prototype, in this process geometrical variables have been taken into consideration:

- Iwan models with different depth to width ratios (D:W) from 1:1 to 1:2 changing by 0.1.
- Simulating and analysing of the models in different orientations in every 15° starting from 0° to 345° azimuth angle.

In total, the process of simulating and analysing has been repeated 264 times by using EnergyPlus software, which is a reliable whole-building energy simulation program (EnergyPlus 2017). In addition, the required weather data of Sulaymaniyah is used in the software.

The results, which are the monthly average of incident solar radiation (insolation) per area on four faces in each iwan, are calculated. The considered faces are a floor, two side walls and a back wall. The solar incident is not always an asset; it is a liability especially in hot seasons. It increases the cooling loads because of excessive heat gain. For the purpose of discerning the positive (asset) and negative (liable) values of insolation, the research depends on (Abdulrahman 2013). It considered the months of January, February, March, October, November and December as cold months in which insolation is desirable; whereas, the months of April, May, June, July, August and September are considered as hot months in which insolation is not desirable. Therefore, Annual Insolation Value (AIV) is calculated for each case by using the following equation:

$$AIV = (X_1+X_2+X_3+X_{10}+X_{11}+X_{12}) - (X_4+X_5+X_6+X_7+X_8+X_9) \quad (1)$$

Where $X_{1,\ 2,\ 3 \ldots\ 12}$ = the insolation value for each month of any orientation

The numbering index refers to the months. i.e. 1 = January, 2 = February.

Based on Equation (1), the AIV for each proportion of iwan in different orientations is calculated and the values are negative. For example, the value for the iwan with 1:1 proportion and due south (180°) is (-232 W/m²), which is the best case because it has the biggest AIV (least negative value). The negative sign shows undesirability for insolation exposure in hot months. Whereas for iwan with 1:2

proportion and due north (0°), the value is (-504 W/m²) and this is the lowest AIV (largest negative value), and the negative sign here refers to lack of insolation exposure in cold months (Table 2). Therefore, higher AIV of an iwan indicates the higher annual solar performance of the iwan during a year.

9. Results and discussion

The results show that changing both variables, which are depth to width ratio of the iwan and its orientation, causes changing (AIV) of inside faces of the iwan. Firstly, in order to understand the effects of variables separately; it is better to analyse them individually. Figure 3 shows the annual insolation value of an iwan with D:W ratio of 1:1 changes dramatically by changing the orientation of the iwan. According to the obtained data, south (180° azimuth angle) is the best orientation for annual solar performance where the highest amount of AIV is recorded; whereas the north (0° azimuth angle) oriented iwan has the least amount of AIV. It increases when the orientation of the iwan changes toward the south.

The gradient of AIV is a little bit different in the iwan with a 1:1.5 ratio. As shown in Figure 4, there is a significant increase when the iwan's orientation changes from the north toward east or west (90° and 270° azimuth angles respectively). This increase is not considerable when the iwan's orientation changes from the east or west toward the south.

This difference is more obvious in the case of iwan with 1:2 ratio as it is presented in Figure 5. These prove that the annual solar performance of iwan with greater depth to width ratio is almost the same in orientations from east to south and then west; unlike in lower ratio iwan, which has different annual solar performance in different orientations.

The effects of changing the ratios in different orientations, which are shown in Figure 6, are also interesting. For example, there is a significant decrease in AIV in north oriented iwan when its D:W ratio increases from 1:1 to 1:2. This decrease is not considerable in south oriented iwan. In addition, in both east and west oriented iwan, the AIV is almost constant when their D:W ratio increases. These means that changing the iwan's proportions does not affect the iwan's annual solar performance significantly in both east and west orientations; whereas it is effective in south and north orientations.

Figure 7, is a comparative graph showing a comparison between the effects of changing the iwan's proportions on AIV in different orientations. It presents that changing the iwan's ratio is not so much effective when its orientation is almost 45° to 135° azimuth and 225° to 315° azimuth; unlike in iwan, which their orientation is from 135° to 225° azimuth and 315° to 45° azimuth. Moreover, the AIV reached its peak of about -232W/m2 in case of iwan with 1:1 ratio and in south orientation. This is the best case of ratio and orientation. Furthermore, the lowest AIV is obtained in north orientation in case of iwan with 1:2 ratio, which is the worst case.

10. Conclusion

1- Iwan can be used as a traditional architecture space and climatic responsive strategy in designing buildings in Sulaymaniyah.
2- The best orientations for all proportions of iwan are 135° to 225° azimuth angle. In the houses, which their iwans were examined, 82% of their orientations are in the best orientations range (Figure 8).
3- The worst orientations for all ratios of iwan are 315° to 45° azimuth angle. In the examined houses, none of the iwans' orientations is in the worst orientations range (Figure 8).
4- The best case study is the iwan of house number seven in which the depth to width ratio is 1:1.5 and is south oriented (see Table 1) with Annual Insolation Value (AIV) equal to -239W/m2.
5- The worst case study is the iwan of the house number three in which the ratio is 1:1.6 and is oriented to 250° azimuth angle (see table 1) with AIV equal to -287W/m2.
6- According to the AIV results, the annual solar performance of the iwans with lower depth to width proportions is better than those with higher proportions. In the examined houses, 59% of their iwan have the D:W ratio equal and/or less than 1:1.5 and the rest have a higher ratio. This middle ratio (1:1.5) of iwan proportions is repeated twice all over the investigated case studies with

orientations of 180° and 190° azimuth angles.

7- According to the results of the study, one of the main factors of choosing the orientation of iwan in traditional houses in Sulaymaniyah's old town is the annual solar performance of the iwan because most of the cases are in the best range. However, other climatic factors, such as prevailing wind, could be further reasons.

8- Regarding the depth to width ratio of iwan, different ratios are used randomly. The main factor in choosing the dimensional properties of iwan may be architectural space requirements. The space as a transitional and semi-open space was used for multi-purposes such as entrance, balcony and sitting area.

11. Future studies

This paper is the first study dealing with the solar performance and solar incident within iwans in the traditional houses of Sulaymaniyah's old town. In order to better understand the effects of iwan on the energy performance of said houses, it is recommended to work on parametric studies of energy performance of facades with iwan. In addition, innovative forms for iwan could be further studies.

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دراسة المتغيرات على الاداء الشمسي لفضاء الإيوان في البيوت التقليدية بمدينة السليمانية القديمة

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المستخلص

يُعَرف الإيوان كعنصر اساسي في عمارة الشرق الأوسط. وقد استخدم على نطاق واسع كفضاء معماري لأغراض متباينة في أنواع مختلفة من المباني التقليدية مثل المساجد والقصور والمنازل. تركيز هذه الدراسة على الجوانب البيئية لعنصر الإيوان وذلك من خلال البحث في آثار تغيير درجة انفتاح الإيوان على الأداء الشمسي للفضاء في المنازل التقليدية بمدينة السليمانية القديمة.
لقد تم استخدام EnergyPlus و Google SketchUp لإنشاء نموذج ثلاثي الأبعاد وإجراء عملية محاكاة لتحليل كمية الاشعة الشمسية الساقطة لمبنى نموذجي يحوي على إيوان بنسب مختلفة ، كما هو في مركز المدينة القديمة ، كذلك تم استخدام البيانات المناخية الخاصة بمدينة السليمانية (خط العرض 36 درجة) في عملية المحاكاة.
تؤثر العديد من المتغيرات الهندسية بشكل رئيسي على درجة انفتاح الإيوان في البيوت التقليدية بمدينة السليمانية ، وهي كما يلي:
أولاً : ان عامل الطول والعمق متغيّر في فضاء الايوان (في العينات البحثية) ، في حين أن متغير الارتفاع ثابت تقريباً ، وهو نفس ارتفاع المبنى ، الذي عادةً يساوي ثلاثة أمتار.
ثانياً : غالبا ما يكون توجيه فضاء الإيوان نحو الجنوب الشرقي والجنوب والجنوب الغربي ، وكذلك نحو الشرق أو الغرب ، حيث تتم عمليات المحاكاة والحصول على النتائج بشكل منفصل لكل من التوجيهات المذكورة .
مما لاشك فيه ان التظليل يفضل في المواسم التي ترتفع فيها درجات الحرارة ، اما في المواسم الباردة فيفضل تلقي المزيد من الإشعاع الشمسي . تظهر نتائج البحث أنه اذا كان عرض الايوان مقارنة بعمقه أقل فأن أدائه الشمسي يتحسن ، ويتبين أن آثار تغيير انفتاح الإيوان على أدائه الشمسي يختلف بشكل واضح باختلاف درجة التوجه ، حيث ان الايوان الموجه نحو الجنوب لديه أداء افضل من التوجيه الشمالي. ويظهر البحث أن تغىير نسبة العمق لعرض الاىوان الموجه نحو الشرق او الغرب لا يؤثر على الأداء الشمسي للفضاء. اضافةً الى ذلك ، تظهر نتائج هذه الدراسة امكانية استخدام الإيوان في المباني السكنية الخاصة كاستراتيجية تصميمية ذات استجابة مناخية جيدة في المباني السكنية بمدينة السليمانية.

الكلمات المفتاحية: إيوان ، هيوان ، الاداء الشمسي ، الأشعة الشمسية الساقطة ، درجة الانفتاح ، المباني التقليدية ، مدينة السليمانية القديمة.

Figure 1: Six examples of traditional houses with iwan in Sulaymaniyah's old town. (Source: Researchers)

Table 1: Dimensional properties of 22 iwan case studies in Sulaymaniyah city. (Source: Researchers)

House sample no.	Height (m)	Depth (m)	Width (m)	D:W ratio	Azimuth angle
1	2.8	4.2	6.5	1:1.5	190°
2	3	3.6	5	1:1.4	180°
3	3.2	3.65	5.7	1:1.6	250°
4	2.8	4.3	8.1	1:1.9	240°
5	2.8	4.7	5.3	1:1.1	240°
6	2.8	3.5	4.3	1:1.2	180°
7	2.8	3.5	3.8	1:1.1	180°
8	3.15	4.2	8.2	1:2	240°
9	2.7	3.5	3.5	1:1	190°
10	2.9	5	7	1:1.4	170°
11	3	4	6.2	1:1.6	185°
12	3.1	4.45	6.8	1:1.5	180°
13	2.95	3	5.1	1:1.7	160°
14	3.05	2.8	4.8	1:1.7	195°
15	2.7	3.8	6	1:1.6	210°
16	2.9	4	8.1	1:2	225°
17	2.8	4.2	7	1:1.7	160°
18	3.1	5.1	5.4	1:1	200°
19	3	3.1	5.2	1:1.7	185°
20	2.8	3.4	4.5	1:1.3	210°
21	2.85	4.8	7.5	1:1.6	170°
22	3.05	3.6	4.1	1:1.1	160°

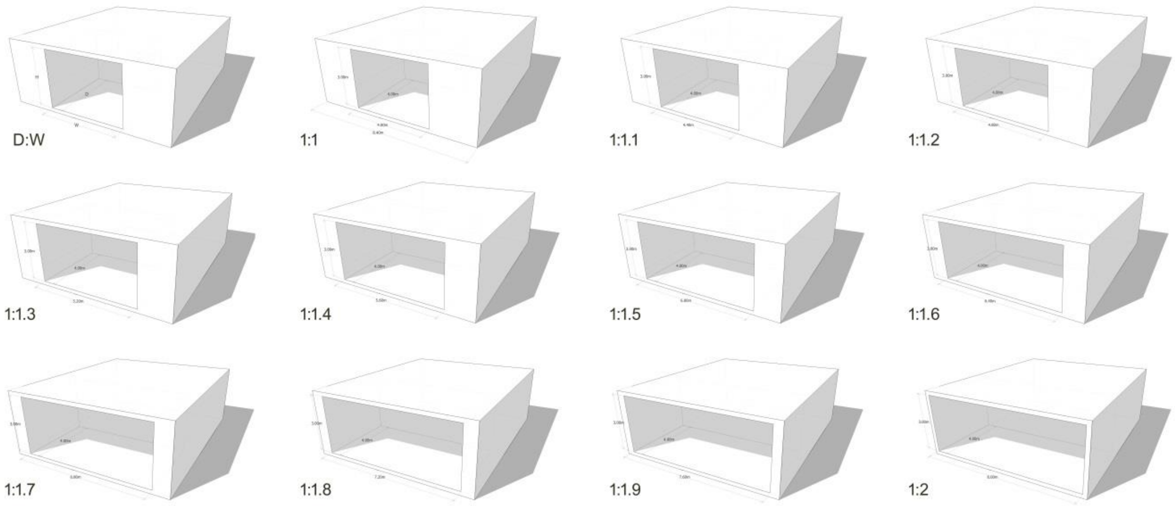

Figure 2: 3D models of considered iwan proportions in simulations. Created in Google SketchUp program. (Source: Researchers)

Table 2: Annual Insolation Value (AIV) of iwan with different D:W ratios and in eight main orientation. (Source: Researchers)

Iwan Proportions (D:W)	Azimuth angle							
	0°	45°	90°	135°	180°	225°	270°	315°
1:1	-404	-390	-316	-273	-232	-271	-313	-388
1:1.1	-420	-397	-313	-276	-239	-274	-310	-394
1:1.2	-433	-402	-311	-278	-245	-276	-307	-399
1:1.3	-446	-406	-309	-280	-251	-278	-306	-403
1:1.4	-457	-409	-308	-282	-256	-279	-304	-407
1:1.5	-467	-411	-307	-284	-260	-281	-303	-409
1:1.6	-476	-414	-306	-285	-264	-282	-303	-412
1:1.7	-484	-416	-305	-286	-267	-283	-302	-414
1:1.8	-491	-417	-304	-287	-270	-283	-301	-415
1:1.9	-498	-419	-304	-288	-273	-285	-301	-417
1:2	-504	-420	-303	-289	-275	-285	-300	-418

Annual Insolation Value (AIV) [W/m²]

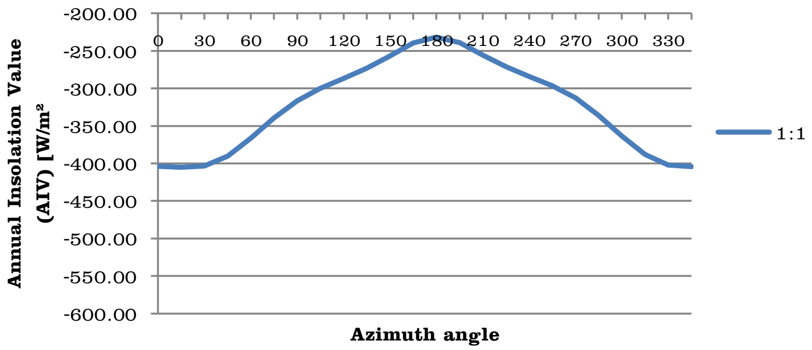

Figure 3: Annual Insolation Value (AIV) of an iwan with D:W ratio of 1:1 in different orientations. (Source: Researchers)

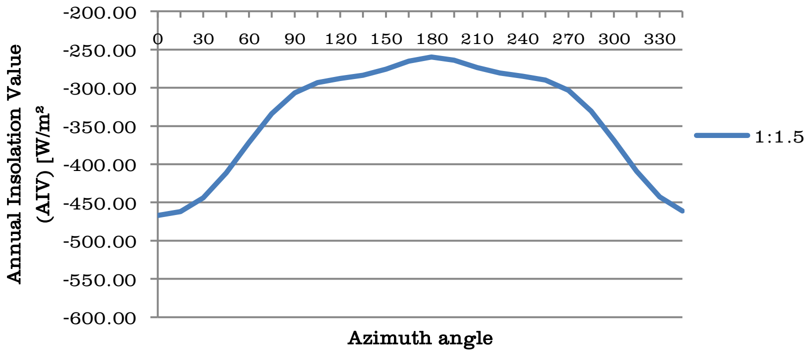

Figure 4: Annual Insolation Value (AIV) of an iwan with D:W ratio of 1:1.5 and in different orientations. (Source: Researchers)

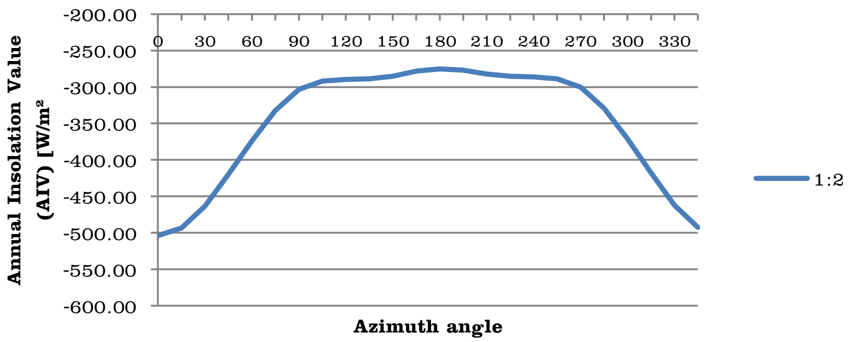

Figure 5: Annual Insolation Value (AIV) of an iwan with D:W ratio of 1:2 and in different orientations. (Source: Researchers)

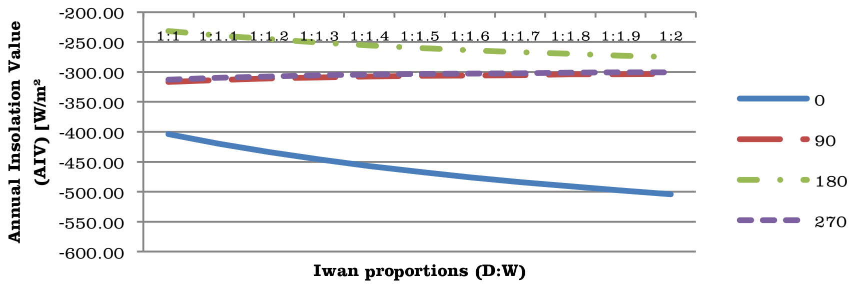

Figure 6: Annual Insolation Value (AIV) of iwan in different orientations and with different D:W ratio. (Source: Researchers)

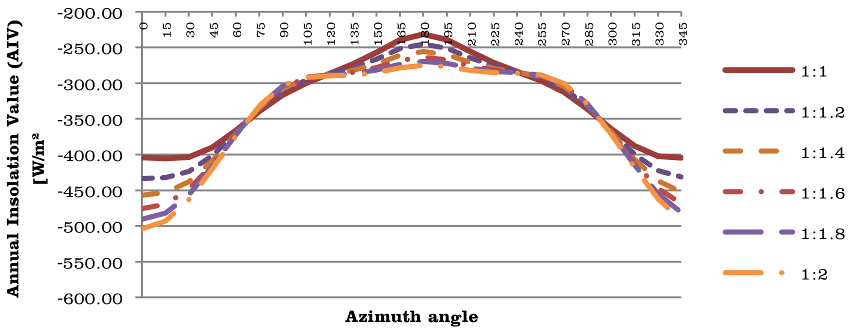

Figure 7: Annual Insolation Value (AIV) of iwan with different D:W ratios and in different orientations. (Source: Researchers)

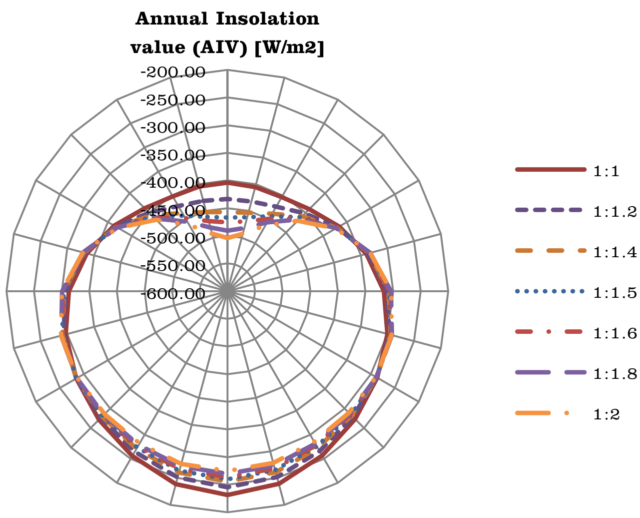

Figure 8: Annual Insolation Value (AIV) of iwan with different D:W ratios and in different orientations. (Source: Researchers)