SSRG International Journal of Civil Engineering
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V7I8P102

Volume 7 Issue 8, 3-14, August 2020

The Impact of Shading device on Energy Consumption in the Hot-Humid climate of Saudi Arabia

Abuelzein O. A.

Faculty of Architectural Engineering, Najran University, KSA

Received Date: 17 July 2020
Revised Date: 1 August 2020
Accepted Date: 06 August 2020

Abstract

Energy conservation has become the main objective for development in many developed and underdeveloped countries. In the hot climates of Saudi Arabia, people tend to use air conditioning extensively. This situation causes the electricity bill to rise high and the country to spend more on electricity generation. The key driver for energy consumption is the hot climate, which requires the cooling of buildings to provide the desired indoor conditions. The need to lower the consumption of Energy requires immediate improvement in buildings' thermal performance for efficient energy use to avoid future economic consequences in the country. There are many ways to reduce the cooling load. Intercepting the incident solar radiation on the building surfaces is one of the effective ways of reducing heat gain. Using shading devices in windows participates strongly in this process. This article focuses on the effect of different shading devices on energy consumption. King Abdulla public housing project in Jazan suburb was chosen for this study. A base case from this project was simulated using Energy plus with the Design-Builder computer program interface. The final result indicates that 50 cm timber horizontal overhang and side fins were proved the best shading device type is saving about (4.41 kwh/m^2) per annum.

***Keywords** - Energy consumption, Hot-Humid Climate, Jazan city, Shading Device, Solar Radiation..*

I. INTRODUCTION

(Buildings and construction together account for 36% of global final energy use and 39% of energy-related carbon dioxide (CO2) emissions [1]-[2]. Demand for energy services will grow 30 percent by 2040 [3]. Residential buildings worldwide account for surprisingly as high as 40% of global energy consumption [3]. Buildings in Saudi Arabia are a major contributor to energy consumption, with about 78.5% of the total energy consumed in Saudi Arabia (KSA) [4]. In 2011, KSA consumed almost 80% of the total electricity generated, of which residential buildings use 51.2%, and energy consumed by air conditioning (AC) represents 70% of the total national electrical demand. According to the Saudi Energy Efficiency Centre (SEEC), 2013 [4], the average annual consumption of electricity for the residential unit amounted to about 2,200 Kilowatt-hours per month. This is equivalent to a bill of 440 riyals per month, which is close to global rates. For example, monthly spending on electricity in the United States is equivalent to 428 Saudi Riyals (SR), in the United Kingdom is 450 SR including the cost of heating gas and 476 SR in Australia including the cost of domestic gas [5]. The harsh climate in the Jazan city causes high cooling demand during the summer.

Furthermore, huge Energy waste is due to the lack of building codes and the use of low-efficiency appliances, high living standards, and Energy-intensive lifestyle. Energy consumption per capita in the Gulf Cooperative Council (GCC) is one of the highest rates in the world and even far above industrialized countries. By 2025 it is expected that the total population will reach around 59 million while the total electrical energy consumption will jump to 1094 TWh. Moreover, with the recent fall in global oil prices, the contribution of oil exports to the economy of the GCC is adversely affected [6].

The openings in the buildings have a significant impact on the internal thermal environment as they transfer direct and indirect solar radiation and allow hot air into buildings. The use of a shading device is one of the effective tools to interrupt or at least reduce heat gain to the internal environment.

II. STATEMENT OF THE PROBLEM

(The weather of the city of Jazan is hot and humid that forces citizens to use mechanical cooling extensively especially in long, muggy summer. This leads to a large consumption of electricity and thus a prohibitive cost of the electricity bill for most of the inhabitants.

A. Importance of shading devices

- The significant reason for using shading devices is to prevent the penetration of direct solar radiation and impede the indirect one into buildings [7]. Shading devices can reduce solar heat gain through windows by up to 80% [8]. By designing shading devices according to the sun's seasonal path, both in summer and winter, solar gain can be controlled. Shading devices types could be fixed or movable. The movable ones are adjusted either by hand or by solar sensors [9]. Fixed shading devices can be mounted outside or inside the windows.
- There are different shading device types used to improve building energy performance, like overhangs, external roller shades, and Venetian blinds. Four of these types are commonly used in the area of the study. These are the vertical, the horizontal, the egg-crate, and the overhang.
- In this study, external fixed shading devices are used for both controlling solar radiation and saving Energy see photos3a, 3bb, 3c, 3d. On the other hand, these shading devices can block the daylight entity or partially, cause the need
- for artificial light. Fortunately, skies in Saudi Arabia are mostly clear, and
- so there is an abundance of daylighting [10]. As a result, it is very important to use the proper type of shading device in the correct place to have enough daylight and minimum solar gain. For instance, Jazan lies within the tropics, between latitude 160 88' N. This implies that the sun is about eight months shining on the south facades of the buildings and about four months on the northern facades. This situation justifies the use of external fixed shading devices.

III. LITERATURE REVIEW

Al-Tamimi N. et al. [11] stresses the effect of shading devices on the indoor temperature of high-rise residential building in hot-humid climate of Malaysia. A computerized simulation tool (IES<VE>) was used for the investigation in a high rise building in Penang island. The results indicate that egg-crate; shading type has a significant impact on decreasing discomfort hours compared with other shading device layouts.

Minseok Kim et al. [12] analyze the impact of effective shading design for office buildings in South Korea. Different shading design was applied for each direction. Using this shade design, the daylighting performance and the reduction

in cooling loads during the overheated period were evaluated. The results show a 35% reduction in cooling loads.

Gon Kim et al. [13] state that to eliminate the effect of absorbing solar heat, shading systems should be located in the external part of the window. An external shading device requires many design considerations such as solar geometry, the physical dimension of the elements, materials, finishes, control strategies, and aesthetics. This study proposes an experimental configuration of an external shading device that can be applied to apartment houses in South Korea. To verify the advantage of the external device, conventional daylighting devices have been examined and compared in terms of energy savings for heating and cooling. A series of simulations by an energy analysis program, IES_VE, has revealed that the experimental shading device promises the most efficient performance with various adjustments of the slat angle. A secondary advantage is that it also provides better views for occupants. Ana I. et al. [14] studied the effect of louvre shading devices applied to different façades of a building is carried out for different locations (latitudes). Building energy requirements for a building in the cooling and heating seasons are quantified for different window and louver areas, under climatic conditions of Mexico (Mexico), Cairo (Egypt), Lisbon (Portugal), Madrid (Spain), and London (UK). Also, operative and indoor temperatures were calculated through simulations using TRNSYS software, whereas the model for the shading geometry study was solved with EES software. Both horizontal and vertical louver layouts were considered. The results show that the integration of louver shading devices in the building leads to indoor comfortable thermal conditions and may lead to significant energy savings, by comparison to a building without shading devices. Dilshan Remaz et al. [15] investigates the effect of six different alternatives of external horizontal shading devices on incident solar radiation, transmitted solar heat gains, natural light penetration, and energy consumption was carried out using a standard, single fenestration perimeter office room in a typical high-rise office building in Malaysia. The investigation is conducted using eQUEST-3, which is a dynamic energy simulation program supported by the DOE2.2 calculation engine. The results showed several optimum geometries of the external horizontal shading device depending on incident direct solar radiation, transmitted solar heat gains, natural-light penetration, and energy consumption. This study concludes, considering the trade-offs between total heat gain and natural-light penetration to optimize the total energy consumption as the best option in designing external solar shading in hot and humid climates.

Dilshan R. Ossen et al. [16] report that the interception of the radiant heat wave before penetrating the internal environment through envelope openings is the main criterion in designing solar shading. In a hot and humid climate, one drawback of using shading devices is the risk to reduce daylight level, thus increases in the use of artificial lighting. Therefore it is important to understand the magnitude of energy consumption for cooling and lighting when shading devices are adapted to analyze optimum shading as an energy conservation option in high-rise office buildings. In other words, little is known about the relationship between energy use and external horizontal shading device geometry. In an attempt to elucidate these complex relationships, a simple experiment of an office room is carried out using a dynamic computer simulation program eQUEST- 3 (DOE 2.2). The study indicated the depth of the external horizontal overhang could be manipulated to obtain optimum energy use in high-rise buildings. The results showed that the correlation between overhang depth and Energy is an important aspect compared to the correlation between overhang depth with building cooling loads and daylight level, especially in tropical climate conditions.

Laura Bellia et al. [17] analyses the influence of external solar shading devices on the energy requirements of a typical air-conditioned office building for Italian climates. A type of office building widespread in Europe has been considered. The energy-saving related to solar shading refers only to summer air conditioning. Still, the evaluation has been carried out for the entire year by using a building energy simulation code. The energy demand of the main technical systems (heating, cooling, and lighting) and the energy-saving related to the use of solar shading devices have been evaluated, as a function of the most significant parameters, such as the climate, the geometrical characteristics of the shadings and the building, the thermal transmittance of the building envelope and the building orientation. The solar shading devices have shown the highest energy efficiency for warm summer climates: for example, the global annual energy saving related to the use of suitable shading devices has been evaluated between 8% for Milan (the coldest climate) and 20% (for Palermo, the warmest one).

Jaepil Choi et al. [18] developed a parametric design methodology that combines parametric design with thermal analysis in Seoul, Korea. This new approach suggests that a form emerges from a performance-based analysis. The result of the study is a parametric louver design system, which optimizes a louver form based on its direct solar radiation control performance. The system is composed of three parts: the analysis part, parametric design part, and optimization part. Each part functions interactively to produce an output. The output is the best performing louver form for the given site from the aspect of its yearly direct solar radiation control performance. The study applies the suggested design system to a case study, which is a virtual curtain wall office building in Seoul, Korea. The system produces the best performing louver form for each of the building's two main facades. The study compares the thermal performance of the best performing louver design with a commonly used louver design using different software, Ecotect Analysis 2011. The Ecotect's thermal analysis confirms that the suggested louver forms perform better, reducing the building's heating and cooling loads. The building's thermal loads have been reduced by 931 (Wh) per m² in a year by installing the best performing louver design.

A. Summary

1. All researchers confirm that the interception of the radiant heat wave before penetrating the internal environment through envelope openings is the main criterion in designing solar shading.

2. A limited number of articles are published on this topic worldwide. None of the published articles is on the tropical hot, humid climate of Saudi Arabia.

3. Some of the reviewed articles were carried out in the Mediterranean countries, some in Southeast Asia except London city, Lisbon, and Mexico City. My research in the Red sea area, somehow in between these countries.

4. Although all the eight articles were carried out in nearly similar climates (warm humid), different types of shading devices were proven to be the best. Maybe due to the little differences in climatic conditions and the percentage of humidity.

5. One drawback of using shading devices is the risk to reduce daylight level, thus increases the use of artificial lighting.

6. Nearly all authors used the trade-off way of experiments or manipulation of different types of shading devices to reach the best performance. Also, all of them used simulation computer models.

7. All authors simulated the whole designed year but computed Energy used for cooling only.

8. In Malaysia, egg-crate, external horizontal overhang, have the best performance in lowering the internal air temperature and consequently lowering energy consumption. In Italy, a solar shading device in summer did have a better thermal effect, without mentioning the type of shading device. In Seoul, South Korea, louvres and different shading devices were used and have better performance. In Cairo, London, Lisbon, Madrid, and Mexico, louvers shading devices were used and have better performance.

9. It is obvious from point (g) that, the same type of shading device suited different geographical places or different continents.

10. Not all the quoted researchers have quantified the final results. Some expressed in terms of improvement in thermal conditions and thus in thermal comfort. Some in lowering the cooling load. Those who quantified the final results quoted for example 35% reduction in energy consumption, some between 8 to 20% according to climatic conditions. Some quoted a reduction of 931 (Wh) per m² per year.

11. It is obvious from point (h) that, the reduction in energy consumption ranged from a high percentage of 35% to a low one of 9% to a very low of 0.022% which is equivalent 931Wh/m2/year.

IV. THE CLIMATE OF JAZAN

Jazan city lies between latitude 160 88' N on the red sea with an altitude of 24 meters above sea level. It has a hot-humid type of climate. June is the hottest month with air temperature rises to 33.5 0C, January (Jan) is the coldest month with air temperatures be as low as 25.7 0C. The annual daily range is about 7.8 0C. The highest level of rainfall occurs in August (Aug) with 19mm, and the lowest level happens in June with 1mm. The difference in rainfall between the driest month and the wettest month is 18 mm, see Table 1.

A. Table 1: Monthly Averages Air Temperature and Rain Fall in Jazan [19]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Avg. Temp °C	25.7	26.4	27.9	29.9	32.2	33.5	33.3	33.2	32.3	30.9	28.1	26.4
Min. Temp °C	21.7	22.4	23.7	25.3	27.5	29.2	29.5	29.3	27.9	25.7	23.4	21.5
Max. Temp °C	29.7	30.5	32.2	34.5	37	37.8	37.1	37.1	36.7	36.1	32.9	31.3
Rainfall mm	11	5	7	8	7	1	8	19	8	8	13	12

Jazan experiences some seasonal variation in the perceived humidity. The muggier period of the year lasts for 10 months, from December 8 (Dec) to October (Oct) 16, during which time the comfort level is oppressive, or miserable at least 90% of the time. The muggiest day of the year is Aug. 10th, with muggy conditions 100% of the time. The least muggy day of the year is November 6 (Nov), with muggy conditions, 87% of the time, see Figure 1a.

The windier part of the year lasts for 4.6 months, from June 27 to Nov. 16, with average wind speeds of more than 7.4 miles per hour. The windiest day of the year is July 24, with an average hourly wind speed of 8.0 miles per hour. The calmer time of year lasts for 7.4 months, from Nov.16 to June 27. The calmest day of the year is May 12, with an average hourly wind speed of 6.8 miles per hour, see Figure 1b

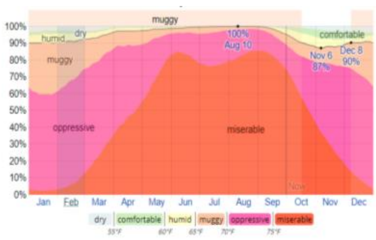

Figure 1a: Humidity Comfort Level [19]

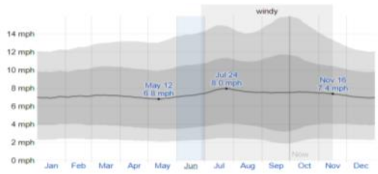

Figure 1b: Average Wind Speed [19]

The length of the day in Jazan varies over the course of the year. In 2019, the shortest day was Dec. 22, with 11 hours, 7 minutes of daylight; the longest day is June 21, with 13 hours, 8 minutes of daylight. The earliest sunrise is at 5:35 am on June 5, and the latest sunrise is 1 hour, 7 minutes later at 6:42 am on Jan. 21 (Jan). The earliest sunset is at 5:33 pm on Nov.23, and the latest sunset is 1 hour, 14 minutes later at 6:47 pm on July 7, see Figure 1c.

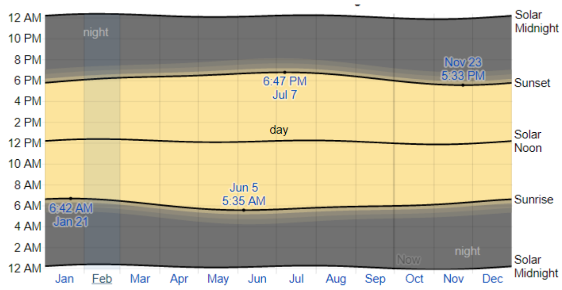

Figure 1c: Sunrise & Sunset with Twilight [19]

A. Summary:

Residential buildings in Jazan city need to be air-conditioned all Summertime, nearly ten months a year.

V. METHODOLOGY

Firstly, A theoretical method was used to review the literature and cover all the readings written and published on the subject.

Secondly, the King Abdulla housing project in the Jazan suburb was considered for this study [20]. It consists of 261 villas with all the necessary amenities and services. A base case from this project was selected and simulated using the DesignBuilder computer program.

VI. THE BASE CASE

The plans of all villas are typical. Each villa consists of two floors. The ground floor consists of a male quest room, dining room, family hall, master bedroom, a kitchen, two toilets, and a staircase. The top floor is composed of two bedrooms, two toilets, and a terrace [20].

Construction details were described and made ready for simulation.

Monthly electricity bills for all the villas were brought from the electricity company web site for one year (2017). Ten of them were selected randomly as there was no policy for the orientation of the villas. The only measure I observed was that the selected bills should contain some of the highest, lowest, and medium ones [21].

A household survey was conducted to know the family size, how the inhabitants live in their villas as for the use of each room in summer and winter.

For the purpose of the comparison between the actual electricity consumption and the simulated one, the annual consumption was calculated for each villa. Then I divided it by the built-up area, which is 2382 to get the annual consumption per square metre, see Table 2. The base case was simulated, and the annual consumption per square metre was obtained.
The average consumption of the ten villas is 148.6 KW/h/m2.

Table 2: The Annual electricity consumption of the ten villas [21]

Flat no	Account no	Consumption /y	Consumption /y/m2
1	26,038	10049548394	**109**
2	39,094	10049453371	**164**
3	24,621	10049548591	**103**
4	23,103	10049545187	**97**
5	59,785	10049453601	**251**
6	42,476	10049625116	**102**
7	31.507	10049451831	**132**
8	39,303	10049553081	**165**
9	63,674	10049452801	**267**
10	26,038	**10049547600**	

A. Building the simulation model

The building materials used in the different construction components, walls, the roof, floors, windows, and doors were described as follows:-

1. Materials used in walls

Walls are constructed from two leaves, the inner leaf is 100 mm thick, and the outer one is 50mm. Both walls are from lightweight concrete blocks. The external finish is 25mm and 03mm cement sand rendering (CSR) and gypsum plaster (GP), respectively. The internal finish is 25mm CSR. Wall is insulated with 50mm expanded polystyrene placed between the two wall leaves. The overall wall thickness is 253mm.

2. Materials used in the roof

The roof is made of 150mm reinforced concrete slab, finished externally with 25mm plain concrete tiles (PC), 20mm CS screed (CSS), 40mm sand and gravel (SG), 60mm extruded polystyrene heat insulator (HI), and 03mm rubber damp proof course (DPC). It is finished internally with 20mm (CSR). The overall roof thickness is 318mm.

3. Materials used in the ground floor

The first floor is composed of 100mm RCS finished with 20mm rubber DPC, 60 SG, 20mm CSS, and 10 ceramic tiles. The overall thickness is 210mm.

4. Materials used in the 1st floor

The first floor is composed of 100mm RCS finished with 20mm rubber DPC, 60 SG, 20mm CSS, and 10 ceramic tiles. The overall thickness is 210mm.

5. Doors and Windows

The building has 15 doors for the two floors with an area of 2.2 m2 for most of them. There are 14 windows in the building, 8 on the ground floor and 6 on the first floor. There is one window on the north side, which is 0.60 * 0.60, and two windows on the east side are 1.50 * 1.00 and 5 windows on the south side are 1.50 * 1.00, 0.60 * 0.60, and 6 windows. On the western side, the dimensions are 1.50 * 1.00, 0.60 * 0.60 and 0.80 * 1.00, and the WWR is 4.35%. Windows are made of 6 mm glass in aluminum frames.

6. Rooms usages schedule for all rooms in summer and winter.

All times during which AC and lighting are used are to be presented later depending on the household survey conducted by the researcher.

7. Air conditioning in summer for all rooms.

The bedrooms

The Air conditioning operates in the bedrooms on working days from 10 pm to 7 am and from 2 pm to 4 pm. On weekends, the AC is operated from 1 am to 10 am and from 3 pm to 4 pm.

The Sitting room

Air conditioning is operated in the living room on working days from 6 am to 7 am and from 11 am to 12 pm. And from 1 pm to 2 pm then from 7 pm to 9 pm. In the weekend, from 9 am to 11 am and from 2 pm to 4 pm then from 8 pm to 11 pm.

The Dining room:

Air conditioning is operated in the dining room in working days and weekends from 1 pm to 2 pm and from 8 pm to 9 pm.

The Kitchen:

The air conditioning is operated in the Kitchen during working days and weekends from 11 am to 1 pm and from 7 pm to 8 pm.

Living room:

The air conditioner is operated in the sitting room on weekend days from 7 pm to 9 pm.

The Lobby:

The displaced air ventilates it. Natural ventilation is used in the hall throughout the summer season.

The Staircase and the Toilets:

The staircase is ventilated through the air replacement. Only mechanical ventilation (exhaust fan) is used here.

Air conditioning in winter:

Since the climate in the Jazan region in the winter is moderate, there is no need for air conditioning in December, January, and February. All the spaces are naturally ventilated.

8. Artificial lighting in summer and winter.

The use of lighting in the building vary according to the need, I will explain each space separately.

Bedrooms:

Lighting is used in the bedrooms on working days from 5 to 6 am and from 2 to 3 pm. Then from 7 to 9 pm. In weekend is from 10 am to 11 am, from 3 pm to 4 pm, and from 8 to12 am.

Dining room:

Lighting is used here in the working days from 6 to 7 am, from 1 to 2 pm, and from 7 to 8 pm. At the weekend, it is used from 7 to 8 pm.

Kitchen:

Lighting is used on working days from 5 am to 7 am, from 12 pm to 2 pm, from 6 pm to 7 pm, and from 8 pm to 9 pm. At the weekend, it is used from 9 am to 10 am, from 11 am to 1 pm, and from 7 pm to 8 pm.

Living room:

Lighting is used on working days from 6 am to 7 am, from 11 am to 12 pm, from 1 pm to 2 pm, and from 7 pm to 8 pm. At the weekend, lighting is used from 9 am to 11 am, from 2 pm to 4 pm, and from 8 pm to 10 am.

Sitting Rooms:

Lighting is used at the weekend from 7 pm to 9 pm.

Lighting in the auxiliary spaces:

Energy-saving lamps are used in the staircase, lobby. I assumed that they consume negligible electricity.

B. Simulation of the base case: (Verification run)

As mentioned earlier, the electricity consumption starts in February with a high rate of increase until it reaches the maximum in August, the worst climatic conditions then decreases until it reaches the minimum in November. The total electricity consumption for AC and lighting for the year 2017 has amounted to 29939.75 KWh. The consumption per m2 is then equal to 147.81 KWh/m2, see Figure 3.

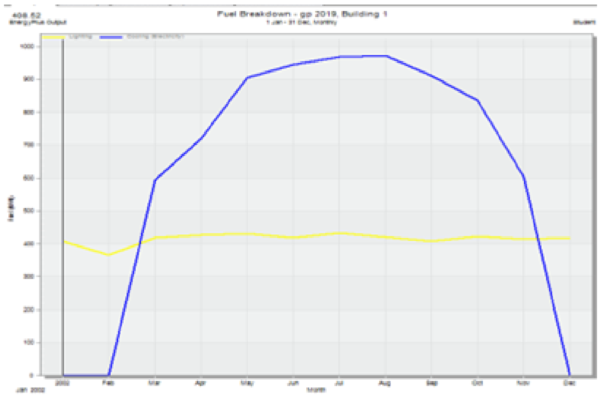

Figure 2: Electricity consumption by AC and lighting for the year 2017

When comparing the actual annual electricity consumption per square metre, which is 147.81 KWh/m2 with the simulated one, which is 148.6, the difference is 0.8 KWh/m2 which is negligible and proves that the simulated results are acceptable.

C. The shading device design:

To design the shading device, the solar incident angles should be calculated.

α=90+δ…………………………………………….(1)

Where α is the solar angle, δ is solar deflection

δ=23.45 sin (360(n-80)/3650-16.88……………….(2)

N= The first day in the month is calculated sequentially from the first day in the year. [22].

N for January is 1, for February is 32, for March is 60, for April is 91, for May is 121, for June is 152, for July is 182, foe August is 213, for September is 244, for October is 274, for November is 305, for December is 33.

Using equations 1 and 2, solar angle α for the twelve months are calculated on the twenty-first day of each month as it is frequently needed for solar geometry calculations.

The solar angle for January is 53.4^0, for February is $62.\ 6^0$, for March, is 73.52^0, for April is 85.40^0, for May is 93.65^0, for June is 96.55^0, for July is 95.93^0, for August is 84.17^0, for September is 72.12^0, for October is 60.68, for November is $52.\ 30^0$, for December, is 49.69^0.

2. Design of solar breakers

Horizontal (H) shading device (Sh. D.) in the northern hemisphere is primarily used on the south (S) façade [23].

Southern façade window [1.50 * 1 m.]

The aim that should be achieved by the design of Sd. D. is to intercept the incident solar radiation in the specific days set. Accordingly, Sh. D. is designed. Using trial and error, certain dimensions of Sh. D. are found to fulfill our goal.

The width of the breaker is 12.50 cm. The length of the breaker is 1.50 cm. I choose aluminum, timber, and concrete for the sun breaker as they are commonly used. Three distances between the breakers are used 14.3, 12.3, 9.3 cm. for the three types of materials respectively.

Vertical breakers (V) are designed using the same procedure as in the H. one. Three different distances between the breakers are used 13.6, 11.6, 8.6 cm for the three types of materials respectively.

Shading device in the Eastern (E) Facade. Window Sizes 1.50 * 1 m.

Vertical breakers are designed using the same procedure as in the H. one. Three different distances between the breakers are used 13.6, 11.6, 8.6 cm. for the three types of materials respectively.

Vertical (V) shading device in the western (W) façade sizes of window 1.50 * 1 and 0.90 * 1.00 m [3]

Vertical breakers are designed using the same procedure as in the H. one. Three different distances between the breakers are used 13.6, 11.6, 8.6 cm. for the three types of materials respectively. For the smaller window, the following in-between distances are used respectively 12.85, 10.85, 7.85cm.

Egg-crate shading device in the southern, western, and eastern façades. Window sizes 1.50 * 1 m.

Egg-crate Sh. D. are designed using the same procedure, in-between distances, and materials as for the S., E., and W. facades. It is H. and V. Sh. D. combined.

VII. THE EXPERIMENTS

A. First experiment:

In this experiment, H. Sh. D. in the S. façade and V. in the E. and W. facades are used, 2 mm thick and 12.5 cm wide aluminum sheet is used at 14.3 cm apart for the H. Sh. D. in the S. facade and 13.6 cm for the V. Sh. D. in the W. and E. elevation

Results:

When H. aluminum Sh. D. is used in the S. facade and V. in the W. and E. facades, the electricity consumption per square meter for AC increased from Feb. until it reached the peak in Aug. (920 KWh / m2). From May to Sept. represents the highest consumption per year. Electricity consumption for lighting reached the lowest (400 KWh / m2) in Dec. and in Feb. It continued constant (465 KWh/m2) until the end of the year. See Figure 3. The annual consumption per square meter was about (148.51 KWh/m2). The saving in electricity consumption is 0.09 KWh/m2, which represents (0.06%).

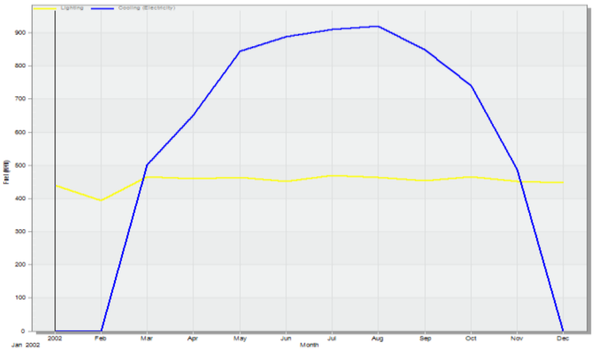

Figure 3: Annual electricity consumption/m2

B. Second experiment:

In this experiment, 2 mm thick aluminum egg-crate Sh. D. is used, 12.5 cm in width, 14.3 cm apart for H. breakers, and 13.6 cm for the V. breakers.

Results:

When an egg-crate-shading device is used in the S., W., and E. of aluminum, electricity consumption per square meter for AC increased from Feb. on until it reached its peak reached in Aug. (900 KWh/m2). Consumption from May to Sep. Represent the highest in the year. Electricity consumption for lighting in Dec. and in Feb. Reached the lowest (415 KWh/m2). It continually continues until the end of the year (490 KWh/m2). See Figure 4. The annual consumption per square meter was (150.14 KWh/m2). The increase in electricity consumption is (1.54 KWh/m2), which represents (1.03%).

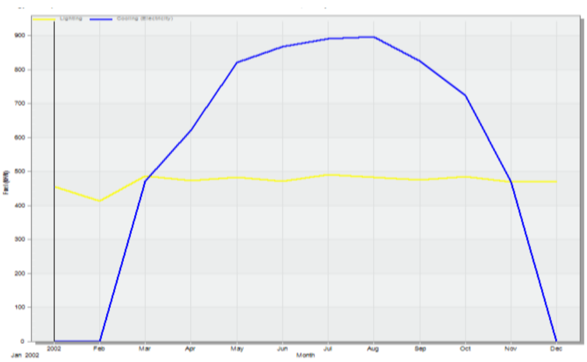

Figure 4: Annual electricity consumption per m2

C. Third experiment:

In this experiment, a 2 cm thick of timber is used for the H. Sd. D. in the S. façade and V. ones in the W. and E. facades. Its width was 12.5 cm, 12.3 cm apart for the H. Sd. D., and 11.6 cm for V. ones.

Results:

When H. Sh. D. is used in the S. facade, and V. in the W. and E. façades of timber, electricity consumption per square meter for air conditioning increased from Feb. until the peak was reached in Aug. (905 KWh/m2). The highest consumption per year was reached between May and Sep. The electricity consumption for lighting from Dec. to Feb. was 415 KWh/m2. It constantly continues until the end of the year of about (480 KWh/m2) see Figure 5. The annual consumption per square meter was about (149.77 KWh/m2). The increase in electricity consumption is (1.17 KWh/m2) which represents (0.78 %).

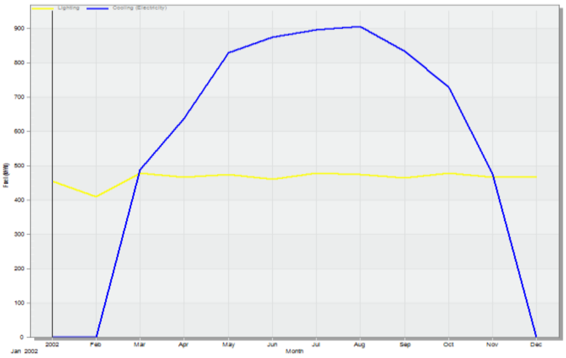

Figure 5: Annual electricity consumption/m2

D. Fourth experiment :

In this experiment, 2 cm thick from timber egg-crate Sh. D. is used, 12.5 cm in width and 12.3 cm apart for the H. breakers and 11.6 cm apart for the V. breakers.

Results:

When egg-crate Sh. D. is used in the S., W., and E. façades of 2cm of timber, electricity consumption per m2 for AC increased from Feb. until it reached its peak in Aug. (900 KWh/m2). The highest consumption per year occurred between May and Sep. Electricity consumption for lighting was the lowest between Dec. and Feb. (420 KWh/m2). It continues continuously until the end of the year (485 KWh/m2). See Figure 6. Annual consumption per square meter was about (150.14 KWh/m2). The saving in electricity consumption is (1.54 KWh/m2) which, represents (1.03 %).

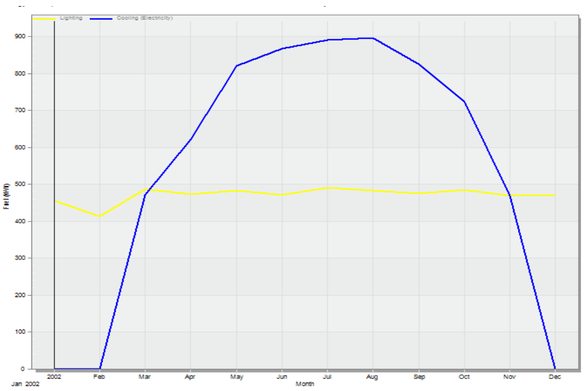

Figure 6: Annual electricity consumption/m2

E. Fifth experiment:

In this experiment, 5 cm concrete H. Sh. D. is used in the S. façade and V. Sh. D. in the E. and W. facades. Its width was 12.5 cm and 9.3 cm apart in the S. façade and 8.6 cm for V. Sh. D. in the W. and E. façades.

Results:

When 5 cm concrete H. Sh. D. is used in the S. facade and V. in the W. and E. facades, electricity consumption per m2 for AC increased from Feb. until it researched its' peak in Aug. (910 KWh/m2). The period from May to Sep. Represents the highest consumption per year. Electricity consumption for lighting in Dec. and Feb. reached the lowest value (412 KWh/m2). It continually continues until the end of the year of about (475 KWh/m2), see Figure 7. The annual consumption per m2 was about (149.77 KWh/m2). The difference in electricity consumption is (+1.17 KWh/m2), which represents 0.78%.

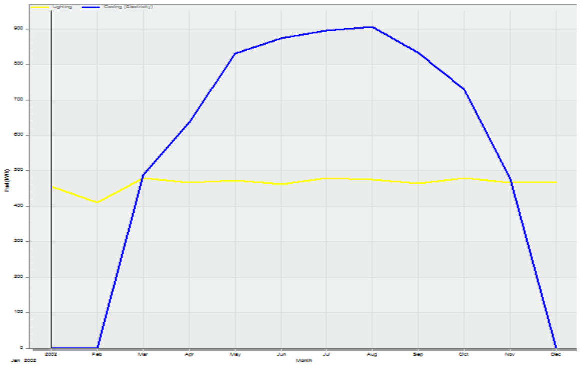

Figure 7: Annual electricity consumption/m2

F. Sixth Experiment:

In this experiment, 5 cm thick concrete egg-crate Sh. D. is used, 12.5 cm apart and 9.3 cm for H. Sh. D. and 8.6 cm for V. Sh. D. in the W. and E. facades.

Results:

When the egg-crate, concrete Sh. D. is used in the S., W., and E. façades, electricity consumption per m^2 for AC increased from Feb. until it reached its peak in Aug. (900 KWh/m^2). The period from May to Sep. Represents the highest consumption per year. Electricity consumption for lighting reached the lowest consumption between Dec. and Feb. (420 KWh/m^2). It continues continuously until the end of the year at about (480 KWh/m^2). See Figure 8. Annual consumption per m^2 was about (150.14 KWh/m^2). The improvement in electricity consumption is (1.54 KWh/m^2), which, represents (1.03 %).

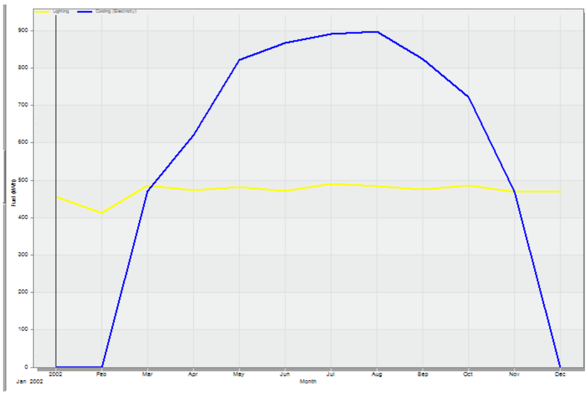

Figure 8: Annual electricity consumption/m2

G. Seventh experiment:

In this experiment, 2mm thick, 14.3 cm apart aluminum H. Sh. D. is used in the S. façade, and V. in the W. and E. facade, 25 cm wide, 13.6 cm apart.

Results:

When aluminum H. Sh. D. is used in the S. facade and V. in the W. and E. facades, electricity consumption per m2 for AC increased from Feb. until it reached its peak in Aug. at (903 KWh/m2). The period between May and Sep. Represent the highest consumption per year. Electricity consumption for lighting reached its lowest values between Dec. and Feb. (420 KWh/m2). It continues continuously until the end of the year (480 KWh/m2), Sees Figure 9. The annual consumption per m2 was about (150.21 KWh/m2). The saving in electricity consumption is +1.61 KWh/m2) which, represents (0.81%).

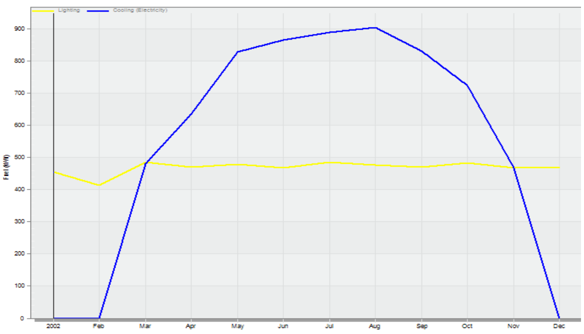

Figure 9: Annual electricity consumption/m2

H. Eighth experiment:

In this experiment egg-crate of 2 cm thick, 25 cm wide timber H. and V. Sh. D. are used with 12.3 cm apart for H. breakers, and 11.6 cm for V. breakers.

Results:

When egg-crate timber Sh. D. is used in the S. facade in the W. and eastern façades, electricity consumption per m2 for AC increased from Feb. until it reached its peak in Aug. at (903 KWh/m2). The period from May to Sep. Represent the highest consumption per year. Electricity consumption for lighting researched its lowest value between Dec. and Feb. at about (420 KWh/m2). It continues continuously until the end of the year of about (485 KWh/m2). See Figure 10. The annual consumption per m2 was (150.21 KWh/m2). The difference in electricity consumption is (+1.61 KWh/m2), which, represents (1.08%).

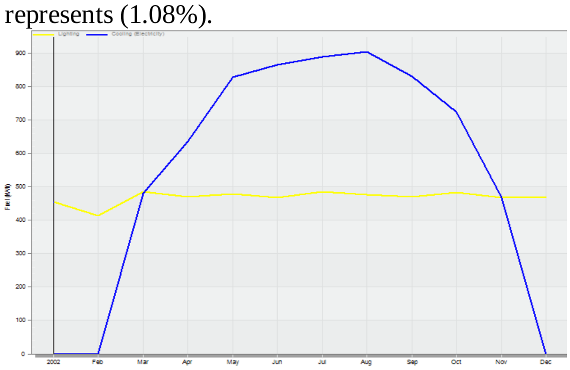

Figure 10: Annual electricity consumption per m2

I. The ninth experiment:

In this experiment, 2 cm thick timber H. overhang Sh. D., 50 cm projection from the top and right and left of the window is used.

Results:

When 2cm thick, 50 cm H. overhang, and 50 cm side fins, timber Sh. D. in the S., W. and E. façades are used, Electricity consumption per m2 for AC increased from Feb. until it reached its peak in Aug. at (930 KWh/m2). The period from May to Sep. Represent the highest consumption per year. The lowest consumption for lighting was between Dec. and Feb. (370 KWh/m2). It continually continues until the end of the year of about (425 KWh/m2). See Figure 11. The annual consumption per m2 was about (144.19 KWh/m2), the improvement in electricity consumption is (4.41 KWh/m2) which, represents (2.96%)

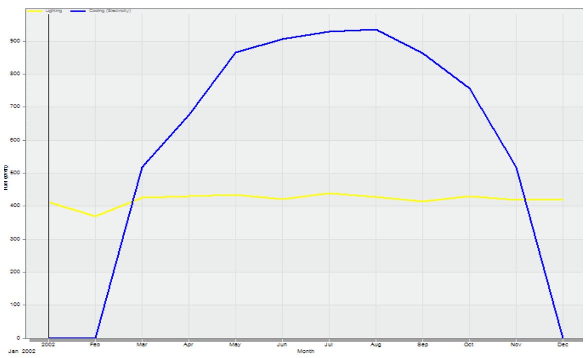

Figure 11: Annual electricity consumption per m2

J. Tenth experiment:

In this experiment, 2 cm thick of timber and 75 cm for the H. overhang and the side fins with the same width are used.

Results:

When 2 cm thick, 75 cm H. overhang and side fins timber Sh. D. is used in the S., W. and E. façade, the consumption of electricity per m2 for AC increased from Feb. until it reached its peak in Aug. at (940 KWh/m2). The period from May to Sep. Represent the highest consumption per year. Electricity consumption for lighting was the lowest between Dec. and Feb. (388 KWh/m2). It constantly continues until the end of the year (455 KWh/m2). See Figure 12. The annual consumption per m2 was about (147.87 KWh/m2). The improvement in electricity consumption is (0.73 KWh/m2) which, represents (0.49%).

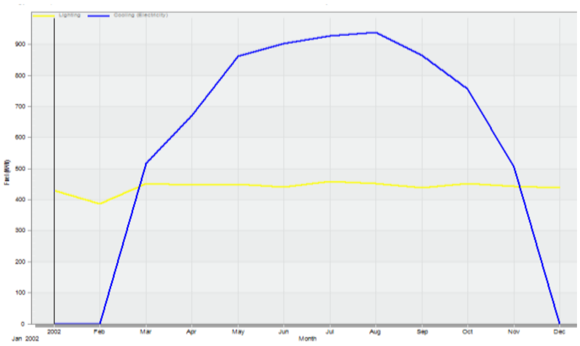

Figure 12: Annual electricity consumption/m2

K. Eleventh experiment:

In this experiment, 2 cm thick, 100 cm H. overhang, and 50 cm side fins of timber is used.

Results:

When 2 cm thick, 100 cm H. overhang, 50 cm side fins of timber Sh. D. is used in the S., W. and E. façades, the consumption of electricity per m2 for AC increased from Feb. until reached its peak in Aug. at (940 KWh/m2). The period from May to Sep. Represent the highest consumption per year. Electricity consumption for lighting in Dec. and Feb. was the lowest (398 KWh/m2). It continues continuously until the end of the year at (460 KWh/m2). See Figure 13. The annual consumption per m2 was about (149.47 KWh/m2). The saving in electricity consumption is (+0.87 KWh/m2), which represents (0.58%.)

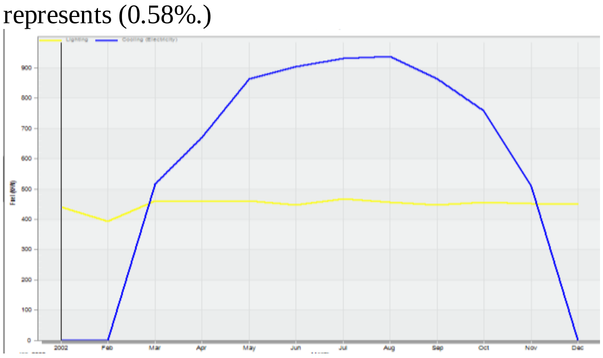

Figure 13: Annual electricity consumption/m2

L. Twelfth experiment:

Here, 2 cm thick, 50 cm H. overhang and side fins of timber Sh. D. is used but, situated 30 km away from the edge of the window.

Results:

When 2 cm thick, 50 cm H. overhang and side fins timber Sh. D., but 30 cm away from the edge of the window, in the S., W and E. façades, electricity consumption per m2 for AC increased from February until reached its peak in Aug. at (945 KWh/m2). The period from May to Sep. Represent the highest consumption per year. Electricity consumption for lighting in Dec. and Feb. reached its lowest value (375 KWh/m2). It continues continuously until the end of the year at (420 KWh/m2). See Figure 14. The annual consumption per m2 was about (144.36 KWh/m2). The saving in electricity consumption is (-4.24 KWh/m2), which represents (2.85%).

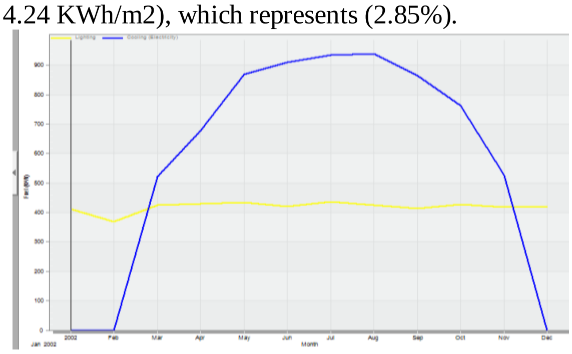

Figure 14: Annual electricity consumption/m2

Table 3: Summary of experiments results

Exp.	Measured Consumption Kwh/m²/y	Simulated Consumption Kwh/m2/y	The diff.	%
1	148.6	148.51	-0.09	0.06
2	148.6	150.14	+1.54	1.03
3	148.6	149.77	1.17+	0.78
4	148.6	150.14	+1.54	1.03
5	148.6	149.77	1.17+	0.78
6	148.6	150.14	1.54	1.03
7	148.6	150.21	+1.61	1.08
8	148.6	150.21	+1.61	1.08
9	148.6	144.19	4.41-	2.96
10	148.6	147.87	-0.73	0.49
11	148.6	149.47	+0.87	0.58
12	148.6	144.36	-4.24	2.85

IX. DISCUSSION OF THE RESULTS

The maximum reduction in energy consumption is 4.41 KWh/m2, which happened when I used a 50 cm deep horizontal overhang and two same depth fins on both sides. They were made of 2 cm thick timber plates. See Table 23. This result happened because there is more free space in front of the window for the air to move. In other words, there is no trapped air adjacent to the window. In humid climates, convective currents should be encouraged to remove the hot air adjacent to bodies. This final result which is 4410 Wh/m2/y, is far better than the improvement made by Jaepil Choi et al. when they used louvers in Seoul Korea to reduce energy consumption.

The annual saving in the electricity when I used the shading device mentioned in the first point will be 4.41KWh/m2*.02SR*238m2 =209.9 SR.

The final results would have been better if the horizontal overhang and the side fins were parted from the wall leaving a slot to allow hot air to escape. Therefore, heat would not be transferred to the inside space.

The worst result, which is an increase in energy consumption by 1.61 KWh/m2, happened when I used a 2mm thick aluminum horizontal shading device, 25 cm wide in the southern façade, 14.3 cm apart, and vertical ones in the western and eastern facade 13.6 cm apart. In addition. It also happed when I used timber egg-crate of 2 cm thick, 25 cm wide, and 12.3 cm apart for horizontal members, and 11.6 cm for vertical members, see Table 23. It is apparent that either horizontal, vertical, or egg-crate louver traps the hot air in between them then it transfers to the inside space.

Energy consumption rose slightly when aluminum horizontal shading devices were used in the South façade and vertical ones in the West and East facades compared to timber shading devices. The difference is about 0.09 kwh/m2. This due to the slightly higher heat capacity of timber.

X. CONCLUSIONS

1. The climate of Jazan city is characterized by a reasonable figure of an annual average air temperature of 300 C but unbearable because of the high humidity which is described as oppressive and miserable in most of the years' time. The proximity of the city to the red sea is the main cause of high humidity; see Table 1 and Figure 4, respectively. The slow wind speed, about 7m/h does not help the stuffy state of the weather. There are plenty of sunshine, more than twelve hours per day. A person in such type of weather does not live without air-conditioning.

2. The abundant solar brightness makes no problem as for daylighting. Thus if architectural designs in Saudi Arabia, make use of daylighting, buildings will never need much artificial lighting, see Figure 19.

3. The building orientation as regard solar radiation or natural ventilation was not considered. It is an intense heat inductive factor. Probably, the consultant was asked not to consider orientation when sitting villas.

4. Energy per floor square meter per year is used in this research as an index for energy consumption as the Institute of Energy, and electrical engineers (IEEE) has assigned Energy use intensity (EUI) as an index for energy consumption in buildings, which is Energy per unit floor area per year.

5. The effect of the material of the shading device on the energy consumption is negligible.

6. Building orientation and shape are ignored in the local building by-laws.

XI. RECOMMENDATIONS

1. I recommend the use of 50 cm wide horizontal overhang with slot, and 50 cm side fins with slot as shading devices for windows in the hot, humid climate of Jazan. This is to allow the adjacent hot air to move away from the window.

2. Timber is more likely to suit the hot, humid climes as a material for the shading devices.

3. Building orientation and shape has to be considered when siting plot and blocks in any housing project. It conserves a lot of Energy.

ACKNOWLEDGEMENT

I would like to thank Mr. Mubarak Al Mukhallas and Mr. Faris Al Hannan for their efforts in carrying out the family survey and the simulation runs.

REFERENCES

[1] UN environment, towards a zero-emission, efficient, and resilient building and construction sector-2018.

[2] Luis Pe' rez-Lombard, JoséOrtiz, and Christine Pout, A review on buildings energy consumption information, Energy and Buildings 40 (2008) , 394–398.

[3] IEA, World Energy Outlook 2018, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2018 Middle East Economic Digest.

[4] SEEC & K.A.CARE, 2013.

[5] Asif, M. Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. Renew. Sustain. Energy Rev. 55(2016) 1267–1273.

[6] Abdullah Al-Badia and Imtenan AlMubarakb, Growing energy demand in the GCC countries Arab Journal of Basic and Applied Sciences, ISSN: (Print) 2576-5299 (Online) 12 Journal homepage: https://www.tandfonline.com/loi/tabs20 (2019).

[7] Platzer, WJ. Evaluation of overheating protection with sun shading; Solar Energy 69 (2001) 59–74. Google Scholar.

[8] Marco Sala, Sustainable Buildings in Mediterranean Area, Sustainability, Energy and Architecture, (2013),289-329 E-Book. ISBN 9780123972699

[9] Athanasius Tzempelikos and Andreas K. Athienitis, The impact of shading design and control on building cooling and lighting demand, Solar Energy, 81(3) 369-382.

[10] Marie-Claude Dubois, Solar shading for low energy use and daylight quality in offices simulations, measurements and design tools, Solar Shading for Low Energy Use and Daylight Quality in Offices n.d.:1–94. Printed by KFS AB, Lund 2001.

[11] Nedhal A. Al-Tamimi and Sharifah Fairuz Syed Fadzil, The potential of shading devices for temperature reduction in high-rise residential buildings in the tropics, published in Procedia Engineering 21(2011) 273-282.

[12] MinseoK Kim, Taeyeon Kim, Sooyoun Cho, and Seung-Bok Leigh A Study on External Shading Devices for Reducing Cooling Loads and Improving Daylighting in Office Buildings, Journal of Asian Architecture and Building Engineering, (2015).

[13] Hong SooLim, Tae SubLim, LauraSchaefer, and Jeong Tai Kim, Comparative advantage of an exterior shading device in thermal performance for residential buildings, Energy and Buildings.,46(3)(2012) 105-111.

[14] Ana I., Palmero-Marrero, and Armando C. Oliveira, Effect of louver shading devices on building energy requirements, Applied Energy,. 87(2010).

[15] Faraz Ahmed, Zaki Masood, and Faiza Sabir, Energy Consumption of Array-Based Logic Gates SSRG International Journal of VLSI & Signal Processing 4(3) (2017) 1-5.

[16] Dilshan Remaz Ossen, Mohd. Hamdan Ahmad & Nor Haliza Madros, Optimum Overhang Geometry for Building Energy Saving in Tropical Climates, Journal of Asian Architecture and Building Engineering 4(2)(2018) 563-570, DOI: 10.3130/jaabe.4.563.

[17] Dilshan R. Ossen, M Hamdan Ahmad and Nor Haliza Madros, Impact Of Solar Shading Geometry On Building Energy Use In Hot Humid Climates With Special Reference To Malaysia, NSEB2005 – Sustainable Symbiosis, National Seminar on Energy in Buildings, UiTM Holiday Villa, Subang Jaya, (2005) 10-11.

[18] Laura Bellia, Francesco De Falco, and Francesco Minichiello, Effects of solar shading devices on energy requirements of standalone office buildings for Italian climates, Applied Thermal Engineering 54(1)(2013) 190-201.

[19] Jaepil Choi, Taekyoung Lee, Euisoon Ahn & Gensong Piao, Parametric Louver Design System Based On Direct Solar Radiation Control Performance, Journal of Asian Architecture and Building Engineering, 2018 ISSN: 1346-7581 (Print) 1347-2852 (Online) Journal homepage: https://www.tandfonline.com/loi/tabe20.

[20] Weather sparK.com.jizan Housing-king-abdulla-suburb-jazan&lang=enhttps://www.se.com.sa/enus/customers/pages/ebill.aspxsolar angle/

[21] Austin Stack, John Goulding, and J. Owen Lewis, Shading Systems Solar Shading for the European Climates, Publisher ENERGIE Programme of the European Commission, (2010).