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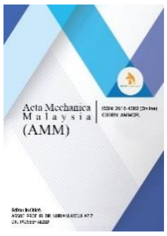

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RESEARCH ARTICLE

THE EFFECTS OF SOLAR RADIATION AND THERMAL INSULATION ON ENERGY CONSUMPTION AND SAVING IN BUILDINGS

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ABSTRACT

The solar energy falling on the earth is a huge energy. Research and studies are still being developed to improve this energy. This research works on the optimal exploitation of solar radiation falling directly on the building of the Faculty of Engineering at the University of Sirt and calculating the amount of heat in summer and winter. The amount of heat energy transferred in winter is much less than that which enters the building in summer. Calculations proved that the amount of heat gained through the wall of the room reached (8662.27 W) in the summer on the date (10/7/222), while the amount of heat energy in the winter (5705.10 W) on (10/1/2022), The amount of heat gained through a concrete wall is less than that gained through glass.The room was insulated using polystyrene with thermal conductivity properties (0.036 W/m^2) and the amount of heat entering the room was 702.77W in summer and 5702.36 W in winter. Through the comparisons, it becomes clear the importance of using thermal insulation, as the thermal energy entering the building without insulation was higher than it was when using insulation. In the same circumstances, the use of photovoltaic panels for electricity is very important, which explains the possibility of using solar energy in the same site to produce electricity to run air conditioning units in the summer and operate heating units in winter, and the possibility of this succeeding or not.

KEYWORD

Solar energy, Optimal exploitation of solar radiation, Photovoltaic panels for electricity

1. INTRODUCTION

After the imposition of solar energy as one of the most important renewable energies, it became necessary to study all the details related to this technology to reach the best consumption of this source that never runs out. Solar energy directly depends on solar radiation, which varies from one region to another. Sirt city is located in the middle in north of Libya at longitudes (16.606983) and latitudes (31.177789). where a sufficiently of sunshine during the whole year (320 day) is obtainable.

One of the most important factors is the optimal design of buildings and facilities, so that they are balanced in the issue of heat energy gained and lost, according to climate conditions given the amount of heat gained in the summer. Which is considered very high, as a result of the fall of the largest amount of solar radiation, it is worth thinking about a way to prevent the complete entry of heat into the building and this method is called thermal insulation using insulation materials with as little thermal conduction as possible. According to confirmed calculations of solar radiation and the duration of solar brightness, in North Africa it is possible to receive 7.5 w/m^2 per day, and this region receives solar radiation for 330 sunny days annually (Hu et al., 2010;Maio, 2009).

2. MATHEMATICAL ANALYSIS

2.1 Calculate The Amount Of Heat Entering The Room

Calculate the amount of heat entering the room from either through the wall or through the glass exposed to direct sunlight Accordingly:

The amount of heat entering the glass can be calculated through the following equation.

$$Q_{glass} = I\ (\tau)\ .\ A_g \qquad (2.1)$$

The amount of heat gained through the concrete into the room can be calculated through the following equation

$$Q_{concrete} = U_c . A_c . (T_a - T_r) \qquad (2.2)$$

The overall heat coefficient is:

$$\frac{1}{U} = \frac{1}{\alpha_i} + \sum_{i=1}^{n} \frac{e_i}{\lambda_i} + \frac{1}{\alpha_a} \qquad (2.3)$$

Table 2.1: Thickness and Thermal conductivity coefficient for some materials used

Subject	λ(W/m.k)	e(m)
Reinforced concrete	1.57	0.25
Cement plaster	0.72	0.05
PVC	0.19	0.01
Polystyrene	0.036	0.10
Cement block	1.1	0.20

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The value of the surfaces roof convection factor is related to the air velocity adjacent to the surfaces. The following table gives the surfaces convection factor

Table 2.2: Thermal conductivity coefficient for surfaces

α(W/m².k)	Surface quality
25	The outer surface exposed to the wind
15	The outer surface not exposed to the wind
9	Interior surface with natural runoff

2.2 Calculate The Total Amount Of Heat

$$Q_{wall} = Q_{concrete} + Q_{glass} \tag{2.4}$$

2.3 The Basic Conductivity Equation For Roof Heat Gain Is

$$Q_{roof} = U_{roof}\, A_{roof}\, (T_a - T_r) \tag{2.5}$$

2.4 Calculating The Amount Of Heat Emitted By People

$$Q_{sensible} = N_P\,(Q_S)\,(CLF)\,, \tag{2.6}$$

$$Q_{Latent} = N_P\,(Q_L)\,(CLF) \tag{2.7}$$

$$Q_{people} = Q_{sensible} + Q_{Latent} \tag{2.8}$$

2.5 Calculating The Amount Of Heat Emitted By The Lighting

$$Q_{Light} = N_L \cdot P_L \tag{2.9}$$

N_L: - the number of lighting in the place, P_L: power consumed by lights Where the cooling load is calculated by the following equation

$$Q_{C.L} = \frac{(Q_{wall} + Q_{people} + Q_{Roof} + Q_{Light}) * Fs * 11}{Operating\ hours} \tag{2.10}$$

2.6. Power consumed in the building, Power consumed in the building can be calculated by the following equation

$$P_{building} = P_{Room} * N_{Room} \tag{2.11}$$

$$P_R = P_{A.C} + P_L + P_{E.D} \tag{2.12}$$

3. Experimental Work

3.1 Description Of The Building

The total building area is 4279 m², divided into a ground floor of 2275m², a first floor of 1002 m² and a second floor of 1002 m², where the building consists of several laboratories, an administrative clerk and teaching rooms, as shown in the attached maps below (Kwon et al., 2006; EREC. 2005; Mertens, 2008). The total rooms in the building is 49.

From the attached maps, the building consists of the northern and southern sections (Kolhe et al., 2002; Ajan et al., 2003). Experiments were conducted on the southern section of the building because it is the most exposed to direct sunlight and the longest period, as direct solar radiation periods reach more than 10 hours in the summer, and therefore we calculated on this side as it represents the largest possible amount of. The heat energy gained in each room through which the largest cooling load can be calculate

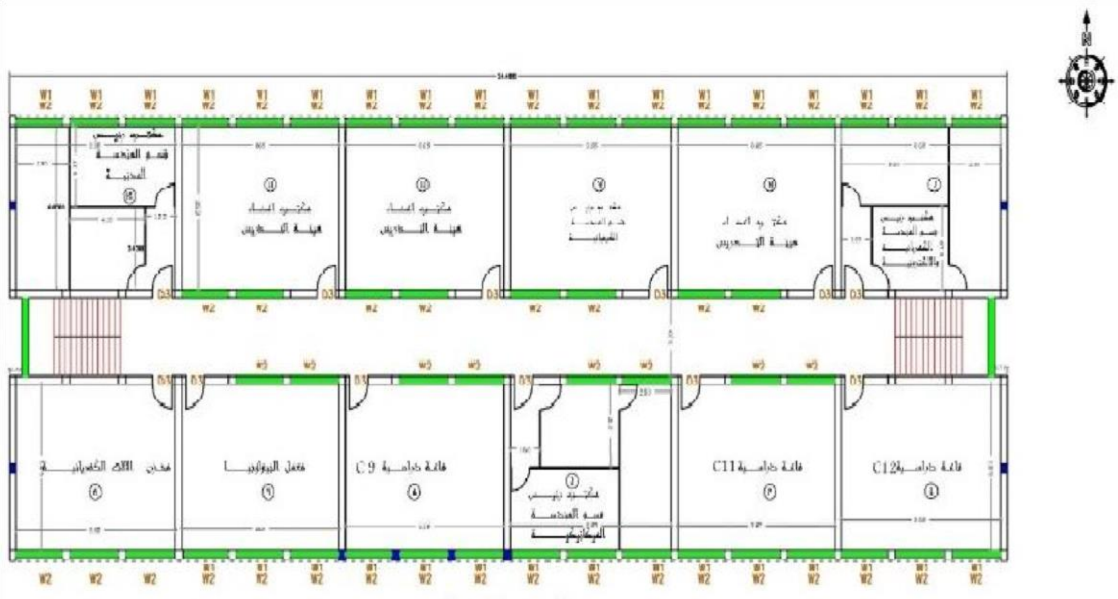

Figure 1: The second floor

The room occupies an area of (58.9 m²) length (8.6 m), width (6.85 m²) and height (3.45 m²) as shown in the figure.

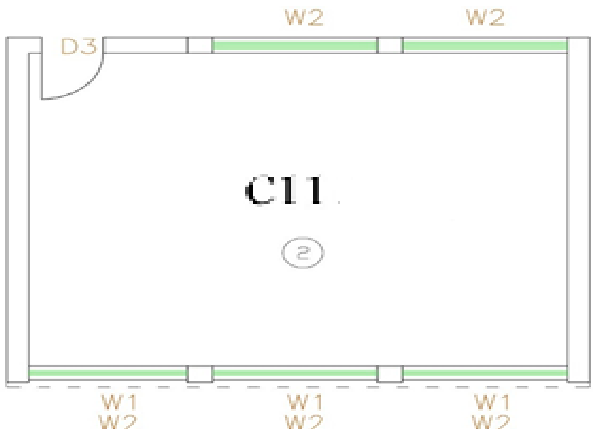

Figure 2: Classroom C11

Table 3.1: Geometrical and technical Specifications of buildings and constructed materials

Parameter	Symbol	Value
Room length	L	6.85 m
Room width	W	8.60 m
Room height	H	3.45 m
Ground floor area	A_{gro}	2275 m²
First floor area	A_f	1002 m²
The space of the second floor	A_s	1002 m²
Glass area	A_g	15.8 m²
wall area	A_c	13.9 m²
overall heat coefficient of	U_c	2.26 w/m².k
overall heat coefficient of polystyrene	U_p	0.039 w/m².k
transmission coefficient of glass	τ	0.73

4. Results and Discussion

4.1 Calculation The Amount of Heat Transfer For Room In Summer

Calculating the values of solar radiation at longitude and latitude (31.177789, 16.606983) for the laboratories of the College of Engineering for the summer and winter (Nafeh, 2009). Seasons via a web site Global solar atlas.

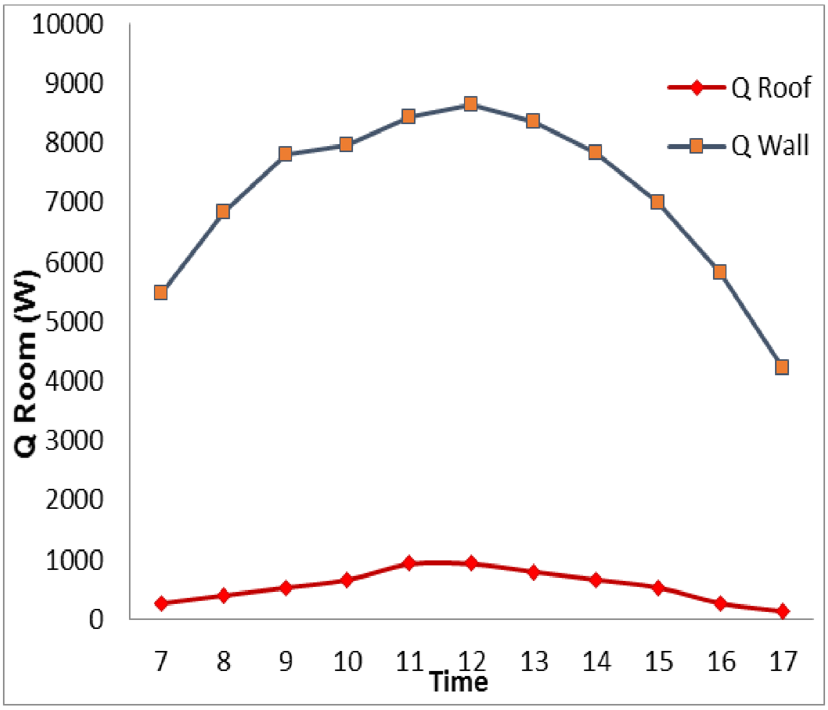

Figure 3: The Amount Of Heat Transferred Through The Wall And Roof Without Insulation In Summer

a)- For wall the radiation was 469.8 w/m^2 at 7 am and continues to rise until it reaches a peak of 730.1 w/m^2 at 12 pm, the amount of heat was 8662.27 W and the temperature was 36 c° and then it began to decrease gradually with time due to the decrease in solar radiation in the evening (Said and Abdelrahman, 1989).

b)- For roof the radiation was 469.8 w/m^2 at 7 am and continues to rise until it reaches a peak of 730.1 w/m^2 at 12 pm, the amount of heat was 1077.34 W and the temperature was 36 c°.

4.2 People

$Q_{sensible}$= N (Q_S) (CLF) = 10*67.39 w = 673.9 W

Q_{Latent}= N(Q_L) = 10* 55.67 w = 556.7 W

Note: CLF 1.0, if operation is 24 hours or of cooling is off at night or during weekends

Q_S , Q_L Sensible and Latent heat gain from occupancy is given in 1997

ASHRAE Fundamentals Chapter 28, Table 3)

Q people = Q sensible + Q Latent = 1230.6 W 4.3 Light

Q_{Light} =N_L .P_L = 12 * 36 w = 432 W

4.3 Cooling load without insulation

$$Q_{C.L} = \frac{(Q_{wall} + Q_{people} + Q_{Roof} + Q_{Light})*Fs*11}{Operating\ hours} = \frac{(8662.27+1230.6+1077.34+432)1.1*11}{8} =$$

17245.85 W =58859.56 BTU/h

Based on this result, we found that the room will need large cooling load to reach the required room temperature and this will lead to high consumption of energy.

4.4 Insulation In Summer

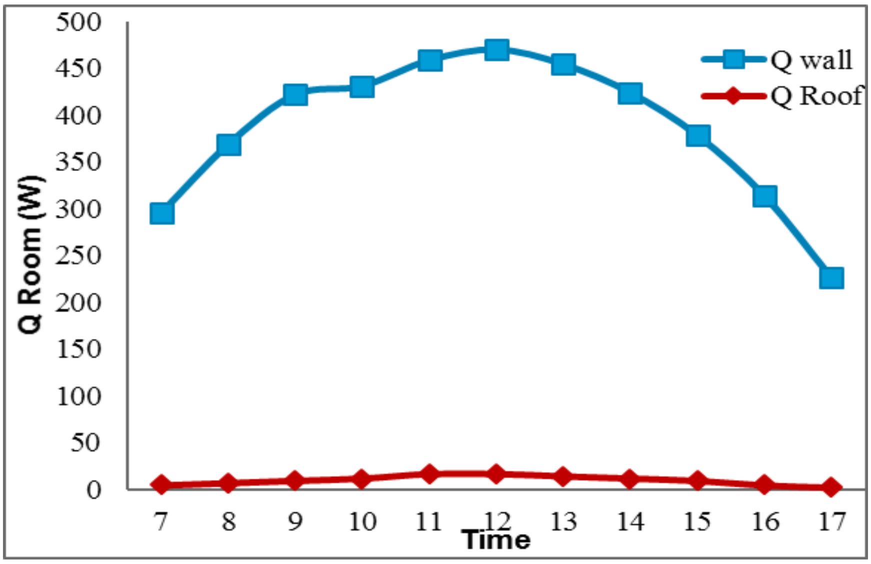

Figure 4: The Amount Of Heat Transferred Through The Wall And Roof With Insulation In Summer

a)- for wall The radiation was 469.8 w/m^2 at 7 am and continues to rise until it reaches a peak of 730.1 w/m^2 at 12 pm, the amount of heat was 572.49 W and the temperature was 36 c° (Al-Homoud, 1997).

note that there is a large difference in the amount of heat transfer to the Wall with and without insulation. The largest amount of heat transfer in summer with and without insulation was 572.49 W and 8662.27 W respectively.

Note Heat transfer through glass is neglected in this case due to its less effect compared to PVC .

b)- for roof The radiation was 469.8 w/m^2 at 7 am and continues to rise until it reaches a peak of 730.1 w/m^2 at 12 pm, the amount of heat was 130.28 W and the temperature was 36 c° (Al-Homoud, 1997).

note that there is a large difference in the amount of heat transfer to the room with and without insulation in the summer. The largest amount of heat transfer in summer with and without insulation was 130.28 W and 1077.34 W respectively.

4.5 Cooling Load For Summer With Insulation

$$Q_{C.L} = \frac{(Q_{wall} + Q_{people} + Q_{Roof} + Q_{Light}) * Fs * 11}{Operating\ hours} = \frac{(572.49+1230.6+130.286+432)1.1*11}{8}$$

=3577.36 W =12209.4 ≈ 12000 BTU/h based on this result, the room need 1 air conditioner (A.C) that consume 1350W .

4.6 Power Consumed In The Building

$P_R = P_{A.C} + P_L + P_{E.D}$ = 1350 + 432 + 500 = 2282 Wh

$P_b = P_{Roof} * N_{room}$ = 2282 *49 = 111818 Wh =111.818 Kwh ≈ 112 kWh

4.7 Calculation The Amount Of Heat Transfer For Room In Winter

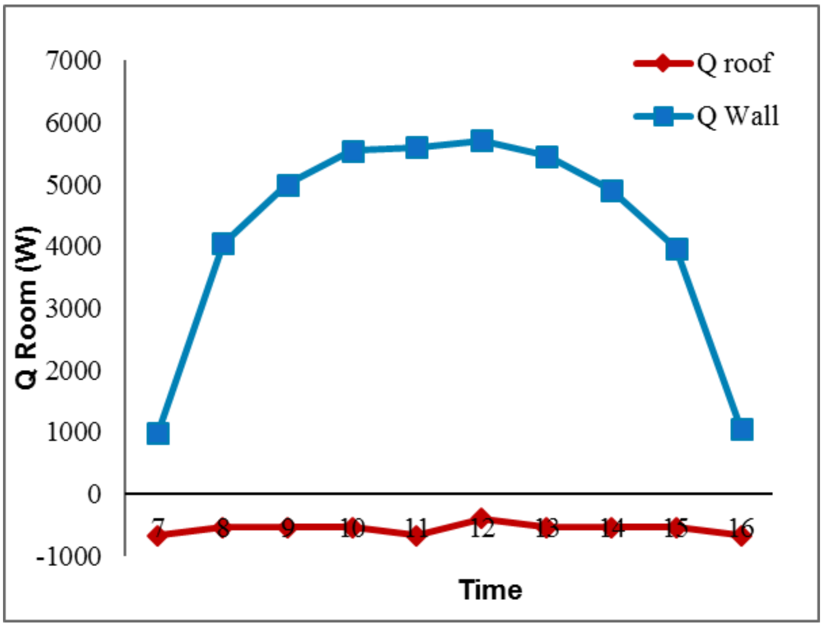

Figure 5: The Amount Of Heat Transferred Without Insulation Through The Wall And Roof In Winter

a)- For wall The radiation was 100.2 w/m^2 at 7 am and continues to rise until it reaches a peak of 503.6 W/m^2 at 12 pm, the amount of heat was 5705.10 W and the temperature was 17 c° and then it began to decrease gradually with time due to the decrease in solar radiation in the evening (Cha and Lee. 2008).

b)- For roof The radiation was 100.2 w/m^2 at 7 am and continues to rise until it reaches a peak of 503.6 w/m^2 at 12 pm, the amount of heat was -461.71 W and the temperature was 17 c°. the highest heat transfer through the roof was -769.52 W. From these results, we notice large heat gain and lost during summer and winter respectively.

4.8 Insulation In Winter

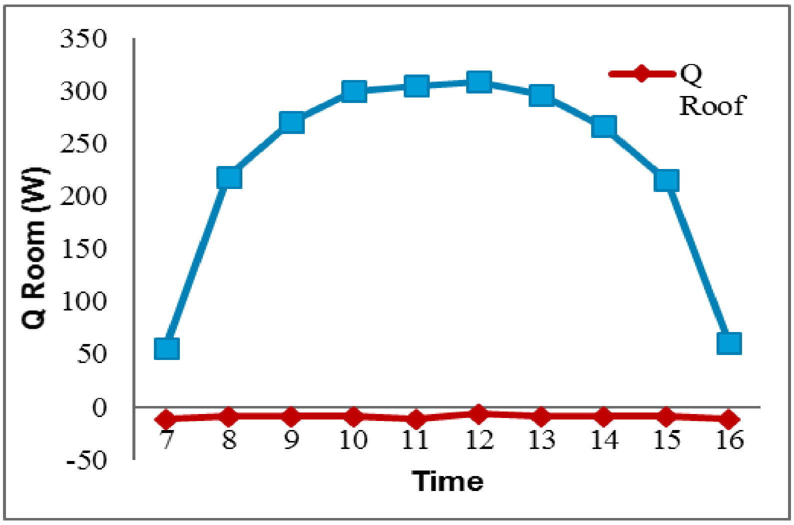

Figure 6: The Amount Of Heat Transferred Through The Wall And Roof With Insulation In Winter

a)- for wall After using the insulation, it was found that there was a decrease in the amount of heat transfer. at 12 o'clock the amount of heat was 5795.42 W, then it began to decrease gradually.

b)- for roof After using the insulation, it was found that there was a decrease in the amount of heat transfer. at 7 o'clock the maximum amount of heat was -93.06 W

5. Conclusion

I. The used wall is mainly made of a material with high thermal conductivity, which is cement.

II. The glass used is single-layer, as it is colored and has less transparency than ordinary transparent glass.

III. The highest amount of heat entering the room was on (9739.61 W) at 12 pm, the same date, but when using thermal insulation for the building, the amount of heat entering the room was (702.77 W).

IV. In the 10^{th} of January in winter, the maximum amount of heat with and without insulation are (5702.36 W) and (4935.58 W) respectively. Negative sign indicates that the amount of heat is transferred from the inside to the outside.

V. The highest solar energy transferred through the building was by the glass. The solar energy transferred through the roof was higher than concrete.

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Nomenclature

Description	Symbol	Unit
Room length	L	M
Room width	W	M
Room height	h	M
Ground floor area	Agro	m2
First floor area	A_f	m2
The space of the second floor	A_s	m2
Glass area	A_g	m2
Wall area	A_c	m2
Overall heat coefficient of concrete	U_c	$W/m^2.k$
Overall heat coefficient of polystyrene	U_p	$W/m^2.k$
Transmission coefficient of glass	τ	……
Intensity of solar radiation	I	W/m^2
Outside temperature	T_a	c°
Room temperature	T_r	c°
Amount of heat entering the glass	Q glass	W
Amount of heat entering the concrete	Qconcrete	W
Amount of heat entering the wall	Q wall	W
Amount of heat entering the roof	Qroof	W
Overall heat coefficient of roof	U roof	$W/m^2.k$
Area of roof	A roof	m^2
Amount of heat emitted by people	Q people	W
Latent heat gain from people	QLatent	W
Sensible gain from people	QSensible	W
Cooling load	Qc.L	W
Number of people	N_p	….
The number of lighting	N_L	….
Power consumed by lights	P_L	W
Amount of heat emitted by the lighting	QLight	W
The room energy consumption	P_R	W
The number of rooms	N room	…..
Safety factor	FS	…..
Power consumed in the building	Pbuilding	W
The room energy consumption	P_{Room}	W
The energy consumed by the air conditioner	$P_{A.C}$	W
The energy consumed by electrical appliances	$P_{E.D}$	W
Electricity power	P	W
Electrical voltage	V	Volt
Electric current	II	Ampere
Thermal load coefficient for internal surfaces	α_i	$W/m^2.k$
Thermal load coefficient for external surfaces	α_a	$W/m^2.k$
The thickness of any material	e_i	m
Thermal conductivity coefficient for any material	λ_i	W/m.k
Overall heat coefficient of PVC	UPVC	$W/m^2.k$