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Research Article

THE IMPACT OF AWNING ON CONSUMING FOR COOLING AND HEATING ENERGIES AT A RESIDENTIAL CONSTRUCTION WITH NUMERICAL SIMULATION

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ABSTRACT
In this essay we have covered the impact of awning on consuming for cooling and heating energies at a residential construction with numerical simulation. The equations were solved accurately by FORTRAN program. We examined the Awning impact on cooling energy in the warm seasons and the reducing impact of solar energy on building Thermal load. The results show that awning should be designed so as to prevent direct sunlight in the summer, but not block out the sunlight in the winter. Use of solar energy in winter reduces the heating load and thermal energy. So awning should not block out the sunlight. Moreover, in the winter, the more the number of windows, the more effective solar energy is in reducing the building's thermal energy. The sun's energy is different at different geographical directions and that is the reason why different results are obtained for different modes.

Keywords: *Awning, Construction, Numerical Method, FORTRAN, Heating and Cooling*

INTRODUCTION
Open parts of the exterior walls of the construction (windows, skylights and so on) that are placed to provide a lighting by the sun, are like the gates that in the cold season should be prevented as far as possible from letting direct rays of the sun enter the building. Akbari (Elahi, 1996) by doing some research on energy efficiency in constructions in Bahrain whose climate is similar to the south of our country believe that we can reduce our electricity consumption by 32 percent. Rohles *et al*., (1993) in his research on the effect of air velocity on thermal comfort has shown that through using a ceiling fan, it is possible to reset ventilator temperature from 26°C to 29°C and thus, reduce energy consumption in buildings. Bahadori (1986) has done his research on natural ventilation. In this research, the effects of various factors contributing to thermal comfort have been stated. Moreover, practical ways and effective factors to reduce the need for cooling; and they indicate the use of ceiling fans and night air to reduce the temperature of indoor parts.
Fanger, (1972) believed that the heat which human body loses through evaporation from the surface of the body and respiratory organs, relocation from the body surface of the human body and radiation transfers to the environment. This lost heat should be compensated by the refrigeration system; and this heat transfer varies according to the type of person and type of their activity. Teitel and Tani, (1996), by the body of research they have done, have provided a way to reduce heating load at buildings. They offered a method for mixing a room's air (to avoid spatial gradient of temperature). The air warmed by a central device because of the low specific gravity moves toward the roof and so the air near the ceiling is warmer than the air near the floor. By using the ceiling fan we can push the air near the ceiling to the floor, remove the spatial gradient of temperature and reduce the amount of heating energy consumption.
Dubois, (1997) investigated the effects of awning on cooling load and showed that solar awnings can reduce the cooling load of the building in the summer. The results showed a reduction of between 23 to 89 percent in the construction cooling load for different awnings. Studies show that the awnings have a negative impact on the thermal load in the winter, because they reduce useful solar heat load. Dubois, (1999) conducted several studies about the effects of awnings on heating in the winter time. His results have indicated that the building required heating load has increased by 31 percent. Sheikh Zadeh and his colleagues (2006) by considering a room in a building in three different positions in different climates and using Carrier determined the effect of various awnings on solar acquired load and providing proper

awning. Ana *et al*., (2010) considering horizontal and vertical awnings in different climates in Britain, Portugal, Spain, Egypt and Mexico studied the effects of them on their heating and cooling loads and they showed that the use of awnings cuts energy costs. In this study, we have been evaluated the economic aspects of the awnings located at the top of windows. To this end, and according to the cost of creating the cool being three times more than the cost of creating the heat; the size and distance of the awnings from the top of the window is determined in a way that In a warm season it impedes the direct sunrays entering from the window pane; and also in the winter, this incoming radiation can contribute to heat the construction as more as possible. Khorasani Zadeh *et al*., (2006) investigated the economic aspect of use of awnings at the top of a window in the south wall in Kashan.

Miahi *et al*., (2012) have analyzed the impact of exterior awnings on reducing the temperature resulted from of the sun's heat in a humid climate. Ratzinger *et al*., (1979) by conducting an analytical study have stated the whole radiation entered through a window with a horizontal awning above it in terms of geometrical conditions as a function of the ratio of monthly received direct radiation by the window having an awning to window without an awning against direct radiation, fi, vision coefficient of the window for sky spread radiation, Fr–s. In this study, they covered hourly calculation of the values off land Fr-s for all types of geometry of awning in latitude 34 degrees. Saelens *et al*., (2014) described the rays of the sun when they hit the window awnings. This is done using software TRNSYS which is a powerful tool for designing and simulation of dynamical heating and cooling systems, energy analysis of buildings and their economic analysis.

Ahmadi *et al*., (2006) examined the decline in residential heating and cooling energy use with Ceiling Fans. Conducting research on energy efficiency in buildings needs more work and in terms of the overusing of energy in Iran, doing so is vital. Elahi, (1996) believes that by using efficient methods of energy use in buildings there would be an equivalent to 2.5 billion dollars a year worth of reduction in energy consumption. If we assume the required investment for each new job $ 2,500, this means the possibility of creating a million new jobs. If we also the results of reducing environmental pollution we can conclude investing in these methods is necessary and worthwhile. On the other hand, reducing energy consumption means not losing valuable resources.

The aim of carrying out this study is to investigate the potential for energy savings in heating and cooling residential buildings. In this project by simulating residential building, we see the impact of awning on heating and cooling energy in a particular climate with numerical simulations. We use the FORTRAN programming language in order to analyze the equations in the project.

MATERIALS AND METHODS

Method

Addressing the Problem

In order to find out the Cooling and heating loads for constructions we must write the equations of heat transfer relations system for different parts of the building. Before examining these equations, we consider simple hypotheses which are used to solve the equations (Rahbar *et al*., 1996):

- ❖ We assume heat transfer on all the walls, ceiling and floor happens in one dimension and in the direction of their thickness. This assumption is reasonable for walls. Most of errors in this part are related to the perimeter of walls in which heat transfer faces a problem with assuming being one-dimensional; and in ratio to the entire wall we can ignore it.
- ❖ Sky is considered like a black substance, which an equivalent temperature has been appointed for it.
- ❖ The earth surface temperature is considered roughly equal to the ambient air temperature.
- ❖ The materials of walls, ceiling and floor are considered invariable, and its conductivity and specific heat capacity and its other characteristics can be determined according to the ingredients.
- ❖ Room air temperature is assumed to be constant at all points.
- ❖ For the internal surface of the wall, an average temperature is considered in order to ignore thermal radiation of surfaces to each other.

❖ All solar radiation incoming into the building through the windows is received by the floor. (The rest of the construction interior surfaces receive the sunlight reflected by the floor, according to their visibility factor in ratio to the floor.)

❖ Interior walls work just as energy storages, so the all interior walls are considered as a block in the middle of construction according to their total volume and area.

❖ The temperature at the depth of 30 cm from the floor is assumed equal to the average daily temperature.

The Basic Governing Equations

Governing Equations: Now we investigate the relations between heat transfer in a residential building, including relations for the external walls (eastern, western, northern and southern), ceiling, floor, door and exterior glasses, interior walls and room air according to thermal network in each part.

a) The equations of the external walls (eastern, western, northern and southern): we assessed 6 nodes on thickness of wall, and j_1 node belongs to the outer layer of exterior wall and j node is for the inner layer of exterior wall and j_2 to j_5 nodes are for wall thickness.

j_1 *node*:

$$\frac{k_w}{d}\left(T_{j2}-T_{j1}\right)+h_{j-1sky}\left(T_{sky}-T_{j1}\right)+h_o\left(T_o-T_{j1}\right)+\alpha_j G_j+h_{j1-ground}\left(T_{gr}-T_{j1}\right)=\rho C_w\frac{d}{2}\frac{T'_{j1}-T_{j1}}{\Delta t} \quad (1)$$

Each term in this equation is:

h_0: Heat transfer coefficient of displacement between the air and the wall that is calculated from this linear relation:

$$h_o = 3.3878\, V_w + 11.35 \quad \frac{W}{m^2K} \quad (2)$$

h_{j1-sky}: Radiativeheat transfer coefficient between the wall and the sky that is calculated according to the following equation

$$h_{j1-sky}=\frac{\varepsilon}{\varepsilon+1}\sigma\left(T_{sky}^{\,2}+T_{j1}^{\,2}\right)\left(T_{sky}+T_{j1}\right) \quad (3)$$

ε is the emissivity coefficient of the outer surface of the wall and $\sigma = 5.67\times10^{-8}\frac{W}{m^2K^4}$ is Stefan–Boltzmann constant.

$h_{j1-ground}$: Radiativeheat transfer coefficient between the outer surface of the wall and the ground that is calculated according to the following equation:

$$h_{j1-ground}=\frac{\varepsilon}{\varepsilon+1}\sigma\left(T_{gr}^{\,2}+T_{j1}^{\,2}\right)\left(T_{gr}+T_{j1}\right) \quad (4)$$

T_{Sky} : Equivalent sky temperature being at the room temperature and dew point of that moment is calculated according to the following equation (Ahmadi *et al*., 2006):

$$T_{Sky}=T_o(.8+0.004\,T_{dp})^{.25} \quad (5)$$

K_w : Conductive heat transfer coefficient of the wall

C_w : Wall thermal capacity

Δt : Time step

d: 1/5of the wall thickness

α_j : Wall absorption coefficient

G_j: The total amount of solar radiation reaching the outer surface of the wall

T_{gr} : The equivalent temperature of the earth's surface

T_{j1} : The temperature of the outer surface of the wall at the current time

T_{j1}' : The temperature of the outer surface of the wall at the next time step

node j_m: m= 2, 3, and 4:

$$\frac{K_w}{d}\left(T_{j(m+1)}-T_{jm}\right)+\frac{K_w}{d}\left(T_{j(m-1)}-T_{jm}\right)=\rho C_w d\frac{T_{jm}'-T_{jm}}{\Delta t} \quad (6)$$

node j_5 :

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$$\frac{K_w}{d}\left(T_j - T_{j5}\right) + \frac{K_w}{d}\left(T_{j4} - T_{j5}\right) = \rho C_w d \frac{T_{j5}^{'} - T_{j5}}{\Delta t} \quad (7)$$

In two previous equations, left side of the equation representing conductive heat transfer and the right side represents heat stored in a layer of wall d thick over time Δ t.

Node j:

$$h_j A_j\left(T_i - T_j\right) + (1-\alpha_f)Q_{su}F_{fw'}\frac{A_j}{A_{w'}} + h_{tfw'}A_f\frac{A_j}{A_{w'}}\left(T_f - T_j\right) + h_{tcw'}A_c\frac{A_j}{A_{w'}}\left(T_c - T_j\right) + \frac{K_w}{d}A_j\left(T_{j5} - T_j\right) + Q_{ir}\frac{A_j}{A_t} = \rho C_w \frac{d}{2} A_j \frac{T^{'}_j - T_j}{\Delta t} \quad (8)$$

Each terms of the above equation is as follows:

$h_{tfw'}$ *and* $h_{tcw'}$ *are* Radiativeheat transfer coefficient between the inner surface of wall and the floor and between the inner surface of wall and the ceiling respectively, and according to the following equation they are calculated:

$$h_{tfw'} = \frac{\sigma\left(T^2{}_f + T^2{}_{w'}\right)\left(T_f + T_{w'}\right)}{\frac{1-\varepsilon_f}{\varepsilon_f} + \frac{1}{F_{fw'}} + \frac{1-\varepsilon}{\varepsilon}\frac{A_f}{A_{w'}}} \quad (9)$$

$$h_{tcw'} = \frac{\sigma\left(T^2{}_c + T^2{}_{w'}\right)\left(T_c + T_{w'}\right)}{\frac{1-\varepsilon_c}{\varepsilon_c} + \frac{1}{F_{cw'}} + \frac{1-\varepsilon}{\varepsilon}\frac{A_c}{A_{w'}}} \quad (10)$$

ε : Emissivity coefficient F_{ij} : Visibility coefficient

Q_{su} : The amount of solar energy that enters the building through the windows

$$Q_{su} = \sum_{j=1}^{4}\left(\tau r_j A_{gj} G_j\right) \quad (11)$$

A_{gj} : The Level of windows on each side of the construction

τr_j: Transmission coefficient of the glass

$A_{w'}$: The entire area of inner surfaces of the construction

$$A_{w'} = \sum_{j=1}^{4}\left(A_j + A_{dj} + A_{gj}\right) + 2(A_{wd} + A_{dd} + A_{gd}) \quad (12)$$

$T_{w'}$: The mean temperature of the internal surfaces of the building (it is assumed that all internal surfaces are at a same temperature in order to ignore Radiation of internal surfaces to each other.

$$T_{w'} = \frac{\sum_k (A_k T_k)}{\sum_k A_k} \quad (13)$$

A_{dj} : Doors level on each side of the building

In the above equations j can vary from one to four, j = represents the southern wall, j = 2 represents the northern wall, j = 3 represents the eastern wall, and j = 4 represents the western wall. For equations of the ceiling, floors, windows and doors, we write similar equations and by nodding the ceiling and floor nodes, we write equation for each node.

b) The equation of room air:

The equation of the node i (the air inside the room):

$$h_i(\sum_{j=1}^{4} A_j(T_j - T_i) + 2[A_{wd}(T_{wd} - T_i) + A_{gd}(T_{gd} - T_i) + A_{dd}(T_{dd} - T_i)] + h_{ic}A_c(T_c - T_i) \quad (14)$$
$$+ h_d A_f(T_f - T_i) + \left[\sum_{j=1}^{4}(U_{dj}A_{dj} + U_{gj}A_{gj}) + P_o C_p \dot{n} V\right](T_o - T_i) + Q_{ic} + Q$$
$$= p_i C_v V\left(\frac{T'_i - T_i}{\Delta t}\right)$$

Q: Heating or cooling load
Q_{ic}: Sensible heat load produced by residents and heat generators
U_{dj} : Overall heat transfer coefficient for the doors that is calculated based on this equation:

$$U_{dj} = [\frac{1}{h_i} + \frac{d_{dj}}{K_{dj}} + \frac{1}{h_o}]^{-1} \quad (15)$$

U_{gj}: Overall heat transfer coefficient for the windows that is calculated based on this equation:

$$U_{gj} = [\frac{1}{h_i} + \frac{d_{gj}}{K_{gj}} + \frac{1}{h_o}]^{-1} \quad (16)$$

∀: The volume of the room ṅ it is exchanging Room air volume, and by solving equations representing the problem, the amount of air getting into the building is calculated by using the flow-network (Bahadori *et al*., 1985).

Determining the Temperature of the Ambient Air: We can use the following equation to obtain the temperature at any time (Bahadori *et al*., 1986):

$$T_O = 0.5\left[(T_{max} + T_{min}) + (T_{max} - T_{min})\cos\frac{\pi}{12}(\text{Time} - 15)\right] \quad (17)$$

T Max and T_{min} values, belonging to Tehran for each month, are in Table 1 (Ahmadi *et al*., 2006).

Determining the Amount of Radiation: Air clearness index is defined as the ratio of the average daily radiation on a horizontal plate on the ground for a particular day to its average radiation on a horizontal plane in the outer surface of the atmosphere. (This ratio is shown as K_t). K_t values for Tehran and for several months are in Table 1 (Ahmadi *et al*., 2006).

$$K_t = \frac{G_h}{G_{oh}} \quad (18)$$

The total amount of incoming radiation for a plate with slope β at any given moment is defined by the following equation (Duffie *et al*., 2006):

$$G_t = G_{bh}R_b + \frac{1 + \cos\beta}{2}G_{dh} + \frac{1 - \cos\beta}{2}\rho_{gr}G_b \quad (19)$$

In this equation, t, b, h and d represent the steep, straight, horizontal, and diffuse respectively.
$R_b$amount *is* obtained by using the information of solar angles (Duffie *et al*., 2006).
The rest of the parameters in the equation are (Duffie *et al*., 2006):

$$K_t = [a + b\cos\omega(\text{time} - 12)]K_t \quad (20)$$
$$G_{oh} = 1353\left[1 + 0.033\cos\left(\frac{360N}{365}\right)\right]\cos\theta_z \quad (21)$$
$$a = 0.0409 + 0.5016\sin(\omega_s - 60) \quad (22)$$
$$b = 0.6607 - 0.4767\sin(\omega_s - 60) \quad (23)$$
$$\omega = \frac{2\pi}{24} or \frac{15°}{h} \quad (24)$$

The ratio of diffuse radiation to the total radiation for a horizontal plate is defined as follows:

$$\frac{G_{dh}}{G_h} = 1 - 0.249\ K_t K_t \leq 0.35 \quad (25)$$

$$\frac{G_{dh}}{G_h} = 0.35 \leq K_t \leq 0.75 \quad 1.557 - 1.84\,K_t \qquad (26)$$

$$\frac{G_{dh}}{G_h} = 0.177 \qquad K_t \geq 0.75 \qquad (27)$$

In the above equations the parameters N and ρ_{gr} represents day, year and earth reflection coefficient.

Table 1: Air Filter Coefficient Values, Maximum and Minimum Average Ambient Temperature at Tehran (Ahmadi *et al*., 2006)

Month	Air Filter Coefficient k_t	Maximum Average Temperature	Minimum Average Temperature
21st March- 20th April	0.52	21.5	9.8
21st April – 21st May	0.52	28	15.3
22nd May- 21st June	0.56	38.8	19.9
22nd June- 22nd July	0.57	36.4	22.8
23rd July – 22nd August	0.57	35.3	22.1
23rd August- 22nd September	0.54	31.3	18
23rd September- 22nd October	0.5	24.5	12.2
23rd October-21st November	0.51	16	5.4
22nd November- 21st December	0.47	9.7	0.3
22nd December- 20th January	0.48	7.7	-1.5
21st January- 19th February	0.5	10.5	0.4
20th February- 20th March	0.51	15.5	4.6

Program Control: In order to solve the equations, governing the system, computer and finite difference method were used.

Before dealing with equations solving method, first, we consider the nodes determined in the building. These nodes are 6 ones in the side walls (eastern, western, northern, and southern), 4 ones in the ceiling, 4 ones on the floor, 4 ones in the interior walls, 2 nodes in each door and interior windows and finally a node for the room air which comes to 57 nodes in total.

In order to investigate the validity of computer code used in this project, cooling or thermal load are calculated by Carrier software calculated and compare it with the results achieved by the program. By adopting the Carrier software in terms of conditions and measurement of building we have found peak heat load, and the result is shown in Figure 1.

	DESIGN HEATING		
	HEATING DATA AT DES HTG HEATING OA DB / WB -5.5 °C / -8.8 °C OCCUPIED T-STAT 24.4 °C		
		Sensible	Latent
SPACE LOADS	Details	(W)	(W)
Window & Skylight Solar Loads	14 m²	-	-
Wall Transmission	117 m²	7790	-
Roof Transmission	105 m²	7301	-
Window Transmission	14 m²	2673	-
Skylight Transmission	0 m²	0	-
Door Loads	3 m²	610	-
Floor Transmission	105 m²	1305	-
Partitions	0 m²	0	-
Ceiling	0 m²	0	-
>> Total Zone Loads	-	19679	0

Figure 1: Heating Load Obtained by Using the *Carrier* Software: The Obtained Peak Heat Load from the Applying the Written Program is 19460 Watts, which has One Percent Difference

RESULTS AND DISCUSSION

Result

A Construction with Windows in all Aspects

We consider a construction which has windows in all its aspects, so that the total area of the eastern and western walls is 90 square meters and total area of Northern and southern walls becomes 30.5 square meters. The total area of windows is 12 square meters. We evaluate the results for three conditions of normal, a lack of sunlight and direct radiation (Rb=0), reflected and diffuse (G=0). In fact, once we apply an awning which only prevents direct sunlight and other times we use a complete awning. The results have been shown in Figure 2 to 6 and Tables 2 and 3 below.

Table 2: The Total Cooling Load in a Complete Day (Q_{sum} (J))

Month	21st April – 21st May	22nd May- 21st June	22nd June- 22nd July	23rd July – 22nd August	23rd August- 22nd September
Normal mode	9.3387368E+07	5.1361936E+08	7.2069882E+08	6.2968275E+08	2.8348266E+08
Rb=0	5.9784844E+07	4.6741430E+08	6.7348000E+08	5.8865894E+08	2.5685878E+08
G=0	3.6088392E+07	4.4059779E+08	6.4692179 E+08	5.6680403E+08	2.4097653E+08

Table 3: The Peak of Cooling Load (Q_{sum} (W))

Month	21st April – 21st May	22nd May- 21st June	22nd June- 22nd July	23rd July – 22nd August	23rd August- 22nd September
Normal Mode	6930	12338	14711	13491	9148
Rb= 0	6256	11413	13749	12648	8633
G=0	5462	10576	12914	11872	7974

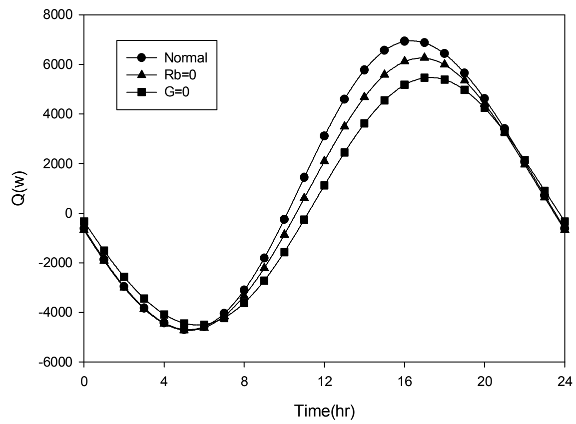

Figure 2: Change in Cooling Load Over Time between 21st April and 21st May When We have Windows in all Aspects of a Construction

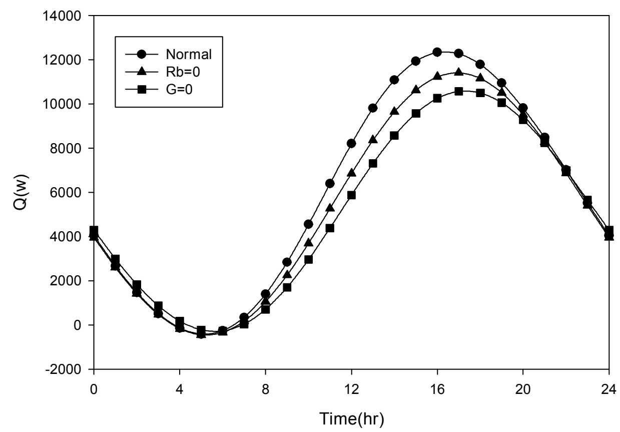

Figure 3: Change in Cooling Load Over Time between 22nd May and 21st June When We have Windows in all Aspects of a Construction

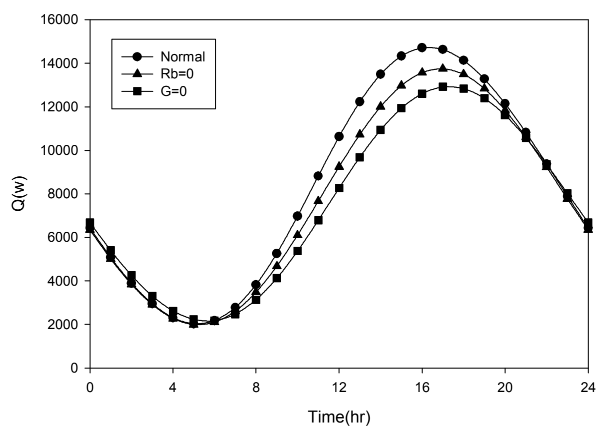

Figure 4: Change in Cooling Load Over Time between 22nd June and 22nd July When We have Windows in all Aspects of a Construction

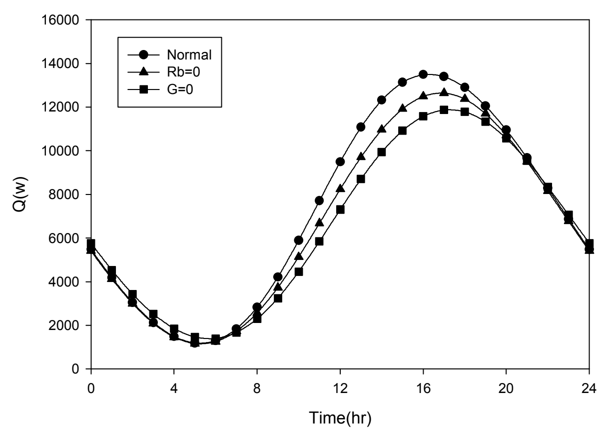

Figure 5: Change in Cooling Load Over Time between 23rd July and 22nd August When We have Windows in all aspects of a Construction

Calculation of Heating Load in a Building with Windows on the Southern and Northern Aspects

This time we evaluate Heating load for the cold seasons, and we see the effect of the solar energy on reducing heating load and thermal energy.

If awning is designed wrongly in a way that in winter it impedes the sun's radiation, which increases the building heating load and it increases energy consumption in the building which leads to wasting energy and increasing costs.

Results for the cold seasons are shown in Figures 7 to 12. The results have been obtained once for having the Sun again and another time for not having direct sunlight (Table 5).

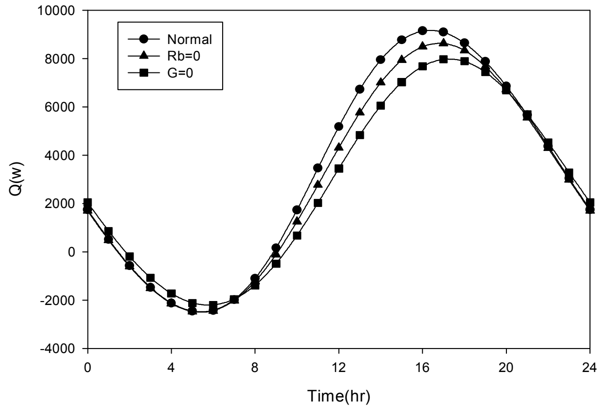

Figure 6: Change in Cooling Load Over Time between 23rd August and 22nd September When We have Windows in all Aspects of a Construction

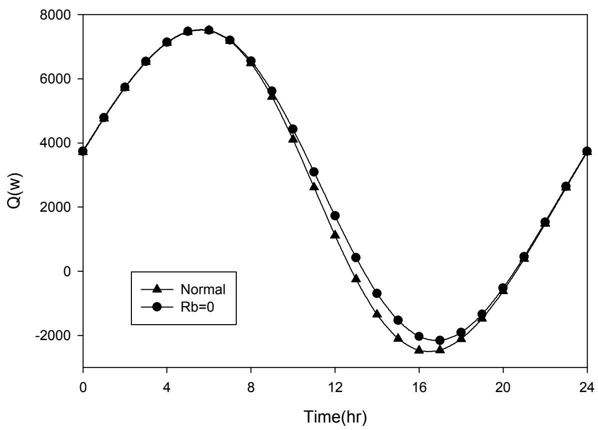

Table 7: Change in Heating Load Over Time between 23rd September and 22nd October

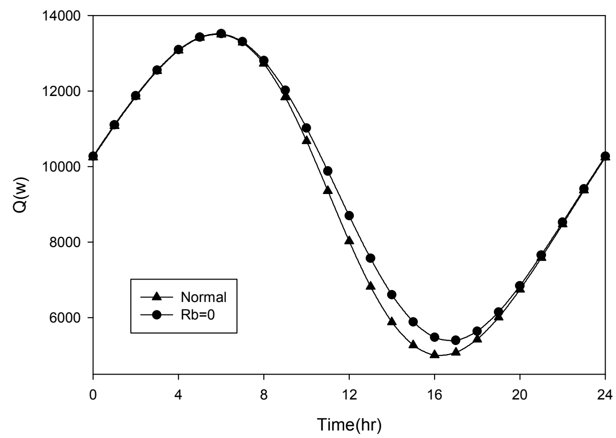

Figure 8: Change in Heating Load Over Time between 23rd October and 21st November

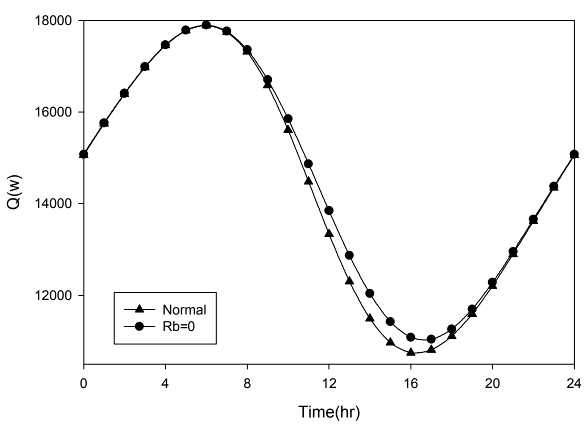

Figure 9: Change in Heating Load Over Time between 22nd November and 21st December

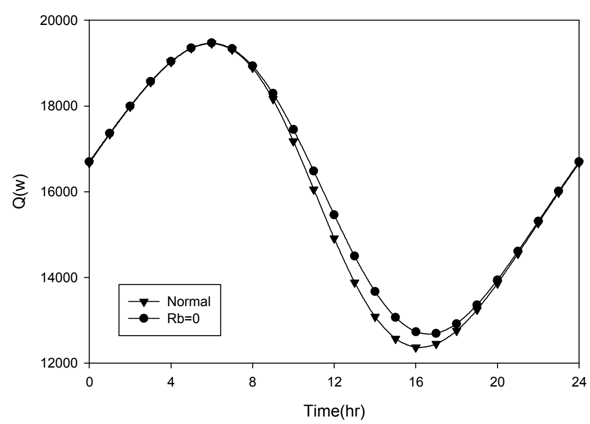

Figure 10: Change in Heating Load Over Time between 22nd December and 20th January December

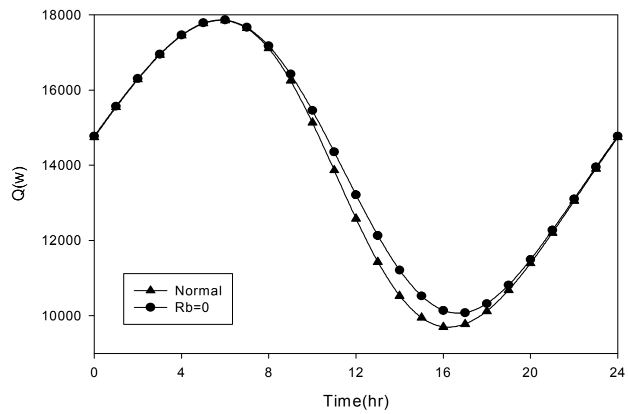

Figure 11: Change in Heating Load Over Time between 21st January and 19th February December

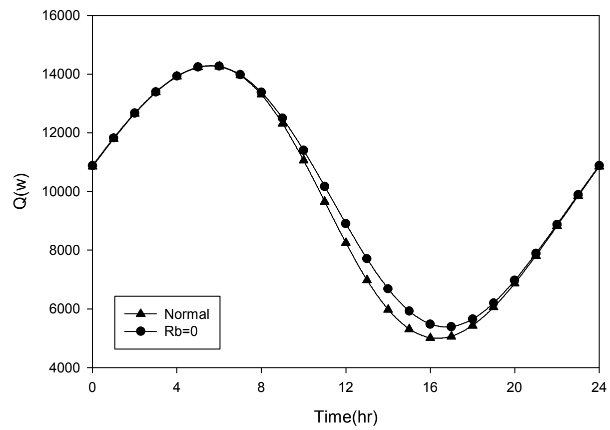

Figure 12: Change in Heating Load Over Time between 20th February and 20th March December

Table 5: Total Heating Load in a Whole Day (Q_{sum} (J))

Month	Normal Mode	Rb=0
23rd September- 22nd October	2.2102456E+08	2.3906496E +08
23rd October-21st November	8.0375763E+08	8.2345094E +08
22nd November- 21st December	1.2401056E+09	1.2544588 E +09
22nd December- 20th January	1.2784040E+09	1.3940449E +09
21st January- 19th February	1.1948737E+09	1.2132842E +09
20th February- 20th March	8.3815123E+08	8.5752410E +08

Conclusion

In this study, the effect of awning on heating and cooling energy was examined. The present equations were solved by FORTRAN program explicitly. The impact of awning on heating energy in the warm seasons and was examined as well as the impact of solar energy in reducing heating load in a building. In general, the results can be summed up as follows:

- Awning should be designed so that to impede the direct sun light only in summer but not in the winter.
- The effect of awning on reducing the cooling load when it fully impedes solar radiation, including direct, diffuse, reflected radiation is more than an awning which impedes only direct sunlight.
- Use of solar energy in winter reduces the heating load and thermal energy. So the in the winter, awning should not impede the sun radiation.
- The more the number of windows, the more visible the effect of awning in the summer more, and we save more cooling energy in the winter.
- The more the number of windows in the winter, the more effective solar energy is in reducing the building's heating energy.

- The amount of solar energy is different for different geographical directions and that is the reason why different results are obtained for various modes.

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