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Potential of Using Window Films to Support Protection of the Environmentin Kurdistan of Iraq

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Abstract:- Glazed buildings directly exposed to the sun become unbearably hot during summer and cold during winter. Huge amounts of energy are required to keep them comfortable. Application of thermal insulation such as Window films significantly reduces energy required for heating and cooling. A Window film can block a significant amount of the sun's heat, reducing the load on air conditioner for the buildings. In this study, a test wooden cabinet was built as a building simulation. The results of an experimental investigation aimed at assessing the performance of thin films windows in a wooden cabinet are presented. The research is performed under real weather conditions. Experimental tests are carried out as a function of time, and weather conditions. The data are integrated with spectro-photometric measurements. Concerning the environmental issues, the reduction of carbon dioxide (CO_2) due to save in electrical energy by window film was calculated.

Keywords:- Control of solar heat gain; reduction of carbon dioxide (CO_2); Solar Control Window Films; greenhouse gases

I. INTRODUCTION AND BACKGROUD

Our sun rains down a large quantity of energy on the earth. For the houses and buildings during the hot season, this large amount of energy creates a thermal heating load that becomes a challenge and need to be removed by air conditioning. Households in Kurdistan of Iraq pay high bills for electricity in summer due to the excessive use of fans, evaporative coolers and air conditioners. Also, the rise in the use of air conditioning in residential buildings is having serious impacts on the electricity transmission and distribution system. This could leads to high levels of carbon dioxide and other greenhouse gases (GHG) emissions.

The understanding and application of building engineering physics allows us to design and construct high performance buildings which are comfortable and functional.. Construction across the world is facing an unprecedented challenge in recognizing and addressing the fact that energy consumption in buildings is responsible for a substantial proportion of CO_2 emissions. The drivers are not just the mitigation of future climate change, but also addressing unnecessary energy demands in preparation for the time when we are far more reliant on variable output renewable energy generation [1].

Zero or Low -energy buildings (meaning zero CO_2 emissions) are gaining considerable interest as a mean to lessen greenhouse gases (GHG) emissions and conserve energy. Low-carbon buildings have been recently manifested in several countries notably, US, UK, UAE, Australia, etc. [2, 3].

The solar radiation intensity in Duhok city (Kurdistan of Iraq) at mid noon in summer season nearly exceeds 1000 W/m^2 and the air temperature goes as high as 42-45 ^oC. In order to decrease the solar heat gain, window films like those used by car owners may be a good choice against the solar heat gain caused by the windows in the building.

In this study, a test wooden cabinet was built as a building simulation. The results of an experimental investigation aimed at assessing the performance of thin films windows in a wooden cabinet are presented. The reduction in Solar Heat Gain (SHG) due to the application of the window film is measured using an approximated modified equation.

Concerning the environmental issues, the reduction of carbon dioxide (CO_2) due to save in electrical energy by window film was calculated.

In recent decades the development of new technologies applied to glass to minimize the gain or loss of energy in buildings has been of great importance especially in European countries in order to reduce CO_2 emissions [4].In recent years, glazing technologies have progressed significantly to improve the energy performance of buildings. In particular, advances in thin-film coating, among many other technologies, have fueled the continuous development [5]. Solar control films are design to absorb or reflect the incident solar radiation, in order to diminish solar heat gains through the glass. Lambert [6] presented an extensive review on this technology.

Most of the solar heat gain in buildings is by direct radiation through windows. This heat gain via windows can be useful for winter heating. The rate at which heat from the sun can be used is dependent on many factors, including the time of day and year.

The most straightforward approach to achieving a high-performance glazing system is to use multiple panes of low-E films. The number of radiative and convective transfers occurring in series is thereby increased, reducing the overall U-value.

Solar control are generally made of thin layers of polyester, stuck together with an extremely even and thin adhesive layer, for a total thickness which may vary from 25 to 350 μm [7]. The different layers may contain colored materials or may be treated superficially so as to obtain the desired optical properties [8]. The optical and thermal properties of these films were investigated by many researchers [9-14].

Rongxinet. al. [15] showed through a simulation that two factors significantly influence the effect of the window film. These factors include the position of the installed window film and the configuration of the original glazing system. The effect of the window film on the performance of the curtain wall glazing system varies greatly, depending on the type of film and how it is applied. The film can decrease the shading coefficient and solar heat gain coefficient by 44% and 22% if applied on the outside and inside of the existing windows, respectively. For a double pane, low- E glazing system, the building cooling load through the windows on design day is reduced by 27.5% and 2.2% for outside and inside window films, separately.

II. THEORY

The overall thermal transfer value and day lighting are two main parameters for controlling building energy use. Solar heat gain through fenestration is considered as the largest provider to building envelope cooling load and the most important parameter for the overall thermal transfer value determinations. The heat gain in building comes also from different other sources, walls, roof, floor, electrical domestic appliances, occupant, etc. An approximated equation was used by Alnaser [16] to model the solar heat gain in a car after exposure for time interval, t. That equation modified here in order to fit the case of solar heat gain P_1 for a room in a building:

$$P_1 \cong \tau I A_g + \{\rho_{air} V_i C_{air} (\Delta T)\} / t + \{\sum \left(m_i C_i\right)\} \Delta T / t + \varepsilon \sigma A_i \left(T_f{}^4 - T_i^4\right) + A_{d+w+r} \left(T_{f'} - T_i\right) / \sum (L_i / K_i) \quad \ldots(1)$$

Where τ is the glass transmissivity, I is the solar radiation (W/m^2), A_g is area of the glass windows (m^2), ρ_{air} is inside room air density (kg/m^3), V_i is the volume of the room interior (m^3), ΔT is the temperature difference between outside and inside room air temperature, C_{air} is the air specific heat capacity (J/kg K), m_i mass of the heat generating appliances (kg), C_i is their compound specific heat capacity(J/kg K), ε is the emissivity, (σ = 5.6697x10^{-8} W/m^{2}K^4) is the Stefan-Boltzmann constant, A_i is the room interior area, T_f is furniture final temperature and T_i is furniture initial temperature (K),A_{d+w+r} is the door, walls and roof area (m^2), $T_{f'}$ - T_i is the temperature difference between the door exterior and door interior, L_i is the total thickness of the door, wall and roof (m) and finally K the thermal conductivity (W/m. ^{o}C). When the selective absorbing window film is applied to the windows, it will act to reduce the solar radiation that will enter the room through the window. This will cause the solar heat gain of the building or room to be reduced to some lower value P_2, and the difference in solar heat gain ΔP will be given by:

$$\Delta P = P_1 - P_2 \quad \ldots(2)$$

According to Alnaser, [16], when the window film is applied, the main change will occur in terms 1st, 2nd, and 4th of the equation (1).Then the difference in solar heat gain ΔP in the room before and after applying the film can be estimated as:

$$\Delta P = (\tau_b - \tau_a)\ I\ A + \rho_{air} V_i C_{air} / t\ \{(\Delta T_b - \Delta T_f)\} + \varepsilon \sigma A_i \left(T_{fb}{}^4 - T_{ff}{}^4\right) \quad \ldots(3)$$

Where, τ_b is trasmissivity of the window glass, τ_a is the transmissivity of the window glass after the application of the film.

The temperature difference ΔT_b will be given by:

$$\Delta T_b = T_{fb} - T_{ib} \quad \ldots(4)$$

T_{fb} is the final room temperature before applying the film to the window, T_{ib} is the initial temperature in the room before solar gain. And the temperature ΔT_f will be given by:

$$\Delta T_f = T_{ff} - T_{if} \quad \ldots(5)$$

T_{ff} is the final temperature in the room after applying the window film and T_{if} is the initial temperature in the room before solar gain.

III. EXPERIMENTATION

In order to show the effect of the window film in reducing the solar heat gain in buildings in Duhok city, a test wooden cabinet (of dimensions, 120 cm height, 70 cm length, and 40 cm width) as shown in figure (1) was built as a building simulation.

The cabinet consists of two sections, upper and lower that were separated from each other by a wood shelf. There are two glass windows through each of the front and rear faces of the upper part. Each glass window is 26 cm wide, 112 cm high and 0.3 cm thick. The front side of the cabinet is directed to the south. The solar radiation intensity, temperature and relative humidity were measured inside and outside the cabinet for nine hours from 8.30 am to 17.30 pm local time. In order to measure the effect of the window film on the solar heat gain in the cabinet, a Solar Control Window Film was applied to the windows of the cabinet and the same measurements above were repeated. The solar radiation intensity for both cases, with film and without film was measured during all the nine hours both outside and inside the cabinet using solar radiation intensity meter. The temperature and relative humidity were also measured for the same cases and period using ordinary thermometer and simple hygrometer. Readings of the solar radiation intensity, temperature and humidity were recorded each hour. Because of the semi-darkness inside the cabinet after applying the window film, a small aperture was made in the cabinet to make the task of taking the readings of the measurement devices easy.

The amount of solar radiation that passes blocked by the Solar control films was measured using UV, VIS, and NIR spectroscopy (Perkin Elmer, Lambda 25) to examine the absorbance and transmittance of the window glass as well as the films.

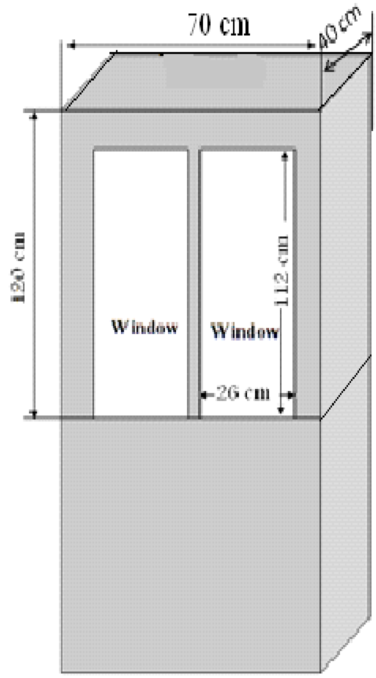

Figure 1:A test wooden cabinet

IV. RESULTS AND DISCUSSION

A. Weather Data

Figure. 2 shows the indoor–outdoor hourly temperatures of the cabinet from 8:30 am to 6:30 pm on July 14, 2011 with and without window film installed on the window.

It shows that in summer temperatures reach values in excess of comfort levels, particularly in the course of heat waves when even during the night the temperature does not fall sufficiently.

The hot season in Duhok, usually falls in July and August .Figure 2 indicates that the maximum temperature on 14 July 2011 (highest value = 47 ^{o} C for outside the cabinet) observed between 15:30 and 16:30. While the highest temperature= 68 °C for inside the cabinet (without solar window films). With solar window films, significant reductions in the maximum temperature are observed between 13:00 and 17:00 (temperature= 58 °C).

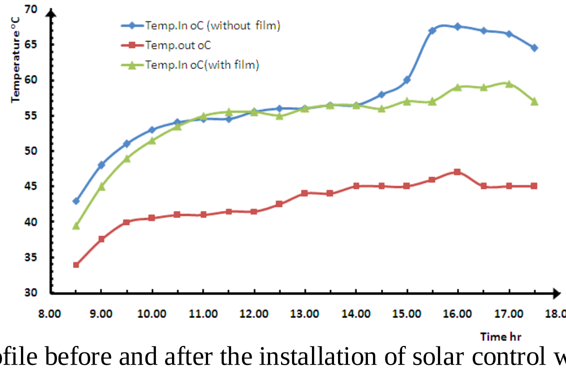

Figure 2. Temperature profile before and after the installation of solar control window film on the window.

Figure 3 shows the indoor and outdoor relative humidity profile after the installation of solar control window film on the window. It was found that there is no much noticeable change in the humidity for both cases (indoor and outdoor).

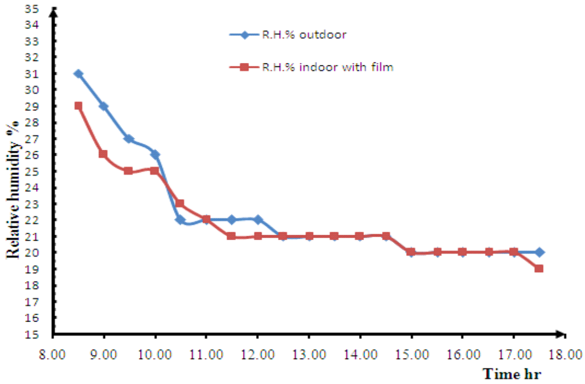

Figure 3. The indoor and outdoor Relative Humidity profile after the installation of solar control.

Figure4 shows the transmittance for solar control film in the UV-Visible-NIR region. It indicates that there is no light transmitted in the UV region. The transmittance for solar control film is less than 3 % at wave length of 400 to 630 nm. Then it increases exponentially to about 50 % (between wave length of 630 to 800 nm).

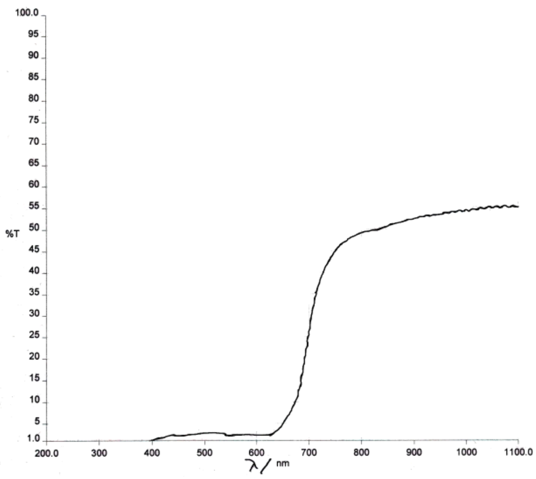

Figure 4. The transmittance for solar control film in the UV-Visible-NIR region.

Figure 5 shows the Blocking of the solar radiation for solar control film. This graph highlights the performance of the solar control film.

It was shown that thin film's blocking depends on the time of day, and on weather conditions, e.g...clouds, haze, etc. The results show that thin film is blocking between 50- 90 % of the solar radiation, between 8:30 and 13:30.

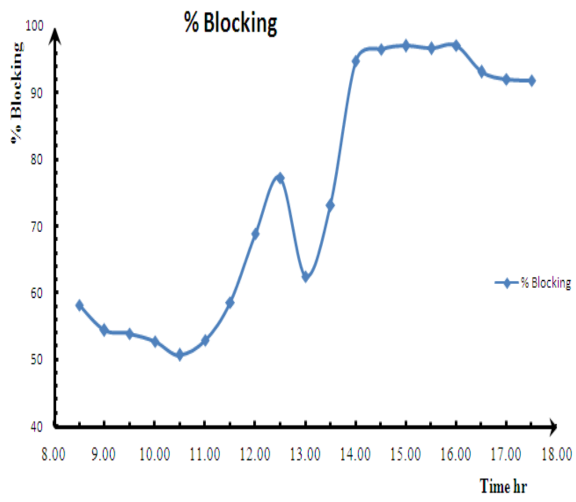

Figure 5. The Blocking of the solar radiation for solar control film.

As expected, the maximum solar heat reduction appears at the peak solar heat value. For instance, in the morning, when the solar radiation data are mainly diffuse of low values, the solar heat transmittance becomes smaller.

Afternoon (when the time of day is between 14:30-16). Thin film is blocking about 97 % of the solar radiation. Large reduction in solar radiation usually represents a sunny sky with a large portion of direct component. There is drop in the blocking value when the time of day is between 12:30 and 13:00. This lower reduction in solar radiation indicates a cloudy sky, which is dominated by diffuse solar component.

This means that the solar heat reduction ability of the film coating is directly proportional to the amount of solar radiation received and depends on the types of solar radiation (direct components or diffuse components).

B. Calculations Of Solar (Heat) Gain

Equation (3) was used to calculate the reduction in the solar heat gain in the wooden cabinet under test. Following are the calculations of reduction in solar heat gain.

First term:

The difference between the transmissivity of the window glazing of the test cabinet under test before applying the film and after applying is given by: $\tau_b - \tau_a$ = 0.88-0.5=0.38.

Therefore the reduction in the amount of solar heat gain due to the change in transmissivity of the window glazing caused by window film application is given by the amount of ($\tau_b - \tau_a$)IA which is first term of equation (3). The average value of I is (800W/m^2) and the total area of the glazing is 1.17 m^2.

Thus the value of the first term of equation (3) is

($\tau_b - \tau_a$).I.A=355.68 W.

Second term:

Volume of the air in the wooden cabinet (V_i);

V_i = 1.2x0.70x0.4= 0.336 m^3.

Time, t = 9x3600=32400 sec

ρ_{air} = air density= 1.25 Kg/ m^3,

C_{air} = specific heat of air = 993 J/Kg. ^oK .

ΔT_b = T_{fb}- T_{ib}= 64.5-43.0= 21.5 ^{o}C

ΔT_f = T_{ff}- T_{if}= 57.0-39.5= 17.5 ^{o}C

$\Delta T_b - \Delta T_f$ = 21.5-17.5= 4.0 ^{o}C

Thus the value of the 2^{nd} term of equation (3) is

$$\rho_{air} V_i C_{air} / t\{(\Delta T_b - \Delta T_f)\} = 0.0514\ W$$

Third term:
The emissivity ε is about 0.6 ,
σ = 5.6697x10^{-8} W/m^{2}K^4,
A_i= total area of the chamber cabinet
= 2(0.4x0.7+1.2x0.4+1.2x0.7)
=3.2 m^2
T_{fb}^4= (64.5 +273)^4= 1.2974x10^{10} k^4
T_{ff}^4= (57+273)^4= 1.1859x10^{10} k^4
Thus the value of the 3rd term of equation (3) is

$$\varepsilon\sigma A_i\left(T_{fb}^{\ 4} - T_{ff}^{\ 4}\right) = 121.42\ W$$

Total difference in solar (heat) gain will be:
ΔP_{gain} = 355.68 + 0.0514 + 121.42
= 477.15 W.

The ratio of the glazing area to the total area Ag/A$_i$ = 0.365 , it is considerably high, and this led the first term of equation (3) to be dominant. The second term is almost negligible.

Accordingly, for a large scale practical case, if a window film of similar properties is applied to the windows of a Lab at Duhok University (with dimensions: Width= 10 m, height= 3 m, length=12m) containing five windows, of total net glazing area of 20m^2, and by considering that the temperature difference ΔT_b and ΔT_f of equations (4) and (5) have the same values for both cases (i.e. the test cabinet and the case of LAB), the results will be as follows: the value of the first term of equation (3) is 6080 W. The value of the 2nd term of equation (3) is 55.166 W. And the value of the 3rd term of equation (3) is 14110.069 W. This causes the reduction in solar heat gain to be almost ΔP_{gain} =20245 W.

In case of LAB, the ratio of the glazing area to the total area A/A$_i$ is only 0.053. This makes the 3rd terms of equation (3) to be dominant, while the second term became also significant in the case of LAB, due to the increased air mass ($\rho_{air} V_i$).

Total difference in solar (heat) gain will be:
ΔP_{gain} = 6080 W + 55.166 W + 14110.069 W
= 20245.235 W

C. Calculations of the reduction in CO_2 emissions

According to the calculations and analysis regarding to solar (heat) gain , we can calculate the reduction in CO_2emissions. Modifying building envelope by using solar window films, will significantly reduce energy required for heating and cooling.

The total energy consumption of heating, ventilation and air-conditioning (HVAC) systems will reduced by total difference in solar (heat) gain. In case of the test cabinet; (ΔP_{gain} = 477.15 W) which save about 1741.415 k W h / year. The estimated reduction in CO_2 is 1236 Kg.CO_2 or 1.236 tons CO_2 in the case study (in case of the test cabinet). This was calculated on a factor of 0.71 Kg.CO_2 for every kWh. [17].
Likewise, for the LAB case;total difference in solar (heat) P_{gain} gain will be 20245.235 W, which save 73895.10775 k W h / year. In this case, the estimated reduction in CO_2 is about 52.5tons. And for ten Labs in the University the estimated reduction in CO_2 emissions will be about 525 tons.

V. CONCLUSIONS

The rise in the use of air conditioning in residential buildings in Kurdistan of Iraq is having serious impacts on the electricity transmission and distribution system. This could leads to high levels of carbon dioxide and other polluting gases, such as NOx, in the atmosphere. IF we are to mitigate climate change, CO_2 emission, and secure our future energy supplies with the minimum economic impacts, we must change the way in which we design, procure and operate buildings in Kurdistan of Iraq. Using solar control window film for building will reduce the fuel consumption in the building and subsequently the CO_2 and other greenhouse gases (GHG) emissions. Further advantages in using such films are reducing the glare, heat and UV. It was found that solar control window film can block a significant amount of the sun's heat. This could led to reducing the load on air conditioner for the buildings. It was observed that solar control thin film's blocking depend on the time of day, and on weather conditions, e.g..clouds, haze, etc. The maximum solar heat reduction appears at the peak solar heat value. Calculations of reduction in solar heat gain for a small scale test-cell (wooden cabinet), and for a

Lab at Duhok University, Kurdistan of Iraq,indicated that the total difference in solar (heat) gain are about 477 W, and 20245 W respectively. Calculations of the estimated reduction in carbon dioxide (CO_2) emissions due to save in electrical energy by window films, was about 1.24 tons and 52.5tons in case of a small wooden cabinet, and in case of LAB respectively.

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