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Original Contribution

SIMULATION OF BUILDING WITH TRANSPARENTLY INSULATED WALLS IN EDIRNE/TÜRKIYE

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ABSTRACT

The rate of energy consumption is rising rapidly due to population increase, urbanization, consumer tastes, industrial activity, transportation and etc. Increasing population means construction more buildings, which rises energy consumption. The annual increase in population in Turkey is determined as about 1.5 % and, in parallel, building construction also gets increased. The increase in building construction was 79% between 1985 and 2000. When the distribution of energy consumption in various sectors in Turkey is examined, it has been seen that the industry and building sectors have the biggest rates among the others. It is generally admitted that most of energy loss in building elements arises due to walls and roofs. Therefore, the solution in preventing the heat loss is the application of the insulation materials on the external walls. Thermal insulation in buildings provides energy saving and a comfortable and hygienic indoor climate at low ambient temperatures. Opaque insulation materials only reduce the heat loss from the inside of the building to the outside. But transparent insulation material has the property of being transparent to solar radiation while at the same time acting as heat insulation. Transparent insulation does not only present savings in heating costs, but it also increases the thermal comfort, as the wall temperature is often higher than the indoor temperature. Furthermore, the troubles such as moisture and mould can also be prevented with the application of transparent insulation because of the higher temperature on the wall inner surface. In this study, the thermal behaviour of transparent insulated external wall construction is investigated under Edirne-Turkey climatic conditions.

Key Words: *opaque insulation materials, transparent insulation material*

INTRODUCTION

Today, energy consumption is continuously increasing because of population, urbanization and industrialization[1]. A significant part of the consumed energy is based on fossil sources such as coal, petrol, natural gas. However, the most significant problem in consequence of the consumption of fossil energy sources is global climate change. Therefore, the most important part of the national energy strategies is energy saving.

Energy consumption is generally examined under four main sectors such as industry, buildings, transportation, and agriculture. The consumed energy in buildings is about 30% in total energy consumption. In the most countries, energy consumption for heating is about 40% of the consumed energy in buildings (Table 1).

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Table 1. *Distribution of energy consumption in buildings [1,2]*

	Space heating	Water heating	Air condition ventilation	Lighting illumination	Cooling freezing	Other
Houses	40	17	7	7	12	17
Commercial	32	5	22	25	-	16

About 35% heat lose in buildings comes about through exterior walls (Table 2).

Table 2. *Distribution of heat loses in buildings [1,2]*

Exterior walls	Roof	Window	Floor	Infiltration
% 35	% 25	% 22	% 10	% 8

Insulation applications on exterior walls and heat gain through solar energy are considerable methods for diminishing energy consumption for heating.

TRANSPARENT INSULATION MATERIALS (TIM)

Opaque insulation materials have generally been used for the insulation of exterior walls. But these materials do not transmit solar energy. Transparent insulation materials have been applied on massive walls to increase insulation properties of buildings and to gain heat from solar radiation. The massive walls on which transparent insulation has been applied work like solar collector. Absorbed solar energy is stored in massive walls. The heat lose from exterior wall is fairly low because of transparent insulation. Therefore, a significant part of the stored energy has been transferred to interior volume. Heat conductivity coefficients of transparent insulation materials change between 0,6 and 1,1 W/m^{2}K depending on thickness and type of material [3,4,5]. And the solar radiation permeability is about 70%. Advantages have been supplied by using transparent insulation. By transparent insulation, some benefits are obtained which are increase in exterior wall insulation and thermal comfort, decrease in facade condensation, lag on solar heat gain, applicable on existing building and increase in heat storing capacity of massive walls. However, excessive heat may appear during summer months.

MATHEMATICAL MODEL

When the model is established, it is assumed that there is one-dimensional transient heat conduction in wall construction and governing equation may be written as [6].

$$(\partial T / \partial t) = \alpha * (\partial^2 T / \partial x^2) \qquad (1)$$

where T(x,t) is the temperature t and x stands for the time and space coordinates, α is the thermal diffusivity. When the absorption of the solar radiation is taken into account; from the energy balance, the heat-flux in the outer surface(x=0) of the wall is:

$$q_{out}(t,\ 0) = \alpha_g * I(t) + h_{out} * [T_{out}(t) - T(t,0)] \qquad (2)$$

where I(t) is the total solar radiation incident on the wall surface, α_g is the absorption of the outer wall surface for solar radiation, h_{out} is heat transfer coefficient between the outer surface of wall and outdoor, $T_{out}(t)$ denotes outdoor temperature, T(t,0) is the outer surface temperature.

The heat-flux in the inner surface of the wall is:

$$q_{in} = h_{in} * [T(t,L) - T_{in}] \qquad (3)$$

where h_{in} is the heat transfer coefficient between inner space and inner surface of the wall, T_{in} denotes indoor temperature, T(t,L) is the inner surface temperature of the wall.

In the study, the daily thermal behaviours of transparent insulated wall constructions that have been tested under current climatic conditions are simulated. The one-dimensional transient heat conduction equation is solved by employing an explicit finite-differences procedure taking into account the thermophysical characteristics of the layers.

Using the energy balance method, the explicit finite-difference equations are derived for the boundary node on the outside surface, interface nodes between layers, interior nodes inside the layers, the boundary node on the outside surface.

The resulting finite-difference equations are given as follows:

The boundary node (0) on the outside surface:

$$T_0^{p+1} = T_0^p \left[1 - 2\, Fo_1 \left(1 + Bi_1\right)\right] + 2\, Fo_1\, T_1^p + 2\, Fo_1\, Bi_1\, T_S \tag{4}$$

where

$Fo_1 = \alpha_1\, \Delta t / \Delta x$ and $Bi_1 = h_{out}\, \Delta x / k_1$

and sol-air temperature T_S is defined as follows:

$$T_S = T_{out}(t) + \alpha_g\, I(t) / h_{out}\,. \tag{5}$$

Interface node (i) between different layers (K) and (K+1):

$$T_i^{p+1} = \frac{(k_K / \Delta x) T_{i-1}^p + (k_{K+1} / \Delta x)\, T_{i+1}^p \;\; - T_i^p\, [B + (k_K / \Delta x) + (k_{K+1} / \Delta x)]}{B} \tag{6}$$

where $B = (\rho_K\, C_K\, \Delta x\, + \rho_{K+1}\, C_{K+1} \Delta x) / 2\, \Delta t$.

Interior node (j) inside the layer (M):

$$T_j^{p+1} = T_j^p \left(1 - 2\, Fo_M\right) + Fo_M \left(T_{j-1}^p\, + T_{j+1}^p\right) \tag{7}$$

where

$Fo_M = \alpha_M\, \Delta t / \Delta x$.

The boundary node (n) on the inside surface:

$$T_n^{p+1} = T_n^p \left[1 - 2\, Fo_N \left(1 + Bi_N\right)\right] + 2\, Fo_N\, T_{n-1}^p + 2\, Fo_N\, Bi_N\, T_{in}^p \tag{8}$$

where

$Fo_N = \alpha_N\, \Delta t / \Delta x$ and $Bi_N = h_{in}\, \Delta x / k_N$.

The set of the finite-differences equations is solved iteratively by using the Gauss-Seidel iteration method. The stability criterion belonging to every layer has been taken into account in solutions.

FINDINGS

The hourly variation ambient temperature is between -1.44 and 5.60 C. In January condition, daily solar radiation incident on a horizontal surface and on the wall surface are 4.68 MJ/m^2, 3.56 MJ/m^2 respectively. The climatic condition for January in Edirne is shown Fig. 1.

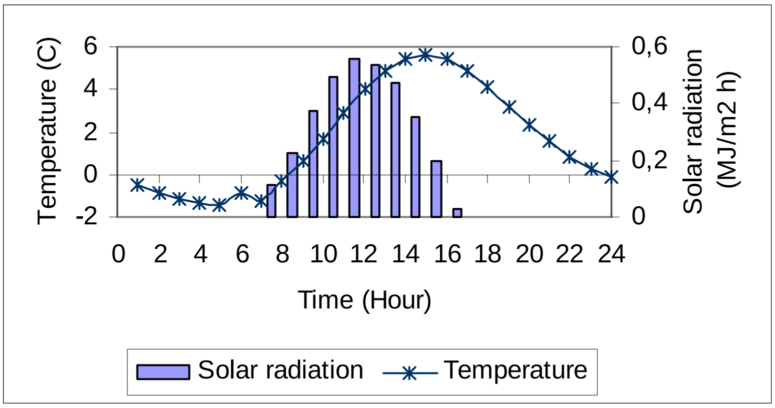

Figure 1. *Variation of climatic data in Edirne*

The average temperatures of outer and inner surface are 18.31 C and 19.19 C, respectively (Fig 2).

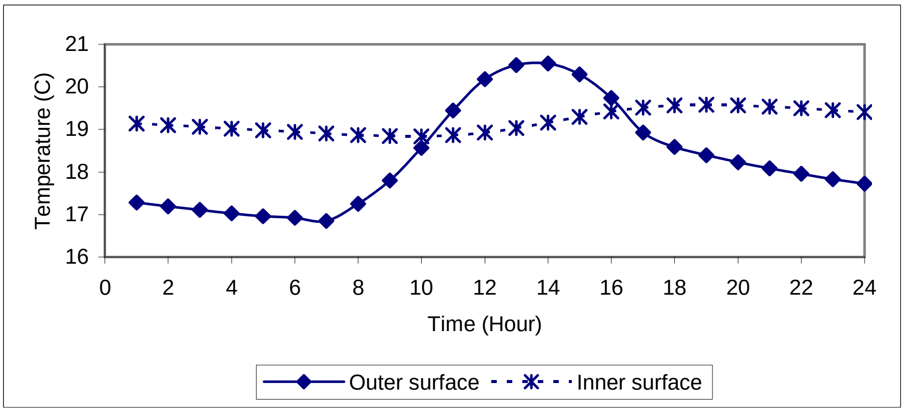

Figure 2. *Hourly variation of thermal behaviour of transparently insulated wall*

The maximum and minimum temperatures of the outer surface of transparently insulated wall are 20.55 C and 16.84 C respectively, whereas 19.58 C and 18.33 C are found out respectively on the inner surface of transparently insulated wall.

A transparently insulated wall works like solar collector. Therefore efficiency of transparently insulated wall is the ratio of heat-flux in the inner surface to solar radiation on the wall surface. Efficiency of transparently insulated wall is plotted as a function of $(T_{in}-T_{out})/H_T$. where H_T is hourly solar radiation incident on a wall surface.

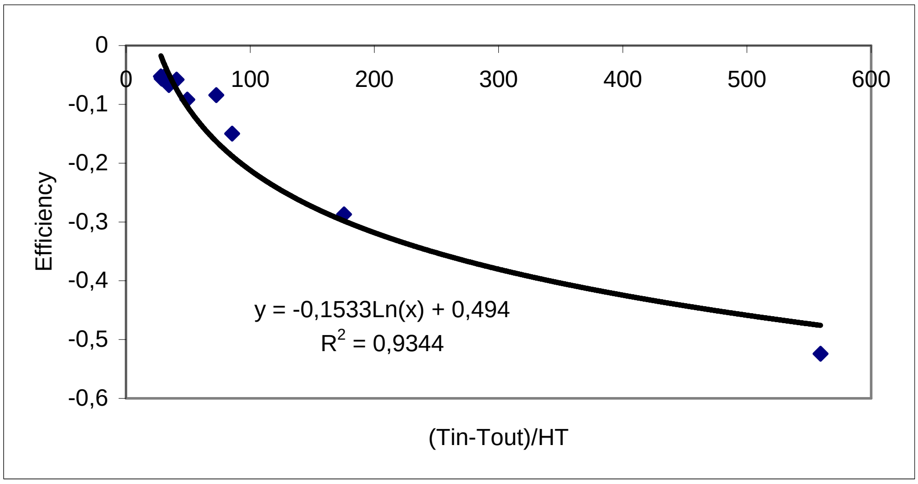

Figure 3. *Thermal efficiency of transparently insulated wall*

DISCUSSION AND CONCLUSION

Transparently insulated walls are the significant components in passive solar buildings. Contrary to conventional opaque insulation, a transparently insulated wall not only reduces transmission losses of a building wall, but also heats the room behind the TI wall. Using transparent insulation materials, it is possible to decrease the heating demand. Furthermore the increase of the interior surface temperature contributes to the thermal comfort of the room. The temperature of the wall is above ambient temperature for most of the time.

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