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Experimental evaluation of the performance of reflective insulation for improvement of indoor thermal environmental conditions

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Abstract: - This research work focuses on the evaluation of reflective insulation when it is placed inside the wall construction for the improvement of indoor thermal environmental conditions. To meet this objective a model room has been designed and constructed at the campus of the Technological Educational Institution of Chalkida located in the agricultural area of Psachna. First results show that the existence of reflective insulation during summer period deters the super heating at the interior of the model room. Because of the reflective insulation characteristics a better attenuation of temperature variations is achieved and a normal behaviour in temperature variation through the wall construction is noticed.

Key-Words: - reflective insulation, experiment, model room

1 Introduction

In buildings large amounts of energy are consumed especially for heating and cooling purposes. The residential, commercial and institutional building sector consumed 31% of global energy and emitted 1900 mega tons of carbon in 1990 while by 2050, its share is expected to rise to 38% and 3800 mega tons respectively [1]. In European Union energy consumption in buildings represents about 40-45% of the produced energy [2] while the importance of energy conservation in the building sector is depicted from the Directive of the European Parliament and of the Council on the energy performance of buildings [3].

The use of energy efficient methods in building element components construction is among the possible ways to achieve energy efficiency and conservation in buildings. The heating and cooling load can be reduced through many means and among them is the proper design and selection of building envelope components. The proper use of thermal insulation in buildings does not only contribute in reducing the required air-conditioning system size but also in reducing the annual energy cost.

The thermal performance of building envelope is determined by the thermal properties of the materials used in its construction characterized by its ability to absorb or emit solar heat in addition to the overall U-value of the corresponding component including insulation. The placement of insulation material within the building component can affect its performance under transient heat flow [4]. Materials frequently used for building insulation are chosen for their low thermal conductivity and their ability to block the conductive heat flux. Materials having low or high reflectance are also used. For example, reflective insulation consists of one or more low emittance surfaces, such as metallic foil or metallic deposits, unmounted or mounted on substrates [5]. Unlike the other insulation materials, reflective insulation works by reflecting incident infrared radiation, thus reducing radiant heat transfer. Its performance depends on a number of factors [6] including the radiation angle of incidence on the reflective surface, the temperature difference between the spaces on both sides of the reflective material, the material emissivity, the thickness of the air space facing the reflective material, the direction of heat flow.

In view of the above, this research work focuses on the evaluation of reflective insulation when it is placed inside the wall construction for the improvement of indoor thermal environmental conditions. To meet this objective a model room has been designed and constructed at the campus of the Technological Educational Institution of Chalkida located in the agricultural area of Psachna. The dimensions of the model room are 4m x 6m x 4m and its roof is covered with roman tiles and a radiant barrier reflective insulation system. The side-walls are a two series brick construction with a bubble material laminated between layers of aluminum foil placed in the 20mm gap of the brick layers.

Reflective insulation is a part of the model room wall construction, and more specifically: 1. Heat insulation material of the vertical wall construction to all directions (North, South, East, West), 2. Temperature and humidity insulation element of the roof.

Research work will be carried out through various steps. At the current first step, the outer surface of the model room wall construction is not covered with plaster. Temperature measurements have already been conducted so as to obtain a clear understanding of the reflective insulation behavior for this configuration. First experimental results that were obtained during August 2005 show that because of the reflective insulation characteristics a better attenuation of temperature variations in the model room is achieved and a normal behaviour in temperature variation through the wall construction is noticed.

2 Experimental Installation and Procedure

2.1 The model room

A model room has been designed and constructed at the campus of the Technological Educational Institution of Chalkida located in the agricultural area of Psachna. The dimensions of the model room are 4mx6mx4m (Figure 1) and its roof is covered with roman tiles and a radiant barrier reflective insulation system.

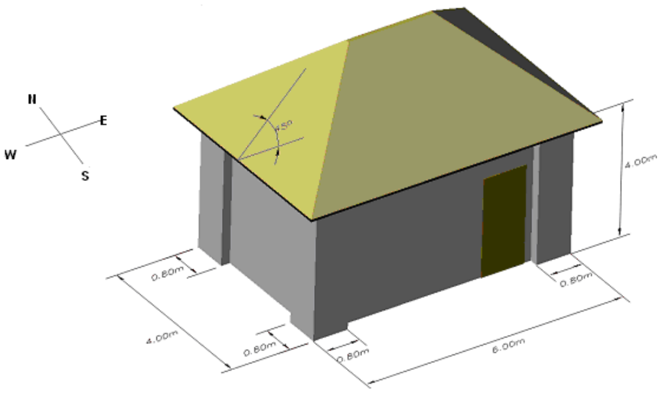

Fig. 2 View of the model room.

The side walls are a two series brick construction with a bubble material laminated between layers of aluminum foil placed in the 20mm gap of the brick layers. The total wall thickness consists of 90 mm brick, 10mm air gap, 1mm or 2mm reflective insulation, 10mm air gap and 90mm brick (Figure 2). The walls can be coated internally and externally resulting to a total width ranging from 200mm to 240mm (including a 20 mm thickness of the wall sheathing –plaster- in each side). The selection of the above mentioned insulation materials used in residential construction in attics, walls, ceilings, and radiant floor heating applications is due to the requirement for an excellent thermal resistance regarding the shell of the model room.

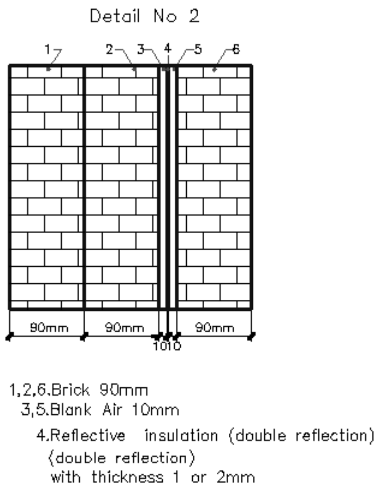

Fig.2 Details of the wall construction.

Reflective insulation is a part of the model room wall construction, and more specifically:

1. Heat insulation material of the vertical wall construction to all directions (North, South, East, West),
2. Temperature and humidity insulation element of the roof.

The roof is constructed of roman tiles based on a wooden support which is protected through the application of reflective insulation and it consists of the following layers: joists support of roof, wooden support with thickness 10~15 mm, cleats of reflective insulation and tiles (wooden or other material e.g. plastic) with thickness 2x10mm, and roman tile.

2.2 About reflective insulation

Thermal insulation is a material or combination of materials, that, when properly applied, retards the rate of heat flow by conduction, convection, and radiation. It retards heat flow into or out of the building due to its high thermal resistance [6]. Reflective insulation consists of one or more low emittance surfaces, such as metallic foil or metallic deposits, unmounted or mounted on substrates [5]. Because reflective insulation is usually manufactured with highly reflective, aluminum foil surfaces, 95-97% of the radiant heat that strikes the surface is reflected, and only 3-5% of the heat is emitted through the insulation. The major benefit of this reflective property is that in the winter, heat inside a building is reflected off the insulation's surface back into the building so that the heat is retained inside. In the summer, heat that's radiated through the roof is reflected off the insulation's surface back to the roof and not inside the building keeping temperatures inside the building cooler. Unlike the other insulation materials, reflective insulation works by reflecting incident infrared radiation, thus reducing radiant heat transfer. Its performance depends on a number of factors including the radiation angle of incidence on the reflective surface, the temperature difference between the spaces on both sides of the reflective material, the material emissivity, the thickness of the air space facing the reflective material, the direction of heat flow.

2.3 Experimental plan

The experimental plan focuses on the evaluation of the performance of reflective insulation for both summer and winter periods. Research work will be carried out through three steps. At the current first step, the outer surface of the model room wall construction is not covered with plaster. Temperature measurements have already been conducted so as to obtain a clear understanding of the reflective insulation behavior for this configuration. At a second step, after two years the outer surface of the model room wall construction will be covered with plaster and will be painted in white color. Finally, as a third step, after one year the outer surface of the model room wall construction will be painted in gray color. Similar measurements will be conducted for the second and third step so as to define the reflective insulation performance under different levels of radiation absorbance.

2.4 Experimental methodology and equipment

Experimental methodology is compatible with the international standards and the certified methods [7] for the determination of the thermal behavior of the wall construction and the other elements of the building cell. Based on the development of the periodic environmental behavior on a 24h basis and the measurements analysis the total contribution of the reflective insulation to the energy operation of the wall construction (for each orientation), and the overall behaviour of the model room will be certified.

The experimental equipment used for the evaluation of reflective insulation consists of temperature and humidity sensors connected to a data logging system [8-10]. All the measurements were programmed to have a frequency of a measurement per 5-10 minutes. Temperatures were measured at different levels inside and outside the model room as well as inside the wall construction.

In each wall of the model room for the determination of the thermal dynamic behaviour and the effects of the reflective insulation, conditions of one dimensional thermal flow have been developed which will be certified through consequent temperature measurements with devices that have been put in characteristic points of the wall construction both at the outer surfaces and inside the wall construction (Figures 3a,b). The surface exterior and internal wall temperature are recorded, at the north and south orientation. They are placed at the centre of each wall (at the height of 2 m from the floor and in equal distance from the two vertical edges of the walls).

At the distance of 100 mm from each wall both inside and outside the model room thermocouples have been installed for the measurement of the local air temperature. Temperature variation with height and for each direction can be determined with these thermocouples so as to evaluate inlet and outlet air temperature.

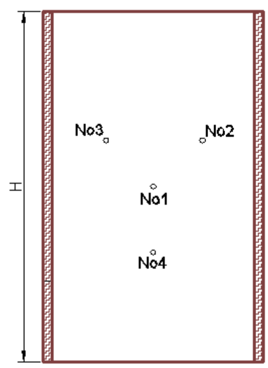

Fig.3a Temperature measurement points at the outer surface of the wall construction.

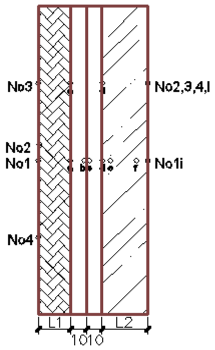

Fig.3b Temperature measurement points inside the wall construction.

Furthermore, temperature measurements are also obtained providing information for the radiation energy that falls or emits to/from the wall surface. The measurement plan is completed with the measurement of dry bulb and wet bulb temperature at the centre of the model room and at distances 300 to 500 mm from each surface.

Finally, a small meteorological station has already been installed equipped with components and sensors that measure wind speed, wind direction, rain gauge, air pressure, temperature, relative humidity, total solar radiation and diffused solar radiation focusing on the determination of the external environment thermal behaviour. For the measurement accuracy the developed methodology requires the existence of uniform materials of 1.5m x 1.5m or 2.0m x 2.0m. so as to exclude the possibility of non one–dimensional flow at the middle of the working surface. For each orientation conditions of non-steady one dimensional heat flow at the central points of the uniform walls are developed (2,0mx4.0m and 4.0mx4.0m respectively to each direction). The perturbation of the thermal equilibrium because of the solar radiation that falls on the wall surface does not cause problem to the measurements accuracy because of the application of a high number of measurements with accuracy of 0,1^{o}C and with high duration of 7 days.

3 Results and Discussion

In this section typical results from the measurements inside and outside the model room that were obtained during August 2005 are presented and discussed. During the experimental period, the meteorological conditions were characterized by clear sky, quite high temperature and low wind speed.

In Figures 4 and 5 typical temperature values at the surface of exterior and internal walls of the model room are presented, at points located at the north and south orientation and at the centre of each wall (at the height of 2 m from the floor and in equal distance from the two vertical edges of the walls as it is shown in Figure 3a).

Despite the high temperature variations of the external wall of the model room during summer period, during the week and on a 24h basis the temperature variation at the internal walls and inside the model room is quite mild. Temperature at the surface of the external wall of the model room ranges from 20^{o}C early in the morning to about 40^{o}C at 15:00-16:00 in the afternoon.

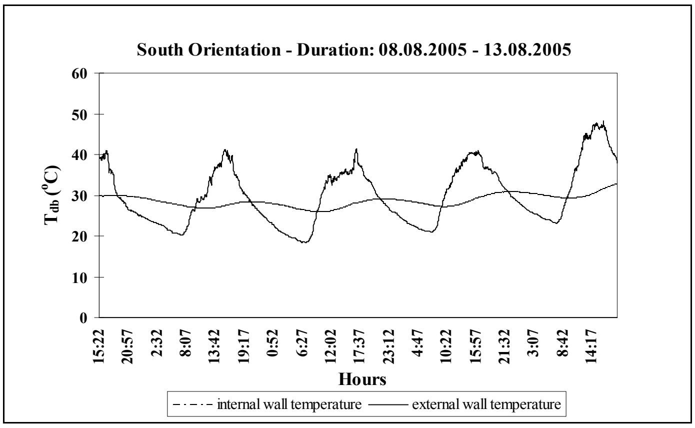

Fig. 4: Temperature at internal and external walls of the model room during the period 08.08.2005-13.08.2005. South orientation.

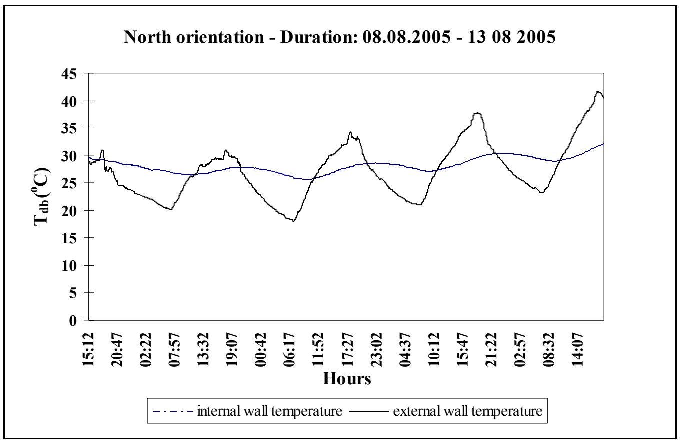

Fig. 5: Temperature at internal and external walls of the model room during the period 08.08.2005-13.08.2005. North orientation.

However, temperature at the surface of the internal wall of the model room is about 28-30^oC during the whole day. This is mainly due to the existence of reflective insulation which during summer period deters the super heating at the interior of the model room. During a summer day where temperature outdoors is high, the construction elements of the model room absorb heat increasing their temperature and retaining the temperature indoors at low levels.

In Figure 6 temperature values inside north wall of the model room during the day of 12.08.2005 are shown. Because of the reflective insulation characteristics a better attenuation of temperature variations is achieved and a normal behaviour in temperature variation through the wall construction is noticed.

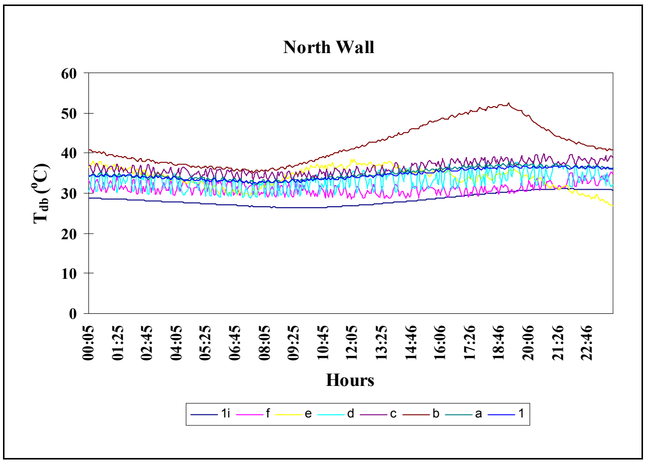

Fig. 6: Temperature inside north wall of the model room during the day of 12.08.2005.
1i, a,b,c,d,e,f,1: measurements points shown in Fig. 3b.

4 Conclusion

A model room has been designed and constructed at the campus of the Technological Educational Institution of Chalkida located in the agricultural area of Psachna at Evia island. The scheduled experimental work focuses on the evaluation of the performance of reflective insulation for both summer and winter periods. First results show that the existence of reflective insulation during summer period averts the super heating at the interior of the model room. Because of the reflective insulation characteristics a better attenuation of temperature variations is achieved and a normal behaviour in temperature variation through the wall construction is noticed.

5 Acknowledgement

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References:

[1] IPCC Technologies, Policies and Measures for Mitigating Climate Change – IPCC Technical Paper 1; Geneva: Intergovernmental Panel on Climate Change, 1996, 84pp.

[2] N. Zografakis, Technologies for rational use and savings of energy in buildings, Energy (in Greek), Vol. 62, 2000, pp. 112–114.

[3] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, 4/1/2003, Official Journal L1 65.

[4] K.A. Antonopoulos, F. Democritou, M. Vrachopoulos, An experimental system for the transient, non-periodic thermal analysis of structural elements, Energy, Vol. 19(4), 1994, pp. 383-395.

[5] ASTM C1224-03 Standard Specification for Reflective Insulation for Building Applications, ASTM International, 2005.

[6] American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). Handbook of Fundamentals, Atlanta, GA, USA, 2001 [Chapter 23].

[7] ISO 7726, Ergonomics of the thermal environment – Instruments for measuring physical quantities, International Organization for Standardization, Geneva, Switzerland, 1998.

[8] Supco DLTH Temperature/Humidity Data Loggers, Instruction manual, USA, 2002.

[9] Supco LOGiTpc Interface Software, User's Guide, USA, 2002.

[10] ANSI/ASHRAE 55, Thermal Environmental Conditions for Human Occupancy, 1992.