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Verification of the thermal insulation properties and determination the optimal position of the reflective thermal insulation layer in the wood based envelope

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Abstract

To achieve thinner wood based envelope is necessary look for an alternative thermal insulation material, which will have the best possible thermal insulation properties while maintaining affordability. One such material is also reflective thermal insulation layer, but it is necessary to verify the thermal insulation properties and determine the optimal position in the wood based envelope.

Key words: reflective thermal insulation layer, experimental measurements in climate chambers, the optimal position, thermal resistance

1 Introduction

Using high performance reflective insulation in combination with traditional thermal insulating materials based on mineral wool, wood-fiber insulation or insulation made from renewable raw materials should be achieved by reducing the total required thickness of the insulation. The question is what extent will affect the position of reflective thermal insulation layer its thermo-technical properties (reflectance and emissivity) in the composition of wood based envelope. The objective of measurement is using the measured surface temperature and heat flux density planted specimens to determine the optimal position of reflective insulation at which maximize the use of its reflectivity (achieving the lowest possible heat loss) and verify the thermal insulation properties [1, 2].

2 Methodology

Before measuring is necessary to test the airtightness planted specimens and also the airtightness of the dividing wall between the two rooms of climatic chamber. Also is necessary to test the functionality and accuracy of measurement sensors [3]. The measurement is carried out at fixed temperature boundary conditions. Boundary conditions of measurement:

A) Θi = 20°C, φi = 50%, Θe = -11°C, φe = 84%

B) Θi = 24°C, φi = 80%, Θe = -11°C, φe = 84%

C) Θi = 20°C, φi = 50%, Θe = -18°C, φe = 84%

D) Θi = 24°C, φi = 80%, Θe = -18°C, φe = 84%

Time of measurement depends on the time needed to reach steady-state temperature. Recording of measurement data is set to minute interval. Measured parameters of the steady (stationary) conditions are: the temperature and the relative humidity of the external and internal air, the temperature inside the structure, internal and external surface temperatures and heat flow.

Collect data from the sensors will be by fully automatic measuring control panel connected with the data cable to PC. To collect data from the sensors will be used Almemo software. Data will be recorded at minute intervals with subsequent evaluation and necessary adjustments. Temperature sensors will be placed in the middle of planted specimens, the distance from the edges is 300 mm in order to reduce the impact margins. Heat flow sensor is also placed on the center of the measured fragment nearest to the sensor of surface temperature.

3 Instrumentation

Climatic chamber Thermotron 8800 consists of two separately accessible isolated room. Hygrotermal boundary conditions are selectable via computer. Both rooms have separate HVAC units, which are designed to operate independently. Rooms of the climate chamber are equipped with two separate anemometers and temperature sensors. These sensors record the measured values and also serve to control boundary conditions of the chamber.

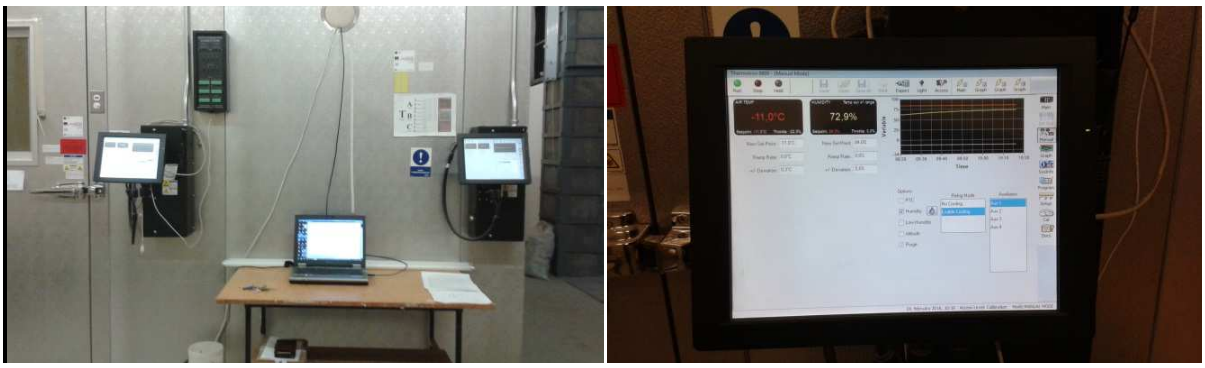

Figure 1: Climatic chamber Thermotron 8800 with control panels

For measuring the temperature there are used the sensors based on the type of tip resistance without PT, Ntc and NiCr with a measuring range of -50 to +125 ° C and hundredth resolution on linear accuracy ± 0,05 K. The heat flow density is measured in the range -260 to +260 W/m2 with a resolution hundredth W/m^2.

Figure 2: Climatic chamber and data logger Almemo 5690-1 connected to PC

4 Experimental samples

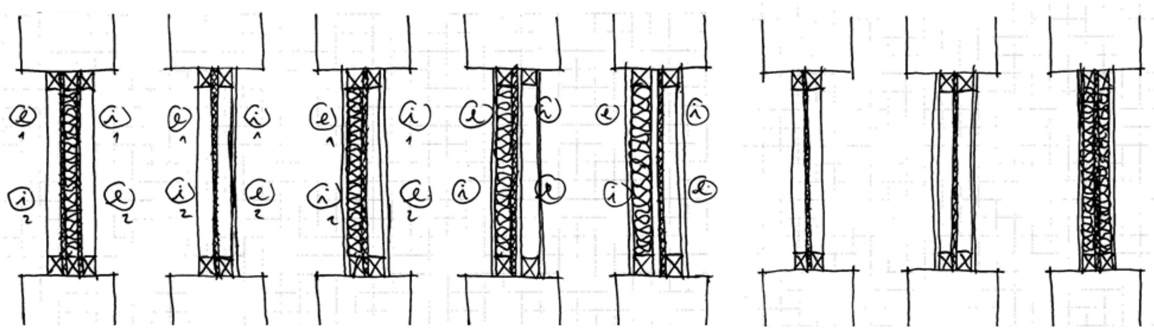

Figure 3: The initial proposal of experimental samples

During the experiment will be simultaneously measured three experimental samples with dimensions of 600x600mm. Figure show the position of the sensor and the design of individual samples with different positions of reflective insulation in the building envelope. Compositions and position of the reflective insulation were designed in order to compare the efficiency of the reflective thermal insulation layer (the emissivity) for the insulation and insulation with additional thermal insulation - mineral wool from both sides, the insulation with a closed air gap of different thicknesses and use reflective insulation in different position of the outer wood based panels.

The position of the reflective insulation in test samples during the measurement:
1) the reflective thermal insulation,
2) the reflective thermal insulation with enclosed air gaps thick 50mm,
3) the reflective thermal insulation with mineral wool from both sides of reflective thermal insulation

4) the reflective thermal insulation with enclosed air gaps thick 30mm
5) envelope equal envelope 6) without reflective thermal insulation
6) envelope with reflective thermal insulation in enclosed air gap (25mm) and mineral wool (50mm)
7) the reflective thermal insulation with enclosed air gaps thick 20mm
8) envelope equal envelope 9) without reflective thermal insulation
9) envelope with reflective thermal insulation in enclosed air gap (25mm) and mineral wool (100mm)
10) the reflective thermal insulation with enclosed air gaps thick 10mm
11) envelope equal envelope 12) without reflective thermal insulation
12) envelope with reflective thermal insulation in enclosed air gap (10mm) and mineral wool (100mm)
The first experimental sample - just reflective thermal insulation layer (RTI).

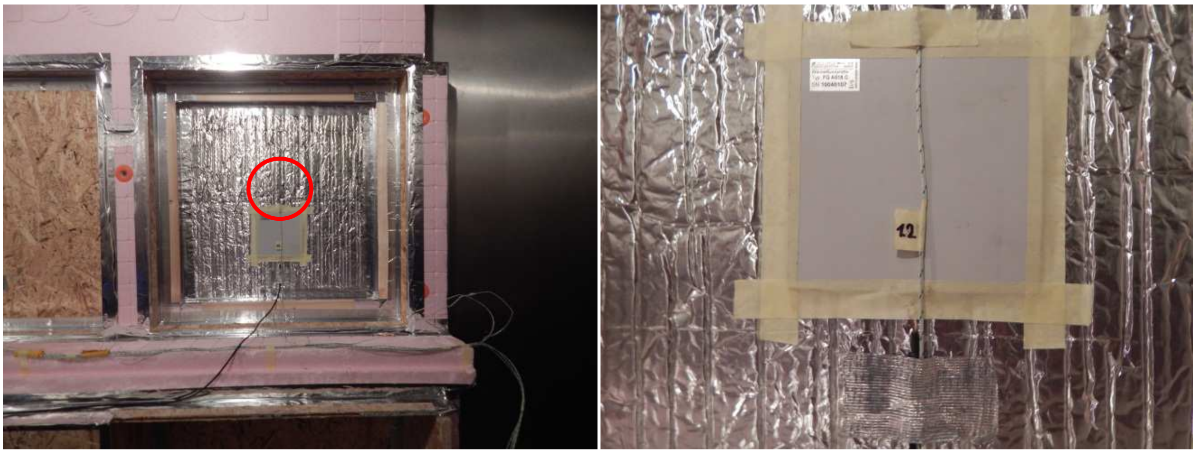

Figure 4: Location of the sensor of surface temperature and heat flux density

The second experimental sample - RTI with enclosed air gaps on both sides with a thickness of 50 mm.

Figure 5: Location of the sensor of temperature in structure and surface temperature

The third experimental sample - RTI with 50 mm of mineral wool on both sides.

Figure 6: Inserting thermal insulation layer - mineral wool and installation sensor of surface temperature

Other experimental samples have different thickness of enclosed air gap and thermal insulation layers and have different position of RTI (described samples 1-12).

5 Calculation of thermal resistance of RTI from measured data

Energy emitted by the thing may be partially absorbed by the surrounding environment; it may turn out to other bodies and the variance in the surrounding area. Capacity to absorb various things is not the same. The intensity of heat exchange by radiation is different in different things, depending on their temperature capability lettuce, absorbing and reflecting heat from the shape, dimensions and relative positions of irradiated structures [4, 5].
During the heat technical calculations according to STN 730540, the building structures evaluate the steady-state temperature, which separates the two environments with constant temperature [6]. If we assume a one-dimensional array temperature, then the temperature in the different points of construction as for the position of $\theta = f(x)$. When a one-dimensional propagation of heat is used Fourier differential equation of the form:

$$q = -\lambda \frac{d\theta}{dx} = -\lambda \, grad\, \theta \tag{1}$$

The density of the heat flow can be calculated for the design steady-state temperature in the one-dimensional heat transfer from the relation (2).

$$q = \frac{\lambda}{d}(\theta_{si} - \theta_{se}) = \frac{1}{R}(\theta_{si} - \theta_{se}) \tag{2}$$

From equation (2) is derived an equation for calculating the thermal resistance (3), which will serve for mutual comparison of thermal resistance achieved by the individual experimental samples.

$$R = \frac{d}{\lambda} = \frac{(\theta_{si} - \theta_{se})}{q} \tag{3}$$

To determine the thermal resistance of reflective thermal insulation layer use the temperature measured in samples and the calculated resistance value of the samples.

$$\theta_x = \theta_i - U.(\theta_i - \theta_a).(R_{si} + R_x) = \theta_i - \frac{\theta_i - \theta_e}{R_0}.(R_{si} + R_x), R_x = R_1 + R_2 + ... + R_n \tag{4}$$

Substituting the known values and expressed of thermal resistance of reflective layer get an equation with one unknown (5). A prerequisite for such a calculation is to achieve equality of heat flows (steady state temperature) during the measurement.

$$R_n = (\theta_x - \theta_i).\frac{-R_0}{\theta_i - \theta_e} - (R_{si} + R_1 + R_2 + ... + R_{n-1}) \tag{5}$$

6 Results

Reflective thermal insulation used in sample with closed air gaps with a thickness of 20 mm on both sides had the highest thermal resistance. The smallest thermal resistance was achieved in sample with closed air gaps with a thickness of 30 mm (Figure 7). The decrease in thermal resistance of closed air gaps with a thickness of 30mm is due to the flow of air in the closed air gap, which occurs in a closed air gap when is thicker than 28 mm.

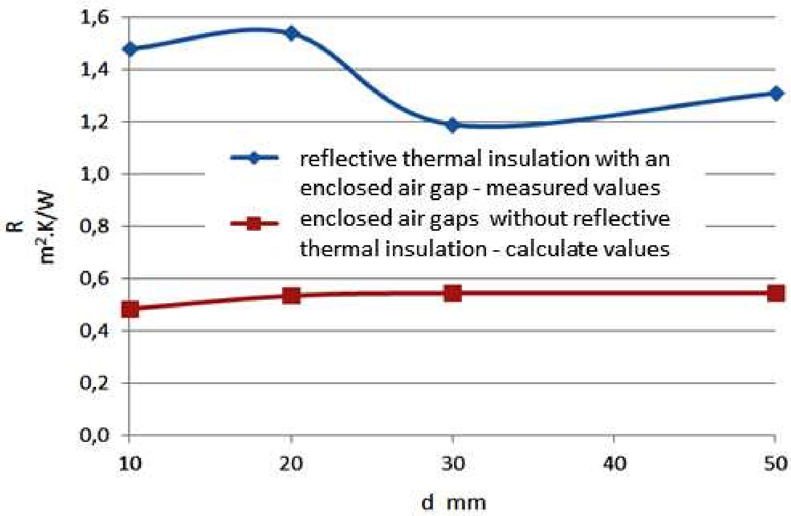

Figure 7: Thermal resistance of reflective insulation with varying thickness of sealed air gaps

The difference between blue and red lines is thermal resistance achieved by a reflecting insulation and is in ranges between 0,65 to 1,00 m^{2}K/W (Figure 7), it depends on the thickness of the enclosed air gap.

On the last picture (Figure 8) is shown the thermal resistance of the reflective insulation which is in the position of installation enclosed air gap in the wood based envelope with mineral wool with a thickness of 50mm and 100mm between support columns. In order to determine the thermal resistance of the reflective insulation directly from measurement were simultaneously tested wood based envelopes (samples) with reflective insulation and identical compositions without reflective insulation. Achieved difference in thermal resistance is equal 1,00 m^2K/W and these values represent thermal resistance of reflective thermal insulation layer.

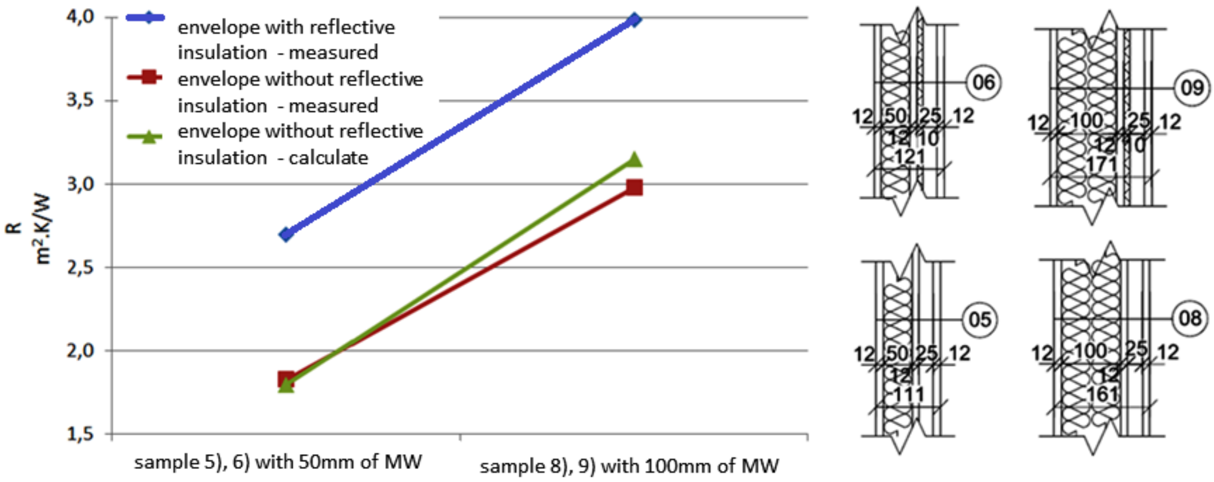

Figure 8: Thermal resistance of reflective insulation in installation enclosed air gap in the wood based envelope with a mineral wool 50 mm and 100 mm thick

7 Conclusion

Separate reflective thermal insulation has a thermal resistance 0,4 m^2K/W. In a position between two enclosed air gaps has a thermal resistance from 0,65 to 1,00 $m^2.K/W$ depending on the thickness of the enclosed air gaps. The highest thermal resistance was achieved at a thickness of enclosed air gap between 20-25 mm. The optimal position of the reflective thermal insulation is in the installation enclosed air gap where achieve thermal resistance equal 1,00 m^2K/W at a thickness of 25 mm of installation gap where also performs the function of a vapor barrier. Manufacturer's specified thermal resistance R_{eqv} = 5,70 m^2K/W [7] (which is verified only by calculating) don't confirm results from measurement.

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