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Surface Temperature of Flat Roofs with Waterproofing Polymer Membranes

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Abstract. This paper deals with the problematics of the surface temperature of flat roofs, where the waterproofing layer is used as polymeric waterproofing membrane of softened PVC. Currently, it is possible to encounter defects on flat roofs due to the high surface temperature of the waterproofing layer. The consequence of such a high surface temperature is, for example, the sublimation of the thermal insulation of the foam polystyrene. The paper focuses on the influence of the color of the plasticized PVC membrane on the surface temperature. The aim of this paper is to determine the maximum surface temperature of a polymeric PVC membranes in the dependence on color on the basis of experimental measurements and furthermore, to determine the maximum temperature on the surface of the thermal insulation under PVC polymeric membrane. Measurements were taken during a warm summer day. Used samples were represented by polymeric membranes in green, gray, red and brown colors. Mineral wool was used as a substrate under the polymeric membrane.

1. Introduction

This paper is focused on the analysis of the surface temperature of waterproofing polymeric membranes made of soft PVC in the compositions of flat roofs with the classical order of layers. In compositions with the classical order of layers, where the waterproofing is above the thermal insulation layer, the polymeric membranes are exposed directly to the sunlight. One waterproofing layer systems, either bitumen sheets or polymer membrane, can be damaged easily [1-2].

The high surface temperature is one of the causes of failure on flat roofs with coated waterproofing. These failures are manifested, for example, by sublimation of the thermal insulation of the foam polystyrene. Previously it has been dealt with the problem of surface temperatures on polymeric membranes in [3]. As a result, is the following finding: the temperature of the thermal insulation surface in the combination with the reflection of solar radiation exceeds 80°C for a long time.

The surface temperature of polymeric membranes is mainly influenced by [4]:

1. Surface properties of bitumen membranes (emissivity, reflection),
2. Substrate (thermal capacity),
3. Ambient (air) temperature;
4. Radiation in surroundings

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5. Air flow and humidity,
6. Position in relation to cardinal points;
7. Waterproofing position (a slope in relation to the horizontal position).

In view of the surface properties of the polymeric membranes, the choice of the surface color is important for the solar reflectance and emissivity of the surface.

The aim of this paper is to find out what maximum temperatures are achieved on the surface of polymeric membranes and on the surface of thermal insulation in terms of color of the membrane without the influence of the reflection and whether this temperature approaches the limit of 80°C. This value is the limit guaranteed by manufacturers of foam polystyrene for its stability [5]. Thus, it is possible to establish the hypothesis that the surface temperature of the polymeric membranes and the thermal insulation surface does not exceed the value of 80 °C. Another hypothesis that can be put forward is as follows: Does the temperature range between the maximum temperatures of different colors reach values of more than 10°C? The last hypothesis would be formulated as follows: will be the lowest temperature achieved in light colors and the highest temperature will be achieved in dark colors.

Nowadays, when temperatures rise every year in the summer months, this issue becomes very actual. The measurements were carried out during the summer of the year 2018 in the range from 12.8.2018 to 14.8.2018. In the long term, the summer 2018 can be considered the second warmest summer in the 245-year history of temperature monitoring in the Czech Republic [6].

2. Material and methods of testing

2.1 Material

2.1.1 Samples of polymeric membranes

For the experimental part, polymeric membranes of softened PVC of the thickness 1.6 mm with a surface texture were chosen. As to the the color selection, light gray, dark gray, red, brown, light green, dark green and gray samples were used, see Figure 1. The 100 x 50 mm polymeric membrane samples were laid loosely on a mineral wool substrate (λ_D = 0.037 W/mK) of thickness 100 mm in special wooden frame. The sample frame lay on a flat roof. The samples were directly exposed to the sunlight without further reflection of the sun rays.

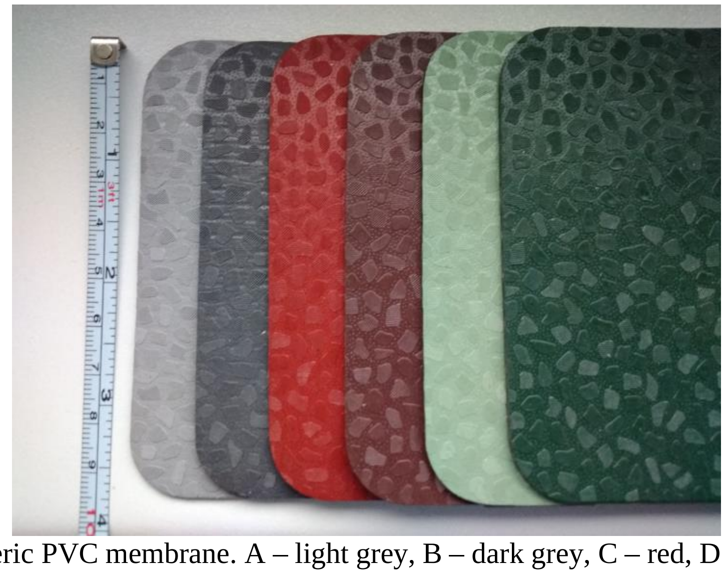

Figure 1. Polymeric PVC membrane. A – light grey, B – dark grey, C – red, D – brown, E – light green, F – dark green.

2.1.2 Apparatus
Two methods were used for the temperature measurement – a contactless and a contact method. The contactless method measures the temperature on the surface of the polymeric membrane and also contains the reflected component of the solar radiation. For measurements by the contactless method was used IR thermometer Voltcraft IR-650-12D with the temperature resolution of the value 0.1°C and with the basic accuracy of ± 3°C. The set emissivity of the value 0.92 corresponded to the surface behaviour of the polymeric membranes in the IR spectrum. The emissivity value of common building materials ranges from 0.85 to 0.95.

The contact method measures the temperature on the lower surface of the polymeric membrane, i.e. the upper surface of the thermal insulation, by means of a thermocouple. The universal measuring device ALMEMO 2590-4 with a thermocouple TYPE K - T190-1 with a temperature resolution of 0.1°C and a measurement accuracy of 0.03% of the unmeasured value was used for the contact method.

2.2 Methods of testing
Samples of polymeric membranes were placed on a flat roof with a 5° inclination oriented to the southeast. In terms of air flow, the roof is located in a normal landscape, on a protected, detached building at a height of about 2.0 m above the terrain at an altitude of about 425 m above sea level in the village called Planá nad Lužnicí (GPS: 49.3630811N, 14.7196306E). The air temperature was measured about 15 mm above the mineral wool substrate using a TyP K thermocouple. A low aperture was created around the samples to eliminate the effects of wind [4].

3. Results
Results of the measurements using both methods are given in Table 1. The maximum surface temperatures were recorded at the air temperature in 13.8.2018 at 42.6°C. The maximum temperature at the measuring station of the Czech Hydrometerological Institute (CHMU) on this day in the Czech Republic was measured in Radovesnice at 35.7°C [7]. It was the 7th - 9th hottest day of summer 2018 [7].

Table 1. Overview of measured maximum temperature values of polymeric membranes in dependence on surface color.

Color	**Contactless method (13.8.2018)** [°C]	**Contact method (13.8.2018)** [°C]
light grey	70.2	68.8
dark grey	80.3	71.0
red	77.0	71.9
brown	79.7	70.6
light green	70.4	69.1
dark green	77.3	69.6

4. Discussion
The maximum temperature of 80°C was reached on a single surface during a non-contact measurement. The hypothesis was therefore only partially confirmed. In the case of the contactless method, temperatures from 68.8°C to 71.9°C were reached. Thus, the temperature range was 3.1°C. Temperatures of 70.2°C to 80.3°C were achieved by using the contact method. Thus, the temperature range was 10.0°C. Thus, a hypothesis on a temperature range of more than 10°C was confirmed.

The temperature difference in the group of samples of various colors for the non-contact and contact method is significantly lower than in the case of bitumen membranes [4]. This small difference, in the case of non-contact method (only 3.1°C), is due to the low specific capacity of the thin polymeric membrane. Large differences when using the contactless method can be attributed to the reflected component of the solar radiation. In all cases, the temperature on the surface of the thermal insulation was lower than on the surface of the polymeric membrane. Contrary to the assumption, for all materials, there was a little difference between the non-contact and contact measurement method for the same sample. It was confirmed for both methods that the highest temperatures were reached for samples in dark colors. The hypothesis was therefore confirmed.

5. Conclusion

The obtained results show that the color of the polymeric membrane has a significant effect on the surface temperature and thus the acceleration of the aging process. Although the assumption of reaching the temperature of 80°C on the surface of the thermal insulation has not been confirmed, light colors should be preferred over dark colors.

In the next phase of the research we would like focus on the measurement of surface temperatures on thermal insulation of foam polystyrene (EPS). In the case of this type of thermal insulation, a separation layer is sandwiched between the soften PVC membrane and the thermal insulation. The separation layer is a high basis weight geotextile and may affect measurement results.

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