Heat transfer analysis of roof drains in the calorimetric chamber

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Abstract: - The paper describes the non-stationary behavior of a roof drain during experimental measurement in the climate simulator. Many buildings use a fully or partially flat roof where it is necessary to use the roof drainage. Thermal behavior of roof drainage is very important from the point of view of heat transfer analysis and potential condensation inside buildings. The measurement was performed for two types of roof drains. The first drainage is a simple single-shell and the second is double-shell drainage. The results show the effect on the thermal transmittance of the roof section and also the minimal effect of condensation on the non-insulation part of the drainage

Key-Words: - Roof drain, heat transfer coefficient, heat loss, non-stationary behavior

1 Introduction

Drainage systems of roof areas are an important task in modern residential, industrial or commercial construction. The use of internal rainwater drains is very common not only for flat roofs. The roof drainage is important in term of the thermal insulation properties of the roof.

Some studies verify modification of the length of the downpipe and its impact on increasing the flowrate [5]. Roof drainage systems are designed to the size of the roof, the number of drains and also the estimated amount of water as is described in [4].

There are not so many studies that investigate the influence of roof drainage on the thermal parameters of the roof. However, there are standards to indicate requirements for surface indoor temperatures due to the possibility of condensation of water inside buildings as describes [1].

Many roof designs have exposed to heavy seasonal rain and designers need to take increased rainfall intensity. The roofs may be drained by two basic methods, towards the outer edges and into external gutters or towards internal gutters or drainage outlets within the main roof area [3]. Gutters can be blocked by hail or due to rainfall intensity. Therefore it is important to evaluate and to compare the width of the drainage. The requirements for the location of roof drains are described in [7,6]. Thermal transmittance describes the insulation capacity of a building structure. The roof drain slightly deteriorates the insulation properties of a building structure. Due to this fact, we try to evaluate the influence of roof drain in the roof.

Roof drain causes a thermal bridge through the roof structure. Such a construction may cause the surface temperature of the structure to fall below the dew point. Therefore it is important to measure surface temperature on the surface that is directly in contact with the outside environment.

In this paper, the thermal properties of the roof drainage will be investigated and the surface temperature will be measured on the critical parts of the roof drainage under the different climatic conditions.

2 Methods

The measurement was performed on the two types of roof drains. The inlet of the first drain is 212 mm wide and is formed by a one-sided layer. The second drainage has inlet 130 mm wide and the wall is double-shell. Both drains are used for a 100 mm drainage line. These roof drains were measured in specific measuring box which was installed in the calorimetric chamber. The thermal parameters of the measuring box are similar to the actual roof structure. The both drains were equipped with a 100 mm strong polystyrene for testing the thermal behavior. This allows for a view of the heat transfer towards the connected duct pipe and only the part of the inlet body, which usually adjoins with the ceiling concrete slab. The dimension of tested sample and roof of the box are described in Table 1

Table 1 Dimensions of constructions

Construction	Surface [m^2]
Roof of the box	2,25
Single-shell roof drain	0,035
Double-shell roof drain	0,013

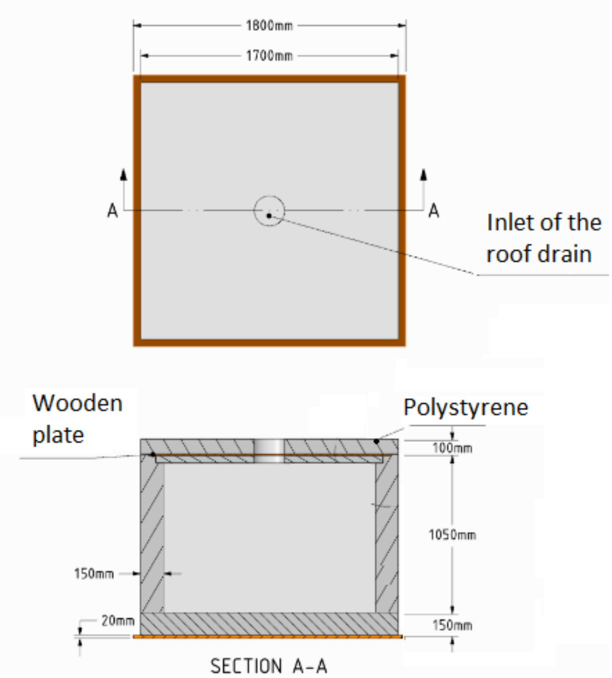

Figure 1 Testing box of roof drains

Figure 1 shows dimensions of measuring box and position of the roof drainage.

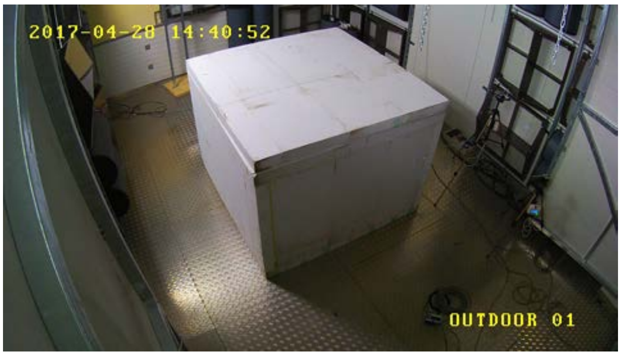

Figure 2 Testing box inside the calorimetric chamber

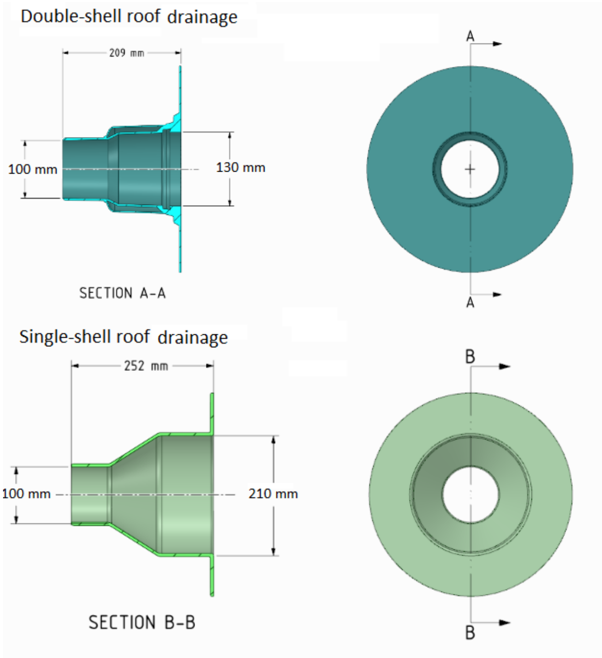

Figure 3 Dimensions of roof drains

As can be seen in Figure 3 the roof drains have a different dimension of the inlet and different depth.

The calorimetric chamber is a device in which the climatic condition can be controlled in the specific temperature range from –20 °C to +50 °C. Each of the roof drains was placed in the testing box and was exposed to three climatic tests as described Table 2

Table 2 Conditions of thermal tests

Test	Air temperature outside [°C]	Initial air temperature inside [°C]
1	10	20
2	2	20
3	-15	20

The heating element regulated the air temperature inside the measuring box for all tests. The thermal performance of this device represented heat loss of the box. The cooling curve was measured by the insulating effect of the inlet at the time-varying non-stationary air temperature inside the box. The air temperature of the exterior was stable during each experiment because temperature fluctuations are minimal during the day in winter. The decrease of the air temperature inside the box on the warm side of the inlet is similar to that of the space heating operation in the space below the flat roof, it can be simulated by switching off the heater.

The thermal transmittance was calculated by equation (1):

$$U = \frac{1}{\left(\frac{1}{h_i}+\frac{d}{\lambda}+\frac{1}{h_e}\right)} \quad (1)$$

Where U is the thermal transmittance [W.m^{-2}.K^{-1}]

h_i the heat transfer coefficient on the inside of the structure [W.m^{-2}.K^{-1}]

h_e the heat transfer coefficient on the exterior of the structure [W.m^{-2}.K^{-1}]

d thickness of the structure [m]

λ thermal conductivity coefficient [W.m^{-1}.K^{-1}]

Heat loss was calculated by equation (2)

$$\phi = \sum(A.U).(\theta_i - \theta_e) \quad (2)$$

where ϕ is heat loss of heated space [W]

A surface of construction [m^2]

Θ_i internal temperature [°C]

Θ_e external temperature [°C]

Table 3 Heat transfer coefficient

Surface	Condensation	Heat transfer coefficient [W.m^{-2}.K^{-1}]
Exterior	Single-skinned	25
Interior	Wall	7,7
	Roof	10
	floor	5,9

The thermal transmittance was calculated for the Czech Technical Standard – Thermal protection of buildings [1]. It was necessary to calculate the average thermal transmittance of the entire roof area with the roof drainage. The thermal transmittance of the roof drainage was established by heat loss of the object and the conversion to the given area.

3 Results

The non-stationary behavior of roof drains was measured for three climatic test for each roof drain. The heat loss were firstly measured for the measuring box without roof drainage in graphs is described as Insulation plate. The thermal transmittance of insulation plate was calculated to evaluate deterioration of heat transmission due to the implementation of roof drainage.

The thermal performance of heating source was tested under the different thermal condition of the measuring box. Three tests were done where the temperature conditions were stably maintained inside and outside the box and this corresponds to the heat performance. The chart directive indicates heat loss of the box without the drainage. Heat loss is 28,5 W for 10°C temperature difference. Application of single-shell drainage increased heat loss up to 32 W and for double-shell up to 30 W.

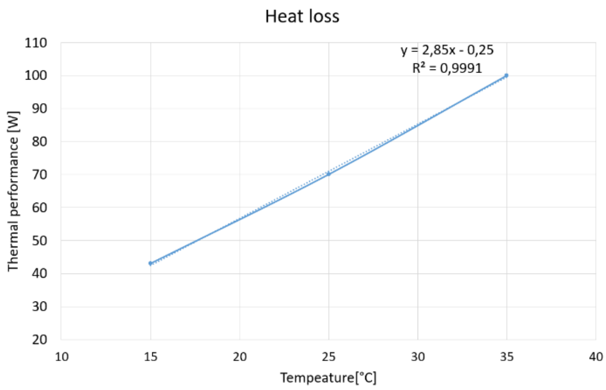

Figure 4 Heat loos of the box

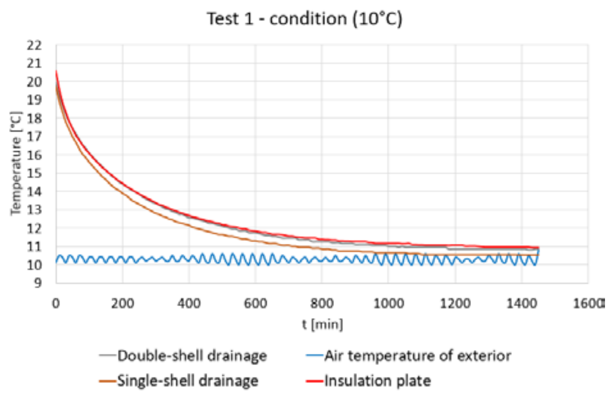

Figure 5 Cooling curve for the air temperature after the heater turned off inside the box, Thermal test 1, Exterior air temperature 10°C

As can be seen in Figure 5 the air temperature decrease faster by using Single-shell drainage than the double-shell drainage. The higher thermal transmittance of single-shell drainage caused faster cooling process inside the box.

Table 4 Results of the thermal transmittance

Thermal transmittance without roof drain	0,257 $W.m^{-2}K$
Thermal transmittance with Single-shell drain	0,318 $W.m^{-2}K$
Thermal transmittance with Double-shell drain	0,296 $W.m^{-2}K$

The thermal transmittance is shown in Table 4. These values are related to the roof area of the box. The thermal transmittance is only reduced by 7%. However, it is the value of the thermal transmittance of the entire roof structure. The results can be recalculated to the example of a flat roof of 100 m^2. This roof should be drained using roof drains with corresponding thermal insulation compared to the insulation which was used in the measuring box. The total thermal transmittance of such a roof can be calculated. The single-shell drainage causes a deterioration of the thermal transmittance by 0,2% than the double-shell drainage. Comparison of the roof without roof drainage with single-shell drainage, a deterioration of the thermal transmittance is by 0,05% and for double-shell is only by 0,03%.

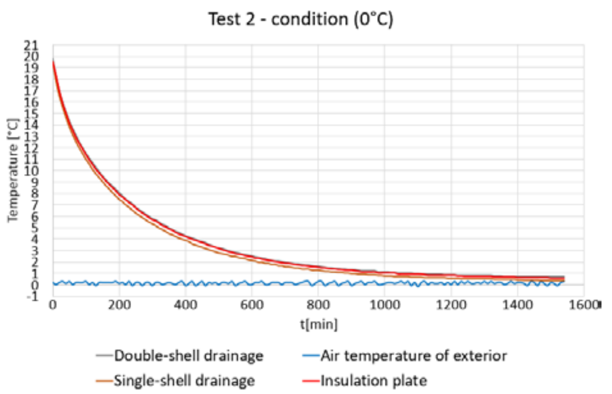

Figure 6 Cooling curve for the air temperature after the heater turned off inside the box, Thermal test 2, Exterior air temperature 0°C.

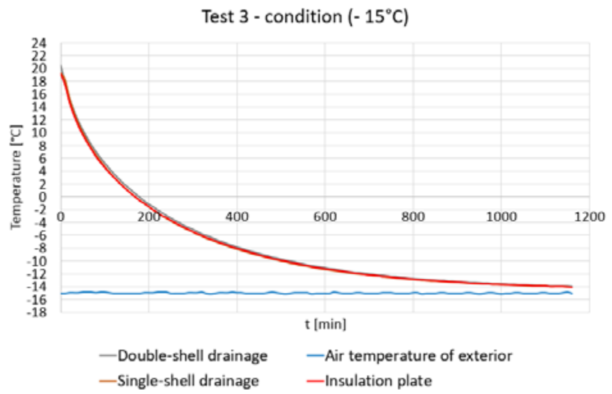

Figure 7 Cooling curve for the air temperature after the heater turned off inside the box, Thermal test 3, Exterior air temperature -15°C

Figure 6 and Figure 6 show minimal temperature differences between single and double-shell roof drainage. It is difficult to verify the cooling process of the box when the exterior air temperature is so low. Due to the minimal difference in the thermal transmittance of the roof drains.

A heat transfer area that does not have additional insulation is for single-shell drain 0,055 m^2 and for double-shell drainage 0,045 m^2. The surface temperature of this area was measured on the both roof drains as is shown in Fig. 7. During the thermal test 3, the surface temperature was higher for single-shell drain than the surface temperature for double-shell drainage, the exterior air temperature was -15 °C and inside the box was 20 °C. This experiment confirmed high insulation properties of the both roof drainage and the possibility of condensation is minimal at the surface of the roof drain.

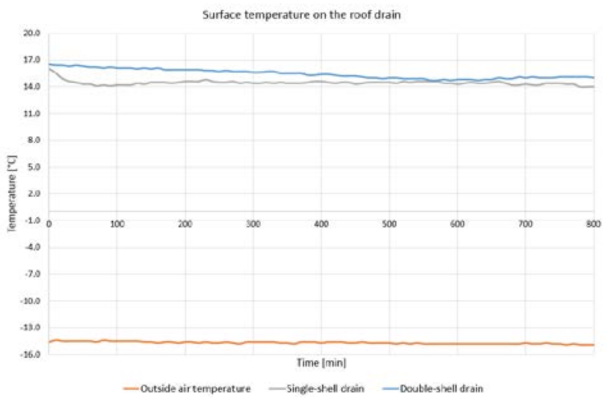

Figure 8 Surface temperature on the roof drain during thermal test 3, Air temperature -15°C

Figure 8 shows the surface temperature on the roof drain. The surface temperature was around 19 °C on the surrounding area of the measuring box. This experiment does not evaluate heat transfer through the roof drain but focuses on dew point issues on the cooled surface of the roof structure. Measurements have confirmed the minimal effect of surface condensation on the roof drain.

4 Conclusion

The experiment was conducted to investigate the non-stationary behavior of the roof drainage. The heat transfer analysis was performed for two types roof drains. These drains were tested under three different climatic conditions in the specific box. The measurement confirmed minimal deterioration of thermal properties of the roof. The surface temperatures were much higher than the dew point on the non-insulated part of the roof drainage during the experimental test when the surrounding temperature was -15°C.

The temperature stratification through the roof drainage will be the subject of the future studies. These studies will be evaluated in simulation software.

Acknowledgement

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