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OPERATING EFFICIENCY OF A NON-MEMBRANE GROUND HEAT AND MASS EXCHANGER AFTER 15 YEARS OF OPERATION

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Key words: ground exchanger, rock bed, operation, air temperature and humidity.

Abstract

This paper presents the results of a study conducted in 1991 and 2006 on a non-membrane ground heat and mass exchanger. The obtained results indicate that under similar operating conditions, the increase in air temperature at the exchanger outlet in the winter fell by approximately 16.5% after 15 years of operation. Relative humidity remained at a similar level within the range of 74-80% which corresponds to standard requirements. In the summer, air cooling efficiency was lower by 17% and air humidity was lower by 5%.

EFEKTY PRACY BEZPRZEPONOWEGO GRUNTOWEGO WYMIENNIKA CIEPŁA I MASY PO 15 LATACH EKSPLOATACJI

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Słowa kluczowe: wymiennik gruntowy, złoże kamienne, eksploatacja, temperatura i wilgotność powietrza.

Abstrakt

W artykule przedstawiono wyniki badań przeprowadzonych w latach 1991 i 2006 na gruntowym bezprzeponowym wymienniku ciepła i masy. Stwierdzono, że w porównywalnych warunkach pracy urządzenia, zimą, przyrost temperatury powietrza na wyjściu z wymiennika był o około 16,5% mniejszy niż przed 15 laty. Wilgotność względna utrzymywała się na podobnym poziomie i wynosiła 74-80%, co odpowiada wymogom normatywnym. Latem schłodzenie powietrza było mniej efektywne o 17%, a nawilżanie powietrza niższe o 5%.

Introduction and Objective of the Study

Non-membrane ground heat and mass exchangers with horizontal air flow have been used in Poland for 30 years. The first exchangers with a granite rock bed were built at the Wrocław University of Technology (BESLER, SPRYSZYŃSKI 1980, BESLER 1985), and exchangers with a basalt bed were built 10 years later at the Institute of Agricultural Engineering in today's Wrocław University of Environmental and Life Sciences (ROMAŃSKI 1995). The main element of the exchanger system, a rock bed, is usually set underground at the depth of more than 2 m. Since at the depth of 3-4 m, ground temperature is roughly constant and it corresponds to the mean annual temperature of ambient air, which reaches around 10°C in Poland's climatic zone, it has been assumed that the parameters of ventilation air can be modified by passing it through a rock bed. In the summer, air is cooled and humidified and in the winter, it is heated and dried before it enters the ventilation system. The structure and the operation of exchangers has been described in detail in the above quoted publications.

Many practitioners presently believe that the efficiency of these types of heat exchangers drops after more than 10 years of operation (PIEŃKOWSKA 2005). Silting decreases the rock bed's porosity and, consequently, impairs its efficiency. The operating parameters of air (temperature, humidity) exiting the heat exchanger are also lower in newly built deposits.

The objective of this study was to confirm or rule out the assumption that operating time affects the parameters of treated ventilation air.

Methodology

The structure of a ground heat and mass heat exchanger has been described in detail by ROMAŃSKI (1995). The diagram of a test stand indicating the location of measurement sensors is presented in Figure 1.

Thermocouples were placed in the rock bed with a 0.7 m scale to measure the temperature of air passing through the deposit. A set of MM1 microclimate meter sensors was used to measure the outlet air temperature, relative humidity and stream velocity. The air stream flowing through the exchanger was measured based on air velocity determined with the use of the continuity equation. The temperature of ambient air at the inlet was measured with a mercurial thermometer (with the precision of 0.5°C), and humidity was determined with an Assman psychometer which was also used to calibrate the microclimate meter.

The study was performed in 1991 and 2006, in the winter and summer. The air stream flowing through the deposit was similar in all measurements, reaching 1300 m^3 s^{-1}.

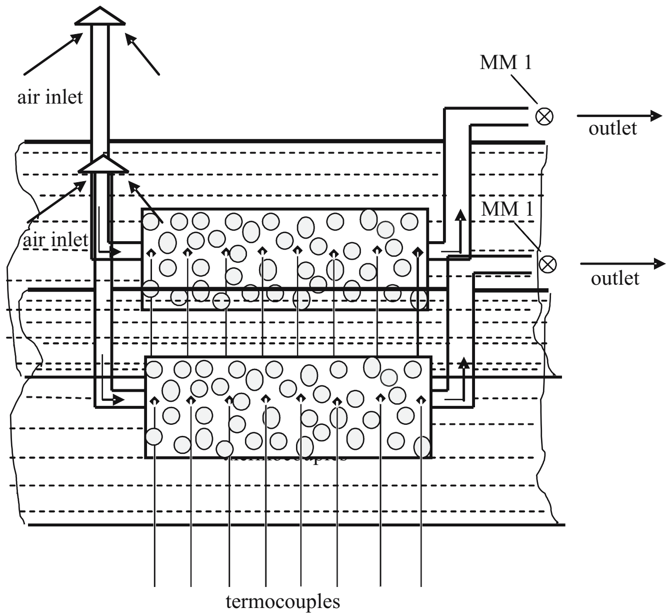

Fig. 1. Diagram of a test stand

Results

In a period marked by low ambient air temperatures, the study was conducted under similar conditions in January and November. The course of air temperature and relative humidity at the inlet and outlet of the exchanger is presented in Figure 2.

Despite similar inlet air parameters, the average increment in temperature at the exchanger outlet was 4.8°C in 1991 (Fig. 2a) and 4.0°C in 2006 (Fig. 2b), indicating a drop of 16%. Since the air stream passing through the exchanger had similar parameters in both investigated years, the only logical cause of the decrease in the average temperature increment at the exchanger outlet in 2006 is the lower porosity of the rock bed. The definition and the method of determining rock bed porosity are presented in a study by ROMAŃSKI (2001).

The drop in air volume between rocks probably resulted from a high water table in some years and the silting up of the deposit. The deposit was opened a year ago to reveal that some rocks had been covered with a layer of soil both at the bottom and in the wall area of the deposit. The above has led to a decrease in the exchanger's cross-section which, in line with the continuity equation, speeded up the flow of the air stream through the exchanger.

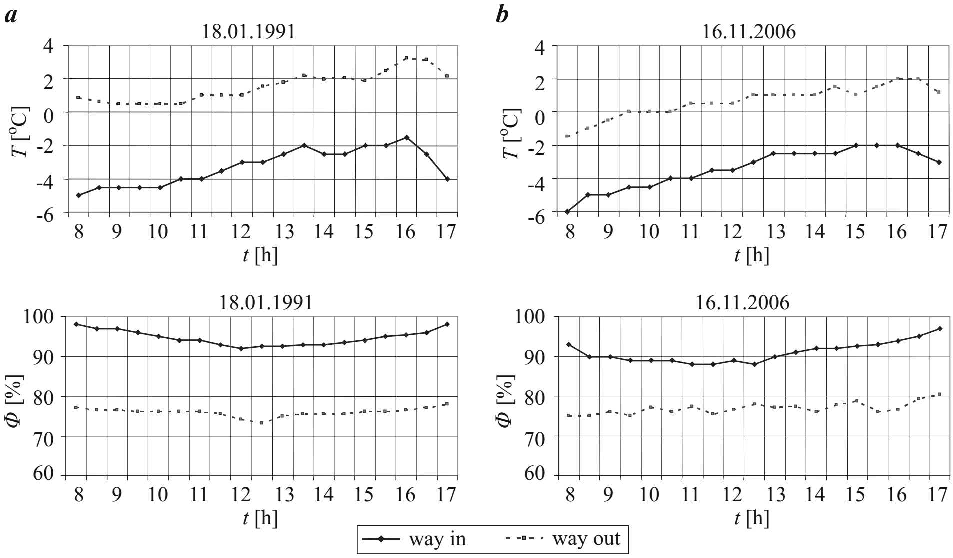

Fig. 2. Changes in the temperature and relative humidity of air at the inlet and outlet of the exchanger in the winter: *a*) 1991, *b*) 2006

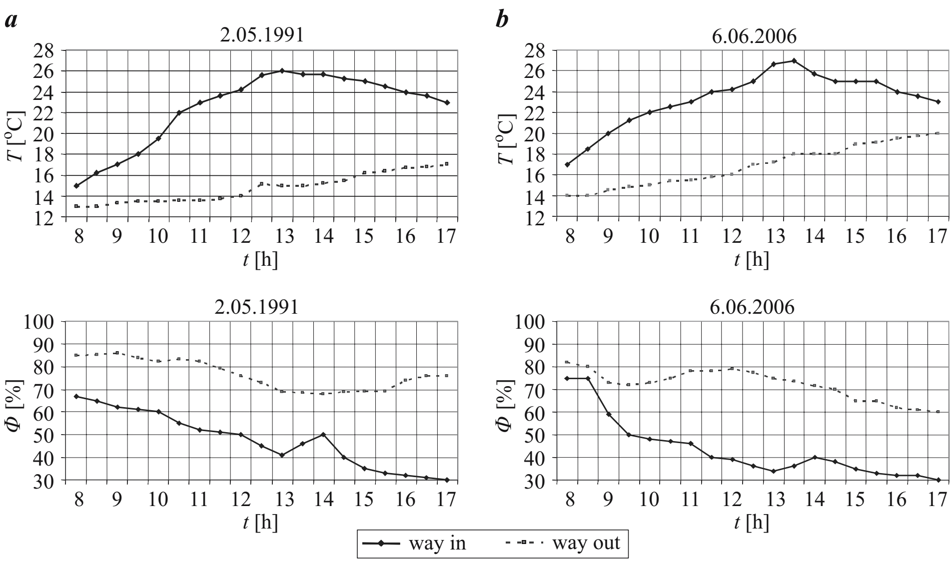

Fig. 3. Changes in the temperature and relative humidity of air at the inlet and outlet of the exchanger in the summer: *a*) 1991, *b*) 2006

Consequently, air was less heated due to a shorter time of passage through the exchanger.

Changes in relative air humidity at the exchanger outlet indicate that in both measurement years, this parameter remained in the range of 74-80% (Fig. 2) which meets standard requirements.

An analysis of temperature changes at the outlet of the ground exchanger in the summer (Fig. 3) shows that the maximum temperature drop (13:00 PM) in a new device (Fig. 3a) was 13°C. Following 15 years of operation of the same device (Fig. 3b), temperature dropped by only 10°C. Therefore, the average drop in the temperature of the air stream after passage through the rock deposit was 17% lower in the summer. Similarly to the drop in air heating efficiency in the winter, the reduced efficiency of air cooling was also caused by lower porosity of the rock bed. Even when the relative humidity of ambient air fell below 40% in the summer, air humidity at the outlet of the exchanger was never lower than 60%.

Thermocouples were placed in the axis of the exchanger rock bed to register changes in the temperature of the air stream subject to the distance travelled in the exchanger (Fig. 4). As expected, air temperature decreased with an increase in the length of the rock bed.

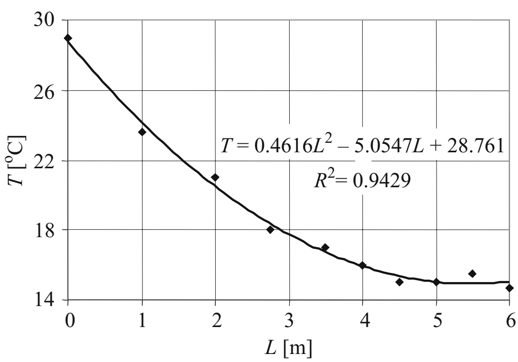

Fig. 4. Relationship between the temperature of air passing through the ground exchanger and the length of the rock bed

Further changes in temperature were not noted when air travelled a distance greater than 4.5 m. This is a very important observation for practitioners as it implies that these types of non-membrane exchangers do not require the installation of rock beds longer than 4.5-5 m.

Conclusions

1. Following 15 years of operation of a ground heat and mass exchanger, the increase in air temperature at the exchanger outlet fell by 15% in the winter. Air cooling efficiency decreased by 17% in the summer.

2. Following the same period of operation, the relative humidity of air at the exchanger outlet remained constant in the winter, while a 5% drop was noted in the summer.

3. The optimal length of the rock bed in a non-membrane ground exchanger with a basalt rock bed is 4.5-5 m.

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