Experimental Research on the Heat Preservation Effect of Water-retaining Roof Bricks in Winter

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Abstract

Roof insulation in winter has an influence on the indoor heat load and causes an increase in the heat on the top room. This paper selects three conditions for testing: (1) comparing a water-retaining roof using bricks with water, a roof with empty bricks and an ordinary roof, (2) comparing different depths of water-retaining roof (from water level h=0cm to h=12cm), and (3) comparing ventilated and non-ventilated water-retaining roofs. In analyzing the effect of water-retaining insulation the results show that: the water-retaining roof is more insulated than the non-water-retaining roof; when the water depth is 8 cm there is no relative need to increase the depth of water to increase its insulation effect; and, air layers play an important role in roof insulation. For energy saving in existing buildings using a water-retaining roof will improve the performance of the roof insulation.

Keywords: water-retaining roof brick; depths of water; ventilation; heat insulation

1. Introduction

In regions of China where it is hot in summer and cold in winter 14.6% of the total built up area has no heating supplied from a central source. In 2010 this amounted to about 8 billion square meters so the scope for energy saving is considerable. Therefore it is necessary to solve problems of thermal insulating on the top floor of buildings with appropriate structural measures.

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The research group developed a type of roof brick which can store rainwater to provide cooling in summer and heat preservation in winter. Meanwhile, the topic of water-retained roofs has become a major issue at home and abroad this year because the evaporation of the city's water can relieve the heat island effect and the dry island effect in urban district. There is a difference between existing buildings and new buildings, for new buildings can change the building structure and the roof structure to store rainwater on the roof, while for existing buildings, we cannot change the building structure and increase its load-bearing. Consequently, the research group chose lightweight ceramsite concrete to manufacture water-retaining bricks. Compared with common concrete (made of stones, river sand and cement), density of ceramsite concrete is smaller, and its heat transfer coefficient is also smaller. This paper mainly discusses the insulation fundamental of water-retaining roof bricks through measuring and researching the insulating effect of lightweight ceramsite concrete in winter. Maybe the water-retaining roof bricks can be used for the existing building.

2. Structure

Water-retaining roof brick size: 300mm × 300mm × 240mm; the thickness of the air layer between the brick bottom and the roof is 20mm; water depth max: 120mm; roof brick thickness is 20mm; the hole area ratio of 30%. The brick structure is shown as Fig.1

![Fig.1.schematics of the test structure](image)

3. Methodology

3.1 Water-retaining roof brick measuring points

This paper established three groups for comparison for the purpose of studying different forms of water-retaining roof insulation effects. Comparative experiments were as follows:
(1) Water-retaining roof bricks and non-water-retaining roof bricks (h=0cm roof and roof),
(2) Different water depth in water-retaining roof bricks,
(3) Ventilation and without ventilation water-retaining bricks.
Water depth is shown as Fig.2. In order to eliminate the influence of the boundary condition, the brick under measuring was arranged with at least two bricks around it. Measuring points are shown in Fig.3. Note: RTWB=roof temperature with brick, RT=roof temperature, AT=air temperature.
3.2. Test data selection

The experiment started on November 5th 2014 and finished on January 20th 2015. We selected test data from consecutive sunny days: from December 28th 2014 to December 31st; from January 6th 2015 to January 8th; and from January 16th 2015 to January 18th 2015.

3.3. Data collection equipment

Test equipment and operation methods are as follows: For total solar radiation intensity, outdoor wind velocity, outdoor air temperature, and relative humidity of outdoor air testing, we used Mianzhou Sunshine Meteorological Science and Technology Inc., PC-4 type of environment monitoring system to monitor the sensitivity of \( \pm 0.2 \, ^\circ\text{C} \), recorded once per hour. The roof measuring points are shown in Fig. 3. Each measuring point temperature was tested using Shanghai ZhaoJie paperless recorder C6108A, accuracy class \( \pm 0.2\% \, \text{FS} \), and recorded once every 4min. This paper used the hourly data to draw the chart of the trend of temperature changes.

4. Results


In summer, the thermal insulation effect of a water-retaining brick on a rooftop is very obvious, for example, when roof temperature rises to \( 60^\circ\text{C} \) during the daytime, roof temperature under the water-retaining brick is only \( 30^\circ\text{C} \). Similarly, in order to explore the thermal insulation performance between a water-retaining brick and non-water-retaining brick on a top room, we did the contrast experiment. We tested the roof temperature under the bricks with water depth 8mm and 0mm, and recorded the changes of the roof temperature. The test time was from 7 a.m. on December 30th 2014 to 7 a.m. on December 31st 2014. This paper gives the results of the hourly variation of the individual monitoring stations in Fig. 4. Note: AT=air temperature, RT=roof temperature, RTWB=roof temperature with brick.
This paper’s analysis results in the following conclusions:

(1) The average roof temperature under water-retaining brick F (h=12cm) is 6.6°C, the average roof temperature under water-retaining brick A (h=0cm) is 6.2°C, a difference of 0.4°C. So the thermal insulation performance of water-retaining brick full of water is better than an empty water-retaining brick.

(2) From the comparison between the roof temperature under water-retaining brick F (h=12cm) and the roof temperature, it was found that the roof temperature is higher during the daytime (from 8 a.m. to 9 p.m.), but at night the roof temperature is lower than the roof temperature with brick. The roof temperature is lower than the roof temperature with brick because water has a higher heat capacity than air, so water stores heat during the daytime and releases heat at night. Thus, it can preserve heat.

4.2. Influence of different water depths on the thermal insulation performance

In order to compare the influence of water depth on thermal insulation performance, this paper compared the roof temperature under different water depth bricks during teasing and monitored two kinds of data: air temperature, roof temperature with brick. This paper shows the hourly variation of individual monitoring stations in Fig.5.
We can analyze and draw the following conclusions:

(1) The curves of the roof temperature with brick E (h=10cm), D (h=8cm) and F (h=12cm) are similar. But the curve of the roof temperature with brick C (h=6cm), E (h=10cm), D (h=8cm) and F (h=12cm) is inconsistent. So, water depth 8cm is the important datum.

(2) The average roof temperature with brick E (h=10cm), D (h=8cm), C (h=6cm) and F (h=12cm) at night (9:00pm-7:00am) are: 8.4°C, 8.1°C, 7.7°C, and 8.6°C. So the average roof temperature with water depth 12cm is the highest one. With the increase of depth, the changes of roof temperature decreases gradually. Considering the weight of water will impact on the bearing load of roof, so, the water depth of 8cm is the perfect value.

4.3. The influence of ventilation in the air layer of bricks on thermal insulation performance

In order to study the influence of ventilation in the air layer of bricks on thermal insulation performance, this paper carried out some contrast experiments between bricks with ventilation and bricks without ventilation in the air layer. This paper gives the results of the hourly variation of individual monitoring-stations in Fig.6.

![Heat preservation effect of contrast](image)

The conclusions:

(1) Roof temperature using ventilated bricks is lower than non-ventilated roof bricks' temperature at night. In the case of no ventilation in the air layer of water-retaining brick D(h=8cm), roof temperature changes smoothly with the rise of environment temperature, but there is a delay. So the roof temperature changes faster in the case of ventilating.

(2) In the case of ventilating in the air layer of water-retaining bricks and no ventilation in the air layer of water-retaining bricks, their temperature is comparable during daytime and the effect of the thermal insulation is almost the same. The ventilated brick's roof temperature is lower than the non-ventilated brick's roof temperature at night. From what has been discussed above, a ventilated roof brick is not conducive to keeping heat.

5. Discussion

A roof pond is a type of passive system and can be used for both passive heating during winter and passive cooling during summer. The most widely used system employs a shallow pond of water in a thermal contact with a strong but highly conducting flat roof and ceiling structure. In N.M. Nahar’s test structure, the top of the roof is provided with a shallow pond with a 100 mm deep water column and 40 mm thick thermal insulation is provided on the sides and top of the pond. In the summer, during the night, movable thermal insulation is taken out and water is
cooled by nocturnal cooling, a unique feature in arid areas where day temperatures are very high, while night temperatures are very low and the pond is covered with thermal insulation during the day. Heat from the building is transferred to the environment through the tank to the ambient environment, and cooling is obtained. Heat load during the day from the roof has also been minimized by using a roof pond with thermal insulation. It cuts off solar radiation from the roof to the building environment. During winter, movable thermal insulation is taken out during the day so that water in the tank gets heated by solar radiation and the heat of the building. The pond is covered with movable thermal insulation during nighttime so that hot water in the pond transfers heat into the building and the indoor temperature goes up a little.

Artemia Spanaki carried out some research to show that a roof pond with the highest possible cooling efficiency in comparison to the lowest maintenance and inconvenience due to stable water would probably result in a more favorable passive cooling technique. The referred to literature on roof ponds show that, shaded ponds, roof ponds with gunny bags, and ponds with movable insulation and spraying at night seem to have the best efficiency in comparison to conventionally formed ones.

This paper selected three conditions for testing, including water-retaining roof bricks and non-water-retaining roof bricks (h=0cm roof and roof without brick), different depths of water-retaining roof bricks, and water-retaining roof bricks with ventilation and no ventilation. Compared to the work of others, the test results are basically consistent. The results show that: a water-retaining roof brick is more insulated than the non-water-retaining roof brick; when the water depth is 8 cm there is no need to increase the depth of water to increase its insulation effect; Air layers play an important role in roof insulation.

Passive cooling techniques when used in combination with conventional systems for cooling and ventilation can significantly contribute to energy saving in a building. Roof ponds, as an effective passive technique can strongly contribute to energy demand reduction in the building sector.

6. Conclusion

Through the research on the heat retaining effect of lightweight aggregate concrete in winter, the research group is aimed at understanding better its insulating properties to provide the basis to further implement and manage water-retaining roofs. The following conclusions are based on the analysis of the measured data:

(1) The results of the test of the water-retaining bricks on the roofs in winter show that the water-retaining bricks on the roofs have certain heat retaining effects in winter.

(2) The insulating effect in winter is best achieved when the water depth is 8cm.

(3) Ventilating can change the temperature on the roofs quickly. Compared with the ventilated roofs, the temperature on the non-ventilated roofs is higher, and it helps keep warmth on roofs in winter.

So we can lay water-retaining bricks on roof to improve the roof thermal insulation performance leading to energy savings in existing buildings.

Acknowledgments

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References


