The change in mass of insulating materials in the Vietnamese climate conditions

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Abstract. In article obtained in laboratory experiments, water absorption characteristics and evaporation of water from the insulation materials to determine their weight change in tropical climates with the following characteristics: high temperature and humidity, a large number of medium and monthly rainfall seasonal rains lasting 6 months. Thus, the obtained results may be used to repair wall enclosing parts in the Vietnam construction industry. The characteristics of waterproof, moisture resistance, water evaporation, biological stability in insulation materials, which are used in the thermal protection of buildings in Russia and in the world. Evaluation experiments were performed on the characteristics of water absorption and water evaporation of heat-insulating materials (mineral wool, polyfoam, extruded polystyrene) in the laboratory in three situations: the location of samples on the surface of the water, drowning of samples in water and evaporation water from water-saturated samples. These tests simulate the impact of rainfall on the insulation material and evaporation of water from the insulation material during a certain time period (e.g., during assembly or during operation, when the protective layer is damaged). The experimental results show the dependence of saturation insulation from direct contact with water in his drowning conditions and arrangement of heat-insulating materials on the water surface. In addition, the rate of evaporation of water in the water depends on the amount of thermal insulation material and its characteristics. Based on the results of such experiments, it is possible to make a choice of types of insulating materials suitable for Vietnamese climatic conditions.

1. Introduction
From the point of view of natural and climatic conditions, the territory of Vietnam is divided into two parts, including 7 climatic subareas (North: IA, IB, IC, ID and South: IIA, IIB, IIC) with the following characteristics [1, 2]:

In the northern part in the summer season, the average temperature is in the range of 24.6°÷28.8°C and the average relative humidity is 81÷85%. And in the winter seasons 16.6÷23.5°C and 81÷88%. Especially in the summer, in the middle of the day, under the influence of solar energy, the temperature of the medium rises to 35÷45°C, and at night it drops to 25÷28°C. Relative humidity changes in a similar way: it drops to 35÷65% during the day, and rises to 75÷95% at night. In addition, seasonal rain lasts six months with an average monthly rainfall of 123÷323 mm. And in the southern part, the climate is divided into the rainy season and the relatively dry season. In both seasons, the average temperature is 25.7°÷28.8°C, the average relative humidity is 73÷88% and the seasonal rain lasts 6 months with an average monthly rainfall of 221÷338 mm.
The investigations have shown that air temperature depends on the location of the sun, solar radiation, building density; due to which the temperature in the city is usually 2÷3°C higher than in rural areas. In Hanoi, the average surface temperature of the structure is in the range of 45÷54°C (concrete external walls over 45°C and asphalt pavement 54°C) [3, 4, 5, 6, 7].

The analysis has showed that the insulation of buildings - it's an urgent problem not only in Russia and Vietnam, but also a big problem in the world in terms of global climate change, the earth warms up, fossil energy sources are reduced. Currently, the materials used for external thermal insulation of the walls of buildings [9, 10, 11, 12] are as follows:

- bulk insulation - vermiculite, perlite and expanded clay gravel;
- mineral wool (teklovata or basalt fiber);
- ecowool;
- insulation - foamed polymers (polyfoam, penozol, extruded polystyrene, penopololiuretan).

When choosing a heat-insulating material, the main role is played by its technical characteristics [8]. There are many different indicators for materials that somehow affect the choice of material: thermal conductivity, moisture permeability, fire resistance, durability, profitability, environmental friendliness, material thickness, ease and ease of installation.

However, at present, in the process of selecting and using heat-insulating materials for exterior walls, only the following properties are taken care of: thermal conductivity, material thickness, fire resistance, profitability, environmental friendliness ... but are not yet interested in the characteristics of water absorption and evaporation of water, especially when heat-insulating material is used in climatic conditions of hot and humid air, a large amount of precipitation and a long rainy season.

Thus, the author has chosen the investigations of the characteristics of water absorption and evaporation of water from the insulation material used for outdoor fencing, with several samples of popular insulation (mineral wool, polyfoam, extruded polystyrene) under conditions of drowning in water, location on the surface of water and evaporation of water from the sample, for simulating the effect of precipitation on the insulating material during assembly or during operation when the protective layer is damaged.

2. Materials and Methods

2.1. Object of study
To determine the ability of water absorption and evaporation of water from the insulation material, experiments were carried out with three insulation materials: polyfoam, extruded polystyrene and mineral wool. Their characteristics are shown below [17, 18, 19].

Mineral wool slab is made of stone wool based on rocks of the basalt group according to GOST 9573-2012 with the following technical characteristics: density 90÷150 kg/m³, thermal conductivity 0.036÷0.038 W/(m.°C), dimensions (LxWxH) 100x60x10cm [13, 14, 16].

Extruded polystyrene has the following technical characteristics: density 26÷33 kg/m³, thermal conductivity 0.029 W/(m.°C), dimensions (LxWxH) 100x60x5cm [15].

The polyfoam plate has the following technical characteristics: density up to 10 kg/m³, thermal conductivity 0.049 W/(m.°C), dimensions (LxWxH) 100x60x5cm [17].

2.2. Experiment content
In order to study the water absorption and evaporation of water from the insulation material in a hot humid climate, a long rainy season and a monthly average high rainfall, the experiment is divided into three stages:

The first stage: the insulation material is superimposed on the surface of the water as in a figure 1.
In the laboratory, for the experiment, a tank of water with a size of 70x55x25cm is used. Material samples are superimposed in the tank and tested for a month.

The second stage: the insulation material is immersed in water, as in a figure 2.

As in the first stage of the experiment, a water tank is used to immerse the samples. The second stage of the experiment also takes place within a month.

The third stage: the evaporation of water from the material of the insulation of water saturation, as in a figure 3.

When the second stage is over, water-saturated samples of materials are presented to the third stage of the experiment on the evaporation of water. The third stage of the experiment also takes place within a month in the laboratory.

2.3. Test method
For the first and second phase of the experiment using three samples with a size 15x15x5cm polyfoam and extruded polystyrene, mineral wool size 15x15x10cm to ensure accurate results. At the beginning of the experiment, the mass of materials is analyzed hourly for 6 hours. Then the mass of materials is determined daily for 30 days. According to the results of measuring the mass of materials calculate the degree of increase in mass of the material according to the formula [20]:

\[ k = \frac{m-m_0}{m_0} \times 100\% \]  

(1)
where \( m \) is the mass of the sample after keeping it in water, g; 
\( m_i \) is the mass of the sample before immersion in water, g; 
k is the degree of increase in mass, \%.

For the third stage of the experiment, three samples of water-saturated material from the second stage are used. At the beginning of the experiment, the mass of materials is analyzed hourly for 6 hours. Then the mass of materials is determined daily for 30 days. According to the results of measuring the mass of materials, the degree of reduction in the mass of water-saturated insulation material is calculated according to the formula:

\[
z = \frac{m - m_i}{m'} \cdot 100\%
\]  

where \( m' \) is the mass of the water-saturated sample before the start of the evaporation experiment, g; 
\( m_i \) - the mass of the sample during evaporation, g; 
z is the degree of reduction in mass of water-saturated insulation, \%.

3. Results

3.1. First stage
The increase in mass of the insulation material in direct contact with the surface of the water is shown in the graphs of figure 4.

![Figure 4](image.png)

- sample weight before the experiment
- PSB – polyfoam
- XPS – extruded polystyrene
- MW – mineral wool

**Figure 4.** The increase in the mass of the insulation material in direct contact with the surface of the water for 30 days (A)

During a 30-day measurement, the degree of increase in the weight of the polyfoam reaches 98÷102\% by weight, like that of mineral wool. The degree of increase in the mass of expanded polystyrene reaches a maximum value of 15÷16\% after 16 days and stabilizes in the range of 13÷15\% in the remaining time of the experiment.

3.2. Second stage
According to these graphs on fig. 5, the insulation drowning in water, their weight has increased strongly in the first 6 hours from the start of the experiment: to polyfoam - 700% by weight, and mineral wool - 900% by weight.

However, for expanded polystyrene, the degree of increase in mass is stabilized in the range of 14÷17% for 6 hours from the start of the experiment and in the range of 30÷35% for 1 month from the start of the experiment.

Basicly, the process of increasing mass is described by the equations:

Table 1. Mathematical equations of the change in mass of insulation materials.

| Experiment | Material       | Equalization               | $R^2$   |
|------------|----------------|----------------------------|---------|
| A          | Polyfoam       | $y = 0.2342\ln(x) + 14.35$ | 0.5102  |
|            | Extruded polystyrene | $y = 0.1086\ln(x) + 27.983$ | 0.4238  |
|            | Mineral wool   | $y = 1.4309\ln(x) + 119.7$ | 0.2003  |
| B          | Polyfoam       | $y = 2.4432\ln(x) + 80.319$ | 0.9272  |
|            | Extruded polystyrene | $y = 0.4044\ln(x) + 36.324$ | 0.6932  |
|            | Mineral wool   | $y = 42.43\ln(x) + 1334.7$  | 0.7863  |

3.3. Third stage

Reducing the weight of water-saturated insulation material in the process of water evaporation in the laboratory, with an average temperature of 23.10°C and average relative humidity 42.37%, is shown in the graph figure 6.
According to the results of experiment 3, we can say that the process of reducing the mass of water-saturated materials is divided into two periods: in the first period, their mass decreases depending on the characteristics of the material. After that, the mass of materials stabilizes - this is the second period.

For polyfoam and extruded polystyrene, the process of reducing the mass of water-saturated samples occurs in the first 4-5 days. In addition, the mass of material in the stabilized period of the 3rd experiment is always greater than the mass before the 1st experiment - (0.15±2) % by mass, because the dust sags on the surface of the material sample (Fig. 7).

However, for mineral wool, the first period of the 3rd experiment occurs within 15-17 days and the mass of the material decreases to the mass of the sample until the 1st experiment due to the fact that mineral wool decomposes in water (Fig. 8), and the mass of materials as a result lower than the initial value - (1.0÷1.2)% by weight.

Basically, the process of reducing the mass of water-saturated insulation is described by the equations:

**Table 2.** Mathematical equations of the change in mass of insulation materials.

| Material         | Phase | Equalization | \( R^2 \)   |
|------------------|-------|--------------|-------------|
| Polyfoam         | 1     | \( y = -2.422\ln(x) + 15.339 \) | 0.9699      |
|                  | 2     | \( y = -2.422\ln(x) + 15.339 \) | 0.9699      |
| Extruded polystyrene | 1    | \( y = -0.193\ln(x) + 32.3 \)   | 0.8106      |
|                  | 2     | \( y = -0.392\ln(x) + 26.101 \) | 0.9713      |
| Mineral wool     | 1     | \( y = 1243e^{-0.14x} \)         | 0.973       |
|                  | 2     | \( y = -0.0074x + 99.838 \)      | 4E-05       |
4. Conclusion and discussion

An analysis result of experiment 1 and 2 has showed that by direct contact with water (at the surface and drowning) of insulation material mass increases. The process of increasing their mass depends on the characteristics of the materials, the level of flooding with water and the time of the experiment. In addition, experiment 3 has showed a change in the mass of materials with a comparison with the initial value before drowning and after drying. Thus, the choice of insulation material in construction is very important and directly depends on the climate of the construction site.

Under a hot and humid climate, the duration of the rainy season and a large amount of rainfall, the using of polyfoam and mineral wool in the structure entails the retention of water in the wall, and also an increase in mass, load on the building, and reduces the durability of the materials of wall fencing. Thus, the using of expanded polystyrene in construction is accordingly preferable to polyfoam and mineral wool under the Vietnam tropical climate conditions.

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