The research of moisture sorption characteristics in mineral wool under the Vietnamese climate conditions

Tien Nam Nguyen and Petr Grabovy
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia
E-mail: nam.itse@gmail.com, osun_kaf@mgsu.ru

Abstract. The article discusses the characteristics of the sorption wet steam of mineral wool in laboratory experiments, necessary to determine the change in its mass in conditions of high humidity of the environment, already a country with a tropical climate. The results can be used in new construction and renovation of facades of buildings in Vietnam. A feature of the application of thermal insulation materials in the system of thermal insulation of facades of buildings in different climatic conditions is a factor in the durability of the materials, etc. The climatic conditions of Vietnam have significant features such as high average temperatures, humidity, rainfall, and a long rainy season. These parameters affect the durability and thermal insulation qualities of materials in the thermal insulation system of building facades. The characteristics of moisture resistance of mineral wool, which are used in the systems of ventilated facade construction for thermal protection of buildings in the world in Russia, are considered. In the laboratory evaluation experiments made mineral wool sorption characteristics: extract samples under direct contact with different degrees of relative humidity for a month. This test simulates the effects of a tropical climate in the mineral wool in assembly or during operation, when the protective layer is damaged. The result of the experiment shows the dependence of the degree of sorption of humid vapors of mineral wool on the value of the humidity of the air environment and the time of its direct contact with humid air. According to the results of such experiments can make the choice of building types and technologies insulating materials suitable for the climatic conditions of the Vietnamese during the repair and construction works.

1. Introduction
In recent years, in Russia and Europe, reconstruction work of the facades of residential buildings has been carried out in order to improve the quality of life of the population and the efficiency of energy use by two groups of the system of thermal insulation of the facades below [1-3]:
- Group No.1: facade insulation systems of plaster type (Fig. 1);
- Group No.2: hinged systems for thermal insulation of facades with an air gap (hinged ventilated facade systems) (Fig. 2).
At present, the following materials are used for external thermal insulation of building walls [4-7]:
- bulk insulation - vermiculite, perlite and expanded clay gravel;
- mineral wool (basalt fiber or glass wool);
- ecowool;
- insulation - foamed polymers (polyfoam, penoizol, extruded polystyrene, polyurethane foam).

Mineral wool, polystyrene foam and expanded polystyrene had the following noticeable advantages: low thermal conductivity, does not mean more material thickness, durability, fire resistance, efficiency, environmental friendliness, ease and ease of installation [8]. However, it does not take into account the characteristics as the water absorption and moisture absorption. These characteristics not only affect the durability and technological installation, but reduces the insulating quality of the material. It is known that the thermal conductivity of water is 25 times higher than the thermal conductivity of air.

The results of the study have shown that such characteristics as water absorption and water evaporation of materials (mineral wool, foam and expanded polystyrene) in direct contact with water depend on the characteristics of the materials, the level of water flooding (on the surface and drowning) and time. With empty structures of heat-insulating materials, the amount of water absorption in mineral wool compared to foam and expanded polystyrene is more than 6 times and 14 times more with direct contact on the surface, and, accordingly, 17 times and 108 times when drowning in water [9, 10].

Thus, for the heat insulating materials is not taken into account avoided by dehumidification, especially under conditions of heated air, high humidity, a large amount of precipitation and prolonged rain season such as country Vietnam.

The natural and climatic conditions of the territory of Vietnam are divided into two parts: northern (I_A, I_B, I_C, I_D) and southern (II_A, II_B, II_C) with the following noticeable characteristics.

In the northern part in the summer, the average temperature is in the range of 24.6 – 28.8 °C, and the average relative humidity is 81 – 85 %, but in the middle of the day, under the influence of solar energy, the temperature reaches 35 – 45 °C, and the average temperature the surface of the structure is reached within 45 – 54 °C (concrete outer walls - more than 45 °C, asphalt street pavement 54 °C) in large cities. In the winter season, these parameters fluctuate between 16.6 – 23.5 °C and 81 – 88 %. In addition, the period of seasonal rains lasts six months with an average monthly precipitation of 123 – 323 mm [11-13].

In the southern part of the country, climatic conditions can be divided into a rainy season and a relatively dry season. During both seasons average temperature is 25.7 – 28.8 °C, average relative humidity 73 – 88 %, during the rainy season lasts 6 months with monthly rainfall of 221 – 338 mm.
For the study, we chose the characteristics of moisture absorption of mineral wool used for external fencing in the hinged system of thermal insulation of facades with an air gap (Fig. 2). To simulate the exposure to high humidity for a heat insulation material during assembly or during operation, when the protective layer is damaged, the tests were conducted in conditions of high humidity with the limit of 70 – 100%.

2. Materials and Methods

2.1. Object of study

To determine the ability of mineral wool to absorb moisture in conditions of direct contact with a high humidity environment, experiments were carried out with a humidity condition varying in the range of 70 – 100%. Its characteristics are presented below [14-16].

Mineral wool is made from stone wool based on rocks of the basalt group in accordance with GOST 9573-2012. The experimental sample (plate) had the following technical characteristics: density 90 – 150 kg/m³, thermal conductivity 0.036 - 0.038 W/(m.°C), dimensions (L × W × T) - 100 × 60 × 10 cm [17-19].

2.2. Content of the experiment

In order to study the mineral wool moisture absorption in a hot and humid climate changing humidity in the range of 70 – 100% experiment was divided into six periods of the same range of 5% and a water retention in the laboratory model in Fig. 3.

![Figure 3. Experiment scheme](image)

In the laboratory, samples of materials were dried in a drying cabinet "E-28" (Fig. 4) with a temperature of 105 °C for two hours, then the samples were placed in a cabinet with a medium without air for 4 hours. Samples of materials with a specific weight of 0% humidity, laboratory model was then used with the size 65 × 40 × 30 cm on the test period for one month period air humidity (70–75 %, 75–80 %, 80–85 %, 85–90 %; 90–95 %; 95–100 %).
2.3. Test method
In each period of the experiment to ensure accuracy of results for three samples used mineral wool size of $15 \times 15 \times 10$ cm. Assayed change material weight daily for one month. The results of measurements performed calculation of degree of weight gain material $k, \%$, according to the formula [20]:

$$k = \frac{m-m_0}{m_0} \times 100$$

where $m$ is the mass of the sample after sorption moisture content, g; $m_0$ is the mass of the dry sample, g.

3. Results
The increase in the mass of mineral wool at sorption humidity with different humidity is shown in the graph in Figure 5.

![Figure 5. Increase in the mass of mineral wool in conditions of high air humidity](image-url)
Mineral wool absorbs the humidity of the air and its mass increases to a value of 2.5 – 3 % by dry mass. This process directly depends on the degree of humidity and time, mainly the increase in the mass of the material can be divided into two periods.

In the first period, the amount of wet steam is absorbed quite strongly and reaches its maximum value. The course of the first period occurs for 13 – 24 days and is inversely proportional to the humidity of the environment. With the beginning of 24 hours of the experiment, the mass of the material increases by 0.35 – 0.95 % by dry weight. In addition, the mass of the material at this point in time is 15 – 30 % by the amount of wet steam.

In the second period, when the concentration of vapor in mineral wool reaches the maximum saturation value, the degree of increase in weight of the material tends to zero. According to the results of experimental, \( \Delta \)-mass depends on the humidity of the environment.

From the beginning of the experiment, the value of \( \Delta \)-mass reaches maximum from 0.31 – 0.82 g for 1–2 days, after that it decreases by time and approaches to zero. Under the condition of increasing the humidity of the environment, the rate of \( \Delta \)-mass raise greatly and their duration of reaching the maximum value decreases.

With the mathematical description, specific rate of moisture sorption in mineral wool by time is defined by polynomial function of degree 6. In particular, coefficient of the 6th degree decreases 200 – 250 times when the humidity raise from 70% to 100%. Therefore, Coefficient of determination (R^2) of these mathematical equations has been showed that, the process of sorption of moisture sorption in mineral wool by time is more stable while increasing the humidity of the environment.

In general, the process of increasing weight of the mineral wool in contact with humid air environment is described by tabulated. 1.
### Table 1. Mathematical equations of the change in mass of insulation materials.

| Phase | Equalization | $R^2$  |
|-------|--------------|--------|
| 95 — 100% | $y = -5E-05x^6 + 0.002x^5 - 0.0332x^4 + 0.2552x^3 - 0.9285x^2 + 1.2938x + 0.0478$ | 0.7968 |
| 90 — 95% | $y = -1E-05x^6 + 0.0007x^5 - 0.0124x^4 + 0.1109x^3 - 0.4693x^2 + 0.7691x + 0.0551$ | 0.7470 |
| 85 — 90% | $y = -4E-06x^6 + 0.0002x^5 - 0.0052x^4 + 0.2508x^3 + 0.4728x + 0.0597$ | 0.7071 |
| 80 — 85% | $y = -2E-06x^6 + 0.0001x^5 - 0.0024x^4 + 0.0269x^3 - 0.143x^2 + 0.3012x + 0.0599$ | 0.6594 |
| 75 — 80% | $y = -1E-05x^6 + 7E-05x^5 - 0.0017x^4 + 0.0203x^3 - 0.1145x^2 + 0.2559x + 0.0551$ | 0.6687 |
| 70 — 75% | $y = -2E-07x^6 + 2E-05x^5 - 0.0006x^4 + 0.0081x^3 - 0.0551x^2 + 0.1489x + 0.0623$ | 0.6926 |

### 4. Conclusion and discussion

Analysis of the experimental results have shown that the direct contact of high moisture mineral wool mass are increased. The process of increasing its mass depends on the air humidity and the time of the experiment.

In the climate conditions of high humidity, the use of mineral wool construction increased weight load of the building, i.e., the durability and quality of thermal insulation materials are reduced. Thus, mineral wool must be protected from moisture for use in thermal insulation system facades of buildings in climatic zones of the territory is very important for the conditions of high humidity Vietnam air.

### References

[1] Zarubina L P 2012 *Thermal insulation of buildings and structures. materials and technologies* (Sankt – Petersburg: BHV – Petersburg) p 408.
[2] Gosstroy of Russia 2004 *Facade insulation systems with an air gap. Recommendations on the composition and content of documents and materials submitted for the technical assessment of the suitability of products* (Moscow: Russian Federation) p 109.
[3] Zorin R N, Levkin V V 2012 Scientific Bulletin of VGASU. Materials of the 15th interregional scientific and practical conference “High technologies. Ecology” Review of existing design solutions for external enclosing structures in frame housing construction (Voronezh - Russian Federation) p 86-89.
[4] Kravchenko K S and Segaev I N 2018 Analysis of insulation during thermal insulation of buildings and structures *Scientific and practical electronic journal Science Alley. No4 (20).*
[5] Ilyasov T I and Smorodova O V 2018 April 2017 Thermal insulation of walls of buildings *Collection of articles of the international scientific-practical conference “New information technologies in science”*, Part 3 p 74-78.
[6] Gafurova G R and Smorodova O V 2017 February 2017 Thermal protective properties of building outer fences *Collection of articles of the international scientific and practical conference “Modern conditions for the interaction of science and technology”*, Part 1 p 33-36.
[7] Dalabaeva A G, Seytkozhina M S, Kibatollaeva A A and Smorodova O V 2017 Thermal insulation of the exterior walls of buildings *Scientific and Practical Electronic Journal Alley of Science, No.6.*
[8] Kitaev S V, Smorodova O V and Useev N F 2016 On the energy sector of Russia *Problems of the collection, preparation and transport of oil and oil products. No.4 (106)* p 241-249.
[9] Tien Nam Nguyen, Grabovoy P G 2020 The magazine “Real Estate: Economics, Management” Study of the characteristics of water absorption of the insulation material used for the repair of external wall fencing of buildings in Vietnam. *No.2* p 55-65.
[10] Tien Nam Nguyen, Grabovoy P G 2020 Form-2020 IOP Conf. Series: Materials Science and Engineering 869 (2020) 052026 The change in mass of insulating materials in the Vietnamese climate. IOP Publishing doi:10.1088/1757-899X/869/5/052026.

[11] QCVN 2009 QCVN 02:2009/BXD Vietnam Building Code, Natural Physical & Climatic Data for Construction. (Hanoi: Viet Nam).

[12] TCVN 1997 TCVN 4088:1997 Climatic data for design in construction (Hanoi: Construction Publishing House).

[13] Nguyen V Ch, Nguyen B D, Le K H, Ngo D N, Hoang H T and Nguyen H T 1986 Architecture and tropical climate in Vietnam (Hanoi: Construction Publishing House) p 246

[14] GOST 2011 GOST 1609-2011 Thermal insulation products used in construction. methods for determining water absorption during short-term partial immersion. (Moscow: Russian Federation).

[15] SP 2012 The code of rules SP 50.13330.2012 “Thermal protection of buildings”. (Moscow: Russian Federation).

[16] GOST 2011 GOST 31913-2011 Heat-insulating materials and products. Terms and Definitions. (Moscow: Russian Federation).

[17] GOST 2012 GOST 9573-2012 Mineral wool slabs on synthetic binder heat-insulating. Technical conditions. (Moscow: Russian Federation).

[18] Smorodova O V 2016 Problems of evaluating the efficiency of heat consumption based on the results of a thermal imaging survey Innovation Science, No. 4-3 p 147-151.

[19] GOST 1994 GOST 17177-94 Heat-insulating materials and products. Test methods. (Moscow: Russian Federation).

[20] B. Stefanczyk and others 2007 “General building engineering Volume I. Construction materials and products”, Arkady (Budownictwo ogólne Tom I. Materiały I wyroby budowlane).