Study on the Properties of Rock Wool for External Thermal Insulation of Buildings under the Soaking and Hot & Humid Conditions

Guozhong Lu
Beijing Building Materials Academy of Sciences Research Co., Ltd, State key Laboratory of Solid Waste Resource Utilization and Energy-Saving Building Materials, No.69 North Road Jinding Street of Shijingshan District, Beijing, China 100041.
Email: luguozhong@163.com

Abstract. In this paper, the tensile strength, moisture absorption, thermal conductivity, moisture permeability and other properties of rock wool under different humid and hot conditions are studied, and the law of rock wool performance changing with different humid and hot conditions is analyzed. The test shows that rock wool has good resistance to humidity and heat and durability and can be widely used in various construction projects. The test data can provide a reference for the better application of rock wool in engineering.

1. Introduction
Rock wool as thermal insulation material is widely used in construction, ship, power, industry and other fields. As a high-quality and efficient thermal insulation material, rock wool has good thermal insulation, sound insulation and absorption performance. Compared with traditional thermal insulation materials, rock wool and its products have the advantages of light weight, small thermal conductivity, non-combustion, fire prevention and non-toxicity, wide application range, stable chemical performance, long service life, etc.

Rock wool strip is a form of rock wool board. Due to the change of direction of rock wool fiber, it not only has the excellent performance of fire prevention, heat preservation, heat insulation and sound absorption of rock wool board, but also has greatly improved its tensile strength and compressive strength[1-3]. The normal rock wool board is parallel to the rock wool board surface structure, while the fiber direction of the rock wool strip is perpendicular to the board surface, so it has stronger tensile strength and compressive strength, and has higher safety factor for external wall insulation[4]. In this paper, the change of tensile strength, moisture absorption, thermal conductivity, moisture permeability and other properties of rock wool under different humidity and other conditions are studied, and the test results are analyzed. The law of rock wool performance changing with different humid and heat conditions is obtained, which proves that rock wool has good resistance to humidity and heat and durability. The research can provide a reference for rock wool better application in engineering.

2. Test

2.1. Test Materials
Rock wool board and rock wool strip are produced by Beijing Jinyu Energy Saving and Heat Preservation Technology Co., Ltd.
2.2. Instrument and Equipment

(1) Constant temperature and humidity test chamber, model DHS-100, produced by Beijing Yashilin Test Equipment Co., Ltd.

(2) Heat conduction instrument, model HFM-436, produced by Germany Netzsch Instruments Manufacturing Co., Ltd.

(3) Electronic universal testing machine, model WDW-1, produced by Shanghai Songdun Mechanical Equipment Co., Ltd.

(4) Electronic balance, model JA 4100g/0.01g, produced by Shanghai Binglin Electronic Technology Co., Ltd.

(5) Water vapor moisture permeability tester, model W3/030, produced by Jinan Labthink Electromechanical Technology Co., Ltd.

2.3. Test Method

(1) Thermal conductivity test shall be carried out in accordance with Rock Wool, Slag Wool and it’s Products for Thermal Insulation (GB/T 11835—2016).

(2) The tensile strength perpendicular to the board surface shall be carried out in accordance with Rock Wool Products for Exterior Insulation and Finish Systems (GB/T 25975—2018).

(3) The specific moisture absorption of quality shall be tested in accordance with the Test Methods for Mineral Wool and its Products (GB/T 5480-2017)

(4) Water absorption shall be tested in accordance with the Test Method for Hydrophobic Nature of Thermal Insulation (GB/T 10299-2011)

2.4. Test Design

In order to better study the different properties of rock wool under the soaking and humid and hot conditions, a series of tests were designed. The test samples and control samples respectively include rock wool bare strip 1 and 2, and mortar composite rock wool strip 1 and 2. The samples were prepared according to the requirements and the preliminary treatment process under different conditions was carried out. See Table 1 for details.

| Table 1. Performance test design of rock wool strip under humid and hot conditions |
|---------------------------------------------------------------|
| **Type of sample**                                      | **Sample preparation requirements** | **Number of samples prepared** | **Test items**                                | **Preliminary treatment conditions** |
|---------------------------------------------------------------|
| Bare strip 1                                             | -                                  | 150mm×150mm 3 pieces           | Tensile strength                             | 1.70℃, 30% relative humidity, 7d; |
| Bare strip 2                                             | -                                  | 300mm×150mm 2 pieces           | Moisture absorption                         | 2.70℃, 60% relative humidity, 7d; |
| Mortar composite Rock wool strip 1                       | Two major surfaces are plastered with 1mm thick plastering mortar, and all around are exposed | 150mm×150mm 3 pieces           | Thermal conductivity                         | 3.70℃, 95% relative humidity, 7d. |
| Mortar composite Rock wool strip 2                       | Two major surfaces are plastered with 1mm thick plastering mortar, and all around are exposed | 300mm×150mm 2 pieces           | Moisture absorption                         |                                    |
| Mortar composite Rock wool strip 1                       | The same as test sample             | The same as test sample         |                                             |                                    |
| Mortar composite Rock wool strip 2                       | The same as test sample             | The same as test sample         |                                             |                                    |
| Bare strip 1                                             |                                    |                               |                                             |                                    |
| Bare strip 2                                             |                                    |                               |                                             |                                    |
| Control sample                                          |                                    |                               |                                             | Laboratory layout                  |
3. Test Result and Analysis
According to the test design, the performance of different samples were tested and analyzed.

3.1. Relationship between Moisture Absorption and Humidity of Rock Wool
The data line chart of moisture absorption rate of rock wool bare strip and mortar composite rock wool strip under different humidity is shown in Figure 1. It can be seen from Figure 1 that the moisture absorption rate of rock wool is the highest when it is left standing in the test room for 7 days. At this time, the moisture absorption rate of rock wool bare strip is 0.48% which is less than the moisture absorption rate 0.60% of mortar composite rock wool strip. In the case of rock wool in the state of bare strip, the mass absorption rate increases with the increase of relative humidity. The mortar composite rock wool strip is in a stable state when the relative humidity is within 30% ~ 60%, and it is in a straight line rising stage after the relative humidity is larger than 60%, but in the environment of nearly 95%, it shows a sharp downward trend. It shows that the moisture absorption rate of rock wool strip is higher under normal humidity.

Figure 1. Line chart for the moisture absorption of rock wool bare strip and mortar composite rock wool strip under different humidity

3.2. Relationship between thermal conductivity and humidity of rock wool
Figure 2 shows the data line chart of thermal conductivity of rock wool strip under different humidity. It can be seen from Figure 2 that the thermal conductivity of rock wool strip is the largest in the 70℃ and 30% humidity environment, which is 0.0446 W/(m·K); the thermal conductivity is the smallest in the 70℃ and 60% humidity environment, which is 0.0398 W/(m·K). The thermal conductivity of each sample is not more than 0.045 W/(m·K). With the increase of relative humidity, the thermal conductivity of rock wool strip first decreases and then increases. When the humidity increases to a certain extent, it is in a stable state, indicating that the change of external environment humidity has a certain impact on the thermal conductivity of rock wool.
3.3. Relationship between Tensile Strength and Humidity of Rock Wool

The data line chart of the tensile strength of rock wool bare strip and mortar composite rock wool strip under different humidity is shown in Figure 3. It can be seen from Figure 3 that under the same environment, the average tensile strength of the mortar composite rock wool strip is lower than that of the rock wool bare strip, and the average tensile strength of mortar composite rock wool strip reaches the maximum value of 0.12MPa in the 70 ℃ and 30% humidity environment. With the increase of humidity, the strength decreases. The average tensile strength of rock wool bare strip also decreases with the increase of humidity, and it reaches the minimum value of 0.19MPa in the 70 ℃ and 95% humidity environment, which indicates that the external humidity and heat conditions have certain influence on the tensile strength of rock wool bare strip and mortar composite rock wool strip.
3.4. Moisture permeability test of rock wool

See table 2-5 for the test results of moisture permeability of various materials such as rock wool strip, and then compare and analyze the test results.

### Table 2. Moisture permeability of board

| Material                  | Thickness (mm) | Moisture permeability [g/(m·s·Pa)] | Moisture permeability coefficient [g/(m·s·Pa)] | Permeability resistance (m²·s·Pa/g) | (m²·s·Pa/ng) |
|---------------------------|----------------|-------------------------------------|-----------------------------------------------|-------------------------------------|-------------|
| Rock wool                 | 50             | $3.6 \times 10^{-8}$                | $7.2 \times 10^{-7}$                          | $1.39 \times 10^{-6}$               | $0.39 \times 10^{-6}$ |
| Rock wool strip           | 50             | $5.5 \times 10^{-8}$                | $11 \times 10^{-7}$                           | $9.1 \times 10^{-6}$                | $0.25 \times 10^{-6}$ |
| Glass wool                | 50             | $4.5 \times 10^{-8}$                | $9 \times 10^{-7}$                            | $1.11 \times 10^{-6}$               | $0.31 \times 10^{-6}$ |
| Pleated glass wool        | 50             | $5.2 \times 10^{-8}$                | $10.4 \times 10^{-7}$                         | $9.6 \times 10^{-6}$                | $0.27 \times 10^{-6}$ |
| Phenolic Foam Board       | 50             | $1.69 \times 10^{-8}$               | $3.38 \times 10^{-7}$                         | $2.95 \times 10^{-6}$               | $0.82 \times 10^{-6}$ |
| Polyurethane board        | 50             | $0.16 \times 10^{-8}$               | $0.32 \times 10^{-7}$                         | $31.25 \times 10^{-6}$              | $8.69 \times 10^{-6}$ |
| Polystyrene board         | 50             | $0.52 \times 10^{-8}$               | $1.04 \times 10^{-7}$                         | $9.62 \times 10^{-6}$               | $2.67 \times 10^{-6}$ |
| Plastic extruded board    | 60             | $0.27 \times 10^{-8}$               | $0.45 \times 10^{-7}$                         | $22.22 \times 10^{-6}$              | $6.18 \times 10^{-6}$ |

Note: $1 \mu g=10^{-11}$g, $1h=3600s$, so $1m^2·s·Pa/g=2.78×10^{-1}$m²·h·Pa/ng.

### Table 3. Moisture permeability of facing materials

| Material               | Wet flow density [g/(m²·h)] | Thickness (mm) | Moisture permeability coefficient [g/(m·s·Pa)] | Moisture permeability [g/(m²·s·Pa)] | Permeability resistance (m²·s·Pa/g) | (m²·s·Pa/ng) |
|------------------------|-----------------------------|----------------|-----------------------------------------------|-------------------------------------|-------------------------------------|-------------|
| Powdered color mortar  | 1                           | 4.23           | $0.066 \times 10^{-8}$                        | $2.78 \times 10^{-7}$               | $3.60 \times 10^{-6}$               | $1 \times 10^{-6}$ |
|                        | 2                           | 4.48           | $0.063 \times 10^{-8}$                        | $2.78 \times 10^{-7}$               | $3.60 \times 10^{-6}$               | $1 \times 10^{-6}$ |
| Granite like coating   | 1                           | 0.30           | $0.001 \times 10^{-8}$                        | $0.16 \times 10^{-7}$               | $61.15 \times 10^{-6}$              | $17 \times 10^{-6}$ |
|                        | 2                           | 0.37           | $0.002 \times 10^{-8}$                        | $0.20 \times 10^{-7}$               | $50.36 \times 10^{-6}$              | $14 \times 10^{-6}$ |
| Paste color mortar     | 1                           | 0.84           | $0.006 \times 10^{-8}$                        | $0.46 \times 10^{-7}$               | $21.58 \times 10^{-6}$              | $6 \times 10^{-6}$ |
|                        | 2                           | 0.76           | $0.006 \times 10^{-8}$                        | $0.39 \times 10^{-7}$               | $25.18 \times 10^{-6}$              | $7 \times 10^{-6}$ |
| Lacquer                | 1                           | 2.91           | $0.034 \times 10^{-8}$                        | $1.63 \times 10^{-7}$               | $6.12 \times 10^{-6}$               | $1.7 \times 10^{-6}$ |
|                        | 2                           | 3.13           | $0.035 \times 10^{-8}$                        | $1.74 \times 10^{-7}$               | $5.76 \times 10^{-6}$               | $1.6 \times 10^{-6}$ |
| Flat coating           | 1                           | 0.50           | $0.001 \times 10^{-8}$                        | $0.28 \times 10^{-7}$               | $35.97 \times 10^{-6}$              | $10 \times 10^{-6}$ |

### Table 4. Test results of moisture permeability of facing materials

| Material               | Water vapor permeability [g/(m²·h)] | Thickness (mm) | Moisture permeability coefficient [g/(m·s·Pa)] | Moisture permeability [g/(m²·s·Pa)] | Permeability resistance (m²·s·Pa/g) | (m²·s·Pa/ng) |
|------------------------|--------------------------------------|----------------|-----------------------------------------------|-------------------------------------|-------------------------------------|-------------|
| Elastic coatings       | 11.82                                | 0.51           | $0.026 \times 10^{-8}$                        | $5.10 \times 10^{-7}$               | $1.96 \times 10^{-6}$               | $0.54 \times 10^{-6}$ |
| Common coatings        | 12.17                                | 0.44           | $0.023 \times 10^{-8}$                        | $5.23 \times 10^{-7}$               | $1.91 \times 10^{-6}$               | $0.53 \times 10^{-6}$ |
| Facing mortar (gridding cloth support) | 44.92                                | 2.24           | $0.419 \times 10^{-8}$                        | $18.71 \times 10^{-7}$              | $0.53 \times 10^{-6}$               | $0.15 \times 10^{-6}$ |
| Facing mortar (non-woven fabrics)  | 22.03                                | 2.12           | $0.192 \times 10^{-8}$                        | $9.06 \times 10^{-7}$               | $1.10 \times 10^{-6}$               | $0.31 \times 10^{-6}$ |
Table 5. Wet flow density of water vapor in thin plastering system

| Common paint finish | 4.1     |
|---------------------|---------|
| Elastic paint finish| 5.8     |
| Decorative mortar facing | 7.5 |
| Coating and glazing of decorative mortar finish | 4.5     |

From the data analysis in table 2-5, it can be seen that the water vapor permeability resistance of rock wool board and rock wool strip is small, and the permeability is good, so it is required that the exterior surface layer also has good permeability. According to the interface condensation checking calculation and internal condensation and moisture checking calculation, the base wall material is reinforced concrete, and the water vapor permeability resistance of the facing material is not more than 0.021 m²·s·Pa/ng, so generally there is no internal condensation and other problems. When the base wall material is aerated concrete, only when the water vapor permeability resistance of the facing material is not more than 0.002 m²·s·Pa/ng can condensation and other problems be avoided. The verification test results show that the water vapor permeability resistance of color mortar, lacquer, flat coating and other facing materials can be less than 0.021 m²·s·Pa/ng, but less of them is smaller than 0.002 m²·s·Pa/ng, so it can be seen that the permeability of rock wool is better. In order to avoid condensation, the permeability of facing materials should also be better and consistent with rock wool.

3.5. Test Conclusion
(1) The moisture absorption rate of rock wool increases with the increase of temperature and humidity
(2) The thermal conductivity of rock wool increases with the increase of temperature and humidity, and its thermal insulation performance decreases.
(3) Rock wool bare strip has higher tensile strength than mortar composite rock wool strip
(4) The water vapor permeability resistance of rock wool board and rock wool strip is small, and the air permeability is good, so the exterior surface layer is required to have good air permeability.

4. Conclusion
This paper is an overall research description, and it is found through study that rock wool, as a high-quality and efficient thermal insulation materials, has a better performance compared with the traditional thermal insulation materials. Rock wool and its products have the outstanding advantages of low thermal conductivity, non combustion, non-toxicity, wide range of application, stable chemical and physical properties, long service life, etc. Rock wool, as an inorganic material, meets the requirements of class A fire protection, has good compatibility with the buildings to which it attaches, and has good heat preservation performance. Therefore, it is a high-performance heat preservation material, which is suitable for application in the construction field.

5. References
[1] Liu Jian, Lu Yonghua, Zhang Peng, et al. 2013 Study on the properties of rock wool for building energy saving [J]. New Building Materials. 3 45-48.
[2] Zhi Jiafang, Zhang Fang, Jinhai, et al. 2013 Research on application technology of rock wool insulation engineering [J]. Engineering Technology. 2 68-74.
[3] Lu Yonghua, Liu Jian, Zhang Peng, et al. 2012 Study on the properties of rock wool board (rock wool strip) for building energy saving [A]. Collected papers of the 5th China international conference on the production and application of dry mixed mortar for construction of 2012. 247-253.