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SELECTED PROPERTIES OF AMPHIBOLITES AND MIGMATITES FROM THE G.A.M. KLUCZOWA MINE**

1. Introduction

Migmatites and amphibolites have been formed under high temperatures ($T > 650°C$) during metamorphism (ultrametamorphism). This metamorphism is accompanied by the partial melting of rocks and silicate melt separation, called migma. Migmatite structure is extremely diversified, often layered, folded. The basic components of amphibolite are amphibole of hornblende type, pyroxenes and plagioclase. The main chemical composition of amphibolites is quartz about 50% [1]. Amphibolites also contain about 10% Al_2O_3 and Fe_2O_3 iron oxide and calcium oxide CaO. Amphibolites and migmatites occur among the metamorphic rocks in the area of Lower Silesia — Kłodzko, Sobotka and in the Owl Mountains. One of the largest deposits of migmatites occur in the area of Brodziszów (50°64′ N, 16°78′ E).

2. Thermal expansion

Thermal expansion was measured with a precision quartz capacitance dilatometer of the original design [2]. For that measurements the samples were prepared as rectangular prism rods (5 × 5 × 4.95 mm). Each thermal process was carried out during heating in the temperature range 240–380 K of the rate of approximately 0.5 K/min. In the Figure 1 the temperature dependence of thermal deformation for migmatites (a) and amphibolites (b) for the one chosen direction are presented.

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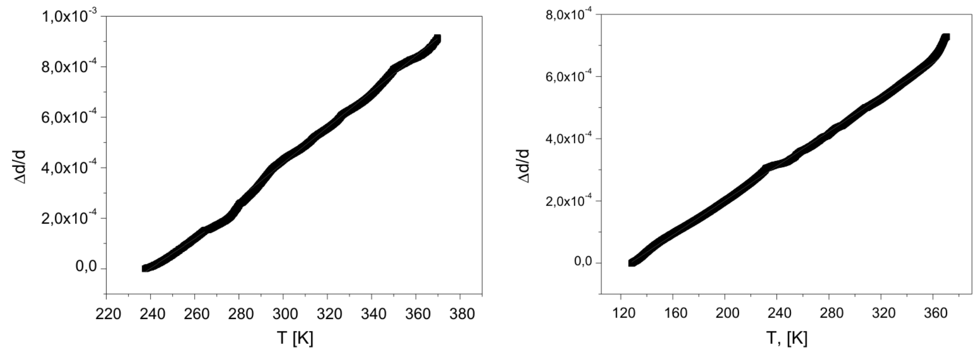

Fig. 1. Thermal deformation versus temperature for the migmatites (left) and amphibolites (right)

Thermal expansion coefficients of migmatites and amphibolites are presented in the Table 1. There was no significant change in the values of the thermal expansion coefficient depending on the direction, therefore the result in both directions were averaged for both migmatites and amphibolites. To compare the thermal expansion coefficient of migmatite $\alpha_M = 5.4 \cdot 10^{-6}$ K^{-1} and amphibolites $\alpha_A = 3.1 \cdot 10^{-6}$ K^{-1} to other rock materials the Table 2 was constructed. It was concluded that migmatites and amphibolites belongs to the group of rigid material with a low thermal expansion coefficient.

TABLE 1

Thermal expansion coefficient of migmatite and amphibolites for the two particular directions

Sample direction	$\alpha_M \cdot 10^{-6}$ [K^{-1}] migmatite	$\alpha_A \cdot 10^{-6}$ [K^{-1}] amphibolites
1	6.7	2.75
2	5.1	3.42

TABLE 2

Thermal expansion coefficient of insulating materials

Material	$\alpha \cdot 10^{-6}$ [K^{-1}]
Migmatite	5.4
Amphibolites	3.1
White Marble	2
Basalt	5.31
Granite	7.9
Sandstone	11.6

3. Measurements of the thermal conductivity coefficient

The thermal conductivity of the samples was measured by the static method based on heat flow through the sample located between heater P_1 and receiver heat P_2 (Fig. 2). On the Figure 3 the sample of the migmatite prepared to the thermal conductivity measurements is presented. The samples of the migmatites and amphibolites have a diameter of 70 mm and thickness of 5 mm. The upper and lower surfaces of samples have been polished to make the best adhesion to the copper plates. Additionally, the contact surfaces copper-amphibolites (copper — migmatites) was applied to a thin layer of conductive paste to eliminate the disruption of heat flow by the air.

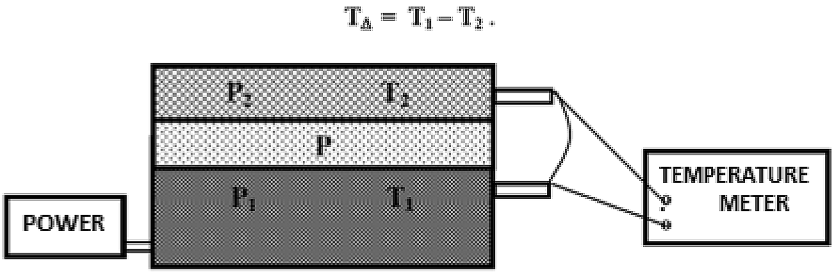

Fig. 2. The set up to the thermal conductivity measurements of isolating materials

Assuming that the heat flux is perpendicular to the surface of the sample the thermal conductivity coefficient can be described by the equation:

$$\lambda = \frac{m \cdot c \cdot n \cdot d_1 \left(r + 2d\right)}{2 \cdot \pi \cdot r_1^2 \cdot \Delta T \left(r + 2d\right)} \tag{1}$$

where:

- m — mass of the heat receiver 0.654 kg,
- c — specific heat of cooper 385 J/mK,
- r — radius of the heat receiver 35 mm,
- d — thickness of the heat receiver 19.65 mm,
- d_1 — thickness of the sample 5 mm,
- r_1 — radius of the sample 35 mm,
- n — cooling rate of the heat receiver.

The thermal conductivity coefficients equals λ_M = 3.73 W/Km for the migmatites and λ_A = 2.26 W/Km for the amphibolites rocks. The values λ_M = 3.73 W/Km and λ_A = 2.26 W/Km were compared with other rocks and isolating materials and summarized in Table 3. It should be noted that thermal conductivity coefficient of migmatites is similar to marble or granite, but more than sandstone.

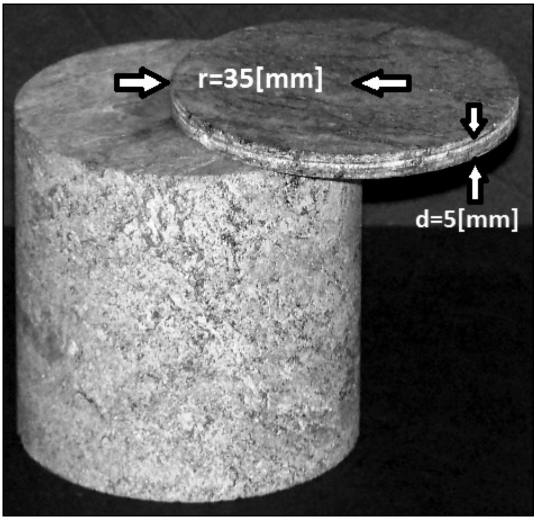

Fig. 3. The photo of the migamtites sample preperd to the thermal conductivity coefficient

TABLE 3
Thermal conductivity coefficients for selected materials

Material	**Gęstość, [kg/m^3]**	**λ, [W/mK]**
Migmatites	2900	3.73
Amphibolites	2987	2.26
Marble, Granite	2800	3.7
Sandstone	2400	2.2
Basalt	2900	1.165–1.768
Reinforcement	2500	1.7
Plain concrete with stone aggregate	2400	1.7
Concrete with limestone aggregates	1200	0.5
Styrofoam	10	0.037–0.045

4. Measurement of the rate of penetration heat wave

Measurements of the rate of penetration of heat wave was carried out on cylindrical samples with radius $r = 35$ mm and height $h = 66$ mm — Figure 4.

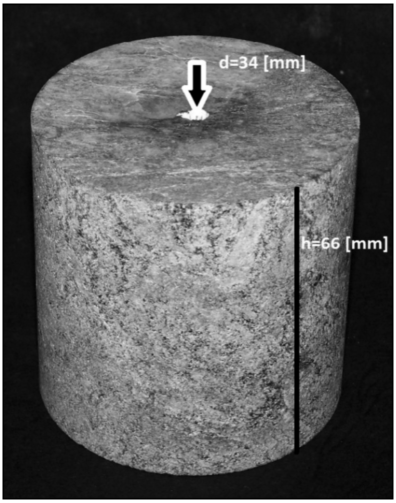

Fig. 4. The photo of the migmatite sample prepared to the measuring the rate of penetration of the heat wave

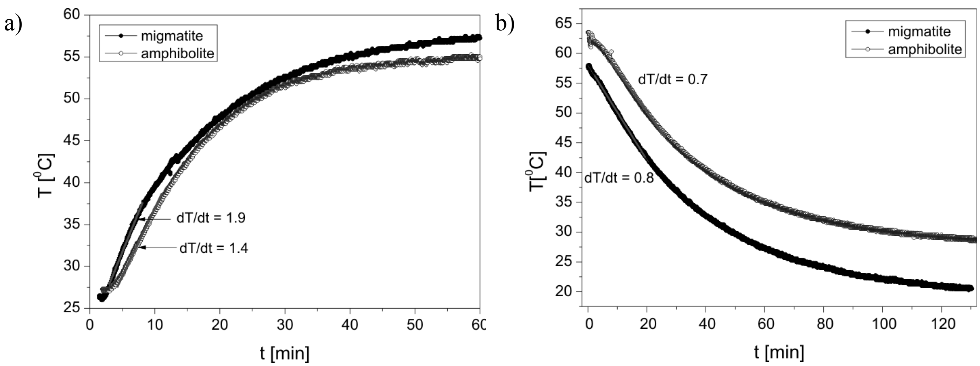

Fig. 5. Temperature of the inside the sample as a function of time: a) for the heating process, b) for the cooling process

Inside the sample the hole was drilled to a depth of 34 mm from the top surface of the sample and into the hole the thermocouple was placed. The measurement consisted of registering the temperature difference between the heater and the inner of the sample. The rate of penetration of the thermal wave was calculated as the derivative of the temperature of the sample over time. The rate of penetration of the thermal wave to the linear part of Figure 5a equals S_M = 1.9 °C/min and S_A = 1.4 °C/min for the migmatite and amphibolites, respectively. In addition, the cooling rate was determined (Fig. 5b) for the migmatite ST_M = 0.8 °C/min and amphibolites ST_A = 0.7 °C/min.

5. Measurement of water absorption by soaking method

The value of the practical application of the material can be determined by measuring the water absorption [3]. The value of the water absorption indicates the amount of open pores in the material. Absorbance of water can be calculated by the equation:

$$W_c = \frac{m_2 - m_1}{m_1} \cdot 100\% \tag{2}$$

where:

- W_c — is the water absorption in the weight percent,
- m_1 — is the mass of the dry sample, g,
- m_2 — is the mass of the wet sample, g.

For this measurements four samples were prepared with 60 × 30 × 15 mm ± 0.1 mm dimension. Two samples were cut from the migmatite and two from the amphibolites. The measured time was 24 h (W_{c24}) and 48h (W_{c48}). The weight of the samples was measured with the 0.1 mg resolution.

The water absorption equals:

— for the migmatite:

$$W_{Mc24} = 0.36\%$$

$$W_{Mc48} = 0.30\%$$

— for the amphibolites:

$$W_{Ac24} = 0.30\%$$

$$W_{Ac48} = 0.40\%$$

Absorption of modern elevation materials shall not exceed 3%. The clinker brick has a water absorption not more than 6%. The low value of the water absorption for the migmatites and amphibolites shows that the material does not have significant porosity and are on the top of elevation materials.

6. Conclusion

The selected physical properties (thermal expansion, thermal conductivity, speed of thermal wave penetration and water absorption) of amphibolites and migmatites were investigated. The results show small values of the linear expansion coefficients for both migmatites $\alpha_M = 5.4 \cdot 10^{-6}$ K^{-1} and amphibolites $\alpha_A = 3.1 \cdot 10^{-6}$ K^{-1}. Thermal conductivity measurements revealed very good isolating properties of this minerals, for migmatites $\lambda_M = 3.73$ W/Km and amphibolites $\lambda_A = 2.26$ W/Km. All these positive parameters lead, sonner or later, to use these materials as tiles for floor heating and wall. The low absorption of water is required in the cladding materials, insulation. Because of the no significant changes in the measured materials in the temperature range –150: 150°C amphibolites and migmatites can be used wherever constant physical properties are required.

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