Solution to the problems of complex use of mineral raw materials

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Abstract. The increasing pace of construction in areas in eastern Russia is leading to an increased demand for building materials. To meet this demand, local raw materials, including basalt, are widely used. In this article, we have shown the possibility of complex use of basalts in the production of various types of products. Using low-temperature plasma, basalt fibre with good physical and chemical characteristics was obtained. It possesses high heat-resistance (up to 700°C) and alkali resistance, and is stable in aqueous medium. Using mechanical activation method composite binding materials were obtained. Technological parameters of their production are determined. It is shown that the binding materials with optimal composition have a compressive strength higher than the strength of the control sample by 18%. The integrated use of mineral raw materials allows us to solve the issues of energy efficiency, resource conservation and environmental safety in the development of mineral deposits and the production of new types of products.

1. Introduction
Great attention is now being paid to the development of the trans-border area in eastern Russia. There has been an increase in the pace of industrial and civil construction. Therefore, this determines the demand for building materials that use local raw materials for production. Basalts are one of the most widespread raw materials. They are used in the production of building ceramics [1], glass ceramics [2], zeolites [3], concrete [4]. The main area of their use is the production of mineral fibres [5–7]. However, not all basalts are suitable for this production [8]. Only high-quality raw materials that meet the requirements for the content of basic oxides are used [9, 10]. Unused basalt remains in quarries and need to be involved in industrial processes.

The purpose of this work is to show the possibility of complex use of basalt rocks in the Republic of Buryatia, Russia.

2. Methods
Physico-chemical and mechanical methods of research were used. Mechanical tests were performed on a PG100 test hydraulic press (DEG, St. Petersburg, Russia) with a load range of up to 10 tonnes and a plate movement speed of 10 ± 1 mm/min. Tests for thermal resistance were carried out in the Laboratory furnaces SNOL 6/11 (Vnieto, Istra, Russia) with a working temperature up to 1,150°C.
3. Results and Discussion

Traditionally, basalt fibre is produced in electric arc and induction furnaces. However, new methods of processing basalt rock with low unit costs are being developed for environmental safety and energy saving purposes. These include plasma technologies.

Mineral fibres with a diameter of 9.7 microns from Buryatia’ basalts have been obtained using plasma-arc processing [11]. In order to establish the quality and the possibility of using basalt fibre in the production of thermal insulation materials, its physical and chemical properties have been studied.

The thermal stability of the basalt fibre was determined by the shrinkage and mass loss of the samples during heating from 100°C to 800°C. The heating rate was 10°C/min, the temperature increased by 100°C, the duration was 4 hours at each temperature. The dependence of mass loss and shrinkage of the samples on the processing temperature is shown in the Table 1.

| Indicators, % | Processing temperature, °C |
|--------------|----------------------------|
|              | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 |
| mass loss    | 0.19 | 0.19 | 0.20 | 0.21 | 0.22 | 0.22 | 0.33 | 0.53 |
| shrinkage    | 0.98 | 1.37 | 2.11 | 2.94 | 3.61 | 5.45 | 20.84 | 66.29 |

It was found that the mass loss of samples during heat treatment is negligible and does not exceed 0.22% when heated to 600°C. This is due to the removal of water contained in the rock. A further increase in temperature leads to a mass loss of 0.53%. At the same time, iron (II) is oxidized to iron (III).

The shrinkage values behave similarly. Up to 600°C, a smooth decrease of the fibre samples was observed. The shrinkage increases sharply at 700°C and the samples lose almost 2/3 of their volume at 800°C. Sintering of the fibrous material occurs, which leads to a loss of its elasticity and strength. At the same time, the thermal conductivity of basalt fibres increases, their thermal insulation ability decreases. Therefore, basalt fibre obtained by plasma-arc processing can be used up to a temperature of 700°C [11].

The resistance of the obtained fibre in aggressive environments has been determined. The samples were boiled in solutions of hydrochloric acid, sodium hydroxide and water. The processing time was 3 hours during which the average mass loss was determining. The study showed that the fibre obtained is highly water-resistant (weight loss was 0.80%). When exposed to 2M NaON, the weight loss of the samples was 15.33%, and when exposed to 2M HCl – 46.68%. Low acid resistance allows to leach basalt fibres quickly and to create on their basis high-temperature materials and adsorbents.

Basalts unsuitable for obtaining mineral fibres can be used in the production of composite binders, provided that they are mechanically activated. During the research in this direction, the effect of basalt addition on the mechanical parameters of the binder compositions was studied [12].

The raw mixture was prepared by simple mixing the components and mechanized for various times. The basalt content in the mixture did not exceed 50% by weight. The gypsum content was 3% of the mass of the Portland cement clinker and basalt. The resulting mixtures were tempered with water at a ratio of water: mixture equal to 0.3. Samples of binding compositions were stored under normal humidity conditions for 28 days. The compressive strength was determined every 7 days.

It is known that mechanical activation of raw materials provides formation of a chemically active surface. The process of hydration of the ground material is accelerated; its physical and mechanical characteristics thereof are improved. This is also true for basalt binders. With an increase in the activation time of the raw mixture, the mechanical parameters of the studied compositions increase. The highest values of compressive strength have samples of binders that have been mechanically activated for 15 minutes. This time is sufficient to obtain a highly developed surface of raw material mixture particles. This allows the ground composition to interact with water in full. An increase in the duration of mechanical activation leads to the adhesion of binder particles. The reactive surface area is reduced, slowing down the hydration of the samples and reducing their mechanical strength. As a result of these studies, it was found that the main strength gain occurs during the first seven days of specimen curing (Figure 1).
Figure 1. Strength dependence of binders with different amounts of additives on curing conditions.

The hydration process then slows down, and by the 28th day the maximum strength parameters of the samples are reached. The addition of basalt has a positive effect on the mechanical strength of the binding compositions. Its optimal amount is 30%. Increasing the additive in the composition of binders does not lead to the desired results. The compressive strength of the samples decreases. The results indicate the possibility of using basalt in obtaining composite binders.

4. Conclusion
Thus, in the course the work, the possibility of complex use of basalts from the deposit of Buryatia has been shown. Basalt fibres have been obtained with low-temperature plasma and their physical and chemical properties have been studied. The temperature range of the fibres has been determined. It has been established that this material can be used up to a temperature of 700°C. Basalt fibres are resistant to water. It has good alkali resistance and insignificant acid resistance and can be used in various industries.

Composite binding materials with the addition of basalt were obtained using the method of mechanical activation. The optimal time of mechanical activation of the raw material mixture was determined to be 15 minutes, at which the mechanical characteristics of the samples are of the greatest importance. The maximum quantity of basalt in the mixture was set at 30%. Under these conditions, the compressive strength of the samples after 28 days of hydration exceeds the strength of the test sample by 18%.

The involvement of rocks in the production of various types of products will make it possible to create low-waste mining enterprises and to solve the issues of environmental safety, energy and resource conservation.

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