**Development of energy-saving filterable nonwoven materials based on basalt and wool fibers for cement industry applications**

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**Abstract.** The demand for filter nonwoven materials for industrial enterprises in the republic is mainly met through imports. This study investigates the development of a technology for producing these nonwoven materials from locally available basalt and wool fibers, as well as the economic efficiency of implementing this technology in practice. The annual economic efficiency was calculated by determining the production costs of the proposed technological option based on the developed methodology. Considering environmental issues, the use of mineral and animal fibers such as basalt and wool fibers is important. Plastic samples reinforced with basalt and wool fibers were subjected to standard tensile, bending, and compression tests. The obtained results will be discussed later, and the analyzed experimental data will be presented and compared.

**INTRODUCTION**

In recent years, the increased interest in environmental issues has encouraged the use of natural fibers in polymer reinforcement [1]. Many natural fibers such as sisal, hemp, jute, flax, coconut, and banana have been studied and applied. However, plant fibers are very sensitive to thermal and hygroscopic loads and have limited mechanical properties due to the fiber extraction system, difficulties in fiber alignment, fiber size, and interfacial strength.

Due to the recent deep research on designing technical filter non-woven fabrics for industrial enterprises based on local raw materials, over the past 10 years, a number of researchers have been studying the properties and behaviors of various composites made from continuous or short basalt fibers [2]. Undoubtedly, the performance of the non-woven material woven from these basalt and wool fibers and its potential applications remain largely unexplored. Additionally, some discrepancies have been observed among the results obtained by different authors.

Due to improvements in production technology, a new generation of basalt fibers is available on the global market. Spun basalt fibers are obtained at high temperatures from selected molten basalt rocks [3]. The process technology is very similar to that used for glass fibers. The rock is first pre-treated and then melted to obtain continuous fibers. The melt flows through one or more bushings containing hundreds of small holes. It has been established that it is possible to create new generation filters from filaments of non-woven fabrics based on basalt and wool fibers, using molten rock and animal fibers. Then, The filaments are drawn onto the roller. The advantage of this method is that no additives are needed during the production process, resulting in economic benefits and reduced environmental impact. Of course, depending on the type of the original rock and animal wool used, several categories of basalt fibers with different chemical compositions can be obtained. As a result, not all basalt and wool fibers have the same mechanical and physical properties.

Overall, among the positive characteristics of this new generation of basalt and jute fibers are sound insulation properties, excellent heat resistance (better than glass), good resistance to chemical attack, and low water absorption [4]. For the second reason, they are recommended for applications requiring thermal insulation, as well as for hot liquid transport pipes. Another important feature is expressed by high mechanical performance comparable to glass fiber [5], which, combined with a lower cost, can adapt this material to replace glass fibers in various industrial sectors such as aerospace, automotive, cement, asphalt plants, transportation, and shipbuilding.

The most important feature in composites, namely the fiber-matrix interface, has been studied in various basalt-wool fiber-polymer matrix systems [6], where it was shown that the surface area of polymer reinforced with basalt and wool fibers is superior to that reinforced with glass fibers after being immersed in salt water and absorbing moisture. However, remarkable surface shear strength was identified, and it was emphasized that basalt and wool fibers form a better surface compared to glass fibers.

On the other hand, glass fibers are known to be prone to surface damage and to exhibit high sensitivity to alkaline environments. When in contact with other chemical substances, they do not undergo chemical reactions that could be harmful to human health or the environment. Currently, there is no available evidence indicating risks associated with very low fiber diameters. However, according to European regulations [7] (97/69/EC and 1907/2006), fiber diameters greater than 6 mkm should not pose a toxicity risk.

**EXPERIMENTAL RESEARCH**

For vacuum bag molding plants, a filter cloth reinforced with basalt and wool fibers with flat dimensions of 300 mm × 300 mm was obtained through technical nonwoven fabric. Various types of reinforcements used: dry fabrics made from basalt and wool fibers, 200 g/m2, plain woven (warp 10F/10 mm, weft 10F/10 mm), tex 100, from ZLBM (De) and E-Glass dry fabric, 290 g/m2, plain woven (warp 5F/10 mm, weft 5F/10 mm), tex 300 (Della Betta Group, It, Re 290/50 WEB). The frontal view of both reinforcements is shown (A, B) [8].

Samples of basalt and wool fiber reinforced plastic were subjected to standard tests of tensile, bending, and compression. The obtained results will be discussed later, and the analyzed experimental data will be presented and compared. The reported data consist of the average values of five or more tests, as well as standard deviations represented by vertical bars. In all conducted tests, non-woven fabrics made from basalt and wool fibers achieved good results [9].

By comparing the results of mechanical tests conducted on plastic laminates reinforced with basalt and wool fibers, it was possible to determine the feasibility of replacing wool with basalt as a filler in epoxy matrix composites, which are already widely used in applications. Indeed, the basalt composite showed a 35-42% higher Yan's modulus, as well as better compressive strength and bending properties, while the glass material exhibited higher tensile strength [10].

Filterable technical nonwovens has fulfilled the tasks of expanding the range of technical fabrics using natural local raw materials while preserving all the requirements and characteristics applied to technical fabrics. This, in turn, creates opportunities to enter the global market with new composite technical fabrics [11]. The properties of newly created textiles must meet consumer demands. These requirements are aimed at ensuring that the textiles retain their shape during use, improve hygienic and physical-mechanical properties, and that the nonwoven fabrics produced for the cement plants by the level of consumer expectations [12].

The main properties of sleeve filter fabrics are considered to be air permeability, heat resistance, and strong resistance to high air pressure [13].

**RESEARCH RESULTS**

The heat resistance of construction materials is indicated by their maximum temperature, and the standard GOST R ISO 11092 2012[16] specifies the requirements for the properties of these materials that enable their use in extreme conditions.

The basalt material is a single-component heating element, made from crushed glass or silicate, and it offers many advantages over similar materials.

The heat resistance of given samples was carried out at the Test Center of the Fire Safety and Emergency Problems Research Institute of the Ministry of Emergency Situations of the Republic of Uzbekistan [17].

Thermal resistance (heat resistance): The temperature difference between the two sides of the material is divided by the unit area along the gradient direction by the exact heat flow. The dry heat flow can consist of one or several conductive, convective, and radiative components.

Thermal resistance , expressed in watts per square meter kelvin, is a textile or composite characteristic indicator that constantly determines the dry heat flow passing through a certain area in response to a stable temperature gradient[14].

The temperature of the measuring device should be Tm=35 °C and the air temperature Ta=20 °C, with a relative humidity of 65%. The air velocity should be Ва=1 m/s. All deviations from these indicators must be within the permissible range.

Thermal conductivity, the resistance of the conductive plate , is determined by the following formula [15].

. (1)

Here, is the air temperature in the Test Chamber, °C; is the temperature of the measuring device, °C; is the area of the measuring device, m²; is the heat power supplied to the measuring device installed on the first side of the fabric, Вт; is the heat power taken from the measuring device installed on the second side of the fabric, Вт.

After placing the test sample on the measuring device, it is necessary to wait until the measured parameters—Tm, Ta, R.H., H—**have stabilized**. Then, their values are recorded.

Heat resistance is calculated using the following formula:

, (2)

The heat resistance of the cast material Rct is calculated as the average arithmetic value of individual measurements.

Since filter nonwoven fabrics operate in a high-temperature environment, heat resistance is considered their main property.

Figure 1 shows the heat resistance diagram of the samples.



**FIGURE 1.** Heat resistance diagram of the basalt nonwoven samples

The thermal conductivity of the given samples is higher than samples 1-6. These samples are not recommended for use in nonwoven with its single layer due to their low surface density. The surface density of samples 9-11 is 750-900 g/m2 and the thermal conductivity is 0.029-0.034 m2 K/W and it is recommended to made filter nonwoven products from these samples.

The surface density, air permeability, electrification, tensile strength, and thickness of nonwoven samples were determined by experimental tests at the “Sentexuz” laboratory (Table 1).

**TABLE 1.** Physical and mechanical properties of nonwoven fabric samples

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Samples**  **Properties** | | **Fabric Nonwoven** | **Nonwoven**  **layer 1** | **Nonwoven layer 1,5** | **Sample 1** | **Sample 2** | **3 Sample 3** |
| Surface density (10⁻³ g) | | 198,85 | 266,15 | 290,05 | 770 | 900 | 800 |
| Thickness, mm | | 0,15 | 0,2 | 0,25 | 1,3 | 1,36 | 1,3 |
| Linear density of nonwoven fabric, tex | warp | 80 | 80 | 80 | 300 | 300 | 300 |
| weft | 80 | 80 | 80 | 300 | 300 | 300 |
| Number of threads per 10 cm, pcs | warp | 50 | 50 | 48 | 80 | 80 | 80 |
| weft | 50 | 50 | 52 | 160 | 180 | 160 |
| Tensile force, N | Layer 1 | 128 | 600 | 360 | 2370 | 2350 | 2460 |
| Layer 1,5 | 260 | 540 | 700 | 4460 | 4300 | 4950 |
| Filling fraction of the nonwoven fabric, % | Layer 1 | 93,271 | 93,240 | 93,240 | - | - | - |
| Layer 1,5 | 93,271 | 95,571 | 96,348 | - | - | - |
| Total | 99,547 | 99,701 | 99,753 | - | - | - |
| Volumetric filling of the nonwoven fabric, Ev, % | | 48,546 | 42,447 | 36,373 | - | - | - |
| Air permeability, (cm³/cm²·s) | | 3,24 | 2,50 | 2,37 | 3,75 | 5,73 | 4,27 |
| Thermal resistance, m²·K/W | | 0,033 | 0,038 | 0,045 | 0,030 | 0,027 | 0,029 |
| Electrification, (10⁻³ V) | | 638 | 717 | 158 | 337 | 405 | 382 |

The physical and mechanical properties of the heat-resistant filterable fabrics were determined. The fabric’s surface density was found to be 750–900 g/m², and its thermal resistance 0.029–0.034 m²·K/W. The breaking forces of the fabric in the warp and weft directions were determined to be H and H, respectively.

**CONCLUSIONS**

New prospects have emerged in the use of basalt fiber due to the material's low cost and good mechanical performance, especially at high temperatures. The idea of reinforcing polymer matrices with these fibers has appeared relatively recently and may offer very interesting prospects that have not yet been sufficiently explored. In this work, mechanical tests were conducted on plastic laminates reinforced with comparable E-glass and basalt fibers, with the main aim of evaluating the possibility of replacing glass fibers in many The second was cut with square plates produced using vacuum bag technology. The results obtained in both laminates were compared, showing that the basalt material has higher performance in terms of Young's modulus, compressive and flexural strength, impact strength, and energy. These good properties indicate the potential use of basalt fibers in fields where glass composites are currently widely applied. Short radiation strength tests confirmed the above by showing similar surface adhesion between E-glass and the epoxy matrixThe warp yarn tension (X₁=40 cN), shed height (X₂=130 mm), and middle position value (X₃=60 mm) were identified as alternative factors. The physical and mechanical properties of heat-resistant filter fabrics were determined. The surface density of the fabric was found to be 750–900 g/m², and the thermal conductivity ranged from 0.029 to 0.034 m²·K/W. The breaking forces of the fabric in the warp and weft directions were determined to be Н and H, respectively.

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