Vol. 35, No. 1 (2013) 36-41

Tribology in Industry

www.tribology.fink.rs

RESEARCH

Examination of Wear Resistance of Polymer – Basalt Composites

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Keywords:

Wear
Basalt
Composite
Polymers

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A B S T R A C T

Olivine basalt, as a natural material, has excellent physical and mechanical properties such as hardness, compressive strength, wear resistance, color and gloss. On the other hand it is difficult for processing, because of its high values of mechanical properties. Retention of physical and mechanical properties of basalt and its formation is only possible by mixing basalt powder with polymers, which would enable the composite material that can be formed by the casting process into complex shapes. The mechanical properties of the obtained composites and production technologies are, to a great extent, unknown in both, local and foreign literature. Researchers conducted and presented in this paper show an overview of tribological behavior of the basaltic composite material, and some technological parameters of the production process. Based on the obtained results, it can be determine the best ratio of components in the composite. These data are important for the development of new composite materials based on basalt, which will have significant application in the future.

1. INTRODUCTION

Research in this work is aimed to create a new composite material, which consists of basalt, polymers and additives.

The main goal of this research is to obtain a basalt-polymer base composite that has properties of basalt (good strength, hardness and toughness) and is also suitable for forming by casting process that is practically impossible for the pure basalt. The combination of these two materials should allow the obtaining of a new material that will keep the characteristics of basalt (primarily high hardness, color, etc.) and polymers that allow its easy forming.

The long geological, mining and technological research tends to show that the basalt ore can be cost-effective for production of various products of basalt aggregates such as: basalt composites, basaltic glass, cast basalt, basalt fibers, and even jewelry whose value is similar to values of jewelry made of semi-precious stones. These researches included defining of the parameter of the process for obtaining composites of basalt and polyester resin (Polipol 357-C, 383, Polipol, BRE-325, etc.), by casting methods.

The process parameters to be determined are: the granulometric compo-sition of basaltic aggregates, type and amount of the resin and additives, elements of casting and pressing process, etc.

2. PREPARATION OF THE COMPONENTS AND MOLDS

Basalt is very strength and hard alumo-silicate rock, which belong to wild group of granites. For the purposes of this research, the basalt is taken from the locality of „Vrelo", situated on the slopes of Kopaonik Mountain in the South-west of Serbia.

From the mineralogical analyses of basalt samples *Vrelo* locality, we can see that these rocks are very compact. Porphyry structure with distinctly marked fenocrystals, 1-3 mm size, was easily noted. Rock mass is very fine-grained, crypto crystalline and mat-black colored. Mineral composition appears on two ways: in olivine fenocrystals that is predominating and pyroxene that is inferior. Physical and mechanical properties of the basalt from *Vrelo* locality are given in Table 1.

Table 1. Physical and mechanical properties of basalt from *Vrelo* locality.

Density (kg/m^3)	2600 – 2630
Melting point (°C)	1150 – 1170
Compression strength (dry state) (MPa)	240 – 260
Compression strength (hydrosaturated state) (MPa)	210 – 225
Compression strength (after freezing) (MPa)	190 – 195
Wear resistance (method Bohme) (cm^3/50 cm^3)	4.1 – 4.5
Wear resistance (method Los Angeles) (%)	11.5 – 12.0

Raw basalt grain size was 3 to 5 mm. This basalt aggregate was milled and micronized in tungsten-carbide vibrating mill. Milling lasted 30 minutes, and after that basalt powder was centrifugally sifted into the following granulations:

- 100 μm,
- 150 + 50 μm,
- 300 + 100 μm,
- 500 + 300 μm i
- 1000 + 500 μm.

For making the composites, polyester resin *BRE 325* (manufacturer *BOYTEK* - Turkey) was used [3]. This is orthophthalic unsaturated polyester resin with low reactivity and medium viscosity. It is used for the construction of sanitary elements and figurines by casting process. After curing, it has high elongation, nice color and very good soaking of fillers. Manufacturer of these polyester resins declared characteristics shown in Table 2 and 3 [3].

Table 2. Physical properties of liquid resin at 20 °C.

Viscosity (cp)	700 – 900
Acid number (max.), (mg KOH/g)	30
Styrene content (% mass)	32 – 38
Exothermic peak (°C)	130 – 140
Time of gelation 1% Co (minutes)	5 – 10
Storage stability (months)	6

Table 3. Mechanical and physical properties of resin in the fully matured state.

Tensile strength (MPa)	55
Modulus of elasticity (MPa)	2800
Elongation (%)	6,5
Bending strenght (MPa)	110
Flexural modulus (MPa)	3100
Hardness (Barkola)	35
Heat distortion temperature (°C)	55

As the catalyst and initiator high active Methyl-ethyl-ketone-peroxide was used. The catalyst is added in an amount of 2% of the mass of resin used. As an accelerant we used Co (6%) at a concentration between 0.2% and 0.6% of the amount of the polyester resin [4,5,6]. Pattern for making molds are made of metal alloy in standard sizes for this type of testing.

Moulds are made of high tackiness silicone (poliysilosan). This is a two-component silicone, where the first component is pure silicone and the second component is a hardener. Mixing silicone and hardener is performed by mixing up to 30 s at 23 °C, until color become homogenous. Molds making is performed by pressing of pattern in the formed mass, and for full curing of molds a period of about 72 h is required [7,8].

This silicone mass is used because it does not glue to polyester resin, and allows easy extraction of test specimens from the mold. The disadvantage is that the silicone molds, do not allow high pressures, because they will elastically deform. Therefore, it is necessary to pour a mixture at low pressure just enough that the excess of material be extruded from the mold [9].

3. PREPARATION OF THE COMPOSITE MIXTURE

This silicone mass is used because it does not glue to polyester resin, that allows easy extraction of test specimens from the mold. The disadvantage is that the silicone molds, do not allow high pressures, because they will elastically deform. Therefore, it is necessary to cast a mixture at low pressure just enough that the excess of material be extruded from the mold [9].

Testing samples are made of composites with the different ratios of basalt powder and polyester resin, different granulation and different content of accelerators. Samples designations with values of their masses are given in Table 4. Designation of samples consists of three ascendants (Fig. 1) where the first ascendant indicates the basalt grain size, the second, amount of basalt in the mixture, and the third, the content of the accelerator in the mixture.

Basalt mixture made of these components are uniformly mixed to homogeni-sation about 10 min and then poured into the mold. Poured mixture solidifies at room temperature and the curing time is 30 to 50 minutes, depending on the percentage of basalt powder in it. After curing, samples, together with molds, transferred into the furnace and heated to a temperature of 60 °C for 3 hours. In the next stage, the samples will be removed from the mold and reheated at temperature of 100 °C for one hour. Completion of the polymerization process continues after removing the samples from the furnace in the next 24 hours. Samples for wear resistance testing are made by this method. Figure 2 shows one of the test samples. In the Fig. 3 is given photos of the wear resistance testing device.

Table 4. Samples for testing resistance wear

Samples designation	Sample mass m_0 (g)
I3a	11.36
I3b	10.29
I4a	10.64
I4b	10.93
I5a	12.60
I5b	11.50
I6a	12.71
I6b	11.87
I8a	13.70
I8b	13.57
II6a	12.16
II6b	12.96
III6a	12.20
III6b	12.64
IV6a	12.37
IV6b	12.54
V6a	13.42
V6b	13.52

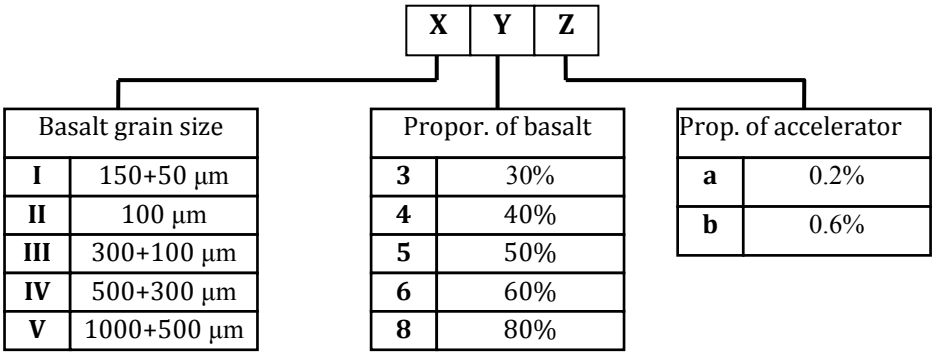

Fig. 1. Schematic presentation of samples designation.

Fig. 2. Wear resistance test sample.

Fig. 3. Tribological and Wear resistance testing device.

4. TEST RESULTS

The procedure for wear resistance testing is the following: rotary abrasive disc made of steel with a diameter of 148 mm overlaps the prepared sample. The disc rotates with speed of 0.05 RPM with 200 revolutions on one sample (Fig. 3). The higher speed is not possible because the samples are quickly heated and burn. Wear resistance is defined as the loss of mass per unit of wear surface. Wear surface in this case is a semi-spherical, so it can be calculated by the expression:

$$P = a \cdot l = a \cdot \frac{r \cdot \pi \cdot \varphi}{180^o} = 10.0037, cm^2$$

where:
a - width of the sample (which is 3.1, cm),
l - length of the port (which is 3.227, cm),
φ -central angle (angle which covers the length of the arc, which is 0.43633, rad).

The loss of mass per surface unit can be calculated using the following equation:

$$O = \frac{m_1}{P}, \ \frac{g}{cm^2}$$

The values of mass loss are shown in Table 5.

Table 5. Test results of wear resistance.

Sample designation	Mass before testing m_0 (g)	Mass after testing m (g)	Mass loss m_1 (g)	Mass loss reduced to wear surface O (g/cm²)
I3a	11.36	11.330	0.030	0.00299
I3b	10.29	10.270	0.020	0.00199
I4a	10.64	10.610	0.030	0.00299
I4b	10.93	10.895	0.035	0.00349
I5a	12.60	12.585	0.015	0.00249
I5b	11.50	11.480	0.020	0.00199
I6a	12.71	12.695	0.015	0.00149
I6b	11.87	11.855	0.015	0.00149
I8a	13.70	13.675	0.025	0.00249
I8b	13.57	13.560	0.010	0.00299
II6a	12.16	12.140	0.020	0.00199
II6b	12.96	12.950	0.010	0.00099
III6a	12.20	12.180	0.020	0.00199
III6b	12.64	12.620	0.020	0.00199
IV6a	12.37	12.360	0.010	0.00099
IV6b	12.54	12.530	0.010	0.00099
V6a	13.42	13.400	0.020	0.00199
V6b	13.52	13.510	0.010	0.00099

4.1. Discussion of the results

Table 5 shows the values of the mass of samples before and after wear, mass loss, and mass loss reduced to wear surface. Based on the results in Table 5 a histogram of mass loss per wear surface is made (Fig. 4).

From the above histogram can be concluded that the least amount of lost material are on the samples with the designation I6a and I6b containing 60% basalt powder and grain size 150+50 μm. Content of accelerator in the first sample is 0.2%, and in the second 0.6%.

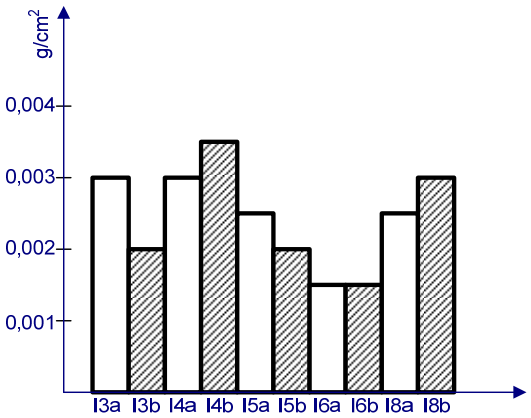

Fig. 4. Histogram of samples mass loss.

Since these samples showed the best wear resistance we continued to test samples with a 60% of basalt powder, but with different grain size. Figure 5 shows histogram the mass loss per wear surface.

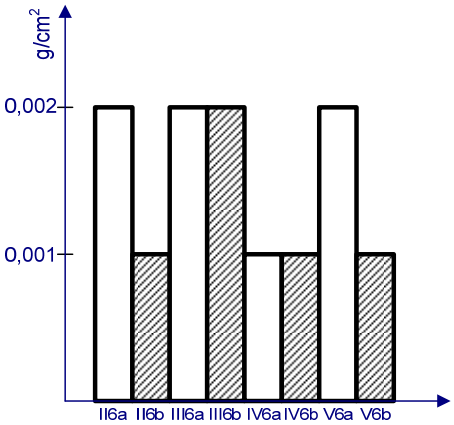

Fig. 5. Histogram of samples mass loss.

On the diagram it is evident that the best values of wear resistance have the samples IV6a and IV6b. These samples contain 60% basalt powder with a grain size of 500+300 μm. Content of accelerator in the first case is 0.2%, and in the second 0.6%. This clearly indicates that the specified granulation of basalt powder gives the highest wear resistance.

5. CONCLUSION

Good characteristics of basalt qualify them for the final works in construction and manufacturing of basalt wool, used as insulating material. During the research, the technological parameters of the production of polymer matrix composites with basalt as reinforcements are established. Further development of these materials will go in the direction of its application for the production of parts in the automotive industry and food production [10,11].

Samples generally showed very uniform values of wear resistance. However, a certain number of samples have reduced value of mass loss per wear surface, which is especially noticeable on the samples: I6a, I6b, IV6a and IV6b. This means that the wear resistance of these samples is the best, and in future work should use these technological parameters. A broader view of all these results is given in the papers [7,8,9].

Technology of the production and design of these composites is now less known in the world. For the production of such composites should define in more detail the technological parameters, equipment, tools, etc. It will probably be the task of future research.

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