Composites based on polypropylene and Georgian minerals

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Abstract. Polymer composites on the basis of secondary polypropylene and high dispersive powders of minerals widespread in Georgia (andesite, quartz sand and a slam) were obtained and investigated their some physical-mechanical, thermal and hydrophobic properties. It is shown that the ultimate strength, and thermal stability extremely depend on the filler concentration and at definite significant of the concentration have maximums. For the composites with binary fillers (quartz sand/slam, quartz sand/andesite and slam/andesite) revealed synergistic effect of anomaly increasing of the ultimate strength at definite proportion of fillers. It is established that modification of the mineral fillers with tetraethoxysilane enhances technical characteristics of the composites.

1. Introduction
Environment ecological protection and utilization of the industrial wastes present today very important and actual problems. From the scientific-technical literature it is known that if the development of the composites based on secondary thermoplastic materials, in which the different dispersive or natural and artificial fiber fillers are used, about 40% of the primary ores can be spared. In the secondary polymer composites the industrial technological wastes as trimming, injection molding heads technical tare, films, bottles and so on are used. The content of such wastes was varied in the range 10 - 40%. In our case the high pressure polyethylene industrial wastes as binder are used.

Polypropylene (PP) now is one of more spread polymer (after polyethylene), which is due to many positive exploitation properties and low cost [1-4].

2. Experimental
2.1 Methods of obtaining of research objects
The high dispersive powders obtained in result of fine disintegration of domestic polypropylene bags were used as binder of composites. The fine dispersed minerals as andesite from village Bakuriani, slam from village Okami and quartz sand from the village Sachkhere were used as fillers for composites. Below the short characteristics of the named fillers are presented:
- andesite (word basis -American mountains Ands) dark red color dense, but sometimes is porous material. Andesite is used as a building and acid proof material;
- Quartz sand includes the quartz particles, contenting silicon oxide near70-85% and rest are iron, calcium and magnesium oxides. Besides of the sand includes 5% clay and dust particles.
- slam is red color micro-porous volcanic generated mineral with high specific surface. In Georgia this mineral is used as warm-isolated material. The slam belongs to basalt type porous variety. It is the glass with alumina-silicate (contents 75-80%). Density 2630 kg/m³.

At the initial stage the mixing of composite ingredients in the propeller mill during 2-3 min. In result of mixing of the polymers and different fillers the homogeneous powder was obtained, which after preliminary drying at 50-
70°C underwent to the pressing in the standard press-forms (cylindrical and rectangular). The samples were obtained after pressing at 8-10 MPa and temperature 140-150°C during 10-15 min.

2.2 Methods of composite testing
The samples were tested on the strengthening at compression, bending and impact viscosity. The water absorption was defined separately. The specific weight was defined with use of standard method. Mechanical parameters were defined on the Germany device of type Dinstant. The temperature stability was defined on the apparatus of Vicat.

3. Results and discussion
First of all it was necessary determination of the dependence of properties of the research objects on the filler concentration. With this aim there were obtained the composites with following concentrations of fillers 20, 30, 40, 50 and 60wt%.

On the Fig.1 it is shown the dependence of the ultimate strength (at compression) on the filler type and content. The corresponding curves are characterized with maximums at different concentrations of fillers, however the filler concentrations, to which are correspond the maximums little differ one from another. It takes place near 40wt%. This fact indicates on the optimal content of the fillers, when swelling of filler particles realized maximally. At more high concentrations of fillers the mechanical strengthening of composites decreases because of starting of formation of filler particle associates in the polymer matrix. Among the fillers the andesite is one, containing of which enhances the strength of composite higher than for other fillers. The selected mechanical properties of composites with andesite appear at their testing on mechanical strengthening (at bending and impact viscosity (Fig-s 6 and 7).

![Figure 1](image-url)

**Figure 1.** Dependence of ultimate strength (at compression) of composites containing andesite (1), slam (2) and quartz sand (3) on the filler concentration.
Figure 2. Dependence of ultimate strength (at bending) of composites containing andesite (1), slam (2) and quartz sand (3) on the filler concentration.

Figure 3. Dependence of impact viscosity of composites based on PP containing andesite (1), slam (2) and quartz sand (3) on the filler concentration.

The Dependences shown on the Figs 1-3 lead to conclusion that the differences between corresponding curves character for different fillers are determined by different level of interaction intensity between polymer matrix and filler particles. First of all the essential effect on the mechanical characteristics has a micro structure of the filler particles. It is clear that the higher is a sum surface of filler particles the higher is the inter-phase square and consequently -the adhesive forces between polymer matrix and filler particles. Besides of the existence of active chemical groups on the surface of filler particles additively can enhance composite because of formation of covalent bonds between phases. On the basis of these supposes it can be concluded, that mineral andesite particle surfaces are characterized with relatively inhomogeneous structure on surface of which some active chemical groups are displaced.

Experiments provided on the composites contenting the binary filler particles show that in this case technical characteristics of the composites can be proved by selection of type and proportion of two different type fillers.
This opinion is confirmed by numerical data of the Table 1. Comparison of these data, obtained for composites containing 40wt% of sum concentration of binary fillers with analogical one obtained for the PP composites containing one of these fillers gives full right to express the opinion presented above.

Table 1. The characteristics of composites based on PP and binary fillers

| Filler (proportion of the fillers in composite) | Impact viscosity, kJ/M² | Ultimate strength at binding, MPa | Ultimate strength at compression, MPa | Thermal stability, °C (by Vica) |
|-----------------------------------------------|-------------------------|----------------------------------|-------------------------------------|---------------------------------|
| Slam                                          | 7.0                     | 41.5                             | 62.3                                | 160                             |
| Andesite                                      | 6.0                     | 46.8                             | 65.1                                | 165                             |
| Quartz sand                                   | 5.1                     | 45.5                             | 60.4                                | 180                             |
| Slam/andesite (2/3)                           | 8.2                     | 50.5                             | 70.0                                | 185                             |
| Slam/quartz sand (1/1)                       | 7.7                     | 56.6                             | 69.5                                | 201                             |
| quartz sand / andesite (2/3)                  | 7.8                     | 54.2                             | 80.1                                | 196                             |

Comparison of the thermal stability of the composites less structural changes undergoes the composite containing slam, which definitely show on the good thermal stability of this filler and the composite filled by them (Fig.4). Analogically can be estimated the effect of quartz sand. Besides of high physical-mechanical characteristics of composites with andesite at high temperatures the pores near the particles surfaces are expanding relatively more intensively and in result of exit of macromolecule fragments diffused in these pores (by other words - degradation of the physical bonds between phases) the thermal stability of this composite decreases.

The experiments on investigation of hydrophobic properties of the composites show that water absorption by composites is rather low (no more than 1.5%). Therefore we decided not to include the data of this parameter to the work.

![Figure 4](image-url)  
**Figure 4.** Dependence of the softening temperature of the composites based on PP containing quartz sand (1), slam (2) and andesite (3) on the filler concentration

4. Enhancing of composite properties by use of modifier

With an aim of improvement of the exploitation properties of the obtained composites the structural modifier of type tetraetoxisilane (TEOS) was used. This modifier was introduced to the composite with amount 5wt% solved in the toluene for obtaining of homogeneous solution, which was evaporated after definite time.

Table 2. Technical characteristics of composites containing of modified by TEOS fillers (in brackets corresponding characteristics for analogues with unmodified fillers)
| #  | Filler        | Specific weight, Kg/m³ | Impact viscosity, kJ/M² | Ultimate strength at binding, MPa | Ultimate strength at compression, MPa | Thermal stability, °C (by Vica) |
|----|---------------|------------------------|-------------------------|----------------------------------|--------------------------------------|---------------------------------|
| 1  | Slam          | 1082 (1174)            | 7.5 (7.0)               | 63.9 (62.3)                      | 43.8 (41.5)                          | 170 (160)                      |
| 2  | Quartz sand   | 1115 (1242)            | 5.0 (5.0)               | 58.0 (60.4)                      | 51.3 (45.5)                          | 200 (180)                      |
| 3  | Andesite      | 1183 (1180)            | 6.0 (6.0)               | 53.7 (65.1)                      | 30.5 (46.8)                          | 160 (150)                      |

On the Table 2 there are presented some technical characteristics of the composites with modified and unmodified by tetraetoxisilane fillers. Data of the Table 2 show that in general the effect of the modifier on mechanical characteristics of the composites is relatively weak, however the effect of modifier is manifested in thermal stability of composites. This parameter increases on 10-20°C. Here the protector role of silicone-organic compounds appears.

**Conclusion**

1. On the basis of industrial residues of the polypropylene it is obtained and studied the composite containing the fine-dispersed mineral fillers spread in Georgia as andesite from Bakuriani, Okami slam and quartz sand from Sachkhere.
2. Experimentally is established that composites physical-mechanical, thermal and hydrophobic properties essentially depend on the type and concentration of the fillers; at definite (for each fillers separately) concentrations of the fillers the materials with best properties are obtained.
3. For the composites contained binary fillers there are fond the optimal concentrations, which ensure the obtaining of composites with improved properties (the synergistic effect is appeared).
4. The composites of PP containing modified by tetraetoxisilane fillers differ from analogues with unmodified fillers with improved technical characteristics.

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