Mechanics and Mechanical Engineering
Vol. 20, No. 3 (2016) 249–254

Mechanical Properties of the Mineral Cast Material at the Macro and Micro Level

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Received (20 January 2016)
Revised (26 January 2016)
Accepted (18 May 2016)

The paper presents the results of experimental examination of the mechanical properties at micro and macro scale of the mineral cast composites.

Studies have been conducted to verify the literature data about the value of tensile strength, compressive strength and Young's modulus. Additionally as a part of this research Poisson's ratio was determined, which has not been encountered in the current literature as deeply as in this work.

In the next step, a scanning electron microscopy (SEM) studies have been carried out to analyze fractures of the samples after tensile and compression tests. These results were correlated with mechanical properties such as tensile strength and compressive strength, respectively. During fracture investigations, the contact interface between concrete filler and polymer was studied. As a result of this research the mechanism of deformation was formulated.

Keywords: mineral cast, composite, mechanical properties, microstructure.

1. Introduction

Thanks to very good dynamic properties and low density mineral casts are more and more willingly put into the machine tool industry, which is constantly looking for new design solutions. In the future, these new materials thanks to their properties will improve product quality, reduce costs associated with the production process, increase the flexibility of that process, etc. [1]. Mineral cast (PC - polymer concrete) is a complex material composed of fine particles of inorganic aggregates such as basalt, spodumene, fly ash, river gravel, sand, chalk, etc. connected together by two-component, chemically hardened resin (usually epoxy resin) [2, 3]. The volume ratio of filler (aggregates) to the binder (resin) is about $9 \div 1$ [4]. Fig. 1 shows an example of the structure of mineral cast with aggregates of different grain size.

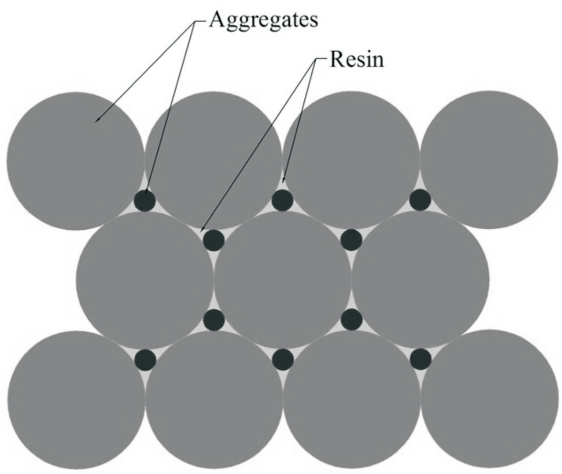

Figure 1 An example of the structure of mineral cast with aggregates of different grain size [1]

Mineral casts have also much better dynamic properties than the commonly used cast iron. The logarithmic decrement of damping of mineral casts is up to 10 times higher than in case of cast iron [1, 3, 5]. Unfortunately, mineral casts have poor mechanical properties. The tensile strength of mineral cast is about 10 MPa [6], while the compressive strength is about 100 MPa [3, 6, 7]. In order to verify the mechanical properties of the mineral cast material the study was carried out.

2. Mechanical properties research

The material which was used for tests is mineral cast material offered by EPUCRET and commercially available under the name EPUCRET 140/5. This material is used for casting small parts of machines such as the guides, tables or beds, which mass is not exceeding 500 kg.

In order to carry out the research two types of samples have been performed. The first type of sample was used in tensile test whereas the second one in compressive test.

The strength tests were carried out on the INSTRON 4485 (Instron, USA) universal testing machine with modified software (Zwick/Roell Group, USA) and equipped with automatic extensometer with programmable measurement base from

10 mm up to 100 mm and resolution of 1,2 mm. To evaluate mechanical parameters such as tensile strength, compressive strength and Young modulus a ten measurements were performed. Firstly, samples were subjected to tensile strength test, where samples were mounted in self–locking holder (Fig. 2a). Next to that, a compression test were provided replacing holder by mounting with high degree of parallelism and low roughness of the surface (Fig. 2b).

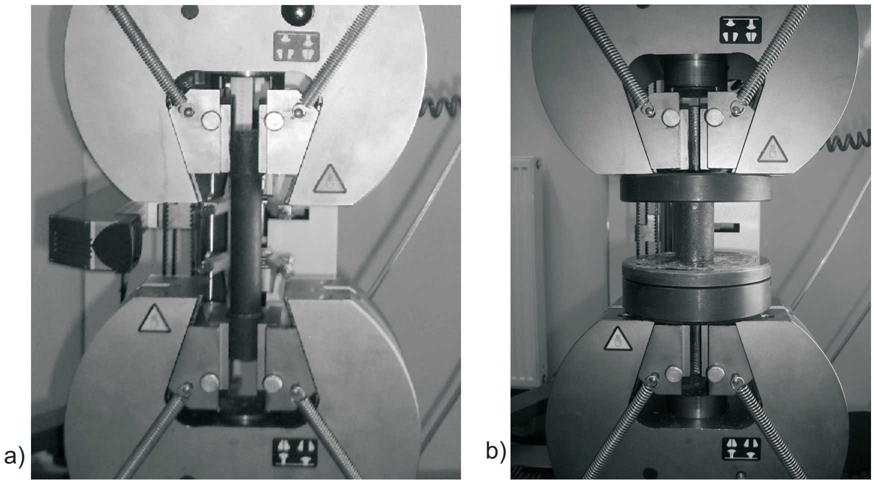

Figure 2 a) View of the tensile strength sample mounted in the apparatus, b) View of the compressive strength sample mounted in the apparatus

Results of the performed tests are given in the Tab. 1. Obtained results contain the particular value of the tensile strength, compressive strength, Young modulus and Poisson ratio, with their average value and standard deviation achieved in the measurements.

As shown in Tab. 1 parameter values in subsequent trials differ from one another. The degree of result variation is well described by the percentage deviation of the average value.

3. Fractographic observations

Examination of the fractures were performed in Scanning Electron Microscopy (SEM) technique. To explain mechanism of strengthening by a mineral filler, studies were performed using JSM-6610LV microscope (JEOL Ltd., Japan). Observations of the microstructure were provided in high vacuum mode with decreased voltage, to avoid local affecting by electron-beam (local melting and degradation of polymer resin) and highly charging up surface of the non-conductive samples.

In this part of the work, analyses were conducted to characterize microstructure and fractures of the mineral cast composites, as well as contact between polymer

Table 1 Results of the research of mechanical properties of mineral cast material

Sample	**Tensile strength** [MPa]	**Compressive strength** [MPa]	**Young's modulus** [MPa]	**Poisson's ratio** [ν]
1	13,01	119,43	34846	0,224
2	17,26	111,64	37426	0,248
3	19,71	114,31	27701	0,209
4	17,76	109,08	22004	0,159
5	20,91	105,79	27084	0,197
6	19,72	87,11	31483	0,237
7	20,52	106,87	27621	0,289
8	17,35	114,69	32574	0,259
9	19,85	107,22	29709	0,220
10	18,09	89,90	26934	0,178
Average value	18,42	106,60	29738	0,222
Standard deviation	2,32	10,44	4468	0,039
Percentage deviation of the average value [%]	12,6	9,8	15,0	17,4

resin matrix and particles of the filler. Such performed examinations were compared with mechanical properties of the material.

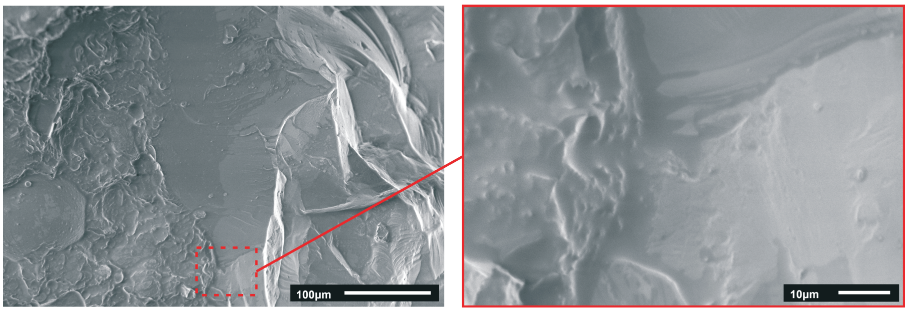

Figure 3 Example of fracture of the mineral cast composite sample after tensile testing

In the images the fractures of the specimens is presence of a brittle cracked inorganic filler and plasticly deformed resin are clearly visible. On the polymer matrix – particle interface, it is noticable that smooth transition can be responsible for relatively good adhesion bonding (Fig. 3). However, for the compressive test, many

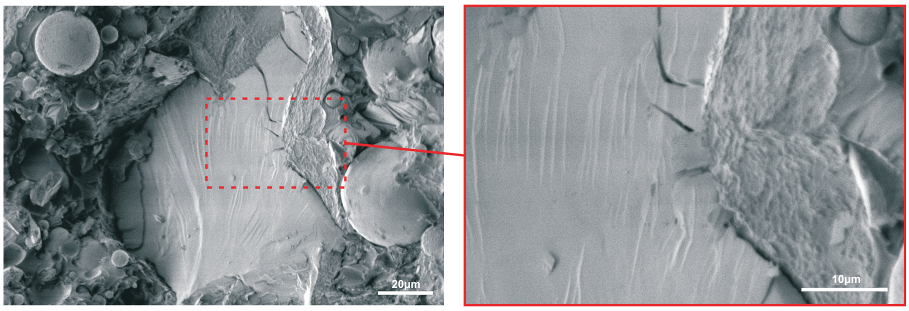

Figure 4 Example of fracture of the mineral cast composite sample after compressive testing

fissures around and cracks inside of the filler grains are present. Mechanism of the cracking during tensile test can be identified as follows: an initiation of a crack takes place inside of the low-strength, inorganic filler and subsequently propagates through polymer resin. For the samples after compression test it can be seen that inside grains of inorganic reinforcement there is a presence of many cracks, that may have been stopped by a polymer resin. When the number of cracks reaches specific value, the sample is damaged (Fig. 4).

4. Conclusions

Based on the survey it can be claimed that the literature data have been confirmed in case of the mechanical properties of the mineral castings. Furthermore, an additional parameter (Poisson's ratio) was determined which has not been given in the literature of mineral casts already.

Small differences of results have appeared due to the selection of the tension or compression speed applied during the study because the literature does not specify what rates of speed were used during earlier tests. Reducing the speed of tension and compression can result in slight increase of tensile strength and compressive strength rates.

In order to characterize mechanism of crack propagation in polymer concrete composites, a fractures of the samples after tensile and compression test were analyzed. As a result of experiments, it was observed that crack initiation occurs in filler grains. Polymer matrix exhibits good adhesion to the concrete reinforcement with relatively favorable stress distribution on polymer/reinforcement interface.

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