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# PREPARATION OF LIGHT FRACTION SILICATE FILER AFTER THE MINING FOR THE BASE LAYERS' ROAD CONSTRUCTION

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Abstract. The article main objective was eco-innovation in the field of utilization and creation of a complex waste-free technology for the separation of components during ore extraction with subsequent processing, recovery of mine tailings in combination with available energy. The article deals with the topic of production and preparation of base layers for road construction in the form of silicate filer after separation of ore mining. The chemical and mineralogical composition on the fine fraction of the separated tailings was carried out by XRD analysis, filer particle size followed up by Laser Granulometry and other comprehensive measurements and the development of basic parameters by individual standard tests. The results determined on the functional sample demonstrated that it is possible to create an almost completely waste-free technology in the field of separation of components during ore extraction and its subsequent processing and use for the base layers of linear road construction.

Keywords: Mine tailing processing, heavy metals, mineral separation.

## 1. Introduction

Recently, due to increasing environmental concerns and material price inflation, there has been a growing interest from the scientific community to replace conventional mined fillers with environmentally friendly alternative materials. New concrete technologies for the development of low-cost and environmentally clean silicate materials with significant use of both new mining residues after the extraction of polymetallic ores, where aggregate heaps burden the existing landscape. While in them lies the potential for the replacement of natural aggregates in concrete mixes [1–3]. Thus, very ecological option is the use of these tailings for the preparation of base layers for linear road construction. It is also for this reason that, in the current period of extreme construction, there is starting to be a shortage of good quality natural aggregate sources for concrete production [2–6].

Silica sand remains one of the most widely used and versatile materials in the world [1–5]. For example, when used as composite fillers, silica materials significantly improve the mechanical, thermal, and rheological properties of polymer matrix composites. Fillers are an integral part of modern building materials. When their function is only filling without any bonding value. It can also be described as the finest part of the aggregate that passes through a certain sieve (0.075 mm in the United States and 0.063 mm in Europe) and occupies certain weight in mixtures. Filler must be free of organic impurities [3–7].

Mining tailings are one of the main wastes generated in the mining industry during the concentration phase of the precious metal extraction process. It is the waste rock that remains after ore processing and is eventually disposed of as fine sand after milling [6–10].

The implementation of the achieved theoretical basis will be carried out according to the developed complex design of the treatment plant technology for the "Zlaté Hory" underground mine with obtaining the residual material from the treatment in a further usable form. The results are summarized in the TREND FW project report 01010061-1-2022.

The treatment plant will be a crushing unit, the first stage of which will be a semi-mobile crushing unit with a wheel-mounted jaw crusher located in the mine area. Input mined material of up to 500 mm fraction will be crushed to an output fraction of up to 200 mm, which will be transported away from the mine to the stockpile. From the homogenization intermediate stockpile, the raw material will be deposited by wheel loader into the hopper of the belt feeder and then by belt conveyor onto a vibratory screening screen with screen openings of 25 and 50 mm. Fractions greater than 25 mm will be crushed on a secondary cone crusher with an output fraction below 25 mm. The crushed material will be conveyed by conveyor belts to a vibratory screening plant with 16, 10 and 1 mm screen drops. The fraction above 16 mm will be returned to the previous crushing stage in the cone crusher. The intermediate product, i.e., the fraction from 1 to 16 mm, will be crushed in the next crushing stage on a roller crusher with an output fraction with a mean grain size of 800 µm. All the material will undergo gravity sorting to a precise fraction size for the silicate filer.

## 2. Material and methods

The test sample is made from a light fraction of aggregate after gravity separation of heavy minerals from the mine "Zlaté Hory" in Czech Republic deposit. A proven separation procedure using a gravity trough was used with basic screening and removal of coarse impurities, followed by gravity separation using a gravity float, after which the light fraction was allowed to settle and dried after decantation. The crushing and separation of the coarser fraction was described in the introduction section. This ochre-colored material is primarily intended to produce cement and polymer-based construction materials. As it is being considered to use the residue for separation both in the processing of fresh residue from active mining and old deposits. Due to the large volume of samples, it was first necessary to perform a coarse sieving to remove impurities using a TECHKON Tajfun trough sieve. This was followed by the removal of lumps and concretions using a jaw crusher. The samples were then separated in an LSV D140 magnetic separator with magnetic field strength on the surface of a Kevlar conveyor belt. The mineralogical composition and granulometry were monitored, especially of the light component, which will be further used to produce road base layers. The XRD analysis on samples was performed using a Panalytical Empyrean diffractometer. The reflection Bragg-Brentano para focusing geometry device is equipped with a Cu anode ($\lambda = 1.54184$ Å) and programable divergence slits a PIXcel3D detector with 255 active channels. The X-ray generator settings were 45 kV and 40 mA. The measured range was 5–80° with a step size of 0.013° and 38 s per step. Each sample was measured four times, and the scans were next simply summed. The total measurement time for each sample was 60 min. The Panalytical HighScore 3 plus software was used to identify the individual phases.

Laser granulometry was used to measure the size and distribution of particles in the sample. The measurements range from tens of nanometers to units of millimeters. The laser granulometer can analyze powdered material in a dry air stream or powder dispersed in a liquid medium. To evaluate the particle size distribution, the laser diffraction evaluation software uses two mathematical models. The simpler Fraunhofer approximation or the more modern and accurate Mie diffraction model.

Furthermore, the mechanical and physical parameters of the silicate filler thus treated and analyzed were determined according to the individual standards: ČSN EN 998-2 Specification of mortars for masonry – Part 2: Mortars for masonry [11], ČSN EN 13139 Aggregates for mortar [12], ČSN EN 1097-3 Testing of mechanical and physical properties of aggregates – Part 3: Determination of bulk density and void ratio of loose aggregates [13], ČSN EN 1097-4 Testing of mechanical and physical properties of aggregates – Part 4: Determination of the gap properties of dry compacted aggregate [14], ČSN EN 1097-5 Testing of mechanical and physical properties of aggregates – Part 5: Determination of moisture content by drying in a drying oven [15], ČSN EN 1097-6 Testing of mechanical and physical properties of aggregates [16].

These standard tests examined the following parameters: Aggregate fraction/fineness, Grinding fineness according to Blaine, Bulk weight (ČSN EN 1097-7 [17]), Bulk density (ČSN EN 1097-3), Chloride content, Sulphates content, Water absorbency (ČSN EN 1097-6), Mass activity index, 226 Ra mass activity (Bq kg$^{-1}$ ).

## 3. Results and discussion

Figures 1 and 2 show the graphical analysis by laser granulometry.

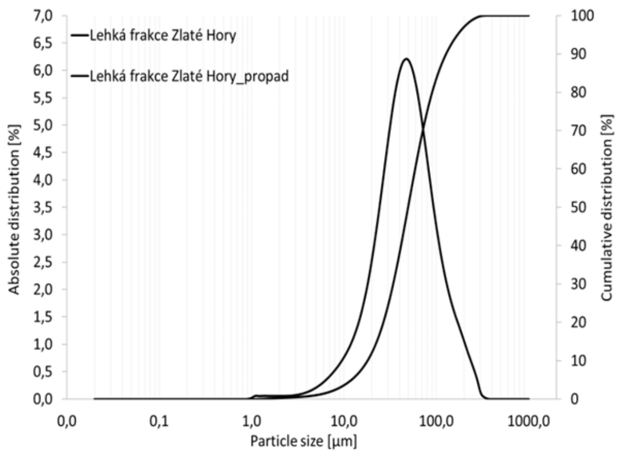


Figure 1. Laser granulometry of silicate filler (light fraction) "Zlaté Hory" *"Lehká frakce" is translated as light fraction in absolute and cumulative distributions.

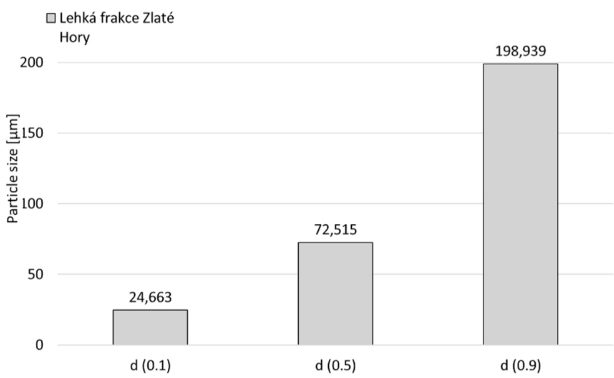


Figure 2. Particle distribution of the light component of the "Zlaté Hory" silicate filler *"Lehká frakce" is translated as light fraction in absolute and cumulative distributions.

These graphs show the result of granulometric analysis of a sample of processed raw material from "Zlaté Hory". It can be seen that the mean grain size of the light fraction d(0.5) was 72 micrometers. The minimum particle size d(0.1) was around 24 micrometers and the maximum grain size d(0.9) was 199 micrometers.

The granulometric parameters of the "Zlaté Hory" silicate sand separated in semi-laboratory quantities were essentially identical to those obtained on small and medium-sized samples.

| Properties | Requirement according to ČSN EN 13139 | Test result of the sample | Declared filler property |
|---|---|---|---|
| Aggregate fraction/fineness | Declaration Filler for mortars | D(90) 0.1965mm | 0 – 0.2 |
| Grinding fineness (Blaine) | – | 335 $m^2\,kg^{-1}$ | <350 $m^2\,kg^{-1}$ |
| Bulk weight ČSN EN 1097-7 | Declared value | 2.630 $g\,cm^{-3}$ (pycnometry) | 2.630 ± 100 $g\,cm^{-3}$ (pycnometry) |
| Bulk density ČSN EN 1097-3 | Declared value | 1 600 $kg\,m^{-3}$ | 1600 ± 100 $kg\,m^{-3}$ |
| Chloride content | Declared value < 0,1 % | does not contain | does not contain |
| Sulphates | FeS < 0.1 % < 1 $g\,kg^{-1}$ | 23.3 $mg\,kg^{-1}$ (dry substances) | < 100 $mg\,kg^{-1}$ (dry substances) |
| Absorbency | Declared value | 4.8 % | < 5 % |
| ČSN EN 1097-6 | < 0.5 | 0.412 ± 0.025 | < 0.5 |
| Mass activity index | < 100 | 25.6 ± 5.2 | < 100 |

TABLE 1. The mechanical and physical parameters of the silicate filler determined according to the individual standards.

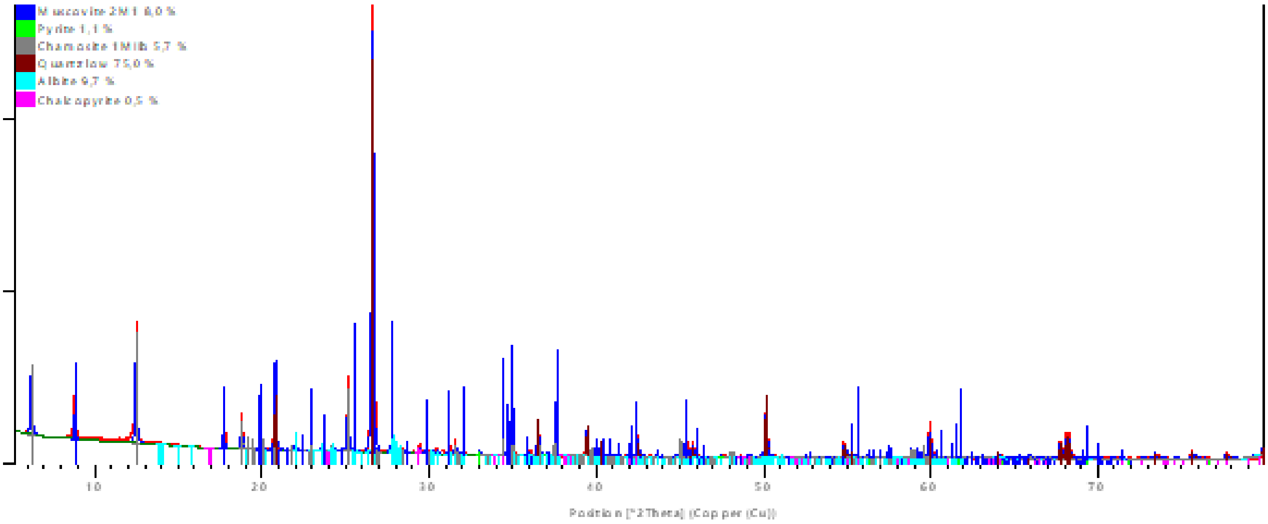


FIGURE 3. Result of XRD mineralogical phase analysis of light component sample "Zlaté Hory" silicate filler, the results shown in the graph are listed in Table 2 below the graph.

| Color | Mineral | Quantity content |
|---|---|---|
| Blue | Muscovite 2M1 | 8,0 % |
| Light Green | Pyrite | 1,1 % |
| Grey | Chamosite 1MIIb | 5,7 % |
| Magenta | Quartz | 75 % |
| Light Blue | Albite | 14,6 |
| Purple | Chalcopyrite | 0,5 % |

TABLE 2. The resulting measured values of the specific weight of the separated tailings.

The result of XRD mineralogical phase analysis after separation for the pyrite-depleted light components is shown in Table 2 and Figure 3.

Mineralogical analysis shows that the proportion of heavy components (pyrite and chalcopyrite) after separation is low. The gravity separation of the heavy component was quite effective. The light component: concentrate separation ratio was determined after processing of 1 000 kg of the deposit and was 81.2 % light component and 15.1 % concentrate. A total of 3.7 % were losses.

The light fraction obtained was used for the preparation of silicate filler and as a source of aggregate which will be further used to produce road base layers. To verify the filler parameters, tests were carried out within the scope of the requirements of ČSN EN 13139 Aggregates for mortars. The parameters verified and the limits set are given in Table 1.

Hardened mixture for base layers of linear civil engineering structures is considered a functional sample. It used regraded and cleaned fractions of aggregates from the tailings after mining at underground mine "Bytíz". The binder phase included, in addition to mixed Portland cement, "Opatovice" fly ash and the basic recipe is given in Table 3.

For aggregate mixtures cemented with cement the ČSN EN 14227-1 [18] standard applies. These mixtures are usable as a base layer for linear civil engineering structures. The aggregate used as filler is "Bytíz" 0/32, which is a residue after separation of heavy minerals from the "Bytíz" deposit. Due to the origin of the aggregate and to improve the grain size curve, the aggregate "Náklo" in the 0/4 fraction was used as a supplementary aggregate. The following

| Name of functional sample | CEM II/A-M 42,5R | Fly ash “Opatovice” | Aggregates “Náklo” 0/4 | Aggregates “Bytíz” 0/32 | Water Water |
|---|---|---|---|---|---|
| FW01010061-V2 | 95 | 65 | 890 | 1 085 | 145 |

Table 3. Overview of parameters of the functional sample containing silicate filler for linear structures.

tests were carried out to verify the parameters of the foundation:

The compressive strength according to ČSN EN 13286-41 [19] was 5.9 MPa after 7 days and 10.4 MPa after 28 days, which is higher than the required value of 5 MPa after 7 days and 8 MPa after 28 days. The bulk density according to ČSN EN 12390-7 [20] exceeded the required minimum value of 2 300 kg m$^{-3}$. The optimum moisture content-Proctor test according to ČSN EN 13286-2 [21] was 6.8 % which is less than the maximum allowable moisture content of 10 % and the maximum dry mix bulk density according to ČSN EN 13286-2 was 2 190 kg m$^{-3}$ which also corresponds to the required standard value of 2 200 $\pm$ 100 kg m$^{-3}$.

## 4. Conclusion

The main objective was the use of tailings for the preparation of base layers of linear road structures and the design and development of waste-free technology to produce base mixtures. Preliminary research on legislative requirements and proof tests was carried out. Samples of structural concretes and mixes for the base layers of linear structures were prepared and tested from samples of “Bytíz” aggregates. The resulting functional sample was classified as SC – Type 4 – 0/32 – C8/10 based on the positive results obtained.


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