

STONE DUST AGGLOMERATION FOR UTILIZING AS BUILDING MATERIAL

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ABSTRACT

In the paper we discuss the possibility of using stone dust for utilizing as building material. The tested material was amphibolite, found in the Sudeten Mountains and the Tatra Mountains in Poland. The chemical composition of dust was determined by means of spectrometry methods. Moreover, the basic physical properties of the material were designated. Stone dust was mixed with starch or cement binder. The binder addition was from 5% to 20% by weight. The water content was adjusted to about 25% humidity. The mixture was then compressed in a hydraulic press at 50 MPa. The results of the mechanical toughness of agglomerates were shown. On the basis of the results, acceptable toughness of agglomerates was found, with the addition of cement in mass share 20% and seasoning for 48 hours. However, starch was not suitable as a binder for agglomeration of amphibolite.

Keywords: agglomeration, stone dust, amphibolite, utilization

INTRODUCTION

Broken aggregates of stone are basic raw materials used mainly in construction, almost from the beginning of civilization. Obtaining specific fractions of aggregates, thanks to the use of specialized machinery and equipment and processing technology, results in significant amounts of dusts. In Poland, the production of aggregates in 2011–2014 amounted from 6.216.000 up to 10.497.000 tons per year [15].

Stone dust is produced by the process of cutting into bricks and cleaning, where it is necessary to use dust extraction systems or water flushing systems. These fractions often exhibit strong mutual attraction, hence the need for separation techniques from coarse particles [14]. Stone dust is used increasingly often to produce road pavements [8, 9]. It is also interesting to use dust for agricultural purposes [5]. Delivery of stone dust to barren soil causes re-mineralization, as stone is

the source of many elements and minerals. Another direction for the use of dust is the ceramic industry, as a component of ceramic tile clinker, and glass industry [15]. The possibility of using basalt dust in cement mortars has been demonstrated [4]. This dust, used as a substitute for sand, increases the strength of cement mortars [2]. It fills the pores in the cement matrix and seals the structure of the mortar with increasing its density. Additionally, it exhibits pozzolanic properties. The addition of basalt dust also increases frost resistance of cement mortars and concrete [3]. Stone dust (granite) was recycled by incorporating it into building materials. Bricks were made in order to study their properties. It was found that the compressive strength of bricks depended on the percentage of dust mixed with fly ash [13]. The above-mentioned discussion proves that the incorporation of stone dust as replacement can solve a part of the problem associated with waste disposal (Fig. 1).

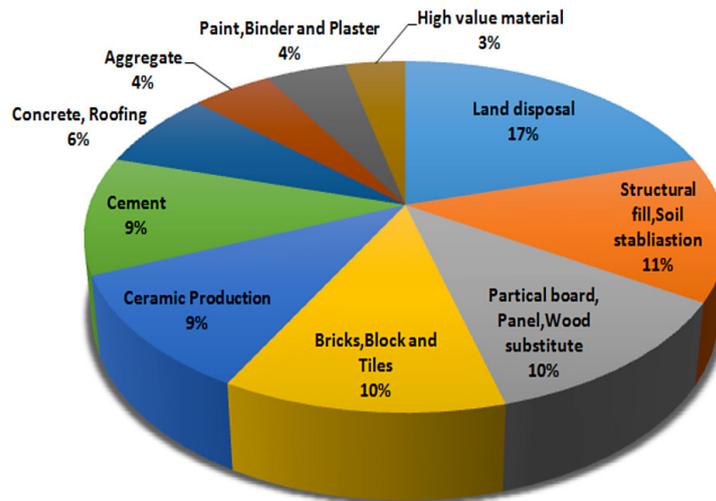


Fig. 1. Stone dust utilization [10]

Stone dust is a serious environmental problem because it is a non-biodegradable material. Stone dust dumped on land can reduce the rate of rain water percolating and deteriorate soil fertility. When dumped in rivers and streams, it contaminates the water. Stone dust can be utilized for developing low cost building materials such as block, brick, tiles etc. [10]. A building product was presented consisting mainly of limestone dust, mixed with Portland cement [6]. They showed that quarry dust-cement mixtures can be used for the production of molded masonry bricks with acceptable mechanical properties. Various methods of agglomerating fine-dust materials, including briquetting, pelletizing and granulation have been investigated [1]. Commonly, there are mineral or organic binders used for agglomeration processes. Moreover, binderless briquetting was found to be successful in the case of the fine and ultra-fine coking coals [12].

The goal of this study is to investigate the possibility of utilizing the stone dust agglomerate as building material. This stone, named amphibolite, are widespread in Poland and are found in the Sudeten Mountains as well as the Tatra Mountains.

MATERIAL AND METHODS

The material we investigated was amphibolite stone dust. Amphibolite is a metamorphic rock, dark green, dark gray, black or brown in color. The main minerals are amphiboles as well as quartz, epidot, zoisite, grenadine, biotite, cordi-

erite, andalusite, sillimanite, tourmaline, titanite, ilmenite and pyroxene.

The material was delivered by the Quarry "Piława Górna" located in Lower Silesia. It is one of the largest raw material fields in Poland for the production of broken aggregates of stone. Production capacity of the mine is about 7.5 million tons per year. Crushed stone is used for the construction of roads, railway lines, and as an ornamental stone to diversify the gardens, whereas stone dust is used for the production of mineral asphalt, mechanically stabilized substructures and high strength concrete.

The mineral composition was analyzed by the X-ray diffraction (XRD) method (Fig. 2). XRD test of mineral composition are aimed at determining the presence of individual elements (qualitative analysis) and the percentage content of compounds (quantitative analysis).

Percentage of chemical compounds was determined with the spectrometry method of fusion-inductively coupled plasma (FUS-ICP). The presence of the most important elements was determined using a spectrometer of total digestion-inductively coupled plasma (TD-ICP) and the method of instrumental neutron activation analysis (INAA). The gradation of stone dust was specified by means of sieve analysis, according to the Polish standard PN-EN 933-1. The basic physical properties of the material were designated and shown in Table 1.

Stone dust was mixed with two types of binders: organic (starch) and mineral (cement). Mixing was carried out with an electric vertical mixer, where the binder was added. The binder

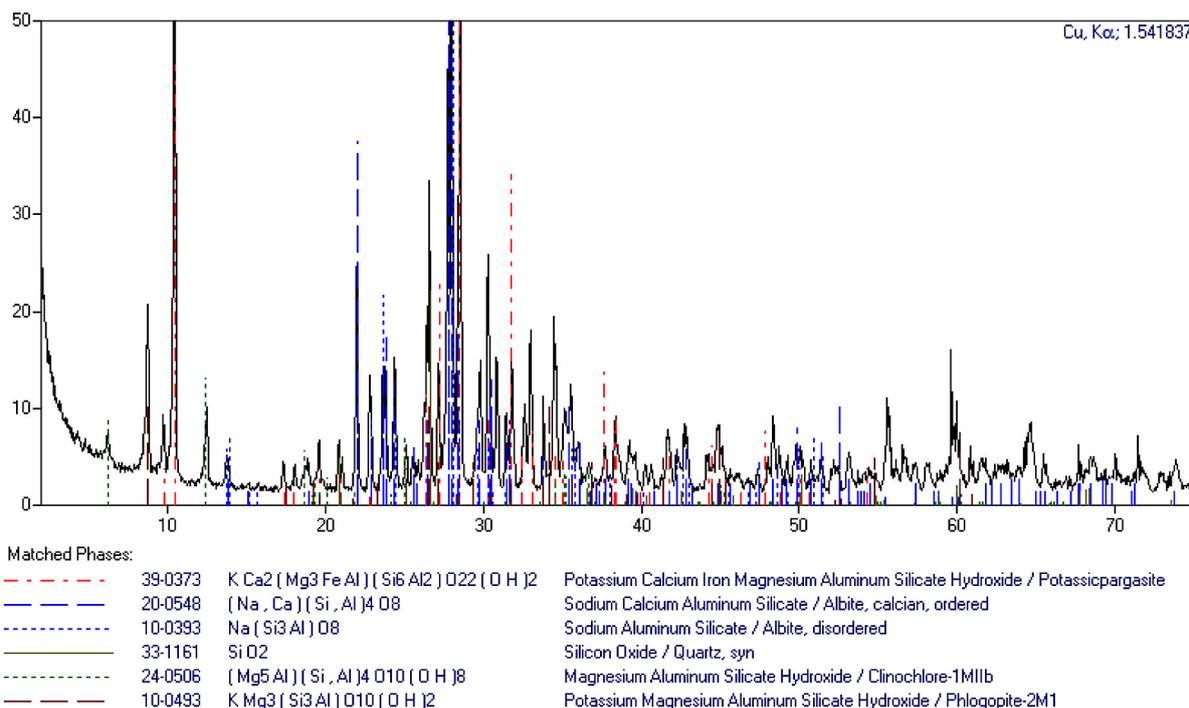


Fig. 2. Sample of XRD of amphibolite stone dust

Table 1. Physical properties of amphibolite stone dust

Properties	Standard	Unit	Result
The content of remains	PN-EN 933-1	%	8.60
Flow indicator	PN-EN 933-6	s	42.0
Dust quality	PN-EN 933-9	g/kg	1.00
Volumetric density	PN-EN 1097-6	Mg/m ³	2.90
Bulk density	PN-EN 1097-3	Mg/m ³	1.65
Absorptivity	PN-EN 1097-6	%	0.50
Fat pollutions	PN-EN 1744-1	%	0.00

addition was from 5% to 20% by weight. During mixing, water content was adjusted to about 25% humidity. The mixture was then compressed in a hydraulic press at 50 MPa (Fig. 3). The press was equipped with a molding matrix consisting of a cylindrical die and a punch (Fig. 4), allowing two samples to be made simultaneously. We obtained uniform agglomerates (briquettes) having a cylindrical shape, a diameter of 28 mm and a height of 14 mm (Fig. 5).

For further study of mechanical toughness, both new-made and seasoned samples were selected. Seasoning consisted in storing samples in a closed airy room for a few days to several weeks after they were made. The toughness of the agglomerates was determined using the gravitational drop test. Samples were dropped three times from a height of 2.0 m onto a metal

base, and weight loss was measured after every drop. Then percentage Impact Strength Index was calculated – minimum index should be at least 90% [1].

RESULTS AND DISCUSSION

Chemical composition and grain size

Table 2 shows the percentage of chemical compounds comprised in the amphibolite stone dust. The presence of the most important elements is shown in Table 3. The results of sieve analysis of stone dust are shown in Table 4.

On the basis of data, a high proportion of silicates in the tested material was found, ranging from 49.66% to 58.38%. Alumina and iron oxides also have a significant share, with a combined



Fig. 3. Hydraulic press (Phot. G. Borowski)

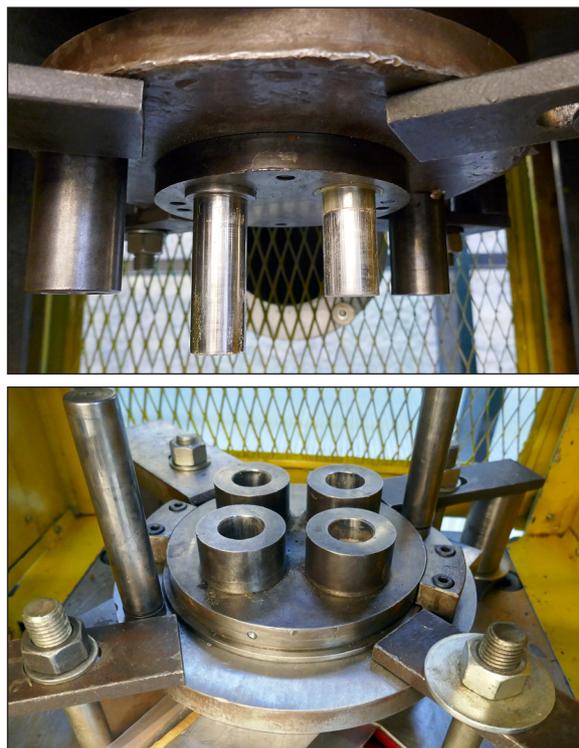


Fig. 4. Molding matrix (Phot. G. Borowski)



Fig. 5. Look of agglomerates (Phot. G. Borowski)

Table 2. Chemical compounds of the amphibolite stone dust

Compound name	Chemical compound content [%]			
	Stone dust	Dust from the collector	Dust from the dump 0-2 mm	Dust from the dump 0-5 mm
SiO ₂	49.66	57.88	58.38	56.13
Al ₂ O ₃	15.56	15.22	15.8	16.04
Fe ₂ O _{3, total}	11.73	9.37	8.33	9.92
CaO	9.49	5.34	3.83	5.19
MgO	6.96	4.26	3.9	4.36
Na ₂ O	2.84	2.39	2.94	2.22
TiO ₂	1.99	1.06	1.04	1.19
K ₂ O	0.49	1.70	1.94	1.98
P ₂ O ₅	0.23	0.20	0.15	0.12
MnO	0.19	0.21	0.20	0.25

Table 3. Content of the most important chemical elements

Name of the element	Content of chemical elements [ppm]			
	Stone dust	Dust from the collector	Dust from the dump 0-2 mm	Dust from the dump 0-5 mm
Ba	89	522	596	569
V	302	238	193	250
Sr	284	150	179	155
Zr	196	209	153	151
Cr	169	132	121	144
Cu	152	86	58	134
Zn	123	128	136	134
Ni	95	84	59	77
Co	49	38	28	44
Sc	36	26	23	34
Y	30	32	27	32
Ce	24	47	52	36
Nd	14	25	16	22
La	12	27	29	17

Table 4. Results of sieve analysis of stone dust

Sieve mesh size [mm]	Residual material [%]	Screened material [%]
4.0	0	100
2.8	0	100
2.0	9	91
1.0	28	63
0.5	19	43
0.25	17	27
0.125	12	15
0.063	6	8.6
0.0	8.6	–

value of 25.48%, on average. The outstanding metal oxides represent an average share of about 22.5%. Among the elements, the highest content was found in the case of barium, as well as vanadium, strontium, zirconium, chromium and zinc. Other metals, including rare earth metals, are present in the amounts lower than the vanadium alone, which is regarded as an additive in the production of high quality steel.

The chemical composition of amphibolite dust is very similar to the composition of basalt dust [11]. Silicon oxide SiO₂ and aluminum oxide Al₂O₃ prevail in its composition constituting a share of 56% by weight, as well calcium oxide CaO and iron oxide Fe₂O₃ [3]. Similarly to basalt, the tested material shows quite a high crystallisation capacity, which supports the use of amphibolite dust for the manufacture of glass and ceramic products [5, 11].

Mechanical toughness

The results of preliminary amphibolite dust agglomeration tests, together with the mechanical toughness of obtained bodies, are presented in Table 5.

On the basis of the presented results, unfavorable properties of starch-enhanced aggregates were found. Seasoning of body led to an increase in their Impact Strength Index, but the required values were not achieved. However, the results of the others research indicate the possibility of obtaining tough organic-binder aggregates in the compacting and briquetting processes [1, 7].

Satisfactory results of the drop tests were obtained for aggregates with cement as a binder. Finding the correct briquettes needs to be seasoned for a minimum of 48 hours. Increasing the binder's contribution raised the Impact

Table 5. The results of gravitational dump test

No.	Type of binder	Binder share [%]	Impact Strength Index [%]	
			New-made sample	Seasoned sample at 48 h
1	Starch	10	57.0	65.2
		15	61.4	68.1
		20	64.8	72.0
2	Cement	10	74.9	82.4
		15	78.6	86.2
		20	84.5	92.0

Strength Index in the gravitational drop test. The best result on average of 92% was achieved for seasoned agglomerates with a 20% share of cement.

According to the literature, increasing in the proportion of binder with stone dust in the compound for agglomeration does not always produce positive results [10, 13]. Acceptable bricks were obtained for the 15% addition of cement in a mixture of limestone and compressive strength was greater than 7 MPa [6]. In the case of the production of fine stone cobble cubes the cement content is from 15% to 30% [14]. It has been noted that attaining agglomerates depends on the molding process and on the range of pressure forces [7].

The authors have plans for further consolidation of stone dust with various types of cement along with the selection of its mass share. This will allow to obtain durable bricks that will be used in the construction industry.

CONCLUSIONS

On the basis of the results presented in the paper, it was stated that:

1. The amphibolite stone dust was defined as "hardly merged". The mechanical strength of new-made samples was insufficient, regardless of the type and proportion of the binder. No satisfactory results were obtained using a starch binder.
2. Seasoning for 48 hours increased the mechanical properties of agglomerates.
3. Agglomerates with acceptable toughness were found with the addition of cement in mass share 20%, compressed in a hydraulic press at 50 MPa.

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