Results of the freeze resistance test, swelling index and coefficient of permeability of fine-grained mining waste reinforced with cements

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Abstract. The article presents the result of laboratory tests for mining waste with grain size of 0 to 2 mm stabilized with cement. Used for stabilization of cement CEM I 42.5 R and blast furnace cement CEM III / A 42.5N - LH / HSR / NA and a plasticizer sealant. Cement was added to the mining waste test in the proportions of 5 - 8% in relation to the skeleton's weight. For the cemented samples, the freeze resistance test, swelling index, coefficient of permeability and pH of water leachate were tested. The addition of a cement binder resulted in diminishing the water permeability of mining waste and limiting the leaching of fine particles from the material.

Keywords: mining waste, mining waste with cements, the freeze resistance test,

1 Introduction

Extraction of mineral ores and energy resources results in mining waste. Since the 1980s, mining waste from various types of mines has been used to build earthworks for flood and road embankments [1, 2, 3, 4, 6, 7]. The mining waste from mines of the Upper Silesian Coal Basin have been stored on heaps for years, which is a big environmental problem. For example, each year, the Sobieski Mining Plant generates 4.6 million tons of coal and 2.2 million tons of mining waste. This waste contains mainly crumbs of claystone's, siltstones, clay minerals, shale and coal. The size of the mining waste distribution depends on the mining plant and the technology they use. Most often, this is waste with grain size from 0 - 200.0 mm, 0 - 125.0 mm, 0 - 31.5 mm, 0 - 2.0 mm and the so-called coal mills.

The article presents the results of freeze resistance tests, swelling and filtration coefficient which were carried out on mining waste from the Sobieski Mining Plant. Wastes with a grain size of 0 to 2 mm were selected for the test, they are not very resistant to physical and chemical ventilation. In the tests on the material, it was found that the material is difficult to compact to a density degree of compaction by 0.97 due to the fact that the material is hardly durable and under the effect of compacting it disintegrates into finer

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fractions [2,4]. In order to improve its physical and mechanical properties, it was proposed to stabilize the material with cement.
In order to improve the physical and mechanical properties, it was proposed to stabilize the material with cement. Cement stabilization is also aimed at limiting the leaching of fine particles from the material when using material for the construction of flood embankments. The mining waste was stabilized with Portland cement CEM I 42.5 R and cement CEM III / A 42.5N - LH / HSR / NA and plasticizing sealant. Portland cement CEM I 42.5 R contains from 95 - 100% Portland clinker and up to 5% calcium sulphate binding time regulator. The main component of cement CEM III / A 42.5N - LH / HSR / NA is ground Portland clinker (35 ÷ 64%), granulated blast furnace slag (36 ÷ 65%) and calcium sulphate binding time regulator (up to 5%). It is characterized by low hydration heat (LH), high resistance to alkaline corrosion (NA) and high resistance to corrosive agents (HSR). For research purposes, also plasticizer sealing concrete and mortar were used to seal and waterproof Soudaproof IW. The Soudaproof IW sealing plasticizer is used for structural concrete which must withstand the external pressure of water, and for retaining walls, underground storeys, basements, foundations, patios, etc.

2 Preparation of trials, procedure, course and test results

The tests of freeze resistance, swelling and filtration coefficient were carried out for extractive wastes from the Sobieski Mining Plant with grain size of 0 to 2.0 mm. The mining waste consists mainly of clays and crushed-coal crumbs, the carbon content exceeds 10%, reaching in extreme cases even 20%. The waste contains up to 5% of sulphur [8,9]. In the grain size distribution test, about 18 - 23% silty and clay fraction and about 77 - 82% of sand fraction were determined. From the graining curve it follows that the waste is equiangular (U = 4.75), so it is a soil that is suitable for stabilization with cementitious cement in terms of grain size [10].
The tests of mining waste have been prepared for research:

- without added cements (ZG S1),
- with the addition of 8% Portland cement CEM I 42.5 R, with a diameter of 70.0 mm and a height of 35.0 mm (ZG S1 + 8% CEM l),
- with the addition of 8% Portland cement CEM I 42.5 R, dimensions 100.0 x 100.0 x 50.0 mm (ZG S1b + 8% CEM l),
- with the addition of 5% Portland cement CEM I 42.5 R and plasticizer Soudaproof IW in a proportion of 1.3 L / 100.0 kg of cement, 70.0 mm in diameter and 35.0 mm in height (ZG S1 + 5% CEM l + P),
- with the addition of 5% Portland cement CEM I 42.5 R and the Soudaproof IW plasticizer in a proportion of 1.3 L / 100.0 kg of cement, size 100.0 x 100.0 x 50.0 mm (ZG S1b + 5% CEM l + P),
- with the addition of 5% CEM III / A 42,5N - LH / HSR / NA metallurgical cement, 70.0 mm diameter and 35.0 mm height (ZG S1 + 5% CEM III),
- with the addition of 5% CEM III / A 42.5N - LH / HSR / NA, size 100.0 x 100.0 x 50.0 mm (ZG S1b + 5% CEM III)

The tests was concentrated in thin layers to the degree of compaction Is from 0.93 to 0.97, the moisture content in the range of 0.7 - 1.15 moisture content. The optimum moisture content for mining waste (ZG S1) was determined according [11] by method I, and it is 13.3%, for mining waste with cement 12.3%.
Attempts with cement additions were secured against moisture loss for 28 days of setting, then tested for frost resistance, swelling, filtration and samples of water leachate for testing pH.

2.1 Freeze resistance test

The freeze resistance test was carried out according to the [8] standard method - Simple method. After cementing, the samples were immersed in water for seven days. After saturation with water, the samples were frozen in air at -18 ° C for 6 hours. The samples were thawed in water at a temperature of ± 18 ° C for 3 hours. The freezing - thawing process was discontinued when clear cracks and cracks appeared on the sample or the percentage loss in mass was more than 5%.

Table 1 shows the weight of the test before and after the freeze resistance test. For mining waste with the addition of 8% Portland cement CEM I, in relation to the weight of the skeleton, during defrosting in water, the total disintegration of the molded sample was observed during the first cycle (SK 6, SK 7). Also two tests of mining waste with the addition of 5% CEM 1 cement and the Soudaproof IW plasticizer (SK 1, SK 2) disintegrated during the first cycle. From the SK 3 sample (ZG S1 + 5% CEM 1 + P), a weight loss of over 40% was recorded (figure 1). In the case of mining waste with the addition of 5% CEM III metallurgical cement, a decrease in the sample weight of over 5% was noted after the third cycle. The tests showed no scratches or cracks, only jagged edges were observed (figure 2).

Fig 1. Mining waste sample with 5% CEM I cement + a plasticizer after the first cycles of freezing - thawing

Fig. 2. Sample of mining waste with the addition of 5% CEM lll cement before and after 3 cycles of freezing - thawing.

Table 1. Test of freeze resistance of mining waste reinforced with cements according to PN-B-06265 "Simple method".

No.	Addition of cement	Weight of the sample before the test [g]	Weight of the sample after the test [g]	Number of cycles of freezing - thawing	Loss of weight
SK6	ZG S1 + 8% CEM lb	925.74	-	I	100%
SK7	ZG S1 + 8% CEM lb	946.98	-	I	100%
SK1	ZG S1 + 5% CEM lb + P	913.81	-	I	100%
SK2	ZG S1 + 5% CEM l b+ P	958.73	-	I	100%
SK3	ZG S1 + 5% CEM lb + P	959.88	392.42	I	40.88%
SK4	ZG S1b + 5% CEM III	959,18	837,37	III	12,7%
SK5	ZG S1b + 5% CEM III	951,58	892,93	III	6.16%

2.2 Swelling index

The swelling process of mining waste and cement-reinforced mining waste was determined by the free swelling index Ep according to G. Olson [5], specifying the percentage increase in the height of the soil sample determined in the oedometer. The initial sample height is 35 mm. Figure 3 shows the swelling course for the samples tested. In the table 2 shows the swelling index for the trials after 10 and 60 minutes and after one day.

Table 2. Swelling ratio for mining waste with cement determined according to G.W. Olson [5]

	Swelling index Ep [%]		
Sample number	After 10 minutes	After 60 minutes	After 2500 minutes
Sample no. 1 (ZG S1)	-0.04	-0.21	-0.34
Sample no. 2 (ZG S1)	-0.02	-0.05	-0.06
Sample no. 3 (ZG S1 + 8% CEM I)	0.20	0.28	0.54
Sample no. 4 (ZG S1 + 8% CEM I)	0.15	0.46	0.81
Sample no. 5 (ZG S1 + 5% CEM I + P)	0.01	0.02	0.05
Sample no. 6 (ZG S1 + 5% CEM I + P)	0.004	0.02	0.05
Sample no. 7 (ZG S1 + 5% CEM III)	0.05	0.09	0.16
Sample no. 8 (ZG S1 + 5% CEM III)	0.004	0.007	0.02

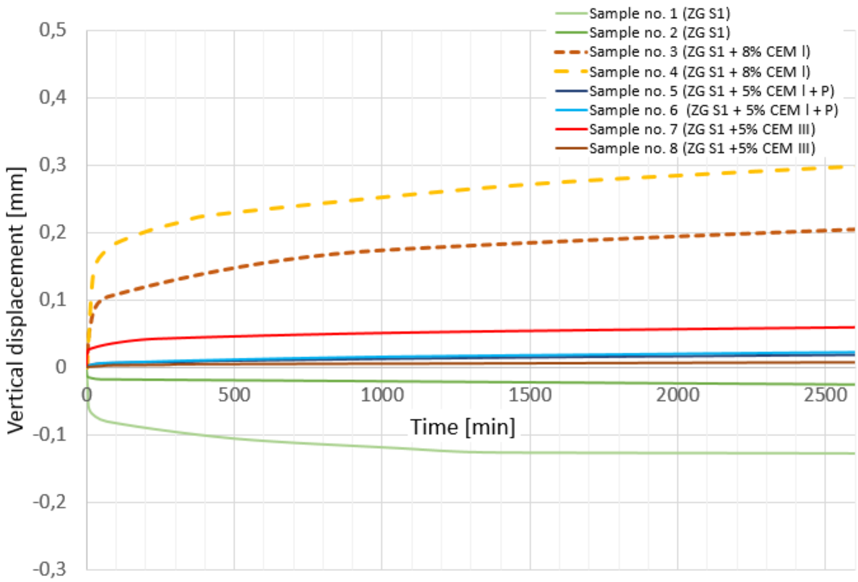

Fig.3 Swelling diagram of mining waste and cement reinforced extractive waste

According to the classific0ation of the free swell index Ep G.W. Olson, the swelling of the mixtures is very low. In the case of mining waste without additions of stabilizing substances, after the saturation of the sample with water, the sample height decreased.

2.3 Coefficient of permeability and pH

The results of the coefficient of permeability k for the mining waste test are presented in Table 3 and in figure 4. The test was carried out in an edometer according to [12] procedure. The measurement was carried out on pre-hydrated samples. Samples of mining waste with added cement showed a change in the coefficient of permeability with each subsequent measurement. The coefficient of permeability for mining waste ZG S1 without additions of binder is $4.3x10^{-4}$ m/s.

Extraction waste with the addition of 8% Portland cement CEM 1 was made for 9 measurements. The first three measurements showed a significant decrease in the coefficient of permeability, whilst subsequent measurements showed similar values, 5.70e-08 m/s, on average. In the case of the ZG S1 test with the addition of 5% Portland cement CEM 1 and the plasticizer in the proportion of 1.3L/100 kg cement, from 10 to 15 measurements were made for two independently cementing tests. The value of the coefficient of permeability changed successively from 1.6e-06 to $5.35x10^{-7}$ m/s. After stabilization, the coefficient of permeability for the ZG S1 sample with the addition of 5% Portland cement and the Soudaproof IW plasticizer is $5.57x10^{-7}$m/s, on average. Extraction waste tests with the addition of 5% CEM III cement also showed a decrease in the coefficient of permeability from $1.62x10^{-6}$ to $8.88x10^{-7}$ m/s, on average. The differences between samples 7 and 8 result from a different density index of the sample.

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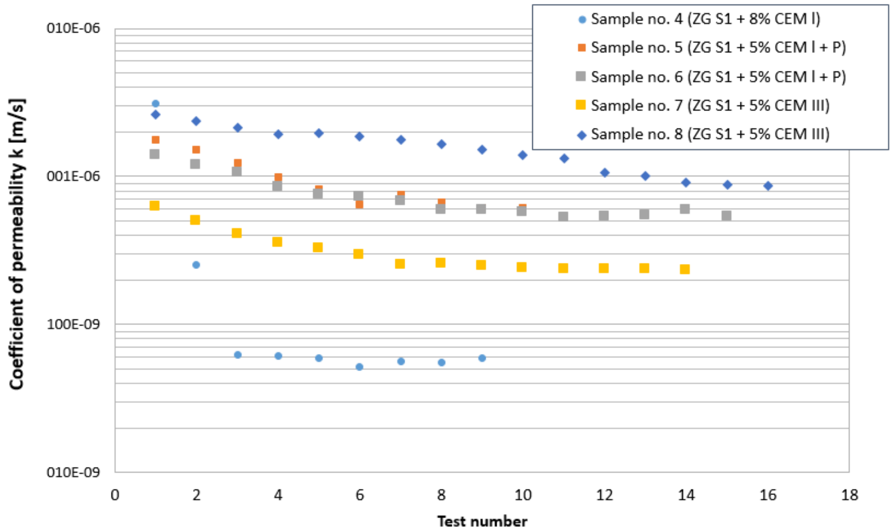

Fig.4 Coefficient of permeability k [m/s] for mining waste from the Sobieski Mining Plant with an addition of cements.

Table 3. Coefficient of permeability k [m/s] based on the procedure in the standard

Sample number	Coefficient of permeability k [m/s]		
	test No. 1	Last test	average value from the last 3 tests
ZG S1 + 8% CEM I	3.10e-06	5.88e-08	5.70e-08
ZG S1 + 5% CEM I + P	1.58e-06	5.35e-07	5.57e-07
ZG S1 + 5% CEM III	1.62e-06	5.52e-07	8.88e-07

Table 4 presents the results of the pH test of water flowing through the sample. In the case of the test with no added cement, it was observed that the water was cloudy and contained fine particles of the sample. The water effluent from the cement-addition trials was free of fine particles and had a more alkaline pH.

Table 4. PH of the water leachate.

Sample number	PH of the water leachate	Temperature [℃]
ZG S1	7.46	21.8
	7.49	22.5
ZG S1 + 8% CEM I	7.81	22.8
	7.92	21.9
ZG S1 + 5% CEM I + P	8.05	22.1
	8.03	21.7
ZG S1 + 5% CEM III	8.23	21.9
	8.34	22.6

3 Summary and conclusions

After the swell ratio test and the filtration coefficient for mining waste from the Sobieski Mining Plant with the grain size from 0 to 2.0 mm, the need to strengthen the research material with binders was identified. The main purpose of adding a cement binder was to reduce the leaching of material particles, reduce the water permeability and swelling, and increase the resistance to frost.

When testing the coefficient of permeability k for mining waste, a turbidity of water was observed. The test of pH of water leachate for samples without additives is 7.46 on average, and for mining waste with the addition of cements are more basic, e.g. with the addition of 5% CEM III cement - 8.34 (tab. 4). The pH of the leachate from the sample without cement additives is more acidic due to the presence of washed particles from the material. Environmental requirements according to the Regulation of the Minister of Environment of July 24, 2006 (OJ No 137, item 984, as amended) for all variants of the tested trials, where the pH range for water leachates ranges between 6.5 and 9.

The addition of a cement binder caused a reduction in the water permeability of the mining waste. In the case of cement tests, both CEM 1 and CEM III, a decrease in the filtration coefficient was observed together with the next measurement (figure 4). This is due to the swelling of extractive waste with the addition of cements and the reduction of pore spaces in the material. In the swelling diagram 1 and the filtration index 2, the relationship between the size and speed of the swelling increase to the decrease in the filtration index can be seen. The lowest coefficient of permeability k at the end of the swelling process was noted in the case of a mining waste test with the addition of 8% Portland cement CEM l and is on average the last three measurements 5.70e-08 m / s (poor water permeability of the material).

In the study of the freeze resistance test of mining waste with the addition of cements using the usual method according to PN-B-06265:1988, a noticeable improvement in strength in the case of mining waste with CEM III cement is noticeable. Samples with the addition of 5% CEM III / A 42.5N - LH / HSR / NA exceeded the permissible weight loss only after the third defrost. It should be noted that the maximum cement content in the sample is 5 - 8% in relation to the skeleton weight and moisture content in the range from 8.75 - 14.15%. The addition of a cement binder to mining waste from the Miners Sobieski Plant resulted in a reduction of leaching of fine particles from the material and reduced its water permeability.

Amongst the above-mentioned stabilization variants of the mining waste which was examined, the best results were obtained for the material stabilized with CEM III / A 42,5N - LH / HSR / NA cement.

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