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FILTRATION RESISTANCE OF HARDENING SLURRIES WITH FLUIDIZED FLY-ASHES UNDER SULPHATE AGGRESSION

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The research paper presents the results of hydraulic conductivity, pore structure, phase composition and microstructural tests of hardening slurries prepared using Portland cement, bentonite, water and fluidized-bed ashes coming from hard coal and lignite combustion. The slurries were subjected to long-term (210 days) exposure to the filtering action of an environment strongly aggressive to a cement binder. A sulphate solution with sodium content of SO_4^{2-} = 6700 mg/l was applied, which modelled sulphate aggression. The comparative base were samples subjected to filtration in tap water (neutral environment).

The test covered dependencies between hydraulic conductivity k_{10} (filtration coefficient) and the parameters characterizing porous structure in the slurry, as well as the impact of an aggressive medium on slurry tightness (its porosity and hydraulic conductivity). Changes in the phase composition and slurry microstructure were analysed in terms of its corrosion resistance to the action of sulphate aggression.

Observations from other researchers have been confirmed that the use of fluidized fly-ash addition has a positive effect on increasing the resistance of cement matrix exposed to sulphate aggressiveness.

Keywords: hardening slurries, cut-off walls, sulphate aggression, fluidal fly-ashes, circular economy

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1. INTRODUCTION

The rising awareness in terms of threats to the natural environment results in great emphasis on developing eco-friendly technologies and expectations that economic and civilization growth will be sustainable. Strategic concepts of complex legal, economic and educational nature are being developed, apart from technical tools. Their objective is to shape a responsible approach of the societies towards environmental protection and natural resources. One of such concepts is an almost zero-waste economy – Circular Economy, which involves striving for multiple re-use of products, including by-products. It requires not only changing habits, legal standards and appropriate economic tools prioritizing secondary materials, but also the development of appropriate technologies, since only they can make secondary products as good as the primary ones.

One of the key issues in EU countries are the millions of tons of coal combustion by-products (CPBs) generated each year [1] and millions more accumulated in landfills. Utilizing CPBs in line with the ideas of Circular Economy, in economy branches such as civil and hydro engineering, agriculture or production of plastics is not always possible due to the particular properties of such waste. According to the data [1], only 25% of the CPBs are re-used, satisfying the principles of Circular Economy. Ashes from coal combustion in fluidized-bed boilers are particularly difficult in terms of reusing. A different crystallographic structure increased (relation to conventional ash) content of calcium compounds and unburned coal components, as well as high water demand, significantly restrict the application-related potential of this waste.

In search for new methods of utilizing fluidized fly-ashes, studies were undertaken regarding the possibility of adding them to hardening slurries [2, 3]. According to the definition [4], a hardening slurry is: a suspension, which contains cement or another binder and additional materials, such as clay (bentonite), ground granulated blast furnace slag (GGBFS) or pulverized fuel ash (PFA), fillers, sand and admixtures.

The cut-off walls made of hardening slurries are crucial elements in hydrotechnical facilities. Their task is, e.g., to protect levees against long-term freshet or the protection of landfill embankments against the migration of polluted eluates to groundwater. In such a context, a hardening slurry must maintain durability in contact with a chemically aggressive aqueous environment. The conducted studies on hardening slurries with an admixture of fluidized combustion ashes indicated an improved resistance of the slurries to corrosion in the case of certain aggressiveness of an aqueous environment and a capillary-diffusive transport of aggressive substances [5, 6].

The presence of sulphates in groundwater or eluates is particularly dangerous in terms of material durability. The sulphate corrosion process has been relatively well studied when it comes to concrete. The sulphate corrosion process can be described in several steps: 1. transformation of portlandite to gypsum, 2. C-S-H gel decalcification, 3. lixiviation of calcium from large cement grains, 4. gypsum and ettringite crystallization, 5. formation of microcracks with a significant growth of concrete porosity and a simultaneous weakening of bonds between the cement matrix components, 6. Destruction of the C-S-H phase [7, 8, 9].

Visible corrosion usually commences after the sulphate concentration exceeds 1000 mg/l, and a once started corrosion process proceeds at an already significant rate [9, 10]. Standard [11], when describing exposure to XA chemical aggression, states limit SO_4^{2-} (mg/l) values for the classes: XA1 = 200-600 – slightly aggressive chemical environmental, XA2 = 600-3000 – moderately aggressive chemical environmental, XA3 = 3000-6000 – highly aggressive chemical environmental.

The resistance of concrete to aggressive waters with sulphates may be achieved by using hydraulic and pozzolanic additives [12, 13]. The impact of pozzolanic additives involves decreasing the $Ca(OH)_2$ value and increasing the share of the C-S-H phase in the paste, which significantly lowers the content of large capillary pores (mesopores) [14].

Therefore, a hardening slurry designed as a material for cut-off walls must exhibit, apart from high weathertightness, also filtration (corrosion) resistance in conditions of dynamic flow of chemically aggressive substances.

The article presents results of an experiment modelling corrosion resistance of hardening slurries with an admixture of fluidized hard and brown coal fly-ashes, subjected to long-term exposure to the filtration long action of sodium sulphate. The study involved using sodium sulphate, which is a substance aggressive towards cement binders, with a SO_4^{2-} = 6700 mg/l content. Corrosion-related changes were compared with samples of a slurry subjected to tap water filtration. The paper also presents the methodology and results of hydraulic conductivity (k_{10}) tests involving hardening slurries.

In order to identify corrosion-related changes, the results of porosity test of slurries after their long-term exposure to the filtration action of sodium sulphate and tap water were presented. The correlations between the parameters characterizing slurry porosity and hydraulic conductivity k_{10} were discussed. It also presents a phase composition study using the X-ray diffraction method as well as a hardening slurry microstructural image obtained using a scanning microscope.

2. MATERIALS USED FOR COMPOSING HARDENING SLURRIES

The slurries used for the research were prepared based on the following ingredients: sodium bentonite, Portland cement CEM I 32.5R, fluidized fly-ash from hard coal, fluidized fly-ash from brown coal. In order to obtain the appropriate values (according to [4]) of the properties in the liquid state (Table 2), the compositions of the FPK and FPB hardening slurries slightly differ (Table 1).

Table 1 shows the composition of investigated hardening slurries with fluidized fly-ash from hard coal – FPK and brown coal – FPB.

Table 1. Compositions of hardening slurries

No.	Component	FPK	FPB
1	2	3	4
1	Tap water [dm^3]	1000	1000
2	Bentonite Dywonit S [kg]	40	30
3	Fluidal fly-ash from hard coal [kg]	323	0
4	Fluidal fly-ash from brown coal [kg]	0	326
5	Cement CEM I 32,5R [kg]	163	170

3. DETERMINATION OF HARDENING SLURRY PROCESS PROPERTIES

Batches of slurries were prepared according to the compositions in Table 1, and their basic properties in liquid state were tested (Table 2).

Tests were performed to determine the density *(ρ)* of liquid slurries, their conventional viscosity ratio *(L),* and 24h water setting (O_d) – [4]. Volumetric density *(ρ)* of the slurries was tested using Barroid's balance, and their conventional viscosity – using a viscometer (Marsh's funnel). The 24h water setting test can be described as determining the percentage share of the volume of spontaneously separating water in 1 dm^3 of liquid slurry after one day of holding it in a measuring cylinder.

Table 2. Properties of liquid slurries.

No.	Parameter	FPK	FPB
1	2	3	4
1	Volume density [g/cm^3]	1,29	1,30
2	Conventional viscosity ratio [s]	45	39
3	24h water setting [%]	3,0	5,0

4. PRAPARATION OF TEST SAMPLES AFTER HARDENING

Hardening slurry test cylinders were prepared in PVC moulds of 8 cm in diameter and 8 cm in height. Before the slurry set, the samples were kept under a foil covering in the laboratory. After 3-4 days, the samples were submerged in water. The water temperature was +18°C ± 2°C. The samples remained underwater until the moment of the measurement. Leak tightness of the sample and mould interface was assured by crimping of the mould internal wall and an additional silicon seal.

Testing of hardened slurries was limited to hydraulic conductivity, porosity measurements, and the phase composition of hardening slurries was determined using XRD and photographs taken with an SEM.

The filtering mediums in the conductivity tests were tap water (the reference base) and a sulphate solution: Na_2SO_4 – liquid aggressive towards cement binders. SO_4^{2-} 6700 mg/l content in the used solution enables classifying the exposure as a chemically aggressive environment (XA3).

The slurries were exposed to filtration for 210 days. By the start of the research program, the samples had matured for 28 days. Measurements of hydraulic conductivity were taken over the testing period to track trends in the changes to this value. After the completion of the exposure period, porosity test material was taken from the slurry samples, and thus, distribution of pore sizes and characteristics of the pores were obtained. Then the phase composition of hardening slurries was tested using X-ray diffraction analysis. Also, a number of microstructural photographs were taken using a scanning electron microscope: SEM.

5. HYDRAULIC CONDUCTIVITY TESTS

5.1. INSTRUMENTS

Hydraulic conductivity tests of hardening slurries exposed to the action of tap water and sulphate solution – Na_2SO_4, were carried out in specially (author's design) constructed chemically resistant plastic apparatus (plexiglass and PVC) [15].

5.2. MEASUREMENT METHODOLOGY

The hydraulic conductivity of hardening slurries is very low (similar to that of cohesive soils), and so the time needed to obtain the balance of supply and outflow of water from the sample is long. In such cases, conductivity tests are performed with a variable hydraulic gradient. This method consists of determining the values of water pressure h_1, h_2 etc. in the supply tube with a cross-sectional area a, over established times t_1, t_2 etc. during the liquid's flow through the sample with a length (height) L and cross-sectional area A. In this case the hydraulic conductivity is calculated with the following formula Eq. (5.1):

(5.1.)
$$k_T = \frac{a \cdot L}{A \cdot \Delta t} \ln \frac{h_1}{h_2}$$

where:
k_T – hydraulic conductivity at temperature T, [m/s]; a – cross-sectional area of the supplying tube, [m^2]; L – length (height) of the sample, [m]; A – cross-sectional area of the sample, [m^2]; Δt – time between pressure measurements h_1 and h_2, $\Delta t = t_2 - t_1$, [s]; $h_{1,2}$ – values of water pressures at times t_1 and t_2, [m].

The main advantage of this testing method is the possibility it offers to measure small water flows and forcing high water pressures. The action of the filtering media: tap water and aggressive water solution on the tested sample was of gravitational nature. The measurements were performed with a decreasing initial hydraulic gradient. The sample was placed in the apparatus and had liquid poured over it, up to a level, which induced a maximum hydraulic gradient equal to 45 (hydraulic gradient is the quotient of water pressure measured in m and height of investigated sample in m). Once a week, a measurement of hydraulic conductivity was taken. The range of hydraulic gradients acting on the samples was from 20 to 45, and gradients lower than 45 were only acting on the days of the hydraulic conductivity measurements (once a week) for no longer than 4 hours. Hydraulic conductivity calculated with formula no. 1 does not take into account the influence of filtering liquid temperature. The k_T values obtained during the tests (at temperature T) were recalculated into k_{10} values corresponding to a temperature +10 °C. The following formula Eq. (5.2) was used:

(5.2.)
$$k_{10} = \frac{k_T}{0,7 + 0,03T}$$

The low concentrations of the solutions Na_2SO_4 entitle one to treat them as tap water, and thus ignore the influence of changes in their viscosity and density on the hydraulic conductivity of the slurries.

5.3. TEST RESULTS

The results of hydraulic conductivity tests – the initial and final values – of hardening slurries exposed to long-term (210 days) filtration of aggressive solution (Na_2SO_4) and tap water are presented in Table 3.

Table 3. Initial and final values of hydraulic conductivity of hardening slurries (FPK and FPB) exposed to long-term (210 days) filtration of aggressive solution and tap water

No.	Type of solution	FPK		FPB	
		Initial values k_{10} [m/s]	Final values k_{10} [m/s]	Initial values k_{10} [m/s]	Final values k_{10} [m/s]
1	2	3	4	5	6
1	Tap water	$2.5 \cdot 10^{-8}$	$2.5 \cdot 10^{-8}$	$1.9 \cdot 10^{-7}$	$2.8 \cdot 10^{-8}$
2	Na_2SO_4	$1.5 \cdot 10^{-8}$	$5.0 \cdot 10^{-9}$	$2.0 \cdot 10^{-8}$	$9.0 \cdot 10^{-9}$

6. SLURRY POROSITY TESTS

6.1. INSTRUMENTS AND TEST DESCRIPTION

For mercury porosity, a Carlo Erba 2000 porosimeter with low- and high-pressure equipment was used. Hardening slurries are porous materials. Pores with the same relative volume in the material can have completely different structures. One of the methods of measuring open porosity is mercury porosimetry. Not only does this method determine the total volume of open pores but it provides information on the volume of pores of specific sizes (the so-called distribution of pore sizes). In conjunction with microscope examination of the structure and density measurements, porosimetry permits comprehensive determination of the structure of a porous material in terms of both quality and quantity.

6.1. TEST RESULTS

The test was performed on samples of hardening slurries with an addition of fluidal ashes (FPK and FPB), after their long-term exposure (210 days) to filtering action of tap water and liquid chemically aggressive towards cement binders. Microstructural parameters of the tested samples were determined on the basis of the diagrams. These values are compiled in Table 4 where the following symbols are used:

Ap – total pore area, [m^2/g];

v_p<0.2 – volume of pores with diameters lower than 0.2 μm;

v_p>0.2 – volume of pores with diameters larger than 0.2 μm;

P_c – total porosity of sample, [-];

d_{max} – maximum diameter of pores, [μm].

Table 4. Specification of microstructural parameters of investigated hardening slurries

No.	Type of solution	FPK	FPB	FPK	FPB	FPK	FPB	FPK	FPB	FPK	FPB
		A_p [m^2/g]		v_p>0,2 μm		v_p<0,2 μm		P_c [%]		d_{max} [μm]	
1	2	3	4	5	6	7	8	9	10	11	12
1	Tap water	99.54	100.91	0.89	0.99	0.46	0.44	76.22	75.90	4.0	7.0
4	Na_2SO_4	89.87	85.88	0.78	0.83	0.44	0.36	74.32	71.04	2.5	10.0

7. X-RAY DIFFRACTION ANALYSIS OF HARDENING SLURRIES

7.1. INSTRUMENTS

X-ray measurements were taken using a Bruker D8 Advance device equipped with a position-sensitive LYNXEYE detector operating over the Bragga-Brentano geometry, using CuKα (λ = 0.15418 nm) radiation with a nickel filter. The measurements were recorded over an angular range 2θ from 8 to 75° with an increment of 0.03° and a recording time of 960 s/increment.

7.2. TEST RESULTS

Fig. 1 shows diffraction images of samples subjected to long-term exposure (210 days) to the filtration action of a solution aggressive to cement binders and tap water.

a. FPK – tap water

b. FPB – tap water

c. FPK – Na_2SO_4

d. FPB – Na_2SO_4

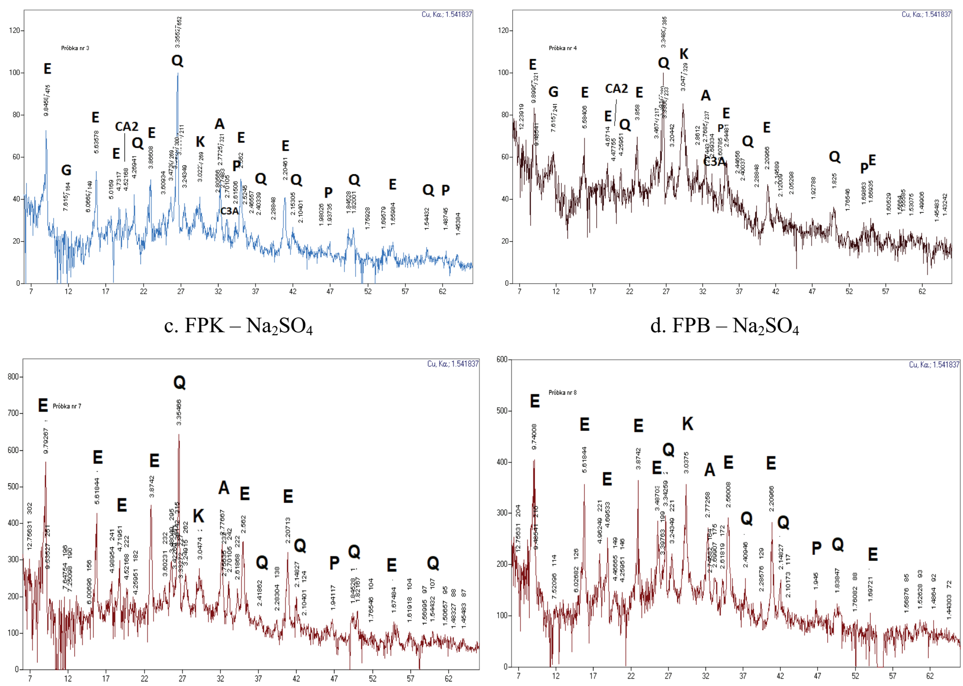


Fig. 1. X-ray diffraction pattern of samples of hardening slurries

A – alite, C3A – tricalcium aluminate, CA2 – grossite, E – ettringite, K – calcite, Q – quartz, P – portlandite, G – gypsum

8. TESTS HARDENING SLURRY MICROSTRUCTURES USING AN SEM

8.1. INSTRUMENTS

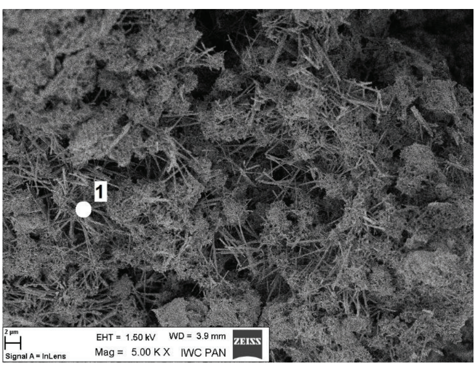
The observations of hardening slurries (FPK and FPB), after their long-term exposure (210 days) to the filtration action of a chemically aggressive liquid and tap water were conducted using a ZEISS LEO 1430 scanning electron microscope equipped with an Oxford ISI 300 energy dispersion detector (EDS) by Oxford Instruments. The preparation of the samples for the test involved sampling their fragments, drying them at a max. temperature of 40 °C, placing on a plate and applying a thin layer of gold dusts. The observations were made in a low vacuum (6·10-5-7·10-6 Torr).

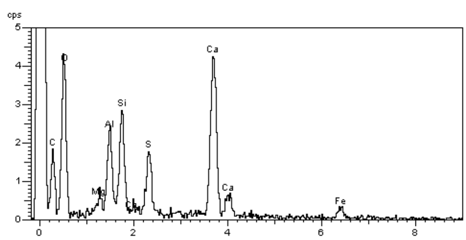
8.2. TEST RESULTS

The observations of hardening slurries (FPK and FPB), after their long-term exposure (210 days) to Selected photographs are presented in Fig. 2.

a. FPK – Na_2SO_4

b. Point 1 EDS analysis





c. FPB – tap water

d. Point 2 EDS analysis

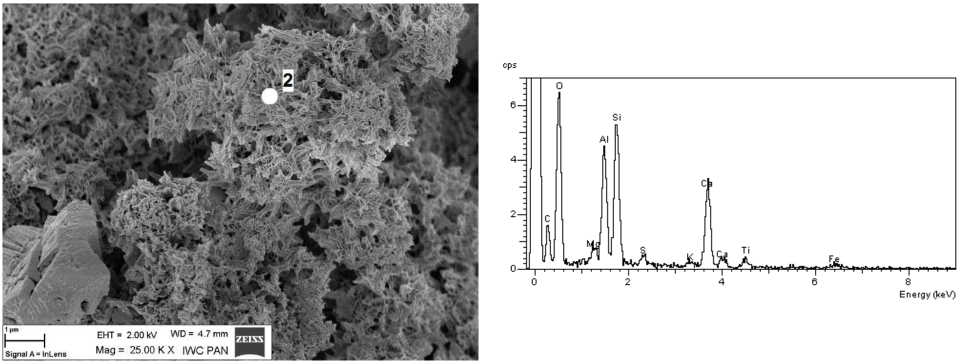


Fig. 2. Microstructure of hardening slurries samples (SEM)

9. ANALYSIS OF TEST RESULTS

The analysis regarding the impact of a long-term exposure to a chemically aggressive solution Na_2SO_4 on the hydraulic permeability of slurries was conducted in comparison to reference slurries - exposed to long-term action of tap water.

The impact of sodium sulphate solution on hardening slurries results in sulphate corrosion. This is a type III corrosion, where the attacking factor are SO_4^{2-} sulphate anions. The attacked component is mainly calcium hydroxide and hydrated tri- or tetra-calcium aluminate, which forms complex salts under the impact of sulphate ions [8, 16, 17]. The formed salts are insoluble in an alkaline environment, yet not fully stable. In the case of concrete, the first phase involves sealing of the structure due to a gradual filling of the pores. However, the further expansion of the crystals results in the formation of internal stresses causing scratches and cracks, until a complete destruction of the material (formation of secondary ettringite) [9, 18].

Long-term exposure of hardening slurries to sodium sulphate filtration (sulphate aggression) indicated filtration resistance of the slurries (both FPK and FPB) to the aggressive action of such substances. The action of sodium sulphate resulted in increased tightness of the slurry structure, which is confirmed by a decrease in the hydraulic conductivity k_{10} from approx. $1.2 \cdot 10^{-8}$ m/s to approx. $3.0 \cdot 10^{-9}$ m/s in the case of FPK and a decrease in the hydraulic conductivity k_{10} from approx.

$1.5 \cdot 10^{-8}$ m/s to approx. $1.3 \cdot 10^{-9}$ m/s in the case of FPB. The recorded tightness of the slurry exposed to tap water filtration was higher for FPB, relative to FPK. This is confirmed by a decrease in the hydraulic conductivity k_{10} from approx. $1.7 \cdot 10^{-7}$ m/s to approx. $1.2 \cdot 10^{-8}$ m/s. The sample of the FPK slurry exposed to tap water filtration exhibits stable behaviour – hydraulic conductivity k_{10} values were around $2.0 \cdot 10^{-8}$ m/s throughout the entire research period.

The next stage of the analysis was the search for relationships between the hydraulic conductivity k_{10} and the values characterizing the microstructure of hardening slurries, which were established after 210 days of exposure. Such correlations can explain the observed changes in the hydraulic conductivity k_{10} of the slurries during long-term filtration of used liquids.

The values characterizing the microstructure, which are highly responsible for the material structure tightness are the total pore area Ap and the volume of pores with diameters above 0.2 μm (mesopores) – vp>0.2 μm. A strong correlation between these values and the hydraulic conductivity k_{10} has already been recorded in the previous research by the Author [6, 15].

A strong correlation can be noted when analysing the values of these parameters for the studied hardening slurries (FPK and FPB) and the two types of solutions used in the experiment, in terms of the k_{10} hydraulic conductivity k_{10} value.

Lower values of hydraulic conductivity k_{10} (Table 3) after exposure to sodium sulphate, both for FPK and FPB, are reflected in respectively lower values for the analysed microstructural parameters (Table 4) relative to the slurries exposed to tap water. The observed tendency is in line with the assumptions that tightness results from lower capillary pores.

The phase composition of the slurries after exposure to sodium sulphate and tap water was studied in search for the causes of the aforementioned phenomenon.

The phase composition analysis regarding hardening slurries after exposure to tap water and sodium sulphate, using the XRD technique, involves analysing the intensity of peaks characterizing appropriate relationships on diffractive images (Fig. 1).

Similar crystalline components were identified in all studied samples (Fig. 1) - clinker relics, ettringite, gypsum, calcite and quartz introduced with ash and bentonite. Furthermore, a compound with a structure resembling calcium bialuminate (CA2) was identified in samples after tap water filtration. Although the structure of the very compound is not thoroughly studied, it is possible to find the results by other researchers, which show a significant improvement of the physical and mechanical properties, as well as corrosion resistance [19] of CA2-based flame-retardant materials. The relics of this compound in the studied slurries can be associated with the composition of ashes and bentonite.

Higher intensities of the peaks characterizing ettringite were recorded for slurries exposed to sodium sulphate (both FPK and FPB), which explains a decrease in the hydraulic conductivity value and lower porosity of the slurries. Peaks characterizing gypsum were identified in samples subject to tap water filtration (especially FPB). This can mean a transformation of ettringite to monosulphate.

Higher intensity of the peaks describing calcite were recorded in FPB samples, which may result from its higher content in brown coal fluidized ash. It should also be noted that calcite content in tap water-filtered slurry (FPK and FPB) is lower compared to hardening slurries (FPK and FPB) after sodium sulphate filtration. This tendency may indicate a more rapid formation of calcium carbonate in the case of a corrosive environment impact.

The aforementioned theses are confirmed in hardening slurry microstructural studies with the use of an SEM. Photos of the microstructure taken using a scanning electron microscope are shown in Fig. 2. An SEM image for an FPK sample after sodium sulphate exposure is shown in Fig. 2a. We can see a filler in the form of hydrated calcium silicates of the C-S-H type, which contains clusters of crystals in the form and shape of needles arranged radially relative to each other. It can be clearly seen that well-developed type I ettringite needles [18] with a length of several micrometres obscure the spaces (pores) in the C-S-H structure. The elemental composition EDS analysis of ettringite formations is shown in Fig. 2b.

Fig. 2c is a microstructural image of an FPB slurry after tap water exposure. We can see a filler in the form of hydrated calcium silicates of the C-S-H type in the form of so-called creased foils – typical for a hardening slurry matrix. A hardening slurry matrix elemental composition analysis (typical for a C-S-H phase) is shown in Fig. 2d. We can also observe numerous voids representing mesopores.

10. CONCLUSIONS

The analysis of the test results regarding hydraulic permeability, pore structure, phase composition and the microstructure of hardening slurries with the admixture of fluidized ashes enables formulating the following conclusions:

1. Slurries exposed to sodium sulphate filtration, which is a solution chemically aggressive to cement binders were additionally sealed relative to slurries exposed to tap water filtration.
2. A slurry with an admixture of fluidized brown coal fly-ash subjected to filtration by an aggressive solution and tap water exhibited a slightly higher structural tightness than a slurry with

an admixture of hard coal fly-ash. This can result from the increased content of calcium compounds in such ashes.

3. There is a close relation between the porosity structure and hydraulic conductivity of hardening slurries with an admixture of fluidized fly-ashes. It is expressed by a correlation between permeability, and the total pore area and mesopore volume.

4. The studies involving phase composition of hardening slurries confirmed the presence of ettringite forms, especially in the case of slurries exposed to sodium sulphate filtration.

5. The microstructural analysis of hardening slurries showed that the resultant ettringite formations crystallize in clusters, obscuring pore spaces within a C-S-H structure, hence increasing matrix tightness.

6. Hardening slurries with an admixture of fluidized hard and brown coal fly-ashes exposed to long-term filtration in strongly chemically aggressive environments (sodium sulphate solution) exhibited filtration (corrosion) resistance. Weakened destructive impact of sulphates resulted from, most probably, the pozzolanic properties of the applied fluidized ashes and the adsorption properties of unburned coal present in such ashes.

7. Fluidized hard and brown coal fly-ashes can be a full-fledge component of hardening slurries following the ideas of Circular Economy.

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LIST OF FIGURES AND TABLES:

ODPORNOŚĆ FILTRACYJNA ZAWIESIN TWARDNIEJĄCYCH Z POPIOŁAMI FLUIDALNYMI NA AGRESJĘ SIARCZANOWĄ

Słowa kluczowe: *zawiesiny twardniejące, przesłony przeciwfiltracyjne, agresywność siarczanowa, popiół fluidalny, gospodarka o obiegu zamkniętym*

STRESZCZENIE

Przesłony przeciwfiltracyjne wykonywane z zawiesin twardniejących mogą być realizowane w obiektach hydrotechnicznych oraz ochrony środowiska, gdzie pracują w warunkach filtracyjnego oddziaływania wód zanieczyszczonych. Tym samym kluczowa staje się kwestia odporności korozyjnej (filtracyjnej) zawiesin w kontekście filtracyjnego oddziaływania różnorodnych środowisk agresywnych chemicznie.

Przedmiotem artykułu są zawiesiny twardniejące cementowo-bentonitowo-wodne z dodatkiem lotnych popiołów fluidalnych ze spalania węgla kamiennego i węgla brunatnego. Głównym celem pracy było określenie odporności filtracyjnej zawiesin twardniejących w świetle długotrwałej ekspozycji na filtracyjne oddziaływanie substancji agresywnej w stosunku do spoiwa cementowego. Zastosowano roztwór wodny siarczanu sodu o zawartości SO_4^{2-} = 6700 mg/l, który modelował agresywność siarczanową.

Badano związki przepuszczalności hydraulicznej z parametrami charakteryzującymi strukturę porów w zawiesinie oraz wpływ agresywnego medium na szczelność zawiesiny (jej porowatość i przepuszczalność hydrauliczną). Analizowano zmiany w składzie fazowym oraz mikrostrukturę zawiesin w kontekście jej odporności filtracyjnej na działanie agresywności siarczanowej. Bazę porównawczą stanowiły próbki poddane filtracji wody wodociągowej (środowisko obojętne).

W artykule omówiono związki korelacyjne parametrów charakteryzujących porowatość zawiesin twardniejących z przepuszczalnością hydrauliczną (k_{10}). Przedstawiono badanie składu fazowego metodą rentgenowskiej analizy dyfrakcyjnej (XRD), a także obraz mikrostruktury zawiesin twardniejących wykonany za pomocą mikroskopu skaningowego (SEM).

Analiza uzyskanych wyników badań zawiesin twardniejących poddanych ekspozycji filtracyjnemu oddziaływaniu roztworu siarczanu sodu pozwala stwierdzić, iż przebieg procesu korozji jest nieco inny niż materiałów budowlanych na bazie spoiwa cementowego.

Potwierdzono obserwacje innych badaczy, iż zastosowanie dodatku lotnych popiołów fluidalnych wpływa korzystnie na zwiększenie odporności matrycy cementowej eksponowanej na agresywność siarczanową. Zidentyfikowane fazy ettringitowe powstałe w matrycy zawiesiny nie spowodowały jej destrukcji, a jedynie zwiększyły szczelność, którą identyfikował wyraźny spadek współczynnika przepuszczalności hydraulicznej k_{10}.

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