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THE TEMPERATURE INFLUENCE ON FINAL COMPRESSIVE STRENGTH OF COAL FLY ASH/CEMENT FREE SAMPLES

WPŁYW TEMPERATURY NA WYTRZYMAŁOŚĆ NA ŚCISKANIE PRÓBEK OTRZYMANYCH Z CEMENTU I POPIOŁÓW LOTNYCH

A b s t r a c t

The inorganic residues arising from coal combustion processes are known as coal combustion by-products (CCBs in USA or CCP in Europe). CCP are mainly fly ash, bottom ash, slag, fluidized bed combustion and flue gas desulfurization by-products. Although some portion of CCP is used by the building industry and others, there is still a proportion which is disposed of in ponds or landfills.
The utilization of coal fly ash has important economical and environmental implications. Thus, it is believed that a ton of fly ash used to replace a ton of cement saves the use of an equivalent of nearly one barrel of oil. An experimental study of a temperature treatment of coal fly ash/cement mixtures with 30 wt.% cement replacement was carried out in 5M NaOH solution at solid/liquid ratio of 0.5. The mixtures were heated for 24 hours at temperatures of 120, 160, 200 and 250ºC in drying-oven. The temperature influence on compression strength development of zeolitized coal fly ash/cement samples after 28 and 90 days of hardening was investigated.

Keywords: coal fly ash, temperature, compressive strength, zeolitization

S t r e s z c z e n i e

Nieorganiczne pozostałości po spalaniu węgla określane są jako produkty uboczne (CCBs w USA lub CCP w Europie). CCP to głównie popioły lotne i denne, żużel, złoże fluidalne oraz produkty z odsiarczania spalin. Pomimo że część z nich jest wykorzystywana m.in. w przemyśle budowlanym, w dalszym ciągu znaczne ilości CCP są składowane. Utylizacja popiołów ma ważne znaczenie ekonomiczne i ekologiczne. Uważa się, że zastąpienie 1 tony cementu popiołem pozwala na zaoszczędzenie baryłki ropy. Badano wpływ temperatury na mieszanki popiół/cement, w roztworze 5M NaOH, przy stosunku masowym fazy stałej do fazy ciekłej równym 0,5, w których 30% cementu zastąpiono popiołem lotnym. Mieszanki wygrzewano w suszarce wysokotemperaturowej w temperaturze 120, 160, 200 i 250ºC przez 24 h. W zeolityzowanych mieszankach badano wpływ temperatury na wytrzymałość na ściskanie po upływie 28 i 90 dni twardnienia.

Słowa kluczowe: popioły lotne, temperatura, wytrzymałość na ściskanie, zeolityzacja

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1. Introduction

Environmental pollution by the coal based thermal power plants all over the world is cited to be one of the major sources of pollution affecting the general aesthetics of the environment in terms of land use, health hazards and air, soil and water in particular, and thus leads to environmental dangers. "Coal combustion residues" is a collective term referring to the residues produced during the combustion of coal regardless of the ultimate utilization or disposal. It includes fly ash, bottom ash, boiler slag and fluidized bed combustion ash and other solid fine particles [1].

Fly ashes are a well-known material in construction and it is used to produce blended cements and concretes. Traditionally, fly ashes have been used as a pozzolanic material to enhance physical, chemical and mechanical properties of cements and concretes. However, only amounts of 20–30% of fly ashes produced are used in these terms and the excess is stored in large extension [2].

A number of hydrothermal activation methods have been proposed to activate fly ash using alkaline solutions (mainly NaOH and KOH solutions). The traditional conversion methods differ in the molarity of the alkaline reagents, activation-solution/fly ash ratio, temperature (80–200ºC), reaction time (3–48 h) and pressure, depending on the type of fly ash used [3].

Our previous studies have shown that the zeolite phase formation influences favourably the process of physico-chemical consolidation at hardening of coal fly ash/cement pastes and leads to higher compressive strength in comparison to a composite prepared without alkaline treatment [4].

Our research was focused on the study of hydrothermal alkaline treatment influence of coal fly ash/cement mixture on mechanical properties of hardened composites in relation to temperature.

2. Materials and Methods

Portland cement (CEM I 42,5) and coal fly ash originating from the Slovakian power plant ENO A in Nováky were used as raw materials. Granulometric composition of original coal fly ash is given in Table 1. The particle size analysis was carried out by dry sieving down to 125 μm on standard series of sieves while undersize was analyzed on the laser granulometer Helos/LA with dry dispersion unit Rodos 11 SR (Sympatec GmbH, Germany).

Table 2 summarizes the chemical composition of coal fly ash in the form of stable oxides. The content of components was determined by AAS analysis (VARIAN, Austria). The total amount of SiO_2 and Al_2O_3 was 82.127%. Based on the chemical analysis, the used coal fly ash is high silica ash with molar ratio of SiO_2/Al_2O_3 = 3.2. The presence of crystalline phases was detected by X-ray diffraction (XRD) analysis on diffractometer DRON 2,0 with goniometer GUR-5 (Technabsexport, Russia). The following minerals of quartz, mullite and hematite are the major components present in coal fly ash (Fig. 1). Cristobalite, magnetite, illite, anhydrite, some silicates, aluminosilicates and their hydrates (albite, andalusite, kaolinite and mordenite) were also identified.

Table 1

Granulometric composition of coal fly ash (CFA)

Fraction [μm]	wt [%]
	CFA
–1.1	1.07
1.1–3.1	2.51
3.1–6	3.39
6–10.50	4.86
10.50–15	5.42
15–25	12.97
25–43	20.43
43–73	27.82
+ 73	21.53

Table 2

Chemical composition of coal fly ash

Chemical composition	Content [%]
SiO_2	62.526
MgO	1.900
K_2O	2.879
Na_2O	1.683
Fe_2O_3	8.068
CaO	2.893
Al_2O_3	19.601
LOI*	2.38

LOI* – Loss of ignition.

Laboratory investigation of alkaline treatment was carried out by activation of coal fly ash/cement mixtures in drying-oven. Coal fly ash/cement mixtures with 30 wt.% cement replacement (sample 2, 3, 4, 5) were chemically treated by mixing in 5 M NaOH solution at solid/liquid ratio of 0.5. The composition of mixtures is given in Table 3. The mixed pastes were put into forms and heated for the subsequent 24 hours at a temperature of 120, 160, 200 and 250ºC in a drying-oven. After the thermal treatment, hardening of samples under laboratory conditions was realized. A comparative cement paste was prepared by mixing only cement with water (sample 1) and kept under laboratory conditions until hardened, too.

The compressive strength values were measured at the fly ash/cement concrete prisms (40 mm × 40 mm × 160 mm) after 28 and 90 days of hardening evaluated according to the STN EN 206.

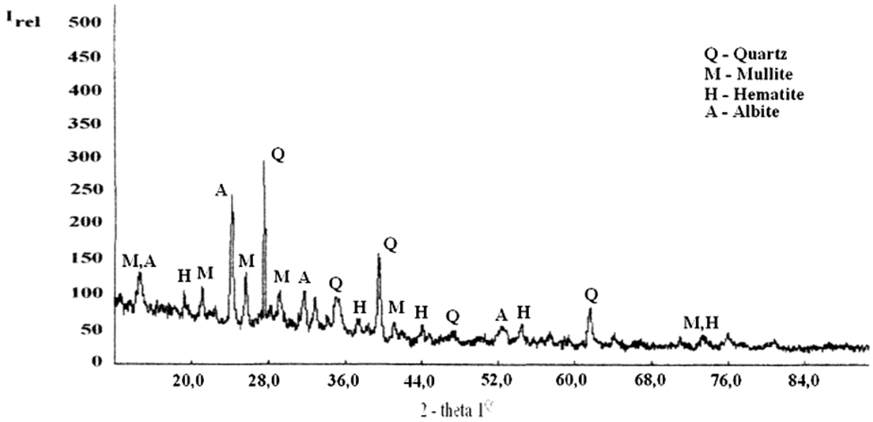

Fig. 1. XRD pattern of starting coal fly ash

Rys. 1. Dyfraktogram wyjściowego popiołu lotnego

Table 3

Composition of coal fly ash/cement mixtures

Sample	Mixtures composition	Temperature [ºC]
1 comparative	100% cement water	–
2	70% cement 30% fly ash 5M aqueous	120
3	70% cement 30% fly ash 5M aqueous	160
4	70% cement 30% fly ash 5M aqueous	200
5	70% cement 30% fly ash 5M aqueous	250

3. Results and Discussion

The compressive strength values of composite samples after 28 and 90 days of hardening are presented in Tab. 4. As it can be seen, compressive strengths of hardened experimental coal fly ash/cement composites reach the values ranging from 7 to 14 MPa.

Compressive strengths of concretes increase with the duration of hardening. However, the compressive strength values of experimental composites are lower than those of a comparative composite (sample 1).

The compressive strength development is closely related to temperature. As it is shown in Tab. 4, compressive strength of composites is in indirect proportion with the temperature increase. From all the investigated composites, the sample 2 that was heated for 24 hours at a temperature of 120ºC accounts for the highest value of 28 and 90-day compressive strength.

Table 4

Compressive strength R_C of composites after 28 and 90 day hardening

Sample	R_C [MPa]	
	28 days	90 days
1	32.1	33.6
2	12.4	13.6
3	7.8	9.8
4	7.1	9.2
5	6.3	8.1

Based on the XRD results of hardened products, zeolitic phases such as analcime and hydroxysodalite were formed during the alkaline treatment of coal fly ash/cement mixtures under selected conditions. It is known that hydroxysodalite can be formed by the conversion of the A zeolite in alkaline solution (>10 wt.% NaOH). According to paper [5], the crystalline phase of A zeolite is created in reaction mixture with SiO_2/Al_2O_3 ratio = 2 within the temperature range from 25 to 150ºC.

Structures of identified phases are different from those of NaP1 zeolite and phyllipsite designated in the case of hydrothermal alternation of coal fly ash alone in autoclave. These phases favourably influence the concrete structure matrix as well as the mechanical properties of a hardened composite [4], which differs from composites based on alkaline and subsequent thermally treated coal fly ash/cement mixtures.

4. Conclusion

According to the standard requirements of STN EN 206, the measured values of 28 and 90-day compressive strengths of composites prepared by alkaline treatment of coal fly ash/cement mixture correspond to the concrete class of C 8/10.

Therefore, concretes with hydrothermal alkaline treated coal fly ash at 30 wt.% cement replacement can be used for non-load-bearing constructions.

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