Available online at www.rajournals.in

RA JOURNAL OF APPLIED RESEARCH
ISSN: 2394-6709
DOI:10.47191/rajar/v9i2.02
Volume: 09 Issue: 02 February-2023

International Open Access

Impact Factor- 7.108

Page no.- 60-65

# Influence of a High Degree of Filling on the Properties of Pozzolanic Cement

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**ARTICLE INFO**

Published Online: 03 February 2023

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**ABSTRACT**

Slagash wastes of the Angren and Novo–Angren TPPs of dry selection high pozzolanic and hydraulic activity and its compliance with the requirements for State Standard of the Republic of Uzbekistan 901 for active mineral additives have been established, and therefore, it is recommended as an active mineral additive for the production of pozzolanic cements with a high degree of filling. Replacing from 25% to 50% of high–temperature portland cement clinker with dry–selection composite ash and slag waste ensures the production of pozzolanic cement grades 400–500. Concretes based on pozzolanic cements with a high content of CASW show a fairly high resistance to the aggression of sulfate salts, frost and changes in atmospheric vibrations, which makes the developed cements in demand in the construction industry of the Republic.

**KEYWORDS:** slagash, pozzolanic cements, mineral formation, high temperature synthesis, hydraulic activity.

## INTRODUCTION

The entire deteriorating environmental situation around the world, including in the Republic of Uzbekistan, dictates the need to take effective measures to protect the environment and ensure the safe life of the country's population. The President of the country pays special attention to the transition to a "green" economy and energy saving, increasing the energy efficiency of production in each sector of the economy and reducing the consumption of fuel and energy resources at strategically important enterprises, the need to achieve these goals by increasing scientific research to develop a "green" economy and development of technologies for the production of innovative products that are cheaper compared to existing analogues [1, 2]. One of the rational ways to improve the environment and ensure a "clean" climate is the disposal of waste from industrial enterprises, which also include ash and slag from thermal power plants [3, 4]. In terms of accumulation among industrial waste in the Republic of Uzbekistan, the leading place is occupied by energy waste – composite ash and slag, the accumulated volume of which in the slag collectors of the Angren TPP and Novo–Angren TPP is about 20 million tons, and therefore the issue of their disposal is of particular state importance. However, due to low hydraulic activity, in the production of various construction products, only about 5–7% of ash and slag waste is processed annually. The reason is that during wet removal, ash and slag pulp in dumps is unevenly distributed over the area, large particles settle along the edges of the dump when the pulp is discharged, and small particles are carried away to the center of the dump. Therefore, "wet" dump ash and slag have a variable granulometric composition, which reduces their consumer properties [5–8]. In order to increase the efficiency of burning high–ash coal of the Angrensky open–pit mine, uninterrupted supply of electricity and heat to the country's consumers, as well as reduce emissions of harmful substances into the atmosphere, a power unit with dry ash removal was put into operation at the Angren TPP, the main consumers of which were the cement plants of the republic [9]. Previously, we found that the replacement of up to 20% of the clinker part in cement with dry selection ash and slag ensures the production of general construction Portland cements with high hydraulic activity [10–12]. In terms of their large–scale utilization, it is of certain scientific and practical importance to study the possibility of obtaining pozzolanic cements by replacing ordinary alite Portland cement clinker with a high content of dry ash and slag waste.

The purpose of the study is to develop a new type of pozzolanic cement with a high degree of filling with a composite ash and slag additive of dry selection.

The objects of study are the Portland cement clinker JSC "Akhangarancement", gypsum stone, composite ash and slag waste (CASW) of the Angren TPP dry selection and pozzolanic cements with its use.

**RESEARCH METHODOLOGY**

Studies of the chemical and technological properties of CASW, the physical and mechanical properties of cement composites based on pozzolanic cement from it were studied by standard test methods in accordance with the requirements of GOST 310.1–310.4. The assessment of the hydraulic activity of cements was carried out in accordance with GOST 10178 and GOST 31108.

**RESULTS AND ITS DISCUSSION**

Dry ash and slag waste is visually represented by a gray polydisperse granular mass. It consists of granular sintered slag and dispersed ash fractions. The solid fraction in the ash and slag is represented by sintered particles with a grain size of not more than 15 mm, the color of the grains is black, light gray and brown (Fig. 1).

a b c

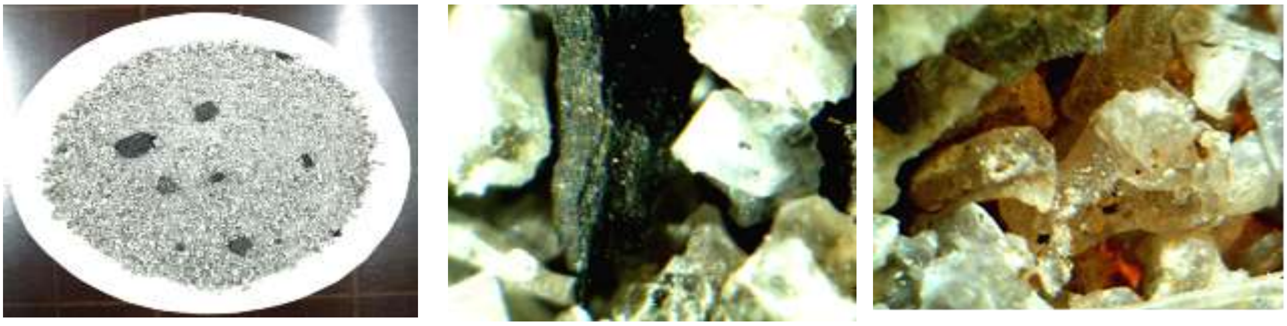

**Figure 1.** General view (a), slagash (b) (c) fractions of dry slagash

According to its chemical composition, CASW belongs to the acidic type ($SiO_2$ content is more than 45%, CaO is less than 10% by mass), according to the content of combustibles, determined by the value of losses on ignition, it belongs to ASW with a low content (no more than 5%). Silicon and aluminum oxides predominate in its chemical composition; impurities of iron, calcium, magnesium oxides, sulfur trioxide, and alkali oxides are present in small amounts (Table 1).

**Table 1.** Chemical compositions of initial components

| Name material | Loss on ignition, % | Mass fraction of oxides,% | | | | | | | | Σ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O_5$ | $SO_3$ | |
| PC clinker | 0,36 | 21,30 | 4,75 | 4,86 | 63,68 | 3,07 | 0,77 | 0,78 | 0,43 | 100 |
| | Technological parameters and mineralogical composition (%) | | | | | | | | | |
| | SF–0,91; n–2,22; p–0,98; $C_3S$–59,09; $C_2S$–16,49; $C_3A$–4,34; $C_4AF$–14,77 | | | | | | | | | |
| Gypsum | 19,25 | 8,76 | 1,82 | – | 28,58 | – | – | – | 42,77 | 100 |
| ASW | 0,61 | 64,79 | 20,64 | 3,99 | 3,36 | 0,80 | 1,64 | 2,02 | 2,1 | 100 |

According to X–ray diffraction data, the main minerals of CASW are quartz, gehlenite, mullite, and low–basic silicates. Its hydraulic activity is high and its value according to student's criterion was t=52.92>2.07. The pozzolanic activity of ASW was 34.7 mg/g CaO, which is 10 times higher than that of ASW hydroremoval. During water storage of cement samples from dry ash and slag, the total alkalinity of the liquid was significantly lower (51.6 meq/l) compared to the liquid containing PC–D0 (68.00) and PC with ASW (104.00 meq/l). l) (Fig. 2).

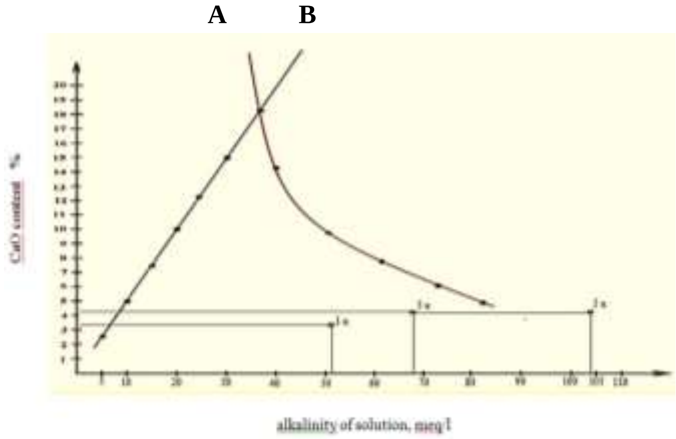


**Figure 2.** The degree of pozzolanic activity of mineral additives.
A – alkalinity attributable to the share of all, except lime, components;
B – lime solubility isotherm at 40o;
1c – CaO content, % in cement slurry with PPC with CASW;
2c – CaO content, % in cement slurry with D–0;
3c – CaO content, % in cement slurry with ASW hydroremoval.

On the basis of the results of the research, it was concluded that it is possible to introduce CASW into cement in the maximum allowable amount. To study the effect of CASW, mixtures containing (25–60)% CASW were prepared (Table 1). When grinding the charge, it was found that their grindability varies depending on the amount of additive (25–60%) in cement: the fineness of grinding "clinker + CASW + gypsum", estimated by the residue on sieve No. 008 (4900 resp./cm2), for 40 min of grinding amounted to (12.0; 10.8; 9.6; 9.2; 8.8)%, respectively, against 12.5% of the residue when grinding the control mixture "clinker + gypsum". The beginning of setting of the obtained cements occurs somewhat earlier than for PC–D0, and the end of setting, except for composition No. 6 (CASW–60%), is within the same limits as for the matrix (Fig. 3). In terms of setting time, all experimental pozzolanic cements (PPC) comply with the requirements of GOST 10178.

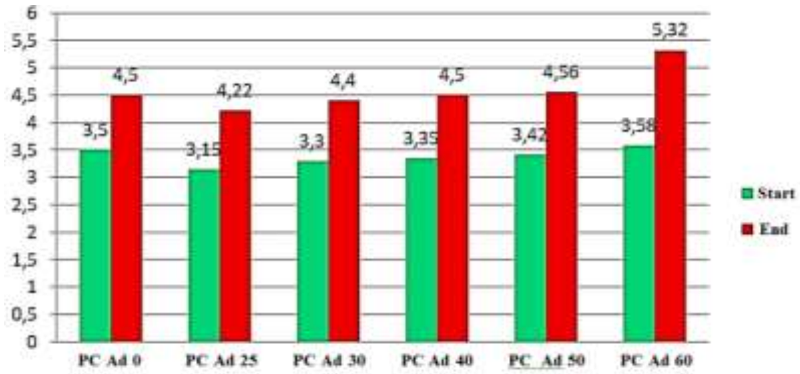


**Figure 3.** Change in the setting time of PPC depending on the content of CASW

Determination of the strength of the obtained cements to optimize their composition in terms of hydraulic activity was carried out on cube samples measuring (2x2x2) cm with a composition of 1:0. The test results are shown in Table 2 and Figure 4. It has been established that the introduction of (25–60)% CASW slows down the hardening of pozzolanic cements in the initial periods up to 7 days: the strength of the samples in these periods is somewhat lower than that of samples from PC–D0. A significant decrease in their strength was noted during the hardening of samples from the composition of PPTs No. 6, in which the content of CASW is 60%.

**Table 2.** Influence of the dose of CASW on the physical and mechanical properties of PC

| № | Conventional designation of cements | Setting time, h–min | | Compressive strength, MPa, after (days) hardening | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Start | the end | 1 | 3 | 7 | 28 | 90 |
| 1 | PC–D0 | 3–50 | 4–50 | 10.3 | 33.4 | 41.0 | 42.5 | 46.8 |
| 2 | PC–D25 | 3–15 | 4–22 | 9.8 | 25.5 | 40.2 | 49.5 | 53.3 |
| 3 | PC–D30 | 3–30 | 4–40 | 8.7 | 24.5 | 34.5 | 52.5 | 54.3 |
| 4 | PC–D40 | 3–35 | 4–50 | 10.0 | 25.0 | 35.0 | 55.5 | 47.5 |
| 5 | PC–D50 | 3–42 | 4–56 | 8.7 | 23.0 | 34.5 | 47.5 | 45.8 |
| 6 | PC–D60 | 3–58 | 5–32 | 8.8 | 15.0 | 30.0 | 38.1 | 38.7 |

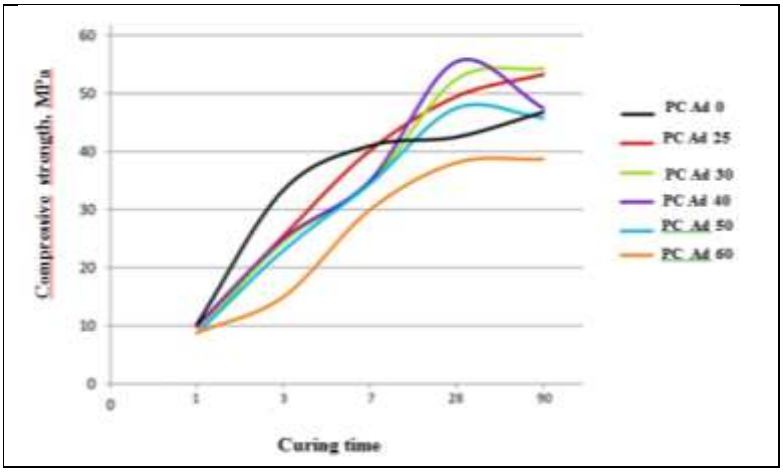


**Figure 4.** Influence of the content of CASW on the physical and mechanical properties of Portland cement

With prolonged hardening, the hardening process and the strength development of samples from PPC with a content of (25–40) % CASW accelerates and the strength of the samples increases sharply, reaching up to 28 days. from 45.8 MPa to 55.5 MPa, which significantly exceeds the grade strength of PC–D0 (42.5 MPa). Samples of cements with (50–60) % CASW, in the first (1–7) days are characterized by the same strength indicators as cements with (25–40) % CASW. In the future, their strength indicators have higher values, which for cement samples with 50% CASW by 28 days slightly higher than the strength of PC–D0. The exception is the composition of PPTs No. 6, which exhibits strength by this time lower than that of the matrix.

To determine the grade of PPC, compositions with the addition of 30 and 40% CASW were chosen as the optimal ones, from which standard samples were made according to GOST 310.4. At the same time, the replacement of (30–40)% clinker with the addition of CASW sharply changes the strength indicators of the PPC upwards, which by 28 days. When compressed, they reached (45.80–50.42) MPa against the indicator of 42.6 MPa of the control PC400–D0, which is from 3.2 MPa (7.51%) to 7.82 MPa (18.36%) higher than that of it (Table 3).

**Table 3.** Comparative indicators of the hydraulic activity of PPC with the addition of CASW

| № | Conventional designation of cements | Tensile strength after 28 days of hardening (MPa) at: | | Regulations mark |
|---|---|---|---|---|
| | | Bend | Compression | |
| 1 | PC–D0 | 7,80 | 42,60 | 400 |
| 2 | PPC–D30 | 7,82 | 45,80 | 400 |
| 3 | PPC–D40 | 8,08 | 50,42 | 500 |

Thus, the real possibility of obtaining pozzolanic cements of grades PPC400 and PPC500 by high filling of Portland cement with CASW additive has been established. On the basis of these data, practical recommendations were issued on the organization of production at the cement plants of the republic of pozzolanic cements M400 and M500 with the addition of (25–50)% CASW.

It was revealed, with almost equal consumption of binders and values of the tensile strength of concrete at the age of 28 days, the content of clinker in concrete from PPC with a content of 40% CASW is significantly less (179 kg/m3) than in concrete from PC–D0 (298 kg/ m3). At the same time, concrete at PPC–D40 has a fairly high frost resistance and has withstood 25 cycles of thermal cycles, which corresponds to their frost resistance grade F125. The same samples also have a higher resistance to the effects of alternating wetting and drying compared to concrete from PC 400–D0: the coefficient of their weather resistance after 25 cycles of thermal cycles was Kam = 0.97, which was significantly higher than the control samples (Katm = 0 .91). Experimental samples from PPC–D40 are also characterized by high sulfate resistance. Their durability coefficient after 6 months. hardening in 1 and 3% $Na_2SO_4$ solutions is significantly higher (KS6month–0.90 and 0.82, respectively) than that of the control cement PC400–D0 (KS6month=0.64) (Figure 5).

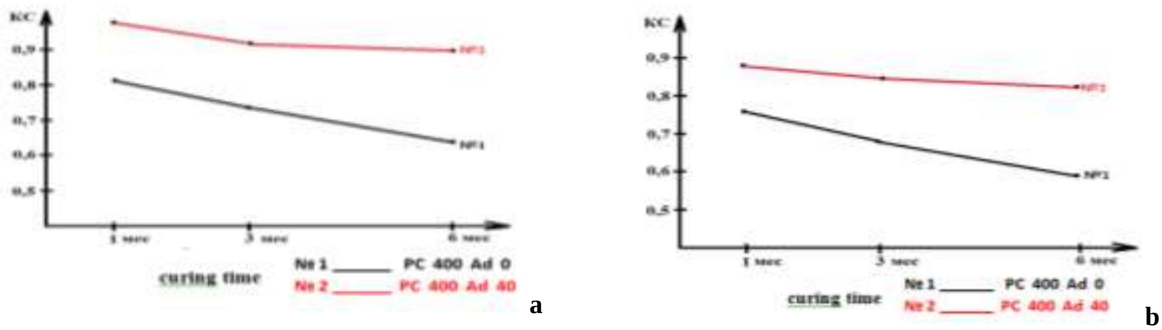


**Figure 5.** Comparative change in the resistance coefficient of PPC–D40 in 1 (a) and 3% (b) $Na_2SO_4$ solutions

The positive role of the CASW additive in the development of sulfate corrosion is explained by the fact that it changes the deformability of the medium in which calcium hydrosulfoaluminate crystallizes, enriching the cement stone with colloidal formations that increase its “elasticity” and relieve emerging stresses. $MgSO_4$ solutions, due to the simultaneous action of $Mg^{2+}$ and $SO_4^{2-}$ ions on the cement stone, have a more aggressive effect on the corrosion resistance of samples from both PC–D0 and PPC–D40.

Therefore, the approach to the disposal of dry–selection TPP ash and slag waste by using them as pozzolanic additives to cement is a rational solution to the problem of providing a “clean” climate, increasing production, reducing costs and improving the performance properties of cement and cement concrete.

## CONCLUSION

Ash and slag wastes of the Angren and Novo–Angren TPPs of dry selection High pozzolanic and hydraulic activity and its compliance with the requirements for State Standard of the Republic of Uzbekistan 901 for active mineral additives have been established, and therefore, it is recommended as an active mineral additive for the production of pozzolanic cements with a high degree of filling. Replacing from 25% to 50% of high–temperature Portland cement clinker with dry–selection composite ash and slag waste ensures the production of pozzolanic cement grades 400–500. Concretes based on pozzolanic cements with a high content of CASW show a fairly high resistance to the aggression of sulfate salts, frost and changes in atmospheric vibrations, which makes the developed cements in demand in the construction industry of the Republic.

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