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Communication

Pozzolanic properties of a geothermal silica waste material

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Abstract

The pozzolanic reactivity of a silica waste from a geothermal power generating plant in Mexico has been assessed. Pastes of portland cement with 25% substitution of the silica waste were hydrated at 10, 30, and 50°C. The concentration of CH and nonevaporable water were estimated by thermogravimetry. The silica waste displayed a pozzolanic behaviour from the early days of hydration that was favoured by the increased hydration temperature. The nonevaporable water percentages of the blended cement were superior to those of the neat cement, which suggested an enhancement of the cement hydration.

Keywords: Thermal analysis; Characterization; Blended cement; Pozzolan; Geothermal waste

The use of cement replacement materials is of great interest not only for the worldwide importance of the building materials. Factors such as savings on energy resources and reduction of pollution have also become of prime interest. Mexico has a large installed capacity of electricity generation in the geothermal field at Cerro Prieto, Baja California. The use of geothermal power brings many advantages compared to the use of fuels. The electricity is generated by extracting the heat of the steam from the geothermal field; during the transit of the steam through the heat exchangers a film is deposited that is rich in silica and also contains some alkalis [1]. The potential uses for these deposits have been researched in various fields [2,3].

The use of this silica waste as a pozzolanic material in portland cement is an interesting possibility due to some of the characteristics of this material. The chemical composition is mostly SiO_2 with some alkalis that can be readily removed if necessary by a wash. The silica waste displays a relatively large specific surface area that makes it interesting for several applications.

In considering this material for use in portland cement, the first approach was to investigate its pozzolanic potential, while further investigations are considered to carry out a thorough characterisation of the material and to study the effect of this material on the cement properties.

1. Experimental

1.1. Materials

A sample powder was obtained from the Cerro Prieto geothermal power plant in Baja California Mexico. A sample of clinker from Cementos Apasco (Holderbank Mexico) was employed for this preliminary investigation. The chemical composition of the materials is presented in Table 1. A cement blend with 25% of silica waste replacement was prepared in the laboratory. The as-received silica showed the presence of NaCl peaks in the X-ray diffraction pattern as shown in Fig. 1. After a simple water lixiviation, the alkalis [2] were removed (Fig. 1). The amorphous halo observed from 15–302 Θ° is typical for SiO_2 amorphous materials. The specific surface area of the material has been previously reported as about 24,000 m^2/kg [1].

1.2. Hydration

Pastes were prepared using distilled water at a water:solids ratio w/s = 0.7. This w/s value was employed as the silica increased the water demand to obtain a workable paste. The pastes were hand-mixed for 8 min in a stainless steel bowl and cast in 3-cm diameter PVC tubes that were sealed and placed at the hydration temperatures of 10, 30, and 50°C. After one day of hydration the pastes were demoulded, cut in pieces of approximately 2-cm thickness, then transferred to plastic containers filled with distilled water and further submerged in isothermal curing tanks at the previously mentioned temperatures.

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Table 1
Oxide composition of the starting materials

Oxide %	Silica as received	Silica purified	Clinker
SiO_2	92.9	98.34	19.8
CaO	0.31	0.12	65.1
Al_2O_3	0.06	0.06	5.8
Fe_2O_3	0.02	0.01	2.3
SO_3	0.18	0.10	2.6
MgO	0.01	0.01	2.1
K_2O	1.29	0.23	0.7
Na_2O	5.34	0.41	0.6

1.3. Characterisation

After each curing period of 1, 3, 7, 14, 21, and 28 days, a piece of hardened paste from each temperature was hand-ground and the relatively coarse powder samples were dried for 4 h at 105°C in a stove. Next, the powders were further ground by hand to pass a mesh of 125 μm by cycles involving grinding, sieving, and regrinding the unpassed material until all the powder had passed through the sieve. Mechanical mixing of the sieved powders was performed to homogenise them. The powders were stored in sealed plastic containers prior to the thermogravimetric (TGA) analysis.

The TGA curves were obtained using a Perkin Elmer TG7 by heating samples of about 30 mg at a rate of 15°C/min in flowing nitrogen. The calcium hydroxide content was determined quantitatively from the step observed in the curve between 425 and 450°C using the procedure described by Taylor [4]. The nonevaporable water was estimated as the weight losses between 150–950°C. The CH and nonevaporable water reported data were referred to the ignited weight that was obtained from TGA experiments as the loss in mass at 950°C.

2. Results

2.1. Evolution of calcium hydroxide

The evolution of CH versus time for the three hydration temperatures is presented in Fig. 2. The curves for the blended cement have been overlapped to those of the neat cement in order to compare the CH evolution in both systems. The CH data from the neat cement were reduced according to the silica replacement level.

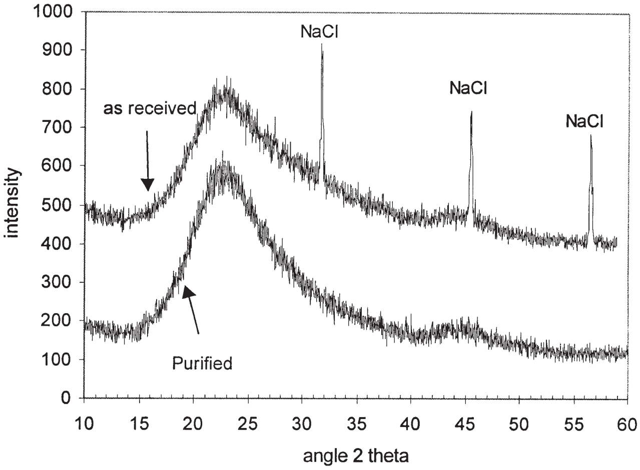

Fig. 1. X-ray diffraction pattern of the geothermal silica waste.

The curves of the neat cement displayed an expected behaviour of increasing CH with time; there is also a higher CH level at higher temperatures. However, the curves of 10 and 30°C cross that of 50°C after 21 days, indicating lower CH contents (or a lower degree of hydration of the cement) at the highest temperature. This effect has been previously reported for other cements [5]. For the blended cement, the curves showed that the CH concentration was consumed with different patterns at the experimental temperatures. The curve at 50°C showed that the CH started to be continually consumed at day one of hydration. For the other temperatures, the curves had an initial increase of CH concentration, reaching maxima values at about 5 and 15 days for 10 and 30°C, respectively; after the peak value of CH, it began to be depleted. Similar patterns were reported for other pozzolanic materials [5,6]. The CH concentrations of the blended cement were lower than those of the neat cement at all temperatures; this suggests that the pozzolanic activity of the silica waste consumed CH since the first days of hydration, at a rate that competed with that of the CH production by the cement.

2.2. Nonevaporable water

Fig. 3 presents the evolution of the nonevaporable water of both cements. The values for the neat cement were reduced according to the replacement level of silica waste. The nonevaporable water in the neat cement was higher at increased temperatures, which indicates (as expected), that the temperature accelerates the hydration of the cement. After 14 days, the curves of 30 and 50°C had similar values,

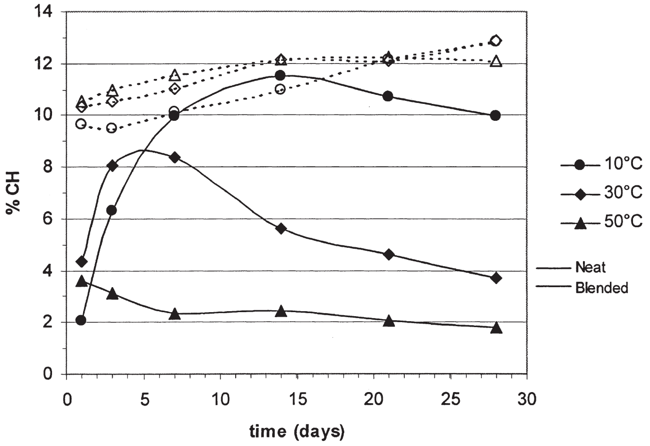

Fig. 2. Evolution of the CH concentration versus time for the neat (hollow symbols) and blended (solid symbols) cements.

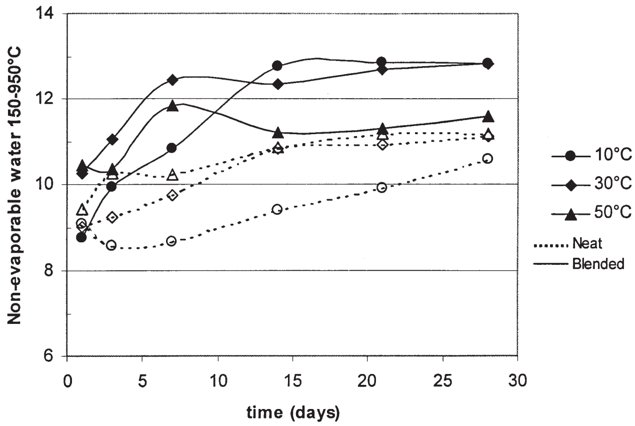

Fig. 3. Nonevaporable water versus time in neat (hollow symbols) and blended (solid symbols) cements.

while that at 10°C had lower values while showing a trend toward increasing hydration.

The nonevaporable water curves from the blended cement showed higher values compared to those of the neat cement at all times. This suggests that the cement hydration was enhanced by the presence of the fine silica; this effect has also been indicated by other studies on cement with various secondary solid components [5,7,8]. The reactions for the formation of additional hydrates from the silica waste could also be absorbing extra water, increasing the values of nonevaporable water. The curves of nonevaporable water for the blended cement showed dependence on the temperature, but the pattern was not clear. After 15 days the highest values were those of 10 and 30°C and the lowest those at 50°C.

The pozzolanic properties of the silica waste and also its physical characteristics (the large specific surface area) bring about interesting possibilities for the use of this material with portland cement as a partial replacement material and also as an additive in the sense of very fine materials like silica fume [9]. More research is needed to increase the knowledge on the silica waste properties.

3. Conclusions

Thermogravimetrical analysis was employed to characterise the potential pozzolanic activity of a silica waste from a geothermal field. The CH concentration was followed and the nonevaporable water was estimated to see any effect of the silica on the cement hydration.

The silica waste material displayed a strong pozzolanic activity. The pozzolanic reaction was favoured by the increased hydration temperature. At 50°C, the CH concentration was depleted from day one, continuing as the hydration progressed. At 10 and 30°C, the CH concentration initially increased but later was depleted after reaching peak values at 5 and 15 days, respectively. The hydration of the cement was enhanced by the presence of the silica waste. This silica waste has potential for use with portland cement as a cement replacement or additive; further investigations are being carried out to increase the knowledge on this material.

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