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The influence of sodium hexametaphosphate ($Na_6P_6O_{18}$) on hydration of calcium aluminate cement under hydrothermal condition

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Abstract

The hydration of High alumina Cement (HAC) in the presence of sodium polyphosphate (sodium hexametaphosphate -$Na_6P_6O_{18}$) was investigated under normal and hydrothermal condition. Reference sample and modified one were submitted to long-term hydration (365 days). It was found out that sodium hexametaphosphate has increased the compressive strength. The main hydration products of HAC (C_3AH_6 and gibbsite) were found stable over time. However, when submitted to hydrothermal curing conditions of 20 bars (corresponding to 220 °C) during 7 days, binder has lower compressive strength values, but increasing with time. Thermal analysis method, X-ray diffraction and Scanning electronic microscopy were used to characterize the reaction products. Under hydrothermal curing (220 °C/ 20 bars), the main hydration products were hydroxyapatite ($Ca_5(PO_4)_3OH$) and nordstrandite ($A(OH)_3$), known as chemically bond ceramics formed by acid-base reaction between HAC and sodium hexametaphosphate.

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Keywords: Hydrothermal curing; hydroxyapatite; Alumina cement; acid-base reaction

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1. Introduction

The hydration process of Calcium Alumina cements (shorthand CAC) has been intensively investigated [1,2]. It depends mainly on temperatures with the formation of CAH_{10} (below 21 °C), C_2AH_8 and AH_3 (up to 35 °C) or C_3AH_6 and AH_3 at higher temperatures. With increasing temperature hexagonal calcium aluminate hydrates (CAH_{10} and C_2AH_8) are converted to the cubic phase (C_3AH_6). As consequence, this conversion causes a remarkable increase in the porosity which is responsible for the strength deterioration, because of the transformation of the voluminous hexagonal hydrates into a higher density cubic phase [1]. Therefore, research works were undertaken to prevent strength decrease by applying supplementary latently hydraulic materials (blast furnace slag, fly ash, silica fume and pozzolan) [3,4] that could displays a retarding effect on the CAC dissolution and cause the formation of gehlenite hydrate C_2ASH_8 and eventually CSH. Moreover, metastable phases CAH_{10} and C_2AH_8 are considered as preferential sites of stratlingite - C_2ASH_8 formation.

Nomenclature

A	Al_2O_3	HG	hydrogarnet
C	CaO	N	Nordstrandite
H	H_2O	B	Boehmite
S	SiO_2	SPP – Sodium polyphosphate of Sodium hexametaphosphate ($Na_6P_6O_{18}$) type	
HA	Hydroxyapatite		
HAC	High alumina cement		
CAC	Calcium alumina cement		

Also, products known as chemically phosphate bond ceramics (hydroxyapatite (HA – $Ca_5(PO_4)_3OH$) [5,6] can be obtained through acid-based reaction of CAC with phosphate compounds under hydrothermal conditions.

The formation of hydroxyapatite (HA) and aluminum hydroxide (AH) proceeds by setting and hardening process under hydrothermal conditions. Sugana [4] found that these products are resistant to leaching as well as carbonation that makes calcium aluminate phosphate binders suitable for geothermal wells.

The hydrations reactions that occur in geothermal wells are strongly influenced by the temperature and steam pressure of fluid surrounding the steel casing [5–7] like those occurring under "hydrothermal curing regimes". In these environments, temperatures and pressures are so high (up to 200 °C and 1.5 MPa in deep wells) that they could be appropriated to ensure the formation of chemically bond ceramics by acid-base reaction between CAC and phosphate compounds. The main advantage that makes calcium aluminate cement more suitable for geothermal exploitation than Ordinary Portland cement (OPC) is that the formation of stable products (HA and AH) are highly accelerated under hydrothermal conditions [5,7].

The present investigation was undertaken to develop an alternative binders with ceramic bonds applying hydrothermal curing to prepare chemically bond hydraulic ceramics by acid-base reaction between CAC and sodium hexametaphosphate as sodium polyphosphate (SPP).

2. Experimental

High alumina cements (HAC) Gorkal 70 from Gorka Poland, sodium polyphosphate (sodium hexametaphosphate -$NaPO_3)_6$ (SPP) and calcium hydroxide (CH) were used as based materials. Oxide and mineral composition given by producer and analyzed in laboratory as well as composition of mixtures are reported in Table 1 and Table 2. To evaluate compressive strength, three prisms of cement paste of each samples (see Table 2) with the dimensions of 160×40×40mm were prepared and cured under normal and hydrothermal conditions. The conditions of normal curing were 90% humidity within the first 24 hours, then under 100% relative humidity for 2, 7, 28, 90, 180 and 365 days. For hydrothermal curing, the specimens were firstly exposed to steam curing condition at 100 °C for 30 minutes and then they were quickly demolded and inserted into the autoclave (High Pressure Autoclave Testing Bluhm & Feuerherdt GmbH) for curing at pressure of 20 bars (corresponding temperature was 220 °C) during 2 and