ALKALINE SILICATE SOLUTIONS PROPERTIES AND THEIR EFFECT ON SAND AGGLOMERATION

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Key Words: Alkaline solution, Sand agglomeration, Silicate species, Ammonium molybdate, Thermal treatment

Nowadays, one of the challenges set by companies is the production of materials with low energy consumption. Governments also encourage this trend as part of environmental respect. This work is focused on the electrical protection domain and particularly concerns the fuse technology. In this context, the consolidation of agglomerated sand at low temperature with alkaline silicate solution is proposed. The agglomeration of sand implies to better understand the various properties and the interactions with alkaline solutions. For this purpose, several silicate solutions with various Si/M molar ratios (M = Na or K) and different dilutions were studied. To determine the behavior of these alkaline solutions, several parameters were studied such as (i) pH values, (ii) the various silicates species present in the solution which depend on the Si/M molar ratio, (iii) the effect of adjuvant such as ammonium molybdate, and finally (iv) the microwave treatment. A correlation between the Si-O-Si peak position, the silicon concentration and the Si/M molar ratio (M = Na or K) of the solutions was determined by infrared spectroscopy. This relation gives nice information about the polymerization of the solutions. ^{29}Si MAS NMR experiments of the various alkaline solutions evidenced the influence of the addition of ammonium molybdate or microwave treatment on the silicate species. Then, the effect of different parameters on the microstructure and mechanical properties of consolidated sand was determined thanks to mechanical tests and scanning electron microscopy. All these characterizations will help to determine the parameters permitting to obtain agglomerated sand with the better properties.

DEVELOPING A GEOPOLYMER BASED COATING FOR USE IN SELF-HEALING CONCRETE

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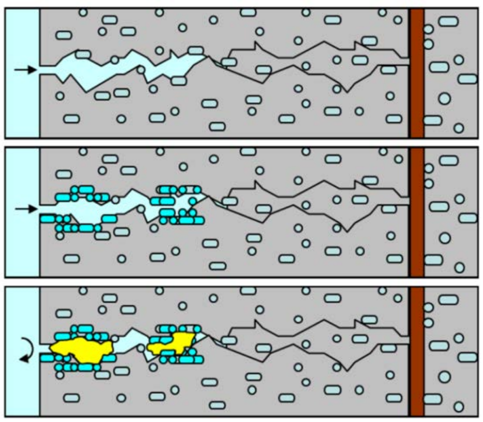
In this study granules to be used in self-healing concrete are coated with a geopolymer layer. Particles to be coated mainly consist of bacterial spores and calcium lactate. When concrete cracks, water can enter and lead to leakage problems or corrosion of embedded steel reinforcement by carrying aggressive agents such as chloride. With bacteria spores and lactate exposed to water in the crack, spores will be activated and bacteria produce calcium carbonate by metabolizing lactate. This seals the crack, resolving leakage problems and protecting the embedded steel from deterioration (schematically depicted in the sketch). The top two pictures (figure on the right) show that without healing agent also some calcium carbonate is formed along the crack, but that the crack remains open. By adding the healing agent, the crack is sealed and the tightness of the concrete reinstated.



Coating healing agent granules is required to retain particle integrity. Calcium lactate is soluble and should be kept together with the spores and not integrate with the cementitious matrix during the wet concrete mixing process. Coated healing agent granules can be added as part of sand and gravel in the concrete mixture. The coating should be water tight, have mechanical properties to survive mixing, be brittle to allow cracking when required and have the possibility to adhere to the matrix to promote particle opening upon matrix cracking. Given cement paste like properties and potential of unreacted constituents to bind to the cementitious matrix, a geopolymer coating was chosen.

Healing agent granules were coated in a low shear granulator by gradually adding fine geopolymer precursor powder while spraying with a geopolymer activator liquid. The main challenge of this process is that coating and geopolymerization will take place simultaneously. In granulation and coating commonly a narrow operating window of liquid binder to solid ratio occurs. When liquid is first used to dissolve active components it is later released upon completion of the geopolymer reaction, which makes it difficult to maintain conditions within the operating window. However, by carefully dosing metakaolinite and sodium silicate, granules with the required properties were made successfully. Properties were analysed by leaching tests, CT scans and ESEM. Granules were embedded in cement paste samples for confirmation of healing agent availability in the matrix.

Currently research focuses for economic reasons on the replacement of metakaolinite by coal fly ash and blast furnace slag. Finally, an LCA will be performed to assess the environmental impact of self-healing concrete compared to normal concrete and the influence of precursor material therein.

SIMULTANEOUS ALKALI ACTIVATION AND HIGH SHEAR GRANULATION

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Key Words: Alkali activation, granulation, lightweight aggregate, geopolymer coating

So far the main application of alkali activated materials has been concrete- or brick-type monolithic products. However, some aluminosilicate wastes have low reactivity which inhibits their usage as strong geopolymer concrete precursor. Instead, utilization of some waste materials as granules could be a better solution. Up to date, artificial (lightweight) aggregates have been prepared either by high temperature sintering or with cement. An interesting option to bypass the high energy costs of sintering and the usage of cement is to granulate aluminosilicate materials with an alkali activator. High shear granulation has the ability to spread viscous fluids, such as sodium silicate, evenly on to precursor powders. The procedure yields in spherical geopolymer granules that could be used in various applications such as in civil engineering, as lightweight aggregate in concrete, or as water purification adsorbent. This poster presents a method to prepare geopolymer granules from various aluminosilicate precursors. Ways to prepare different types of alkali activated granular products are shown and the key parameters determining the success of alkali activated granulation processes are discussed. The operating window (liquid-solid-ratio) of granulation is often very narrow, so the role of water in the reaction must be carefully evaluated. Microstructure and physical properties of alkali activated fly ash granules are presented.

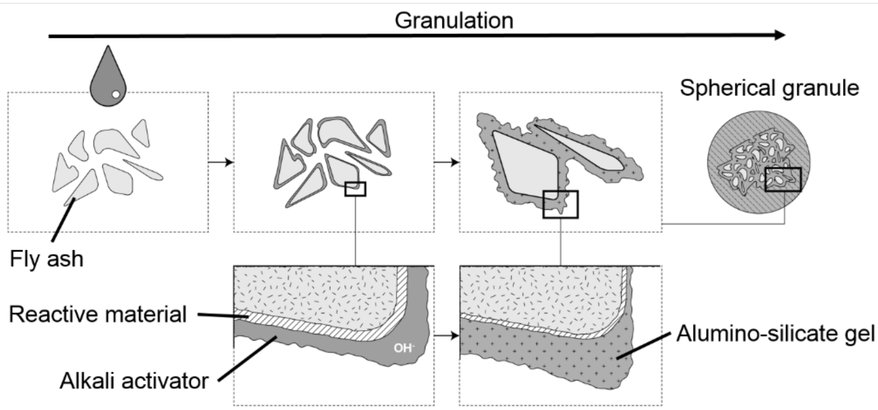

Figure 1 – Descriptive diagram of the granulation-alkali activation process

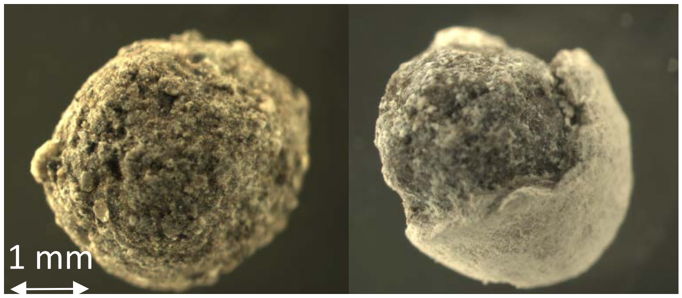

Figure 2 – Microscope images of geopolymer granules. On the left image is an alkali activated fly ash lightweight aggregate. On the right image is a fly ash geopolymer granule coated with alkali activated metakaolin.

EFFECT OF CURING CONDITIONS ON THE PROPERTIES OF ALKALI-ACTIVATED SLAG

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Key Words: alkali-activated slag, curing, shrinkage, mechanical properties, impact-echo method, ultrasonic method.

Combination of fine ground granulated slag with proper alkaline activators gives alkali-activated slag (AAS) – a material with remarkable properties. The properties of alkali activated slag mortars are significantly affected by the curing of the samples. Due to this fact, the main aim of experimental part was to monitor the properties of AAS samples stored for various periods of time in water and in laboratory conditions (temperature 20 ± 2 °C, relative humidity 45 ± 5%). The influences of curing conditions and parameters of mechanical properties and microstructures of AAS were studied and discussed in this paper. The results indicated that the impact of wet conditions was very positive on the level of shrinkage, mechanical strength and homogeneity of the structure. Storage of samples in the laboratory conditions had a rather negative effect on alkali activated slag. It was also proved by impact-echo and ultrasonic measurements.

MICA PLATELET-REINFORCED, GEOPOLYMER COMPOSITES

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The mica flakes were obtained from the Cogebi Company as phlogopite mica paper type Cobebi P160 containing no organic or inorganic binder. Mica can withstand temperatures in excess of 1000°C. Phlogopite, of composition $(KMg_3(AlSi_3O_{10})(OH)_2$ is flame-retardant, non-flammable, does not give off fumes. It conducts very little heat, especially perpendicular to its strata. Natural mica has a dielectric strength greater than 25 kV/mm (625 V/mil), has good resistance to arcing and electrical erosion, and is permeable to microwaves. Mica has good compressive strength. It behaves well in the presence of tensile and bending stresses. It has a high modulus of elasticity. Geopolymer composites based on Na or K where fabricated having a matrix composition $M_2O•Al_2O_3•4SiO_2$ where M = Na or K. Increasing amounts of mica were dispersed in the geopolymer matrix under vibration, and the composites were set under ambient conditions. The mechanical properties were measured in 4-point flexure as a function of in situ and post mortem temperature to 1,000 °C and their Weibull moduli were analyzed from the statistical data. The microstructure was examined by SEM/EDS. The dielectric constants were measured perpendicular to the platelet casting direction.

COMPARISON OF FIBERS IN GEOPOLYMER MATRIX FOR STRUCTURAL REINFORCMENT OF MASONRY (FRGP): COMPATIBILITY, REACTIVITY, DURABILITY

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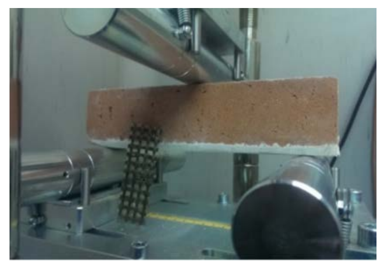
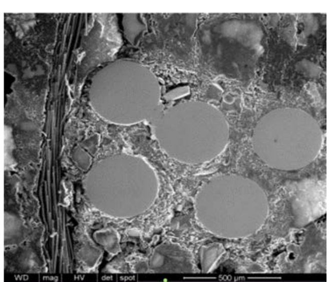
Key Words: geopolymers, fibers, reinforcement, durability, alkali-resistance

New continuous maintenance processes are required to endure the effects of extreme natural events on built heritage and existing masonry buildings and mitigate them promoting activities of structural repair and restoration. The application of Externally Bonded Fiber Reinforced Polymers (EB-FRP) has become a widespread solution for existing masonry buildings, also those belonging to the Cultural Heritage where interventions need to meet strict restoration requirements [1]. Recently, inorganic matrices like cement or lime based mortars have been proposed as an alternative choice to epoxy resin, being considered more compatible with masonry substrates, complying with traditional craftsmanship and displaying a better behavior under high temperatures. Nevertheless, traditional inorganic mortars, especially lime based ones, often present low adhesion to the parent substrate and between the composite layers. Geopolymers have better fire resistance and improved compatibility with restoration requirements compared to organic and cement based matrices and provide better mechanical strength and adhesion to fibers and brittle substrates than lime-based mortars. Fibers currently used for EB-FRP with organic and cement based matrices include steel, carbon, aramid, basalt, AR-glass fibers as well as polymer fibers. For geopolymer matrices, the main factor that may limit the use of some fibers is corrosive attack under the alkaline conditions required for the geopolymer synthesis. While Carbon, steel and AR-glass fibers are stable under the alkaline conditions found in Portland cement and geopolymers [2,3] the alkali resistance of basalt fibers, while better than for E-glass fibers [4], is lower than for AR-glass [3]. The purpose of the present work is to investigate the effectiveness of Externally Bonded Fiber Reinforced Geopolymers (EB-FRGP) for reinforcement of brick masonry. Nets of steel, AR-glass, carbon and basalt fibers were first tested for alkali resistance by accelerated ageing tests in different alkaline solutions followed by Scanning electron microscopy (SEM) inspection and tensile tests, confirming largely the available literature data. EB-FRGPs reinforcements were then applied on one side of soft mud bricks and strong extruded bricks and subject to mechanical tests, including three point bending tests to evaluate the degree of reinforcement of the bricks and pull-off tests to evaluate adhesion of EB-FRGP on the bricks. SEM inspection of the matrix composites before and after fracture was used to evaluate the microscopic fracture activation. As geopolymeric matrix a formulation was chosen based on metakaolin, blast furnace slag, Na and/or K silicate, wollastonite and sand. Freeze-thaw cycle testing was used to evaluate the durability of the EB-FRGPs.



Three point Flexural Test of EB FRGP reinforced Brick (Basalt fabric)



SEM image of steel fibers fabric embedded in geopolymer matrix

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PROPERTIES OF INORGANIC POLYMER CEMENT FROM FERRIC AND FERROUS VITRIFIED RESIDUES OF PLASMA GASIFICATION

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Climate change and resource scarcity pose a need to look for sustainable supply of raw materials and energy. Plasma gasification is an emerging technology for energy production from Refuse derived fuel (RDF) consisting of highly calorific fractions of municipal, industrial or landfilled waste. The molten residue of the process forms a glassy material upon granulation, which currently has limited application. A novel cement has been developed by the authors through alkaline dissolution & polymerization of plasmastone using Na-silicate.
The current paper investigates the role of the glass oxidation state on the properties of the cement, namely the setting and strength development. The methodology applied is as follows: (1) the expected glass chemistry and oxidation state are determined using high temperature modelling; (2) Two glass types with similar glass content and chemistry but different Fe oxidation state (Fe^{2+} vs Fe^{3+}) are compared. Reduced glass is synthesized on lab and pilot scale mimicking glass/gas equilibria in a plasma convertor treating RDF. Oxidized glass is synthesized by remelting the reduced vitreous residue under an air atmosphere; (3) the glass is characterized mineralogical and chemically; (4) Geopolymer cement setting and compressive strength development are tested according to EN 196.

Our results show that the difference in Fe oxidation state leads to a different rate of dissolution, polymerization & gelation of the cement, which reflects in differing setting and strength development. Investigation of the mineralogy, micro-structure and micro-chemistry of the cement will be performed in order to fully understand the cement forming process and explain the difference in property development.

LOW CO_2 BINDER FROM CFBC FLY ASH: MODEL OF PHASE EVOLUTION DURING HYDRATION

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Key Words: CFBC, fly ash, phase evolution, volumetric model, alkali activation

The main objective of this work is to formulate a model of phase evolution during hydration of activated CFBC fly ash paste. The CFBC fly ash is a product of the circulating fluidized bed combustion, where the sulfur-containing coal is burned together with limestone in order to reduce the emissions of SO_2 by in situ capturing and transformation to anhydrous $CaSO_4$ [1], [2].

The model of phase evolution can contribute to a better understanding of the hydration mechanism of the CFBC fly ash paste and can be used for prediction of mechanical properties of composite. The volumetric model of phase evolution (see Figure 1) is based on measured fractions of crystalline phases in CFBC fly ash paste by XRD analysis and on measured DTG curves at different ages during hydration. The measured DTG curves are deconvoluted to distinct contributions of separate phases, see Figure 2. The porosity is measured using MIP+He pycnometry.

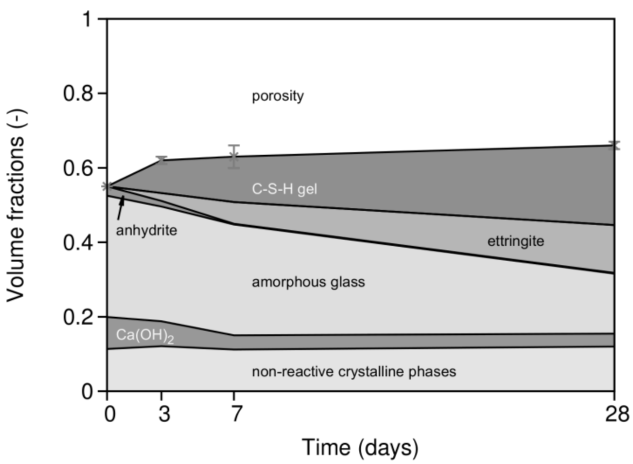

Figure 1 – Volumetric model of phase evolution during hydration of activated CFBC fly ash

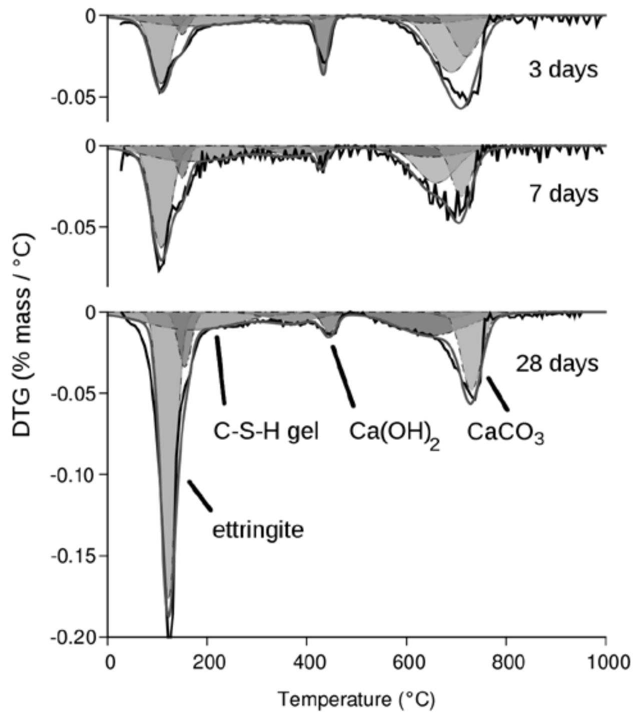

Figure 2 – Deconvolution of DTG curves of CFBC fly ash pastes for different ages and identification of phases

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