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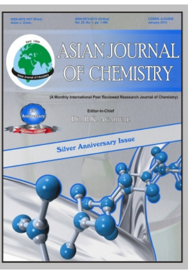

Microstructure of Geopolymer Concrete Based on Fly Ash Using M-Sand

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Geopolymers prepared from a class F-fly ash and a mixed alkali activator of sodium hydroxide and sodium silicate solution were investigated. A high compressive strength was obtained when the modulus of the activator *viz.*, molar ratio of SiO_2/Na_2O was 2.5. Any presence of the temporary phase with different composition was not found between geopolymer and aggregate as it is at the concretes from Portland cement. Geopolymer composition is almost the same in the close nearness even in the geopolymer matrix. Elastic modulus evaluated for the mixed geopolymeric concrete was found to be $E = 4389 (f_{ck})^{0.535}$ Mpa. Such result is comparable (a little bit lower) to ordinary Porland cement pastes.

Key Words: Geopolymer concrete, M-Sand, Fly ash.

INTRODUCTION

When strongly alkali surrounding is effective to aluminosilicate substances like cement, marl, slag, fly ash or heat activated kaolin substances, new materials-geopolymers arise. Their base is two or three dimensioned structure Si-O-Al. Great attention is devoted to these new materials[1-7]. In these works there are mentioned the study synthesis results of geopolymers, microstructures (mainly SEM) but also resulting possibilities how to apply them, mainly when using the waste inorganic materials. Geopolymers give the potential possibilities to prepare inorganic bonds and building materials from the by product of thermal power plant like fly ash. When geopolymers are prepared, the burning process at high temperatures is not needed as it is during production of cement or lime. Building material production from geopolymers does not effect encumbrance the environment by CO_2 emissions and that is why these materials present the potential possibility of building material production without CO_2 emissions[1-7]. Out of the up-to-date knowledge of geopolymer qualities, some materials are obvious to have the same or even better qualities than those based on Portland cement. The materials based on geopolymers are evidently the parts of the ancient constructions aged several thousand years as the detailed search of these ancient constructions in Egypt and other countries shows[8,9]. The attention is mainly devoted to geopolymer´s polymer character (NMR in solid phase), mechanical characters, influence of aggressive environment, ability of leaching and others. This study is based on characteristics of geopolymer concrete.

EXPERIMENTAL

Twenty five 150 mm × 150 mm × 150 mm cubes specimens were casted incorporating M-sand. Optimized mix ratios are taken. For this study, the concrete ingredients were mixed in a pan mixture for about 5 min. Then alkaline liquids were added and mixing was continued for another 5 min. On completion of the mixing, the flow value of fresh geopolymer concrete was determined using the slump test described in IS 516:1959. The fresh concrete could be handled for about 120 min without setting. After the flow test, the fresh concrete was placed in moulds as described in the IS 516:1959. The fresh concrete was cast and compacted by the usual methods as in conventional concrete. The specimens were left for 1 h and then cured at 60 ºC for about 24 h. After cooling, the specimens were tested for compressive strength in accordance with IS 516:1959. The strength data reported here is average of three results (Table-1).

TABLE-1

Content/M-sand Grade	MS 20	MS 25	MS 30	MS 35
Fly ash	410	470	550	620
M-Sand	756.3	667.5	575.2	492
Coarse aggregate	1035	953.2	858.43	767.5
NaOH solution	66.8	81.9	95.85	109.83
Na_2SiO_3	167	204.8	239.64	274.6
Water	16.4	14.1	16.5	12.4
Compressive strength (Mpa)	27	30	36	38

RESULTS AND DISCUSSION

From our experiments, strength of geopolymer concrete based on fly ash are obvious to have increasing character within 28 days according to preparing conditions and composition. The highest geopolymer strength was reached within 27-38 MPa in heat curing after 28 days[10]. The basic material of the geopolymer based on fly ash is of prevailingly amorphous character only seldom containing needle-shaped minority crystals. XRD patterns (Fig. 1) show that the geopolymer materials are prevailingly of X-ray amorphous character where the unique diffraction is that at solely occurring in systems with a high content of slag[10]. The line obviously corresponds to the C-S-H phase formed.

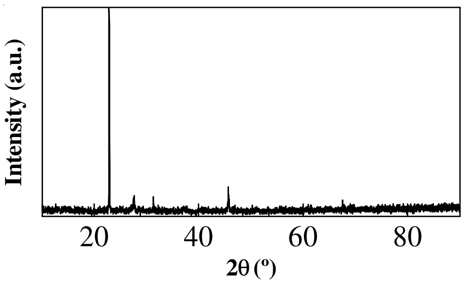

Fig. 1. XRD patterns

It is clear from these results that the structure of product after alkali fly ash activation (geopolymerization) is completely different from the products obtained with alkali activation of portland clinker[11]. Geopolymer's point analysis (SEM) based on fly ash shows the composition of geopolymer. Those spots obviously correspond with the phase C-S-H enriched by Al, which coexist with geopolymer phase. Geopolymer based on fly ash has very similar building units as the mineral analcim $Na_{16}[(AlO_2)_{10}(SiO_2)_{26}]\cdot 2H_2O$. Process of geopolymeration is shown below.

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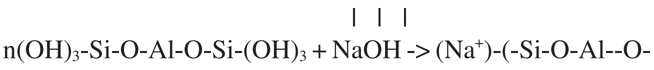
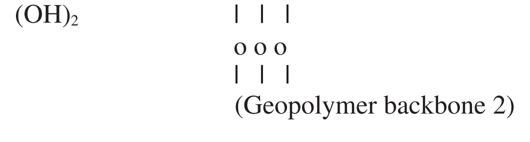
The schematic formation of geopolymer material can be shown as described by eqns. (1) and (2):



$$\underset{\text{(Si-Al materials)}}{n(Si_2O_5,Al_2O_2) + 2nSiO_2 + 4nH_2O + NaOH} \rightarrow Na^+ + n(OH)_3\text{-}Si\text{-}O\text{-}Al\text{-}\underset{\substack{|\\(OH)_2}}{O}\text{-}Si\text{-}(OH)_3$$

(Geopolymer precursor) (1)



$$n(OH)_3\text{-}Si\text{-}O\text{-}\underset{\substack{|\\(OH)_2}}{Al}\text{-}O\text{-}Si\text{-}(OH)_3 + NaOH \rightarrow (Na^+)\text{-}(\underset{\substack{|\ \ |\ \ |\\o\ \ o\ \ o\\|\ \ |\ \ |}}{\overset{|\ \ |\ \ |}{\text{-}Si\text{-}O\text{-}Al\text{--}O\text{-}Si\text{-}O\text{-}}}) + 4nH_2O$$

(Geopolymer backbone 2)

when parts of fly ash are firstly dissolved in strong alkali surrounding solution and then a new geopolymer structure is developed in this solution (Figs. 2 and 3).

Border character of geopolymer and aggregate is completely different. The transmitted layer was not found either morphologically nor by direct measurement of geopolymer composition in the aggregate surroundings, Fig. 3. Proportions of Na_2O/SiO_2 to Al_2O_3/SiO_2, in dependence of the distance from the aggregate part.

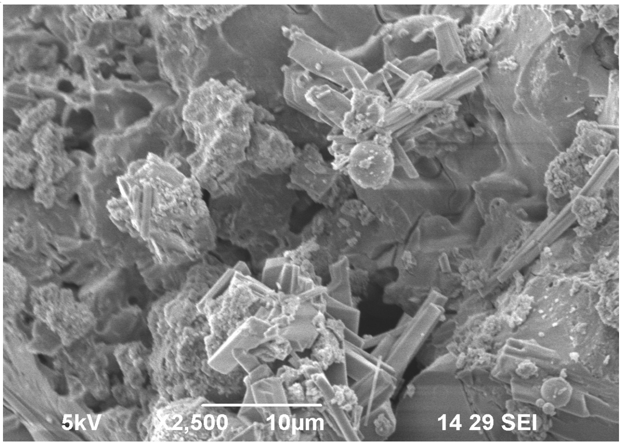


Fig. 2. Typical appearance of the geopolymer from fly ash

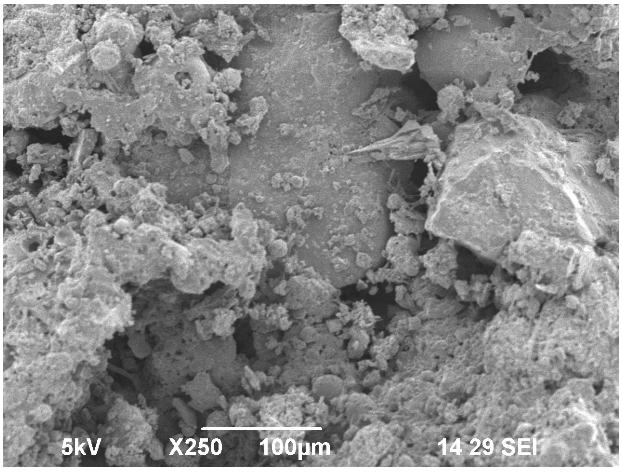


Fig. 3. Interface between aggregate and geopolymer

Conclusion

1) Geopolymer's pastes, mortars and concretes based on fly ash are obvious to have increasing character within 28 days.

2) Geopolymer prepared by fly ash alkali activation contains mainly structures of the types AlQ_4 (4 Si). The main shift-coordination SiQ_4(3Al) and SiQ_4(2-3Al) was found in spectra 29Si NMR MAS. Coordination Si(0Al) has the minority representation, which penetration Al into the net $(SiO_4)4$- proves. Products structure at alkali fly ash activation (geopolymeration) is completely different from the products developed at the alkali activation of Portland cement.

3) Geopolymer is possible to characterize as two up three-dimensioned inorganic polymer (geopolymer) of common pattern $Mn[-(Si\text{-}O)_2\text{-}Al\text{-}O]n\cdot w\ H_2O$.

4) In the presence of Ca contained ingredients (slag) as a result of geopolymer coexistence and C-S-H phase and maximal geopolymer strength was reached.

5) Any presence of the temporary phase with different composition was not found between geopolymer and aggregate as it is at the concretes from portland cement. Geopolymer composition is almost the same in the close nearness even in the geopolymer mass.

6) Elastic modulus evaluated for the geopolymeric phase by means of nanoindentation was found to be $E = 4389 (f_{ck})$ 0.535. Such result is comparable (a little bit lower) to ordinary portland cement pastes.

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