Effect of pumice and fly ash on the corrosion of reinforcing steel in concrete

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Abstract

In this study, the mechanical and physical properties of concrete specimens obtained by substituting cement with finely ground pumice (FGP) at proportions of 5%, 10%, 15% and 20% by weight has been investigated, in addition to analyzing the corrosion behavior of reinforcing steels embedded in these specimens. Besides, with the purpose of determining the effect of fly ash (FA) additive over the corrosion of reinforcing steels embedded in concrete with FGP, FA has been entrained to all series with the exception of the control specimen, such that it would replace with cement 5% by weight. Corrosion experiments were conducted in two stages. In the first stage, the corrosion potential of reinforcing steels embedded in the concrete specimens was measured every day for a period of 60 days based on the ASTM C 876 standard. In the second stage, the anodic and cathodic polarization values of the steels were obtained and subsequently the corrosion currents were determined with the aid of cathodic polarization curves. In the study, it was observed that a decrease in the mechanical strength of the specimens and an increase in the corrosion rate of the reinforcing steel had taken place as a result of the FGP addition. However, it was determined that with the addition of FA into concretes supplemented with FGP, the corrosion rate of the reinforcing steel has significantly decreased.

Keywords: Concrete Corrosion, Finely ground pumice, Fly ash, Reinforcing steel

1. INTRODUCTION

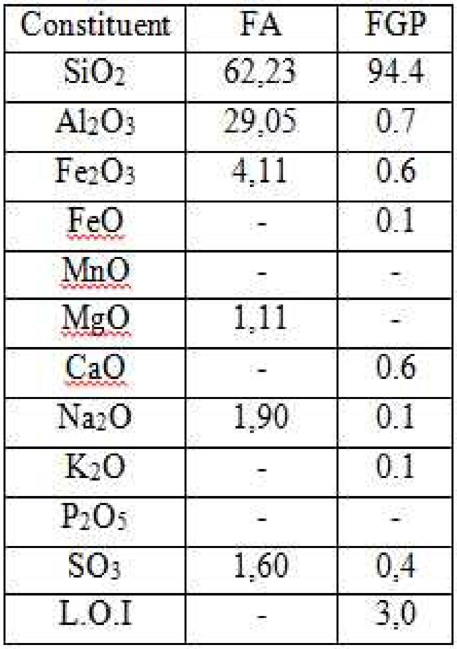
Finely ground pumice (FGP) and fly ash (FA) have been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in high-performance concrete. Mechanical experiments of FGP and FA blended Portland cement concretes revealed that in addition to the pozzolanic reactivity of RHA (chemical aspect), the particle grading (physical aspect) of cement and RHA mixtures also exerted significant influences on the blending efficiency. It is also reported that the microstructure of the cement paste can be significantly improved by adding pozzolanic materials such as, fly ash, silica fume, metakaolin and rice husk ash. The utilization of FA as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions. Reactivity of FA is attributed to its high content of amorphous silica, and to its very large surface area governed by the porous structure of the particles [1–4]. Generally, reactivity is also favored by increasing fineness of the pozzolanic material [5-7]. However, Mehta [8] has reported that grinding of FA to a high degree of fineness should be avoided, since it derives its pozzolanic activity mainly from the internal surface area of the particles. By blending rice husk ash with courser cement, higher packing can be expected, leading to improved behavior of blended systems [9,10]. it was reported that there was a close relationship between the type of pumice coating and reinforcement corrosion. It was also, mentioned that corrosion ratio decreased with increasing amounts of reactive SiO2. Various corrosion tests were applied and the resulting corrosion ratios were determined. Using the results obtained, the optimum mixture ratios were determined for synthesized anticorrosion coating materials [11].

In the present investigation, FA and FGP were blended with ordinary Portland cement at various percentages by simple replacement method and a realistic assessment of the corrosion resistant and the results were compared with conventional Portland cement concrete.

MATERIALS AND METHODS

ASTM C 150 Type I Portland cement was utilized in all the concrete mixtures. PA and FGP were used as fillers. Table 1 shows the chemical composition of Type I Portland cement, MLC and perlite. Potable water was used for mixing the concrete constituents.

Table 1 Chemical composition of Type I Portland cement, FA and FGP Constituent (wt.%)



Constituent	FA	FGP
SiO_2	62,23	94.4
Al_2O_3	29,05	0.7
Fe_2O_3	4,11	0.6
FeO	-	0.1
MnO	-	-
MgO	1,11	-
CaO	-	0.6
Na_2O	1,90	0.1
K_2O	-	0.1
P_2O_5	-	-
SO_3	1,60	0,4
L.O.I	-	3,0

Cylindrical concrete specimens of size 100 mm diameter and 150 mm height were cast with centrally embedded rebar of 15 mm diameter and 100 mm height, containing ordinary Portland cement (control) and OPC replaced by FA and FGP at 5%, 10%, 15% and 20% replacement levels. During casting, the moulds were mechanically vibrated. After 24 h, the cylindrical specimens were demolded and subjected to water curing for 28 days. After curing, the specimens were subjected to corrosion test. The concrete specimens were immersed in 3,5% NaCl solution. The tests were continued over a period of 60 days. Open circuit potential measurements were monitored with reference to saturated copper/copper sulfate electrode periodically with time as per ASTM C876. From the results potential vs. time plot is drawn using the average potentials obtained.

The corrosion potentials were measured using a saturated copper/copper sulfate reference electrode (Cu/CuSO4). The electrical lead from the reference electrode was connected to the negative terminal of a high impedance digital voltmeter while the steel bar in the concrete was connected to its positive terminal Figure 1.

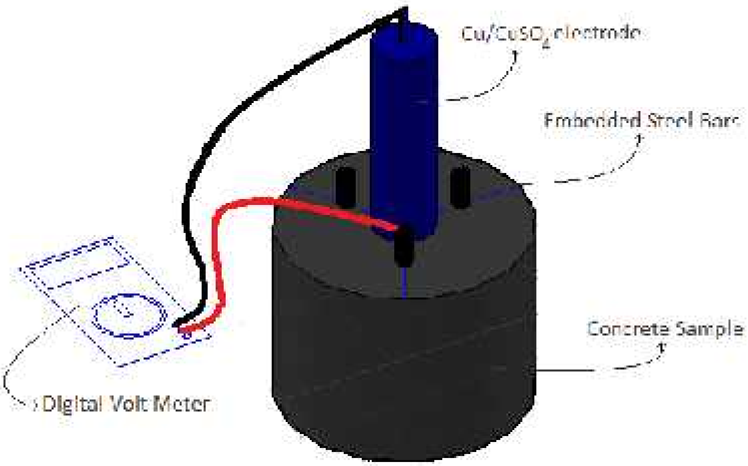


Figure 1 Schematic representation of specimens

The tests were continued over a period of 12 months. Open circuit potential measurements were monitored with reference to saturated Copper/Copper sulfate electrode periodically with time as per ASTM C876. From the results potential vs. time plot is drawn using the average potentials obtained. The three electrode method was utilized to measure the corrosion rate using a Potentiostat/Galvanostat. The steel rod was connected to the working electrode terminal while a steel plate and a reference electrode were connected to the counter and reference electrode terminals of a Potentiostat/Galvanostat, respectively. The steel was polarized from -1.0 V 1,0 V at a scan rate of 2 mV/s and the resulting corrosion rate.

RESULTS AND DISCUSSION

The open circuit potentials of concrete samples are plotted against the period of immersion in Figs. 2–3. The concrete samples with FA and FGB initially showed higher potentials (more negative) or equal potentials as compared to the plain-cement concrete specimens for a certain period of time. At latter stages, however, the specimens containing

FA and FGB exhibited lower potentials (less negative) than plain-cement concrete specimens. Further, FA and FGB specimens generally took longer time to reach the active potential boundary -270 mV than plain concrete specimens.

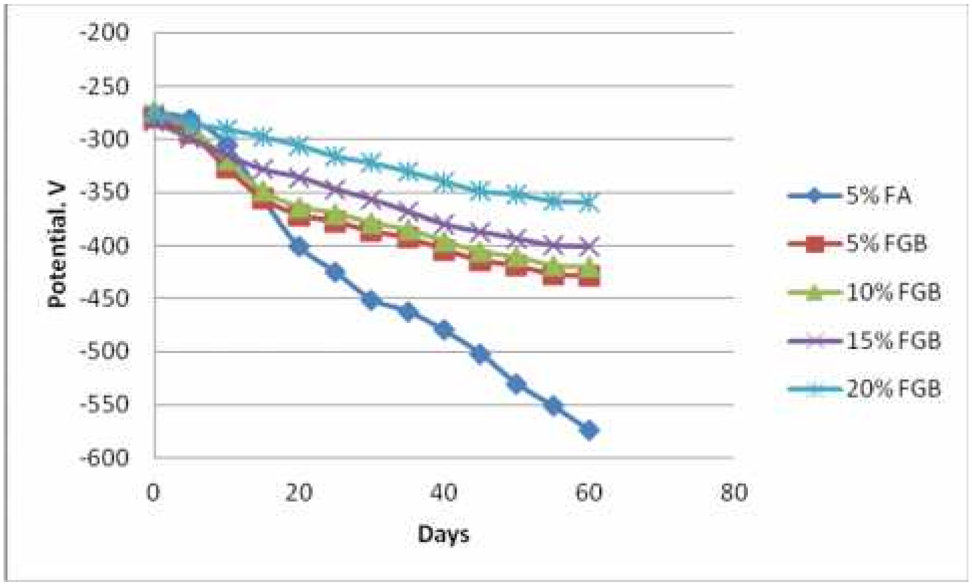


Figure 2 Open Circuit Potentials on reinforcement in different proportion replaced FGB specimens

During the 60 days of exposure the potential values range between -280 and -600 mV. Just after the immersion in the NaCl solution, cement specimens exhibit corrosion potential values ranging between -350 and -450 mV Cu/CuSO4 for FA and FGB specimens, whereas that of the non-additive ones equals -570 mV. Then a decay of Ecor to more electronegative values is observed, which is faster for non additive specimens.

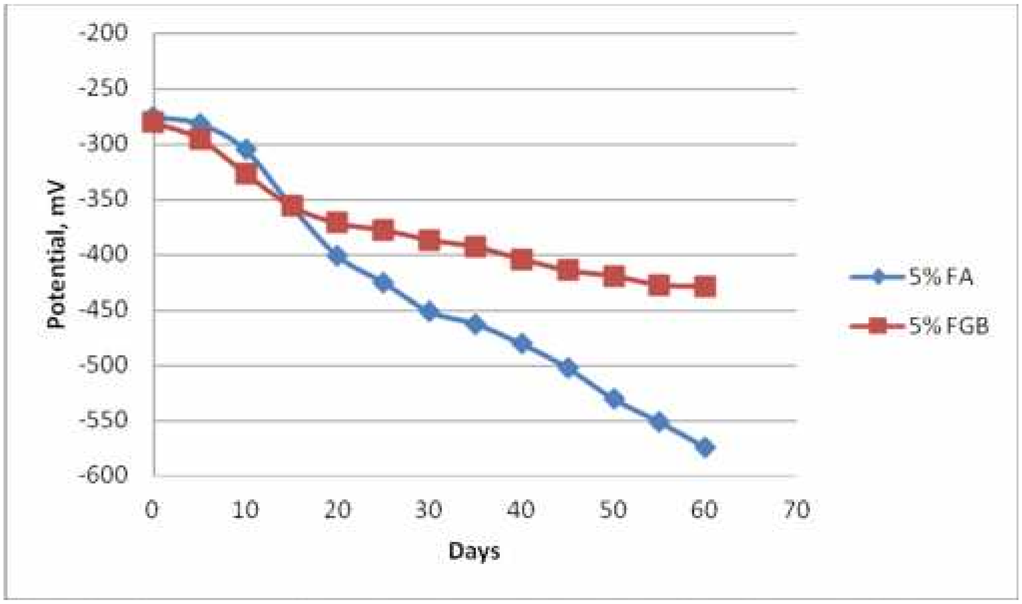


Figure 3 Open Circuit Potentials on reinforcement specimens with replaced FA and FGB

The open circuit potential shifts more electronegative potential with the replaced proportions of FGB increasing.

As it is shown in Fig 5, corrosion rate decreases the specimen prepared MLC and perlite. The corrosion rate measured by Tafel Polarizatin method and determined the corrosion rate 0.08, 0,03 and 0,020 respectively for non additive, replaced FA and replaced FGB specimens. FGB resisted better against corrosion than the FA.

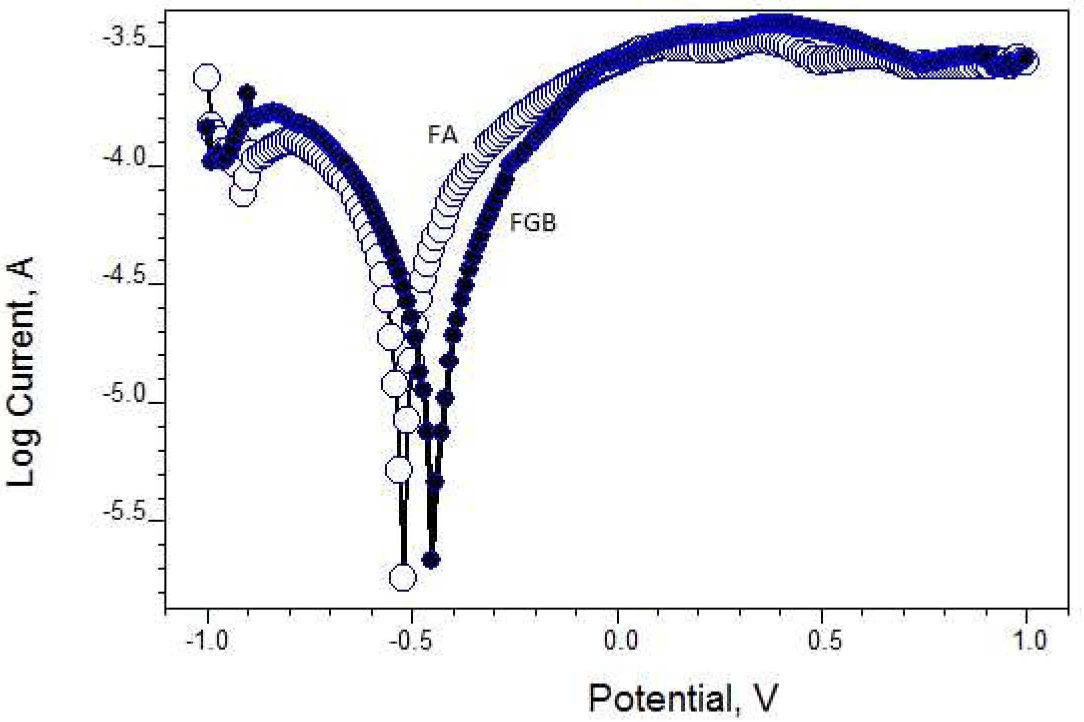


Figure 4 Tafel polarization cuirves for specimens replaced FGB and FA

The results in this investigation show that FA and FGB addition to concrete mixes appears to improve the long-term corrosion resistance of concrete. The role of FA and FGB is related with both the initiation and the progression of corrosion. FA and FGB are added as fine granulates and upon hydration of cement, they have the capability of partially obstructing voids and pores. This leads to a decrease of pore size and to a smaller effective diffusivity for either chloride or other species. This improves the long-term corrosion resistance of concrete structures [12]. The pozzolanic reaction of FA and FGB with calcium hydroxide also produces a denser concrete and thus inhibits the ingress of chloride ions. This takes place at a slower rate.

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