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Effect of the Type of Concrete with Mineral Additions on the Steel Reinforcement Corrosion Induced by Chlorides - Analysis in the Same Mechanical Strength Class

Andrielli Morais de Oliveira[1], Oswaldo Cascudo[1] and Alexandre de Castro[2]

[1] GEDur - Durability Studies Group, Laboratory of Technological Innovation in Civil Construction – LABITECC, PPG-GECON, Civil and Environmental Engineering School, Federal University of Goiás (Universidade Federal de Goiás - UFG), 74.605-220. Praça Universitária, Goiânia – GO, Brazil, andriellimorais@ufg.br, ocascudo@gmail.com

[2] Furnas Centrais Elétricas, Rodovia BR 153, s/n - Zona Rural, Aparecida de Goiânia - GO, 74923-650, Brazil, alexcasp@furnas.com.br

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1 Introduction

The aim of the present paper is to evaluate the protection ability of concretes against the steel bar corrosion. The compared concretes have the same compressive strength (C35 MPa) at the age of 28 days and the same exposure condition in harsh environment, containing chlorides. Concrete with fly ash (FA), silica fume (SF) and metakaolin (Mk) were studied. Additionally, for the concrete with fly ash, the influence of water/binder ratio also were measured (0.30 and 0.40). Thermodynamic (E_{corr}) and kinetic (i_{corr}) parameters of reinforcement corrosion were evaluated.

2 Experimental Program

The composition was Portland Brazilian cement, mineral addition, fine and coarse aggregates, chemical admixtures and water. In the concrete mixtures, 10%, 30% and 20% of cement (by weight) were replaced by silica fume or fly ash or metakaolin, respectively, besides of concrete without mineral additions.

The water-to-cementitious materials ratio was different for the concretes ranging from 0.30 to 0.55. All concretes showed compressive strength at the age of 28 days of 35 MPa. Specifically, for the concrete with fly ash, two water/binder ratios were studied: 0.30 and 0.40.

The corrosion process was induced by wet–dry cycles in NaCl solution during 44 cycles. E_{corr} and R_p techniques were performed by means of a three-electrode arrangement using a potentiostat. Besides that, i_{corr} were estimated from R_p. The ASTM criteria (ASTM C 876: 2015 and Andrade and Alonso (2001) criteria were adopted.

3 Results and Discussion

Figure 1 (a and b) shows E_{corr} and i_{corr} *versus* wet–dry number cycles in NaCl solution, respectively. The results showed an average of 4 rebars for each type of concrete.

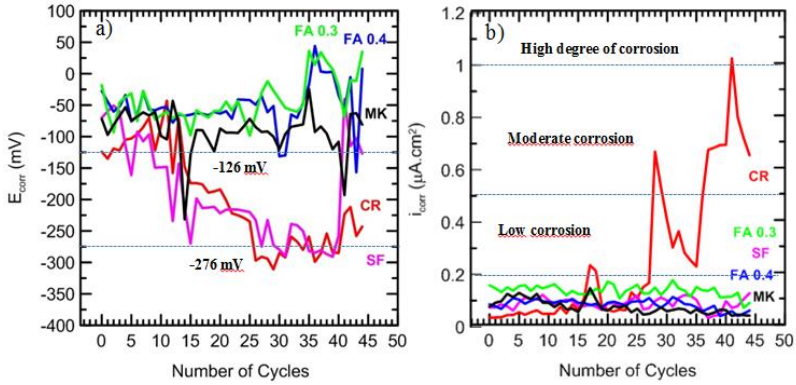

Figure 1. Influence of the type of concrete in terms of initiation and propagation of corrosion induced by chlorides on the concretes performance: average curves of (a) E_{corr} (SCE) (ASTM C 876: 2015) and (b) i_{corr} (Andrade and Alonso, 2001) *versus* wet–dry number cycles in NaCl solution.

From the Figure 1 for concretes with the same compressive strength (35 MPa), it is clear the beneficial effect that the mineral additions provide to the concretes, promoting significantly potential values more electropositive than reference concretes. Thus, it can be seen that the control concrete, compared to the concretes with SCMs, exhibit a greater tendency to the depassivation of reinforcement.

It is worth mentioning the good performance of concretes with fly ash, with behaviors close to concrete with metakaolin. There were no differences between concrete with fly ash. Silica fume concrete did not present a good performance regarding E_{corr}, and the lowest performance was presented by the control concrete. Thus, the effectiveness of mineral additions in physically and chemically protecting the steel bar keeping it passivated as long as possible became evident. Finally, just the control concrete showed increase of values of i_{corr} (corrosion rates). This denotes reduction of service life and durability.

4 Conclusions

The following conclusions can be drawn from the present paper:

- Control concrete protected less the steel bar against corrosion induced by chlorides, indicating E_{corr} more negatives and higher corrosion rates (i_{corr}).
- All concretes with mineral additions have not presented significant corrosion induced by chlorides for the 44 cycles (308 days) analysis period.
- The influence of the small change in water/binder ratio on fly ash concrete was not significant.

ORCID

Andrielli Morais de Oliveira: https://orcid.org/0000-0001-8977-785X
Oswaldo Cascudo: https://orcid.org/0000-0003-1879-6396
Alexandre de Castro https://orcid.org/0000-0001-5089-9788

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