The Impact of Core-shell Micelles on Steel Properties and Microstructural Characteristics in Reinforced Mortar after Corrosion and Cathodic Prevention

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Introduction: This work presents the final results from an initial study on the influence of PEO₁₁₃-b-PS₂₁₈ core-shell micelles on steel behavior and cement-based microstructure of reinforced concrete. The specimens were maintained in conditions of chloride-induced corrosion and two regimes of cathodic prevention for 320 days. The study reveals that a very low concentration of 0.006 wt.% micelles exerts significant alterations in the bulk matrix on one hand, and increases chloride threshold levels on the other. In other words, although 5wt% (per dry cement weight) chlorides were derived in the vicinity of the steel reinforcement for all specimens, corrosion was minimal or not initiated in the micelles-containing specimens, whereas corrosion products accumulation was observed for the micelles-free cells. The microstructural parameters in cells where electrical current flow was involved (as in the two cathodic prevention regimes) were also influenced by the presence of the micelles, presenting a denser pore structure, compared to the micelle-free corroding and control cells.

Materials: The investigated specimens were reinforced mortar cylinders, h = 150mm, d = 40mm, with embedded “as received” construction steel FeB500 HWL of d=8mm (5 replicates per group and per condition were monitored). The specimen designation is as follows: corroding groups OPCcorr (micelles-free) and PoOPCcorr (with micelles) and reference groups, with and without micelles, PoOPCref and OPCref respectively. All specimens used OPC CEM I 42.5, water-to-cement ratio 0.6, cement-to sand ratio 1:3. Curing of the specimens was performed for 7 days in fog room (20°C, 98%RH); conditioning was in lab environment (20°C, lab air) for the total duration of the test of 320 days. The corroding specimens were 1/3rd of height immersed in highly aggressive medium of 10% NaCl, the reference (non-corroding specimens) in tap water.

Four additional groups of specimens were under Cathodic Prevention (CPre and pulse CPre). The cathodic polarization started immediately after immersion of the cells in the 10% NaCl solution. The cathodic current density was 1mA/m² steel surface and increased to 2.5 mA/m² after 90 days. The pulse regime used a block (square) DC pulse at 1kHz, duty cycle of 12.5% and a high impedance current source. Thus, the pulse regime uses 50 % of the current, used within steady CPre i.e. 0.5 until 90 days and 1.75 mA/m² later on.

The electrochemical behavior of corroding and control cells of all types is elaborated in [1]. The conventionally applied decay measurements and potential mapping for the cells under cathodic prevention is discussed in more detail in [2]. This paper gives a correlation of microstructural characteristics, in relation to steel surface properties and global corrosion performance for all investigated conditions.

Results: Figure 1 presents the steel/cement paste interface for: micelles-free corroding specimen OPCcorr (a), micelle-containing specimens PoOPCcorr (b); micelle-free specimens OPCcp and OPCpcp (under conventional and pulse CPre), (c,d) and micelles-containing specimens PoOPCcp and PoOPCpcp for the two regimes of CPre – (e,f) respectively.

Fig.1 Steel/cement paste interface for all studied conditions

Figure 2 depicts the calculated bulk matrix porosity and pore size distribution for specimens OPCcorr and PoOPCcorr (left) and OPCref and PoOPCref (right).

Fig.2 Porosity and pore size distribution in corroding and reference specimens with and without micelles.

Figure 3 presents calculated structural parameters for some cells under CPre in comparison with corroding and control cells.

Fig.3 Porosity and pore size distribution in specimens under CPre and pulse CPre, compared to OPCcorr and OPCref.

Final data processing is still on-going. Main outcomes so far can be summarized as follows: Although according to electrochemical parameters the micelles-containing corroding specimens show active behavior, corrosion in the latter was not initiated. Additionally, increased porosity was observed in the latter specimens. The most plausible mechanism is altered cement matrix (including positive charge, thus enhanced chloride binding), reduced permeability and therefore oxygen diffusion limitation. Cathodic prevention induces densification of the matrix as well and shows effective performance for all conditions and in the two investigated regimes.

1. D.A.Koleva, K.van Breugel, et al. 216th ECS Meeting, Vienna, Austria (2009), No 152.
2. D.A.Koleva, K.van Breugel, et al. 216th ECS Meeting, Vienna, Austria (2009), No 1728.