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Microscopic examination of concrete with and without corrosion inhibitor

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Abstract

The present paper addresses the mineral constituents and microstructural behaviour of concrete with and without corrosion inhibitor (i.e. calcium stearate) observed under petrological microscope. Mineralogically and texturally, these concretes are largely similar but microstructurally they are quite distinct. The concrete samples without calcium stearate are characterized by the occurrence of microcracks, voids and carbonation leading to lower the strength and durability of concrete. However, these features are less abundant in the concrete with calcium stearate. The microcracks and voids are infilled with cementitious materials, if calcium stearate is used as admixture. Therefore, the use of calcium stearate in concrete can enhance the strength and durability properties of concrete.

Introduction

Microscopic study provides information about mineral constituents, and microstructure/texture of the rock or concrete specimens. Stones (*i.e.* coarse aggregate) and sands (*i.e.* fine aggregate) are the most important components of concrete. Microscopic examination plays a vital role in identification of mineral composition of the coarse and fine aggregates as well as the nature of the binding between cement paste and aggregates of the hardened concrete and related building materials. Petrographic study of hardened concrete is a quick and well studied method of diagnosing reason for lack of concrete durability (Jepsen and Christensen, 1989). In the last decade petrography has played an important role in the identification of suitable (non-reactive) aggregates for sound concrete as well as in the identification of reactive aggregates and reaction rims in the expanded/distressed and deteriorated concrete cores (Bhatt and Kumar, 2005). The microstructural behaviour (*e.g.* microcracks, voids etc.), formation of gels, carbonation and presence of remnant cement grains in concrete could be successfully examined under petrological microscope (Jepsen and Christensen, 1989; John *et al.,* 1998; Jana, 2005; Singh *et al.,* 2007; G.D. Ransinchung *et al.,*2008).

The present work deals with the study of microstructures (*e.g.* microcracks, voids etc.) and carbonation in the ordinary portland cement concrete with and without calcium stearate used as admixture. Calcium stearate is generally used as corrosion inhibitor in order to lower the corrosion rate of steel reinforcement in a chloride environment (Abhilash, 2008). The available published works reveal that no detailed petrographic study has been carried out on the concrete with calcium stearate except only a few SEM observations for the concrete with corrosion inhibitor (*e.g.* Wah *et al.,* 2000). However, concrete with microsilica, flyash and wollastonite have been studied microscopically to observe their microstructures (*e.g.* Jepsen and Christensen, 1989; John *et al.,* 1998; Singh *et al.,* 2007; G.D. Ransinchung *et al.,* 2008).

Calcium stearate is a compound of calcium with fine mixture of solid organic acids or some fatty acid obtained from edible sources. It occurs as a fine, white to yellowish white bulky powder having a slightly fatty oder. It is a water repellent chemical and harmless to environment also.

Methodology

The concrete cubes were prepared in the Structural Engineering Laboratory, Department of Civil Engineering, I.T., BHU by using the materials (*i.e.* coarse and fine aggregates; ordinary portland cement; calcium stearate as chemical admixture and tap water) as per IS:456 (2000) mix design for studying the microscopic features and engineering properties. Before making the cubes, the coarse and fine aggregates, that were used in concrete, have been studied petrographically to identify the mineral constituents and texture for inferring whether they are suitable for concrete or not. Dolastones as coarse aggregates (20 mm and 10 mm sizes) and ordinary sand from Chopan area, District Sonebhadra, Uttar Pradesh as fine aggregates were used in the present study. The petrographic features of these aggregates are described below under petrography section. Besides petrographic investigation, the properties of coarse and fine aggregates are also determined as per IS:383 (1970).

Two types of concrete (*i.e.* concrete with and without calcium stearate) were prepared as per IS:456 (2000). The concrete samples without calcium stearate is designated as control system specimen or referral mix M_1 and the samples with the dose of 3% calcium stearate as mix M_2. Concrete cubes with and without calcium stearate were cured in water for 28 days. After that concrete cubes were dried properly for thin section preparation and thin sections were prepared from the broken chips/pieces of these concrete cubes for microscopic examinations.

Petrography

Under petrological microscope, Dalastones are fine to medium grained and composed of the mineral dolomite. It does not show foliation or weak planes. Few grains of quartz and iron-oxides are also observed as impurities. Texture and mineral compositions reveal that Dalastone is a variety of sedimentary rock known as dolostone. On the other hand, the fine aggregate (*viz.* Chopan sand) is grey coloured and medium to coarse grained. It contains dominantly of quartz grains (approximately 90%), feldspar (~6%), mica (~1%) and heavy minerals including iron-oxides (~3%).

Microscopically, the concrete samples with and without calcium stearate show that coarse aggregates, and medium-to coarse-grained minerals of fine aggregate are enclosed within the dark-coloured groundmass of cementing materials. The coarse aggregate constitute small size dolomite mineral that interlocked with each other in comparison to other minerals present in the groundmass. Quartz and feldspar (*i.e.* K-fledspar and plagioclase feldspar) are the main constituents present in the groundmass of cementing materials. Biotite, the brown coloured mica is rarely observed. Quartz occurs more commonly in comparison to feldspars. Quartz grains are generally medium - to coarse-grained, anhedral to subhedral and subrounded in shape. K-feldspar (mostly perthite) grains are more common in comparison to plagioclase feldspar showing albitic nature. Quartz and feldspar grains generally show sharp contact with the cementing materials.

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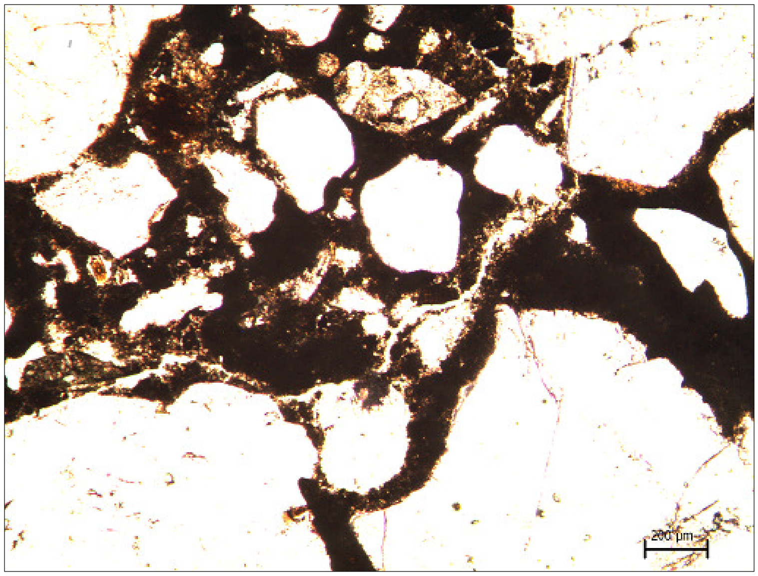

Fig.1. Photomicrograph showing the presence of microcracks in the concrete without calcium stearate. Also notice carbonation along the microcracks (O.L.).

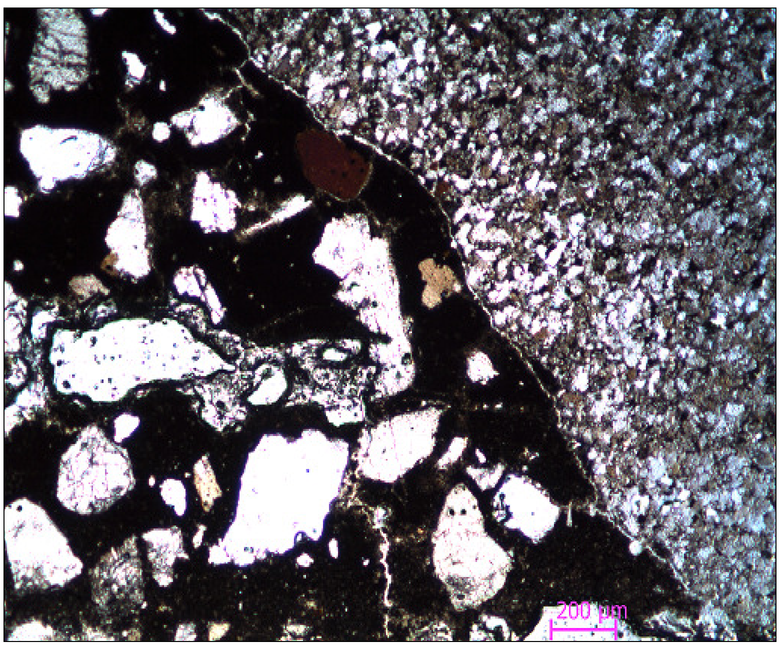

Fig.2. Photomicrograph exhibiting that microcracks running along the periphery of coarse aggregate and also within the groundmass of the concrete without calcium stearate. (C.N.).

It is important to point here that microcrack and large to small sized voids are frequently observed in the specimens of concrete without calcium stearate (Fig. 1, 2 & 3). However, these cracks, if present, in the samples of containing calcium stearate are infilled with cementitious materials (Fig. 4). Further, it is also observed that most of the voids of concrete samples with calcium stearate are generally smaller and partially infilled with cementitious materials (Fig. 4). Intensive carbonation is taken placed in the referral concrete mix M1 (Fig. 1 & 3), whereas these carbonations are rarely observed in concrete sample containing calcium stearate.

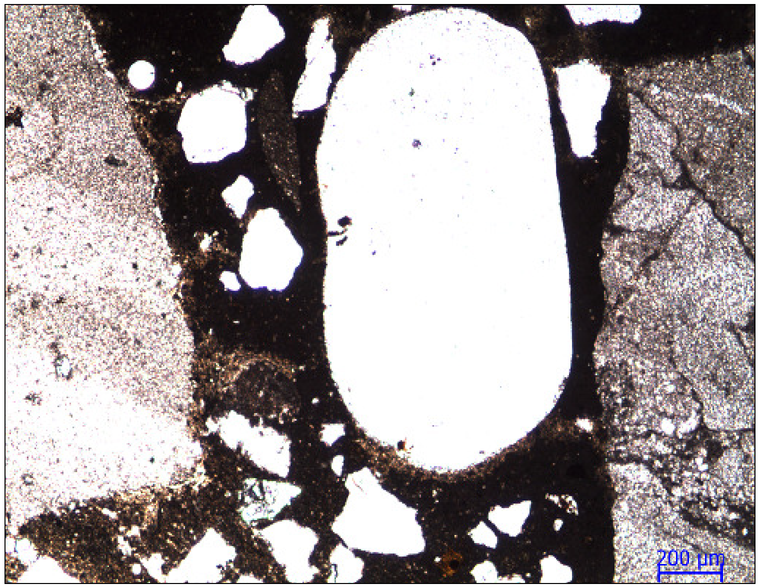

Fig.3. Photomicrograph showing the presence of large to small sized voids within the concrete without calcium stearate. Also notice carbonation along the periphery of the large void (C.N.).

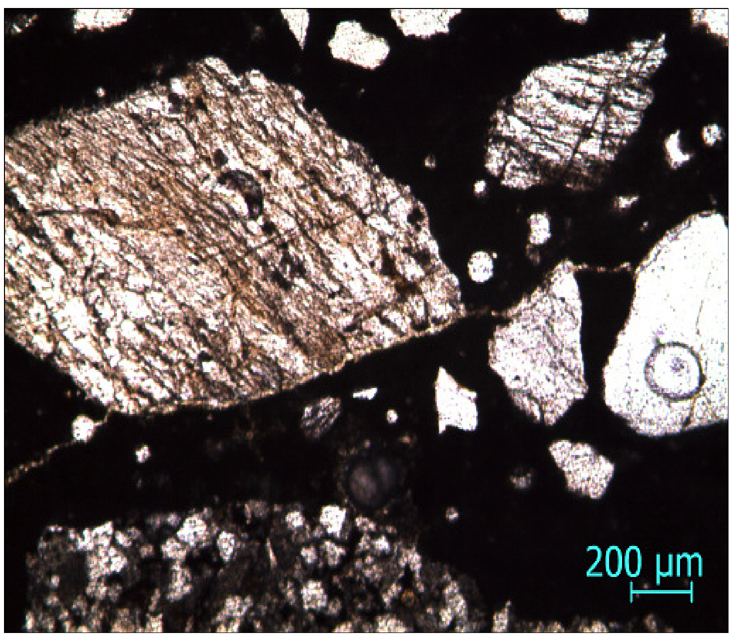

Fig.4. Photomicrograph showing that microcracks and voids are infilled with filler or cementitious materials in the concrete with calcium stearate(O.L.).

Discussion and Conclusions

In the present investigation, concrete with and without calcium stearate have been studied microscopically to observe the microstructures (*e.g.* microcracks, voids etc.) and carbonation. The mineral constituents as well as the textures (*i.e.* size, shape and arrangement of mineral constituents within the groundmass) for both concretes are largely similar. However, microstructurally they are quite distinct.

Microscopic observations reveal that most of the major microcracks in the samples of concrete without calcium stearate are developed at the periphery of the coarse aggregate from which many minor microcracks emerged within the cementitious groundmass (Fig. 2) which is directly responsible for the reduction in strength and durability properties of concrete (John *et al.,* 1998; Ransinchung *et al.,* 2008). Large to small sized voids are also frequently observed in the concrete without calcium stearate (Fig. 3). The presence of more microcracks and voids reduce the strength and durability of concretes (John *et al.,* 1998; Jana, 2005; Ransinchung *et al.,* 2008). On the other hand, the sizes of voids are considerably smaller and partially infilled with cementitious materials in the samples of concrete with calcium stearate (Fig. 4). Microcracks and few voids are infilled with calcium silicate hydrates (C-S-H) gel in concrete mix M_2 (Fig.4). These are most probably due to addition of calcium stearate in the ordinary Portland cement concrete. Clusters of belite and alite have also been observed in dark interstitial matrix of concrete mix M_2 (Fig.4), which is principally responsible for strength development of concrete (Ransinchung *et al.,* 2008). However, Wah *et al.* (2000) have suggested that addition of 0.5% of titanate and 0.2% calcium stearate were able to produce good dispersion of filler materials in the system, while maintaining reasonable properties of tensile and flexural strength.

Further, it is also observed that intensive carbonation has taken place more frequently in the sample of referral concrete mix (Fig. 1 & 3) than the concrete samples containing calcium stearate. This shows that referral mix (M_1) would be more porous in comparison to mix M_2 which would affect the durability properties of concrete. Most of this carbonation has taken place at the interface of the aggregates and few of them are associated with microcracks and voids (Fig. 1 & 3). Carbonation most commonly takes place due to reaction of both calcium hydroxide and cement hydrates with atmospheric carbon-dioxide (John *et al.,* 1998; Ransinchung *et al.,* 2008).

On the basis of present investigation, it is concluded that the use of calcium stearate as admixture can inhance the strength and durability properties of concrete due to batter microstructure, formation of additional C-S-H gels and infilling of pores.

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