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Technical note

A note on the comparison of crack resistance of $Ca(OH)_2$ crystals of unmodified and polymer-modified mortars in carbonated atmosphere

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Abstract

The purpose of this paper is to study morphologically the effects of carbonation on $Ca(OH)_2$ crystals in unmodified mortar and polymer-modified mortars (PMMs). For this purpose, unmodified mortar and PMMs with 25 mix proportions were prepared with various polymer–cement ratios (P/C) and subjected to a nonpressurizing accelerated carbonation test (NPACT). It was concluded that $Ca(OH)_2$ crystals formed in unmodified mortar were weak, unable to withstand stresses generated due to carbonation-related shrinkage and therefore cracked on exposure to CO_2. By contrast, $Ca(OH)_2$ crystals formed in PMMs were strong, withstood stresses generated due to carbonation-related shrinkage and did not crack on CO_2 exposure.

Keywords: Crack detection; $Ca(OH)_2$; Crystal structure; Carbonation; Polymer-modified mortars

1. Introduction

Polymer-modified mortars (PMMs), using recently developed high grade redispersible polymer powders and aqueous polymer dispersions, have become popular construction materials in the world, particularly for finishing and repairing works. This is because of their excellent performance and durability. PMMs are also considered to be able to become highly sustainable construction materials from the global environmental point of view [1]. In order to develop useable models of structure–property relationships for such systems, the authors have focused their studies on microscopic level because such aspects still need more information. This is required because the fracture strength of brittle materials and yield point of ductile materials can often be improved by controlling the microstructure [2]. Both brittle and ductile fractures are dependent on the presence of microscopic cracks, voids, inclusions and other microstructural features [3]. In case of brittle materials, fracture occurs at submicroscopic structural defects or Griffith flaws. Moreover, fracture of brittle materials occurs at applied stress levels far below those expected from a theoretical consideration of the bonding forces in the material. Cement paste or concrete is assumed to posses many flaws whose character needs more explanation. The scanning electron microscope has been quite helpful in making direct observations on the fracture surfaces of complex materials like cement paste and concrete. These observations can be used to characterize the relative effects of microstructural features of cement paste on the fracture process. In more complex materials, it is not sufficient to just identify the Griffith flaws, but it is also necessary to understand how each of the microstructural components affects the fracture process [4]. Keeping in view the foregoing background, the authors have reported their detailed observations on microscopic features such as $Ca(OH)_2$, AFt, AFm, hollow tubules, hollow crystals and hydrogarnet-type cubic crystals in PMMs [5–10].

Because of the more debatable role of $Ca(OH)_2$, the authors have focused more on this aspect [5,6]. Our above-referred findings were based on the samples of unmodified mortar and various PMMs cured in the standard curing conditions. We had pointed out [6] that some of $Ca(OH)_2$ crystals formed in the absence of polymers in unmodified

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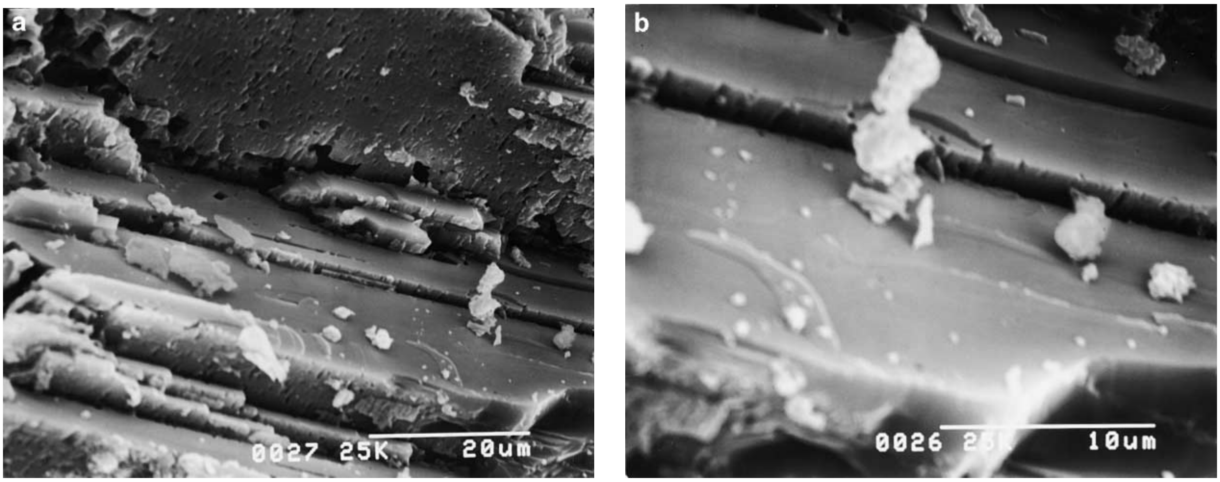

Fig. 1. Cleavage or crack extending through $Ca(OH)_2$ crystals after NPACT. (a) Lower magnification micrograph, (b) higher magnification micrograph.

mortar were weak and were unable to withstand stresses generated during formation. By contrast, $Ca(OH)_2$ crystals formed in PMMs were strong because of improved interparticle bonding due to the presence of polymer particles between them. This made them capable of withstanding various stresses [5,6].

But studies concerning the effects of carbonation on microstructural aspects of $Ca(OH)_2$ crystals in unmodified mortar and PMMs were not available by that time. Carbonation is one of the factors responsible for neutralization of pH of mortars or concretes, and thus is an important corrosion-leading factor. Such studies may help to identify the effects of carbonation-related shrinkage in unmodified mortar and PMMs. The purpose of this paper is to study morphologically the effects of carbonation on $Ca(OH)_2$ crystals in unmodified mortar and PMMs.

2. Materials and testing procedures

For the above purpose, unmodified mortar and PMMs with 25 mix proportions were prepared with various polymer–cement ratios (P/C) and were subjected to a nonpressurizing accelerated carbonation test (NPACT). After NPACT, the fractured surfaces of unmodified mortar and PMMs were observed by a scanning electron microscope. The details of materials, mix proportions and testing procedures are mentioned in Refs. [6,11].

3. Results and discussion

The present studies reveal the presence of cleavage or cracks extending through $Ca(OH)_2$ crystals in unmodified mortar after NPACT as shown in Fig. 1(a) and (b) at lower and higher magnifications, respectively. This type of cracking occurs after NPACT in $Ca(OH)_2$ crystals of unmodified mortar because they are weak, can cleave easily due to weaker interparticle bonding because of the absence of polymer particles between them [5,6], and hence are unable to withstand stresses generated due to carbonation-related shrinkage. In opposition, no cracking is observed in $Ca(OH)_2$ crystals of PMMs after NPACT and the structure of such crystals is same as already reported by us in Refs. [5,6]. This happens because $Ca(OH)_2$ crystals formed in PMMs are strong due to enhanced interparticle bonding because of the presence of polymer particles between them [5,6], and therefore are able to withstand the stresses generated due to carbonation-related shrinkage.

4. Conclusions

In conclusion, $Ca(OH)_2$ crystals formed in unmodified mortar are weak, unable to withstand stresses generated due to carbonation-related shrinkage and therefore crack on exposure to CO_2. By contrast, $Ca(OH)_2$ crystals formed in PMMs are strong, able to withstand stresses generated due to carbonation-related shrinkage and do not crack on exposure to CO_2.

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