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Effect of polymer modification of the paste–aggregate interface on the mechanical properties of concretes

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ABSTRACT

We investigated the effect of thin viscoelastic polymer coatings around aggregate particles on the mechanical properties of "micro-concretes" with a maximum aggregate diameter of 10 mm. Aggregate particles >5 mm were pre-treated with a latex at dosages of up to 2% by mass and dried prior to using the treated aggregate in the micro-concrete mix. Cured prisms were tested in flexion. The results show that thin polymer coatings on aggregates have a significant effect on micro-concrete cracking behaviour at much lower polymer dosages than are commonly used in polymer-modified mortars. We observed a significant improvement in post-peak energy absorption relative to the use of the same amount of polymer dispersed in the bulk paste. But, under the conditions tested here, reductions in the strengths and moduli of the composites due to the polymer additions appear to have more than outweighed the observed positive effects of increases in fracture energy and characteristic length.

1. Introduction

The use of network polymers, such as latexes or resins, to modify the properties of hardened mortars or concretes is not new [1,2]. Examples include resin-impregnated concretes made by polymerization of a monomer absorbed into the hardened concrete, or latex-modified mortars in which a part of the cement paste is replaced by a latex which coalesces during hardening. The polymer serves either to make the product more "flexible" or to reduce its permeability, or both. However, very high polymer dosages, of the order of 10–20% by mass of cement, are usually required in order to obtain a useful effect. Considering the difference in density, this amounts to about 30–60% by volume of cement—a very high dosage. Thus, due to the relatively high cost of polymers, polymer-modified cement products are too expensive for most uses.

It occurred to us that such network polymers might be used more effectively in mortars and concretes if they could be concentrated at the paste/aggregate interface. It was already well known that the paste/aggregate interface has an important role in reducing the brittleness of mortars and especially of concretes, principally by deflecting crack propagation and increasing crack surface area, so we hoped that the use of suitably-tailored polymers designed to absorb energy during crack opening might help to further increase the work of fracture and thus further reduce the brittleness of mortars and concretes, preferably without any negative effect on other properties.

Given that it is difficult to obtain a significant concentration of polymers at the paste–aggregate interface after the polymer has been dispersed into the fresh concrete or mortar, we decided that the best initial approach was to pre-treat the aggregates with polymer so as to ensure that a stable polymer coating of the desired thickness was formed before using the coated aggregates to make mortars or concretes. If a desirable range of polymer properties and coating thicknesses can be found by this simple approach, we believe that it might in the future be possible to find a way of applying such a coating as an integral part of the concrete mixing process.

2. The role of the paste–aggregate interface in the mechanical properties of concrete

Concretes and mortars can for many purposes be treated as two-phase composites composed simply of paste and aggregates. However, if we compare the mechanical performance of any chosen composite of this type with those of its two individual constituents prepared under ostensibly equivalent conditions, we usually find that the maximum stress at rupture for the composite is less than that for either of its two component phases. This reduction in strength is generally attributed to the relative weakness of the paste/aggregate interface, which is difficult to avoid completely, as explained below.

Many microscopists have reported an apparent transition zone, often said to be of the order of 50 μm in thickness, around the aggregates in polished sections of hardened concretes and mortars. This zone appears to have a composition different to that of the

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