# LOW-DRYING-SHRINKAGE CONCRETE CONTAINING CARBON FIBERS AND ITS APPLICATIONS IN STRUCTURE REPAIR

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## INTRODUCTION

The most widely used method of concrete structure repair is the bonding of new concrete to the old concrete needing repair. The success of this method is limited by the insufficient bonding between the old and new concretes, in spite of the use of admixtures such as silica fume and latex in the new concrete. In this paper, by the addition of short carbon fibers to the new concrete, the bond strength between the old and new concretes was increased by up to 89% beyond the levels achieved by the use of the admixtures mentioned above. This effect of the fiber addition is attributed to the decrease in drying shrinkage [1,2] and the resulting decrease in stress between the new and old concretes.

## EXPERIMENTAL METHODS

The carbon fibers used were nominally 5 mm in length, unsized and made from isotropic pitch, as provided under the trade name Carboflex by Ashland Petroleum Co., Ashland, KY. The dispersion of the fibers requires additives, such as latex, methylcellulose and/or silica fume.

The cement used was Portland cement (Type I) from Lafarge Corp. (Southfield, MI). The sand/cement ratio was 1 for all specimens, except that it was 1.5 for the drying shrinkage test specimens. The mortars studied were (i) plain mortar, (ii) mortars with methylcellulose, (iii) mortars with methylcellulose and silica fume, (iv) mortars with latex, and (v) mortars with epoxy. In all cases (other than plain mortar), mortars with and without carbon fibers in the amount of 0.35 vol.% (corresponding to fibers in the amount of 0.5% by weight of cement) were compared.

The bond strength between new and old mortar was measured using a shear test configuration. Two mortar pieces labeled A (poured first) sandwiched a mortar piece labeled B (poured 28 days after pouring A) and the A-B joints were subjected to shear when B had been cured for 28 days.

The drying shrinkage was investigated by measuring the length change (ASTM C490-83a). The specimen size was 1 x 1 x 11.25 in. The accuracy in the length change measurement was ± 0.0001 in.

Compressive strength testing (ASTM C109-

80) was conducted on mortar specimens of size 2 x 2 x 2 in.

## RESULTS AND DISCUSSION

The fibers increased the shear bond strength by up to 89%. Their effectiveness was greatest when latex was used. When fibers were absent, the use of methylcellulose + silica fume gave the highest shear bond strength. When fibers were present, the use of latex gave the highest shear bond strength. However, the difference in bond strength between the case with methylcellulose + silica fume and the case with latex is small, whether the fibers were present or not.

The drying shrinkage was decreased by the fiber addition. Among the three dispersants used with the fibers, namely (i) methylcellulose, (ii) methylcellulose + silica fume, and (iii) latex, latex gave the largest drying shrinkage.

The fiber addition slightly decreased the compressive strength at 28 days. The use of methylcellulose + silica fume gave the highest compressive strength.

The fiber addition increased the bond strength and decreased the drying shrinkage. The use of latex + fibers gave the highest bond strength, but it gave the largest drying shrinkage, compared to the case of methylcellulose + fibers and the case of methylcellulose + silica fume + fibers. This means that the quality of the concrete-concrete interface is not only governed by the drying shrinkage, but also by the adhesion ability of the concrete. Latex appears to help the adhesion ability, so that the use of latex + fibers resulted in the highest bond strength, even though it did not result in the lowest drying shrinkage. In other words, both a low drying shrinkage and a high adhesion ability contribute to providing a high bond strength.

## CONCLUSION

The addition of short carbon fibers (0.35 vol.%) resulted in mortars that could bond more strongly to old mortars. The increase in shear bond strength was up to 89%. The fibers were particularly effective when they were used with latex. The use of methylcellulose + silica fume + fibers gave slightly less bond strength than the use of latex + fibers, but gave higher compressive strength and was less expensive (due to the small amount of methylcellulose and the large amount of latex used). The increased bond strength provided by the fiber addition is attributed to the lowering of the drying shrinkage. Both a low drying shrinkage and good adhesion ability contribute to achieving a high quality mortar-mortar interface, thus making the use of latex + fibers give the highest bond strength.

## REFERENCES

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