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EFFECT OF METHYLCELLULOSE ADMIXTURE ON THE MECHANICAL PROPERTIES OF CEMENT

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ABSTRACT

Methylcellulose addition (0.2-0.8% by weight of cement) to cement paste was found to increase the tensile strength by up to 72%, increase the tensile ductility by up to 620%, decrease the tensile modulus by up to 57%, decrease the compressive strength by up to 30%, decrease the compressive ductility by up to 34%, increase the compressive modulus by up to 17%, and decrease the apparent coefficient of thermal expansion (390 Pa, 30-35°) from 10×10^{-6} down to -4×10^{-6} °C^{-1}. All effects increased with increasing methylcellulose content.

Introduction

As an admixture to cement, methylcellulose serves to increase the bond strength between cement and steel [1] and, in the case of cement with carbon fibers, it also serves to help disperse the fibers in the mix [2]. On the other hand, the addition of methylcellulose to cement decreases the thermal stability and the apparent coefficient of thermal expansion [3]. The effect of methylcellulose on the tensile and compressive properties is the subject of this paper, since these properties are critical to the practical use of cement with methylcellulose and little work had been previously reported [3,5].

Experimental Methods

Cement paste made from Portland cement (Type I) from Lafarge Corp. (Southfield, MI) was used. Methylcellulose (Dow Chemical, Midland, MI, Methocel A15-LV) was used in the amount of 0 (i.e., none), 0.2, 0.4, 0.6 and 0.8% by weight of cement. A defoamer (Colloids, Inc., Marietta, GA, 1010) in the amount of 0.065 vol.% for every 0.2% (by weight of cement) of methylcellulose was used. In other words, the defoamer amounted to 0, 0.065, 0.130, 0.195 and 0.260 vol.% when methylcellulose was at 0, 0.2, 0.4, 0.6 and 0.8%, respectively, by weight of cement. A water reducing agent (TAMOL SN, Rohm and Haas Co., Philadelphia, PA, 93-96% sodium salt of a condensed naphthalenesulfonic acid) was used in the amount of 1% by weight of cement. The water-cement ratio was 0.32. No aggregate (whether fine or coarse) was used. The slump was 150 mm.

A Hobart mixer with a flat beater was used for mixing. Methylcellulose was dissolved in water and then the defoamer was added and stirred by hand for about 2 min. Then this mixture, cement, water and the water reducing agent were mixed in the Hobart mixer for 5 min. After pouring the mix into oild molds, a vibrator was used to decrease the amount of air bubbles. The specimens were demolded after 1 day and then allowed to cure at room temperature in air for 28 days.

Compressive testing according to ASTM C109-80 was conducted on specimens of size 2 × 2 × 2 in (5.1 × 5.1 × 5.1 cm), using a hydraulic Materials Testing System (MTS) with a crosshead speed of 1.27 mm/min. Dog-bone shaped specimens of the dimensions shown in Fig. 1 were used for tensile testing. They were prepared by using molds of the same shape and size. Tensile testing was performed using a screw type mechanical testing system (Sintech 2/D). The displacement rate was 1.27 mm/min. During compressive or tensile loading up to fracture, the strain was measured by the cross-head displacement in compressive testing or by a strain gage in tensile testing. Six specimens of each composition were tested for each type of test.

The change in thickness of a disc-shaped specimen (0.5 in or 1.3 cm in diameter, about 2 mm in thickness) was measured as the temperature was increased from room temperature to 120° at a heating rate of 5°/min. For this purpose, a Perkin-Elmer TMA7 thermal mechanical analyzer was used. The probe force was 50 mN, which corresponds to 390 Pa acting on the top face of the specimen. The sample chamber was purged with helium at a flow of 30 cc/min. The method is the same as that of Ref. 3. Six specimens of each composition were tested.

Results

Table 1 shows the tensile and compressive test results of cement pastes with various amounts of methylcellulose. The tensile strength and ductility increased with increasing methylcellulose content, while the tensile modulus decreased with increasing methylcellulose content. The compressive strength and ductility decreased with increasing methylcellulose content, while the compressive modulus increased with increasing methylcellulose content. The effects on the tensile strength and ductility are due to the inherently low values of these quantities for cement paste without methylcellulose and probably the decrease of void content by the methylcellulose addition. The effects on the compressive strength and ductility are due to the inherently high values of these quantities for cement paste without methylcellulose and probably the decrease in the degree of continuity of the cement phase by the presence of methylcellulose. The decrease of the tensile modulus by the methylcellulose addition is due to the inherently high value of this quantity for cement paste without methylcellulose and probably the relatively low

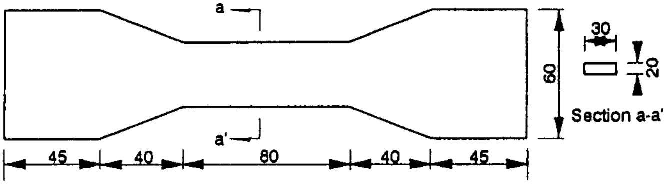

FIG. 1.
Shape and dimensions (in mm) of the specimens tested under tension.

TABLE 1
Effect of Methylcellulose on the Mechanical Properties of Cement Paste. Standard Deviations are Shown in Parentheses

	Methylcellulose-cement ratio				
	0	0.2%	0.4%	0.6%	0.8%
Tensile					
strength (MPa)	0.89(±3.1%)	0.98(±2.9%)	1.38(±3.2%)	1.42(±2.3%)	1.53(±2.4%)
modulus (GPa)	11.13(±2.9%)	8.68(±2.4%)	6.89(±1.9%)	5.95(±2.5%)	4.74(±2.3%)
ductility (%)*	0.0052(±0.9%)	0.0124(±1.3%)	0.0213(±0.8%)	0.0254(±1.1%)	0.0375(±1.2%)
Compressive					
strength (MPa)	58.82(±4.2%)	49.63(±3.3%)	46.93(±2.5%)	43.42(±3.5%)	41.25(±2.1%)
modulus (GPa)	2.87(±1.4%)	2.94(±3.1%)	3.08(±2.1%)	3.16(±2.5%)	3.37(±2.8%)
ductility (%)*	1.75(±1.2%)	1.53(±0.6%)	1.40(±0.8%)	1.28(±1.1%)	1.16(±0.7%)

*Strain at failure.

tensile modulus of the methylcellulose-cement microconstituent. The increase of the compressive modulus by the methylcellulose addition is due to the inherently low value of this quantity for cement paste without methylcellulose and probably the relatively high compressive modulus of the methylcellulose-cement microconstituent.

Table 2 lists the apparent coefficient of thermal expansion (CTE) for the various cement pastes at 30-35°, as obtained from the slopes of the curves of fractional expansion vs. temperature, like Fig. 2 of Ref. 3. The CTE decreased with increasing methylcellulose content due to the decrease of the mechanical weakening onset temperature (defined as the temperature at which the strain starts to decrease with increasing temperature while the specimen is under a constant compressive stress of 390 Pa [3]) with increasing methylcellulose content.

Discussion

Methylcellulose addition improves the tensile properties, but degrades the compressive properties and the thermal stability. The larger is the methylcellulose content, the greater is each effect. However, the effects on the tensile properties are much larger than those on the compressive properties. Therefore, the overall effect on the mechanical properties is positive. The largest gains in tensile strength and ductility occur at ≤ 0.4% methylcellulose (by weight

TABLE 2
Apparent CTE of Cement Pastes with Various Amounts of Methylcellulose. The Standard Deviations are Shown in Parentheses

Methylcellulose-cement ratio	CTE (10^{-6} °C^{-1})
0	10.23 (±1.2%)
0.2%	-0.83 (±1.5%)
0.4%	-1.56 (±0.7%)
0.6%	-2.58 (±2.1%)
0.8%	-3.83 (±0.9%)

of cement). Therefore, a methylcellulose content of 0.4% by weight of cement is recommended for practical application. This methylcellulose content of 0.4% is the same as the amount used in concrete for dispersing carbon fibers [4].

Latex is another polymer admixture. It is actually more commonly used than methylcellulose. However, latex is typically used in amounts of 10-20% by weight of cement [6]. Latex addition (20% by weight of cement) decreases the compressive strength and apparent CTE of cement paste at 7 days of curing even more than methylcellulose addition (0.4% by weight of cement) [3], at least partly due to the large latex content. Latex addition (20% by weight of cement) also increases the tensile strength and ductility of cement paste at 7 days of curing even more than methylcellulose addition (0.4% by weight of cement [5]. Hence, the effects of latex addition are in the same direction as those of methylcellulose addition. On the other hand, methylcellulose addition is less expensive than latex addition due to the small proportion of methylcellulose.

Conclusion

Methylcellulose addition (0.2-0.8% by weight of cement) to cement paste increases the tensile strength and ductility, but decrease the compressive strength and ductility. Moreover, it decreases the tensile modulus, but increases the compressive modulus. The effects on the tensile properties are larger than those on the compressive properties. The apparent CTE at 30-35° and a compressive stress of 390 Pa is decreased by the methylcellulose addition, becoming more negative as the methylcellulose content increases. All mechanical and thermal effects increase monotonically with increasing methylcellulose content.

References

1. Xuli Fu and D.D.L. Chung, Cem. Concr. Res., in press.
2. Yoshihiko Ohama, Carbon 27(5), 729 (1989).
3. Pu-Woei Chen and D.D.L. Chung, Cem. Concr. Res. 25(3), 465 (1995).
4. Pu-Woei Chen and D.D.L. Chung, Composites 24(1), 33 (1993).
5. Pu-Woei Chen, Ph.D. dissertation, State University of New York at Buffalo, 1994.
6. Xiaoming Yang and D.D.L. Chung, Composites 23(6), 453 (1992).