SUBMICRON CARBON FILAMENT CEMENT-MATRIX COMPOSITES

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Introduction

As the environment is increasingly sensitive to electronic pollution, the ability of a building to shield electromagnetic radiation is of increasing importance. As cement itself lacks the ability to shield electromagnetic radiation, admixtures are needed in order to attain the ability to shield. Earlier work [1] has shown that the addition of short carbon fibers (10 μm diameter) is effective for enhancing shielding. Due to the skin effect, electromagnetic radiation at high frequencies interacts only with the region of a conductor (such as a carbon fiber) near its surface. As a result, the shielding effectiveness is expected to increase with decreasing fiber diameter, when the fiber volume fraction is fixed.

Conventional carbon fibers are typically of diameter around 10 μm. Carbon filaments made catalytically from carbonaceous gases (such as methane) are typically 0.1 μm in diameter. Though conventional carbon fibers are straight, carbon filaments are bent and intertwined, resembling cotton wool. In spite of considerable previous work on the use of conventional carbon fibers in concrete [2,3], no previous work has been reported on the use of carbon filaments in concrete. This paper shows that the use of the carbon filaments is much more effective than the use of conventional carbon fibers in enhancing the electromagnetic shielding effectiveness, but is less effective as a reinforcement.

Experimental Methods

Cement paste (without aggregate) made from Portland cement (Type I) from Lafarge Corp. (Southfield, MI) was used. The admixtures included (i) latex, a styrene butadiene polymer (Dow Chemical Co., Midland, MI 460NA), such that the latex (20% by weight of cement) was used along with an antifoam (Dow Corning Corp., Midland, MI, #2210, 0.5% by weight of latex), (ii) methylcellulose (Dow Chemical Corp., A15-LV, 0.4% by weight of cement), which was used along with a defoamer (Colloids Inc., Marietta, GA, Colloids 1010, 0.13 vol.%), (iii) silica fume (Elkem Materials Inc., Pittsburgh, PA, 15% by weight of cement), (iv) carbon filaments, which were of diameter 0.1 μm and length > 100 μm, as obtained from Applied Sciences Inc. (Cedarville, Ohio), and (v) carbon fibers, which were of diameter 10 μm and length 5 mm, as obtained from Ashland Petroleum Co. (Ashland, Kentucky). The filaments or fibers were used in the amount of 0.5% by weight of cement (i.e., 0.51 vol.%). The water reducing agent was a sodium salt of a condensed naphthalenesulfonic acid (TAMOL SN, Rohm and Haas Company, Philadelphia, PA).

A Hobart mixer with a flat beater was used. After pouring the mix into oiled molds, an external 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 (relative humidity = 30%) for 28 days. All testing was performed at 28 days.

The shielding effectiveness was measured in terms of the attenuation using the coaxial cable method. The set-up consisted of an Elgal SET 19A shielding effectiveness tester with its input and output connected to a Hewlett-Packard (HP) 8510A network analyzer. An HP APC-7 calibration kit was used to calibrate the system. The frequency was scanned from 1 to 2 GHz such that 21 data points were taken within this frequency range. The sample placed in the center plane of the tester (with the input and output of the

Table 1 Shielding effectiveness and electrical resistivity of cement pastes without and with carbon filaments.

Cement paste	Water/ cement ratio	Shielding effectivenes			
		Attenuation (dB)		Thickness (mm) (± 0.2 mm)	Resistivity (Ω.cm)
		1.0 GHz	1.5 GHz		
Plain	0.45	0.4(±3.1%)	0.5(±2.5%)	3.6	1.62×10^5
+ F	0.40	26.4(±1.8%)	25.8(±2.2%)	4.0	1.93×10^4
+ M + F*	0.32	27.5(±3.3%)	27.1(±2.7%)	3.8	2.75×10^4
+M + SF + F*	0.35	29.7(±3.2%)	28.8(±2.8%)	3.9	1.34×10^4
+ L + F	0.23	30.2(±1.9%)	28.7(±3.1%)	4.1	8.14×10^4

*With water reducing agent, 1% by weight of cement.
Note: F = filaments, M = methylcellulose, SF = silica fume, L = latex.

tester on the two sides of the sample) was in the form of an annular ring of outer diameter 97 mm and inner diameter 32 mm. The sample thickness ranged from 3.6 to 4.1 mm. Six specimens of each type were tested.

Results

Table 1 shows the shielding effectiveness at 1.0 and 1.5 GHz for plain cement pastes and four types of pastes with carbon filaments. The filaments greatly increased the shielding effectiveness, whatever other ingredients were present. Comparison with corresponding data for cement pastes with carbon fibers [1] shows that the filaments are much more effective than the fibers for shielding. For example, at similar volume fractions, fibers gave 10 dB at 1.5 GHz, whereas filaments gave 26 dB at 1.5 GHz.

Table 1 also shows the electrical volume resistivity for each type of paste. The filaments decreased the resistivity, whatever other ingredients were present. Among the four types of pastes with filaments, the one containing latex gave the highest resistivity while the one containing methylcellulose + silica fume gave the lowest resistivity, because methylcellulose + silica fume is most effective for dispersing the filaments while latex is least effective, as previously shown for the case of carbon fibers [11].

The cement pastes with filaments exhibited lower strength, modulus and ductility (both tensile and compressive) than the counterparts with fibers. Nevertheless, the filaments were still an effective reinforcement, as shown by comparison with plain cement paste. Due to the impossibility of single filament tensile testing, the mechanical properties of the filaments are not known, though those of the fibers are known. The inferior mechanical properties of the cement pastes with filaments compared to those with fibers is probably due to the difference in the mechanical properties and morphology between filaments and fibers.

Conclusion

Carbon filaments of diameter 0.1 μm were much more effective than carbon fibers of diameter 10 μm in electromagnetic interference shielding, but were less effective as a reinforcement.

References

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