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USE OF POST-CONSUMER WASTE PLASTICS IN CEMENT-BASED COMPOSITES

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ABSTRACT

This paper describes an innovative use of post-consumer waste HDPE plastic in concrete as a soft filler. A reference concrete was proportioned to have the 28-day compressive strength of 5000 psi (35MPa). A high-density plastic was shredded into small particles for use in the concrete. These particles were subjected to three chemical treatments (water, bleach, bleach + NaOH) to improve their bonding with the cementitious matrix. The plastic particles were added to the concrete in the range of 0 - 5% of total mixture by weight. Compressive strengths were measured for each test mixture. The results showed that chemical treatment has a significant effect on performance of the plastic filler in concrete. Of the three treatments used on the plastic, the best performance was observed with the alkaline bleach treatment (bleach + NaOH) with respect to compressive strength of concrete. *Copyright © 1996 Elsevier Science Ltd*

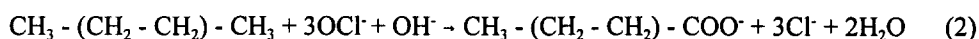
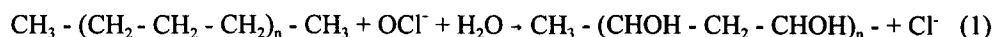
Introduction

Inclusion of plastic particles/fibers in concrete should improve its fracture resistance, but it could have a negative impact on compressive strength and creep behavior. There is an urgent need to develop the technology to employ substantial amounts of discarded plastics in portland cement concrete without compromising its performance for particular applications. The present study was mainly oriented toward establishing a technique for use of high-density polyethylene (HDPE) plastic as a flexible particulate filler (reinforcement) in concrete.

Theoretical Considerations

In general, plastics do not achieve chemical bonds with cementitious materials. Therefore, chemical treatments of plastics are needed to enhance bonding characteristics with the cementitious matrix for developing plastic containing cement-based materials with improved properties. It was anticipated that reaction of plastics with oxidizing chemicals would produce

reactive chemical species on the surface of polymers which could participate in cementitious reactions. Such a reaction will produce concrete like product, but at an improved ductility due to the presence of polymeric substances. For example, treatment of high-density polyethylene (HDPE) with hypochlorite could be expected to lead to reactions such as:



The R-OH and R-COOH species are much more reactive with cementitious materials than the polymeric hydrocarbons, i.e. $\text{HC} - (\text{CH}_2 - \text{CH}_2 - \text{CH}_2)_n$. This research was carried out to validate the above concepts concerning addition of plastics, and the effect of chemical treatment of the plastic surface on resulting concrete performance.

Experimental Program

An experimental investigation was planned to determine the effects of inclusion of post-consumer plastics in concrete as a filler. A HDPE plastic was shredded to small particles for use in manufacture of plastic containing concrete.

The materials used were an ASTM Type-I portland cement, plastic (HDPE), water, 6 mm natural sand, and 19 mm coarse aggregate. The shredded HDPE plastic particles were obtained

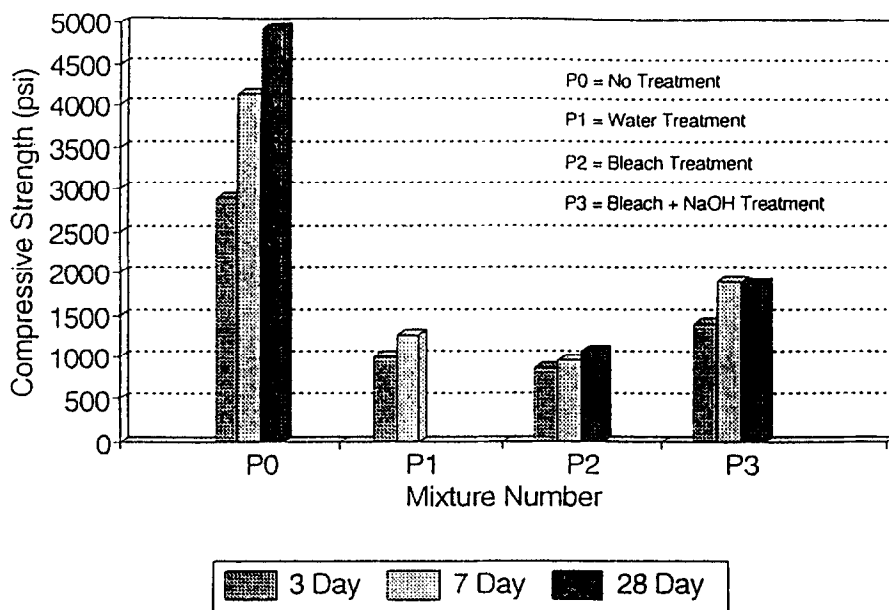


FIG. 1.
Effect of treatment on compressive strength of concrete.

from a local recycling company. The plastic was shredded into irregular shaped flat particles of varying sizes. An average thickness of plastic particles was about 1 mm. The particle size analysis revealed that the shredded particles were outside the ASTM C 33 limits for fine aggregates. Therefore, the material passing through 3/8 in. sieve and retained on #4 sieve was used in this investigation.

A reference concrete without plastic was proportioned to obtain the 28-day compressive strength of 5000 psi (35 MPa). The reference mixture was composed of 603 lb cement, 286 lb of water, 1433 lb sand, and 1788 lb aggregate per yd^3 of concrete. Other mixtures with plastics were also proportioned. The plastics were added to the reference mixture in various amounts ranging between 0.5 and 5% of total weight of the mixture. The plastic samples were treated by soaking them in water, bleach (5% HOCl), and bleach plus NaOH (5% HOCl and 4% NaOH). Some plastic samples were subjected to water pretreatment in order to separate impurities (nonplastic particles) from plastic particles. This treatment also caused dissolution of detergent and surfactant from polymer surfaces.

Results and Discussion

Compressive Strength. As could be anticipated the effect of soft plastic as "aggregates" on all concrete mixtures containing 4.5% post consumer plastics (Mix P1, P2, and P3) showed lower compressive strength than the reference mixture without plastic (Fig. 1). This was attributed to lower compressive strength of the plastic particles compared to cementitious matrix as well as natural fine and coarse aggregates. Among the various treated samples (Mix P1, P2, and P3)

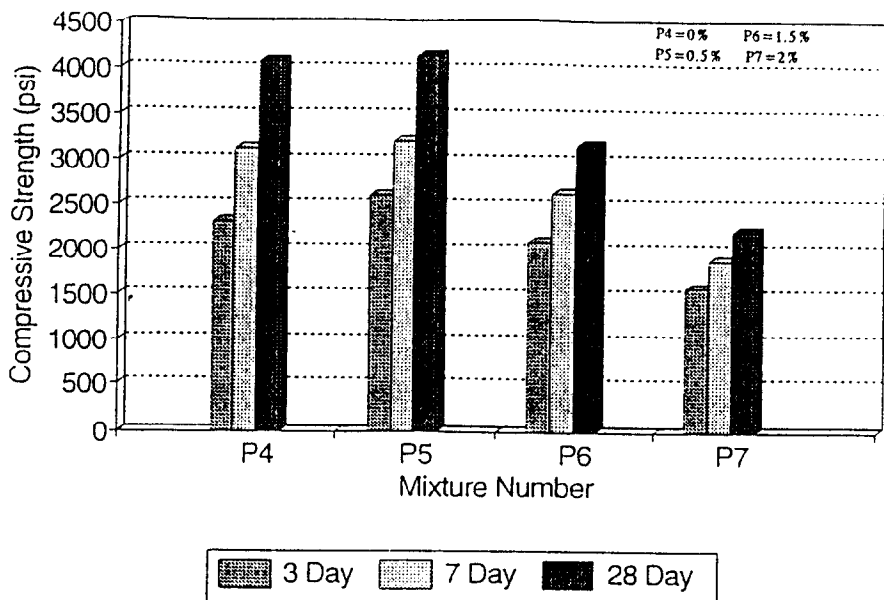
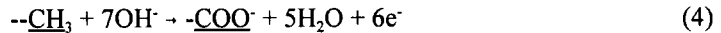
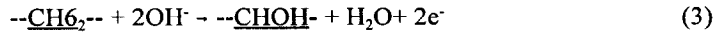


FIG. 2.
Effect of HDPE quantity on compressive strength of concrete.

the sample treated with bleach oxidant plus NaOH gave the best results (Fig. 1). The sample soaked in water showed better results than the sample treated with bleach alone.

The improved performance of plastic treated with alkaline bleach was probably due to increased coverage of the polymer surface with $-O^-$ and $-COO^-$ sites produced by the alkaline oxidizing conditions, as follows, with surface species underlined:



Equations (3) and (4) illustrate the fact that the oxidation potential for such heterogeneous reactions are enhanced by high pH on the solution side of the interface.

The effect of amount of the plastic particles are shown in Fig. 2 Mix P1. At the 0.5% plastic level (Mix P5), compressive strength of the concrete was either comparable or superior to that of the reference mixture without plastic (Mix P4). However, beyond 0.5% plastic addition, compressive strength of concrete decreased significantly.

Conclusion

1. In general, effect of chemical treatment of the plastic particles produced significant influence on compressive strengths of concrete at a plastic concentration 4.5 percent.
2. Of the three treatments used (water, bleach, and alkaline bleach) used, the highest compressive strength was achieved when the plastic was treated with alkaline bleach, and the lowest when treated with bleach alone.
3. As expected, compressive strength decreased with increase in the amount of the plastic in concrete, particularly above 0.5% plastic addition. Therefore, in order to maintain a particular compressive strength level, plastic concentration in concrete must be controlled. However, the amount of plastic addition can be increased substantially if particles are further processed to improve the bond area and stress transfer capacity of the particles.

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