4th International Conference on Composites Engineering. July 6-12, 1997, Big Island of Hawaii. ICCE/4. Edited by David Hui. International Community for Composites Engineering and College of Engineering, University of New Orleans. 1997.

Effects of Civil Engineering Environments on Interfacial Properties of Polymer/Glass Fiber Composites

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Introduction

There is an increasing interest in the use of fiber-reinforced polymeric composites in building and construction. However, little information is available on the effects of civil engineering environments on the interfacial properties of these materials. This paper presents results on the effects of water, artificial seawater, and simulated concrete pore solution at 60 °C on the interfacial laminar shear strengths of glass fiber/polymer composites made with three different polymeric matrices.

Experimental Procedures

An epoxy (Tg=75 °C), a vinyl ester (Tg=111 °C), and an isophthalic polyester (Tg=118 °C) were used as the matrices and a commercial, unidirectional E-glass tape was selected for the fiber. Unidirectional composites were prepared using a modified reaction injection molding process. The fiber volume fraction was controlled by the number of tape layers and the thickness of the spacers. The fiber was uniformly distributed and little evidence of voids in the fabricated composites was observed by scanning electron microscopy. The fiber volume fraction of all composite sheets was between 60 and 64 %, as measured by scanning electron microscopy/image analysis. After curing, conditioning, and surface sanding, specimens of 2.5 mm x 5.5 mm x 18 mm were prepared. Specimens were immersed in distilled water, artificial seawater (salt solution, 0.58 mol/L NaCl in water), and simulated concrete pore solution (consisting of 0.23 mol/L KOH, 0.14 mol/L NaOH, and 0.2 x 10^{-2} mol/L $Ca(OH)_2$ in water, pH = 12.5) at 60 °C. Interlaminar shear strength (ILSS) was measured before and after specified immersion times in the solutions up to 700 h using the three-point short beam test (ASTM D2344). The reported results are the average of five specimens; the coefficients of variance were less than 5 % in all cases.

Results

Interlaminar shear strengths of all glass fiber/matrix composites decreased substantially, but reached a stable minimum, with exposure time in all three solutions at 60 °C (Figure 1). The rate and the time for reaching the minimum were a function of both the matrix and the test solution. Among the solutions, simulated concrete pore liquid had the greatest effect. For example, the vinyl ester composite lost 60 % of its ILSS in concrete pore solution after 350 h as compared to 10 % in water or artificial seawater. Little difference was observed between water and artificial seawater. Among the matrices, the ILSSs of vinyl ester composite were less affected than those of epoxy and polyester (Figure 2). For example, the vinyl ester composite lost 25 % of its ILSS after 500 h in artificial sea water as compared to 70 % for the epoxy or polyester material for the same duration in the same solution. Further, the ILSSs of both epoxy and polyester composites decreased sharply in the first 100 h of exposure to each of the three solutions and leveled off thereafter. On the other hand, the ILSS loss of vinyl ester composites was nearly linear with exposure time.

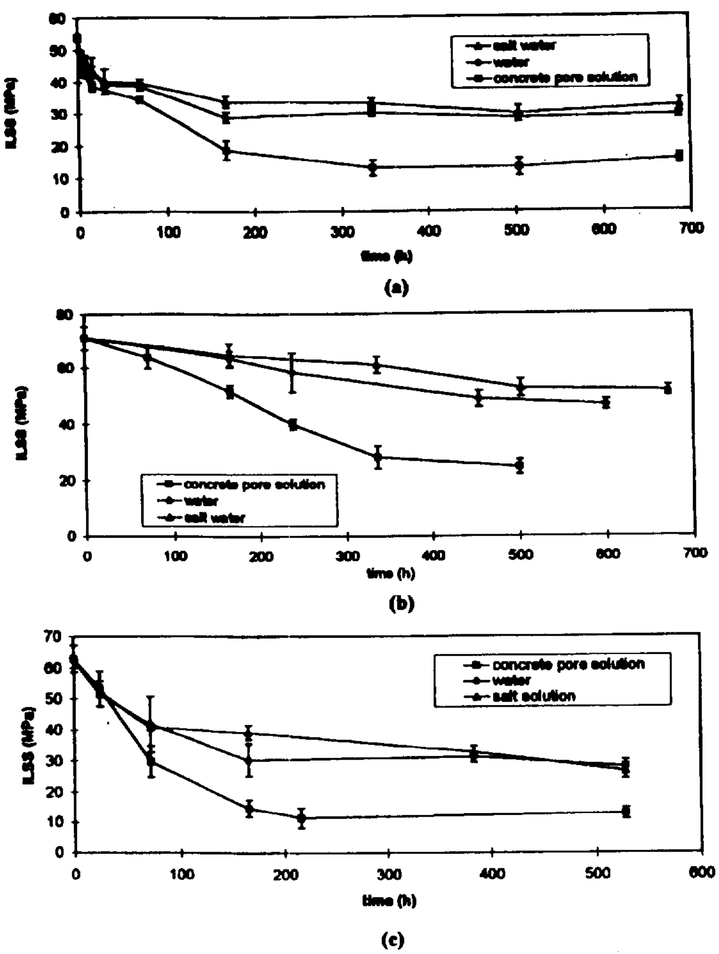

Figure 1. ILSS vs. time in solutions: a) epoxy/glass, b) vinyl ester/glass, and c) polyester/glass.

Conclusions

Civil engineering solutions: water, artificial sea water, and concrete pore solution had a marked effect on the interlaminar shear strengths of glass fiber/polymer composites. Among the solutions, concrete pore solution had the most effect, and among the matrices, vinyl ester was least affected.

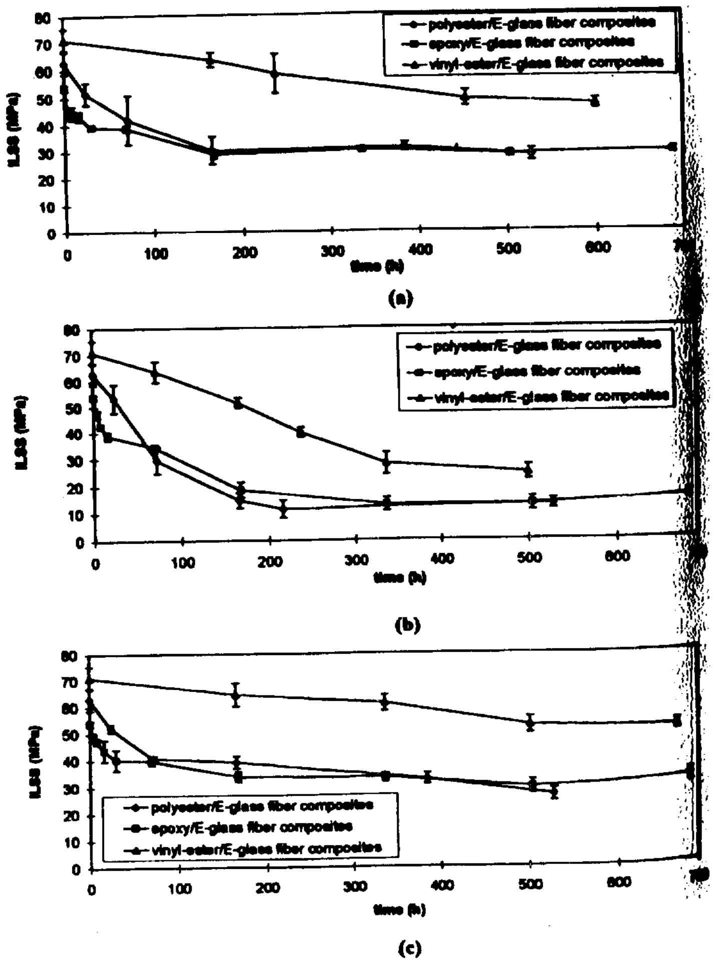

Figure 2. ILSS vs. time in solutions for glass composites made with different matrices: a) distilled water, b) concrete pore solution, and, c) salt solution.