Damage Process of CFRP Composites-Concrete Interface Under Fatigue Loading at Low Temperatures

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Abstract

This paper presents the experimental and theoretical studies on the feasibility of using CFRP laminates for strengthening damaged reinforced concrete beams in cold environment. Experimental work includes investigation on fatigue strength, ultimate capacity and failure modes of repaired reinforced concrete beams in cold environment and room temperature. The study also includes investigation of thermal response of repaired plain concrete beams with CFRP laminates subjected to thermal cycles.

Repaired reinforced concrete beams with CFRP laminates bonded with Sikadur 30 and Hysol 9330 adhesives were subjected to fatigue loading up to 1 million cycles in a cold environment (-20° C). The crack propagation was faster in beams tested in room temperature than those at cold temperatures. Analytical studies on the distributed shear forces and peeling forces of repaired reinforced concrete beams were carried out to analyze the interaction between the laminate and the concrete interface. The temperature distribution and strains developed by the temperature differential are determined and the analytical results compared with the measured values.

KEY WORDS: Retrofitting CFRP laminates, thermal cycling, fatigue, low temperatures

Introduction

The deterioration of the infrastructure systems represents a serious problem facing the nation as it moves towards the 21st century. The United States has an estimated "as built" investment of $6 trillion in civil infrastructure systems of which a major part was constructed of reinforced concrete whose expected service life is at least 50 years. Bridges represent a major proportion of engineering structures.

Several rehabilitative methods have been developed to increase the load carrying capacity of existing structures. These methods include external post-tensioning, epoxy bonding of steel plates to the tension flange, and epoxy bonding of fiber reinforced plastic (FRP) composite laminates to the tension flange.

The use of corrosion resistant advanced high strength composites would provide an excellent alternative to conventional materials used for repair and replacement of concrete bridges (Ehsani and Saadatmanesh 1994). The fiber reinforced plastic (FRP) laminates have very high strength and rigidity in the fiber direction and outstanding fatigue characteristics. Other advantages include their cost effectiveness in field application due to low weight and easy application to structural members.

Temperature affects the way composites react under loading. The change in temperature affects the strength, modulus, toughness, failure modes, and the damage tolerance. Extensive testing has been reported on the effects of temperature on fracture behavior. At failure of composites, fracture energies are absorbed by matrix cracking, fiber breaking, fiber-matrix debonding, and frictional work following debonding and fiber pullout. Changes in temperature have an adverse effect on all the above failure processes. Further problems arise with the incorporation of the freeze-thaw cycles. The absorption of water into the material can cause additional damage through structural modifications on a microscopic level. A few parameters that are affected include the fiber/matrix interfacial properties, volume ratios, and fiber orientation.

Development of significant internal stresses was observed in the commercially available FRP under thermal cycling as a result of residual stresses from curing. The ultimate tensile strength of polymer resins is expected to be about 10,000 to 12,000 psi; and it has been shown that the excursion to -60° C could easily push the matrix to its tensile limit, producing microscopic cracks (Dutta 1995).

The behavior of concrete is greatly affected by the type of loading. For instance, failure caused by fatigue loading is due to repeated application of loads that are not large enough to cause failure in a single application. This implies that under repeated stresses, an internal permanent structural change takes place which may be referred to as