PERFORMANCE OF EPOXY ADHESIVE BOND BETWEEN CFRP AND CONCRETE

S.R. Adhikarinayake [1*], K.D.J.A. Gayan[1], N.G.T.T. Thathsarani[1], J.C.P.H.Gamage[1]

[1*]Corresponding Author, Department of Civil Engineering, University of Moratuwa, Sri Lanka, E-mail: sandunika.adhi@gmail.com

[1] Department of Civil Engineering, University of Moratuwa, Sri Lanka.

ABSTRACT

Carbon Fibre Reinforced Polymer (CFRP) strengthening is widely gaining appeal in strengthening and rehabilitation of structures. The most common adhesive used in the industry to create the bond between CFRP and concrete is two part epoxy resin. The system shows very good short term performance with this resin. However, epoxy adhesive used in Civil Engineering constructions is very sensitive to the temperature. This paper presents a review of bonding techniques, limitations of using epoxy adhesive and finding alternative bonding agent to replace epoxy adhesive.

Key words: Carbon Fibre Reinforced Polymer, Epoxy bonding, glass transition temperature, elevated temperatures

1. INTRODUCTION

Carbon Fibre Reinforced Polymer (CFRP) is one of the increasingly notable materials used in structural engineering applications in modern world. It has proved itself cost effectiveness and capability of strengthen an existing structure or as an alternative reinforcing (or pre-stressing material) instead of steel from the outset of a project. Retrofitting is popular in many instances as the cost of replacing the deficient structure can greatly exceed its strengthening using CFRP. But the behaviour of bond between concrete and CFRP membrane mainly depend on the epoxy adhesive which is used as the bonding agent as it is undergoes a rapid strength loss in temperatures.

1. CARBON FIBRE REINFORCED POLYMER AND ITS USES

Carbon Fibre Reinforced Polymer (CFRP) is a layer of carbn fibre embedded in a polymer which is often epoxy. A CFRP system consists of the carbon fibre fabric or porcured CFRP are low self weight, high strength, corrosion resistancem low thermal expansion and ease of application. CFRP have been successfully used both internally as an alternative to steel reinforcement, and externally as a prpairing agent. Typical properties of CFRP are shown in tabel 1.

Table 1: Typical CFRP Properties (dry fibre)

	E-modulus (GPa)	Ultimate Strain (%)	UTS (MPa)
CFRP (laminate)	1565-215	1.3-1.4	2500-3000
CFRP (sheet)	240-640	0.4-1.6	2650-3800

CFRP has been used in main structural engineering applications to improve flexure and shear strength and also confinement of concrete. Mainly it is used to increase the load bearing capacity of old structures that were designed to tolerate lower service loads than they are experiencing today and to repairing damaged structures. CFRP applied to enhance shear strength of reinforced concrete by wrapping fabrics around the section. This also enhances the ductility of the section.

2. BONDING OF CFRP CONCRETE COMPOSITES

Different methods are available to bond CFRP sheet or plate to the concrete substrate. A great attention should be given to the bond because it is the mean for transferring stresses between the concrete and CFRP in order to develop composite action. In many situations epoxy is used as the bonding agent. Epoxy provides very good bond to concrete and is durable material.

A research has been performed on bonding techniques of CFRP in strengthening concrete structures (Jumaat et al, 2011) and it sates that two general methods are used for strengthening with CFRP such as externally bonded system and the near-surface mounted (NSM) system. In both these systems, epoxy adhesive is used as the bonding agent. The externally bonded system has been more popular due to its simple installation procedure.

Jumaat and Rahman (2011) states that various anchor system such as bolts, mechanical anchors, or U-shaped sheets have been investigated as end anchors for the epoxy bonded system. In research done by Miller (1999) tp an address the factors affect on the bond between CFRP sheets and concrete, series of specimens were tested and found that the bonded length did not affect on the bond strength. They showed that the failure was occurred in the concrete-adhesive interface. In addition to that further research (Yuan et al 2004, Pham and Mahaidhi 20002) shows that the ultimate load of bonded joints increases with the bond length before the effective bond length is reached and remains constant afterwards. All these investigations were based on short term performance of the system. Design guidelines have also been developed and documented for short term strength designing (ACI 440, fib TG). However, there is lack of data available for fire and service performance of the composite.

3. LIMITATION OF USING EPOXY ADHESIVE IN CFRP CONCRETE COMPOSITES

The greatest impediment to use of Carbon Fibre Reinforced Polymer (CFRP) composites in buildings and bridges are their susceptibility to degradation when exposed to elevated temperatures even for environmental temperature fluctuations in some part of the world. At elevated temperature, all polymer resins which are used as the bonding material will soften and eventually ignite; causing the resin matrix to weaken. Therefore, a raising potential concerns regarding the structural integrity of CFRP strengthened concrete structures during fire in the applications of buildings.

The fire behaviour of CFRP concrete composites depends predominantly on the behaviour of the polymer resin matrix/ adhesive. Polymer resins soften at their glass transition temperature, T_g thus limiting the transfer of stress between the fibres. Carbon fibres tend to oxidize at temperatures above 300 to 400^0C and melt at temperature is around 4000^0C. Therefore CFRP membranes consist of high thermal capacity especially polymers that contain carbon fibres (Chowdhury, Green, Bisby, Bênichou,Dodur, 2007). This shows very good thermal performance of CFRP material. However, the composite action depends not only of CFRP laminate but also on the bonding agent. The exposure to elevated temperatures will lead to rapid and severe deterioration of the CFRP/concrete bond, resulting in delamination of the CFRP sheet and loss of its effectiveness. At elevated temperatures, the most critical component of the CFRP-concrete composites is the epoxy adhesive, and the bond properties mainly depend on the adhesive temperatures is debonding failure between the externally glued laminate and the concrete substrate. By a research on bond behaviour of CFRP strengthened concrete members under exposure to elevated temperatures done by Gamage et al (2005) has noticed a rapid strength loss in epoxy bond when it exposes to temperatures above 60^0C due to reaching the glass transition temperature of polymer resin.. Peeling off of CFRP sheet was the observed failure pattern at elevated temperatures and that proves the requirement of exploring advance techniques to improve thermal properties of epoxy resins as bonding material and also requirement of alternative with better performance to replace the epoxy adhesive bond.

Fractional changes can be observed in resistance for the carbon fibre epoxy-matrix composite (without a substrate) during thermal cycling in which the temperature rang was from 10^0C to 40^0C, the resistance decreased slightly. This is probably due to post-curing occurring at 40^0C. the post-curing caused the fibre to be closer to one another, thereby causing the resistance to decrease (Gamage et al, 2009).

4. ALTERNATIVE FOR EPOXY ADHESIVE

Limited research has been carried out to explore alternative bonding systems for CFRP/concrete composites. According to Siavash and Al-Mahaidhi (2009 concluded requirements for the matrix material as follows:

- Sufficient mechanical properties for load transfer
- Correct consistency, good penetration of the fabrics, and good bond characteristics for embedded fabrics
- Thermal and chemical compatibility of the fibres and the substrate and thermal and fire resistance
- Workability on site
- The demand of environment acceptability

Their experimental study was focused on investigation for flexural behaviour of CFRP strengthened beams using different type of mortars as bonding agent and three different mixes have been used including silica fume, latex modified adhesive containing SBR latex and Micro-cement. From this research it was found that higher level of load carrying capacity can be achieved by OC mortar without any substantial additives compared to latex modified mortar. The best flexural performance was obtained from the micro-cement added mortar. In addition, Author concludes that it is not economical to add SBR latex to the mix. The current undergraduate research study in Moratuwa University, Authors exploring new techniques and materials to overcome these barriers in the CFRP/concrete system.

5. CONCLUTIONS

This paper reviews the research works based on performance of different bonding techniques and adhesives used in CFRP concrete composites. It mainly focuses on the limitations of epoxy adhesive which is commonly used as the bonding agent in concrete composites. Furthermore it discusses little research done on alternatives with better performance to replace the epoxy adhesive. The need for further research to improve fire performance of the composite is also identified.

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