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Mechanical properties of pultruded carbon fibre-reinforced polymer (CFRP) plates at elevated temperatures

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ABSTRACT

The use of fibre-reinforced polymer (FRP) composites is becoming increasingly widespread in civil infrastructure for strengthening and repair applications as well as whole FRP members and structures. A question which, however, continually arises from all stake-holders is the performance of FRP materials under elevated temperatures. An accurate understanding of the material properties and behaviour of FRP at such high temperatures is crucial, and they are necessary pieces of information that are surprisingly scarce in the literature. This paper therefore presents the mechanical properties of pultruded carbon fibre-reinforced polymer (CFRP) plates at elevated temperatures. More specifically, CFRP pultruded plate coupons were tested at steady and transient states for temperatures ranging from approximately 20 to 700 °C. The tests showed that, for the temperature ranges 20–150 °C and 450–706 °C, reductions of the tensile strength of the pultruded CFRP plate occurred. Between these temperature ranges, the tensile strength decreased by a small amount, while at 300 °C the ultimate strength was approximately 50% of the room-temperature strength. In addition, the tensile strength of the plate was as low as 7% of the room-temperature tensile strength at the approximate peak temperature of 700 °C. Finally, an equation that relates the tensile strength of the plate to the entire tested temperature range which has been calibrated with all the test data is proposed.

1. Introduction

Existing reinforced concrete (RC) infrastructure can be strengthened and repaired with externally bonded fibre-reinforced polymer (FRP) composites or externally mounted post-tensioned FRP tendons and plates. An abundance of research exists on the experimental validation of these various strengthening technologies to RC structural members at room temperature or common operating conditions (e.g. [1,2]). There is, however, a distinct lack of research on the characterization of FRP construction materials as well as the strengthening of RC structures strengthened with FRP composites at elevated temperatures and under fire conditions.

Fibre-reinforced polymer composites consist of fibres embedded in a resin matrix [1]. The commonly used fibres of carbon and glass can withstand a high temperature, and in the case of carbon fibres this temperature can exceed 2000 °C [1]. The epoxy used in the resin matrix and also the epoxy used to bond the FRP composite to concrete surfaces, however, degrades mechanically with increased temperature. Such degradation commences before the glass transition temperature, T_g, is reached. In this case, the ability of the resin matrix to transfer forces amongst the fibres is lost in addition to the ability of the resin to transfer forces between externally bonded FRP strengthening to the adjacent concrete substrate [3]. The T_g value can lie in the range 50–90 °C for commercially available products used in civil infrastructure applications [4], and, interestingly, such temperatures can be reached on surfaces exposed to direct sunlight in hot environments. Research on the ability of insulation systems to keep the temperature in the epoxy below critical temperatures for a certain period of time is gaining momentum [5–8]. Such research on insulation systems is, however, outside the scope of this paper.

Of the limited research undertaken to date on FRP-strengthened members exposed to elevated temperatures, Kodur et al. [9] have provided design guidance. Such guidance represents a culmination of tests on FRP-strengthened RC structural elements such as beams, slabs, and columns, conducted under elevated temperatures. Such testing [6,10–12], though, has considered the behaviour of the entire strengthened member and not the individual materials and components. In addition, the tests were conducted in a transient state manner in which the member was initially loaded and then a fire curve (e.g. [13]) applied. More recently, Foster and Bisby [4] identified a lack of research and understanding of the mechanical properties of FRP strengthening systems in isolation that are available to the construction industry. They also identified a lack of research on the bond between the FRP and the concrete substrate. The work presented in [4] was therefore directed towards enhancing the limited research on the mechanical properties of commercially available FRP materials under elevated

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