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Fire testing of concrete beams with fibre reinforced plastic rebar

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Abstract

The behaviour of glass fibre reinforced polymer (GFRP) rebar reinforced concrete beams when exposed to fire is presented in this paper. The experimental programme involved fire tests based on British Standard 476 on two full-scale GFRP rebar reinforced concrete beams with dimensions in cross-section 350 mm×400 mm and 4400 mm total length with a span length of 4250 mm. The beams were designed and constructed according to Eurocode 2 and ACI-440. The purpose of this work was to evaluate the fire resistance of the GFRP reinforced concrete (RC) beams. GFRP rebars with thermoset resin were used for reinforcing beam 1 and GFRP rebars manufactured with thermoplastic resin were used for reinforcing beam 2. Shear reinforcement for beam 1 was GFRP stirrups and for beam 2 steel stirrups were used. Degradation in the flexural capacity due to fire was evaluated and compared. In this study, loaded heating tests were implemented with the aim of collecting basic data for the validation of a model presented in preceding papers by the authors.

Keywords: Glass fibre reinforced polymer rebar; Concrete beams; Failure time; Temperature profile; Fire resistance

1. Introduction

Most building structures must satisfy the requirements of building codes, which relate to the behaviour of those structures in a fire. A measure of fire ratings for buildings refers to the time available in a fire before the structure collapses. The relevant property of the composite rebar is not its flammability or reaction to fire, but rather its ability to continue to sustain loads in an environment of rapidly rising temperatures. The properties of steel at different temperatures are relatively well known, as are the thermal properties of the material, and this allows the modelling of structures with some degree of accuracy to predict a time scale for the ultimate loss of structural integrity. Data is required for glass fibre reinforced plastic (GFRP) rebar in order for similar calculations to be made. GFRP rebars have a wide range of potential applications but their advantages and limitations must be ascertained so they can be used appropriately. UK Building Regulations 2000 [1] has identified the specific requirements for each category of structural element in a building in terms of resistance to collapse (load bearing capacity). The minimum period of fire resistance for the elements of most structures is 90 min.

In this study, GFRP reinforced concrete beams using continuous fibre bars as the main reinforcement were subjected to heating while under load. The three beams in this project were designed based on Eurocode 2 [2] and ACI-440 [3] recommendations and constructed at Queen Mary, University of London. One of these beams was tested as a control in room temperature. This test was carried out for the evaluation of the flexural behaviour of the beam and to choose a sustained load for the fire test. The objective of the study was to determine the fire resistance of GFRP reinforced concrete beams experimentally and to validate predictive models for fire resistance, which have been introduced in previous papers [4,5] by the authors.

2. Test programme

Three reinforced concrete beam specimens were cast, using marine siliceous gravel as coarse aggregate. The dimensions of the beams were 350×400 mm in cross-section, 4400 mm in overall length, and 4250 mm in supported span. The concrete composition for these beams is given in Table 1. In addition, three 100 mm concrete

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Table 1
Concrete composition used for casting the testing beams

Item	kg/m^3
Ordinary Portland cement (OPC)	380
20 mm siliceous aggregate	700
10 mm siliceous aggregate	360
Sand	735
Water	148
Water reducing admixture	(1% of OPC) 3.8

cubes were cast using the same concrete. These gave an average compressive strength of 42 MPa after 28 days of casting.

2.1. Control beam and beam 1

GFRP rebar reinforcements for the control beam and for beam 1 were supplied by Hughes Brothers Inc. Fig. 1(a) illustrates the various GFRP pieces. From left to right; L-shaped #7 (22 mm) used for end rebar, U-shaped #3 (9 mm) used as shear reinforcement by attaching two pieces with plastic coated wires together and a cut piece of #4 (12 mm), used for the main reinforcement. Fig. 1(b) shows the arrangement of the reinforcement in the cross-section of the beam.

2.2. Beam 2

Beam 2 was reinforced by GFRP rebar manufactured by the Dow Chemical Company. This rebar utilised a thermoplastic polyurethane resin matrix. Fig. 2 illustrates the various pieces used for the construction of beam 2. From left to right; L-shaped #4 rebar used for end rebar, steel stirrup, and a cut piece of #4 (12 mm) GFRP rebar, used for the main reinforcement. Tables 2 and 3 give details of the reinforcement specifications used in this work. The reinforcements arrangement shown in Fig. 1(b) is used in beam 2. Steel shear reinforcements were used in beam 2 in order to enhance the shear resistance. The beams were 350 mm width and 400 mm in height with effective depth of 325 mm. The beams reinforced with nine of 12 mm rebars, seven at the tension face and two at the compression face the ratio of GFRP reinforcement 0.89%.

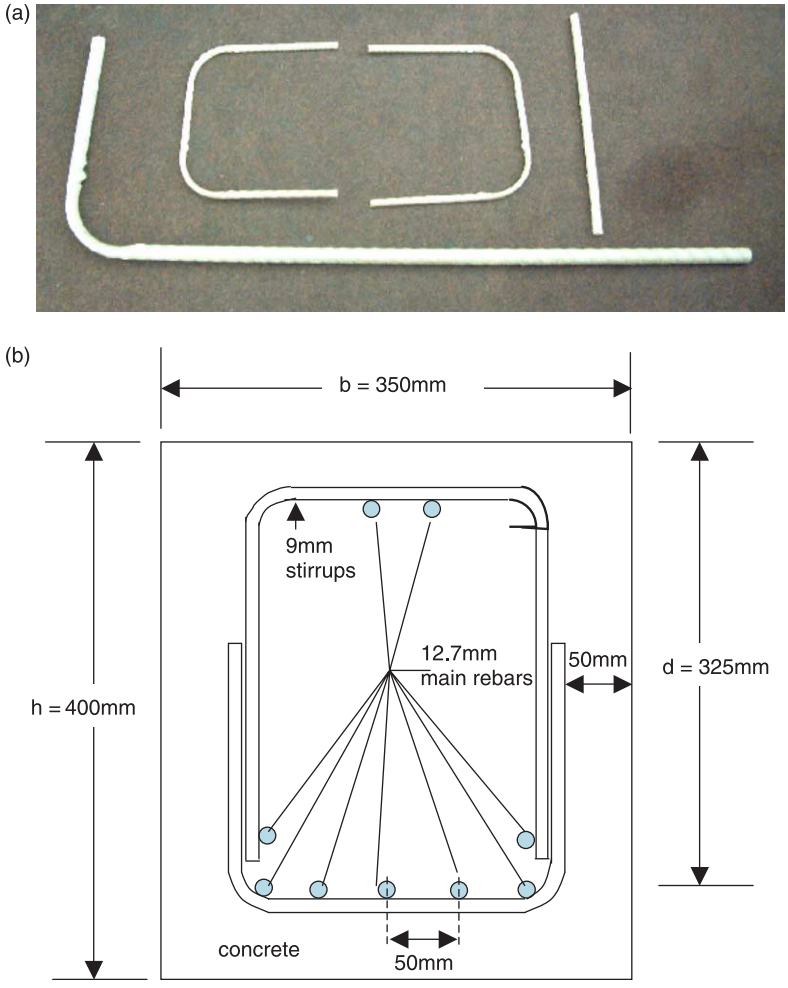

Fig. 1. (a) GFRP rebar shapes used as reinforcement for control beam and beam 1. (b) Beam cross-section with reinforcement arrangement.