Achieving Optimum Rotation Capacity from Concrete Pre-tensioned with AFRP

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1 Introduction

The focus of the present study is aramid fibre reinforced plastics (AFRPs) in pretensioned concrete applications. Many of the problems that arise are due to the brittle nature of the tendons. Complete bond leads to failure by the snapping of the tendon, which is catastrophic and occurs without warning. Unbonded tendons, on the other hand, can slide relative to the concrete, which allows considerable rotation of concrete elements at hinge positions when the structure is overloaded [1].

Clearly, *some* bond is essential, since the advantages of pretensioning are lost if anchorages are required. Thus, the project is designed to determine the amount of bond and its optimum distribution, to allow the concrete/AFRP composite to achieve its optimum performance.

The work is being carried out in two phases. The first, experimental, phase investigates flexural tension on small scale samples made in the laboratory. A second, developmental, phase will be carried out in conjunction with Costain Dow Mac. During the second phase, full scale (7-8m) prototype bridge beams using only FRP reinforcement will be manufactured and tested. The design of these beams will be based on the results of the experimental phase and will act to consolidate our knowledge of the structural behaviour of FRP reinforcement.

This paper describes the current status of the first phase of the proposed research programme and presents an outline of the future work.

2 Experimental Phase - Flexural Tests

The flexural tests investigate the behaviour of FRP prestressing tendons in pretensioned concrete beams. Two types of aramid FRPs, Technora (Teijin Ltd.) and FiBRA (Mitsui Construction Co. Ltd.), are being used. Steel prestressing tendons are also included in the study for comparison purposes.

The flexural tests consider the beam as a composite and look into the behaviour of both the concrete and the FRP prestressing. Of particular interest is the bond between the tendon and the concrete. Each type of tendon has a different surface characteristic and hence potentially differing bond properties. The FiBRA has a braided surface; Technora a deformed surface and the steel is essentially smooth.

The effects of bond are being examined by running three types of tests, an unbonded case, a fully bonded case and a partially bonded case. Two methods of providing partial bond will be investigated; by providing intermittent bond with staggered bonded and unbonded lengths of the tendon, and by coating the surface of the tendons with a resin with a known shear strength.

The work carried out to date includes an investigation of the use of expansive cement couplers to link FRP to steel wire, the casting and testing in flexure of pre-tensioned beams with bonded or unbonded tendons, and a series of pull-out tests.

2.1 Expansive Cement Couplers

The difficulty of providing a suitable method of anchoring FRP tendons without inducing stress concentrations in the fibres has been identified as a problem. FRPs have a low transverse strength and hence conventional methods used to anchor steel tendons are unsatisfactory.

Harada et al.[2] have carried out work on the use of expansive cements to anchor prestressing tendons. The advantage of this system is that the expansive cement grips the tendon evenly and without inducing stress concentrations. Since proprietary anchoring systems were not available for the small diameter tendons used in our tests, a system, based on Harada's work, was developed. Each end of the aramid tendons were coupled to steel prestressing wire (steel/aramid/steel) using expansive cement couplers and the (steel/aramid/steel) tendon specimen was stressed and anchored using standard collets and wedges for steel prestressing tendons. The pre-tensioned concrete FRP beams were then cast between the couplers. Further details of this work can be found in a recent paper [3].

2.2 Fully Bonded Beam Tests

The concrete beams were 100x200x2800mm and contained either two tendons, in the case of Technora or steel, or three, in the case of FiBRA, pre-tensioned to approximately 65% of the ultimate strength of the tendon. A high strength concrete was used and the beams were tested in flexure 7 days after casting. Although both the steel and FRP beams showed a good crack distribution, the failure modes differed with the beam containing steel failing due to concrete crushing and the beams with FRP failed due to the tendons rupturing, as expected.

A computer program based on strain compatibility was written to predict the response of the fully bonded beams. Both the cracking and failure loads predicted using the program were in line with the experimental results which confirmed that conventional beam theory is applicable to beams prestressed with FRP reinforcement.

2.3 Unbonded Beam Tests

An initial series of unbonded beams have also been cast and tested. The beams were identical to the bonded beams except that a tendon length of 1200mm in the centre of the beam was unbonded.

In contrast to the bonded specimens, the flexural response was characterised by one major crack. The failure for the beams with FRP tendons was due to concrete crushing; the ultimate capacity was lower than that of the bonded beams, but significant rotation occurred.

2.4 Bond Tests

Pull out tests are currently being carried out to learn more about the fundamental bond properties of the FRP tendons. The results of the bond tests will dictate the bonded and unbonded lengths to be used in the partially bonded beam tests.

The aims of the partially bonded beam tests are twofold; to achieve a good crack distribution (as in our bonded beam tests) and to ensure that failure is due to concrete crushing (as in the unbonded beam test). In order to design such a beam, an in-depth knowledge of the actual bond strength between the concrete and tendon is therefore required.

3 Associated Work

Investigations into the optimum layout of shear links and the effects of concrete confinement in the compression zone will be carried out to provide a design basis for the prototype beam.

The enhancement of the concrete ductility in the compression zone is of particular interest since a corollary of our partially bonded beam tests is that flexural failure will occur due to concrete crushing. Hence an improvement in the ultimate strain capacity of the concrete would improve the beam performance.

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