COMPOSITE ELEMENTS OF BASALT FIBRE RODS AND LOW GRADE GLULAM

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ABSTRACT: In recent years, increased focus has been placed on the development of timber as a natural renewable construction material. However, there exists significant potential for the development of environmentally friendly engineered structural elements by combining timber based products with other natural materials. Basalt is one such natural material and limited research has been undertaken into the use of basalt fibres for strengthening engineered wood products. This paper describes experimental test programmes whereby the pull-out performance of adhesively bonded-in basalt fibre reinforced polymer (BFRP) rods in timber was examined as well as the flexural performance of glued laminated timber strengthened using BFRP rods. The results showed that good quality bonds can be achieved with BFRP rods for non-moisture cycled and moisture cycled specimens when using carefully selected epoxy adhesives. Furthermore, moderate enhancements in stiffness and considerable improvements in ultimate moment capacity were recorded when BFRP rods were used as reinforcement in glued laminated timber. Increased ductility was associated with the reinforced beams in comparison to that of the unreinforced beams.

KEYWORDS: Basalt rods, Low grade timber, Mechanical performance, Strengthening

1 INTRODUCTION

The environmental benefits of the use of sustainable materials such as timber in the construction industry have, in recent times, been well emphasised. There is, at present, significant interest in improving the mechanical performance of timber with the use of secondary materials. Researchers are examining many possibilities with the use of steel bolts and screws and products manufactured from synthetic fibres such as glass or carbon. However, the reinforcement of structural timber elements with a product manufactured from another natural material would be strongly favoured from an environmental aspect. Basalt is one of the most commonly occurring rock types. Basalt fibres have lower embodied energy than glass or carbon fibres. Composite bars manufactured using basalt fibres possess significantly lower global warming potential than steel, are lightweight and have excellent chemical and corrosion resistance. Such basalt fibre reinforced polymer (BFRP) materials could be used as adhesively bonded-in reinforcements to improve the mechanical performance of structural timber elements. This paper discusses an experimental investigation that was undertaken to investigate the adhesively bonded performance of BFRP rods into timber as well as the improvements in mechanical performance that between BFRP reinforced glued laminated timber beams in comparison to unreinforced glued laminated timber beams.

1. EXPERIMENTAL TESTING

1.1. PULL-OUT TESTING OF BFRP RODS

A pull-out test programme was undertaken to examine the durability of the bonded connection between the BFRP rods and timber. Three different 2-part gap filling commercially available epoxy adhesives were investigated. The performance of both non-moisture cycled and moisture cycled specimens was assessed. The moisture cycling procedure involved a severe five-cycle vacuum pressure soak drying procedure. Over twenty-five non-moisture cycled specimens and ten moisture cycled specimens were tested at approximately 12% moisture content for each adhesive which gave a full sample set of approximately a hundred and five specimens. The test programme was carefully arranged such that non-moisture cycled specimens and moisture cycled specimens were taken from the same boards and consequently no bias would be introduced in the results. Each test specimen comprised two timber test cubes, of 100mm edge length, with the BFRP rod bonded parallel to grain into a centre lamination. The only surface preparation needed for the...
BFRP rods involved cleaning with methylated spirits because of the inherently coarse surface associated with the material. The specimens were tested in a specially designed rig.

1.2. FLEXURE TESTING OF UNREINFORCED AND REINFORCED BEAMS
The performance of unreinforced and BFRP rod reinforced glued laminated timber beams was examined in relation to flexural stiffness, ultimate moment capacity and ductility in the beam test programme. In total, fifteen glued laminated timber beams of 3420mm span were manufactured from mechanically stress graded spruce laminations and initially tested in the unreinforced state for flexural stiffness. Ten of the beams were subsequently strengthened using BFRP materials bonded into routed out grooves which were strategically located towards the tension zone of the member. The performance of two different BFRP rod reinforcement configurations was examined in the experimental investigation. Reinforcement was placed in two grooves routed into the soffit in one configuration and in the second configuration the rods were placed in a groove routed on either side of the beams in order to preserve the aesthetics of the bottom of the beam. The remaining five beams were tested to failure in their unreinforced state. One unreinforced beam and one beam from each of the two reinforcement configurations were instrumented with strain gauges at midspan so that the strain profile distribution could be analysed.

2. RESULTS
2.1. PULL-OUT TEST RESULTS
The three epoxy adhesives performed satisfactorily in relation to pull-out strengths for non-moisture cycled and moisture cycled specimens (Figure 1). A noticeable reduction in shear strength performance is associated with the moisture cycled specimens but this is believed to be primarily as a result of the weathering of the timber. Epoxy A was selected as the best adhesive for the beam test programme based on a balance between mechanical performance and cost.

2.2. FLEXURE TESTING RESULTS
All of the reinforced beams displayed significant ductile compressive behaviour prior to failure whereas the unreinforced beams failed in tension after little or no nonlinear behaviour. Typical load-deflection curves for the beams reinforced with the BFRP rods in the tension zone are illustrated in Figure 2. In all the reinforced beams, improvements in stiffness were noted although these improvements were not significant. Greater improvements were noted in relation to the ultimate load carrying capacity of the reinforced beams particularly when the reinforcement is located at the soffit of the beam. No premature bond failures to the BFRP rods were recorded during the testing. The strain profile distributions demonstrate that increased utilisation of the compressive characteristics of the beams is achieved when the BFRP reinforcement is included. Best performance was achieved by the soffit reinforced beams where the rods were positioned at the maximum distance away from the neutral axis.

3. CONCLUSIONS
The following conclusions were drawn from the experimental test programmes undertaken in this study:
- Carefully selected epoxy adhesives can form strong durable bonds between wood and BFRP rods although the cost of the adhesives should also be noted.
- Moderate enhancements in stiffness can be achieved with the use of bonded-in BFRPs.
- Considerable improvements in ultimate moment capacity can be achieved with the use of the reinforcement.
- The distance of the BFRP reinforcement from the most highly stressed fibres is important as the reinforcement can reduce the critical tensile stresses in the timber.
- Increased ductility is associated with the reinforced beams in comparison to the unreinforced beams as seen from the load-deflection curves and strain profile distributions.
- The long term performance of BFRP rod reinforced glued laminated timber, both in relation to creep and fatigue, needs to be investigated.
- The development of a BFRP reinforced glued laminated timber beam has considerable potential as an environmentally friendly sustainable hybrid element.