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VISCOELASTIC CREEP IN REINFORCED GLULAM

Conan O’Ceallaigh\textsuperscript{1}, Karol Sikora\textsuperscript{2}, Daniel McPolin\textsuperscript{3}, Annette M. Harte\textsuperscript{4}

1 INTRODUCTION

The mechanical and physical properties of softwood timber can vary considerably as a result of the age and rate of growth of the tree and other environmental factors which affect the wood cell density and strength [1]. Sitka spruce is characterised as a fast growing, low density timber which when subjected to flexural loading generally fails in tension due to the presence of knots [2]. When combined to create a composite element such as a glued laminated beam, the capacity of this softwood timber may be greatly increased. The short-term stiffness of these fast-grown glued laminated beams has been shown to further benefit from the addition of a fibre reinforced polymer (FRP) material of superior properties [2]. The effect of this FRP reinforcement on the long-term performance of these beams requires attention [3]. Currently, there are no long-term creep factors defined in design codes for reinforced timber elements, which prevent structural engineers and designers from utilising the increase in stiffness provided by reinforced elements. This study aims to investigate the long-term creep behaviour of timber elements reinforced with basalt fibre reinforced polymer (BFRP) rods and compare the results to similar beams in their unreinforced state.

2 EXPERIMENTAL PROCEDURE

This project is designed to study the long-term performance of BFRP reinforced glued laminated beams manufactured from Irish grown Sitka spruce. The lay-up of each glued laminated beam is carefully designed and manufactured to create beams with uniform properties. A proportion of the beams are reinforced with BFRP rod reinforcement. These beams underwent short and long-term flexural testing in a controlled, constant environment.

2.1 Reinforced Glulam Manufacture

The grade of timber used in this study was C16. Each laminate was strength graded using a mechanical grading machine and ranked in descending order of modulus of elasticity. Forty beams were designed and manufactured in the Timber Engineering Laboratory at the National University of Ireland, Galway. The beams were laminated by applying a 1:1 phenol resorcinol formaldehyde adhesive and clamping to a pressure of 0.6 N/mm\textsuperscript{2} for 24 hours in accordance with EN 14080 [4]. The final beams consist of four laminations, each measuring 98 mm x 125 mm x 2300 mm. Each beam was conditioned in a constant climate condition at a temperature of 20 ± 2 °C and at a relative humidity of 65 ± 5 %, prior to reinforcement. Twenty beams are reinforced with two, 12 mm BFRP rods positioned in two circular routed grooves in the bottom tensile laminate. This BFRP rod has an elastic modulus of approximately 50,000 N/mm\textsuperscript{2}. A two-part structural epoxy adhesive was chosen to bond the reinforcement to the timber. The 40 beams were split into two groups, Group A which contains 20 unreinforced beams and Group B which contains 20 reinforced beams.

2.2 Short-term Testing

The short-term bending test set-up is in accordance with EN 408 [5] (Figure 1). The load is applied through a hydraulic actuator at a rate of 0.15 mm/s. The test is limited to a maximum of 40% of the ultimate failure load.

Figure 1: Bending test set-up [5]

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The deflection at the midspan of the beam was measured using two LVDTs, one for determining the local stiffness and the other for the global stiffness. This short-term test was performed on all unreinforced beams to determine their flexural stiffness. This includes the twenty unreinforced beams in Group A and the twenty unreinforced beams in Group B prior to reinforcement. Subsequently, the twenty beams in Group B were reinforced and retested to observe the percentage increase in stiffness.

2.3 Long-Term Testing

A long-term creep test frame was designed to implement the same test configuration described in EN 408 [5]. A constant dead load is applied to induce viscoelastic creep with time. The sustained load is applied through a lever arm as seen in Figure 2. Each beam is loaded to a bending stress of 8 MPa in the compression zone. This corresponds to a total vertical load of approximately 6241 N and 5748 N in reinforced and unreinforced beams respectively.

The mid-span deflection is measured using a dial gauge and longitudinal strain is measured using electrical resistance strain gauges on the tension and compression faces. The beams are tested in a climate chamber at a temperature of 20 ± 2 °C and at a relative humidity of 65 ± 5 %, which coincides with Service Class 1 as defined in Eurocode 5.

3 RESULTS

The short-term test results for the Group B beams are presented in Table 1. The mean local and global stiffness is presented for beams in their unreinforced and reinforced state. The percentage increase in stiffness is also presented.

<table>
<thead>
<tr>
<th>Stiffness (N/mm²)</th>
<th>Unreinforced</th>
<th>Reinforced</th>
<th>Percentage Increase (%)</th>
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<tbody>
<tr>
<td>EI Local (x10¹¹)</td>
<td>1.46 (.120)*</td>
<td>1.69 (.119)</td>
<td>16.30 (3.66)</td>
</tr>
<tr>
<td>EI Global (x10¹¹)</td>
<td>1.35 (.123)</td>
<td>1.47 (.113)</td>
<td>8.8 (5.90)</td>
</tr>
</tbody>
</table>

*Mean Values (Std. Deviation)

The long-term deflection test results are expressed as relative creep (Cₚ) deflection, which is defined as the increase in deflection at time t, expressed in terms of the initial elastic deflection as seen in Equation (1)[6].

\[
C_p(t) = \frac{\Delta w(t)}{w_0} = \frac{w_t - w_0}{w_0}
\]

Where \( w_t \) is deflection at time t, (t) and \( w_0 \) is the initial elastic deflection defined as the elastic deflection taken 60 seconds after loading is complete. Figure 3 above presents the mean relative creep deflection results with time for the unreinforced Group A and the reinforced Group B beams in a constant climate. Although there is a reduction in the overall deflection in Group B due to the FRP reinforcement, there is less than 1% difference between the measured relative creep deflections of both groups indicating no significant reduction in viscoelastic creep due to the FRP reinforcement in a constant climate. Similar trends can be seen from the strain gauge results when comparing the long-term performance of unreinforced and reinforced beams in a constant climate.

ACKNOWLEDGEMENT

This work has been carried out as part of the project entitled ‘Innovation in Irish timber Usage’ (project ref. 11/C/207) funded by the Department of Agriculture, Food and the Marine of the Republic of Ireland under the FIRM/RSF/COFORD scheme. The authors would also like to thank ECC Teo. (Earrai Coillte Chonnacht Teoranta) for supplying all the timber used in this project.

REFERENCES


