Development of Novel Prestressed Timber Composites

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Introduction

The overall objective of this research programme is to analyse the flexural performance of prestressed timber using steel threaded bar.

It is expected that benefits of prestressing would be:

- Increased load carrying capacity
- Increased span lengths
- Potential for decreased structural depth
- Reduced service deflections due to camber caused by pre-stressing

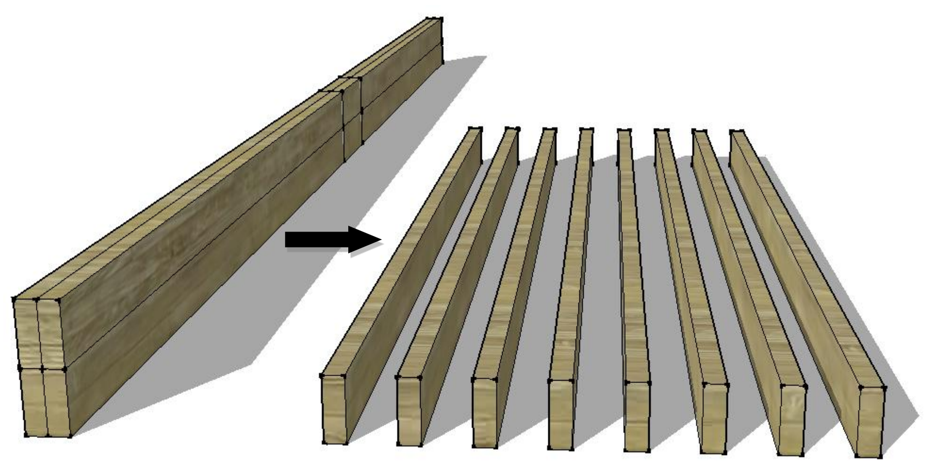
The development of prestressed timber could help increase the range of applications which timber may be used for in the construction industry, creating the opportunity to use a sustainable material in situations which it had not previously been suitable.

The experimental work carried out in this research programme involved the testing of six unreinforced timber control beams, and six prestressed timber beams using 8mm steel threaded bar which were post tensioned in nature.

Fabrication of Test Beams

For this test programme and two additional research projects, three 90 x 270 x 6000mm beams of grade GL28c timber were originally provided.

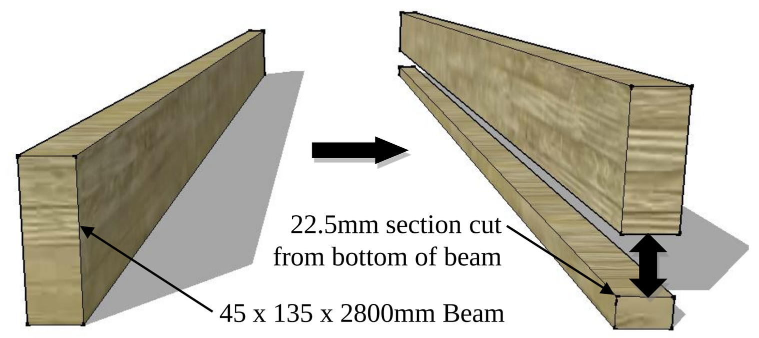
In order to reduce the prestressing forces required during testing for safety reasons, and to create a larger test sample required for more reliable results, the original beams provided were sawn into eight 45 x 135 x 2800mm smaller beams.



Original beams sawn into eight smaller beams

In order to allow the beams to be prestressed a hole firstly had to be formed through the length of the beams. To do this a 22.5mm section of timber was cut from the bottom of the beams.

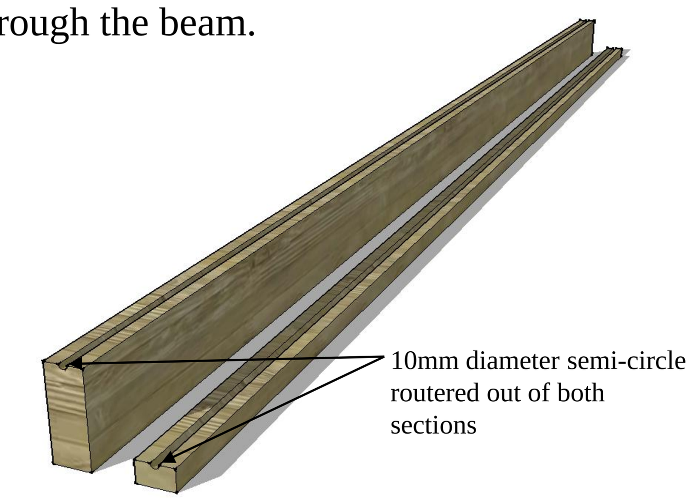
This cut measured 1/6 of the overall member depth and coincides with the thickness of a laminate on one of the full scale original beams.



22.5mm section removed from bottom of beam

A 10mm router bit was then used to carve a semi-circle of material from both sections of the timber beam.

Once this was completed the sections were then glued back together allowing the 8mm steel threaded bar to pass through the beam.



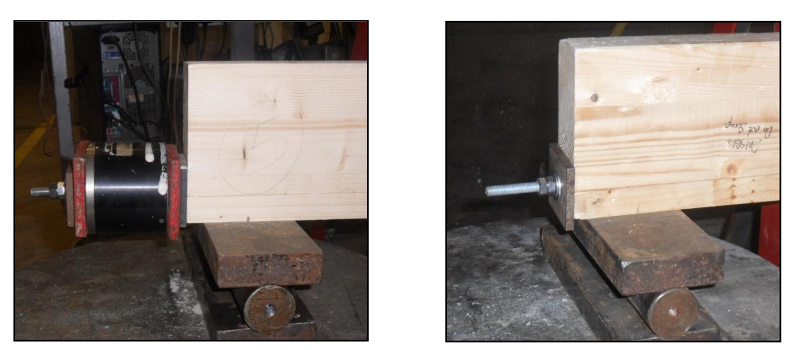
Both sections of beam routered out

Method of Prestressing

As prestressing forces required in this test programme were quite low, it was found that using a spanner to tighten nuts at either end of the beam was an adequate means of applying the prestress force.

Steel pressure plates were used with this arrangement in order to avoid localised crushing of the timber.

A 25kN load cell was used to measure the prestress force being applied to the beam.



Load cell & Steel pressure plates secured in place

Experimental Setup

Testing of both the control and prestressed beams was carried out using the Large Dartec testing machine.

Experimental setup

A quarter point loading was used, as uniformly distributed loads cannot easily be applied in the Heavy Structures Laboratory.

The beams were loaded twice to the elastic limit of 5kN and then finally to failure.

Spreader beam used to transfer point load to ¼ points of test beam

Testing of Control Beams

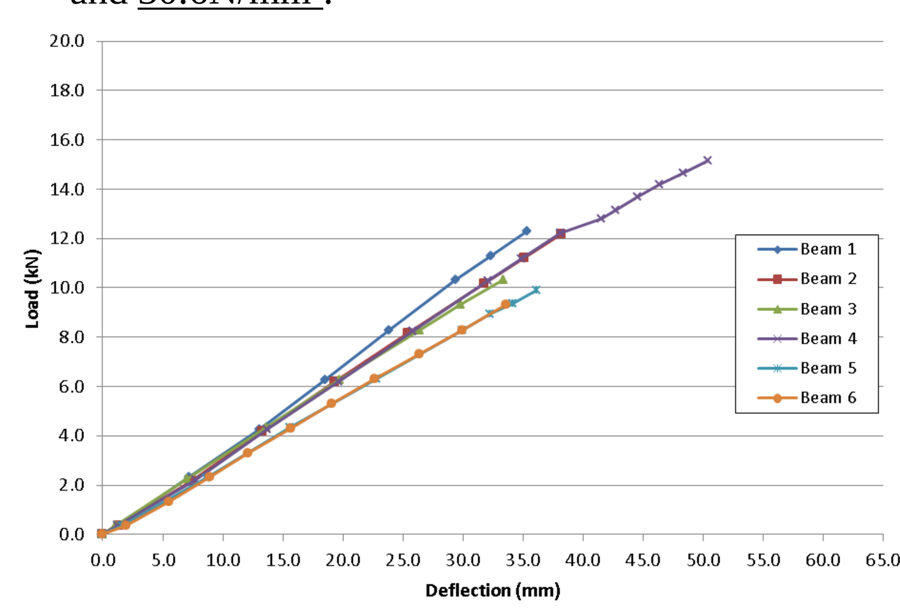
Failure of the unreinforced beams occurred as expected, with a tensile failure taking place close to or between the points of loading.

Failure generally initiated at the location of defects (knots) in the timber before spreading along the section.

The control beams demonstrated linear elastic behaviour up until the point of sudden failure which is to be expected with a tensile failure.

Example tensile failures at knots in control beams

- Average failure load <u>11.5kN</u>
- Average deflection before point of failure <u>37.8mm</u>
- The average experimental stresses recorded at the ultimate loading of the beam were <u>-24.5N/mm²</u> and <u>30.6N/mm²</u>.



Load Defection graph for control beams at failure

Testing of Prestressed Beams

The prestressed beams were tested within the elastic limit without any steel reinforcement, and with steel in place with prestress levels of 0kN, 5kN and 10kN.

Before tensioning of the threaded bar took place a zero deflection reading was recorded. The prestress force was then applied to the threaded bar and the upward deflection measured.

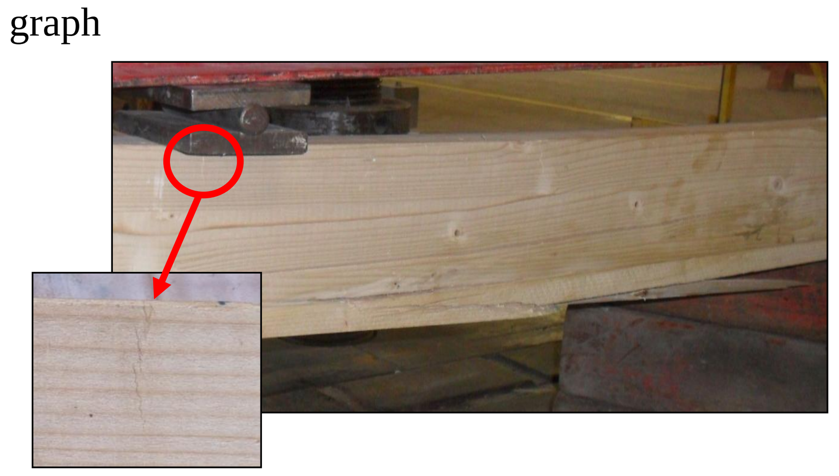
Test Beam	Initial Precamber (mm)	
	5kN Prestress	10kN Prestress
1	1.50	2.96
2	2.55	4.91
3	1.47	3.52
4	2.47	4.68
5	1.51	2.47
6	1.05	2.32
Average	1.76	3.48

Initial precamber induced due to 5kN & 10kN prestressing forces

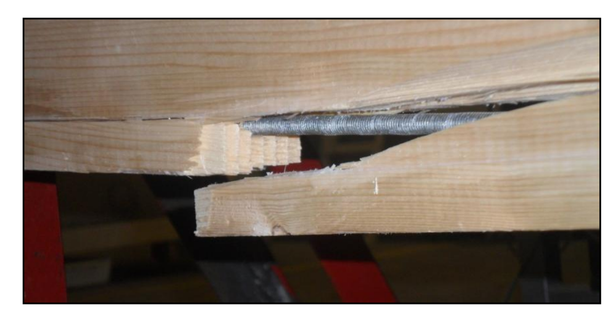
Unlike the control beams the failure mode of the 10kN prestressed beams was not as clearly defined.

- 3 beams failed in tension, two of which failed at finger joints, and
- 3 beams initially displaying signs of compression failure before the eventual tension failure of the beam.

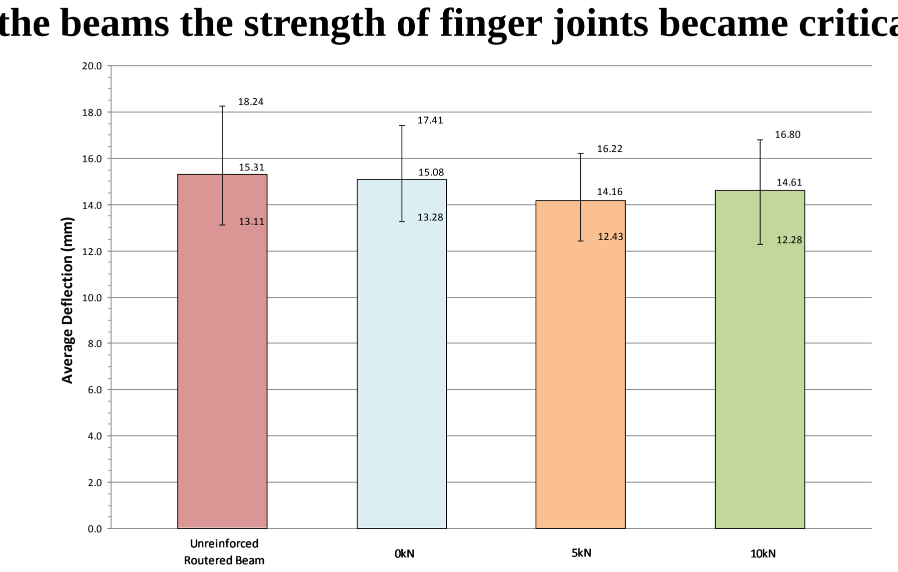
The prestressed beams generally demonstrated linear elastic behaviour, however, a small amount of non-linear softening can be seen in the load deflection graph



Example of initial compression failure of 10kN prestressed beams



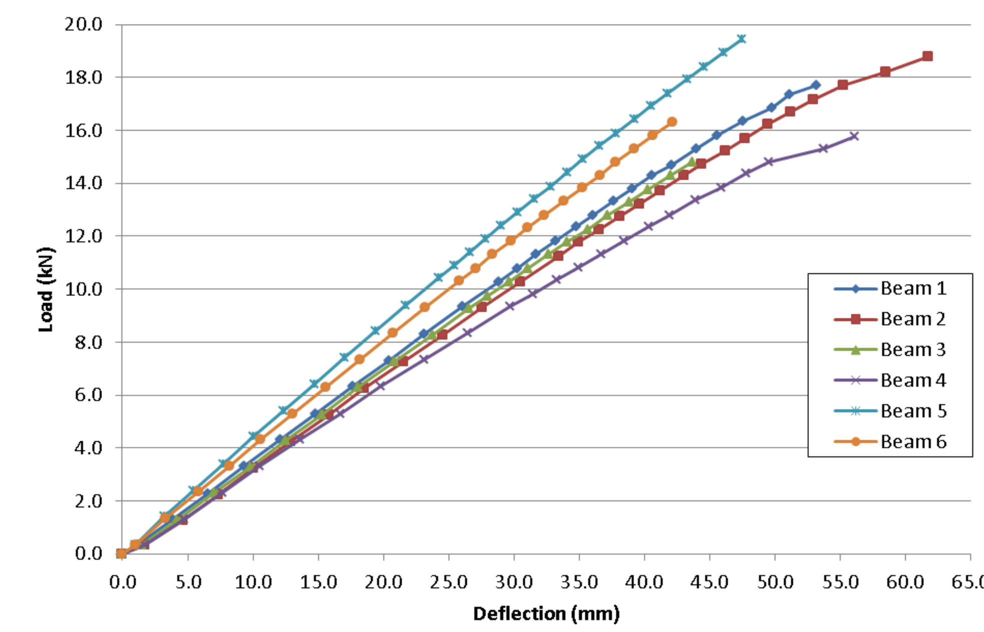
With an increase in stress induced in the tension region of the beams the strength of finger joints became critical



Deflection under a 5kN external loading at varying levels of prestressing force effectively remains the same, indicating that prestressing has little impact on the stiffness

Prestressed Beams Results

- Average failure load <u>17.1kN</u>
- Average deflection before point of failure <u>50.7mm</u>
- The average experimental stresses recorded at the ultimate loading of the beam were <u>-36.8N/mm²</u> and <u>33.6N/mm²</u>.



Load Defection graph for prestressed beams at failure

Conclusions

- Prestressing significantly increases the ultimate load carrying capacity of timber. An average increase in ultimate load carrying capacity of 48.7%was recorded over that of the unreinforced control beams.
- Post-tensioning of beams does not greatly affect the stiffness of timber. For a prestressing force of 5kN stiffness increases of 6.2% were recorded, while for a prestressing force of 10kN only a 4.9% increase was experienced.
- The real benefit of the prestressing process on the reduction of service deflections is the introduction of precamber. With the effect of precamber removed, for a 10kN prestressed beam under an external load of 5kN, a reduction in total deflection of 4.6% was observed over the equivalent unreinforced section. However, with the introduction of precamber a reduction in net deflection of 27.3% was recorded.
- Prestressing timber altered the failure mode of three of the beams from a tensile failure to a compression-tension sequence of failure. The average stress recorded at the top edge of the prestressed beams at failure displayed an increase in 50.2% over the stress recorded at failure of the unreinforced beams.
- The deflections recorded at failure of the prestressed beams were substantially higher than that of the unreinforced beams. The average increase in deflection at failure was recorded to be 34.1%.

Acknowledgements

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