Innovative Timber Composites:

Improving wood with other materials

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Investigation of the potential of hot-pressed wood in all-timber connections

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Introduction

•Bonded-in rod connections are becoming a popular connecting method.

•The problems include:

1. Material disharmonisation
2. Use of adhesives or glues

•Some systems have tried to address the issue of material disharmonisation, such as glass fibre reinforced polymer (GFRP) glued-in rods.

•Some adhesives used in an external environment have also been known to leach into the surrounding eco-system causing deterioration

•This project proposes a new system, binderless hot-pressed dowel, to tackle the issues addressed

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Hot-pressed wood

- C16 Red Western cedar (*Thuja plicata*) with average density of 390kg/m^3 was used.
- The platens of the hot-pressed machine were pre-heated to 130^{o}C
- wood specimens were then placed between platens and pressed for 5 minutes with compression ratio of 40%.

$$C = \frac{R_0 - R_c}{R_0} \times 100[\%]$$

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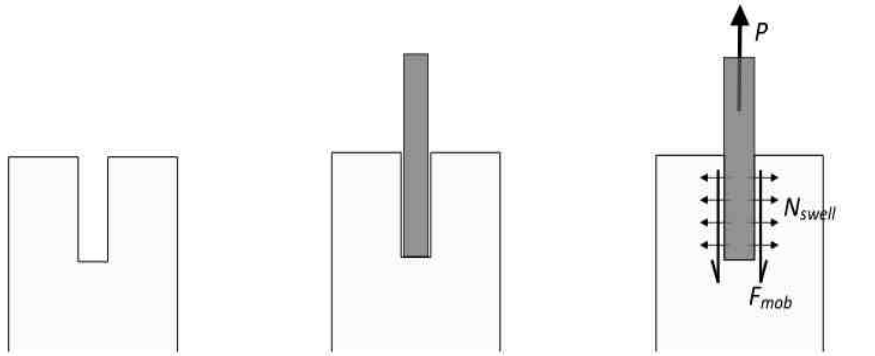
Proposed connection



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Dowel bending tests

- A total of 10 hot-pressed specimens were then cut into dimensions of 12x12x240mm for bending tests.
- The effective span between supports was set to be 200mm. All testing procedures and determination methods were conducted in compliance with BS EN 408:2003.

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- Average Modulus of Elasticity (MOE) of 13.2kN/mm with a standard deviation of 0.64kN/mm, comparable to timber with strength class of C35 ($E_{0,mean}$=13 kN/mm).
- The 5% MOE ($E_{0.05}$) is 11.91kN/mm, comparable to timber with strength class of C50 (11.05kN/mm).
- The MOE has increased by two times compared with strength class C16 after the hot-pressed process

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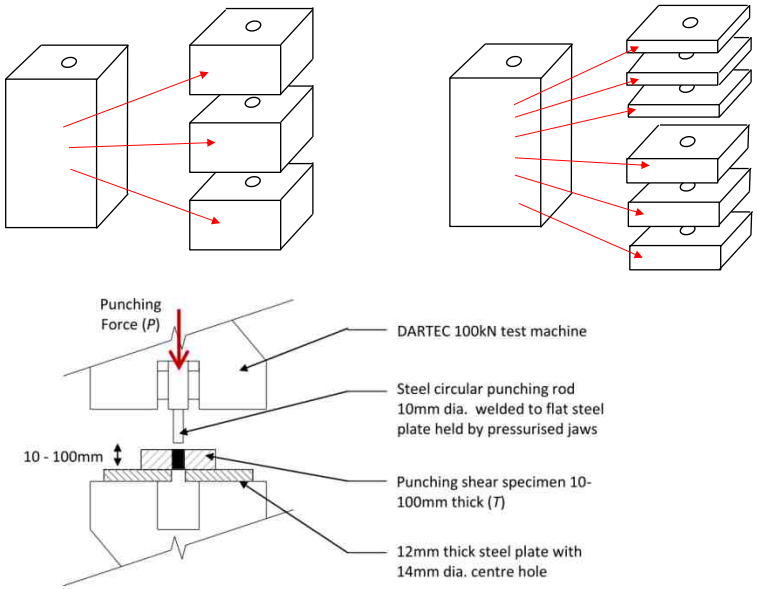
Punching Shear Tests

- Clear and small Western cedar samples were prepared and hot-pressed from 23mm to 14mm thick.
- The series A were left for 4 days to allow for spring back then shaved into 12mm diameter round dowels.
- The series B were shaved into 12mm diameter round dowels right after the completion of hot-press process.
- Thicknesses tested include 10, 20, 30, 50, 80, 100 and 150mm.



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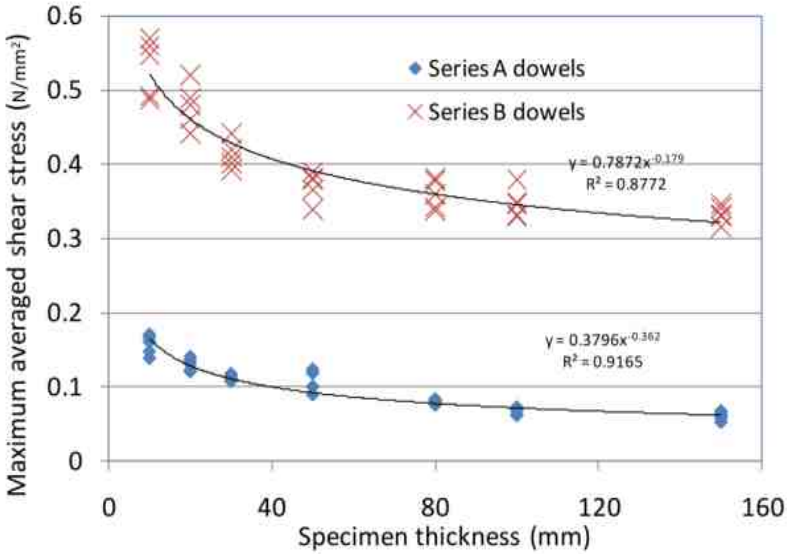
- Series B show much higher peak values, and in consequence lead to higher averaged maximum shear stresses.



Specimens series	Averaged P_{max} (N)	Maximum averaged Shear stress, $\tau_{av, peak}$ (N/mm²)	Specimens series	Averaged P_{max} (N)	Averaged maximum Shear stress, $\tau_{av, peak}$ (N/mm²)
A-10	58.89 (5.05)[1]	0.156 (0.013)	B-10	200.41 (14.62)	0.532 (0.039)
A-20	97.57 (6.39)	0.129 (0.008)	B-20	361.01 (22.55)	0.479 (0.030)
A-30	125.99 (4.70)	0.111 (0.004)	B-30	467.32 (21.61)	0.413 (0.019)
A-50	199.81 (26.56)	0.106 (0.014)	B-50	700.07 (36.83)	0.371 (0.020)
A-80	237.05 (10.14)	0.079 (0.003)	B-80	1085.73 (60.62)	0.360 (0.020)
A-100	251.08 (18.39)	0.067 (0.005)	B-100	1310.42 (75.52)	0.348 (0.020)
A-150	339.29 (31.74)	0.060 (0.006)	B-150	1884.20 (66.84)	0.333 (0.012)

[1] **standard deviations shown in brackets**

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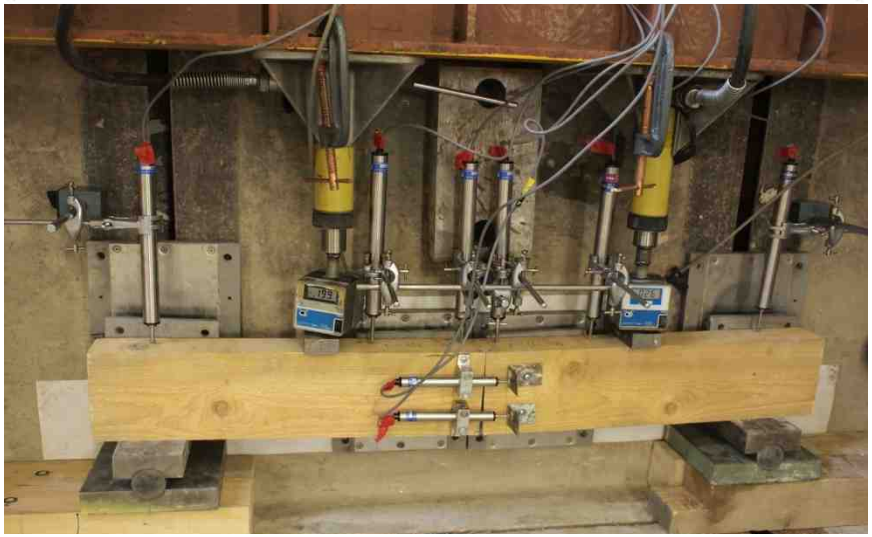
Beam tests

- A hot pressed dowel was used to connect two pieces of timber with dimensions of 75x150x600mm to build a beam with length of 1.2m.
- The edge distances tested include: 2d (24mm), 3d (36mm), 4d (48mm) and 5d (60mm); where d is the dowel diameter.

Specimens	type of dowel[1]	edge distance	No. of specimens
A-2d	1	2d	3
A-3d	1	3d	3
A-4d	1	4d	3
A-5d	1	5d	3
B-2d	2	2d	3
B-3d	2	3d	3
B-4d	2	4d	3
B-5d	2	5d	3

[1] "1" represents the same process of dowels in group A in punching shear tests; whereas "2" means the group B.



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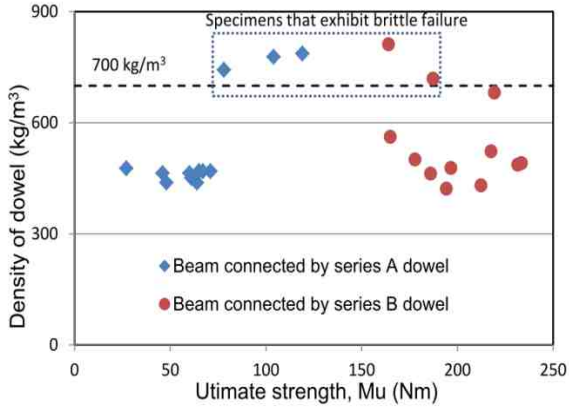
- Observations from experimental results have shown that 9 out of 12 beam specimens connected with series A dowels and 10 out of 12 specimens connected with series B dowels have exhibited ductile failure.
- Specimens that failed in a ductile manor seemed to partially snap forming an intact hinge at peak moment.
- It was found that those specimens connected by dowels with density higher than 700kg/m^3 exhibit failure in brittle manner.

Specimens	Ultimate strength M_{ult} (Nm)	Initial Rotational Stiffness k_i (kNm/rad)	Rotation at Peak Moment θ_{peak} (rads)	Rotation at Failure $\theta_{failure}$ (rads)
A-2d	84.67 (29.94)[1]	2.76 (3.08)	0.14 (0.07)	0.27 (0.05)
A-3d	58.00 (8.89)	2.78 (1.46)	0.11 (0.04)	0.34 (0.04)
A-4d	72.33 (29.37)	1.01 (0.34)	0.16 (0.12)	0.34 (0.04)
A-5d	55.00 (25.87)	0.75 (0.33)	0.25 (0.13)	0.37 (0.02)
B-2d	227.48 (8.68)	6.32 (1.03)	0.18 (0.06)	0.33 (0.04)
B-3d	206.26 (16.85)	5.87 (1.52)	0.16 (0.02)	0.36 (0.01)
B-4d	192.27 (5.57)	3.63 (0.73)	0.20 (0.08)	0.29 (0.06)
B-5d	168.88 (7.73)	2.88 (0.47)	0.14 (0.04)	0.26 (0.03)

[1] standard deviations shown in brackets



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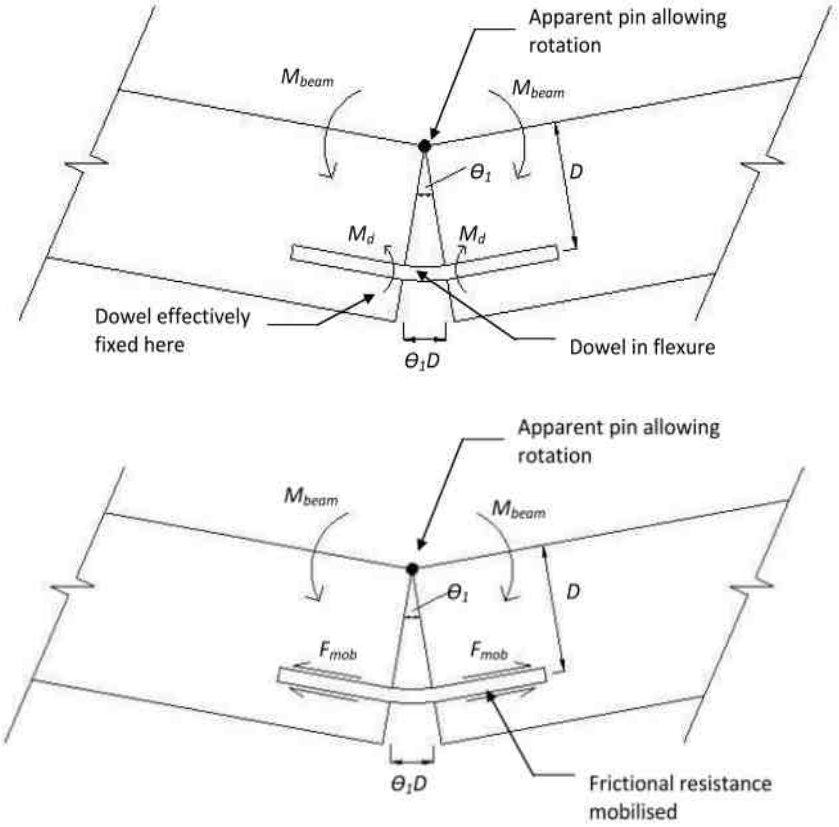
The analytical approach considers:
1.Dowel as a beam in pure flexure
2.Friction between dowel and parent material

$$M_{Rd} = M_d D\left(\frac{1}{E_d I_d} + \mu\frac{3}{2l}\right) + \frac{1}{2}\mu f_{swell} l D \pi d$$

Where M_{Rd} is the ultimate moment in the beam, μ is the kinetic coefficient of friction, M_d is the dowel bending capacity, D is the lever arm, f_{swell} is the swelling pressure of dowel, E_d is the modulus of elasticity of dowel.



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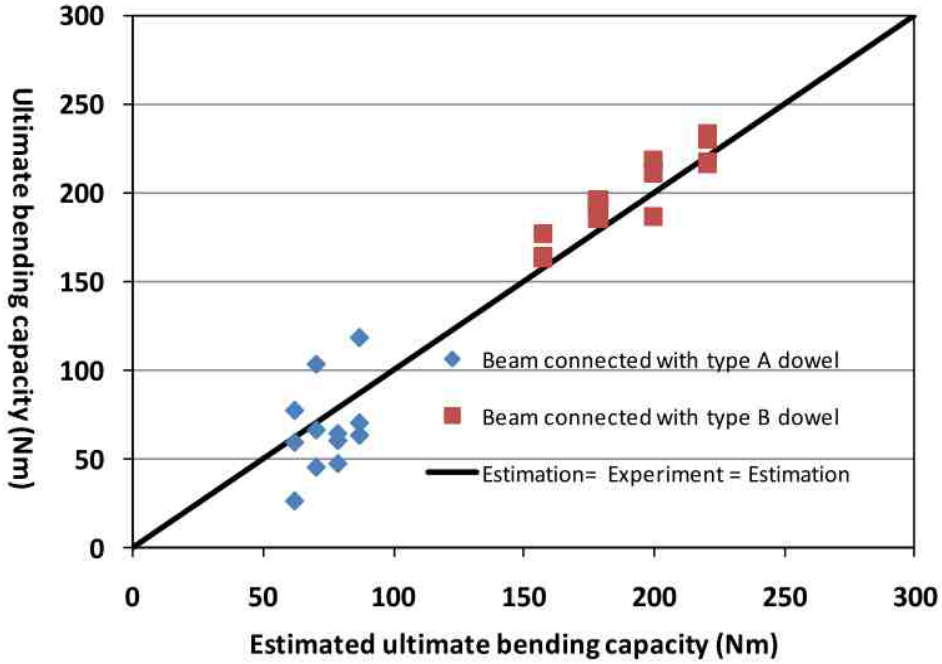
Good agreement was found in comparison between the estimated moment capacity of beam and those results obtained from experiments.



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Conclusions

- The hot-pressed process will significantly enhance the mechanical properties of timber.
- Fairly modest moment capacities in the region of 0.055 – 0.085 kNm was observed for specimens with type A dowel and 0.16-0.24 kMm was observed in the specimens with type B dowel.
- All the specimens showed very high rotations at failure around 0.30 – 0.35 radians (17 – 20^{o}) which is favourable for structural applications to provide early pre-collapse warning.