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PULL-OUT CAPACITY OF BFRP RODS IN LOW GRADE SITKA SPRUCE

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Background

Indigenous low grade timber has great potential for use in low-impact buildings but is currently under utilised in construction due to it's low classification – typically grade C16.

Table 1: Properties of Sitka Spruce

Property	BS EN 338	Tested
Bending strength (N/mm^2)	16.0	16.9
Compression strength (N/mm^2)	17.0	17.0
Shear strength (N/mm^2)	3.2	8.7
Mean MOE (N/mm^2)	8000	9540
Density (kg/m^3)	310	381

Glued-in rods (GiR) are an efficient alternative to traditional connections and reinforcement. However there are currently no pan-European standards for their design.

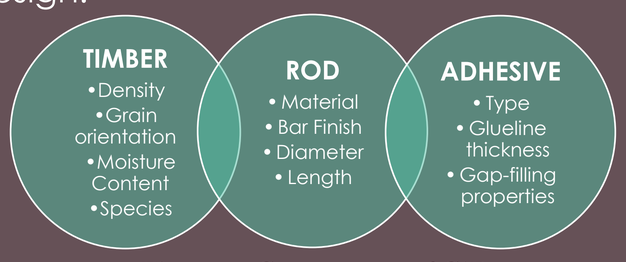

Figure 1: Components of GiR

Pull-out Testing

In practice GiR will be subject to both bending and axial forces.
A pull-out test with a pull-bending setup based on the beam test proposed by RILEM (1982) can replicate this loading combination.

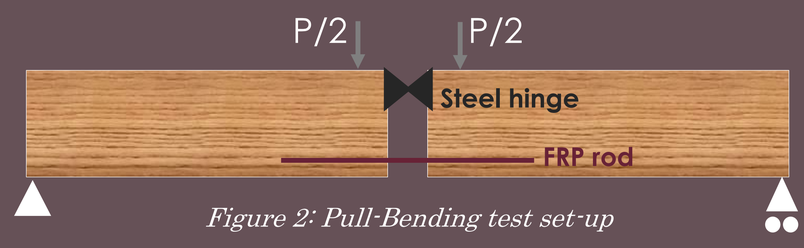

Figure 2: Pull-Bending test set-up

Experimental Results

Embedded length, l_b

A clear increase in pull-out strength was observed with an increase in embedded length (Figure 3).

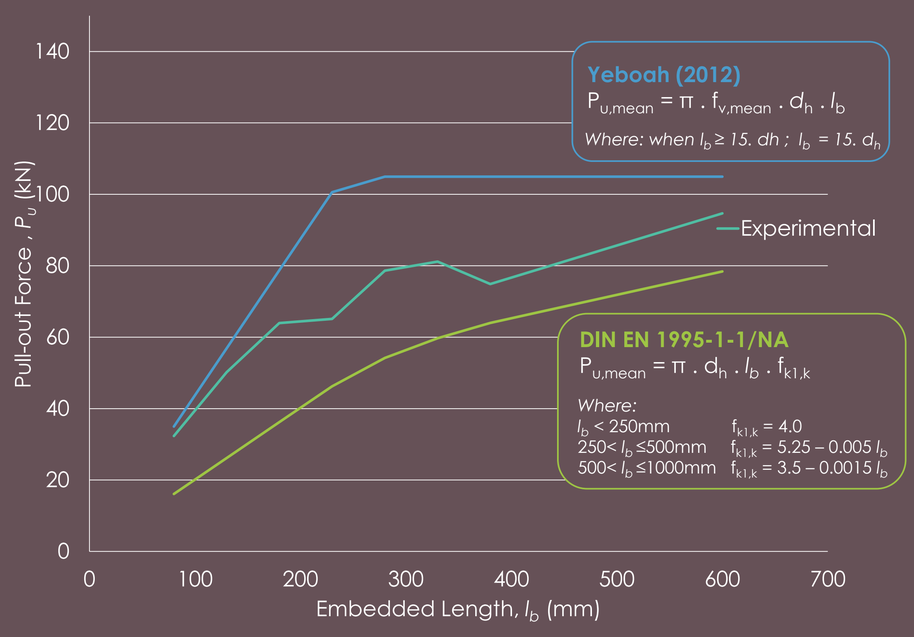

Figure 3: Pull-out capacity with increasing embedded length

The most prevalent failure mode observed was failure in shear of the timber (Figure 5.1) with a total of 64% of all samples failing in this manner.

Edge Distance, *a*

At ULS two groupings were clear - pull-out failure was significantly higher in specimens where splitting occurred than where it did not.

At slip limit a gradual decrease of strength of the GiR was observed with increasing embedded length (Figure 4). Three distinct failure modes were observed as shown in Figure 5.

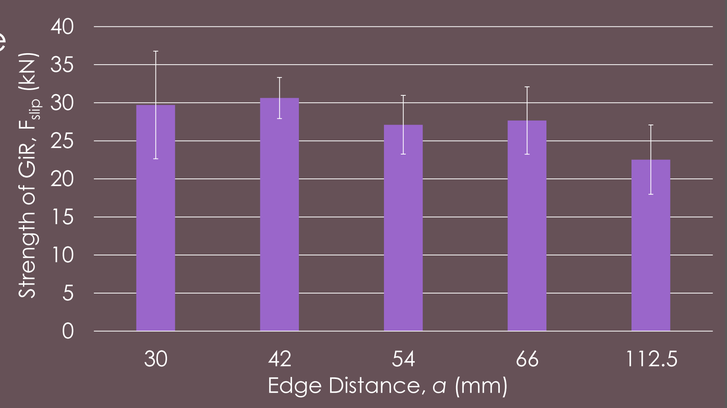

Figure 4: Pull-out force at Slip limit

Figure 5: Failure modes : (1) Shear plug, (2) Rod/adhesive failure, (3) Splitting

Durability

Research into the durability behaviour of GiR is limited. A pressure regime was used to simulate deteriorative effects of long term moisture ingress. Specimens were places in a pressure vessel to saturate then were dried prior to ultimate strength testing.

Figure 6: Pressure soaking and testing

Failure loads were compared to those without pressure soaking. Average pull-out force was 39.1kN: a 22% decrease in strength. It was evident that some delamination occurred by debonding of the glue and the rod. Delamination was identified as the main failure mode in 5/9 aged specimens.

Figure 7: Delamination

Conclusions

Increasing embedded length increases pull-out capacity. Experimental values for strength obtained in this study fall between conservative and enhanced predictions from previous research.

Increasing end distance has no significant benefit on pull-out capacity but leads to a change in failure mode.

GiR are subject to delamination with aging, leading to a reduction in strength.

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Application of Research

GiR as frame corner moment-resisting connections will be tested with frames constructed of OSB/C16 box sections.

Timber buildings using these GiR connections are lightweight and sustainable. Advantages of such buildings include:

- Construction in poor ground conditions
- Suitable for marine environments
- Can achieve a large clear span
- Low energy
- Rapid construction – prefab and on-site
- Fire protected connections
- Hidden connections with aesthetic appeal
- Create a comfortable internal environment

Figure 8: Portal frame in timber box sections