Master's Thesis Engineering Technology

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Experimental evaluation of the mechanical properties of bamboo reinforcement for reinforced concrete beams

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Master of Civil Engineering Technology

Introduction

As a follow-up to a previous study by **UHasselt** [1] and in collaboration **with Ethiopia's Jimma University**, this research investigates **the possibility of replacing steel reinforcement with bamboo**. Due to its material properties and large presence in Ethiopia, bamboo is a good candidate to be a more economical to standard steel reinforcement. To assess the suitability of **bamboo** as a **reinforcement** material, its **bending resistance** and **bonding with concrete** are analysed by means of three different tests:

- **Pull- out test,**
- **Three-point bending test,**
- **Four-point bending test.**

Pull-out test

Three-point bending test

Four-point bending test

Experiments

To assess **the bond strength** between bamboo and concrete, tests are done on the influence of three different factors: **knots, bitumen coating** and **addition of sand**. The test pieces consist of a bamboo stick fixed along both sides in a concrete bar over a length of 10 cm. During the test, pulling is done along both bars while **measuring the force and displacement**.

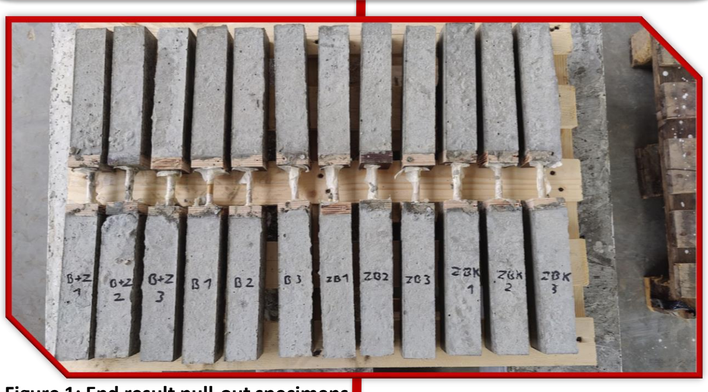

Figure 1: End result pull-out specimens

On **eight concrete beams (length of 0.95 m)** consisting of **four different types** of reinforcement, the bending strength is tested using the three-point bending test. During the test, the necessary **force and displacement** are measured until failure.
The types of reinforcement of the beams:

- **Plain concrete (PC),**
- **Steel reinforced concrete (SRC),**
- **Bamboo reinforced concrete (BRC),**
- **Bamboo bitumen reinorced concrete (BBRC).**

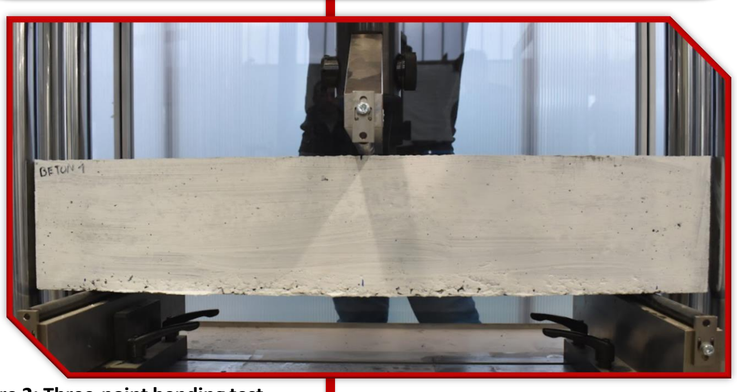

Figure 2: Three-point bending test

Based on the results of the three-point bending test, the four-point bending tests are done on **four beams** with two new types of reinforcements. The bending strength is measured on beams with a **length of 2.5 m**.
The types of reinforcement of the beams:

- **Steel reinforced concrete (SRC),**
- **Bamboo bitumen reinforced concrete (BBRC),**
- **Bamboo bitumen steel reinforced concrete (BBSRC),**
- **Bamboo bitumen grooves reinforced concrete (BBGRC).**

Figure 3: Four-point bending test

Results

The findings show that the adhesion strength **between clear bamboo** and **concrete** varies between **0.06 N/mm²** and **0.12 N/mm²**, with the thickness of the bamboo stick playing a crucial role. **Bitumen coating increases** the maximum bond strength **to 1.58 N/mm²**, but the **addition of sand decreases** adhesion **to 0.38 N/mm²**. The use of bamboo **with knots** produces significantly **higher bonding forces, up to 1.72 N/mm²**, with the variation **in thickness of the knots** being the **main influencing factor**.

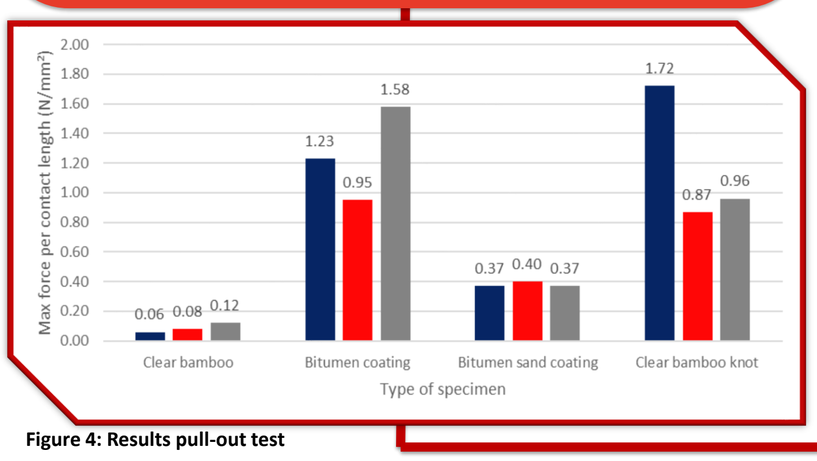

Figure 4: Results pull-out test

Figure 5 shows the **load as a function of deformation** for each type of reinforcement. **SRC** with a maximum load of 69.68 kN has **the greatest flexural strength**. **The maximum strength of BRC and BBRC** are 40.32 kN and 38.26 kN, respectively; these values **are around the values of PC** with a maximum bending strength of 38.46 kN. **The deflection** of BRC1, BRC2, BBRC1 and BBRC2 is **833%, 600%, 450% and 417%,** respectively, **compared with PC2.**

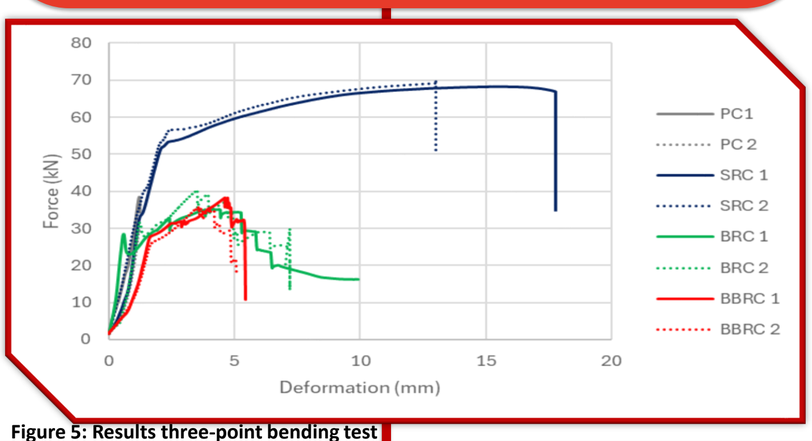

Figure 5: Results three-point bending test

For the four types of specimen the **load in function of the deformation** is shown in Figure 6. **BBSRC has the greatest maximum load** with 101.1 kN with **the smallest deformation** of 57.62 mm. **BBGRC** has **the lowest maximum load** of 77.8 kN and a deformation of 87.29 mm. **BBRC** has **a lower deformation** of 77.2 mm but **a larger maximum load** of 83.3 kN in **comparison with BBGRC**. **SRC** has **the largest deformation** of 172.5 kN. **The values** are **not representative for comparison** as the strength of the reinforcements differ.

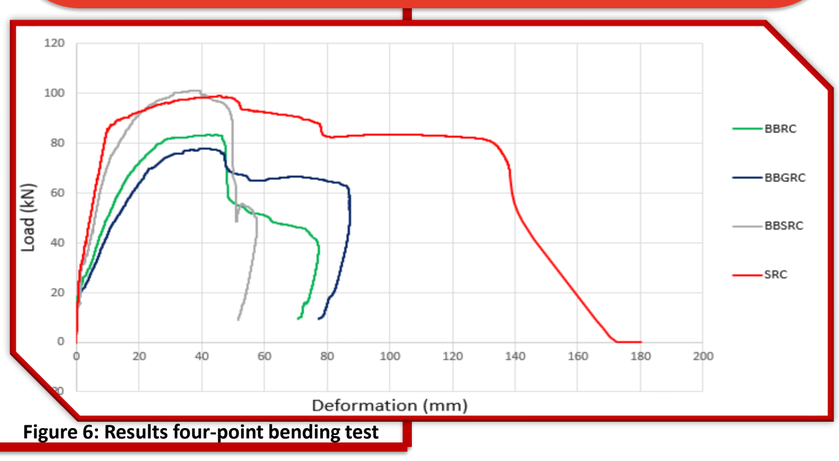

Figure 6: Results four-point bending test

Conclusion

The use of **untreated bamboo** as a reinforcement material is **impractical** due to significant **adhesion issues**. Applying a **bitumen coating enhances** the maximum **bond strength** by a factor of 13 compared to untreated bamboo. The **quantity** and **diameter of knots** significantly **affect adhesion**. On a **small scale**, **bamboo** does **not enhance the bending resistance** of beams but does **improve deformation**. On a **larger scale**, **hybrid reinforcement** appears to be a **viable** and **economical** reinforcement method. Incorporating **grooves** in the bamboo reinforcement can make its **performance more comparable to steel.**

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[1] D. Mendoza and J. Van Moorsel, "Experimentele bepaling van de mechanische eigenschappen van bamboe als vervanger van staal in gewapend beton [Thesis]," Diepenbeek: Joint study programme Industrial Engineering UHasselt & KU Leuven, pp. 1-97, 2022-2023.

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