

Dissertation Title	Development of Cementitious Composite Using Recycled Pulp from Beverage Cartons and Virgin Bamboo, and Eucalyptus Fibers as Reinforcement
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ABSTRACT

Concern about environmental degradation, climate change, and sustainability development is increasing internationally. The production of building materials is a major contributor to greenhouse gas emissions. Several research groups are making an effort to reduce the carbon footprint in the construction materials sector by encouraging innovative methods and materials. The steady increase in innovative construction materials could help reduce energy consumption and lower CO₂ emissions, leading to reduced climate change-related impacts from CO₂ emissions.

There has been an increased effort to promote a circular bio-economy by using recycled pulp in developing new composite materials. This dissertation sought to develop an environmentally friendly, commercially competitive natural cellulose fiber-reinforced cement composite by using recycled pulp from beverage cartons (RPBC). The properties of recycled pulp-reinforced cementitious composites were assessed in comparison to those of other natural fiber-reinforced cementitious composites.

The research process involved several steps: Firstly, the recycled pulp from beverage cartons and natural fibers (bamboo and eucalyptus fibers) were prepared. The properties of reinforcement fiber were characterized. As a result, the RPBC has different freeness levels of 650, 600, 550, 500, and 400 mL CSF after mechanical treatment. The minimum fiber length ranged from 0.14 to 0.33 mm and the maximum fiber length ranged from 4 to 5.1 mm. The average fiber length for 650, 600, 550, 500, and 400 mL CSF was 1.91, 1.76, 1.58, 1.45, and 1.36 mm, respectively. The minimum width of RPBC ranged from 5 to 9 μm . The maximum width fluctuated from 60 to 90 μm . The average fiber width for 650, 600, 550, 500, and 400 mL CSF was 31, 31, 32, 32, and 34 μm , respectively. The fiber length and width of virgin bamboo after the treatment with 10% NaOH-catalyzed hydrothermal have an average value of 2.07 mm and 20 μm , respectively. Virgin eucalyptus fiber has an average length of 2.65 mm and an average width of 41 μm . The fiber strength was determined by measuring the zero-span tensile index of the RPBC, BF, and EF handsheets. RPBC, BF, and EF had tensile indexes of 29 N.m/g, 20 N.m/g, and 24 N.m/g, respectively. It was found that RPBC has a short fiber length but shows a high tensile index, while BF and EF exhibit a long fiber but have a lower tensile index. The high fibrillation of RPBC (550 mL CSF) contributed to its high tensile index, whereas BF and EF have a freeness of 730 and 710 mL CSF, respectively. RPBC fibrillation improves fiber interfacial bonding, resulting in high tensile strength.

The next experiments involved the formation of cementitious composites reinforced with RPBC, BF, and EF. The properties of the composites were evaluated, and the fracture surfaces of the corresponding composites were analyzed. The results showed that the flexural strength of composites reinforced with RPBC increased with an increase in fiber content and reached a maximum value of 12 MPa at a fiber content of 14 wt%, while composites reinforced with BF and EF achieved maximum flexural strengths of 9 and 10 MPa at a fiber content of 8 wt%. In contrast to the flexural strength, BF and EF-reinforced composites demonstrated fracture toughness of 1.35

kJ/m^2 and 3.6 kJ/m^2 . These values were higher than those of the RPBC-reinforced composite by 114% and 457%, respectively, at the same fiber content.

The last part of the experiment was focused on the improvement of the properties of the RPBC-reinforced cementitious composite, particularly the fracture toughness. The fracture toughness of the RPBC-reinforced composite was very low (about 0.6 kJ/m^2). To improve the fracture toughness of the RPBC-reinforced composite, the RPBC was partially substituted with virgin cellulose fiber. Eucalyptus fiber was selected as virgin cellulose to mix with RPBC in different ratios. As a result, the fracture toughness of the hybrid fiber-reinforced composite increased by 370% at a fraction ratio of 1:1 (RPBC:EF) compared to the pure RPBC-reinforced composite. It had a flexural strength of 11 MPa.

In conclusion, using RPBC as a reinforcement to produce a cementitious composite is flexible. The flexural strength and the fracture toughness achieved 12 MPa and 1.6 kJ/m^2 at a fiber content of 14 wt%. When combining the RPBC and virgin EF with a ratio of 1:1, the fracture toughness increased by a third-fold, and the flexural strength was 11 MPa at a fiber content of 8%. This value meets the requirements of grade II according to the standard specification ASTM C-1186-02 (2002).

Keywords: Recycle Pulp, Beverage Cartons, Bamboo, Eucalyptus, Cement Composite, Fracture Toughness, Flexural Strength, Hybrid Fiber, Bioeconomy