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Concrete Columns Wrapped with Hemp Fiber Reinforced Polymer – An Experimental Study

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Abstract

Concrete confinement with Fiber reinforced polymers (FRP) is a method widely used for strengthening and rehabilitation purposes. The replacement of synthetic fibers with natural fibers is a step to achieve a sustainable construction. In this research, an experimental study reports the efficacy of the use hemp FRP as external confinement for concrete columns and the effect of different parameters that may affect the structural behavior of concrete columns confined with FRP. The test variables are: the number of confining layers, and the columns slenderness ratio. Uniaxial compression test was done for a total number of 30 specimens. The axial stress-strain curves, structural ductility measured by fracture energy and failure modes were analyzed. Also, the applicability of existing stress and strain models available in the literature is checked. It was found that the number of confining layers and columns slenderness ratio have a significant effect on the confinement effectiveness and ductility. This study gave promising results vis-à-vis the use of natural fibers as external confinement despite the tensile strength of hemp FRP that are significantly lower than that of synthetic FRP.

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Keywords: Compressive strength; Confinement effectiveness; Ductility enhancement; Compression test.

1. Introduction

Many existing structures worldwide are either in need of rehabilitation or retrofitting due to the deterioration resulting

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from actual service and aging, exposure to extreme natural events such as floods and earthquakes and many more. For example, in the case of road infrastructure, the transport of heavier payloads is now possible with the advances in transportation logistics, also the new highway management systems have led to increase in traffic volumes. These increases will therefore translate into higher demand loads for bridges that may outcome their rated capacities [1]. Experimental studies proved that providing external confinement to concrete structural element substantially enhances both the axial compressive strength and the ductility of the concrete element. With the increase of environmental concerns, the use of natural and bio-based fibers, as a replacement of synthetic polymers, is gaining popularity nowadays. Some natural fibers such as hemp, jute, flax, coir and many more have the potential to replace the synthetic materials as they also have attractive physical and mechanical properties [2]. Many existing researches have demonstrated the effectiveness of the use of the natural as external confinement or in cementitious matrices [3,4].

2. Materials and Experimental Procedure

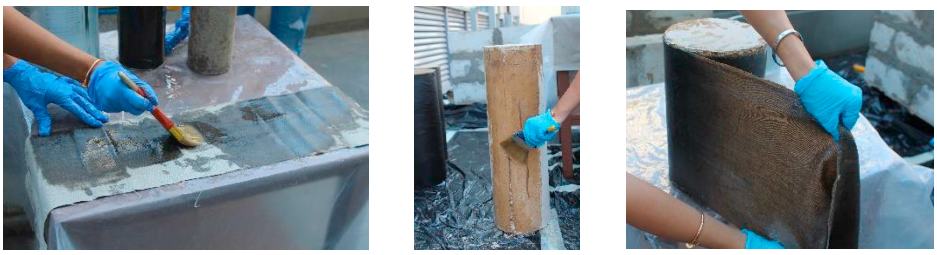
2.1. Materials

2.1.1. Concrete

Low strength concrete is used throughout the study. Ready-mix concrete is chosen over the conventional mix because of the large amount of concrete needed and since concrete itself is not the main focus of the study. The concrete compressive strength, at 28 days, is 20 MPa. All columns specimens were cast vertically from one batch of concrete. After 7 days, all specimens were demolded and cured until testing.

2.1.2. . Hemp Fabrics

Commercial bidirectional hemp fabrics are used in this study. Fabrics were cut into designated sizes with an overlap equal to half perimeter. The fabrics and concrete surfaces were saturated with epoxy. The saturated fabrics were applied to the columns surfaces by hand, using the wet lay-up technique. When applying the fabric, a slight constant pull was maintained across the width of the fabric in order to ensure a flat adhesion to the concrete and to squeeze out any air pocket. Once the specimen is fully wrapped, a final coat of epoxy was applied mainly at the ends to ensure a complete saturation as shown in figure 1.



(a) (b) (c)

Figure 1. (a) Fabric preparation, (b) Concrete surface preparation, and (c) Application of hemp FRP wraps.

2.2. Test Instrumentation

2.2.1. Tensile Testing of Hemp-Fiber Bundle

The tensile testing was performed using ASTM D 3822-14 [5]. The gauge length of the specimens is kept constant throughout the test. The rate of extension or pull was set to 1 mm/min for all the tests. Clamps with flat jaws were used to grip the fiber specimens and minimize slippage. The test setup is shown in figure 2(a).

2.2.2. Compression Testing of Hemp-Fiber Confined Concrete