# MICRO-CT ANALYSIS OF BRAIDED BFRP COMPOSITES FOR CIVIL ENGINEERING APPLICATIONS

S. Antonopoulou[1] and C. McNally[1]

[1] University College Dublin, School of Civil Engineering, Dublin, Ireland
Email: sofia.antonopoulou@ucd.ie, Web Page: http://www.ucd.ie/civileng

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**Abstract**
This paper focuses on the use of micro computed tomography (CT) methods for fibre composite material analysis and evaluation of braided Basalt Fiber Reinforced Polymer (BFRP) reinforcement. More specifically, a combined experimental and computational study towards a complete 3D geometrical model of braided BFRP rebars is presented here. Rebars are designed using basalt fibres and epoxy resin as reinforcement and matrix respectively; composites are developed in three different sizes and configurations, using braiding and a vacuum assisted resin infusion technique. All samples are scanned using micro-CT imaging and their microstructure is assessed. Geometrical consistency is validated, including measurements on layer thickness, braiding angle and fibre orientation;; yarn cross section deviations from the idealized elliptical shape along the yarn path and nesting effects were observed. Defect and void development, yarn damage and calculation of fibre volume fractions, is completed with ImageJ software. In addition, realistic geometrical modelling of braided composites based on these measurements is carried out using TexGen software, towards simulation of their mechanical response with FEA methods.

## 1. Introduction

The increasing rate of degradation of reinforced concrete structures due to corrosion of steel is identified as one of the main causes of structural deficiency that severely affects structural safety of RC elements [1-2]. Advanced composite materials, such as Basalt Fibre Reinforced Polymer (BFRP), were recently introduced as a potential replacement to traditional steel in civil engineering applications, due to both their high strength-to-weight ratio and their excellent corrosion resistance. These materials can be used as internal concrete reinforcement to overcome the inherited corrosion-related deficiency of steel reinforced concrete structures and thus, to extend infrastructure's long-term durability and total service life [3-5]. However, their mechanical in-plane properties are influenced by the textile nature of braided composites, as out-of-plane and in-plane waviness is evident on interlacing yarns [1, 6].

The aim of this study is to analyse the geometrical properties of a braided BFRP rebar composite part using the X-Ray μ-CT method. The size and shape of individual yarns (basalt and PET) along the yarn paths are measured, fibre orientations and braiding angles are investigated and void content throughout the braid structure is accurately estimated. The fibre volume fraction of the composite is calculated using an image processing technique and a compete 3D reconstruction model of the sample is presented. Those measurements are necessary to improve the current braid geometrical models and to assess the quality of the braiding manufacturing process. Understanding the three dimensional geometry of braided composites will lead to improved analytical models.

## 3. Micro X-Ray Computed Tomography and image processing

The internal micro-structure of the manufactured braided BFRP composite rebar was examined using X-ray micro computed tomography. More specifically, the 3D X-ray microscopy was performed using a Phoenix Nanotom M with DXR flat panel detector nanofocus CT system at the UCD Rosemount Environmental Research Station facilities. The scan was performed at a resolution of 4.2 μm over a 360° rotation using 2400 projections and 80 kV voltage. The total scan time was 2 hours and a stack of 1000 cross-sectional, gray-scale digital images were produced. Prior to μ-CT scanning, the sample was adhered to a small finishing nail and mounted in the X-ray microscope as shown in Fig. 2.

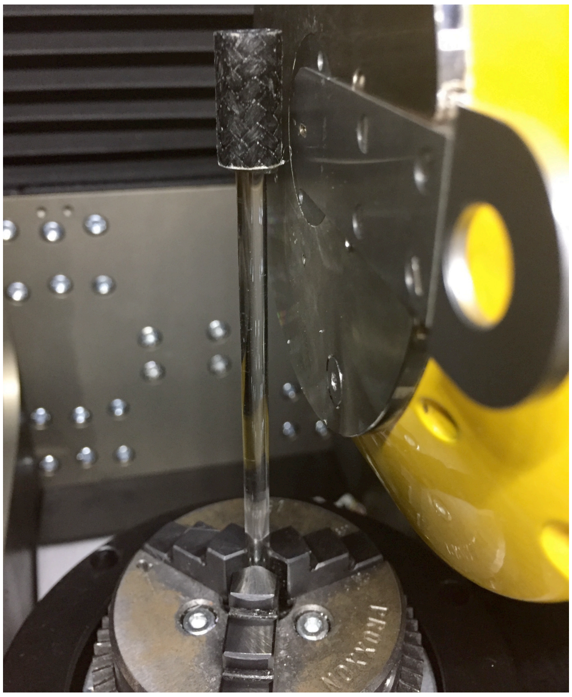

**Figure 2.** The braided BFRP specimen mounted inside the μ-CT microscope.

Image processing analysis was then performed using ImageJ software and the main outcome was the detailed qualitative examination of the composite sample. More specifically, the tomography was employed to analyse the composite's geometrical properties – size & shape of individual yarns along the yarn paths, fibre orientations, braiding angles -, calculate its fibre volume fraction, identify voids & defects and complete a 3D reconstruction model of the sample from μ-CT scanner data sets.

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