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An alternative method for determining tensile properties of engineered cementitious composites

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Abstract

The framework of a practical test method that can be used to provide indirect assessment of the tensile properties of ECC is presented. Particular emphasis is placed on providing the underlying concept, modelling strategy and constitutive relations underpinning the proposed framework. An analysis case study, examining the effect of tensile stress-strain profiles on the flexural response of an ECC beam, is presented to demonstrate the capability of the modelling approach. The results of further parametric analysis are also provided to establish equations that can be used for determining equivalent tensile properties of ECC based on a given set of flexural test data. A web portal is provided as a simple tool for practitioners and researchers involved in mix development and quality control testing.

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Keywords: ECC; practical test; tensile properties; quality control; virtual laboratory; website

1. Introduction

An Engineered Cementitious Composite (ECC) is a fiber reinforced cement-based composite which possesses ultra-ductile tensile properties, typically a few hundred times larger than those possessed by concrete with no and regular fiber reinforcement [1–3]. The material's high tensile strain capacity is attributed to its ability to form closely-spaced fine cracks when subjected to tension, allowing it to deform plastically like a metal – a response which is known as a strain hardening [4]. This is in contrast to the post-cracking response of ordinary concrete which

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is characterized by a brittle, strain softening response. Apart from its high ductility, ECC is known for its crack control ability, with crack widths typically less than 100µm during the strain hardening [5]. It is these two ECC features that have attracted widespread interest from the engineering community.

In the United Kingdom, where this research is conducted, ECC has yet to be used in civil engineering applications, with the work still being at a research and development stage (see, for example, [6–9]). In order to promote the use of ECC in the construction industry, this work seeks to develop a simple test procedure that can be used for quality control testing in large volume applications. While the uniaxial tensile test has been the primary method used for ascertaining the tensile stress-strain properties of ECC and provides results which are easy to analyze, the test is often difficult to perform to an acceptable quality and thus can be impractical for use in normal construction practice. It is for this reason that a simpler test method is developed in this work. Although the proposed method can stand alone, it is not the intention of the authors to replace the standard tensile test, but rather to use it alongside the existing test method which should be used for validating the results periodically.

2. Heriot-Watt University (HWU) Method

A flowchart detailing the work undertaken to develop the HWU method is presented in Fig. 1, with the dashed lines highlighting the scope of this paper. The proposed method is similar in many respects to the University of Michigan (UM) method [10,11] on the basis that it only requires the peak load and the corresponding point-load deflection to be measured from a test. Similar to the UM method, the proposed method also does not require the use of special devices to take strain readings; rather, this can be determined using predefined equations, which can also be used to determine tensile strength. The proposed method is distinct from the UM method in that it offers an improved representation of the effect of micro-cracking on beam curvature and deflection profiles, making it more closely aligned with the principles of mechanics (Fig. 2). Another important aspect of the HWU method, when compared to the UM method, lies in the use of refined stress-strain relations which are used consistently throughout the calculation process. Fig. 3(a) presents the test setup used to derive equations used in the proposed method.

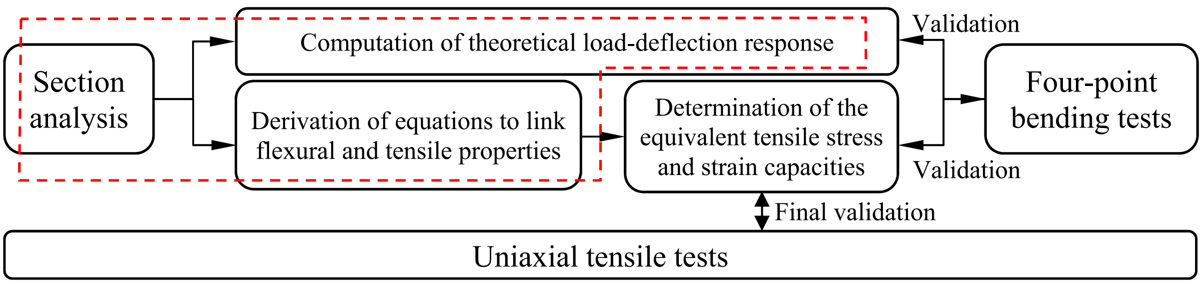

Fig. 1. Framework for the development of the HWU method.

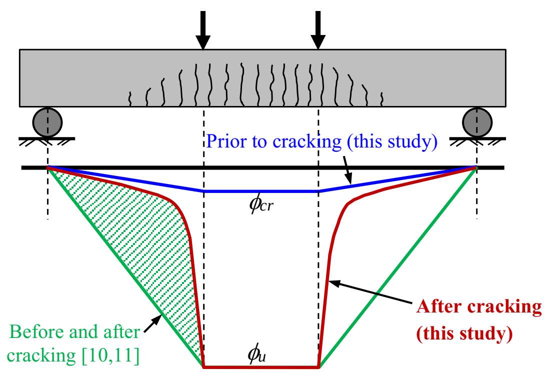

Fig. 2. Comparison of the assumed curvature profile in HWU and UM methods, with the hatched area highlighting the difference.