Direct tensile and pullout behavior of Ultra high-performance concrete coupled with micromechanical modelling

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Introduction

Ultra high-performance concrete (UHPC) is an advanced form of cementitious composite with enhanced mechanical and durability properties. It is characterized by compressive strength of over 120 MPa and tensile strength of over 8 MPa. Such high mechanical properties is the result of improved particle packing and dense microstructure. A key characteristics of UHPC is the addition of discontinuous steel fibers which imparts ductility to the UHPC matrix.

In this work we aim to study the tensile and pullout behavior of UHPC with different steel fibers combined with micromechanical modelling.

Research significance

There are an abundance of work studying the tensile and pullout behavior of UHPC, using different types of discontinuous fibers. However, very few work have been done trying to quantify the contribution of fibers in the tensile behavior of UHPC and correlate it with the pullout behavior of individual fibers. In the current work, we intend to study the tensile and pullout behavior of UHPC matrix combining it with micromechanical model with the objective of improving the fiber utilization in the composite. Since fibers are the most expensive component of UHPC (1.5 vol% of 13 mm length and 0.2 mm diameter high strength steel fiber can account up to \$600 and approximately 50% of UHPC material cost) and are under utilized, with this work we intend to achieve efficient fiber utilization in the UHPC matrix.

Fiber efficiency factor (F) will be calculated as a function of the bond strength (τ), embedment length (l_e), fiber aspect ratio(A_f), fiber volume (v_f), cost of fiber (C_f), Elastic modulus of fiber and matrix ($E_f$and E_m).

F= f(τ, l_e,A_f,v_f, C_f, E_f, E_m)

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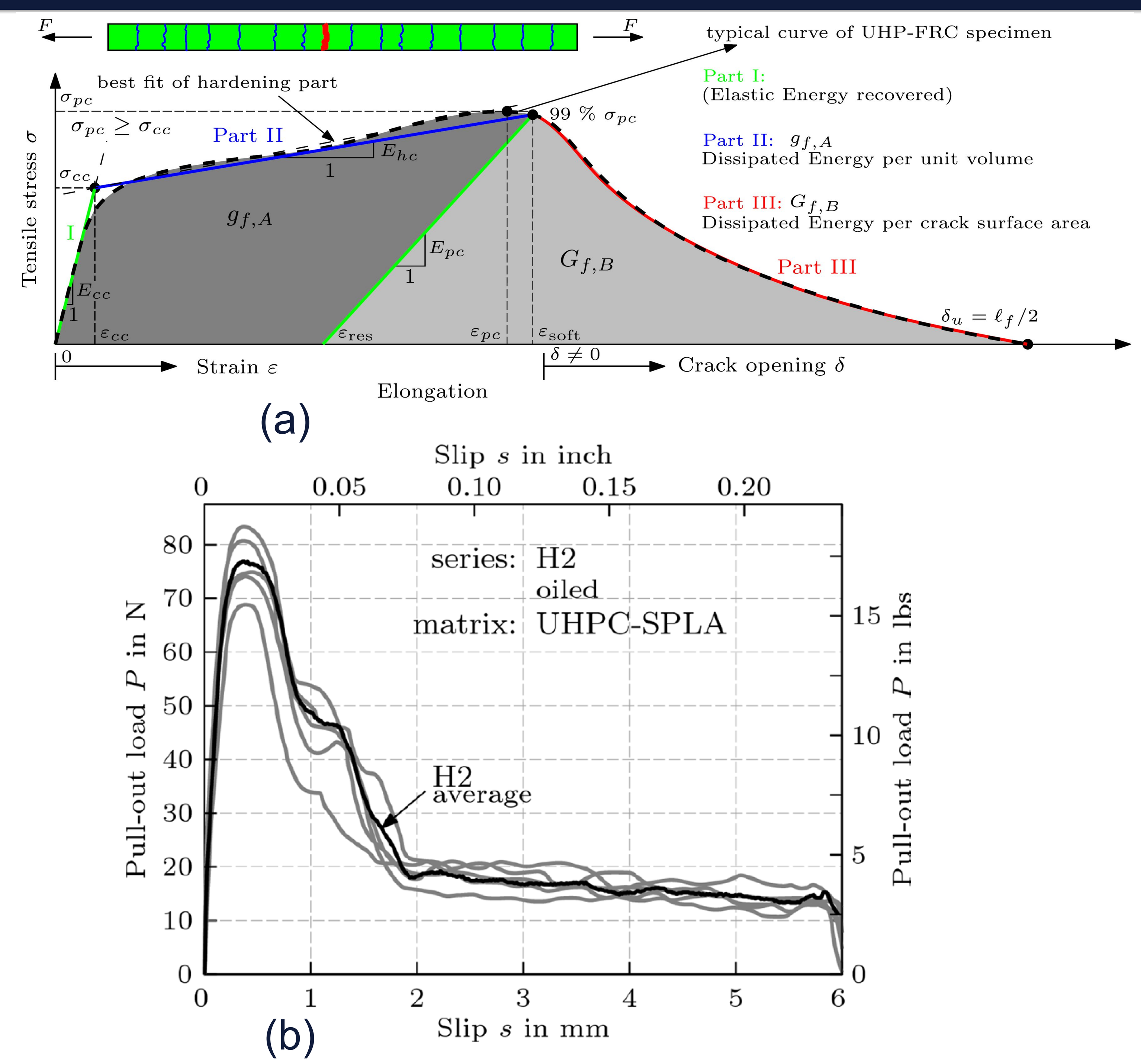

Fig. 1. (a) Typical tensile and (b) pullout behavior of steel fiber in UHPC [1,2].

Methodology

Direct tensile tests will be conducted using different steel fibers of varying dosage from 1-2% fiber vol. while pullout tests will be conducted by embedding pristine fibers in UHPC matrix, both under displacement control. The contribution of individual fiber can be calculated by counting the number of fibers bridging the matrix cracking plane. This can then be compared with the results from single fiber pullout and can be helpful in knowing the degree of fiber utilization and thus the fiber efficiency factor.

In addition to this the softening curve will be predicted using micromechanical model suggested in [3] as a reference. Further improvisation will be made on the model to improve the accuracy of prediction with the experimental results.

$$\sigma_c = \frac{F}{A_c} = \frac{V_f}{A_f}\int_{z=0}^{L_f/2}[\int_{\Phi=0}^{\arccos(\frac{2z}{L_f})} P(l,\Phi,\delta)p(\Phi)d\Phi]p(z)dz$$

Where, σ_c is the composite stress, δ is the crack opening, other parameters are as mentioned in fiber efficiency factor determination.

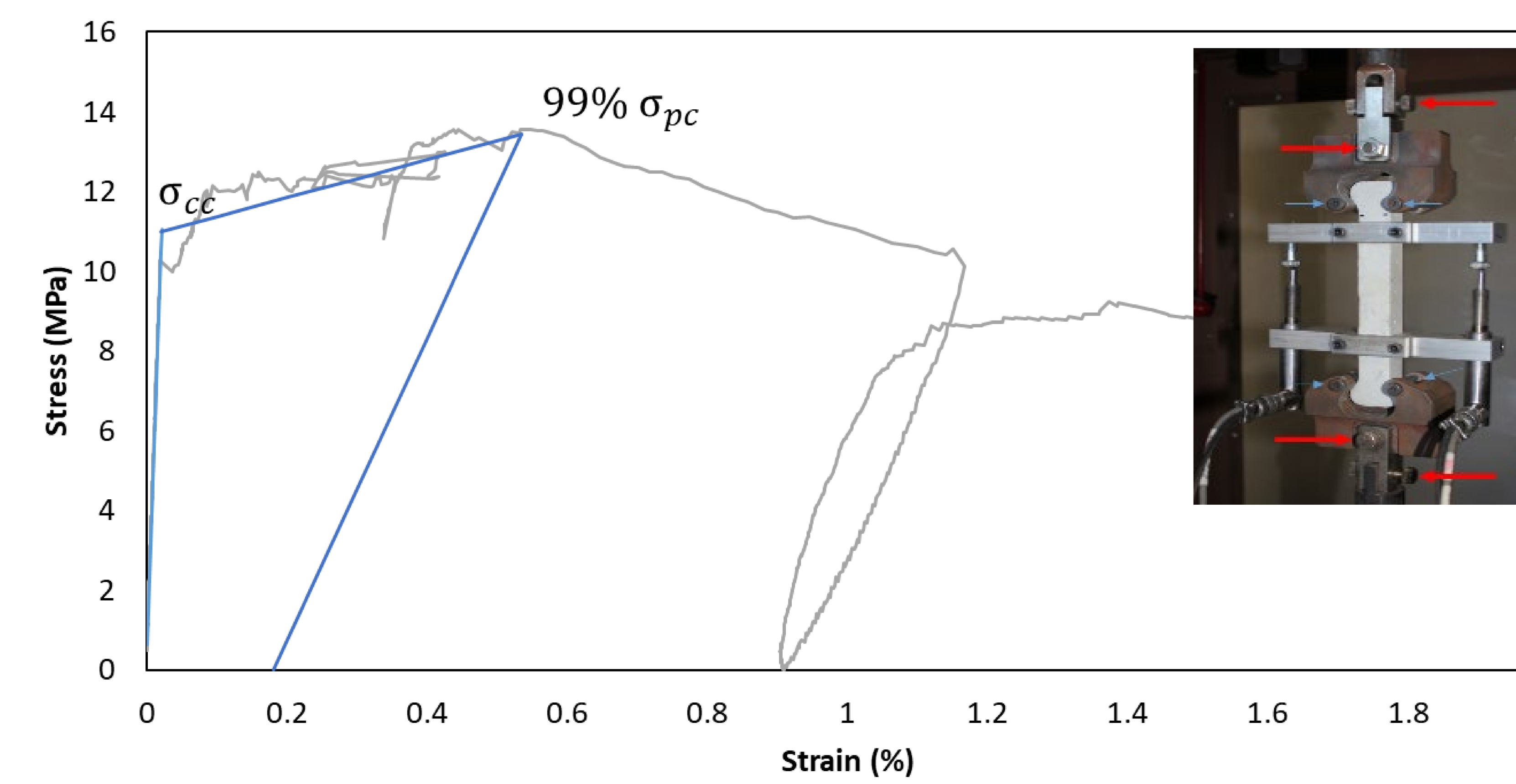

Fig. 2. A typical example of unloading line and bi linear (with testing setup for direct tensile test).

Summary and future work

Through our preliminary tests, we were able to obtain tensile data with unloading line post peak load including the bi linear model following the steps mentioned in [1]. This can be used in calculating energy dissipated during strain hardening ($G_{f,a}$) and softening ($G_{f,b}$) (in Fig.1) [1].

In the future, more samples will be prepared with multiple fiber volume, fiber length and the tensile behavior of UHPC will be studied alongside the fiber pullout behavior. In addition to the experimental results, a reliable model will be developed using micromechanics theory which can predict the experimental results with high accuracy.

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