



International  
Standard

**ISO 13180-1**

**Fibre-reinforced cementitious  
composites (FRCCs) — Direct tensile  
test method —**

**Part 1:  
Strain hardening FRCCs**

*Composites à base de ciment renforcés par des fibres — Méthode  
d'essai de traction directe —*

*Partie 1: Composites à base de ciment renforcés de fibres à  
durcissement sous contrainte*

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# Sample Document

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## Foreword

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This document was prepared by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, Subcommittee SC 6, *Non-traditional reinforcing materials for concrete structures*.

A list of all parts in the ISO 13180 series can be found on the ISO website.

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## Introduction

Strain hardening fibre-reinforced cementitious composites (FRCCs) have been demonstrated to have superior tensile strength, ductility, energy absorption capacity and fracture toughness compared to normal concrete. Strain hardening FRCCs include high performance fibre-reinforced cementitious composites (HPFRCCs)<sup>[1,2]</sup>, engineered cementitious composites (ECCs)<sup>[3,4]</sup> and ultra-high-performance fibre-reinforced concretes (UHPRCCs)<sup>[5-9]</sup>. The superior mechanical and material resistance of strain hardening FRCCs compared to normal concrete and strain softening FRCCs have motivated structural engineers to apply them to civil infrastructure and buildings<sup>[6,7,9,10]</sup>.

Strain hardening is defined as the material behaviour observed over a specified tensile strain range following the initiation of cracking, in which the initial peak stress decreases or nonlinear behaviour begins, and the tensile stress subsequently increases to a value exceeding the initial cracking strength. Within the defined strain range, strain hardening is characterized by a monotonic increase in tensile stress with increasing strain. Local stress fluctuations or oscillations are not considered to satisfy the definition of strain hardening unless they are explicitly permitted and technically justified. This definition is intended to ensure an objective interpretation of test results and to enable clear identification of the peak tensile stress associated with strain-hardening behaviour.

The use of strain hardening FRCCs is highly expected to enhance the mechanical resistance of infrastructure and buildings especially under extreme loads including earthquakes, impacts and blasts. Moreover, the smaller width of multiple micro cracks of strain hardening FRCCs compared to that of normal concrete and strain softening FRCCs is expected to enhance the durability of structural members and eventually to lengthen the service life of infrastructure and buildings.

However, the use of strain hardening FRCCs is still very limited even though there have been increasing applications of those strain hardening FRCCs. The reasons for limited applications of strain hardening FRCCs are the absence of International Standard test methods and design codes in addition to the high cost of strain hardening FRCCs versus normal concrete<sup>[10]</sup>. Current ISO standards such as ISO 19044, ISO 21022 and ISO 21914 are applicable for evaluating the uniaxial and biaxial flexural behaviour of FRCCs, but not the uniaxial tensile response of strain hardening FRCCs.

Although many research papers have reported direct tensile stress versus strain response of various HPFRCCs, ECCs and UHPRCCs, the responses were obtained from the specimens with different geometry and different test setups<sup>[4,7]</sup>. Consequently, it is difficult to quantitatively compare the tensile resistance of various strain hardening FRCCs for the purpose of design consideration without standard test methods.

The test method defined in this document specifies requirements for specimen geometry and test setups of strain hardening FRCCs under direct tension. The reported test parameters of various strain hardening FRCCs using this document are expected to be classified into several categories of strain hardening FRCCs for structural engineers, contractors, etc. The tensile parameters are determined from the measured tensile stress versus strain curve obtained by testing a specimen under uniaxial tension without any parasitic bending moment during the test.