Construction and Building Materials 71 (2014) 510–520

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Mechanical properties of high performance fiber reinforced cementitious composites

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HIGHLIGHTS

- Compressive and flexural strength of HPFRCC follow normal distribution.
- Linear relationship exists between flexural and compressive strength of HPFRCC.
- Increasing fiber content improves mechanical properties of HPFRCC.
- Increasing fiber content enhances first crack and failure strength of HPFRCC.

ARTICLE INFO

Article history:
Received 6 February 2014
Received in revised form 21 August 2014
Accepted 24 August 2014
Available online 20 September 2014

Keywords:
Compressive strength
Flexural strength
Impact resistance
Statistical data analysis
Probability distribution
Energy absorption

ABSTRACT

Extensive experimental studies on High Performance Fiber Reinforced Cement Composites (HPFRCC) owing to their remarkable properties have been carried out. Statistical studies have been mainly focused on Fiber Reinforced Concrete (FRC). An extensive study, including an experimental/statistical approach addressing key mechanical properties (compressive and flexural strength) and impact resistance of such high performance composites with inclusion of different volume of fibers has been carried out on two-hundred and forty specimens in this research.

Results from this study revealed that compressive and flexural strength as well as impact resistance of HPFRCC follow the normal distribution. Furthermore, statistical data analyses (both parametric and non-parametric) showed higher percentage of fibers led in greater values for mechanical properties and impact resistance of HPFRCC. Moreover, based on acquired test results, equations were developed between mechanical properties and impact resistance of HPFRCC materials.

1. Introduction

High Performance Fiber Reinforced Cementitious Composites (HPFRCC) is a class of fiber cement composites with fine aggregates, demonstrating remarkable properties such as improved resilience and sustainability. HPFRCC materials also exhibit improved properties compared with normal concrete (NC) and/or Fiber Reinforced Concrete (FRC) in terms of higher ductility, durability and energy dissipation capacity. This material can be characterized by a pseudo-ductile tensile strain hardening behavior with multiple cracking prior to failure [1,2]. Tensile behavior of NC, FRC and HPFRCC materials are compared in Fig. 1. This figure clearly exhibits three distinct behavior upon cracking. When concrete, mortar or FRC are subjected to tension, brittle degrading behavior at first cracking due to inability to transfer tensile stresses across the crack surface is observed. In contrary, HPFRCC materials undergo multiple cracking after first cracking, exhibiting a

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http://dx.doi.org/10.1016/j.conbuildmat.2014.08.068
0950-0618/

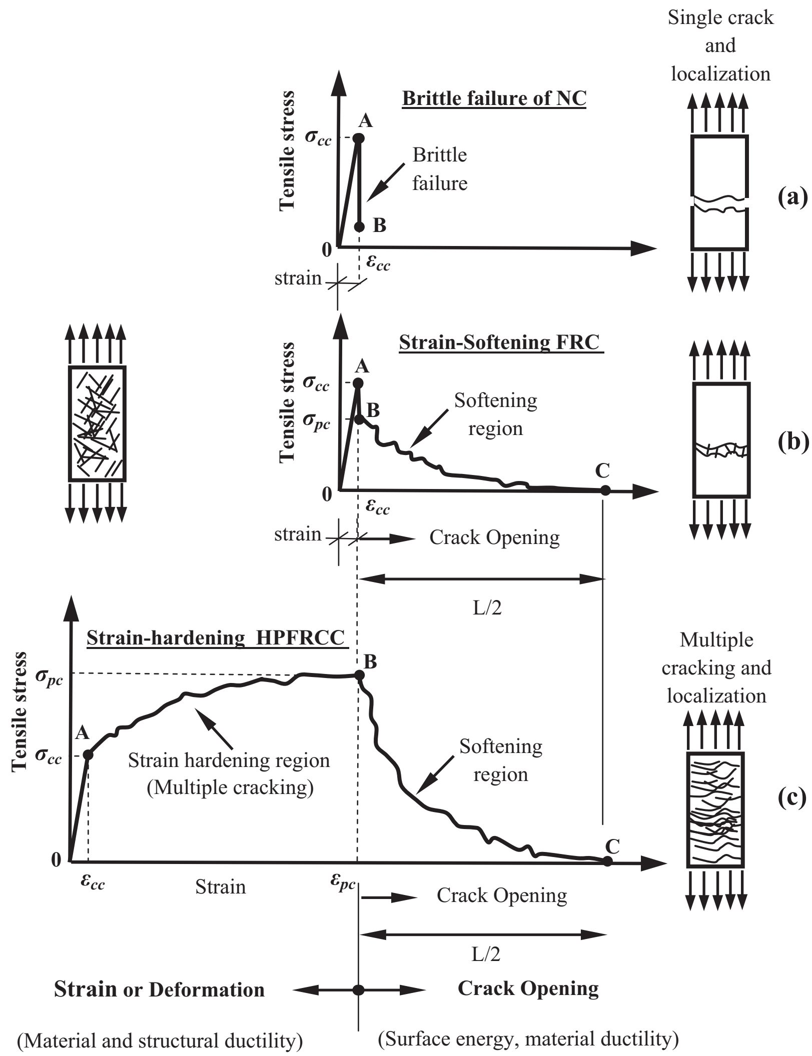

Fig. 1. Typical tensile stress–strain or deformation relation up to failure of: (a) normal concrete (NC); (b) Fiber Reinforced Concrete (FRC); and (c) High Performance Fiber Reinforced Cementitious Composites (HPFRCC), adopted from [2,10].

Table 1
Typical mechanical and physical properties of ECC [8].

Compressive strength	First cracking strength (MPa)	Ultimate tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Ultimate tensile strain (%)	Density (g/cm^3)
20–95	3–7	4–12	10–30	18–34	1–8	0.95–2.3

hardening behavior, i.e., strength increase after first cracking. Only for the HPFRCC materials the post cracking strength, σ_{pc}, is higher than the first cracking strength, σ_{cc}.

In recent years, a new class of HPFRCC materials called engineered cementitious composites (ECC) has emerged, offering promising solutions for structures with longer service life featuring enhanced structural performance. Developed at the University of Michigan, ECC exhibits a typical moderate tensile strength of 4–6 MPa and ductility of 3–5% [3]. Besides, other types of ECC materials including self-consolidating ECC, early high strength ECC, light weight ECC and green ECC were introduced and studied by various researchers [4–7]. Typical Mechanical and physical properties of ECC material is presented in Table 1 [8]. Polyvinyl alcohol (PVA) fibers have been widely used in development of ECC materials. However, fiber selection depends on different parameters including: (1) fiber properties (diameter, surface roughness and mechanical behavior), (2) characteristics of matrix (crack resistance and fiber–matrix interfacial bonding strength), (3) performance objectives of ECC (desired properties, durability, and sustainability), and (4) cost considerations of ECC materials in filed applications [9].

As set forth earlier and illustrated in Fig. 1, adding fibers into concrete may enhance concrete mechanical properties, including flexural strength, fracture toughness, thermal shock strength, fatigue strength and impact resistance [10–15]. Many studies revealed the superior performance of HPFRCC materials based on its observed static mechanical properties. Little research has been undertaken on the loading rate effect on the mechanical behavior of HPFRCC materials. Behavior of fiber, matrix and the interfacial bond between them is dependent on loading (strain) rate [2]. Thus, impact tests are valuable tools to characterize completely the behavior of HPFRCC materials under high strain rate loadings.