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Advanced concretes for high temperature applications

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1 Abstract

The mechanical properties of concrete deteriorate at high temperatures. Strain-hardening cementitious composites (SHCC) are a special class of fiber-reinforced concretes that exhibit strain-hardening behavior in direct tension. The mechanical behavior of a SHCC made using polyvinyl alcohol (PVA) fibers is characterized after exposure to temperatures up to 800°C. The effects of temperature on compressive strength, splitting tensile strength and modulus of rupture are reported. For comparison, a normal strength conventional concrete of similar compressive strength to the SHCC was heated and tested in the same conditions as the SHCC. The normalized tensile strength of SHCC at room temperature, and after exposure to high temperature, is significantly greater than the value for conventional concrete. The PVA fibers provide crack-bridging capacity up to about 200°C (melting point of PVA fibers is 230°C), leading to improved tensile behavior. At greater temperatures, the fibers melt, creating pathways for steam to escape, reducing micro-cracking and significantly improving mechanical behavior with respect to conventional concrete. SHCC is a robust alternative to conventional concrete for high temperature applications.

Keywords: Concrete; fire; high temperature; fiber-reinforced concrete; SHCC; compressive strength; tensile strength.

2 Introduction

The mechanical properties of concrete, similar to other materials, deteriorate with a significant increase in temperature above ambient. Structural design standards, such as Eurocode 2, recommend a reduction of about 20% and 80% in concrete compressive strength at 400°C and 800°C, respectively. The deterioration in concrete properties stems from a variety of physicochemical changes taking place in concrete's ingredients and microstructure. At temperatures of up to 400°C, the primary source of damage is the conversion of water to steam and its expansion, resulting in micro-cracking and spalling. This, combined with the thermal incompatibility between aggregates and cement paste, causes deterioration of concrete strength and elastic modulus. At temperatures greater than 400°C, the chemical decomposition of the hardened cement paste further degrades the mechanical properties of concrete [1-4].

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