Fire resistance of ultra-high performance fibre reinforced concrete due to heating and cooling

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Abstract. This study investigated the performance of ultra-high performance fibre reinforced concrete (UHPFRC) at elevated temperatures. The specimens were exposed to high temperatures, specifically 200, 400, and 600 °C, for 2 h.The fire resistance performance of the specimens was classified on the basis of their compressive strength, spalling, and weight loss; residual strength after heating was also examined. Results showed that UHPFRC processes excellent fire resistance in terms of flame spread and fire growth. While strength loss was not significant at low temperatures, the specimen subjected to high temperature spalled severly and showed deterioration because of heat.

1 Introduction

Ultra-high-performance fiber-reinforced concrete (UHPFRC) is a breakthrough in modern concrete mix design with compressive strengths benchmarking 150 MPa and above and tensile strengths of over 10 MPa. Previous studies clearly show the advantages of using high-performance fiber-reinforced cementitious composites, such as UHPFRC, engineered cementitious composites, and slurry-infiltrated concrete, in structural members under static loading conditions [1-3]. In a related study, [4] found that UHPFRC has outstanding material characteristics, such as self-consolidating workability, very high mechanical properties, and low permeability, all of which result in excellent environmental resistance. Millon et al. [5] reported that UHPFRC can significantly improve the impact resistance of cladding panels and walls while maintaining its standard thickness and appearance. UHPFRC is a cementitious composite reinforced by fibers with characteristic values exceeding 150 N/mm^2 in compressive strength, 5 N/mm^2 in tensile strength, and 4 N/mm^2 in first cracking strength [6]. This concrete also shows compressive strengths over seven times and tensile strengths greater than three times those of conventional concrete [4]. The fibers in UHPC provide tensile capacity across cracks, resulting in high shear capacity in bending members. These fibers improve tensile strength. Parsekian et al. [7] reported that small brass-coated steel fibers with a diameter of 0.185 mm and a length of 14 mm are commonly used as reinforcements in UHPC. Synthetic fiber and poly-vinyl alcohol have also been used [8]. The high compressive strength of UHPFRC is achieved by the densely packed state of the cement matrix, and its tensile strength is attributed to steel or polypropene fibers embedded in the matrix. The superior characteristics of UHPRFC allow its use in different applications that demand high strength and durability, including bridges, tunnels, and high-rise buildings. Massive structures may be at risk and endanger lives if UHPFRC is not resistant to fire exposure. Conventional fiber-reinforced concrete exhibits good capacity to absorb impact energy [9].

Despite the positive characteristics of these structures, they are still susceptible to fire. Fire exposure induces temperatures of up to 1000 °C, which could be detrimental to the structural integrity of UHPFRC. Water stored in the fine pores of the dense matrix evaporates under temperature extremities, and pressure builds up internally. When stresses cannot be withstood, explosion of concrete follows, a phenomenon known as spalling. Unfortunately, spalling is unpredictable; it can occur during the heating or cooling of UHPFRC. The behavior of UHPFRC during and after fire exposure requires further study to fully understand the mechanism of failure and risks in using this concrete [10].

The present research principally focuses on the fire reactions of UHPFRC. In this work, two types of UHPFRC mixes are prepared and subsequently subjected to high temperatures and fire resistance tests to observe their physical characteristics, spalling, and strength loss. Considering that the behavior of the concrete under fire is unknown, this research assists in understanding how the product behaves during fire. Use of UHPFRC not only reduces the amount of concrete required but also increases the serviceability and durability of the resulting structures. Understanding fire resistance is crucial to gain

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