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Influence of fire on temperature gradient and physical-mechanical properties of macro-synthetic fiber reinforced concrete for tunnel linings

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HIGHLIGHTS

- Temperature gradient was found to increase with the duration of fire, and to reduce at greater distances from the fire.
- The temperature inside the MSFRC seems to increase at a constant rate as a function of the distance from the fire only.
- MSFRC loses residual flexural strength with fire exposure both in SLS and ULS.
- The compressive strength and elastic modulus of MSFRC gradually reduce with temperature increase.

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ABSTRACT

This study aims to evaluate the effect of fire on the physical, mechanical, and microstructural properties of macro-synthetic fiber reinforced concrete. Results demonstrated that internal heating rate is constant through time and is a function of the distance from the fire. Temperature gradient values are nonlinear, reduce at greater distances from the heated surface and with the duration of the fire. Microstructural analysis shows the severe dehydration of hydrated products, which negatively influences the mechanical properties of the composite. Above 205 °C the formation of nesosilicates is verified. Residual flexural strength values reduce by over 85% after the fire exposure due to deterioration of the reinforcing mechanism. Compressive strength and elastic modulus drastically reduce with temperature increase. The present study contributes to the absent literature on the post-fire mechanical behavior of MSFRC, suggests an alternative approach to the post-fire evaluation of tunnel structures, and aids in the definition of post-fire safety parameters.

1. Introduction

Fiber reinforced concrete (FRC) is a composite material that has proven to be a competitive material for structural applications [1–3]. The use of FRC is particularly interesting since it enhances toughness, provides a pseudo-ductile behavior to plain concrete, and improves mechanical properties such as resistance to fatigue [4]. In particular, the use of FRC for the production of segmental linings of tunnels built by means of Tunnel Boring Machines (TBM) has many advantages [5–9]. The advantages in this application are mainly associated with the material's response to impact and the diffused loads that may occur during production (e.g. storage, transportation, handling), concentrated loads (e.g. thrust of the jacks), and service stage (e.g. irregular loads resulting from the contact between the tunnel lining and the soil). It is important to mention that only service conditions are relevant references for tunnel safety assessment in the event of a fire since the possibility of fire affecting the segments under transient conditions would entail the elimination of their application.

In the fabrication of segments, the use of steel fibers as total or partial substitution to steel bars have proven to improve production efficiency, economic competitiveness, and performance related to corrosion [5,10–12]. As a complementary alternative to steel fibers, the use of macro-synthetic fibers may provide environmental benefits, such as reduction in carbon footprint [13]. It also ensures compliance with the requirements for flexural, splitting and minimum shear reinforcement, and also to static spalling

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