Predictive testing for heat-induced spalling of concrete

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Abstract

This paper describes a project which sets out to define a practical predictive test method for heat-induced explosive spalling of concrete. The method is based on a novel testing apparatus known as the Heat-Transfer Rate Inducing System (H-TRIS), previously developed at The University of Edinburgh. A series of 75 samples were tested using a large-scale standard fire testing furnace at CERIB (France) and using H-TRIS in Edinburgh. Within the scope of this project, a thorough examination of the thermal exposure was carried out in order to ensure repeatability of the thermal exposure imposed during testing. The H-TRIS method and apparatus was successful in accurately replicating the thermal exposures experienced by samples in the fire testing furnace when testing to both the ISO 834 and modified hydrocarbon (HCM) standard fire curves. The testing has also provided insights into the influence of sample size, polypropylene fibre content, and moisture content on the propensity for heat-induced concrete spalling.

Keywords: Concrete spalling; H-TRIS; HCM; Thermal Exposure; Polypropylene; Fire testing; Polypropylene fibres

1 Introduction

Despite more than a century of study [1], heat-induced spalling of concrete during fires remains poorly understood [2]. There is no systematic method to predict or test for spalling resistance, nor any validated guidance for designing concrete mixes to avoid heat-induced spalling. As a result, spalling continues to pose a serious and difficult to quantify risk during design, construction, and operation of concrete structures, including bridges. This is of greatest concern where modern, high performance, low permeability concretes are used, and when there is risk of rapid fire growth (e.g. tunnels).

In the majority of fire incidents where heat-induced spalling occurs, substantial repair works are required. The fire at Deans Brook viaduct (UK) in 2011 [3] is one of many examples where severe fire damage, and therefore disruption to critical infrastructure, was caused by spalling during fire (Figure 1). Fires causing damage to bridges are unlikely to pose a risk to life safety in most cases, but in many cases will have a considerable impact on transport networks and indirect economic losses. Whilst historically fire has not been seriously considered as a significant risk to transport infrastructure, a number of recent fires causing failures of bridges has led to an increased interest in this issue globally [4]. A predictive test method needs to be established so that bridge and structural engineers can begin to properly understand and quantify spalling risk on real projects.

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