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Mechanical behaviour of steel fibre reinforced SCC after being exposed to fire

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Abstract. The focus of this paper is given to the investigation of mechanical properties of steel fibre reinforced self-compacting concrete after being exposed to fire. The research programme covered tests of two sets of beams: specimens subjected to fire and specimens not subjected to fire. The fire test was conducted in an environment mirroring one of possible real fire situations where concrete surface for an extended period of time is directly exposed to flames. Micro-cracking of concrete surface after tests was digitally catalogued. Compressive strength was tested on cube specimens. Flexural strength and equivalent flexural strength were tested according to RILEM specifications. Damages of specimens caused by spalling were assessed on a volumetric basis. A comparison of results of both sets of specimens was performed. Significant differences of all tested properties between two sets of specimens were noted and analysed. The limit of proportionality method proved to be not feasible for testing fire damaged beams. Flexural characteristics of steel fibre reinforced self-compacting concrete were significantly influenced by fire. The influence of fire on properties of steel fibre reinforced self-compacting concrete was discussed.

Keywords: concrete; fire; fibre; SCC; SFRC

1. Introduction

One of the key advantages of using steel fibre reinforced concretes (SFRC) instead of traditionally reinforced (by re-bars and stirrups) concrete is their much higher resistance to fire. The presence of a dispersed steel in the whole volume of concrete influences its thermal conductivity. SFRC can reach thermal conductivity up to 40% higher than ordinary concrete (Blesak *et al*. 2016). High thermal conductivity allows SFRC to quickly dissipate heat in much larger volume than in ordinary concrete. This way, significantly longer time is needed by SFRC to start chipping and spalling.

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Explosive spalling is also limited by the presence of fibre (Ding *et al.* 2016). The coefficient of thermal expansion is not influenced by fibre reinforcement (Firmo and Correira 2015). All the above facts make SFRC particularly suited for specialised applications where fire resistance is the key factor for the safety of a structure. Traditionally, underground structures were considered as especially vulnerable to fire, thus SFRC is becoming a popular main construction material for shield tunnel segments and similar elements (Yan *et al.* 2015). Currently, terrorist-proof structures are quickly becoming the main application of SFRC due to its desired dynamic characteristics (Cichocki and Ruchwa 2015). These structures, apart from being resistant to impact and blast loadings are also foreseen to resist effects of subsequent fire. The characteristics of fire taking place in confined underground or closed space and fire taking place in open air is very different (Taylor *et al.* 1992). So far, the majority of fire tests of ordinary concrete and SFRC have been realized to mimic the conditions in confined underground or closed space (Šimonová *et al.* 2018a, Šimonová *et al.* 2018b). There is a need to fill the gap in knowledge about behaviour of SFRC in an open air fire scenario. One should also take into account new types of concrete matrix used for creation of fibre concrete. The newest trend in development of SFRC is utilizing self-compacting concrete (SCC) as a matrix for fibre reinforcement. The concept of SCC was born in Japan in late 1980s and first full scale applications took place in the 1990s (Okumura and Ozawa 1996). Combining SFRC and SCC (SFR-SCC) has a wide range of potential of previously unknown structural applications (Ponikiewski and Katzer 2015). Fibre spacing in SFR-SCC is different than in ordinary SFRC (especially when considering thin elements). It was also proven that fibre spacing in SFR-SCC elements varies due to the casting process, mix flow rate, the wall effect, the location of mix casting point and the proximity to the bottom of a mould (Bui *et al.* 2003, Bywalski and Kamiński 2011, Martinie and Roussel 2011). The mix composition of SFR-SCC differ significantly from ordinary SFRC due to fineness of used aggregate, amount of used: cement, water, fine fillers and volume of added chemically active admixtures. The volume and spacing of air pores is also different in hardened SFR-SCC than in ordinary SFRC (Ponikiewski and Gołaszewski 2016, Ponikiewski and Katzer 2016). All the above facts influence behaviour of SFR-SCC when exposed to fire. Multiple differences between internal structure of SFRC and SFR-SCC disable utilizing knowledge about behaviour of SFRC under fire loading for forecasting behaviour of SFR-SCC under fire loading. Moreover, majority of research programmes focused on fire resistance of SFRC were conducted using only high temperature environment (Abdallah *et al.* 2017, Arioz 2009, Dugenci *et al.* 2015, Guerrieri *et al.* 2009, Hager *et al.* 2015). Such tests gave us thorough knowledge about thermo-hydral processes taking place inside concrete but do not reflect majority of real fire situation. Specimens placed in a lab oven with uniformed and stable high temperature conditions are useful for following the phenomenon of generating high pore pressure and pressure gradients but do not mirror exposure of concrete surface to flames which takes place in many of real fire scenarios. Such scenarios are particularly important in case of open air civil engineering structures vulnerable to terrorist attacks such as bridges, dams, towers, large scale retaining walls, piers etc. Taking into consideration the above facts, authors decided to conduct a research programme focused on SFR-SCC which would create fire test environment as close to a real fire scenario as possible, including extinguishing process. On the other hand SFR-SCC specimens were prepared using casting procedures used on an average construction site. The size of cast specimens was in scale of 1:2 of a real-life precast elements. Different types of surfaces exposed to fire were of interest, too. The main aim of the research programme was to test mechanical properties of hardened SFR-SCC being exposed to fire for one hour and then extinguished using cold water. Mechanical characteristics of SFR-SCC subjected to fire and