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Local bond–slip behavior of medium and high strength fiber reinforced concrete after exposure to high temperatures

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ABSTRACT

This study aims to investigate the influence of individual and hybrid fiber on the local bond–slip behavior of medium and high strength concrete after exposure to different high temperatures. Tests were conducted on local pullout specimens (150 mm cubes) with a reinforcing bar embedded in the center section. The embedment lengths in the pullout specimens were three times the bar diameter. The parameters investigated include concrete type (control group: ordinary concrete; experimental group: fiber concrete), concrete strength, fiber type and targeted temperature. The test results showed that the ultimate bond stress in the local bond stress versus slip curve of the high strength fiber reinforced concrete was higher than that of the medium strength fiber reinforced concrete. In addition, the use of hybrid combinations of steel fiber and polypropylene fiber can enhance the residual bond strength ratio of high strength concrete.

1. INTRODUCTION

Reinforced concrete (RC) is by far one of the most widely used construction material in the world. In general, the performance of RC structures depends mainly on sufficient bond strength between reinforcing steel and surrounding concrete (ACI Committee 408 2003, Golafshani et al. 2012, Alexandre et al. 2014, Deng et al. 2014, Golafshani et al. 2014a, Golafshani et al. 2014b, Dehestani and Mousavi 2015, Golafshani et al. 2015, Mo et al. 2015, Tang 2015, Choi and Lee 2015, Zhang and Yu 2016, Tang 2017). According to the ACI 318 (ACI Committee 318 2014), bond stress is a shear stress transmitted along the interface between reinforcing steel and surrounding concrete. Basically, the bond behavior between rebar and surrounding concrete is mostly composed of three resistance mechanisms: adhesion, friction

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resistance, and rib support. Among them, rib support is the most important mechanism. However, the bond performance in RC structures under elevated temperatures will gradually decline owing to incompatible dimensional changes between cement paste and aggregate. As a result, the structural performance of RC structures will be seriously affected.

Based on compressive strength, concrete can be classified into four broad categories: low strength concrete (less than 20 MPa), moderate strength concrete (20 to 40 MPa), high strength concrete (more than 40 MPa), and ultra high strength concrete (more than 150 MPa). However, the bottom range of strength of various concrete varies with time and geographical location. In the North American practice (ACI 318, 1999), high strength concretes (HSCs) are those that attain cylinder compressive strength of at least 41 MPa at 28 days. While, in the FIP/CIB (1990) state-of-the-art report on high strength concrete, it is defined as concrete having a 28-day cylinder compressive strength of 60 MPa. In the study, medium strength concrete is tentatively defined as the concrete having the strength of 40-60 MPa, while HSC is defined as the concrete having the strength of more than 60 MPa. HSC has many advantages, which have been widely used in various construction projects. For instance, the use of HSC can reduce size and reinforcement in structural members, such as columns, and increase useable space, especially in high-rise buildings.

High temperature will cause the volume change of concrete, which is the sum of the changes in volume of cement paste and aggregate. In particular, HSC exposed to an abrupt temperature rise is more likely to lead to explosive spalling, which refers to a sudden and violent breaking away of a surface layer of heated concrete. The spalling is caused by the thermal stress due to the temperature gradient during heating (Ko et al. 2011). In view of this, there are many studies to explore the spalling behavior of HSC subjected to elevated temperatures. For instance, the use of fiber reinforced concrete (FRC) is a viable option (Mehta and Monteiro 2006). Compared with ordinary concrete, FRC has better toughness and impact resistance (Xiong and Richard Liew 2015, Xu et al. 2016, Kim et al. 2016, Lee and Yi 2016, Kim et al. 2017, Nematzadeh and Poorhosein 2017, Saleem 2017). Varona et al. (2018) investigated the influence of high temperature on the mechanical properties of hybrid fiber reinforced normal and high strength concrete. Their test results showed that the effect of high temperature on the residual mechanical properties of hybrid fiber reinforced concretes was less severe than in steel fiber reinforced concretes found in previous references. On the other hand, it was observed that polypropylene fibers can mitigate or prevent the explosive spalling (Poon et al. 2004, Siddique and Kaur 2012, Ding et al. 2012, Ozawa and Morimoto 2014, Yan et al. 2015). This is because the polypropylene fibers melt after the temperature inside concrete reaches approximately 170 °C, which produces micro channels for release of vapor pressure of concrete; and thus, the amount of heat absorbed is less for dehydration of chemically bound water (Bilodeau et al. 2004, Kodur 2014, Xiong and Richard Liew 2015). However, at different temperatures, the effect of polypropylene fiber on compressive strength and flexural strength of HSC with different strength levels is very different, that is, its recovery strength is questioned (Chan et al. 2000, Poon et al. 2004).

In view of the above considerations, the microstructure and mechanical properties of concrete under elevated temperatures may significantly deteriorate and thus affect