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Local bond–slip behavior of fiber reinforced LWAC after exposure to elevated temperatures

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Abstract. The effect of individual and hybrid fiber on the local bond–slip behavior of lightweight aggregate concrete (LWAC) after exposure to elevated temperatures was experimentally investigated. Tests were conducted on local pullout specimens (150 mm cubes) with a reinforcing bar embedded in the center section. The embedment lengths of the pullout specimens were 4.2 times the bar diameter. The parameters investigated included concrete type (control group: ordinary LWAC; experimental group: fiber reinforced LWAC), concrete strength, fiber type, and targeted temperature. The test results showed that for medium-strength concrete, the use of steel fibers did not significantly improve the residual bond strength of LWAC after exposure to elevated temperatures. Moreover, the addition of fiber on the residual bond strength of high-strength LWAC after exposure to a temperature of 800 °C was not significant.

Keywords: fiber reinforced lightweight aggregate concrete, residual bond strength, pullout test

1. Introduction

Lightweight aggregate (LWA) with a smaller unit weight or specific gravity can be used to replace ordinary aggregate to produce lightweight aggregate concrete (LWAC) (Somayaji 2001). The use of LWAC can reduce structural weight by more than 20%, and thus effectively decreasing the seismic loads on building structures (Chandra and Berntsson 2002, Tang 2015, Tang 2017). It also can reduce the installation and transportation costs of pre-cast members. However, LWAC exhibits higher brittleness and lower mechanical properties than normal weight concrete (NWC) of the same compressive strength (Gao *et al.* 1997, Hassanpour *et al.* 2012). Studies have shown that the use of fibers in LWAC is a suitable solution to resolve such problems (Ding and Kusterle 2000, Li 2002, Mehta and Monteiro 2006).

According to the nature of fiber, it may be classified into the metallic fiber, inorganic fiber, and organic fiber. Fibers of various shapes and sizes made of steel, plastic, glass, and natural materials are often used in concrete (Metha and Monteiro 2006). Incorporation of fibers will affect the fresh and mechanical properties of concrete, depending on the type and percentage of fiber (ACI Committee 544 1982, Nematzadeh and Poorhosein 2017). In general, the incorporation of fibers in LWAC, as single or hybrid forms, can improve its mechanical properties, and significantly increase

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its toughness, ductility performance, and energy absorption, while decreasing its workability, particularly when steel fiber is used in LWAC mixture (Campione *et al.* 2005, Kurugol *et al.* 2008, Hassanpour *et al.* 2012).

In reinforced concrete (RC) structures, the bond strength between reinforcing steel and surrounding concrete plays a crucial role, which is the essential element for concrete and steel to work together as a kind of composite material (ACI Committee 408 2003). The effect of rebar diameter, rebar embedded length in concrete, concrete strength and type, cover thickness, and crack spacing on the bond strength between rebar and concrete has been extensively investigated. (Hossain 2008, Alexandre *et al.* 2014, Deng *et al.* 2014, Golafshani *et al.* 2014, Dehestani and Mousavi 2015, Mo *et al.* 2015, Choi and Lee 2015, Kim *et al.* 2016, Lee and Yi 2016, Xu *et al.* 2016, Zhang and Yu 2016, Al-Shannag and Charif 2017, Bilek *et al.* 2017, Saleem 2017, Ahmad *et al.* 2018, Tang 2018). Overall, their test results indicated that the load-slip behavior of the deformed steel bars embedded in concrete was mainly dependent on concrete compressive strength, diameter of rebar, and length of rebar embedment. Moreover, the lower particle strength in LWAC resulted in lower bond splitting strengths and reduced post-elastic straining as compared to NWC. Therefore, ACI 318-14 recommended some correction factors to reflect the lower tensile strength of LWAC, which can reduce shear strength, friction properties, splitting resistance, bond between concrete and reinforcement, and increase development length, compared with NWC of the same compressive strength. (ACI 318-14 2014).

Personal safety in the event of a fire is one of the important considerations in residential, public, and industrial building design. Once the firing temperature reaches the critical concrete temperature of 500 °C, the structural performance of RC structures will be seriously degraded (Newman and Choo 2003). In essence, a concrete behavior is the result of many simultaneous interactions when exposed to high temperatures. Generally, the high temperature will cause the dimensional change of concrete, which is the sum of the changes in the volume of cement paste and aggregate (Metha and Monteiro 2006). In particular, the bond performance in RC structures under elevated temperatures will gradually decrease owing to incompatible dimensional changes between cement paste and aggregate. Moreover, high strength concrete (HSC) in an environment with a rapid increase in temperature is more likely to lead to explosive spalling that is caused by thermal stress due to temperature gradient during heating (Ko *et al.* 2011). This has greatly compromised the structural integrity of RC structures. Therefore, the spalling behavior of HSC subjected to elevated temperatures has attracted many researchers' interest (Xiong and Richard Liew 2015). The literature shows that polypropylene fibers can mitigate or prevent explosive spalling (Poon *et al.* 2004, Ding *et al.* 2012, Ozawa and Morimoto 2014, Yan *et al.* 2015). This is mainly due to the fact that polypropylene fibers melt after the temperature inside concrete reaches approximately 170 °C, which produces micro channels for the release of the vapor pressure in concrete (Bilodeau *et al.* 2004, Kodur 2014, Xiong and Richard Liew 2015).

In view of the above considerations, the microstructure and mechanical properties of concrete under elevated temperatures may significantly deteriorate and thus affect the bond performance in RC structures. The review of the literature indicates that little research has been undertaken to investigate the role of fibers in maintaining the post-heating bond between LWAC and steel rebar. Further study of the bond behavior of LWC after high temperatures should contribute to the enhancement of existing code provisions for LWAC. Therefore, this study aimed at investigating the local bond–slip behavior of various fiber-reinforced LWACs after exposure to elevated temperatures.