Critical Temperatures for Splitting of FRP-reinforced Concrete with Thermal Expansion

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Summary

Fiber reinforced polymer (FRP) bars have been widely used as substitutes for traditional steel bars to prevent reinforced concrete structures from corrosive environments. However, under elevated temperatures, the low compatibility of transverse coefficients of thermal expansion between FRP and concrete can cause splitting of the concrete cover. As a result, the bonding of FRP-reinforced concrete may not sustain its function to transfer load between the FRP rebar and the surrounding concrete.

The current study investigates the splitting resistance of FRP-reinforced concrete against the thermal expansion based on a mechanical model. The proposed model adopts the thick-wall cylinder theory by subdividing the concrete cover into two zones, i.e. cracked and uncracked. The concrete that does not crack is considered to sustain its elastic behaviour whereas the tensile softening behavior is employed for cracked concrete. The proposed model is then used to estimate the critical temperature increment at which the splitting failure of the concrete cover occurs. The predicted critical temperature increments are compared with the results obtained from the previous experiments and formulations. A simplified equation for estimating the critical temperature increments is also derived for the design purpose. Based on the critical temperature increments, structural engineers can evaluate the safety of FRP-reinforced concrete members from concrete splitting under elevated temperatures.

Keywords: thermal expansion; FRP reinforced concrete; splitting crack; tensile softening.

1. Introduction

Fiber reinforced polymer (FRP) bars can be used in concrete structures to avoid the corrosion problem of traditional steel bars. The composite material of FRP (fibers, organic or inorganic, and a polymeric resin) causes an anisotropic behavior for both mechanical and thermal properties. For the thermal properties, the transverse coefficient of thermal expansion (transverse CTE) of FRP is higher than that of concrete [1]. Under elevated temperatures, the differential thermal expansion of the FRP bar and concrete can be considered as the thermal pressure at the FRP bar-concrete interface which is resisted by the radial splitting resistance of the surrounding concrete. Once the thermal radial pressure exceeds the splitting resistance of concrete, the concrete cover may split. Many previous experimental results have shown that the concrete cover of FRP-reinforced concrete can split at a certain temperature increment, the so-called critical temperature increment [2 – 4]. The splitting phenomenon degrades the bond strength and may cause the bonding failure of FRP-reinforced concrete [5].

To investigate the splitting resistance of FRP-reinforced concrete under elevated temperatures, the current study incorporates the effect of the thermal pressure due to thermal expansion by using a mechanical model based on the thick-wall cylinder theory [6], Tepfers' model [7] and a tensile softening model of Wang and Liu [8]. The proposed model is used to estimate the critical temperature increments, which are verified herein through a comparison with the results obtained

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