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Using modified core drilling method to estimate the damage of fire exposed concrete

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Abstract

In a fire scenario, the temperature gradient in concrete structural member leads to damage gradient. However, the traditional detection methods have issues in determining the damage gradient of concrete in post-fire assessment. The present study aims to propose a novel method to solve the problem. A special drilling machine was retrofitted to perform core drilling on damaged concrete under constant pressure. The rate of steel bit penetrating was adopted to reflect the damage variation induced by elevated temperatures. To validate the proposed method, a series of experiments were conducted on concrete specimens heated to different temperatures. The rate of penetration (ROP) was found significantly related with elevated temperatures. Comparative study was carried out on the obtained values of ROP, ultrasonic pulse velocity, compressive strength, tensile strength, loss of ignition (LOI) and hardness of concrete after thermal treatment. By comparison, ROP is demonstrated sensitive to the fire damage of concrete and has the possibility of revealing the fire damage gradient in concrete with satisfied accuracy for engineering practice.

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Keywords: fire damage; concrete; damage gradient; core drill; rate of penetration;

1. *Introduction*

In recent years, numerous researchers studied the mechanical properties of concrete after elevated temperatures. The experimental investigations demonstrate the elevated temperatures have negative effects on compressive strength, tensile strength and elastic modulus of concrete, but with different levels [1,2]. When a steel reinforced

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concrete (RC) structure is exposed to fire, the low heat conductivity of concrete results in temperature gradient in the depth direction of concrete. Due to the existence of temperature gradient, fire damage varies inside RC member. Generally, concrete near the fire-exposed surface suffers more serious damage than the internal region does. To accurately evaluate the mechanical reduction of fire-damaged concrete, a number of techniques were developed by researchers and engineers, which can be classified as qualitative method and quantitative method.

Erlin B [3]introduced some qualitative methods, for example visual examination and hammer impact, to evaluate the near-surface damage of concrete exposed to fire. The qualitative methods are high efficient and convenient in application, but suffer a tremendous influence from human factor. Moreover, they always have the issues in detecting the damage gradient in concrete.

A number of researchers proposed quantitative methods to obtain the fire damage of concrete both in mechanical and non-mechanical aspects. 1) the modified mechanical methods. A variety of techniques are available for the mechanical evaluation of concrete at ambient temperature, for example, the rebound hammer test, the ultrasonic pulse velocity method [4] and the compression test on drilled core [5]. Researchers modified these methods and made them adaptable to the fire-damaged concrete. Logothetis L [6] tested two series of concrete specimens with rebound hammer and ultrasonic pulse velocity (UPV) before and after heating, and then established the relations among temperature, rebound value and pulse velocity. Dilek U [7] evaluated the damage in fire damaged RC wall by means of in-situ UPV test. The damaged concrete cores were obtained by core drill machine and sliced for laboratory test. The UPV test on sliced disks showed an advantage over compression test on cores involving damage variation. Yang H et al. [8] conducted a series of tests to examine the relation between UPV and concrete strength of concrete at elevated temperatures. Cylindrical specimens were heated in an electric furnace at the temperatures ranging from 400 ºC to 600 ºC. The relation between the compressive strength and corresponding UPV was expressed as a fitting equation. However, all the modified methods above are incapable to reflect the damage gradient in concrete. Rebound hammer only detects the hardness of near surface concrete. Although ultrasonic wave can propagate in the damaged concrete, it is nearly impossible to determine the specific damage inside. Similar, the uniaxial compression test on drilled core can reliably obtain the comprehensive strength, but not the damage gradient. 2) Non-mechanical methods. Physical and chemical properties of concrete change at elevated temperatures, inducing the reduction in strength of concrete.[9] Experiments were carried out to study the impact of temperature on the physical and chemical changes. Short N R, et al.[10] used color image analysis and optical microscopy to quantify changes in color for concrete subjected to elevated temperatures. Samples were examined in reflected light and measurements of huge, saturation and intensity for color definition. This technique is superior to the subjective visual assessment currently used. The full development of the pink/red color is coincident with substantial reduction in compressive strength and the method may be used to define the distance from a heated surface to where strength degradation has occurred. Acoustic techniques were used to observe the damaged zone by Biolzi L.[11]. Electronic speckle interferometry provided high resolution measurements of the displacement field due to the development of fracture. The size and shape of the localized damage zone were identified through the acoustic emission due to pre-peak micro cracking, one of the significant factors influencing the strength of quasi-brittle materials. Handoo S K, et al. [12] used X-ray diffraction (XRD) and differential thermal analysis/thermal gravimetric analysis (DTA/TGA) to establish the effect of elevated temperatures on the mineralogical changes occurring in the hydrated phases of concrete. Scanning electron microscopy (SEM) studies showed distinct morphological changes corresponding to deterioration of concrete exposed to higher temperatures. The proposed non-mechanical methods can effectively figure out the fire damage gradient in concrete. However, these methods are proposed based on the relations between non-mechanical property and temperature. To evaluate the mechanical deterioration, further relations between non-mechanical property and strength of concrete have to be established. The additional procedure will undoubtedly magnify error and reduce the reliable of damage evaluation. Therefore, how to directly and objectively predict the fire damage gradient of concrete remains one of the main concerns in the study of the fire-damaged RC structures.

With all the points in mind, the present authors are motivated to develop a method, which could be used to directly determine the mechanical damage gradient of concrete and also convenient in engineering application. The principle of method is to reveal the concrete damage gradient by the penetration rate of drilling bit. The following sections introduce the process of retrofitting a commercial core drill machine, developing a motion measure system and validating the proposed method by experimental test. Two points are highlighted in analysis, i.e., the impact of elevated temperature on ROP, and the relation between ROP and the mechanical properties of fire damaged concrete.