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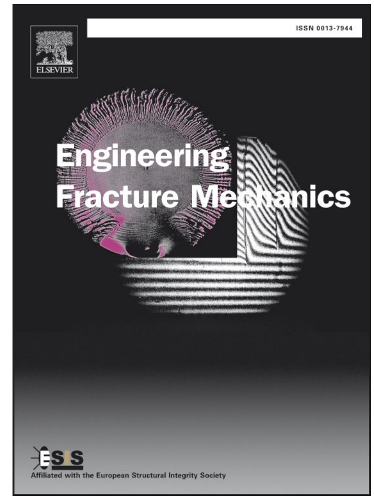

Elevated temperature inversion phenomenon in fracture properties of concrete and its application to maturity model

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ABSTRACT

The effect of elevated curing temperature on the fracture properties of concrete was investigated. Fracture experiments were carried out on wedge splitting specimens exposed to temperatures ranging from 5 to 60 °C. A new maturity model was then proposed for describing the combined influence of the temperature and aging on the fracture properties of concrete. The results show that the fracture energy of concrete subjected to high temperature is high at early ages; however, the effect of curing temperature on the fracture energy was reversed after 14 days, with greater later-age fracture energy corresponding to lower temperature and vice-versa. The effective fracture toughness of concrete also exhibited the same temperature inversion phenomenon. The optimum curing temperature was found to be approximately 40 °C for development of concrete fracture properties. The value of activation energy changed with fracture properties, temperature ranges and the development stage of a given fracture property. The proposed model accurately predicts the fracture properties of concrete and significantly simplifies the calculation process of the maturity index relative to the existing maturity method.

1. Introduction

Concrete structures are often subjected to elevated temperatures owing to hot weather, hydration heat accumulation, high temperature curing, or a combination of these factors. For instance, the maximum temperature in the outer containment of the Taishan Nuclear Power Plant reaches 58 °C [1]. The hydration process of cement at a high temperature is markedly different from that at a normal temperature, thus significantly affecting the concrete performance [2]. The maturity method can be used to estimate the development of fracture behavior of concrete structures under these conditions.

The maturity concept was originally proposed by Saul [3] to describe the combined effect of temperature and aging on the compressive strength. The major drawback of the maturity formulation is the lack of physical meaning, and it is assumed that the temperature has a linear effect on the strength development. The linear approximation was found to be invalid when the curing temperature varies over a wide range [4]. Typically, this temperature function greatly underestimates the effect of temperature at low maturities and overestimates it at high maturities. To improve the disadvantages of Saul’s formulation, several different nonlinear temperature functions have been proposed [5, 6], which were summarized in [7]. Among these functions, the most famous is the equivalent age formula derived from the Arrhenius equation [5]. This formula yields the most accurate prediction and provides insights into the physical meaning of maturity by modeling the rate of cement