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Equivalent maturity for ambient temperature effect on fracture parameters of site-casting dam concrete

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HIGHLIGHTS

- A concept of equivalent maturity suitable for dam concrete was proposed.
- Different age of dam concrete specimens were poured on site in summer and winter.
- Variations of fracture parameters with ambient temperature and age were revealed.
- Relationship between fracture parameters with equivalent maturity were obtained.

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ABSTRACT

This paper presents the influence of ambient temperature on the fracture properties of site-casting (or cast in-situ in other words) dam concrete. By virtue of the mixing tower system in the site of a super-high arch dam, the wedge splitting specimens with the maximum aggregate size of 150 mm were poured in summer and in winter seasons, respectively. The variations of fracture parameters obtained by experiment with different age were revealed, and the results show that the dam concretes poured in summer and in winter seasons show much difference in fracture characteristics at the age of 28 days, however, with the increase of age, the difference in fracture behavior decreased, and was almost zero at the age of 180 days. On top of that, by introducing the concept of equivalent maturity, the relationships between fracture parameters of site-casting dam concrete and equivalent maturity were obtained.

1. Introduction

Many 300 m high (called super-high) concrete arch dams have been being constructed in China. As a specific type of concrete with maximum aggregate size d_{max} = 150 mm, dam concrete is widely used in construction of concrete dams. However, a key problem for dam concrete is its definite cracks, which significantly affects the working performance and safety of super-high arch dams. The reason for cracking is that the construction period of a super-high concrete dam is relatively long, usually in several years, and the dam concrete poured in different time is affected by different external conditions, and therefore has different temperature, age and curing conditions. It has been generally known that temperature, age and curing conditions will all influence the mechanical properties of concrete (strength, elastic modulus) [1–5]. Therefore, studying the fracture behavior of dam concrete is of utmost importance, taking into account the effect of real temperature, age and curing conditions.

Some experimental researches have been carried out on how temperature, age and curing conditions affect the fracture properties of normal concrete. Bažant and Prat [6] investigated mode I fracture energy of concrete under the temperature from 20 °C to 200 °C, and found that the variation of temperature resulted in different fracture characteristics of concrete. Baker [7], Abdel-Fattah and Hamoush [8], and Yu et al.'s experiments [9] also confirmed this conclusion. Experimental researches were carried out to examine the age effect by Wittmann et al. [10] (age of specimen ranging from 2 days to 28 days), Zollinger et al. [11] (1.5 days to 28 days), Gettu et al. [12] (4 days, 10 days, 31 days and 232 days, respec-

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tively) and Kim et al. [13] (1 day–28 days), and the results indicated that the fracture parameters of concrete increased with age. In addition, the experimental researches were carried out to examine the effect of curing condition by Hillerborg [14] (lime-saturated water, underwater, various humidity, and lab conditions), Hordijk and Reinhardt [15] (under water, oven-dry at 110 °C, and lab conditions), and Mechtcherine [16] (sealed or unsealed conditions), and the results demonstrated that the curing conditions influenced the fracture characteristics of concrete. So far, researches on the hybrid effect of temperature, age and curing conditions on fracture properties of dam concrete are very rare, only Li et al. [17,18] carried out experiment on fracture properties using dam concrete cast in laboratory under standard curing conditions.

Accordingly, in this paper, the influence of ambient temperature on fracture parameters of dam concrete was analyzed combining with the conclusions in Ref. [19]. The wedge-splitting specimens for dam concrete were also employed for test, cast in winter on site using mixing tower system for a super-high arch dam during the construction period in southwest China the same as Ref. [19].

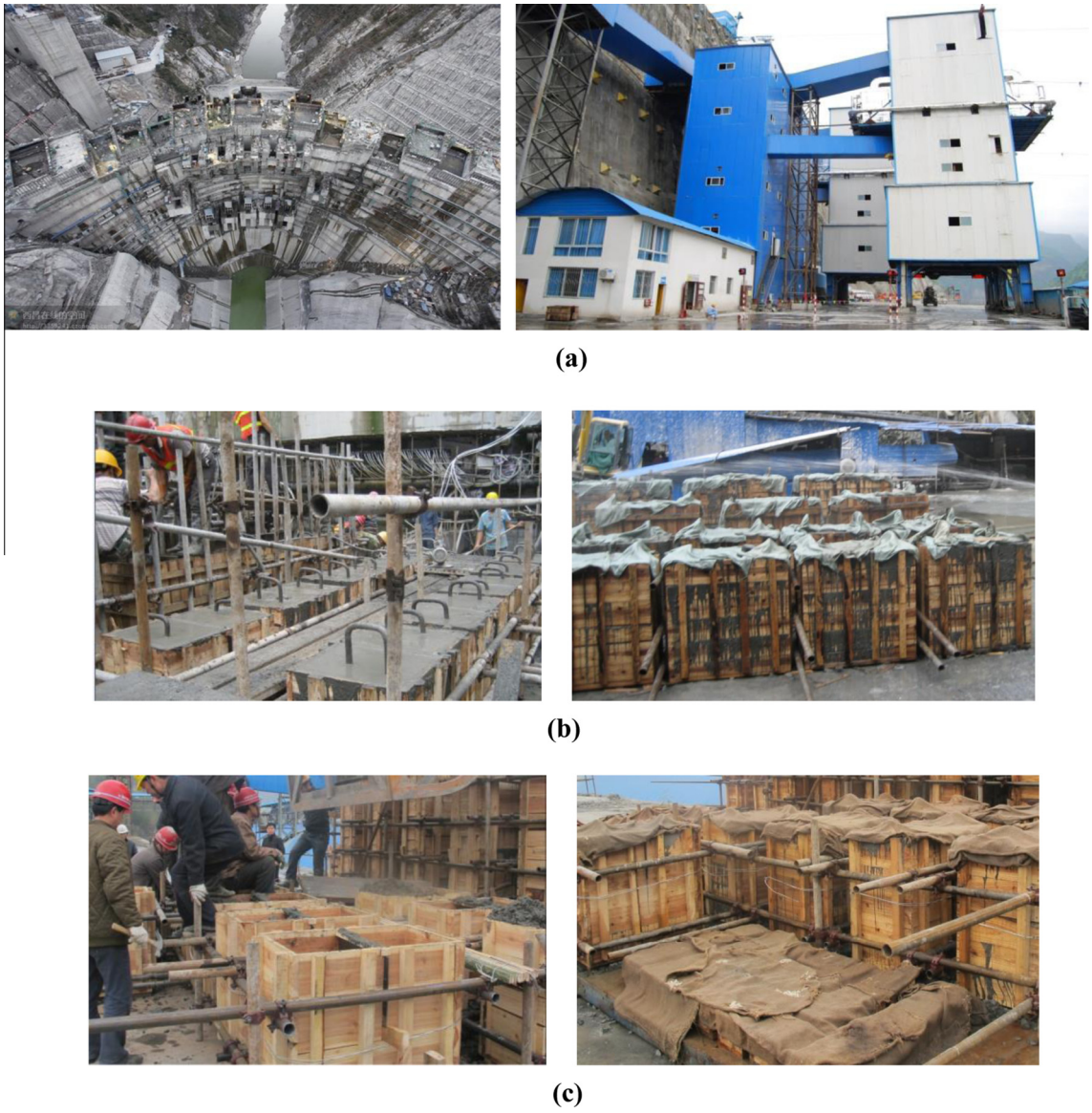

Fig. 1. Actual specimen cast in a construction site of a super-high arch dam: (a) super high arch dam and concrete mixing tower; (b) casting and curing in summer [19]; (c) casting and curing in winter.

Table 1
Mixture proportions.

Cement (kg/m^3)	Fly ash (kg/m^3)	Water (kg/m^3)	w/c	Aggregate (kg/m^3)				Sand (kg/m^3)	HRWRA (kg/m^3)	AEA (kg/m^3)
				5–20 mm	20–40 mm	40–80 mm	80–150 mm			
129	69	81	0.41	377	427	599	498	571	1.188	0.0257

Notes: HRWRA = high-range water-reducing admixture; and AEA = air-entraining agent.