Fatigue & Fracture of Engineering Materials & Structures

WILEY

FFEMS Fatigue & Fracture of Engineering Materials & Structures

ORIGINAL ARTICLE

Effect of Aggregate Size on the Fracture Behavior of Concrete Under Modes I, III, and I/III Conditions

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Received: 9 January 2025 | **Revised:** 12 June 2025 | **Accepted:** 29 June 2025

Keywords: aggregate size | crack twisting angle | edge notched disc bend (ENDB) specimen | fracture toughness | mixed-mode I/III loading | three-dimensional fracture criteria

ABSTRACT

In this paper, the effects of aggregate size and its corresponding appropriate specimen size on the fracture behavior of concrete under pure mode I, pure mode III, and mixed mode I/III are examined experimentally. The innovation of the present study lies in the use of edge notched disc bend (ENDB) specimens with sizes appropriately scaled to a wide range of aggregate gradations, from mortar to coarse-grained concrete, allowing for meaningful assessment of fracture behavior under mixed-mode I/III conditions. The outcomes provide new insights into the effects of aggregate size on fracture toughness, crack propagation, and applicability of various fracture criteria. It was revealed that aggregate size has a substantial impact on crack propagation behavior under diverse loading conditions. By clarifying the distinction between aggregate volume fraction and maximum aggregate size, we found that fracture toughness generally increases with aggregate size. Larger aggregates contribute to enhanced fracture resistance by promoting greater energy dissipation and facilitating crack bridging mechanisms. Moreover, the experimental results are predicted using several three-dimensional fracture criteria. It is shown that strain-based fracture models exhibit better performance in forecasting fracture behavior in the samples containing larger aggregates than their energy-based and stress-based counterparts.

1 | Introduction

Understanding the fracture behavior in concrete is essential for the structure's integrity and estimating its life expectancy. For this reason, investigations on concrete's fracture under various loading conditions have continuously increased over the past few decades [1]. Even though concrete is considered a complex material due to its extreme heterogeneity, it is typically simplified and studied on a macroscopic scale as a three-phase composite consisting of a matrix, an interfacial transition zone, and aggregates. The interaction among these phases plays an important role in the determination of crack initiation and propagation in such mediums [2–4]. Aggregates, which are predominantly small rocks or sand particles, form a major component of the concrete mix. Their adhesion with the cement paste strongly influences the overall mechanical properties of the concrete, such as strength, stiffness, and fracture toughness [5, 6]. Moreover, the quality of the adhesion is greatly dependent on the size of the aggregate. Thus, investigations on the impact of aggregate size on concrete material characteristics parameters and subsequently their effect on crack propagation in such materials are abundant in the literature. For instance, Moseley et al. [7] used three different concrete batches with various aggregate sizes to study mode I fracture toughness of several notched cylindrical specimens. This investigation revealed that the critical