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Hysteresis energy-based failure indicators for concrete and brittle rocks under the condition of fatigue loading

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Abstract: Hysteresis energy-based failure indicators for concrete under cyclic loading conditions are proposed: hysteresis occurrence ratio (HOR) and hysteresis energy ratio (HER) considering the hysteresis characteristics and dissipated energy. A two-step approach to predict the failure of concrete is introduced. The first step: HOR has two critical values. These two critical values for the specific concrete used in our laboratory testing are 75% and 95%. In detail, when HOR is under 75%, the concrete has no risk to fail, when HOR is between 75% and 95%, the concrete has the possibility to fail, when HOR is larger than 95%, the concrete will fail very likely within the next few cycles. The second step contains two criteria: if HOR is larger than 75% and HER is larger than 0.3 at the same time, the concrete will fail. Different multi-level cyclic loading strategies have been designed to verify the effectiveness of these failure indicators and the failure prediction approach. First laboratory test results verified that HOR and HER are reliable failure indicators.

Key words: concrete; fatigue test; damage indicator; hysteresis; dissipated energy

1. Introduction

Due to the relatively low costs, good applicability and durability, concrete is the most widely used man-made construction and building material in the world [1]. Until now, the investigation on stability and durability of concrete is still a research hotspot [2]. If external load reaches a critical value, progressive material deterioration and finally structural failure will occur which creates serious threats to engineering projects [2–8]. Therefore, the quantitative characterization of damage of concrete structures subjected to external load is of great significance for safety and stability analysis.

It is documented that approximately 80% of failure cases of engineering structures are induced by repeated or cyclic loading, also called fatigue loading [9,10]. Compared to monotonic static loading, several specific aspects of mechanical behavior of concrete can be observed when subjected to cyclic loading. Most typical observations are the following: 1. failure of concrete can happen even