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Relationship of brittleness and fragmentation in brittle compression

AkinbinuVictor Abioye

Department of Mining Engineering, Federal University of Technology, P.M.B. 704, Akure, Nigeria

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ABSTRACT

The aim of this research is to investigate whether a relationship exists or not between various brittleness concepts and fragmentation of rock under brittle compression. The term 'brittleness' at present has no clear definition. Fragmentation of rock under compression depends on it self-sustaining failure and the energy available at the peak strength to shatter the rock. It appears from review of the literature that no research has attempted to link rock brittleness and its corresponding fragmentation in compression. Rock failure under conventional compression tests and the subsequent fragments size distribution is a little-understood phenomenon. The research carried out involved determination of post-peak modulus for various rocks using a closed loop servo-controlled testing machine and fragmentation of the rock in brittle compression in accordance to ISRM (2007) suggested methods. Various brittleness concepts were evaluated from static mechanical properties, energy balance, normalised pre-failure curves and extension strain criterion. They were compared with fragments size obtained from compression. Brittleness concepts form static mechanical properties show that the higher its value the finer the fragmentation. Both concepts from normalised pre-failure curves and extension strain criterion appear to treat fragmentation of Class I and Class II rocks as a separate entity. They show better correlation with fragmentation for the segregated samples, Class I and Class II than other concepts. The concepts correlated with the post-peak modulus of the rocks and as such could be useful to quantify the brittleness of the rock under compression.

Contents

1. Introduction

This research investigates the relationship between the shattering of brittle rocks under compression and its brittleness. The fragmentation produced under this condition depends to a large extent on the energy available to cause fragmentation and its self-sustaining failure or brittle

E-mail address: akinbinuvictor@gmail.com.

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nature of the rock (Akinbinu, 2016). The brittleness of a rock has a significant effect on its behavior under such loading conditions and in the fragments that result. In the literature (Andreev, 1995; Gong and Zhao, 2007; Hajiabdolmajid and Kaiser, 2003; Yagiz, 2009) it appears that no research has attempted to link brittleness and fragmentation and the self-sustaining failure behavior of rocks. Therefore in this work, brittleness is considered a very important intact rock mechanical property that has a strong influence on the failure process and on the fragmentation of rock. The ISRM (2007) suggested methods were used to estimate parameters for quantifying the various brittleness concepts and are compared with fragments size from compression test. Various rock types were tested using a closed loop servo-controlled testing machine to determine the post-peak characteristic behavior of the rocks. The rocks are classified into Class I and Class II based on the signs of their post-peak modulus, positive for Class II and negative for Class I.

The purpose of this investigation is to determine whether a relationship exist between brittleness and fragmentation under steady compression. The research seeks to provide answers to the following questions:

(a) Is there a link between fragmentation and brittleness under compression?
(b) In addition, Class II rocks have self-sustaining fracturing response during unconfined uniaxial compression test. Therefore, do Class II rocks relate more to fragmentation than Class I rocks under compression?

The study contributed to knowledge by providing:

(a) An understanding of the relationship between the brittleness and fragmentation of rocks,
(b) Information on Class I and Class II rocks behavior under brittle compression.

At present, the term 'brittleness' has no clear definition. Different definitions and methods used to determine this term are based on the purpose and its use. Therefore, their values vary from method to method. These methods include: determination from energy ratio, strength ratio, stress–strain curves, strain ratio, and ratio internal friction etc. Comprehensive definitions of brittleness in the literature are discussed in Akinbinu (2015). This research assessed different brittleness concepts in order to give a true definition to brittleness based on its characteristic brittle behavior under compression.

2. Concept of rock brittleness

Brittleness is described as a property of material to shatter with little or no ductility (Yarali and Soyer, 2011). The ductility of a material is the ability of the material to tolerate a large inelastic deformation with no loss of its load-carrying capacity (Brady and Brown, 2006). In contrast, the brittleness of a material is demonstrated by its decrease in load-carrying capacity as the strain increases with little or no inelastic deformation. This differs from the failure of ductile materials where shear slip surfaces form in such a way that continuity of material contact is maintained. However, brittle failure is a process whereby continuity is dislocated to create chunks or blocks that are separated with feasible failure modes (Hajiabdolmajid and Kaiser, 2003).

A general theory with regard to rock brittleness states that a more brittle rock will break under very little deformation (Gong and Zhao, 2007). A material can be considered brittle or ductile with respect to its mechanical properties as well as with respect to its behavior under the loading conditions (Andreev, 1995). Since the definition of brittleness is described by deformation behavior of rock and failure subject to the loading condition, the measurement of brittleness is not yet standardised (Gong and Zhao, 2007). An earlier work by Hucka and Das (1974) agreed that the notion of brittleness is not yet completely

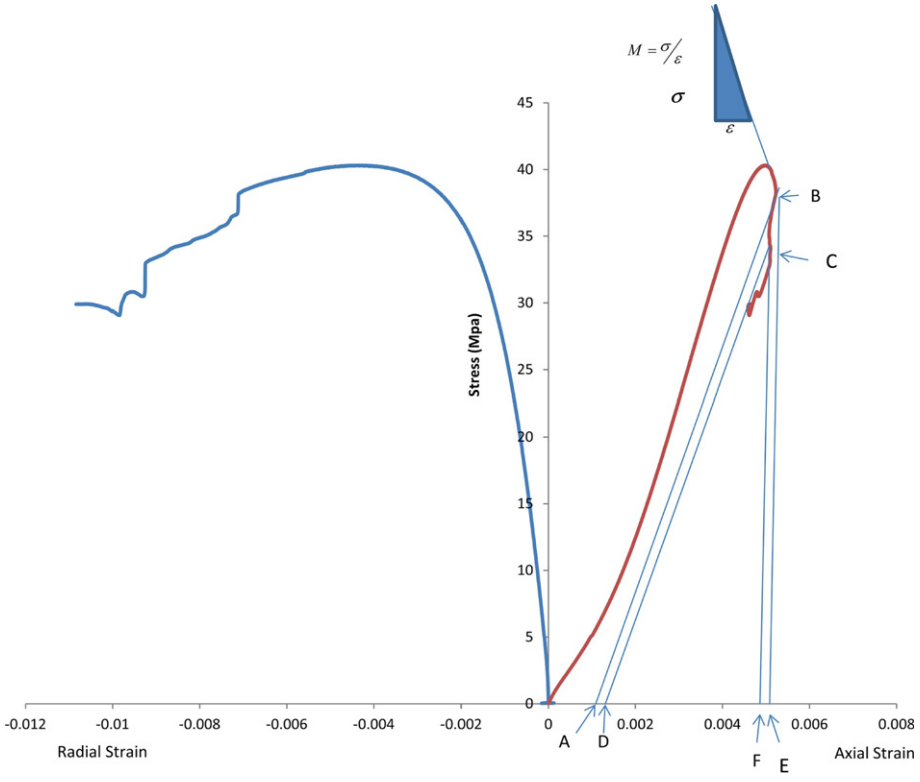

Fig. 1. Calculation of energy released at post-peak for sandstone.