International Journal of Rock Mechanics & Mining Sciences 94 (2017) 10–17

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Dynamic failure of a phyllite with a low degree of metamorphism under impact Brazilian test

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A R T I C L E I N F O

Keywords:
Phyllite
Dynamic tensile strength
Layer plane
Anisotropy
Brazilian test

1. Introduction

Transversely isotropic rocks are frequently encountered in underground construction and mining activities. Many sedimentary rocks and some metamorphic rocks, such as shale, sandstone, siltstone, slate, gneiss, belong to transversely isotropic rocks. In past decades, the mechanical properties of transversely isotropic rocks have attracted much interest.[1–5] The main reason is that this type of rock generally shows anisotropic behavior.[6–9] Another reason is that many projects are built in this kind of rocks. It is necessary to understand the anisotropic behavior of these rocks, for example, exploitation of shale gas,[10,11] roof support design of transversely isotropic rock,[12] and excavation of anisotropic rocks in tunnels.[13,14]

Recently, some researchers have successfully observed the anisotropic behaviors and fracture growth by experiments and numerical simulations.[15–20] The fracturing behavior of transversely isotropic rock is more complex than that of isotropic rocks. Some factors, including mineral composition, porosity, dip angle of layered plane and water content etc., will influence the strength and elastic modulus of transversely isotropic rocks. Firstly, the strength and elastic modulus are directionally dependent. In the case of uniaxial and triaxial tests, the variation of strength and elastic modulus often exhibit a U-shape trend.[9,21,22] For Brazilian tests, the variation of tensile strength of rocks shows more complex behavior. For example, Vervoort et al.[6] observed four trends of variation of tensile strength by Brazilian tests on nine types of rocks. Tan et al.[23] found that the tensile strength firstly decreased and then increased with the increase of foliation-loading angle. However, Gholami and Rasouli[24] considered that there were no apparent relationship between angle of anisotropy and tensile strength. Although there are diverse results, one fact remains: the strength of a specimen with a weak plane vertical to the loading direction is higher than that with a weak plane parallel to the loading direction.

The fracturing behavior and failure patterns of transversely isotropic rock are complex. Fracture growth also depends on the orientation of weak planes. Often, crack occurs and extends along weak planes at a series of specific dip angles. For other dip angles, fractures occur in rock matrix. For example, Tan et al. found that transversely isotropic rock with different foliation-loading angle had five types of failure patterns.[23] In their study, crack extended along schistosity planes at foliation-loading angle θ=0°, 15°, 30° and 45°, and extended in rock matrix at θ=90°. Besides, fractures occurred along schistosity as well as in rock matrix at θ=60° and 75°. In the triaxial compression test of meta-sedimentary rocks, Li et al.[25] also observed four main kind of failure patterns which included shear failure across bedding plane, shear failure along bedding planes, tensile-splitting across bedding planes and tensile-splitting along bedding planes.

The previous researches have been more focus on static mechanical response of layered rocks. However, the influence of dip angle on dynamic properties of layered rocks remains unclear. It is of significance to study the dynamic properties of layered rock, since many structures (e.g., tunneling and underground cavern) are built in these rock types, where dynamic loads such as earthquakes, blasting loads and mechanical disturbance are unavoidable. Recently, some researchers have reported the influence of jointed structure and fractured structure on dynamic mechanical properties of rocks. For example, Li et al. reported that the behavior of waves propagating through jointed rock mass can be influenced by dip angle and thickness of joint rock mass.[26,27] Young's modulus of non-penetrating fractured rock increase

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http://dx.doi.org/10.1016/j.ijrmms.2017.02.013
Received 7 July 2016; Received in revised form 15 February 2017; Accepted 17 February 2017
1365-1609/

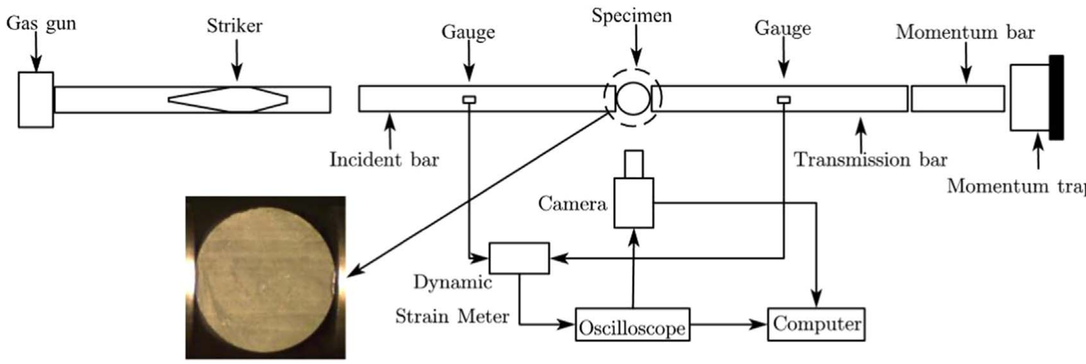

Fig. 1. SHPB experimental system for dynamic Brazilian test and monitoring devices.

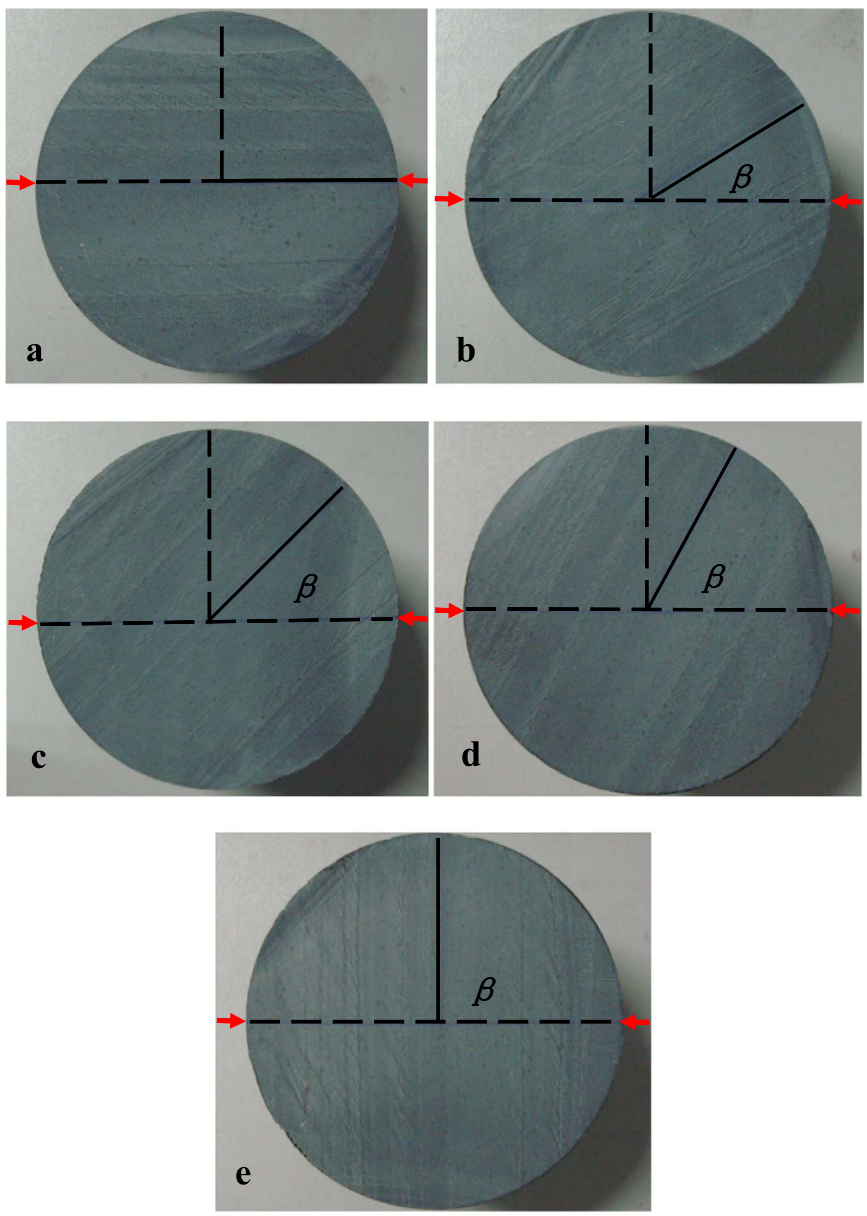

Fig. 2. Five types of specimens with different dip angles (a. *β=0°*; b. *β=30°*; c. *β=45°*; d. *β=60°*; e. *β=90°*).

with the increase of dip angle.[28] Generally, jointed rock and fractured rock are considered as discontinuous medium, but the layered rock belongs to continuous medium. Thus, the understanding of layered structures on dynamic tensile mechanical properties and fracturing behavior in layered rock are significant and necessary.

In our recent studies, we have found that the dynamic strengths (including dynamic compressive and tensile strengths) and the dynamic compressive fracturing behavior of bedding sandstone are