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Stability analysis of rock blocks around a cross-harbor tunnel using the improved morphological visualization method

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ABSTRACT

The morphological visualization method is improved by introducing the separating axes method to the element-block aggregation algorithm and the weighted quick-union method to the complex-block construction algorithm to enhance the computational efficiency of BLKLAB (Zhang and Lei, 2013a). The usage and effectiveness of the modified BLKLAB code are demonstrated through a case study of Xiang'an tunnel in Xiamen City of China. In this case study, the DifFUZZY method was employed to cluster the orientation data and probabilistic analysis was then performed to get a combination of geological and mechanical properties of discontinuities that is most detrimental to the stability of rock blocks and associated ground-supports. Based on these previous analyses, the fracture network was constructed. The stability of rock blocks around the tunnel was then evaluated, using the improved morphological visualization method in conjunction with the stereo-analytical method. A combination of shot concrete and bolts was proposed as the optimal support system, which agrees with the real situation.

1. Introduction

Understanding the mechanical behavior of rock masses after excavation is recognized to be a challenging issue, especially when discontinuous layers, e.g., bedding planes and joints, are presented. The overall response of discontinuous rock masses is dominant by the structural and mechanical characteristics of the discontinuities. Traditional elasto-plastic mechanics failed to provide satisfied solutions to such a problem. Therefore, a number of attempts have been made to develop new methodologies to evaluate the stability of jointed rock masses and to identify the underlying failure mechanism in the past decades, e.g., Trollope (1968) analyzed the static equilibrium of the rock masses; Cundall (1971) proposed a distinct element method to calculate the movement of the rock masses; Goodman (1976) proposed a stereographic projection method to analyze the stability of rock masses; and Kawai and Toi (1977) proposed the rigid element method to solve plane strain problems. In particular, the block theory has attracted great attention since the pioneering work of Goodman and Shi (1985) due to its simplicity.

A complete procedure of stability analysis using block theory consists of the following steps: (a) constructing the fracture network including both deterministic and stochastic discontinuities; (b) generating the block system according to geometrical characteristics of discontinuities and the excavation; (c) identifying all the potentially removable blocks and associated failure mode; and (d) evaluating the stability of removable blocks. Steps (a) and (b) are usually known as pre-processing procedure, aiming to generate topological information of the rock system, while topological and mechanical analyses are involved in steps (c) and (d). The effectiveness of the block theory in predicting the stability of rock blocks and providing guidance to excavation as well as design of support system has been demonstrated by a number of researchers (Elmouttie et al., 2010; Gokceoglu et al., 2000; González-Palacio et al., 2005; Grenon and Hadjigeorgiou, 2003; Hatzor, 1999; Kulatilake et al., 1996; Lana and Gripp, 2003; Ohnishi et al., 1985; Park et al., 2005; Park and West, 2001; Shi, 1982; Um and Kulatilake, 2001; Wu et al., 2011; Zhang and Kulatilake, 2003).

The description of block geometry and removability is undoubtedly of great importance for computer modeling and mechanical evaluation of large-scale rock mass systems. However, the original block theory did not provide solutions to such issue for blocks with complex geometry, e.g., concave blocks. This difficulty can be overcome by resorting to the morphological visualization method which is able to describe specific structural features of complex rock blocks (Zhang and Lei, 2013b). The morphological visualization method involves classification, characterization and visualization of blocks with arbitrary shapes and the determination of their removability (Zhang and Lei, 2013b). Thus it is a very useful pre-processing tool to obtain the geological information for block theory analysis. Morphological visualization analysis,

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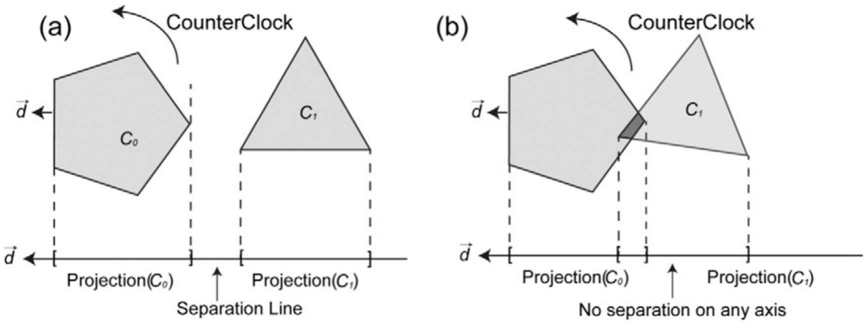

Fig. 1. Illustration of the separating axes method (a) detaching case; (b) intersecting case.

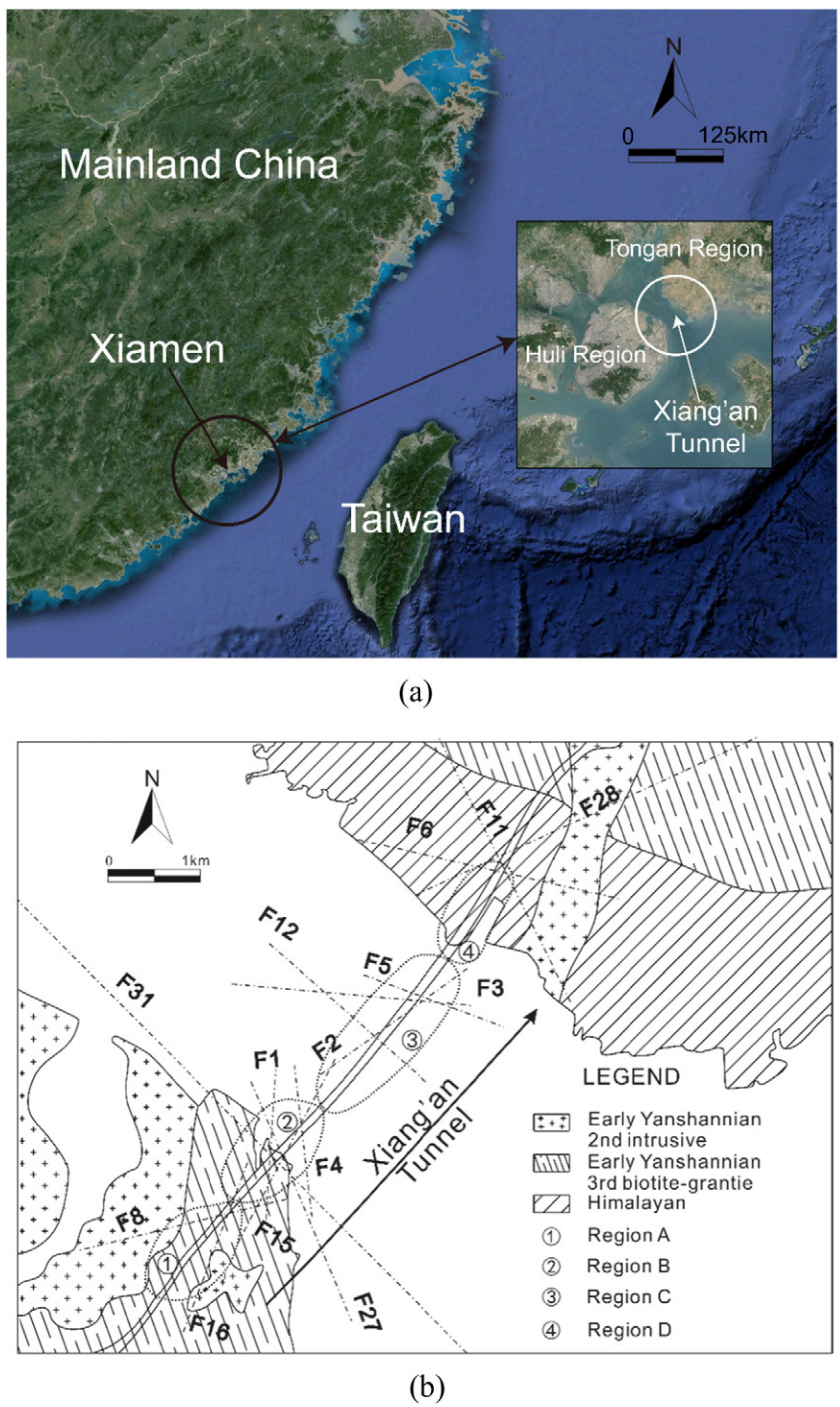

Fig. 2. Location and geological conditions of Xiang'an tunnel (a) location (b) geological conditions.