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Fracture behaviour of cemented tailing backfill with pre-existing crack and thermal treatment under three-point bending loading: Experimental studies and particle flow code simulation

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ABSTRACT

The three-point bending test was performed on cemented tailing backfill prepared with different offset notches by a loading system with high-speed camera. And the effect of heated temperature on CTB fracture behavior has been investigated. These results indicate that the influence of pre-existing notch and temperature on CTB fracture feature is obvious. The peak load increases linearly with the increasing of the offset ratio when the depth-height ratio of notch is fixed at the same value, while the fracture peak loading decreases sharply with the increase of the notch depth when the offset ratios are the same level. The fracture toughness decreases by 63.5% as the heated temperature rises from 20 °C to 120 °C. The fracture toughness is directly proportional to the porosity of CTB. The increasing of porosity leads to the decrease of the fracture toughness mainly due to the decomposition of hydration products and the coarsening of the pore structure of CTBs. The crack propagates along the interface among tailing particles, resulting in a rough and jagged edge propagation path. The rack propagation pattern of CTB samples contains transgranular fracture and intergranular fracture. The intergranular fracture is clearly predominant during crack propagation. The rack propagation and failure pattern of CTB specimens from numerical modeling are conformed to the failure pattern of samples obtained by experimental testing. PFC is an effective numerical analysis method for exploring the fracture mechanism of micro-cracking in CTB.

1. Introduction

The introduction of underhand cut and fill mining (UCFM) in 1980s made hard and fractured rock mining in hazardous ground conditions safer. Over the past decades, UCFM method has been widely used all around world in view of the advantages of effective ground control, environmental surface disposal of mine solid waste and high ore recovery [1–4]. Underhand mining uses cemented tailings for backfilling the mined-out stope cut, and makes the mining operations in the following cuts safer, because the personnel are always working beneath the backfill, which will not collapse during mining process [5]. As mining depths increases, the stress of surrounding rock increases, and the ground conditions in stope cut become more challenging. In addition, based on an average geothermal gradient (3 °C/100 m) of crustal rocks, the highest temperature may reach 60 °C at the depth of 2000 m without

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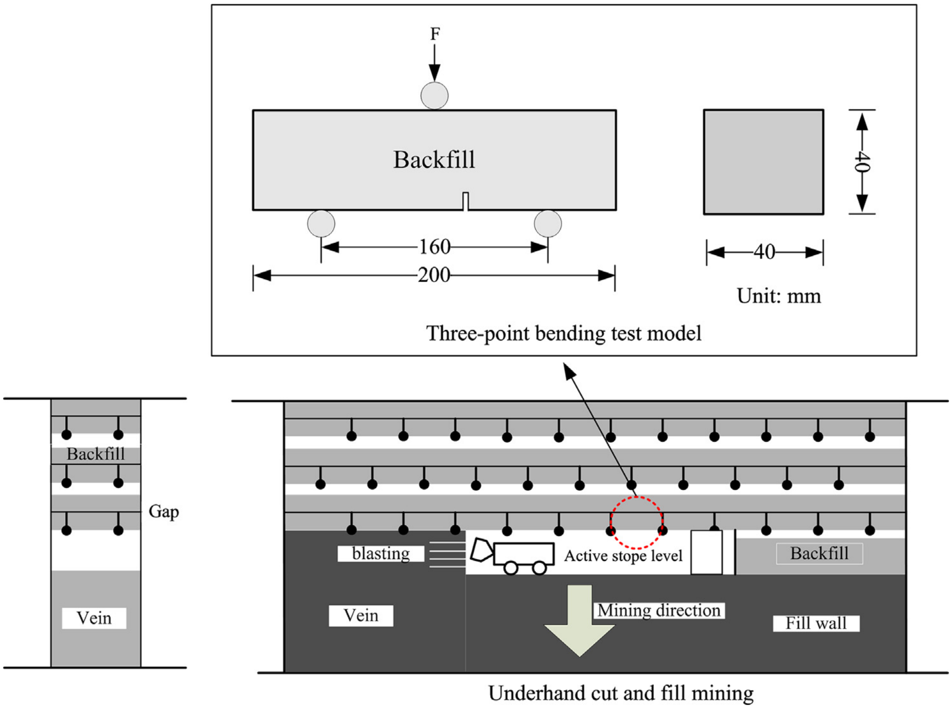

Fig. 1. Schematic diagram of the underhand cut and fill mining.

consideration of heat from exothermic ore deposit. Therefore, the temperature becomes another important factor affecting the stability of the backfilling body as the increasing of mining depth [6,7]. The schematic diagram of underhand cut and fill mining is shown in Fig. 1.

A key issue in underhand cut and fill mining stope cut is the overall stability of the overlying backfill, and the quality of backfill roof is required to develop enough strength to protect miners working under it [5]. As one of man-made structure materials, cemented tailing backfill (CTB) in UCFM stoping composed of cement, tailings matrix and voids, is a complex heterogeneous material and exhibits complex mechanical behaviors [8,9]. Bayram E. et al. [10]'s experimental results have indicated that the influence of binder type and dosage on the mechanical properties and microstructure of cemented tailing backfill are significant. M. Fall has presented a design method for mix proportioning of CTB to minimize the number of trial mixes and provided an appropriate mix proportion [11]. However, most of the researches are focusing on the compositions of the material itself and relatively little studies are conducted on mechanical properties or fracture characteristics of CTB. As fundamental problems in mining engineering, microcrack or damage produced by frequently mining disturbance and blasting vibration are primary source of degradation of cemented backfill especially in underhand cut and fill mining stope and can significantly reduce the backfill service capacity, so that the crack and fracture is a main type of distresses. Consequently, the cracking propagation mechanism and fracture features of cemented backfill have draw more and more attention in recent years.

The mechanical behaviors of overlying CTB in UCFM stoping are significantly affected by stope geometry design, consistent fill quality, loading conditions, seismic effects (blasting vibration and mining disturbance), and support placement as well as other factors [12]. Han et al. [13] have reported that the riskiest position is located in the middle of two braced forces in the lower surface of the bearing stratum. CTB is an artificial engineered mixture, and gains the mechanical through hydration reaction, has the similar structure to rock or concrete materials [14]. Therefore some results and methods of fracture from the rock and concrete studies can be resorted to analyze the fracture characteristic of CTB. Zuo et al. [15–17] have obtained that the fracture characteristics, the microstructure change and the crack propagation model of the granite after the heat treatment, and the crack propagation characteristics of the different bias cracked basalt have also been revealed. Most studies show that the whole process of crack propagation is important for the fracture characteristics of rock [18–20]. Besides, the particle flow code, as a kind of discrete element numerical simulation software, has been widely used to analyze the micro mechanism of rock. These studies show that there is a potential link between the PFC meso-scale strength parameter and the fracture toughness of the rock [21]. The fracture toughness of CTB depends on solid content, binder-to-tailing ratio and curing age [22]. Its fracture characteristics are fundamentally different from those of rock and concrete materials. Therefore, it is necessary to study the fracture mechanics behavior of CTB. However, as of the present, little studies have conducted the fully investigation of fracture characteristic of CTB in UCFM stope. Consequently, a solid knowledge of the crack propagation and fracture characteristic is vital for the rational design, and a safe and efficient analysis of the stability of CTB in UCFM stope. Therefore, to better understand the crack propagation that occurs in the CTB. The above authors will present and discuss some tests to understand the characteristic of CTB samples prepared with different offset notch (different offset ratio and seam-height ratio) and thermal treatments during the whole process of the three-point bending testing. In addition, we will simulate the crack