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Assessment of the Blasting Efficiency of a Long and Large-Diameter Uncharged Hole Boring Method in Tunnel Blasting Using 3D Numerical Analysis

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Abstract: Cut blasting is one of the most essential processes to reduce blast-induced vibration in tunnel blasting. The long and large-diameter uncharged hole boring (LLB) method is an example of one of the cut blasting methods, which utilizes large-diameter uncharged holes drilled in the tunnel face. In this study, blasting simulations were performed to analyze its blasting mechanism, and the LLB method and the traditional burn-cut method were simulated to compare their blasting efficiency. A 3D numerical analysis using LS-DYNA code, a highly non-linear transient dynamic finite element analysis using explicit time integration, was used to simulate the blasting process, and a Johnson–Holmquist constitutive material model, which is optimal for simulating brittle materials under dynamic conditions, was used to simulate the rock behavior under blasting. The modified LLB method showed a 3.75-fold increase in the advance per round compared to the burn-cut method, due to the increased formation of long and large-diameter uncharged holes compared to blast holes. This modified LLB method used 30% less explosives, so its failure range was approximately 1.25 times less than that of the burn-cut method, but its advance was approximately 4 times larger than the burn-cut method, which was similar to the original LLB method. This confirmed that the modified LLB method is significantly more efficient in terms of increased blasting efficiency (particularly the advance per round) as well as reduced blast-induced vibration, compared to the traditional cut blasting method.

Keywords: tunnel excavation; cut blasting method; LLB method; uncharged hole; numerical simulation

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1. Introduction

A drill and blast method is the most common rock excavation method in mining and civil engineering. However, this method causes environmental pollution and hazards such as noise, vibration, and flying rocks generated by the blasting, and blast-induced vibration can damage nearby structures in urban areas, when it exceeds specific values [1,2]. In tunnel construction, the advance rate is one of the key factors because it is directly related to the overall construction period and influences the economic feasibility of a project. Therefore, the ultimate goal of blast excavation in the new Austrian tunneling method (NATM) is to maximize the advance per round, while meeting the allowable criteria for blast-induced vibration. It is well known that blast-induced vibration is the most significant factor that affects the surrounding structures [3]. In the rock fragmentation caused by blasting, it has been found that only 20–30% of the energy is used in the breakage of the surrounding rocks, while the residual energies are dissipated in the forms of vibration, noise, and flying rocks [4,5]; thus, the current blasting techniques have inevitable limitations [6]. When the vibration exceeds a critical value, internal cracks in the rock mass can be induced, potentially harming nearby structures [7]. Given the recent rise in environmental concerns,