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Development of a novel cartridge for expansive cement application to hard rock breakage

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ABSTRACT

Expansive cement (EC) is generally a slurry that it is poured into vertical holes for surface rock breakage applications. This paper describes the development of a novel cartridge for extending EC applications from gravity-filled vertical holes to horizontal, uptilted, and wet boreholes. Four cartridge prototypes were made from low-cost and readily available plastics using three-dimensional printers. The performance of each cartridge was investigated in unconfined rock slab tests. The polylactic acid (PLA) cartridge was found to be superior to the thermoplastic polyurethane, polyethylene terephthalate glycol, and acrylonitrile butadiene styrene cartridges. Through partial heat containment, the PLA cartridge accelerated the EC hydraulic reaction and shortened the onset of rock destruction by 30% relative to vertical, gravity-filled EC. Finally, rock breakage with EC was demonstrated in an underground mine using PLA cartridges. This novel type of cartridge could not only suit various applications beyond the scope of the current EC surface applications but also significantly improve the rock fracturing efficiency of EC.

RÉSUMÉ

Le ciment expansif (EC) est généralement une boue que l'on verse dans des trous verticaux pour briser la roche en surface. Cet article décrit le développement d'une nouvelle cartouche permettant d'étendre les applications du ciment expansif des trous verticaux remplis par gravité aux trous de forage horizontaux, inclinés et humides. Quatre prototypes de cartouches ont été fabriqués à l'aide d'imprimantes tridimensionnelles à partir de plastiques peu coûteux et facilement disponibles. Les performances de chaque cartouche ont été étudiées lors d'essais en dalles rocheuses non confinées.

La cartouche en acide polylactique (PLA, de l'anglais *polylactic acid*) s'est avérée supérieure aux cartouches en polyuréthane thermoplastique, en polyéthyléne téréphtalate glycol et en acrylonitrile butadiéne styréne. Grâce au confinement partiel de la chaleur, la cartouche PLA a accéléré la réaction hydraulique de l'EC et a raccourci le début de la destruction de la roche de 30 % par rapport à l'EC verticale remplie par gravité. Enfin, la rupture de la roche avec l'EC a été démontrée dans une mine souterraine à l'aide de cartouches en PLA. Ce nouveau type de cartouche pourrait non seulement convenir à diverses applications dépassant le cadre des applications actuelles de l'EC en surface, mais aussi améliorer de maniére significative l'efficacité de la fracturation de la roche par l'EC.

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MOTS-CLÉS
acide polylactique (PLA), agents de démolition, ciment expansif (EC), applications sur le terrain, essais de laboratoire, rupture de roche non explosif

INTRODUCTION

Expansive cement (EC), also known as a soundless chemical demolition agent, is a potential alternative to rock fracturing with explosives. Although first marketed in the early 1970s, EC drew little attention until 40 years later, when the patent expired and more manufacturers made it available on the market (Huynh & Laefer, 2009). Over the last decade, EC has been used in surface engineering projects such as dimension rock quarrying and explosive-free concrete demolition (Cho, Nam, Kim, Lee, & Sohn, 2018; Jiang, Zheng, Li, & Guo, 2021; Kim, Cho, Sohn, & Lee, 2021). In addition to being environmentally benign, the EC method offers other advantages over blasting for rock fracturing applications: It does not generate toxic fumes or noise vibration, and it greatly reduces ventilation requirements in underground spaces (Habib, Shnorhokian, & Mitri, 2022). Due to increasing environmental and political restrictions on the use of explosives, it is important to develop EC as an alternative to the conventional explosive method for rock fracturing projects in both civil engineering and mining engineering fields.

EC is a chemically based, powdery material consisting mostly of Portland cement and expansive additives (Figure 1a). After mixing with water, the EC slurry is poured into a confined borehole, where it expands and creates a fracture network in the surrounding material (Figure 1b). The EC expansive pressure stems primarily

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