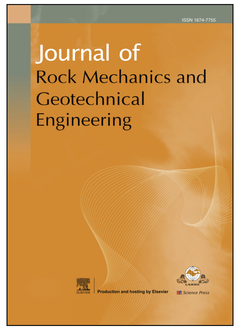

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PII: S1674-7755(17)30262-7
DOI: 10.1016/j.jrmge.2017.11.007
Reference: JRMGE 415

To appear in: *Journal of Rock Mechanics and Geotechnical Engineering*

Received Date: 26 July 2017
Revised Date: 12 October 2017
Accepted Date: 7 November 2017

Journal of Rock Mechanics and Geotechnical Engineering

Journal online: www.rockgeotech.org

Utilizing a novel fiber optic technology to capture the axial responses of fully grouted rock bolts

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Received 26 July 2017; received in revised form 11 October 2017; accepted 7 November 2017

Abstract: Rock bolts are one of the primary support systems utilized in underground excavations within the civil and mining engineering industries. Rock bolts support the weakened rock mass adjacent to the opening of an excavation by fastening to the more stable, undisturbed formations further from the excavation. The overall response of such a support element has been determined under varying loading conditions in the laboratory and in situ experiments in the past four decades; however, due to the limitations with conventional monitoring methods of capturing strain, there still exists a gap in knowledge associated with an understanding of the geomechanical responses of rock bolts at the microscale. In this paper, we try to address this current gap in scientific knowledge by utilizing a newly developed distributed optical strain sensing (DOS) technology that provides an exceptional spatial resolution of 0.65 mm to capture the strain along the rock bolt. This DOS technology utilizes Rayleigh optical frequency domain reflectometry (ROFDR) which provides unprecedented insight into various mechanisms associated with axially loaded rebar specimens of different embedment lengths, grouting materials, borehole annulus conditions, and borehole diameters. The embedment length of the specimens was found to be the factor that significantly affected the loading of the rebar. The critical embedment length for the fully grouted rock bolts (FGRBs)was systematically determined to be 430 mm. The results herein highlight the effects of the variation of these individual parameters on the geomechanical responses FGRBs.

Keywords: fiber optic technology; fully grouted rock bolts; load transfer; stress distribution

1. Introduction

Rock bolts have been used for over 4 decades in mining and civil engineering applications as part of a reinforcing system within underground excavations due to their ease of installation, efficiency and relatively low costs (Stillborg, 1986). They reinforce rock mass by restraining the deformation around the periphery of the excavation. In this manner, the stresses experienced by the rock mass are transferred to the rock bolt most commonly as an axial load. The proper in situ application of rock bolts is crucial, as improper technique and installation can lead to the loss of lives, poor overall support design and elevated project costs. This highlights the importance in understanding the composition of such a reinforcing element, not only within the overall support scheme when using rock bolt support, but also at the smaller scale in terms of various components that contribute to their behavior and performance.

Local instability issues arise around the material surrounding the excavation zone (i.e. zone of plasticity (Vlachopoulos and Diederichs, 2009) or excavation damaged zone (Diederichs et al., 2004). The stability of the opening depends on the stresses and conditions of the rock mass adjacent to the excavation boundary. Rock support refers to the steps taken and the materials used to maintain the load-bearing capacity of the rock near the opening (Brady and Brown, 2004). Support of underground openings covers a wide range of subsets including rock bolts, dowels, cables, mesh, straps, shotcrete, and steel ribs. More specifically within these, fully grouted rock bolts (FGRBs) are paramount as they constitute the most used support in both mining and civil engineering applications (Li, 2007).

2. Background

In the simplest form, a rock bolt support system consists of a plain steel rod that is chemically or mechanically anchored at one end and contains a faceplate and a nut at the other end. An FGRB has the entire length of a steel element grouted. This is commonly referred to as the embedded length. FGRBs are proposed to minimize the effect of corrosion on the performance of mechanically anchored rock bolts as the grout provides a protective barrier to the bolts from moisture within the ground. An FGRB consists of a steel bar that can be smooth or deformed (e.g. "rebar" or "thread bar"). The grout can consist of cementitious grout containing mixture of Portland cement and water or resin grout made up of polyester resin and organic peroxide hardener.

During the installation of FGRBs, a load can be applied to the support element by tensioning the bolt at the excavation periphery. Thus bolt can apply a positive reinforcing load at the excavation periphery via the arrangement of faceplate and nut. This type of reinforcement is regarded as active support. However, previous research efforts have indicated that actively tensioning the bolt is not beneficial for all conditions. This is because in most cases, the length of bolt embedded within the rock mass is not long enough to develop sufficient shear strength to support the loads that it will sustain throughout its lifetime (Haas, 1975). Where no reinforcing load is applied at the excavation periphery, a rock bolt will begin to provide support only once the rock mass experiences movement. Under these conditions, a rock bolt is identified as passive support.

Windsor (1997) stated that a reinforcing system comprised of four main elements (see Fig. 1), i.e. rock, reinforcing element, internal fixture, and external fixture. As it pertains to FGRBs, the reinforcing element is the bolt itself. The external fixture is recognized as an arrangement that aids in the load transfer at the excavation periphery, i.e. nut and faceplate assembly. The internal fixture refers to the medium that transfers the load from the rock to the support element. The internal fixture is of utmost importance to the success of load transfer in a rock bolt system since it provides a coupling interface between the rock and the support element. For the FGRBs, this load is transferred throughout the system mainly in the shear resistance induced along the material interfaces. This shear resistance is made up of chemical

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