



Effect of bolt rib spacing on load transfer mechanism



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ARTICLE INFO

Article history:

Available online 13 April 2017

Keywords:

Fully grouted bolt
Profile study
Rib spacing
Pullout from concrete

ABSTRACT

Rock bolting has firmly used as the coal mine roof reinforcement in underground coal mine. The bolting effect of fully grouted rebar bolt is closely related to the bolt surface profile. This paper provides an experimental study to confirm that bolt rib internal length has great influence on bolting effect. Pull-out tests were conducted using rebar bolt with different rib spacings of 12, 24, 36 and 48 mm representatively from steel tube and from concrete. Results show that peak load increases 25.3% for bolt with large rib spacing. For pull out using concrete block, the increment of peak load between large and small rib spacing is not significant, but the bolt with large rib spacing has great absorption of deformational energy than small rib spacing bolt. This study provides experimental evidence towards optimum design of rock bolt for understand coal mining industry.

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1. Introduction

The stability of underground excavations and surface slopes is of major concern to geotechnical engineers and mine operators. Rock bolting technology has firmly used as the coal mine roof primary reinforcement system in underground coal mine support design due to a better understanding of load transfer mechanisms of rock bolting and advances made in the bolt system technology [1]. In 2011, around 66% of nearly 97 million roof bolts installed in United States coal mines were fully grouted resin bolts [2].

Rock bolts used for rock formation reinforcement in mining industry is developed from ribbed steel tendon used in concrete reinforcement in building construction; however, it differs in function from the concrete beam reinforcement as the roof bolt in underground coal mine is confined by boundless surrounding rock.

A reinforcement system of rock bolt comprises five elements: the rock, the grout, the bolt and the rock/grout interface and the grout/bolt interface. Consequently, axial failure mode of grouted rock bolt system is in one or more of the manners: the bolt, the grout, the rock, the bolt-grout interface or grout-rock interface [3]. The type of axial failure depended on the properties of individual element. The steel bar is the govern element the axial behavior of the reinforce system. If the bolt had sufficient length to transfer the entire load to the surrounding rock mass it would fail. The shear stress at the bolt/grout interface was often greater than that

at the grout/rock interface because of the smaller contact area. If the grout and rock were of similar strengths, failure could occur at the bolt-grout interface. If the surrounding rock was softer, then, failure could occur at the grout/rock interface.

Studies of bolt/grout interface for rebar show that bonding forces is made up of three components: chemical adhesion, friction and mechanical interlock. The adhesive strength between the bolt-resin interface is negligible [4,5]. In addition, the adhesive strength of the bond cannot be mobilised with frictional strength during the pullout process [6]. The frictional components can be categorised into dilation slip, shear failure of surrounding medium and torsional resistance of bolt [7]. It should be noted that pressure generated by the internal reaction forces of the whole system has great influence on these two components.

The mechanical interlock component of the bond strength plays an important role in the load transfer capacity of the rock bolting system. It is created by the bolt profile configuration. The profile configuration is defined by the rib profile shape, and height, angle of wrap and spacing or distance between the ribs (Fig. 1). Among them, rib height and spacing are the most important profile parameters in term of load transfer for rebar bolt subjected to axial load.

Experimental and numerical studies have confirmed that bolt surface profile plays an important role on load transfer of fully grouted rock bolting systems [9–12]. Fabjanczyk and Tarrant investigated the load transfer mechanism in push out tests for rebar bolt with various rib heights [13]. They found that bolts with a lower profile height had smaller stiffness and concluded that the load transfer was a function of parameters such as hole diameter, resin mechanical properties, and bar surface configuration. Lin

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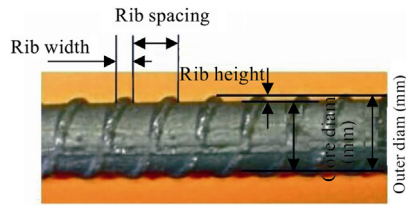


Fig. 1. Steel bolt rib profile configuration [8].

Table 1
Parameters of tested bolts.

Item (mm)	B12	B24	B36	B48
Rib spacing	12	24	36	48
Rib height	1.8	1.8	1.8	1.8
Rib width	4.3/5.7	4.3/5.7	4.3/5.7	4.3/5.7

and Kang provided a review of resin anchored rebar including steel quality, profile shape, rib height and spacing in coal mine industry in China [14]. Later, an experimental study conducted by Kang et al. found that increasing rib height from 0.48 to 1.42 mm improved bolting performance of fully grouted rock bolt [15,16].

For rib spacing study, Blumel was the first to report the influence of rib spacing on load transfer capacity of the bolt [17]. Pull tests were conducted using a 500 mm length steel pipe filled in concrete. The bolt was anchored in the steel pipe using cementitious grout. Result shows that pull-out loads increase with an increase in rib spacing, of 13.7, 27.4 and 54.8 mm, respectively. Following study of the experimental findings showed that higher axial stresses were developed in case of the larger spaced ribs as compared to the small rib spacing [18]. Aziz and Webb studied profile configurations by push testing of bolts resin grouted in 75 mm cylindrical steel tubes. However, the length of steel tube was found to be of insufficient to accommodate adequate number of bolt ribs [5]. Further study indicated that increased profile spacing contributed to improvement in bolt anchorage stiffness, as indicated in Fig. 2 [19].

Previous studies provide a fundamental understanding of the role of the bolt profile and its influence on rock bolting failure. However, all tests were undertaken using steel tubes as confinement to simulate the surrounding rock mass. There has been no reported attempts made to evaluate the bolting effect for rebar bolt with different rib spacings embedded in concrete block, which can better simulate the realistic geo-conditions of underground coal mines. Accordingly, this paper presents a series of laboratory pull-out tests anchored in concrete block to evaluate bolting effect for rebar bolt with different rib spacings. In addition, pull-out tests are also conducted for bolting specimens using steel tube as confining material as a comparison to previous studies. This research work provides experimental evidence for achieving optimum bolt design in engineering applications.

2. Experiment

In order to examine the influence of increased rib spacing to bolt axial load capacity, two series of tests were carried out on bolts with different rib spacings anchored in concrete block and anchored in steel tube. For all tests, core diameter 20 mm steel bolt was used. Table 1 and Fig. 3 show a summary of the profile dimen-

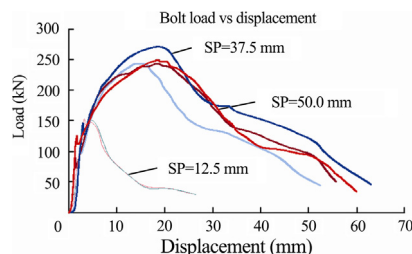


Fig. 2. Laboratory studies of steel bolt pull-out tests showing the maximum load for various spacing of the bolt profile [19].

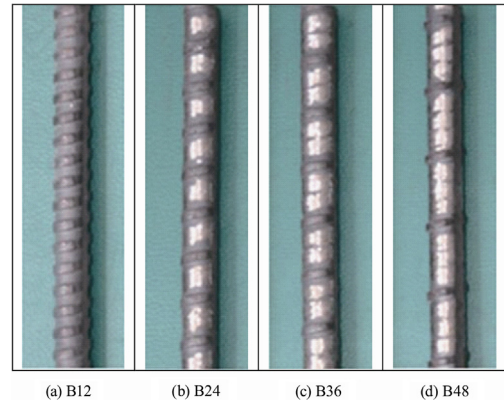


Fig. 3. Samples of tested bolts.

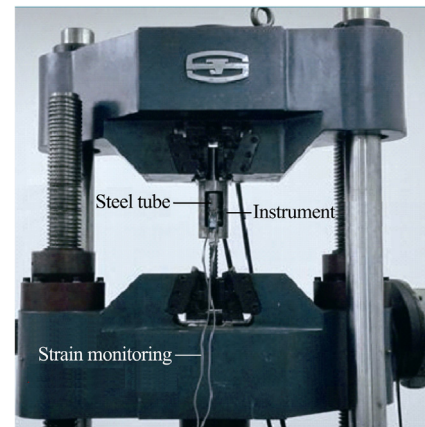


Fig. 4. Pull-out test of steel tube bolt specimen.

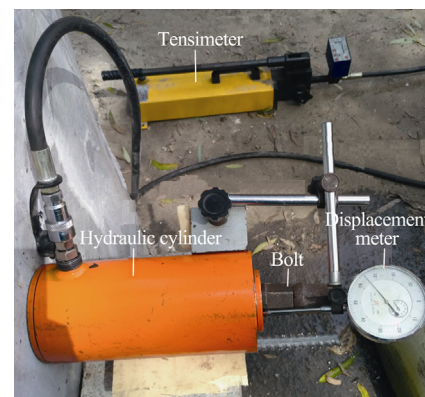


Fig. 5. Pull out test from concrete block.

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