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Mechanical behavior of rock bolts under a high temperature environment

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1. Introduction

As an effective support measure in the tunnel engineering, rock bolt supports are widely used.[1,2] When rock bolts are applied in a geothermal active tunnel, they can seriously affect the performance of the bolting support and may lead to the bond degradation and structural damage to the anchorage body, compromising the durability and safety of the entire tunnel structure. Therefore, it is necessary to study the influence of pullout strength of the rock bolts under a severe environment such high temperatures and loadings and different levels of roughness of the surrounding rocks.

Since the inception of the rock bolt structure, scholars at home and abroad have conducted many experiments and theoretical studies on the performance and influence of the pullout behavior of the rock bolt, and have achieved some valuable research results. Delhomme et al. and others[3–6] carried out many theoretical analyses and experimental studies on the mechanical principles and anchorage mechanism of the rock bolt. Zou et al. and others[7–9] established a differential equation for the load transfer of a rock bolt when the rock and soil mass was damaged, and derived an analytical solution of the distribution of axial force, shear displacement, and side friction along the length of a rock bolt.

The engineering practice shows that the temperature and roughness of surrounding rocks play a crucial role in the performance.[1] Up to now, numerous studies have been conducted on pullout strength of a rock bolt, but little research focuses on the effects of high temperature and loadings, especially, with diff rent levels of roughness of the surrounding rocks. Consequently, studying the relationship of the pullout strength with different temperature, loads and roughness is of great theoretical and practical significance for understanding the mechanism of anchorage to the surrounding rocks. In this work, through two pullout tests of rock bolts, their pullout strength are investigated, aiming at a theoretical basis for rock bolts used in a complex environmental engineering.

2. Testing conditions and procedures

In the practical engineering, the drill hole with a diameter larger than the anchor rod should be set up first, then the anchor rod is inserted and inject into the mortar bond. For the protection of slope and foundation pits, the diameter of the drilling hole and the diameter of anchor cable can reach more than 5:1. Based on the above principles, in the present work, the rock bolt specimens were designed as four parts: a steel pipe with an inner diameter of 75 mm and length of 100 mm, rock bolt with length of 300 mm and diameter 25 mm, a diameter ratio of 1:3 between rock bolt and pipe, a waterproof cushion and grouting materials between the steel pipe and the rock bolt, as shown in Fig. 1.

The experiment was divided into two parts. For the first part, the ultimate pullout force of the rock bolt was investigated under the loadings and high temperatures. For the second part, the ultimate pullout force was investigated under the influences of roughness of the surrounding rocks and high temperatures.

After the specimens were prepared, they ware put into a box with a constant temperature of 20 ± 0.2 °C, 35 ± 0.2 °C, and 50 ± 0.2 °C, respectively, with ages of seven days, then a jack reaction apparatus was used, as shown in Fig. 2, to apply a load to the specimens. Meanwhile, the whole loading apparatus was still maintained in a constant temperature box, at temperatures of 20 ± 0.2 °C, 35 ± 0.2 °C, 50 ± 0.2 °C, respectively, with ages of 28 days (GB50086-2001). Then, an universal hydraulic testing machine was used to conduct the pullout tests. For the slip displacement between the rock bolt bar and the grouting materials,

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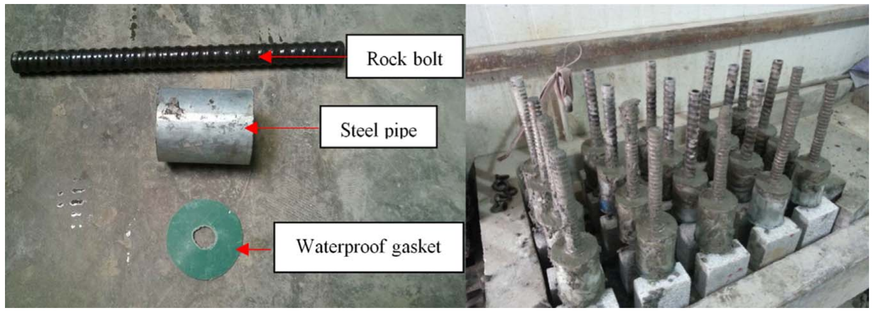

Fig. 1. Photos of the specimens.

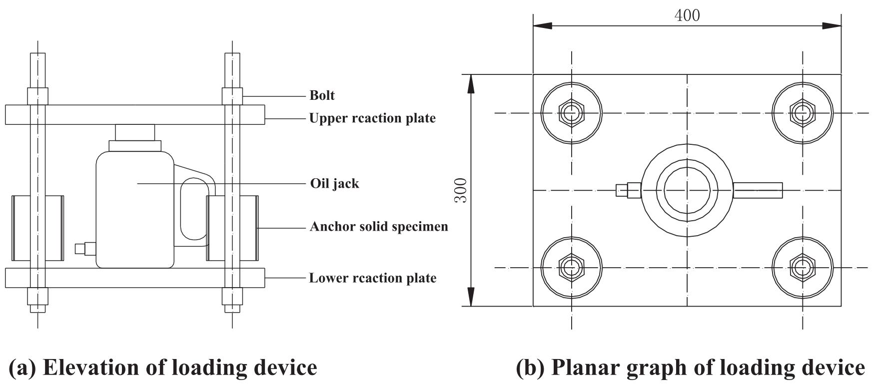

Fig. 2. A schematic drawing of the apparatus for the rock bolts preload (unit: mm).

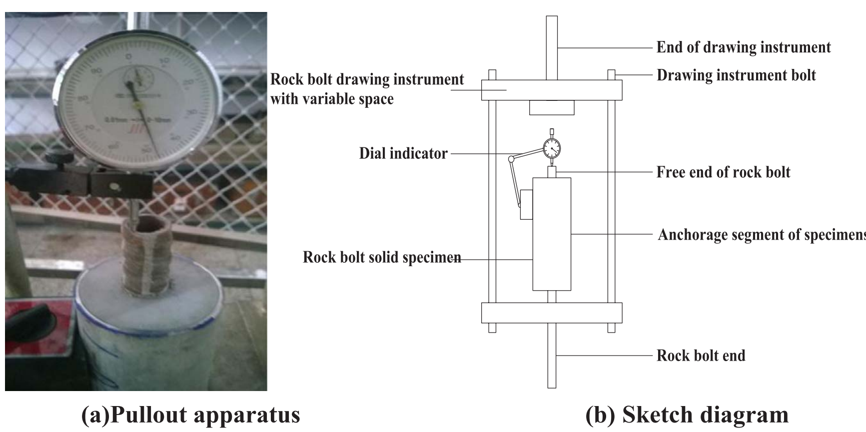

Fig. 3. A schematic drawing for the measuring equipment.

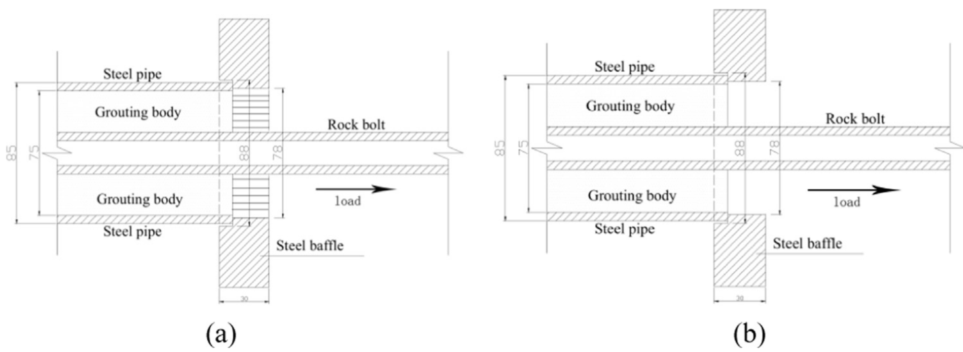

Fig. 4. A schematic drawing for loading process.