Improved Performance of Rock Bolts using Sprayed Polyurea Coating

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Introduction

The deficiencies in tunnel supports led to improvements, including the use of new materials. Because underground water can substantially affect steel materials and decrease their load-bearing capacity, especially for long contact times and acidic water conditions, researchers have been trying to find economical ways to solve the problems of steel corrosion for many years (Ranasooriya et al. 1995; Li and Lindblad 1999; Komurlu 2012; Hassell and Villaescusa 2005).

The application of a polyurea-type thermoset polymer coating was assessed in this study. Polyurea is an isocyanate-based copolymer used for surface treatment applications, such as liners for truck beds, tanks, ships, buildings, pools, and waste deposition isolation plants, beacause of its good water-resisting performance (Komurlu and Kesimal 2012). In addition, it is becoming popular for application on sewage walls because of its resistance to chemical degradation from sulphuric acid and hydrogen sulfide gas (Muynck et al. 2009).

Polyurea is being used as spraying membrane in tunneling and a support called thin spray-on liner (TSL) (Tannant 2001). It is known that polyurea has good adhesion with rock, concrete and steel surfaces (Ozturk and Tannant 2010; Ozturk 2012; BASF 2009).

Polyurea polymerizes owing to the chemical reaction between two liquid ingredients. The liquid phase time of mix can be chosen in accordance with the type of product. The material used in this study is immediately activated within two or three seconds after being blown out of the sprayer gun nozzle.

To test the load-bearing capacities of polymer-coated rock bolts (PCRBs) and the corrosion prevention performance of the polyurea coating, a copper mine in the northeastern region of Turkey was chosen as the case study area.

Field Study

A field study was performed under acidic underground water conditions at the Cayeli copper mine, which has sulfur-containing minerals. Rebar and split-set type rock bolts applied in the mine were used to test the effect of polyurea coating on load-bearing capacity and corrosion prevention. The steel surfaces of 30 rock bolts (15 rebars and 15 split sets) were treated by polyurea spraying (Fig. 1). A liquid-phase mixture of the polyurea ingredients (isocyanate and amine) was sprayed onto aligned rock bolts that were sometimes rotated to cover all sides uniformly. The rebars and split sets used in the mine are 2.4 m in length. Galvanized steel split sets with a nominal diameter of 39 mm were installed in holes of 36 mm diameter. The rebars have a diameter of 22 mm and non-galvanized ribbed surfaces. As seen in the following figure (c part), the shape of the ribs was maintained when coated with thin polyurea lining.

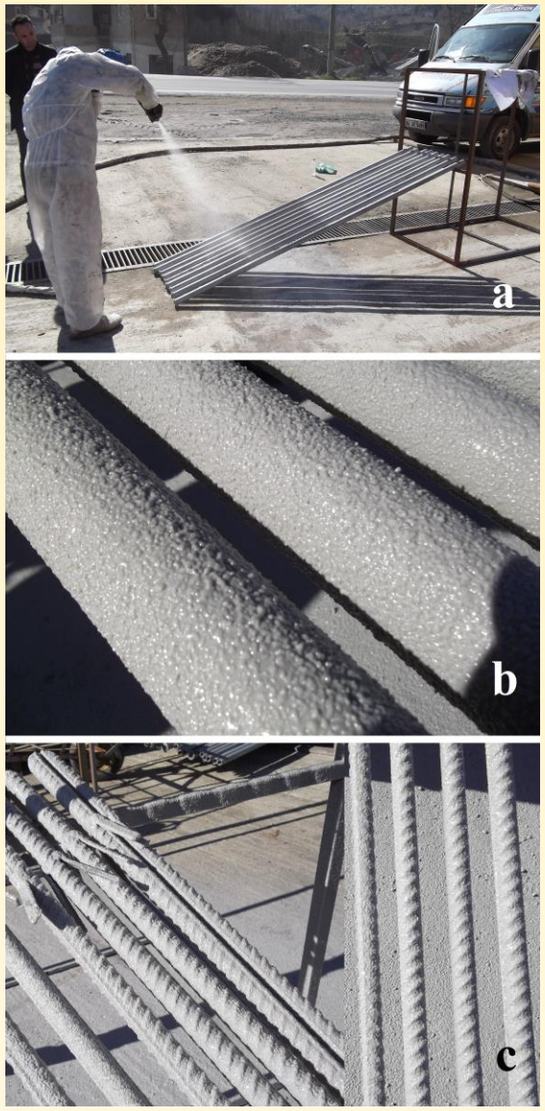

Fig. 1. a) Spray-application of polyurea coating, b) polyurea coated split sets, c) polyurea coated rebars

A part of the mine with water-related problems was chosen for the installation of the rock bolt specimens. Pull-out tests were separately performed on coated and uncoated rock bolts to examine the effects of the surface treatment after one week, five weeks, and six months from installation (Table 1). The load-bearing capacity of the uncoated split sets was excessively reduced by corrosion. On the other hand, there was no adhesive failing between the PCRB (polymer coated rock bolt) and the hole surfaces. As shown in Fig. 2, the steel of the polymer-coated split sets broke at the end of pull-out test.

A mix of ordinary Portland cement and water was used as the injection material for the rebars. According to routine tests applied to hundreds of uncoated rebars, ultimate loads from the first to the sixth month varied within a large range, between 70 kN and 120 kN.

Exact pull-test loads could not be applied to coated rebars because the maximum load capacity of the machine was 200 kN. There was neither steel failure nor an adhesively failed rebar bolt surface. Therefore, it can be concluded that the ultimate load-bearing capacities of rebars with polyurea coatings were greater than 200 kN for all terms of the tests (Table 2).

Table 1. Pull-out test results for split sets (*Fu* = ultimate load, *S. D.* = standard deviation, PCRB: polymer coated rock bolts, Uncoated: rock bolts with galvanized finish, Spec.=Specimen)

Specimen	F_u (kN)	*S. D.* (kN)	Spec. Number
PCRB (1 Week)	82.4	6.6	5
PCRB (5 Weeks)	83.8	5.8	5
PCRB (6 Months)	78.2	5.4	5
Uncoated (1 Week)	40.4	3.7	5
Uncoated (5 Weeks)	33.4	4.9	5
Uncoated (6Months)	21.4	3.2	5

Table 2. Pull-out test results for grouted rebars

Specimen	Testing Time	F_u (kN)
PCRB	1 to 6 months	>200
Uncoated	1 to 6 months	70-120

Fig. 2. Example of broken steel of split set with polyurea coating after a completed pull test

Cost of Polyurea Coat

According to the materials consumed during the spraying application, the cost of the polyurea coating is approximately USD 0.6/m. In addition, high-quality polyurea spraying applications require sophisticated machines that typically cost around USD 25,000. On the other hand, workmanship costs for the surface treatment are quite low; two people can easily coat more than 100 rock bolts in one hour.

Conclusion

The load-bearing capacity of PCRB was found to be higher than that of uncoated rock bolts. It was confirmed by the tests applied on the grouted rebars that polyurea has excellent adhesion with steel and cement mix injections. In addition, the substantial increase in pull-out test results for the split-set-type frictional bolt showed that the polyurea coating adheres well to the hole surface. The results indicate that polyurea coating gives a significantly increased frictional performance at the contact between the bolt and the rock surface in the bolt hole.

No decrease in the load-bearing capacity was observed for the polyurea-coated split sets from the pull-out test results, whereas half of the load-bearing capacity of uncoated split sets was lost within the first six months. The significant increase in load bearing capacity after six months indicates that this method of polymeric coating of bolts is advantageous for mining. Further investigations for the possible use in rail or motorway tunnels with required long service life times are recommended.

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