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Performance tests on short length cable bolts in an underground room and pillar mine

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ABSTRACT : Cable bolting is performed, as a pilot study, in a Greek underground bauxite mine as an alternative to the conventional expansion shell rock bolt support system. Appropriate cement grout mixtures have been selected and a suitable installation technique has been chosen. The installed cables have been tested following a pull out testing procedure. The application of the particular cable bolting support system has been successful and promising.

1 INTRODUCTION

Cable bolting is performed in a Greek bauxite mine as a pilot study for the reinforcement of the rock mass with fully cement grouted untensioned steel cables. This method is used worldwide for the past thirty years as an efficient rock reinforcement and support technique in both mining and civil engineering excavations. Nowdays its use in underground mining finds a wide variety on ground control prereinforcement applications, such as the untensioned cable bolting of the backs in cut and fill stopes in order to increase safety, reduce overbreak and enhance productivity, bolting of the hangingwall and the crown pillars in open stopes with large spans like V.C.R. and Sublevel Stoping thus improving productivity with low waste dilution, and bolting of drawpoints, ore passes and shafts thus ensuring their stability.

Production of bauxite ore in Greece comes mainly from underground mines exploited predominantly by mechanized room and pillar mining. Bauxite deposits belong mainly to the uppermost third bauxite horizon, which is of diasporic type and surrounded by fully stratified microcrystalline limestone. The ore deposit in which the cable bolting technique is tested, is located 750m above sea level in a depth of 450m with an average dip of 20°, a W-SW/N-NE strike and an average thickness of 5.6m varying between 2 and 14 m. The hanginwall of the deposit consists of fully stratified and thinly bedded limestones which are in conformity with bauxite and are usually intesively karstified.

Mining excavations are supported by abandoned ore pillars. Design of pillar layout and dimensions is based on pillar strength and on the structural geology of the hangingwall. A general assumption is made that stresses at any point within the hangingwall should not cause roof or pillar failure at least until the completion of the depillaring stage, when gradual reduction or total extraction of the bauxite pillar takes place. The immediate roof is reinforced by 2.10m long expansion shell rockbolts. Intense and systematic rock bolting provides additional tensile and shear strength to the bedding planes of the hangingwall. Thus a massive and strengthened rock beam is established which prohibits roof failure and increases considerably the span of the room.

Cable bolting is tried with short, up to 3m long, cables. Its scope is to examine whether cable bolting of the immediate roof can be applied as the main reinforcement system in the mine or in conjuction with conventional rock bolting.

2 CEMENT GROUTS

In order to examine the mechanical properties of various cement grouts, a number of mixtures composed of cement and water without any additives are tested with standard procedures. The cements used are normal Portlant cement (P-35) and fast setting cement (NF P15-315). Chemical composition analysis of P-35 cement is SiO_2 26.18%, Fe_2O_3 2.55%, Al_2O_3 13.27%, CaO 49.5%, MgO 3.28% and SO_3 2.14%. The water/cement ratio of the grouts ranges between 0.3-0.4.

For the preparation of the grouts a Chemgrout CG-550P mini grout pump and mixer is used. This system includes a rotary mixer and a pump which operates with compressed air. For the preparation of each grout sample the correct amount of water

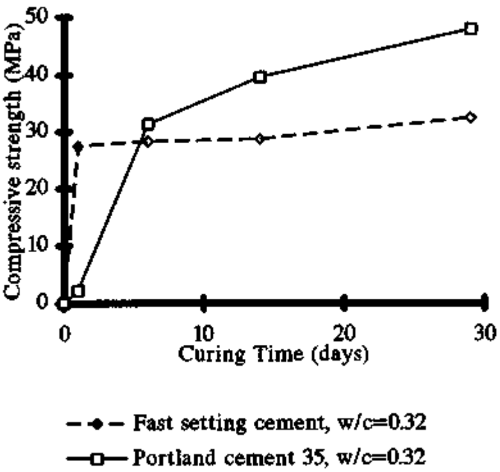

Figure 1. Compressive strength development against curing time of the grouts; w/c = 0.32.

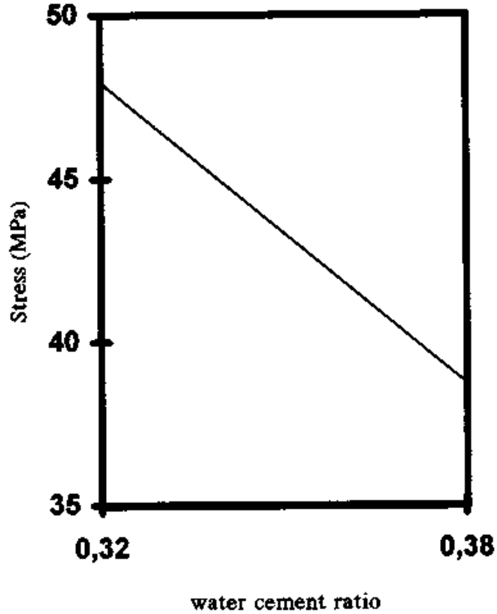

Figure 2. Reduction in strength of Portland cement grouts with increase in w/c.

is put into the mixer and during its operation the cement is added progressively. The time for the preparation of each mixture is about 15-20 min. Test cubes with a sidelength of 0.15 m are cast with various grout mixtures. The grout preparation is performed underground. The cubes are tested in uniaxial compression during the 28 first days of curing. The compressive strength is used to measure the difference in the quality of the grout mixtures (Stillborg, 1984).

Compressive strength test results for the different cement grouts as a function of time, water/cement ratio (w/c) and type of cement are given in figures 1 and 2. From the figures it may be deduced that :

- For grouts with the same type of cement the compressive strength depends on the water/cement ratio. As the water /cement ratio increases the grout compressive strength decreases.
- The grout with fast setting cement increases its compressive strength quite rapidly during the first 24 hours when the greater portion of the final compressive strength is exceeded.
- Portland cement grout is characterised by higher values of uniaxial compressive strength than the fast setting cement grout, when considering 28 days of curing.
- During the preparation of the grouts, fast setting cement mixtures were more fluid than the P-35 cement mixtures. The pump is capable of pumping grout with a water/cement ratio as low as 0.3. Below this ratio there are difficulties with the mixing and with the pumping of the grout.

3. CABLE BOLT INSTALLATION PROCEDURE

Although installation of cables can be a mechanized operation, a manual technique is chosen. Many in situ trial grouts and cablebolt groutings are performed in upholes in order to test the injectability and the consistency of the grout. The 25mm grout injection tube reaches the end of the 38 mm diameter, two to three meter deep, drillhole. Grout is then injected up to the top of the hole; as pumping goes on the elastic tube is pushed down by the pressure of the grout.

When the tube appears at the drillhole the hole is full with grout and the tube is inserted to the next drillhole. After the hole is full of grout one or two 15.2 mm cablebolts are inserted into the grout column manually. There is almost no danger of leaving air voids in the grout column due to the high viscosity of the grout, which has a 0.3-0.35 water/cement ratio, and due to the short pumping depth of the drillholes.

The cablebolt is held in place by a wooden wedge which is placed into the hole collar after its complete insertion. The cablebolts are cut before the installation in predetermined lengths. For the procedure of the cable bolting three men and a platform are needed, i.e. one operator for the mixer and two for the feed of the mixer and the insertion of the grout and cables into the upholes.

Special attention must be given to the correct mixing of water and cement to avoid blockade in the elastic hoses. Cement must be added to the mix progressively. The water and cement of the mix must be clean and without impurities. In addition the drillholes must be cleaned carefully before the cablebolt installation in order to achieve good bond at the rock/grout interface. The elastic tube for pumping the grout into the borehole has to reach its top and to move down slowly during the grout insertion, because its consistency depends on the rate of withdrawal of the tube from the borehole.

There are losses of grout due to the insertion of the cable into the fully grouted borehole and due to its quantity left in the elastic hoses and mixer after the completion of the installation procedure. In order to improve the bond strength between the cable and the grout the surface of the former must be clean and without grease, mud and dirt. The cablebolted stopes have to remain at a standstill until the grout has obtained part of its strength.

Seven strand new 15.2 mm in diameter steel cables are used. Cable bolt patterns with spacings of 1m x 1m and 1.5m x 1.5m are used in the test rooms. The drillholes are normal to the limestone hangingwall and their depth varies between 2m to 3m. One of the rooms tested has completed the retreat stage. The increase in the span of the roof did not cause any signs of failure. The behaviour of the rest of the cablebolted roofs is also till now satisfactory.

Cable bolting is performed by well trained personnel in order to achieve good quality of bolting mainly on limestone roofs and on some bauxite pillars.

4 IN SITU PULL-OUT TESTS ON CABLES

Objective of the in situ pull-out test is the investigation of the significance of the water/cement ratio, of the type of cement used in the grout, and of the time elapsed since the installation of the cablebolt. The quality of the bond between the cable bolt and the grout is controlled by their interface area. Pull out tests are performed on cables with a 300 kN hydraulic ram, hand pumped with a tripod reaction frame which prohibits cable rotation during pulling. An extra fitting is put on the cable behind the ram to anticipate resistance from its load. Nevertheless this fitting may not resist loads over 180 kN and at this load slip may occur.

In figure 3 are given some typical pull out test results performed on various cable bolts. There we may observe :

- The water/cement ratio affects highly the behaviour of fully grouted untensioned cable bolts.
- Cable bolts grouted with fast setting cement are ready to take load from the first day after the installation, while the cable bolts grouted with Portland cement need at least five to seven days to be capable to withstand load.
- The maximum load for expansion shell anchored rockbolts which are used is 120 kN while the maximum load for cable bolts is significantly higher.

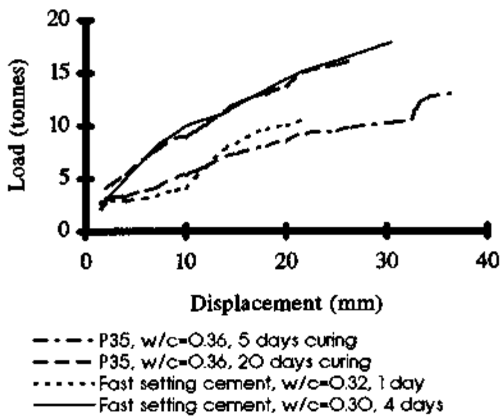

Figure 3. Typical pull-out tests on cable bolts.

5 CONCLUSIONS

A simple method of installing short length cable bolts with cement grouts has been tried in a room and pillar bauxite mine. The optimum water cement ratio has been defined. Further research on monitoring cable bolted roofs has to be continued. Furthermore with the use of cable bolts the mine has an alternative solution in conjuction with rock bolts to confront difficult roof support cases. The combined use of rockbolts with cable bolts of greater length may give the possibility to create even greater roof spans.

Cable bolting has also been tested successfully for the reinforcement of jointed bauxite pillars in order to tie together individual bauxite blocks, thus enhancing stability and reducing spalling.

The cost of cable bolting is found to be 30% lower than the cost of an equivalent expansion shell rock bolting system. Nevertheless cable bolting presents a handicap due to the need of well trained personnel in an independent mining operation.

Further application of cable bolting on roof and pillar rock masses will improve the method and will finally lead to decisions on their feasibility either alone or in combination with the existing expansion shell rock bolting system.

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