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Grouting of Hard Rock with Gelling Liquids

Field and Laboratory Studies of Silica sol

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ABSTRACT
Recent grouting projects in Sweden have concentrated on the grout itself. The only grout normally used in Sweden is a cement-based one. During the past 10 years, the acceptable flow of water into tunnels has been significantly reduced. The current requirements mean that an average fracture aperture of around 0.05 mm has to be sealed. Chemical grouts generally have a low initial viscosity, and the absence of particles means that they can penetrate narrow fractures. Recently, the environmental impact of non-cement grouts has become an important issue. Silica sol is a material that seems to fulfil both requirements, as it is non-hazardous and capable of penetrating narrow fractures.

The main objectives of this study are to investigate the basic concepts of how rheology affects penetration and to develop models for calculating penetration length. Other aims are to analyse the need for sealing of narrow fractures and to find out how the grouting design can be coupled to the characterisation of the rock mass. The three papers that make up this study deal with the sealing of narrow fractures in the field. The papers outline the grouting procedure with silica sol and analyse a concept for evaluating sealing efficiency and penetration length.

In a laboratory experiment conducted with a sand column, the sand was characterised and the grout penetration was measured. The objective of this experiment was to equate the penetration length of the sand with that in a slit. The hydraulic aperture of a fracture in rock can be used to calculate penetration lengths; the equation derived for the equivalent aperture of the sand is proportional only to the porosity and calculated specific surface of the sand itself.

The papers outline the grouting procedure with silica sol and test a concept for evaluating the sealing efficiency and penetration length. The grouting design was based on the characterisation of the rock mass and the grouting parameters. To obtain the desired penetration length, the correct mixing ratio and grouting pressure were determined. The grout used was silica sol, a gelling liquid consisting of amorphous silica particles suspended in water. To initiate and accelerate the gelling process, salt solutions were used.

Models were developed to calculate the grout penetration, with dimensionless parameters, in both one and two dimensions. An interesting feature is that the penetration length calculated in 1-D is twice as long as that for 2-D, which is verified partially by two field studies. In the sand column test, the equivalent aperture of the sand is directly linked to the aperture of a fracture. In the second part of the test, the grout penetration stops long before the gel time of the grout is reached. The final penetration is the same as the penetration calculated by the analytical model with a grouting time equal to gel induction time, t_G . Since the penetration models are based on the grout properties, the proposed calculations can be applied to most types of gelling liquids, provided the basics of the rheology are taken into account.

Keywords: Grouting, gelling liquids, silica sol, colloidal silica, penetration length, hydraulic test, transmissivity, field study, sand column, aperture, propagation, rheology

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