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A review of the Namntall Tunnel project with regard to grouting performance

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ABSTRACT

The 6 km tunnel under the Namntall hill is a part of the Botniabanan railway project in northern Sweden. The tunnels were excavated by means of drilling and blasting and with, for Scandinavian conditions, a normal grouting routine. The grouting is performed to reduce water ingress into the tunnel to the level defined in the contract. When the water ingress requirements proved difficult to meet, it was obvious that the geological and the hydrogeological conditions in the tunnel would dictate the work processes. A distinctive change in rock conditions influenced both grouting performance and seepage into the tunnel. The rock conditions and the grouting were quantified throughout the project and these are summarized in this paper. It can be concluded that the strongest correlation is between the water ingress, the hydrogeological conditions and the density of the zones and the conditions in and around these zones. The paper suggests a different approach to hydrogeological prognosis and the grouting process, such as distribution of grouting classes, increased mixer capacities and regular use of two grouting rounds.

1. Introduction

1.1. Background

The 6 km Namntall Tunnel is a part of the Botniabanan project linking Örnsköldsvik and Kramfors. The tunnel was constructed as part of a Design-build contract consisting of a single-track rail tunnel (65 m^2) and a parallel service tunnel (35 m^2). The client, Botniabanan AB (BBAB), is a partnership (90/10) between Banverket (Swedish Rail Administration) and the municipal authorities in the area. The contract was awarded to Skanska Sverige AB as the main contractor for the civil engineering work. The total scope of the Design-build contract included the 6 km Namntall Tunnel, several over ground parts and a 5 km second tunnel. The tunnels were excavated using the drill and blast method between 2004 and 2007.

For the most part the Namntall Tunnel, with a rock cover of between 20 and 150 m, was excavated in a greywacke and through a major intrusion of granite, Fig. 1. The tunnels were excavated by means of drilling and blasting and with, for Scandinavian conditions, a normal grouting routine, including probe drilling, water pressure tests (Moye, 1967) performed by pressurizing the whole probe/grout hole and measuring the outflow of water for a period of time, evaluation of the water pressure test class (grouting class), drilling of grout holes, cement grouting, drilling of control holes (water pressure tests) and supplementary drilling/grouting. A schematic illustration of the grout fan layout is shown in Fig. 2. The grouting is performed to reduce the water ingress into the tunnel as defined in the contract (temporarily 20 l/min 100 m and in the permanent situation 12 l/min 100 m). Originally, the permissible ingress was stipulated in an environmental court ruling based on, amongst other things, a hydrogeological prognosis (taken from the tender documents, based on the exploratory drillings, Botniabanan AB 2003).

1.2. Hypothesis

This case study of the Namntall Tunnel focuses on the correlation between certain geological and hydrogeological data and grout performance (grout take). More specifically, the density of fractures, “zones”, joint filling, water pressure test measurements and grout take are examined. The analyses are performed using large-scale statistical data that make links and comparisons more reliable, limiting the influence of variations in individual data.

For this case study the following hypotheses are formulated:

- Geological factors, such as rock type, density of zones, fracture frequency or block size and *in situ* stress, could explain the large-scale distribution of water pressure test results in the rock mass.
- The greatest water pressure test value in a grout fan can be used to classify the rock mass and a statistical link to grout take can be established.
- The degree of difficulty of the grouting can be defined by means of geological factors such as fracture filling, density and zone characteristics.

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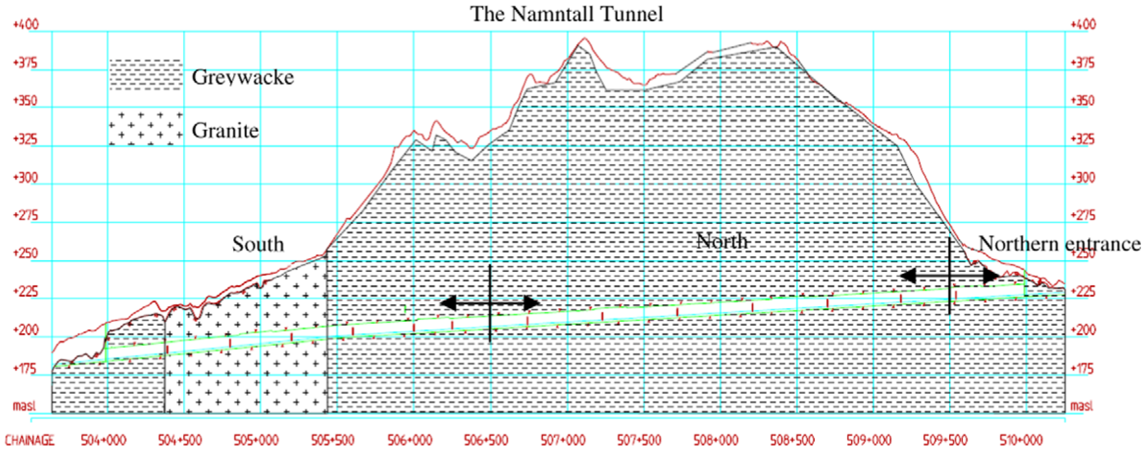

Fig. 1. Longitudinal section of the Namntall Tunnel illustrating the rock cover above the tunnel and the main rock types (Adapted from Botniabanan AB, 2003).

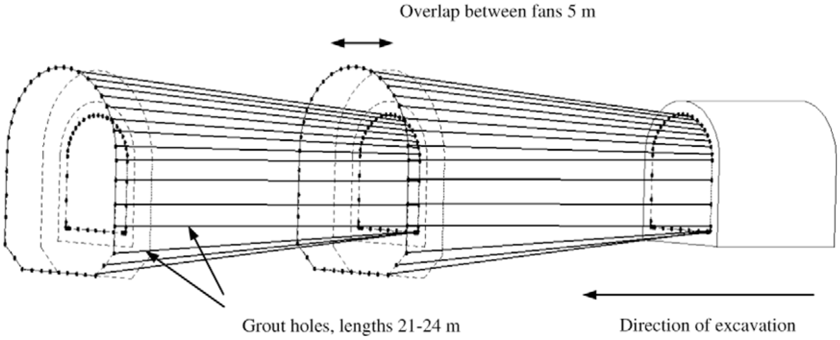

Fig. 2. Schematic illustration of two grout fans. Grouting class A had 10 holes whereas the B and C classes had 20 holes arranged around the tunnel periphery. (Adapted from Butrón 2009).

1.3. Outline of the paper

Paragraph 2 focuses on the geological and hydrogeological conditions in the Namtall Tunnel. It includes the local geological history and a definition of the investigated parameters. The quantification of the data is presented in figures (diagrams) showing the overall tunnel conditions. The investigated data include: "zones", fracture density (block size), joint filling and water pressure test measurements.

Paragraph 3 studies the total grout take along the tunnel, the distribution of grout take for different water pressure test classes and the total grout take related to the largest measured water pressure test. The data are presented as diagrams showing the conditions along the tunnel and statistically in the form of a histogram and a scatter plot.

Paragraph 4 concludes the paper and shows the resulting inleakage along the tunnel after grouting.

2. Geological and hydrogeological conditions

2.1. The geological history of the rock mass in the county of Ångermanland (local orogenesis)

The geological history of the area can be said to have "started" some 1820–1850 million years ago during the Sweco-Karelian mountain chain folding process. The greywacke bedrock was created during this process of intense tectonic events. Originally deposits of sedimentary material comprising of sand and clay, the term greywacke is defined through a relatively large clay content (more than 15% in the matrix). In the Namntall area several metamorphic stages in the greywacke have been observed, ranging from almost intact to a metamorphosed metagraywacke that is gneissic and even migmatized resulting in, among other things, segregation of the mineral components into bands or stripes.

A characteristic of the greywacke is the existence of skarn lenses (metamorphic carbonate congregations) and in some areas it is also rich in graphite and sulphides (Lundqvist et al., 1990).

The bedrock has been intensely folded, which is demonstrated by the steeply dipping foliation. The orientation/strike of the foliation is roughly NE-SW, indicating the probable direction of the local tectonic thrust NW-SE (perpendicular to the foliation) during this early phase of the orogenesis, Fig. 3.

Since the mountain folding process and the regional metamorphosis the rock mass has been subjected to a number of faults, resulting in the local topography. The literature states that "valleys, the course of mires, steps in the terrain and straight lakeshores correlate to steep failure lines in the bedrock" (Lundqvist et al. 1990). Furthermore, the erosion created by the moving direction (NNW–SSE) of the quaternary glacial ice has emphasized the weaker areas in the rock, especially where these coincide. It has also been observed that the deep failure lines also coincide with intrusive rocks such as granites, pegmatites and metabasites (which are considered to be the latest additions to the rock mass, originating some 1200 million years ago). It has been observed that during the intrusions of metabasite dikes the rock mass was subject to a considerable increase in fracturing, including the creation of horizontal crushed zones.

The large intrusion of granite between cross-sections 504 + 370 and 505 + 450 as well as numerous dikes, also supports the theory