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Rock mechanics research for radioactive waste disposal in Finland

E. Johansson
Saanio & Riekkola Oy, Helsinki, Finland

J.A. Hudson
Imperial College and Rock Engineering Consultants, Welwyn Garden City, UK

M. Hakala
KMS Hakala Oy, Joensuu, Finland

J. Sjöberg
Vattenfall Power Consultant AB, Sweden

S. Riikonen
Posiva Oy, Olkiluoto, Finland

P. Syrjänen
WSP Finland Oy, WSP Gridpoint, Helsinki, Finland

ABSTRACT: The design and construction of a final repository for spent fuel deep in the crystalline bedrock requires special considerations beyond those required for a conventional rock engineering structure – in particular, aspects relating to the waste isolation function and the associated extremely long design life. The rock mechanics research necessary to support the design of the repository requires an adequate understanding of the geological setting, together with knowledge of the *in situ* stress state, the anisotropic and time-dependent properties of the intact rock, the thermal properties of the rock mass, the fracture occurrence, the brittle deformation zones, the impact of construction and the long-term behavior of the disposal tunnels and deposition holes. Posiva Oy is currently constructing a rock characterization facility termed the 'ONKALO' in Olkiluoto, western Finland, to an anticipated depth of 420 m. The paper describes these aspects and raises questions concerning the extent to which generic rock mechanics information can be used to support the specific site characterization, and how one can establish that sufficient information has been obtained for numerical modeling and hence for adequate repository design.

1 INTRODUCTION

After the Finnish Government's favourable policy decision in 2001, Posiva Oy has focused further investigations at the Olkiluoto site and began preparations for the construction of an underground characterisation facility termed the 'ONKALO'. The construction of the ONKALO began in June 2004 and it is to be continued untill 2014, with the actual characterisation stage anticipated for 2007–2014. The findings of the ONKALO and other investigations will enable the knowledge needed for an application, supported by a Preliminary Safety Assessment, and to construct a final repository for spent nuclear fuel at the site. Posiva will submit an application for the construction licence for a disposal facility by the end of 2012. The target is to begin disposal operations in 2020.

The access tunnel and shafts of the ONKALO will be excavated to the main characterisation level at a depth of 420 m (Figure 1). The access ramp of the ONKALO has already been excavated to a chainage of ~1800 m, which is equivalent to the depth level of about 180 m because the ramp has an inclination of 1:10. The main rock type in the ONKALO area is foliated migmatitic gneiss.

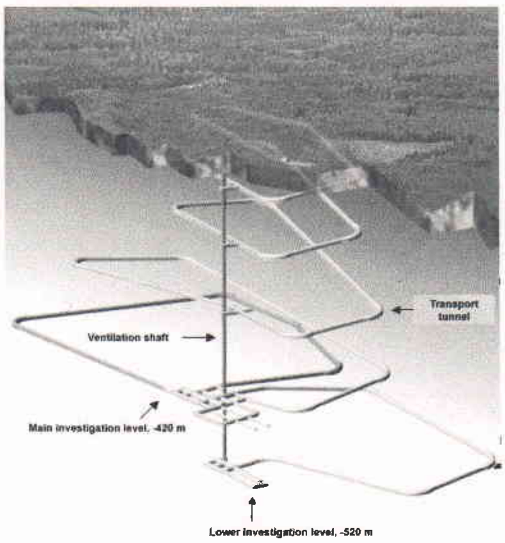

Figure 1. The layout of the ONKALO underground characterisation facility.

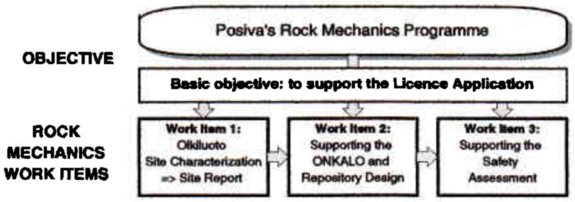

Figure 2. The objective and three associated work items of Posiva's rock mechanics strategy.

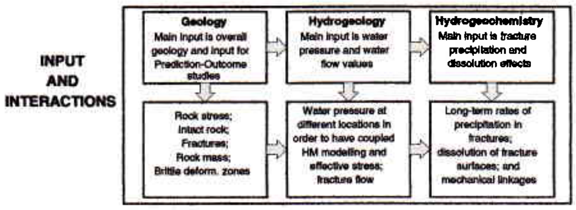

Figure 3. Flowchart Component 2: Input to the rock mechanics work and discipline interactions.

This paper summarizes the rock mechanics research activities and results obtained before the ONKALO construction and the initial results and experiences obtained during the early part of the ONKALO construction work, noting that the ONKALO ramp has enabled direct *in situ* inspection of the underground rock mass, including the exposed brittle deformation zones. Near future rock mechanics measurements and research are also briefly discussed.

2 ROCK MECHANICS STRATEGY

The fundamental objective of Posiva's rock mechanics work is to support the Construction Licence Application for the final repository. This involves three separate areas of work:

1. Rock mechanics characterisation of the Olkiluoto site;
2. Studies supporting the ONKALO and repository design and operations; and
3. Studies supporting the Safety Assessment.

The objective and the three work items are presented in the first flowchart component in Figure. 2.

The next flowchart component, presented in Figure 3 relates to the input information and the interactions with other disciplines. The main input is geology and geological site models – which also provide input to hydrogeology and hydrogeochemistry. However, there are also interactions between rock mechanics and hydrogeology and hydrogeochemistry, which are in detail presented, e.g. in Posiva 2005.

Finally, Flowchart Component 3 summarizes the main rock mechanics work as related to the three work items shown in Figure 2.

In order to execute the strategy, a series of campaigns have been developed relating to the different rock mechanics subjects. Following the establishment of the background rock mechanics knowledge, these campaigns cover the topics of contributions to the Olkiluoto site reports, primary stress, rock properties, deformation zones, impact of construction and EDZ, prediction-outcome studies and characterization level testing. Note that this is an overview of the rock mechanics

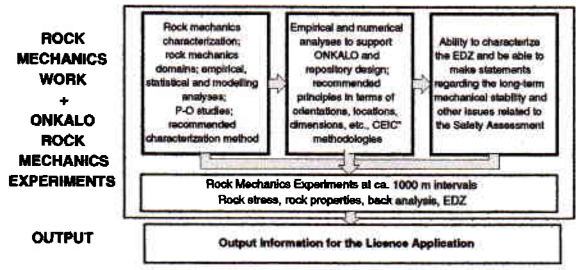

Figure 4. Flowchart Component 3: Rock mechanics work related to the three work items.

strategy and so the listing is not fully comprehensive at this stage.

It is also essential that the current work is based on a complete knowledge of previous related rock mechanics work. A summary description of all the previous rock mechanics work conducted for Posiva is found in Hudson & Johansson, 2006, and the rock mechanics implications of the Olkiluoto geology can be found in Hudson & Cosgrove 2006.

3 ROCK MECHANICS SITE CHARACTERIZATION

3.1 *General*

Site investigations for the disposal of spent fuel at Olkiluoto were already started in 1987; however, recent site investigations at Olkiluoto have concentrated mainly in the ONKALO area. The investigation site to date contains more than 40 deep drillholes, whose main aim has been in obtaining data for planning the ONKALO and also for the development of site understanding. From the start, geological mapping of the ONKALO tunnel has been the most significant investigation method in the ONKALO. Flow measurements in probe holes also commenced at the beginning of construction activities, followed by pilot hole drilling parallel to the tunnel axis and associated investigations. So far, six pilot holes have been drilled and investigated, providing valuable information for construction purposes; pilot holes also have an important role to play in the prediction outcome studies (see further in Chapter 4).

Also, monitoring of the changes caused by construction of the ONKALO has started. The monitoring programme related to the construction includes rock mechanics, hydrogeological and hydrogeochemical monitoring and, in addition, monitoring of the biosphere is also taking place (Posiva 2003).

3.2 *Rock mechanics data*

Rock mechanics investigations are mainly concentrated on obtaining data relating to the *in situ* stresses and the mechanical and thermal properties of different rock domains at different scales. The stress-strength ratio is an important parameter when evaluating the mechanical stability of the anticipated deep repository in the hard, crystalline, rock regime.

3.3 *Rock stress*

In situ stresses have been measured at Olkiluoto at depths of 300–800 m in five deep surface boreholes by using conventional methods, such as hydraulic fracturing to evaluate horizontal stresses and the 3D overcoring methods