



# Minutes of Meeting

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## PARTICIPANTS

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## SKI – SKB Expert meeting on rock mechanics/thermal properties

**Date:** 2006-12-01, 09.00 – 15.30

**Place:** SKB, Brahegatan 47, 7<sup>th</sup> floor

The overall focus of the meeting was to cover CRI-16 and CRI-17.

### Introduction

Welcome address by OO.

He pointed out that more detailed information on the progress of the site investigations will be given at the INSITE meeting the following week.

He also informed that data QA had identified some errors in fracture orientation data. Different types of uncertainties are identified and a plan of action is in progress.

However, it is also concluded that the main conclusions in SR-Can are not affected by the identified data errors.

### Thermal properties of rocks and rock masses (CRI-17)

JS gave an overview of *the large scale anisotropy measurements at Forsmark*.

- Purpose; to investigate the large scale thermal anisotropy
- Design of the experiment.
- The large scale field test was compared to laboratory data (TPS method) and small scale field test (the multi-probe method).
- The anisotropy factor in thermal conductivity is scale dependent. The larger the volume, the smaller the anisotropy factor.
- The results depend somewhat on the time period of the experiment studied.

OS asked how these findings are to be considered in the design. RC said this is currently under investigation, OO underlined that SKB does not intend to optimize the dimensions of the repository at this stage of the project.

JS gave an overview of *the inverse thermal modelling* using data from the Äspö HRL Prototype Repository Experiment /SKB R-05-82/.

- Monitoring layout
- Good agreement between prediction and results of inverse modelling.

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RC gave an overview of *the TERO probe* results.

- The probe has been tested in 56 and 76 mm boreholes down at Simpevarp/Laxemar area.
- Results especially in 76 mm borehole suffered of leakage of water from the test section, as well as short circuit of flow along some borehole sections.
- The probe has also been tested at the site for measurement of thermal anisotropy at the Forsmark site. Thermal conductivity values  $3.5 - 3.8 \text{ W m}^{-1} \text{ K}^{-1}$ . Temperature records not indicating purely conductive heat transfer. The results were affected by flow effects in the holes. Final analysis and reporting is currently being done

RC informed that the *SKB strategy for large scale measurements of thermal conductivity* will be relying on the multi probe. Such measurements have just been completed on outcrops at the Laxemar site.

JS referred to Walsh and Decker, 1966 concerning *the thermal conductivity vs. pressure*. The effect of the crack closure at high pressure is very small in a crystalline rock with small pore volume. OS propose that it shall be mentioned that it is on the conservative side to not account for the possible effect of crack closure on thermal conductivity.

### **Stress measurements and stress interpretation (CRI-16)**

RC gave an overview of *the overcoring measurements* carried out at the Forsmark site.

- Overcoring data will cover boreholes KFM01B, KFM07C and KFM02B. Attempts to measure in KFM07B failed due to systematic bonding problems.
- Overview of the used rating for successful tests, and the actual success rate. There is experienced a high degree of failed tests. Many of the poor tests is caused by bonding problems or geological reasons (steeply dipping sealed fractures not visible in the pilot core occurred in KFM07C).
- Also a possible temperature effect on the strain readings has been identified and is currently subject for further investigations.
- The measurements in KFM02B will be completed mid December. Evaluation of results and reporting is dependent on the completion of the QA control of borehole orientations.

DA gave an overview of *the stress measurements using hydraulic methods* at the two sites.

- DA presented the newly designed equipment and the strategy for measurements. The HTPF (Mosnier) tool is used both for identification of suitable test locations and possible domains, separated by deformation zones.
- Hydraulic methods have been used at the Laxemar site in borehole KLX12A (17 tests) and at the Forsmark site in boreholes KFM07A, 07C, 08A, 09A and 09B (totally 86 tests). The success rate is currently under evaluation.
- The peak and shut-in pressures are used as 99 % confidence intervals.
- There were problems to develop a single fracture in inclined holes. Frequently “en-echelon” fractures were developed in inclined boreholes. Other problems experienced were problems with ground currents disturbing the HTPF tool, packer induced fractures and general difficulties to fracture the low-permeable rock.

- Some preliminary results were presented and discussed.

OS asked if the orientation of the “en-echelon” fractures is parallel to the foliation. They seem rather to be on the vertical side-wall of inclined boreholes. DA suggests that they are formed as shear fractures. DM comments that it seems unlikely to induce shear fractures under the actual loading conditions, and these are likely extension fractures caused by the borehole not being parallel to a principal stress.

DM gave an overview of *studies of indirect stress indicators*.

- Core damage data from the URL, Canada has been compiled. A ratio of core disc thickness/ stress magnitude has been established based on observed disc thickness in the vicinity of tunnels where the stress conditions are known. It is difficult to estimate stress magnitude for disc thickness > 1 – 2 cm. Based on this approach and the fact that no systematic core dishing at Forsmark has been observed, the major horizontal stress at 1000 m depth in the Forsmark site is not likely to exceed 60 MPa.
- Comparing an-elastic strains for URL and Forsmark, there is significantly less crack-volume strain in Forsmark boreholes down to at least ca 700 m depth, compared to URL 420 m level. Suggesting that the stress magnitudes are lower at Forsmark compared to the URL stresses, since the rock strength at both sites is similar.
- Ramböll has processed the acoustic televiewer logs for borehole breakout studies. 8 boreholes totalling 6939 m have been studied. Borehole ovals > 0.1 mm were reported. Breakouts are normally very small, randomly occurring and their frequency is independent of depth. Breakouts are associated with geological structures in 2/3 of the cases. The breakouts indicate a stress orientation parallel to the dominant vertical fracture sets (NW – SE and NE – SW).. The majority of the observations indicate a orientation of the major horizontal stress of 140 - 150°, well in keeping with available stress measurements. The evenly distributed small breakouts indicate a very small stress gradient down to 1000 m depth.

OS request information on locations for some significant breakouts to be tested in Fracom code (*see the actual examples in the .ppt presentations*).

RC gave an overview of the *future plans for reporting* the stress results. Results of overcoring and hydraulic methods shall be evaluated first, and then shall the indirect observations be added.

DM presented some preliminary approaches for conceptual thinking on *the stress modelling*.

- The experiences from the URL indicate the large problem to measure stresses when the stress magnitudes are relatively high. The confidence in understanding the state of stress increases significantly once observations can be done underground.
- Based on a velocity model from seismic reflection measurements /R-02-43/ the rock mass shear modulus was assessed. The modulus would increase for the first 200 – 250 m depth. Under that depth the increase with depth is very small. Applying displacement boundary in a simple 2D finite element model with a modulus gradient that matches the seismic velocity model, generates

horizontal stresses in keeping with the actual data. However, the old overcoring results from DBT-1 do not fit such a model. The reported stress magnitudes at 400 – 500 m depth in that borehole are however unlikely, based on the fact that core diskings should have occurred if the stress magnitudes were as large as those reported..

- A preliminary stress model based on the preliminary results from measurements and indirect observations indicate a horizontal stress at some 20 MPa already at 100 m depth. The magnitude is likely increasing step-wise through the uppermost rock mass that is affected with gently dipping fractures. At larger depth (>300 m) in the more unfractured rock mass the stress gradient is expected to be small.

The *extension of the rock volume* with the actual state of stress was discussed. RC assumes that the gently dipping deformation zone A2 to the south of the detailed investigated area may be a border for an area with more released stresses. It may be possible, but not proved by data, that the lithological borders of the lens may be limiting the actual state of stress to the west and east of the investigated area. The extension towards north is not known.

The *effect of elevated stresses on the repository* was discussed.

- The report SKB R-05-71 by D. Martin has been reviewed by OS and delivered to SKI.
- HH gave an overview of the coupled THM modelling carried out for SR-Can. Two stress models has been applied to a 3DEC model. Independent of stress conditions seems the stability be good for construction. The most cases indicate however some thermally induced spalling to occur in the depositions holes after closure.

### **Strategy for modelling rock mechanical behaviour (CRI-20)**

OS says that according to the current strategy for modelling the rock mechanical properties is SKB only doing a linear analyse. A possible anisotropic behaviour may be expected. RC commented that there are no strong geological indications that the rock mass behaviour is strongly anisotropic. OS recommended that SKB shall look further into the works by Ki-Bok Min on this matter.

### **Summary of the meeting by SKI**

FK concluded that SKI has to wait for the results from ongoing stress estimations before they can provide any review comments. He pointed out that it was valuable to have had the update from the meeting.

OS pointed out that INSITE is concerned about the stress situation at the Forsmark site. He also concluded that the large scale thermal experiment seem to be a good experiment.