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D3.16 Testing plan for EPSP laboratory experiment

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ABSTRACT:

This report presents the plan of laboratory works related to the EPSP experiment. The laboratory work will provide data for the subsequent numerical analysis of EPSP behaviour (WP5). Three groups of data will be produced – input material parameters, material parameters from verification testing (the occasional checking for possible changes as the project progresses) and data from small-scale physical models to be used for the validation of the numerical models.

The improvement of the rock environment in which the experiment will be located and plug construction itself will be subcontracted to outside organisations. The laboratory and in-situ tests have been planned so as to include the checking of the quality of the work performed (rock permeability, deformation and strength parameters, concrete behaviour etc.) and to ensure that the relevant parameters concerning the various rock and concrete plug components have been met in full.

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REVIEW/OTHER COMMENTS:

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APPROVED FOR SUBMISSION:

Johanna Hansen in May 20th, 2013

D3.16 Testing plan for EPSP laboratory experiment

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1 INTRODUCTION

The DOPAS project addresses the design basis and reference designs and strategies for plugs and seals to be used in geological disposal facilities. The project focuses on tunnel plugs for clay rock repositories (French and Swiss repository concepts), tunnel plugs for repositories to be constructed in crystalline rock environments (Czech, Finnish and Swedish repository concepts) and shaft seals for salt rock repositories (German repository concept).

The Czech experiment "Experimental Pressure and Sealing Plug" (EPSP) addresses developments in terms of the design basis, reference designs and strategies including issues of compliance. The participants of the group involved in the EPSP experiment consist of SÚRAO, the Czech Technical University in Prague (Faculty of Civil Engineering) and UJV Řež a.s. The Josef underground facility is hosting the experiment.

The accompanying laboratory work will provide data for the numerical analysis of EPSP behaviour (WP5).

1.1 EPSP concept description

The EPSP plug has been designed as a prototype plug for a deep geological repository for radioactive waste. It is expected therefore to function during the whole of the operational phase of the repository, i.e. 150 years with an expected over-pressure of up to 7MPa.

The plug has been designed as a multilayer system which consists of two main structural elements which ensure the stability of the system, i.e. concrete blocks and a sealing element - the bentonite section between the concrete blocks. In addition to their structural function the concrete blocks also enhance the sealing ability of the EPSP plug – especially in the first phase of the lifetime of the plug when the bentonite has not yet become fully saturated. At this time the first concrete block will be expected to prevent potential excessive water inflow into the bentonite seal (to prevent the risk of piping).

Fibre shotcrete will be used in the construction of the various elements of the EPSP; the bentonite sealing section will be constructed using spraying technology.

The plug will be tested by injecting an air/water/suspension into a pressurizing chamber and the subsequent monitoring of the performance of the plug.

Due to the geological conditions in the EPSP experimental drift of the Josef underground laboratory, grouting had to be used in order to lower the permeability of the rock mass prior to the commencement of the EPSP plug experiment.

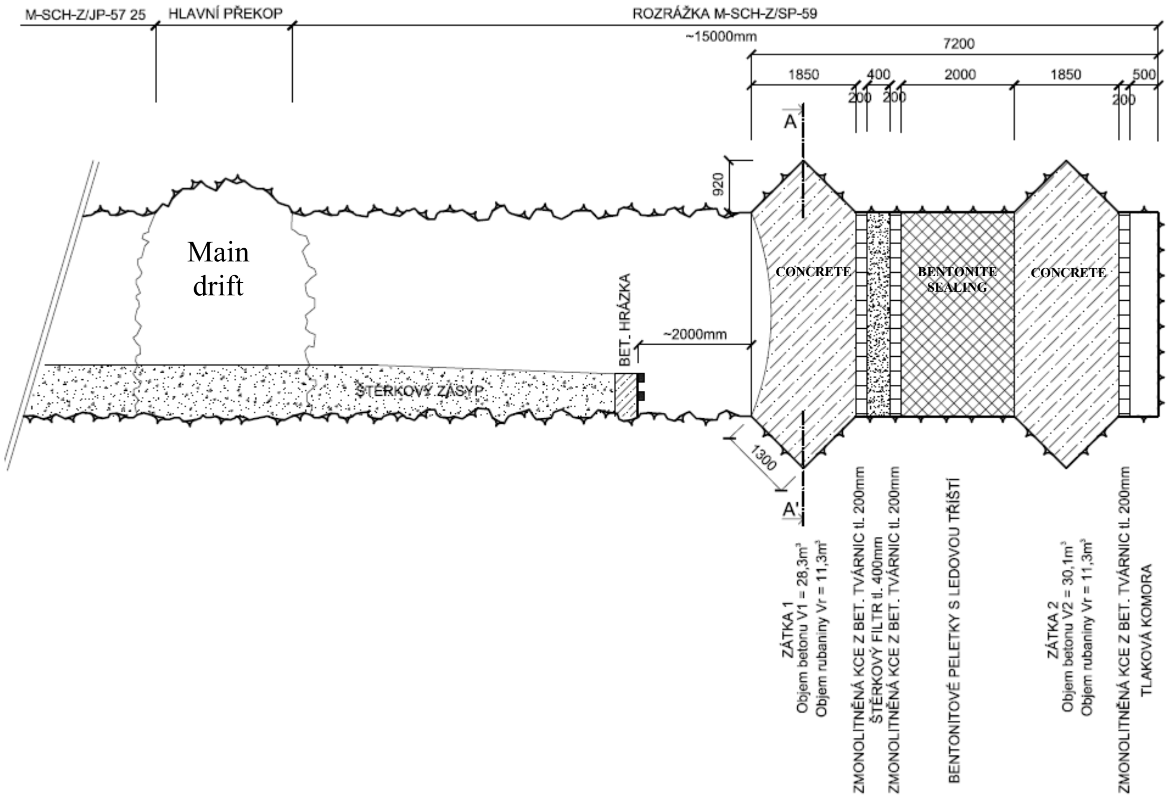

Figure 1 – Scheme of the EPSP plug

1.2 The aim of the laboratory investigation

The laboratory work will provide data for the subsequent numerical analysis of EPSP behaviour (WP5). Three groups of data will be produced – input material parameters, material parameters from verification testing (the occasional checking for possible changes as the project progresses) and data from small-scale physical models to be used for the validation of the numerical models.

The improvement of the rock environment in which the experiment will be located and plug construction itself will be subcontracted to outside organisations. The laboratory and in-situ tests have been planned so as to include the checking of the quality of the work performed (rock permeability, deformation and strength parameters, concrete behaviour etc.) and to ensure that the relevant parameters concerning the various rock and concrete plug components have been met in full.

2 INPUT DATA REQUIREMENTS FOR NUMERICAL ANALYSIS

2.1 Processes

The bentonite between the concrete plugs will be partially saturated during the emplacement process. The water content in the bentonite will be increased gradually up to complete saturation which will be caused either by the inflow of water from the surrounding environment (as in real deep geological repository conditions) or artificially by means of water pressure testing techniques.

The flow of water through the cement plug, the gradual saturation of the in-situ bentonite and the flow of water through the saturated bentonite will be numerically simulated in WP5 using input material parameters determined as part of WP3. Moreover, a series of physical model experiments will be performed in order to calibrate the mathematical models.

2.2 List of parameters

In order to perform the numerical simulation of the EPSP experiment the following parameters will need to be determined experimentally:

2.2.1 Bentonite

- Hydraulic and gas (H_2) permeability
- Porosity
- Swelling pressure
- Retention curve
- Thermal conductivity and heat capacity

2.2.2 Concrete

- Hydraulic and gas (H_2) permeability
- Porosity
- Strength properties
- Thermal conductivity and heat capacity
- pH and composition of the cement water

2.2.3 Grouting substances

- Chemical stability
- Leachability

2.2.4 Granitic rock massif

- Porosity
- Hydraulic conductivity/ hydraulic and gas permeability changes (together with the grouted rock)
- Young/ deformation modulus
- Poisson ratio
- Strength properties

3 MATERIALS

The EPSP sealing system consists of two main structural elements which will ensure the stability of the system – the concrete plugs (concrete with lowered pH) and a sealing element, i.e. the bentonite section between the concrete blocks. The natural surroundings of the plug will consist of granitic rock. Due to the geological conditions of the Josef underground laboratory, grouting has to be used in order to reduce the permeability of the surrounding rock mass. Grouting can potentially also be used for the filling of the shrinkage void between the concrete plug and the rock.

“Bentonit 75” (industrial product, raw material mostly originating from Rokle mining area) was chosen as the sealing material since its properties are well-known from previous research commissioned by ÚJV Řež., a.s., CEG FSv ČVUT and SÚRAO (Holíková & Levorová, 2012; Hausmannová & Vašíček, 2012; Vokál & Vejsadů, 2012).

Construction materials including the concrete and bentonite will be supplied as part of the construction process by suppliers chosen by means of public tenders.

3.1 Bentonite

Following careful consideration of plug construction requirements, factory-produced bentonite (milled, non-activated Ca-Mg bentonite) was selected as the principal material for the bentonite part of the plug. Based on experience from previous projects, “Bentonit 75” was selected due to its fully complying with the required parameters (hydraulic conductivity, swelling pressure).

The key geotechnical parameter values are expected to be as follows:

- Hydraulic conductivity – max. 10^{-12} m/s at dry density 1400 kg/m^3
- Swelling pressure – at least 2MPa at dry density 1400 kg/m^3

3.2 Concrete

Concrete with lowered pH will be used as one of the materials making up the plug. The principal role of the concrete plug components is to fix the middle bentonite section in its initial position. It is envisaged that shotcrete containing glass fibres will be used; it is expected that the glass fibres will enhance the physical properties of the concrete in terms of shrinkage. The influence of alkaline leaching on the bentonite barrier will be minimized through the use of concrete with lowered pH. Highly alkaline leachates contained in normal pH concretes could negatively influence the properties of the bentonite.

The exact consistency of the concrete mixture was determined based on experience gained from previous experiments conducted by the project’s various participants and will be applied by means of shotcrete technology. For the purposes of laboratory testing, shotcrete samples will be prepared – blocks of concrete to be subjected to core drilling. The expected values of the fibre shotcrete are:

- Strength properties - uni-axial strength min. 20MPa
- pH of leachate < 12

3.3 Grouting substances

A commonly used grouting material (based on polyurethane) will be used for the purposes of this demonstration experiment. The chemical composition and stability, possible interaction, physical properties and applicability of the grouting material will be verified (e.g. independent tests and certification). The extent of the interaction of the grouting with the cement and the bentonite leachates will serve to confirm the stability or otherwise of the grouting. Due to the location of the Josef underground facility, at which the plug will be constructed, and its relative proximity to water reservoirs, a certificate confirming zero influence on the environment will be required.

As far as the laboratory tests are concerned, samples of the grouting material as well as of the grouted rock (drilled cores) will be required; such samples will be prepared by the contractor who will have to demonstrate the quality of the grouting by means of water permeability tests.

3.4 Granitic rock

The EPSP experiment will be located in a short gallery situated in the granitic area of the Josef underground facility. Due to geological conditions within the experimental drift grouting will have to be used in order to lower the permeability of the rock mass prior to the commencement of the EPSP plug experiment. Other important parameters (deformation and strength) will also have to be verified following grouting; both laboratory tests on core samples and in-situ tests will be performed as part of the evaluation process.

The main aim of the laboratory tests will be to verify the transport properties of the rock surrounding the plug. Hydraulic conductivity will be determined in order to verify the required rock properties and to provide input for modelling purposes. In addition, rock porosity and permeability and the changes therein brought about by grouting will be determined in order to verify the sealing properties of the grouting.

4 TEST LIST AND RESPONSIBILITIES

The following subchapters set out lists of the various tests involved and a description of test conditions and the allocation of responsibilities.

Note: A separate document (available on DOPAS internal Projectplace) also includes expected numbers of tests.

4.1 Input parameters

Material	Parameter	Responsible institution	Responsible person	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Bentonite	Hydraulic conductivity	CEG CTU	Vašíček	ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil - Part 11: Determination of permeability by constant and falling head	compacted powder, dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite	Swelling pressure	CEG CTU	Vašíček	Testing without volume change, internal description following Dixon et. al., 1999; procedure available on Projectplace	compacted powder, dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite	Hydraulic conductivity	CEG CTU	Vašíček	ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil - Part 11: Determination of permeability by constant and falling head	pellets compacted to dry densities 1100-1800 kg/m3	04/2014-12/2014
Bentonite	Swelling pressure	CEG CTU	Vašíček	Testing without volume change, internal description following Dixon et. al., 1999; procedure available on Projectplace	pellets compacted to dry densities 1100-1800 kg/m3	04/2014-12/2014
Bentonite	Thermal conductivity, heat capacity	CEG CTU	Vašíček	ISOMET 2104 device	powder - compacted, dry densities 1100-1800 kg/m3	12/2013-04/2014

Material	Parameter	Responsible institution	Responsible person	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Bentonite	Specific density	CEG CTU	Vašíček	ČSN CEN ISO/TS 17892-3 - Geotechnical investigation and testing - Laboratory testing of soil - Part 3: Determination of particle density - Pycnometer method	powder	12/2013-04/2014
Bentonite	Hydraulic conductivity	UJV	Večerník / Vejsadů	ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil	dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite	Gas permeability	UJV	Večerník / Vejsadů	internal procedure based on ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil	dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite	Porosity	UJV	Večerník / Vejsadů	internal procedure	dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite	Swelling pressure	UJV	Večerník / Vejsadů	internal procedure based on ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil	dry densities 1100-1800 kg/m3	12/2013-04/2014
Bentonite **technology**	Spraying field tests	CEG CTU	Vašíček	internal procedure	selection/ mixtures of various particle fractions	03/2013-07/2013
Concrete	Thermal conductivity, heat capacity	CEG CTU	Vašíček	ISOMET 2104 device	samples taken during installation, according to Standard	09/2013-03/2014
Concrete	Compressive strength	W2 (CTU)	Vašíček	ČSN EN 12390 (731302) - Testing of hardened concrete	samples taken during installation, according to Standard	12/2013-02/2014
Concrete	Static modulus of elasticity in compression	W2 (CTU)	Vašíček	ČSN ISO 6784 (731319) - Concrete. Determination of static modulus of elasticity in compression	samples taken during installation, according to Standard	12/2013-02/2014
Concrete	Static modulus of deformation	W2 (CTU)	Vašíček	ČSN ISO 6784 (731319) - Concrete. Determination of static modulus of elasticity in compression	samples taken during installation, according to Standard	12/2013-02/2014
Concrete	Composition and pH of leachate	UJV	Večerník	based on SKB report R-12-02	leaching into distilled water	07/2013-03/2014
Concrete	Hydraulic conductivity	UJV	Večerník	based on ČSN CEN ISO /TS 17892	cylindrical sample	07/2013-03/2014
Concrete	Gas permeability	UJV	Večerník	internal procedure	cylindrical sample	07/2013-03/2014
Concrete	Porosity	UJV	Večerník	mercury porosimetry / water immersion method	external analysis / cubes, discs	07/2013-03/2014
Concrete	Hardened concrete testing	W2 (UJV)	Večerník	ČSN EN 12390	Compressive strength, Depth of penetration of water under pressure	07/2013-03/2014
Grouting substances	Interactions	UJV	Večerník	Internal procedure for interaction processes	grouting/plug materials/plug environment	05/2013-06/2015
Rock samples	Compressive strength	W1 (SURAO)	Dvořáková	ČSN EN 1926 - Natural stone test methods - Determination of uniaxial compressive strength	drilled cores	5/2013-7/2013

Material	Parameter	Responsible institution	Responsible person	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Rock samples	Static modulus of deformation	W1 (SURAO)	Dvořáková	ČSN ISO 6784 (731319) - Concrete. Determination of static modulus of elasticity in compression	drilled cores	5/2013-7/2013
Rock samples	Density	W1 (SURAO)	Dvořáková	e.g. ČSN CEN ISO/TS 17892-2	drilled cores	5/2013-7/2013
Rock samples	Permeability	UJV	Večerník	Changes in rock permeability due to grouting,	drilled cores	07/2013-03/2014
Rock samples	Porosity	UJV	Večerník	mercury porosimetry / water immersion method	external analysis / cubes, discs of plug material	07/2013-03/2014
Rock massif	Modulus of deformation	W1 (SURAO)	Dvořáková	Loading plate	1 field test (testing niche)	5/2013-7/2013
Rock massif	Modulus of deformation	W1 (SURAO)	Dvořáková	Menard pressiometer test, Eurocode 7-Part 2	field test, 2 boreholes (5m long)	5/2013-7/2013
Rock massif	Hydraulic conductivity	W1 (SURAO)	Dvořáková	Hydraulic pressure test	field test, 5 boreholes (5 m)	5/2013-7/2013

note: W1 - winner 1 - winner of the public tender (no. 1, by SURAO) on grouting and drilling work
W2 - winner 2 - winner of the public tender (no. 2, by CEG - CTU) on plug construction

4.2 Parameter verification

Material	Parameter	Responsible institution	Responsible person	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Bentonite	Hydraulic conductivity	CEG CTU	Vašíček	ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil - Part 11: Determination of permeability by constant and falling head	pellets compacted to dry densities 1100-1800 kg/m^3	till 06/2015
Bentonite	Hydraulic conductivity	UJV	Večerník / Vejsadů	ČSN CEN ISO /TS 17892	plug material	till 06/2015
Bentonite	Gas permeability	UJV	Večerník / Vejsadů	Internal procedure	plug material	till 06/2015
Concrete	Hydraulic conductivity	UJV	Večerník	Internal procedure	plug material	till 06/2015
Concrete	Gas permeability	UJV	Večerník	Internal procedure	plug material - cylinder	till 06/2015
Concrete	Porosity	UJV	Večerník	mercury porosimetry / water immersion method	external analysis / cubes, discs of plug material	till 06/2015
Concrete	Composition and pH of leachate	UJV	Večerník	based on SKB report R-12-02	leaching into distilled water	till 06/2015
Grouting substances	Interactions	UJV	Večerník	Internal procedure	grouting/plug materials/plug environment	till 06/2015

4.3 Physical models

Material	Parameter	Responsible institution	Responsible person	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Bentonite, concrete, granite	Long-term stability	UJV	Večerník/ Vejsadů	Internal procedure – see Appendix	Cylindrical sample: bentonite, concrete, granite	01/2014-06/2015
Bentonite, concrete	Water content in sample	UJV	Trpkošová / Večerník/ Vejsadů	Internal procedure – see Appendix 1.	App. 50 cm long cylindrical sample, gradual saturation, material interaction studies	01/2014-06/2015

4.3.1 Long-term stability of the plug interfaces

The long-term stability of plug components and interfaces will be tested using a physical model of a simplified plug. The bentonite/grouted granite and concrete/grouted granite interface will be tested with respect to the application of increasing gas or liquid pressures. The main aim of these tests will take the form of the verification of the long-term stability of the grouting when subjected to changing chemical and physical conditions. The testing procedures to which the full-scale plug will be subjected will be applied to the model plug for the appropriate periods of time - for a more detailed description see Appendix 1.

4.3.2 Saturation of the bentonite and system component interactions

The plug constructed in the underground laboratory will not be dismantled and sampled in the time frame of this project; therefore a model of a plug system parts will be constructed at laboratory scale.

The first type of experiments will be carried out with the aim of calibrating numerical models and it is planned that the duration of the experiment will be approximately 1 year. Samples of compacted bentonite (the same as that used in the EPSP experiment) approximately 50cm long will be fitted with RH sensors and gradually saturated. Each sample will be dismantled after the conclusion of the experiment and the water content of each part of the sample determined.

In the second type of experiments the testing procedures applied to the full-scale plug will be applied to the model plug in a simplified form over the appropriate time durations. In order to verify the various ongoing interaction processes which it is expected will occur within the plug, a "post-mortem" analysis of the liquid and solid phases will be performed following the eventual dismantling of the model. The saturation processes occurring within the model system might also be studied within the planned testing time-frame in order to allow comparison with the full-scale plug. For a more detailed description see Appendix 1.

5 LABORATORY WORK ARRANGEMENT

5.1 Work scheduling

The work schedule respects the project plan. Schedule details are provided in Chapter 4 (Test list).

5.2 Key links between the laboratory and modelling work: "laboratory milestones"

The laboratory results will provide input for the numerical simulations of WP5. Therefore the WP5 schedule determines the deadlines for and key links between the laboratory and modelling work ("laboratory milestones"). The first complete set of measured results should be available in January

2014 as input for the modelling plan. The commencement of numerical modelling is planned for April 2014; therefore all the measured input data should be available by the end of March 2014.

Some of the results will serve as input parameters for the public tender for the EPSP construction company. The tender must be announced by August 2013 which itself determines a number of deadlines.

The following "laboratory milestones" have been identified (date, type and reason):

- June 2013: Basic set of initial tests on the bentonite (input for the public tender)
- June 2013: Results of spray field tests on bentonite pellets (input for the public tender)
- June 2013: Completed set of tests on the rock massif (input for the public tender)
- August 2013: D 3.17 Interim results of EPSP laboratory testing
- January 2014: Basic set of input parameters (input for WP5 planning)
- March 2014: Completed input parameter results (input for WP5 models)
- April 2014: Completed set of tests on concrete cores from the plug (input for the testing scenarios and the D3.20 EPSP plug test installation report scheduled for November 2014)
- June 2014, December 2014, June 2015: Regular verification of material parameters – every 6 months
- June 2014, December 2014, June 2015: Results from the physical models - every 6 months (validation of WP5 models)
- September 2015: D3.21 Final results of EPSP laboratory testing

5.3 Work management

The progress of the project is checked regularly on "internal inspection days" which all the Czech partners are required to attend (monthly). The aim of these meetings is to coordinate work on the EPSP (WP2-WP7) project. Particular emphasis is, and will continue to be, placed on the afore-mentioned "laboratory milestones" (see chapter 5.2).

Work management (changes in work program etc.) is handled according to the RAWRA, CTU and UJV internal procedures.

5.3.1 Risks related to laboratory works

Following table presents risks of the laboratory program/ works. Main potential consequences are related to availability of data for WP5 modelling.

No	WP, task	Name of identified risk	Major consequences	Responsibility	Risk grading I-Internal /E-External; Level, Likelihood, Consequences	Counter measures P- prevention M- mitigation
11	3.2	Delay in delivery of material for laboratory testing	Delay in laboratory testing program, delay of inputs to WP5	CTU	I, 2, unlikely, harmful	P - use of "known" materials, delivery of bentonite for laboratory tests independent from tenders
12	3.2	Failures of testing equipment	Delay in laboratory testing, delay of inputs to WP5	CTU, UJV	I, 3, not likely, harmful	P - Use of well-known/ proved equipment, time slots for regular inspection in the work schedule, testing capacity reserve kept

No	WP, task	Name of identified risk	Major consequences	Responsibility	Risk grading I-Internal /E-External; Level, Likelihood, Consequences	Counter measures P- prevention M- mitigation
13	3.2	Delay in laboratory works due to longer duration of individual tests	Delay of inputs to WP5	CTU, RAWRA, UJV	I, 2, unlikely, harmful	P - Proper work planning, capacity reserve kept, regular work inspection M - More capacities allocated to the laboratory works
14	3.2, 3.4	Test plan is insufficient with respect to project aims	Missing inputs to WP5	CTU, RAWRA, UJV	I, 4, not likely, serious	P- Detailed pre-experimental work planning, regular program inspections M - laboratory plan update
15	3.2, 3.4	Missing results/ parameters of laboratory and in-situ tests made as part of public tenders	Missing parameters for subconractors work evaluation, missing inputs to WP5	RAWRA, CTU	I, 4, not likely, serious	P - Regular work inspection, proper formulation of the contracts
16	3.2, 3.4	Delay in delivery of laboratory and in-situ tests results performed as part of public tenders	Missing inputs to WP5	RAWRA, CTU	I, 3, not likely, harmful	P - Regular work inspection, proper formulation of the contracts

5.3.2 System for review and approval of the results and reports

At first stage each partner uses its own internal procedure for review and approval of results and reports. Subsequently the results are reviewed by the rest of the Czech project partners (SÚRAO, CTU and ÚJV).

6 REFERENCES

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APPENDIX – DESCRIPTION OF PHYSICAL MODELS

Physical model – Long-term stability of plug interfaces

This physical model represents a simplified small-scale plug interface. The bentonite/grouted granite and concrete/grouted granite interfaces will be tested with respect to the application of increasing gas and liquid pressure. The testing procedure will correspond to that used in the full-scale plug experiment performed in the underground laboratory. The long-term stability of the various components of the plug, and especially the interfaces, will be tested. The main aim of these tests will be to verify the long-term stability of the grouting with regard to the changing chemical and physical conditions expected during the time the plug will be required to function.

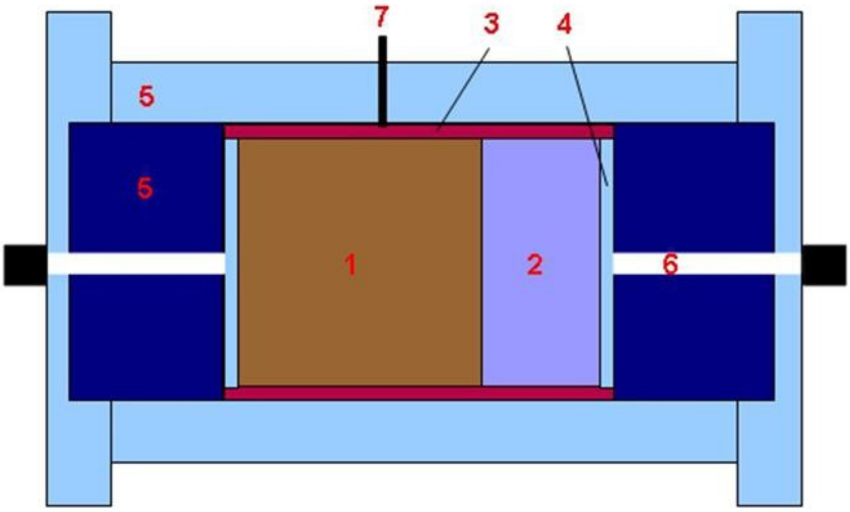

Figure 2 - Schematic view of the physical model for the verification of the long-term stability of the interfaces. 1: Compacted bentonite/concrete, 2: Grouted granite, 3: Sealing, 4: Filter, 5: Supporting elements, 6: Water saturation input/output, 7: Pressure sensor

The testing procedure will involve the study of the following: the effect of both increased gas and water pressure on the bentonite/concrete-grouted granite interface (gas and water pressure applied to the bentonite/concrete and granite sides of the interface); the effect of rising pressure (gas or liquid) on the stability of the grouting in the granite and the measurement of bentonite swelling pressure during the saturation process.

Following the dismantling of the physical model, the analysis of its various components will be used for the long-term prediction of plug evolution, especially concerning the stability of the grouting with respect to high gas/liquid pressure and the effect of water composition changes on the bentonite/concrete-grouted granite interface (the effect of pH and chemical composition).

Physical model – Saturation of bentonite and system component interactions

In the first type of experiment the apparatus will be based on a cell made from a thick-walled stainless steel tube with a length of 50cm equipped with an input/output porous plate with a higher AEV (air entry value) than that of the bentonite under investigation. The diameter of the cell will be determined by the options provided by the ESPS contractor and the material should be in the same condition as that used in the ESPS experiment at the Josef underground facility. The bentonite will be gradually saturated with injected water at a pressure level of around 7MPa (as in the ESPS experiment). Pressure will fluctuate due to the construction of the gas-hydraulic pump; the fluctuation interval selected will be as short as possible so as to best simulate constant injection. The flow of water into the sample and the discharge of water from the sample will be measured using a volume-meter.

The cell will be equipped with at least 2 RH sensors for the monitoring of the evolution of water content. Measurement methodology will be based on that provided in foreign literature.

The duration of the experiment will be around one year according to the development of the experiment, i.e. the development of water content distribution as recorded by the RH sensors).

The experiment will then be dismantled whereupon the bentonite will be divided into cross-sections transverse to the direction of flow, and water content will be determined for each section individually. Special attention will be devoted to the homogeneity of water content distribution.

In the second type of experiment a physical model will be constructed so as to represent a simplified plug (in accordance with the design of the full-scale plug) ideally with the appropriate aspect ratio of the main components to the full-scale plug system. Similar apparatus will be employed as in the first type of experiment, but the porous filter will be replaced by a sample of concrete. Since the full-scale plug in the underground laboratory will not be dismantled and sampled within the time frame of the project, the physical model will be used to verify the ongoing interaction processes which it is expected will occur in the full-scale plug. Following the dismantling of the physical model, an analysis of its components may be used for the long-term prediction of plug evolution (saturation, porosity changes, mineralogical changes, chemical analysis of the materials).

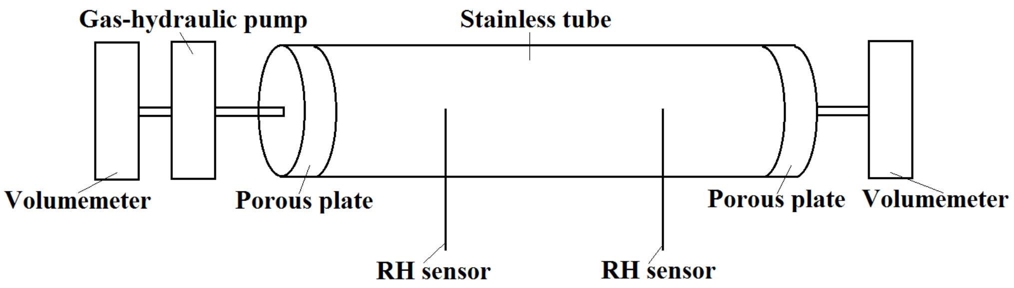

Figure 3 - Schematic view of the physical model for bentonite saturation testing.