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Second joint evaluation report prepared by the Expert Advisory and Review Board

BEACON
Bentonite Mechanical Evolution

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PU	Public	
RE	Restricted to a group specified by the partners of the BEACON project RE	**RE**
CO	Confidential	

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1. Scope of the Expert Advisory and Review Board evaluation

The Expert Advisory and Review Board (EARB) consists of experts which are representatives of organisations from outside of the project, and is in charge to advise the Technical Coordinator, and the Executive Board and the commission with critical evaluation concerning research quality and significance of outputs.

This second evaluation report expresses the EARB's view on the project progress, i.e. deliverables provided until the first annual meeting 28-31 May 2018, work and further planning presented at this meeting.

Deliverables D1.1 and D2.1, which were available in reasonable time before this annual meeting, have been looked at. EARB comments on these deliverables were presented by Wilfried Pfingsten at this annual meeting. This EARB report includes also EARB comments and recommendations on the WP presentations held during the annual meeting at Milos in order to give quick response and recommendations to planned activities in the WPs so that WP leaders and partners may take into account the EARB recommendations already in their project planning of the second year of the BEACON project.

2. Sources of information for the first evaluation

The EARB analysed information gathered through the following sources:

- Grant Agreement, in particular the work description in ANNEX 1
- Deliverables 1.1 and 2.1 as available at of March 2018
- Presentations and discussions during the first annual meeting of the BEACON project, 28 – 31 May 2018, Milos, Greece

3. EARB comments and advice

3.1. On D1.1 State-of-the-Art Report - Bentonite Mechanical Evolution

The questionnaire approach seems appropriate and successful and results in a valuable report providing a good overview with input from 7 WMO (or their representatives) and from 1 NGO. This deliverable discusses comprehensively and thoroughly different disposal concepts prevailing in most of the Europeans countries, with emphasis on the role of bentonite and the occurrence of heterogeneity and the uncertainties related to such heterogeneity. This gives a very good delineation of the scope of BEACON´s undertakings. Nevertheless,

(1) The EARB wonders why there were no questions asked about the material choice (kind / type, origin of bentonite) foreseen or taken into consideration in the concept?

(2) The question "What kind of heterogeneity is expected in your repository concept?"

appears a bit unspecific.

(3) Strictly speaking a “Deterministic approach (upper lower limit, mean values)” is not a way to “address heterogeneity” as such, it is rather a way of ignoring it. If homogenization takes place in the models, such an approach somehow replaces heterogeneity by the uncertainty (or bandwidth) of an upscaled parameter. This is not a problem in itself – the EARB believes that the question was still well understandable for everyone (and this is evidenced by the responses). The terminology becomes evident in GRS’ response: Apparently, GRS applies a probabilistic approach but for homogenized parameter values. However, more careful wording should be used when reporting later about BEACON results.

(4) Under “bentonite modelling” a distinction is made between performance assessment and safety assessment. Internationally, the use of these two terms is sometimes a bit arbitrary and the distinction is not always clear to everyone – was the use of the two terms agreed upon amongst participants?

(5) The question “Which natural properties are required for the bentonite regarding heterogeneity?” seems too general – probably it was intended to ask “Which natural properties are considered relevant for the bentonite regarding heterogeneity?”?

(6) The EARB has the opinion that the document could serve the project even better if more discussions are given in Chapter 6, Bentonite Modelling, to the modelling aspects specifically related to resaturation/heterogenisation processes.

(7) The EARB has the opinion that the document could make a better guidance to the orientation of BEACON project if it could outline relatively more detailed effects the project should focus on (based on the study of the present status of the research in the related areas), just as one example among many other possibilities, deterministic versus probabilistic approaches as indicated in the third sub-bullet point above.

(8) More generally: Could this type of activity (designing a questionnaire) be one for which a priori exchange with the EARB could be considered? Of course, such activity would be ad hoc and go beyond the EARB agreement, but nevertheless … ?

(9) All responses are about bentonite use in general, not just about the three case studies defined: the Andra tunnel plug, the Nagra disposal cell and the KBS-3 deposition tunnel backfill. In the view of the EARB, this is appropriate for the purpose of the deliverable. The EARB also noted, however, that SKB’s response was very much focused on the bentonite buffer, which does not belong to the set of test cases. Need to re-adjust scope of work? Note that even the conclusion section is very much focused on the buffer rather than the backfill!

(10) The EARB noticed that safety relevant properties are not given in a similar way by the partners. Some of the partners are differentiating buffer, backfill and shaft seals, others are not. Safety relevant properties are identified differently by the different partners, which

complicates the comparison. We acknowledge that individual concepts are different and that safety properties can differ from one concept to the other. However, for some properties it is difficult to understand why some properties are considered by some countries and not by others (e.g.: gas transport properties, swelling capacity, heat conductivity, …).These differences should be discussed. A comparison table could be also helpful (see example in appendix for example)

(11) EARB noticed that performance measures are identified differently by the different partners. Some are giving preferred values others are not. A preferred value is not really helpful in terms of performance assessment. One has to know how far one can deviate (e.g. in case of inhomogeneities) from this preferred value to stay in the safety envelope.
It would be preferable to give the performance measures in terms of safety envelope and design target as proposed in GEOSAF II (see Fig. 1).

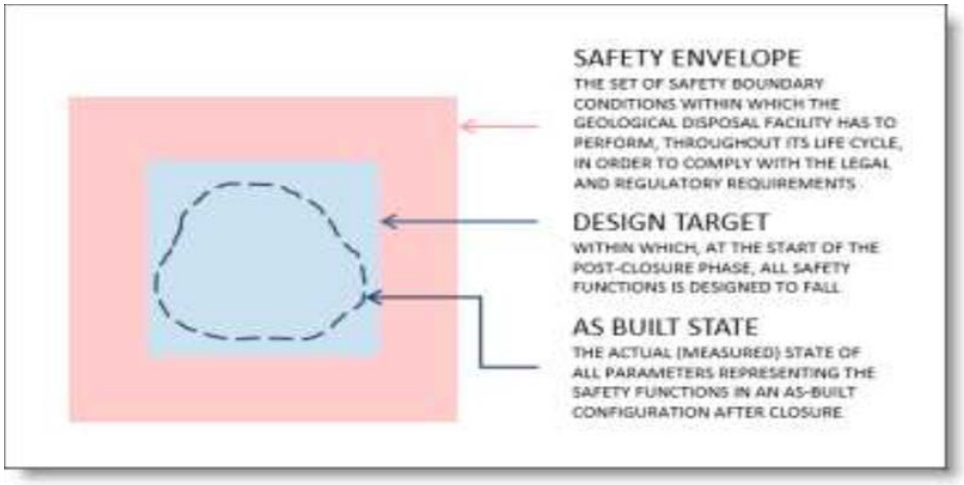

Fig. 1: Safety envelope, design target and as built state as defined in GEOSAF project [GEOSAF]

(12) The conclusions section appears a bit brief and general. E. g., it would have been useful (and easy!) to juxtapose the responses from the organizations, especially the ones given in table format.

3.2. On D2.1 BEACON Initial Workshop

Already sufficiently addressed in the first EARB report (EARB deliverable 1)

3.3. On D2.2 Review of data and models on the mechanical properties of bentonite available at the start of BEACON

The EARB appreciates the well-structured report, including a good “setting-the-frame” in chapter 3. – The working approach seems appropriate. The list of data fields (D.2.2, Table 2) seems comprehensive with regard to experiments.

But

(13) what about the “models available at the start of BEACON” which are also promised by the title of the deliverable? So far, only their names are asked for in the form (and only if they were used for reproducing an experiment). Admittedly, the text says “It is outside the scope of this report to conduct a detailed comparison of modelling approaches; this will be covered in a forthcoming deliverable D3.1.”, but then the D2.2 title is somewhat misleading. At least, at some point the question of how well the models reproduced the experimental data should be addressed – for which deliverable is this foreseen?

(14) In chapter 3.1 there is a comment on flow properties “There is not a single agreed-upon conceptual model for how water flows through bentonite (e.g. Kröhn, 2016) and therefore different authors use different material properties to describe flow” – EARB raises the question if there shouldn’t be a general agreement within BEACON on a common model concept?

(15) The relevant experimental and field work that generates relevant data has been thoroughly reviewed and addressed. Proportions of different types of data available are also outlined. Would it be possible for the Work Package to also give some comments on whether sufficiently qualified amounts are available for each type of data with regard to the need of BEACON´s modelling and other studies?

(16) The EARB has the opinion that the homogenisation of bentonite (which is the main focus of the BEACON project) is strongly related to its resaturation. Several of the modelling works briefly mentioned in Table 1 in D2.2 are based either on Cam Clay (CC) or Modified Cam Clay (MCC) approaches. The project needs to consider the difficulties for such models to handle processes in the unsaturated status of bentonite. Should the project consider to rely more on the approaches of Barcelona Basic Model (BBM) or Barcelona Expansive Model (BExM) which are more handy to deal with the saturation process?

(17) The first part of Section 3.2 gives a very good description of different model approaches that have been adapted for modelling of mechanical processes in clay. Text under the subtitle “Suction” in Section 3.1, page 11, however, needs to be improved. A good description of suction in bentonite can be found in (Fredlund & Rahardjo, 1993) and (Dueck, 2004).

(18) EARB makes the point again (see (8) above). Could this type of activity -designing a questionnaire or a data form- be one for which a priori exchange with the EARB could be considered?

(19) Table 1 summarises modelling approaches, however, the “applications” were qualified with rather qualitative statements (“good fit”), which does not mean that the model concept was “correct”.

(20) All models were applied to “homogenisation test”, but what about their handling of

heterogeneities – are all models applicable to heterogeneous systems?

(21) EARB noticed a good discussion (section 4.3). It could be even further improved if some summary was given to especially shortage of certain types of data from BEACON's perspective.

(22) Is the database only available in table format or also as a "real" data bank (SQL or the like)? Does it make sense to consider the latter, also with a view to the time after BEACON's finalization? Later for modelling studies, perhaps?

(23) The references given in the main report are quite old except the one from Kroehn 2016, which includes the general remark on "not a single agreed-upon conceptual model" … The question arises, whether there are no further newer conceptual models than the one mentioned therein. Is there no recent e.g. multiscale modelling progress internationally, which should be considered within BEACON?

3.4. Remarks on the presentation of WP3 progress at the annual meeting in Milos (the deliverable D3.1 "Description of the constitutive models available at the start of the BEACON project" was not yet available)

(24) It was mentioned that eight individual team reports on their model had been delivered, but 3 are still delayed and a complete description of all models was not yet possible. The models available in the BEACON project seemed to be at different maturity from well-established to recently developed models. So far no decision was taken to decide on which models are capable to achieve the target of modelling the bentonite mechanical evolution with sufficient precision.

(25) Several groups use the commercial software COMSOL multi-physics as the basic package for their model development. EARB raises the question, if a closer cooperation of those groups using COMSOL might be advantageous in order to develop a common modelling tool.

(26) Also, knowing that geochemistry influences the bentonite mechanical behaviour – which is not looked at in the framework of the BEACON project – modellers should be aware of the fact that chemistry (and biochemistry) has to be coupled, maybe at a later stage, with their developed THM models within BEACON. This could be a problem for COMSOL based THM models, because COMSOL does not include chemical equilibrium solvers at all.

(27) EARB thinks that sensitivity modelling could be important to identify key parameters/ processes involved in swelling (e.g. parameters/processes influencing the final swelling pressure). Beyond their importance for model developments, this kind of modelling could also provide the parameters requiring a specific attention during material installation and quality controls.

(28) EARB noted for some modelled cases that modellers were not fully aware about the experimental procedures and conditions (e.g.: the presence, or otherwise, of an annular gap between the sample and the cell, friction or not between the sample and the cell, …). Good knowledge of the tests procedures and conditions are essential because they could significantly influence the results of the test (e.g. could explain the quick pressure build-up of the radial pressure). A closer cooperation between modellers and experimentalists is therefore advised for the remainder of the project.

(29) The EARB considers it very positive that the modelling group (WP 3) tries to interact with the experimental group (WP 4) as much as possible. It can be seen from the presentations and discussions of these two Work Packages during the first annual meeting that the modelling group has tried their best to explain what kinds of data (parameters) are important for their modelling, and the experimental group tried to outline as clearly as possible their experimental conditions so that the data can be used properly in different models.

(30) The EARB has the opinion that the effort of model development during the first year of the project proceeds as planned and the work done is of good quality. The board would like to especially point out that the efforts tried to explicitly couple the chemical process with the other already coupled thermal-, hydraulic-, and mechanical (THM) processes are a big step forward in such modelling (see the presentation of Gharbieh et al. from VTT and UCLM during the second day of the first annual meeting). However, main focus at the beginning of BEACON should be that teams should focus on the improvement of the mechanical constitutive models, but keeping in mind the further coupling to thermal and geochemical coupling capabilities.

(31) The EARB has the opinion that, in the later periods of the project, some more attention needs to be paid to the relation between mechanism understanding, modelling of the coupled thermal, hydraulic, mechanical and possibly chemical evolutions, and the performance of the bentonite at repository conditions. Examples of such relations can be that, inter alia, between saturation and homogenisation (results from PEBS project have shown that density homogenisation lags behind in time the saturation process), between homogenisation and evolution of hydraulic properties, between homogenisation and evolution of swelling pressure (is the difference between the axial and radial swelling transient?).

(32) The EARB agrees with the participants that more attention need to be paid to friction, effect of sample size on the modelling results, and interpretation and upscaling of the outcomes of the project to repository scale.

(33) The use of a hysteretic model should be tested independently to check if this single feature improves model capabilities to reproduce bentonite homogenisation.

(34) The EARB has the opinion that some more attention need to be paid to the double structural distribution of the bentonite.

3.5. Remarks on the presentation of WP4 progress at the annual meeting and related discussion on Milos

(35) Several promising new experimental setups were presented on small and on larger scale with pellets only, pellet-powder mixtures or pellet-block setups at ambient and higher temperatures using quick sensors, newly developed high resolution film pressure sensors or using small Zirconium spheres as markers for displacement measurements. Here, there should be discussion with the modellers, if models are available at all scales for the experiments planned at different scales.

(36) Post experimental analysis is foreseen with micro-CT or neutron scattering techniques. EARB proposes also to consider neutron tomography techniques to monitor saturation and swelling periods using Deuterium.

(37) As proposed by the WP4 leader, there should be an intensified contact between experimentalists and modellers in that way that modellers should request specific data to be measured and boundary and initial conditions to be set. EARB favours this intensified contact and the requested input from the modellers to the foreseen experiments. Even predictive modelling of the foreseen experiments should be performed in order to set up the planned experiments as optimised as possible for benchmarking of codes, for example.

(38) Since more or less all codes include micro and macro structure model concepts, experimentalists should consider to design experiments where this concepts could be tested independently.

3.6. Remarks on the presentation of WP5 progress at the annual meeting and related discussion on Milos

(39) EARB noticed that more or less all modelling groups took part in the modelling of the three “simple” experimental test cases. It was obvious from the results that no model was able to reproduce the experimental results; the results diverged a lot. General trends could be reproduced, but not details. However, some agreement has been achieved for parts of the data (e.g. interim or final period of the experiments). And it seems that the modellers did not use all the same initial and boundary conditions for their modelling, which is a no-go in code comparison (benchmarking). EARB advises the groups and the WP leader to redo this code comparison using these “simple” test cases in order to judge about the codes capabilities. In advance to that, a formal procedure should be implemented in order to ensure that the initial and boundary conditions for these cases are the same for all teams. Using different initial and boundary conditions will not allow a reasonable code comparison, which was the goal of this exercise. Arguments from the WP leader that later on even more complex modelling of different experiments should be done are no excuse for saving time for future modelling, quite on the contrary. And recalculation of the “simple” test cases with

different input parameters shouldn't be a big deal for the already setup code applications.

(40) Finally, criteria should be defined on which capabilities the codes should have. Comparing results and demonstrating problems the codes have at the moment, when modelling "simple" test cases, could not be the real goal.

(41) A stronger involvement in the planned experiments of WP4 is strongly recommended, e.g. by predicted design calculations.

(42) Different groups may consider joining forces and developing or improving together a common code, e.g. COMSOL is used by several groups – why develop in parallel?

(43) EARB considers it positive that the effect of salinity on homogenisation has been studied experimentally (see the presentation during the third day of the first annual meeting by Rinderknecht et al. from KIT, GRS and BGR), using both Pearson type A1 water and Grimsel Groundwater in their experiment. The differences in pressure (or stress) evolution between the samples subjected to the two types of water are worth further study theoretically in models to gain an in-depth understanding of influence of salinity on homogenisation.

(44) The EARB has the opinion that, besides paying more attention to the initial conditions of the modelled experiments, even more attention should be paid to the modelling of the technical/physical gap. The teams should present clearly the different constitutive models used (hydraulic and mechanical) for the gap.

3.7. **Remarks on the presentation of WP6 progress at the annual meeting on Milos and related discussion and on the WP6 deliverable D6.1 "First report from the working group in WP6 on Civil Society Interaction with observations from the start-up workshop, an initial overall analysis and input to WP2" which was available at the annual meeting (May 28, 2018).**

(45) The CS report describes how the 5 CS group members want to organise their work in WP6. It also includes some scientific input to the overall analysis on research on the behaviour of clay in geological disposal facilities for radioactive waste, which is welcomed by the EARB, but it is partially very specific. It is not clear, if the public/CS is able to follow these paragraphs, where parts presented are still controversially discussed in the scientific community.

(46) The report focusses quite a lot on chemical influences on the bentonite evolution, which (as agreed on in the project planning) is not a topic to be addressed in the BEACON project. Nevertheless, it seems clear to all BEACON partners that there is a chemical and even a biochemical and radiation influence on the mechanical bentonite behaviour, but the project excludes these processes as given in the working plan, except for some osmotic processes investigated by EPFL. Therefore, there should not be that much discussion and input requested in this direction in future WP6 reporting.

(47) From the WP6 work plan described it seems that there is only at the very end of the BEACON project a workshop planned where additional CS people are invited to join. It is not clear to whom the WP6 members will report from the BEACON annual meetings in the meantime. Are there just WP6 group internal discussions and reflections giving then back input to the other BEACON WPs?

(48) The EARB welcomed the hint on further experimental information and projects related to mechanical bentonite evolution that should be considered in the WP2 database.

3.8. D7.5 Training Course - The file on projectplace was/is empty.

No comments

4. From the discussions on the EARB deliverables at the annual meeting in Milos

(49) The EARB welcomes the decision that the EARB deliverable should be available 3 months after the annual meeting in order to include also the discussion of the WP deliverables at the annual meetings.

(50) The EARB reports should be available to all WP leaders as soon as possible and there should be some feedback to the EARB on its recommendations – the form has to be decided on.

5. References

Dueck A., 2004. Hydro-mechanical Properties of a Water Unsaturated Sodium Bentonite. Laboratory Study and Theoretical Interpretation. Doctoral Dissertation. Division of Soil Mechanics and Foundation Engineering, Lund Institute of Technology, Lund University, Sweden. Section 2.2. Soil Suction.

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Appendix 1: Example of comparison table of safety relevant properties

	Nagra	SKB	POSIVA	SURAO	ENRESA	ANDRA	GRS
Buffer							
Swelling capacity	X			X	X		
Chemical retention/ sorption	X	Limit mass transfer	Limit& retard radio-nuclides release	X	X	X	X
Low hydraulic conductivity	X			X	X	X	X
Sufficient high viscosity	X						
Sufficient gas transport capacity	X				X		X
Minimising microbial corrosion	X	X		X			
Filter colloids		X			X		
Resistance to mineral transformation	X						
Suitable heat conductivity/ Maximal temp.	X		X	X	X		
Limit transport of corroding substances			X				
Permeability for gases				X			
Protect canister from mechanical load/ processes		X		X			
Resist transformation		X	X				
Isolation				X	X	X	
Maintain chemically favor. conditions			X				
Tunnels & shaft:							
- Keep the buffer in place		X	X				
- Limit advective mass transfer		X	X				
- Avoid formation of new pref. paths		X	X				
- Maintain chemically favor. conditions			X				