D8.9 BEACON Bentonite Mechanical Evolution

EARB second annual project review report

DELIVERABLE D8.9

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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 annual project review report is the third one in the EARB report series. The first one is an evaluation report of the project's application and grant agreement, and the second one is the first annual project review report after the first annual meeting of the project. This report will express the EARB's view on most of the deliverables that are available up to May, 2019, and on the presentations during the project's second annual meeting in Prague. Next evaluation reports will continue to focus on review of the project progress in connection with the third annual project meeting as well as on the review of selected scientific/technical project deliverables.

Sources of information for the first evaluation

The EARB analysed information gathered through the following sources:

- D3.1 Description of the constitutive models available at the beginning of BEACON with annexes
- D5.1.1 Specification for BEACON WP5 verification of models
- D5.2.1 Testing, verification and validation of models, Step 2
- D6.1 A report from the workshop in task 1 including the summary of the analysis of the working group, scoping of the BEACON project, initial civil society (CS) perspectives and enhanced work plan for years 2-4 (revised). Version 15/4/19
- D6.2 Report of the first annual meeting
- D8.1 BEACON data management plan (DMP)
- D8.2 BEACON communication plan
- PowerPoint presentations during the project's 2nd annual meeting 21-22, May, 2019 in Prague.

EARB's General Remarks

The EARB appreciates the responses from the project to our comments. This helps to understand how our advice will be considered for the next steps of the project.

The EARB has the opinion that, compared to other similar projects, the degree of integration between work packages is well-visible, but there is still room for improvements (e.g. feedback on feedback, namely the responses to each other's comments between the modelling researchers and the experiment researchers).

The poster distribution in advance of the second annual meeting was a good idea. It allows for an earlier look at results and allows preparing questions, comments, remarks on specific topics. It might be used also as a "progress report in figures", e.g. about what has been modelled until last annual

meeting, which models (with certain modifications/improvements) are available now, illustrated in easily understandable figures and related equations or model modifications.

EARB's Comments to D3.1

The objective of this deliverable is to present the constitutive models available at the start of the project to address the heterogeneity issues during bentonite re-saturation. EARB has the opinion that the objective is correctly set and is highly relevant to disposal of radioactive waste where bentonite is a barrier material. Heterogeneity during re-saturation is related to a number of issues concerning either the protection capability of the buffer and backfill themselves, or the protection capability of other barriers (e.g. the metal canister).

EARB considers that presentation of the available constitutive models is a right starting point. In order to model the process one needs material's constitutive model together with laws of conservation. Laws of conservation are always the same and it is the material's constitutive models that give detailed and proper description of the relevant processes. The EARB has the opinion that the objective is correctly set and is highly relevant to disposal of radioactive waste where bentonite is a barrier material.

EARB has the opinion that the approach is systematic (as is evidenced by the point-list on page 8 of the deliverable) and the coverage is extensive (as is evidenced by the first 3 points listed on page 7 and the numbered points on page 8 of the deliverable concerning the materials, the underlying processes and the relation between them).

EARB considers that the constitutive models proposed in the deliverable covers a wide range of aspects related to heterogeneity and hysteresis in bentonite during the re-saturation process. The following models are proposed:

- the poroelasticity formulation from BGR,
- the hypoplasticity formulation from CU,
- the Hysteresis Based material (HBM) model from Clay Tech,
- the Advanced Constitutive Model for Environmental Geomechanics (ACMEG) for non-isothermal and unsaturated conditions from EPFL,
- the Imperial College - Double Structure Mode (IC DSM) from ICL,
- the fully-coupled thermo-hydro-mechanical model incorporating the Modified Can Clay (MCC) model from Quintessa,
- the elastoplastic mechanical model using a double structure assumption from VTT,
- the improved version of Barcelona Expansive Model (BExM) from UPC,
- the mixed double-porosity and single-structure model from ULg.

EARB considers it to be constructive that the project focuses on conceptual bases, mathematical description, as well as capability and shortcomings of the constitutive models chosen to be considered in the project. To describe some key qualitative features of the THM-processes in the bentonite is also an urgent demand in the waste management programs. For example, as bentonite is a swelling clay material, there might be special challenging requirements concerning the constitutive models which most often have been developed for description of non-swelling, generic

soil materials. Another challenging issue in the project is the bentonite's irreversible behaviour of hysteresis. A constitutive model in equilibrium thermodynamics describes material's behaviour along a quasi-state path. In order to handle the hysteresis, irreversible thermodynamic approaches might be needed.

A features table describing the models' capability seems lacking in the summary of BGR's work in Section 3.1 as well as in Annex A.

EARB's Comments to D5.1.1

As the work during the first step of the approach, the three swelling test cases (for compacted plugs with free volume available; for pellets mixture and for block and pellet structure) seem to cover a significantly broad range. EARB considers that the approach to start with these simple swelling test cases is appropriate to support the verification and validation of the codes. Description of the cases and requested outputs appear systematic and consistent. However modelling output for specific times could help results comparison. For example, the conclusions at the WP3/WP5 meeting in January 2018 seems lacking in the deliverable. As the issue date of the report is later than the meeting, it would be better to include conclusions from the meeting in the deliverable instead of indicating as "will be discussed".

- An important issue discussed during the first annual meeting was the boundary condition related to the interface between the sample and the cell in test 1. This condition could considerably influence the hydration process. The EARB thinks that it is important to discuss this issue in the report.
- The "project" response to second EARB report indicates that some of tests from task 5.1 will be performed again. Nothing is mentioned about that.
- The EARB thinks that it will be important to spent sufficient time to understand the difference of modelling of test 1 performed in WP5 as input for the next modelling steps.

It might be helpful for the modelers if the presentation of experimental results would include some additional comments on their measured properties, e.g. consistency, possible errors or uncertainties etc., especially for those results, which were not well reproduced so far by the modelers (see posters distributed in advance of the 2nd Annual Meeting). E.g. for test 1a-c (Fig. 3.5), the early part of the radial swelling pressure was not well reproduced by most of the modelers – is there an experimental evidence that the experiment is "well defined"?

Sometimes it is not clear why experimental conditions were chosen as reported, e.g. Table 4-2: why different number of pellets for the different layers (39, 38, 39) or what does pour water on the pellets mean? Homogeneously with a watering can, was it shaken afterwards (after each layer preparation)? Was a homogeneous layer of pellet and crushed pellets produced after the crushed pellet granules are poured on the pellets? Were the layers homogeneously watered? Can images of the sample preparation (Fig 4-3) be used (digitized) to get the individual pellet distributions in the different layers and with this a better definition of the initial condition?

For Test1a02 it is mentioned (in 3.2.3) that the "the initial degree of saturation is very high (close to 100%) and for that reason the swelling started directly, …" Is this a critical issue with respect to modelling boundary and initial conditions?

EARB's Comments to D5.2.1

Several large scale field-test experiments have been included in this deliverable:

- Engineered Barrier Emplacement Experiment (EB) at Mont Terri (~2003-2007, dismantling 2011-2012),
- Full-scale Engineered Barrier Experiment (FEBEX) at Grimsel (1994 – 2008),
- Canister Retrieval Test (CRT) at Äspö (1999 to 2006).

The EARB considers that the choice of these three experiments has fulfilled the criteria set by the WP2 and WP5, i.e. the experiments should be well described and dismantled and relevant to disposal concepts used by the project partners, and it should highlight the role of heterogeneity in bentonite components.

The EARB has the opinion that the selected field-test experiments cover a wide range of experimental conditions and the EARB believes that the outputs could well support the modelling work. They cover varying types of the surrounding rock in different experiments: clay formation and crystalline rocks, varying hydration procedures in different experiments: artificial and natural, varying thermal processes in different experiments: heating and non-heating of the waste containers, as well as varying orientations of disposal, i.e. both horizontal and vertical.

The EARB wonders if modelling attempts have been performed on the proposed large scale experiments, especially if there is information available on the DECVALEX2019 benchmark.

Some of the tests like FEBEX were already largely modelled in the past. It could be interesting to explain what is new in the approach compared with what was performed in the past.

EARB's Comments to D6.1

Apparently, the project participants were taken by surprise by the Commission's decision that "only conventional dissemination work would be allowed". Given that the civil society (CS) involvement had been planned as a pilot activity and therefore was experimental in nature, the EARB considers this change at such a late date as a serious challenge and wonders about its necessity (the EARB has no problems with others providing feedback to the project as well).

The EARB also wonders what exactly is meant by "conventional dissemination". The background Chapter 2.1 names two central issues behind CS interaction: transparency and involvement of CS in decision-making (The deliverable also names "consultation processes".). Obviously, the former is a pre-requisite for the latter but not vice versa. Due to the wording chosen in Chapter 2.2 ("well suited to analyse, discuss, interpret and develop perspectives on the more concrete work with R&D in the BEACON project and to provide the technical writing expertise for dissemination of the results to a broader civil society") the EARB concludes that the focus is (now?) on (one-way) communication of

technical BEACON work to non-specialised actors, is that correct? Or is "to follow, discuss and give feedback on the research conducted" (Ch. 2.3) still an aim?

Given these specific circumstances, the EARB acknowledges that the deliverable has been written in a way accounting for both "perspectives" (the one according to the original plans and the revised one).

The EARB would appreciate if WP 6 would continue to provide feedback to the project. Even though the EARB did not share all the opinions expressed by the WP 6 team in the past it still believes that BEACON and the BEACON scientists benefit from being "challenged" by the WP 6 (cf. the 2018 EARB report).

The EARB believes that the dissemination efforts to be made by WP 6 need careful exchange and interaction with WP 7. This is all the more the case since dissemination should – irrespective of the target group – be consistent and carry a joint set of consistent main messages. In particular, the envisaged Subtask 3.2 needs more detailed planning and close interaction with WP 7.

Given the central aim of "translate the results to the public" (Chapter 5) the EARB believes that a prerequisite for this is a target group analysis and the development of a communication concept ideally in cooperation with WP 7 (see above). Such a concept should address the following issues:

- Aims of dissemination
- Major messages to be delivered
- Target group(s)
- Means of dissemination

The EARB interprets Chapter 4.1 as a first attempt towards dissemination. From the wording and content the EARB concludes that the text could be aimed at interested laypeople. The EARB recognizes that communicating with a target group consisting of interested laypeople requires some kind of simplification but should still account for all major issues. In this specific case, the EARB recommends to address/mention/explain two issues in addition to the ones elaborated on in Chapter 4.1: (i) The role of numerical modelling/computer simulation and its interplay with experimental work (the word "model" appears several times but it is open to interpretation which kind of model is referred to) and (ii) the importance of the construction process and the type of bentonite materials (blocks, granulates, mixtures, etc.) being used. Both issues appear indirectly in Chapter 4.2 but deserve to be addressed more explicitly.

More generally, the EARB feels that if Chapter 4 is to be used for dissemination purposes, there is a need to "build a bridge" between the very general information given in 4.1 and the very formal project description given in 4.2: What is the philosophy behind BEACON and why is it designed in the way described?

Under the circumstances described above, the EARB considers the decision to focus the dissemination work on WP 5 as sound and sensible.

The EARB supports the main idea of Subtask 3.1 of "making the BEACON final workshop/conference in London in 2021 known, available and understandable to a broader, wider and more numerous group of participants from the civil society" and considers it as an opportunity not only for the WP 6 participants but for the whole personnel involved in BEACON – the benefit could be twofold: (i) communication of BEACON-related messages to wider audiences, (ii) "training" of BEACON scientists in communication with such audiences. The EARB recommends an early and thorough preparation along the lines of the communication concept mentioned above.

The EARB understands that Appendix 3 has been drafted in the "original spirit" of "CS interaction" (in order to provide feedback to BEACON scientists). The EARB interprets "more compaction of canisters" as "higher emplacement density" – correct? The EARB understands the motivation behind the suggestions made by the WP 6 team about enlarging the scope of WP 2 but wonders to which extent such enlargement would be manageable given the resource situation and the scope of BEACON.

EARB's Comments to D6.2

Despite of the explanations in the abstract and the introduction, the change of scope for D6.2 became better understandable for the EARB only after the WP 6 presentation at the Prague meeting. However, the EARB got the impression that D6.2, in its present version, constitutes an attempt at dissemination rather than a compilation of "CS perspectives with a focus on verification and validation of models, and comparing models with situations close to disposal conditions" (quotation from the WP 6 Prague presentation). Having said this, the EARB is of the opinion that the report would have benefited from an *a priori* identification/definition of a target group (see remarks about a communication strategy made by the EARB above in its comments about D6.1).

Given that the description in Chapter 2.1 is being made per BEACON WP, the final version should perhaps start by giving an overview of all the WPs and their roles.

The wording in the first paragraph of Chapter 2.1.1 suggests that the WP 6 team had a target group in mind which needs explanations about the function of waste management organizations (WMOs). Note that GRS is not a WMO but a research and consultant organization (although already the Milos WP 1 presentation suggests otherwise).

The EARB gets the impression that the content of the first paragraph of Chapter 2.1.1 seems to be applicable to BEACON as a whole rather than to WP 1.

The EARB acknowledges the efforts to make BEACON work comprehensible for laypeople but does not believe that simplistic or oversimplifying language ("the groups that make models") is helpful in that regard. Actually, it might be more helpful to add a paragraph about the role, use(fullness) and limitations of numerical models – in general and in the specific case if bentonite homogenisation. This would readers also enable to better understand the first paragraphs of Chapters 2.1.3 and 2.1.5.

The EARB is unsure whether the rather complex diagrams aiming at showing the variation of experimental and modelling results are really helpful. Perhaps it would be better to verbally explain

issues and also to explain that WP 5 is addressing reasons for the variation of results (some points concerning this can be found in the Milos presentations).

Language like “allows the groups […] in the project understand what the whole project is aiming at” seems to suggest that the BEACON scientists do not (yet?) know what the objectives of BEACON are – but in the opinion of the EARB this was not the case. Also the repeated use of “so-called” as an attribute of terms which are otherwise not further explained is not really helpful. Still another example concerning the connotation of the language: “As each modelling group had used its own way of doing the modelling …” (Chapter 2.2) gives the (wrong) impression that modelling choices are somehow made arbitrarily.

The EARB is unsure about the usefulness of the figures at the end of Chapter 2.1. Given the lack of radioactive waste management (RWM) and especially of bentonite-related knowledge of the target group which is apparently assumed by the authors, some sketches of repository components as well as photos from experiments are probably more useful.

EARB’s Comments to D8.1

Chapter 4: “Partners should normally use their own procedures and management systems to manage data and models. If such procedures are lacking use the below guidelines.” The EARB wonders whether there are ways to judge whether the partners’ procedures are “lacking” – when are such procedures considered insufficient? Will the WP 8 team evaluate the filled-out appendices?

5.2: Is “types and formats of data” sufficient or is there rather a need to provide also some “semantics”?

The template in Appendix 1 appears comprehensive, while it is not so clear to the EARB whether the one in Appendix 2 might be too general or unspecific. Are there already any experiences with using the templates? Is there a kind of feedback loop planned?

EARB’s Comments to D8.2

The EARB is of the opinion that the deliverable contains elements of such a plan but needs considerable development (see the above comments on D6.1). This development should be a joint effort of WPs 6, 7, and 8.

EARB’s Comments to the presentations during the 2nd annual meeting

WP1

The EARB thinks that expectations from “WP1 – assessment cases” need to be clearly defined, especially the difference with the expectations from the “WP5 large scale test”.

The main added value of WP1-assessment cases could be predictions at long term and more specifically the long term hydration process. This is important to catch if long term hydration will lead to homogenisation, or otherwise. To which extent are chemical processes important and

necessary to be taken into account? Sensitivity assessments on some parameters could also be helpful for a better understanding of the concepts.

WP2

It seems that simplest experiments and their modelling still do not show full agreement. The EARB would like to recall a presentation from WP2 concerning the following points:

- Experimental repeatability/data reproducibility
- Model and data uncertainties/their propagation
- What a good and acceptable model for our purpose? (Many or few parameters?)

WP3

See the comments to Deliverable D3.1 earlier in this review report.

WP4

The EARB considers it impressive that many new characterisation techniques are used:

- Pore size distribution
- Video scripts showing the homogenisation process
- Environmental SEM showing the microscopic structures during homogenisation
- etc.

The EARB was impressed by the BGS presentation. The tests seem to been done very carefully and the obtained results very relevant for the project.

In relation with the presented open questions, the EARB considers it profitable to better understand the complexity of the swelling behaviour and to do long term tests.

WP5:

According to the improvement of the models and the still not full reproduction of the test cases 1a-c, EARB is wondering if model comparison between the different groups takes place in the WP3/5 meeting (chosen numerics, couplings, procedures, etc.).

Also, it should be stated why new models (HBM, ILM,) are developed. What is their advantage compared to the others or would it be enough to improve existing ones?

Some statements have been made that most of the models fit the final state of test cases 1a-c, whereas the transient phase was not captured very well. However, compared to expected repository conditions the transient phase will take much longer time. There will be no artificial watering. In addition, if concrete will be used in the barrier system too, or as tunnel liner, chemical reaction will go on at the bentonite/cement interface leading to porosity decrease, which may cause lower resaturation and much longer resaturation time. Therefore, there should be more focus on the transient time then on the final state. Other concerns about the final state were also expressed: “do we know the final state” also for the test cases 1a-c.

Improvement by the last model applied to 1c (Antonio Gens) seemed to be very good with respect to the transient phase; however, some features were not fitted well yet, but it's a promising improvement.

Concerning the larger scale test cases:
There should be well defined targets for the modelers, however, model have to take into account the physics of the large scale experiments. It would not be reasonable to ignore some properties of the experiments and then conclude after modelling that the model could not reproduce experimental results.