Fourth annual project review report prepared by the Expert Advisory and Review Board

BEACON
Bentonite Mechanical Evolution

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Scope of the Expert Advisory and Review Board evaluation

The Expert Advisory and Review Board (EARB) consists of experts who 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 fourth evaluation report expresses the EARB's view on the following deliverables:

- D5.4-D5.2.2 Synthesis of the results obtained of test cases from task 5.2
- D5.6-D5.3.2 Specifications for Beacon WP5: Testing, verification and validation of models. STEP 3 – predictive test cases
- D6.2 CS perspectives with a focus on verification and validation of models, and comparing models with situations close to disposal conditions (task 5.1 and 5.2)

The core text of the report gives the main outcome of the EARB review, detailed reviews are given in appendices.

EARB's Comments to D5.4-D5.2.2 and D5.6-D5.3.2

The EARB appreciates the clarity of the reports and the appropriate level of detail allowing to understand the modelling approaches followed by the modelling teams and the modelling results. This transparency gives credit to the project and facilitated the EARB's review.

The EARB thinks that the sections comparing the results obtained by the different teams could be better developed by discussing more in depth the differences in the modelling approaches and in the selection of initial states and boundary conditions. The impact of these differences on the observed dispersion of the partner's results is also important to consider. In particular the large range of input parameters selected by the modelling teams is questionable. Summary sections could better point out the lessons learned in terms of modelling approaches and of key processes to be implemented in the models. Plans to remedy the identified area to be improved could also be more explicit.

The EARB understands that final saturated state can be reproduced in terms of water content and dry densities, however the dynamics of the hydration process remains difficult to predict. Understanding the dynamics of the hydration process is especially important when predicting bentonite hydro-mechanical evolution of bentonite barriers within real repositories. More specifically, the EARB thinks that the differences of the hydro-mechanical mechanisms and their effects to the homogenisation process under unsaturated and saturated conditions could be discussed.

The total pressures and displacements remains difficult to reproduce. The EARB believes that adequate prediction of stresses is important since in some concept swelling pressure is a parameter supporting safety functions.

The EARB thinks that the non-sensitivity of the models to the initial dry densities distribution is contradictory to experimental observations (e.g. EB experiment where zone of low initial dry densities does not reach complete homogenization).

The role of friction appears to be key in the modelling of oedometer tests. The EARB recommends to investigate the role of friction in real repositories considering lining/bentonite and bentonite overpack interfaces.

The EARB believes that the BEACON project strategy of performing basic tests to study the processes characterizing the hydration phase and the interaction between different types of bentonite barriers (e.g. blocks, and powder/pellets mixture) is appropriate. The concern to limit the complexity of the tests and to control as much as possible the initial states and the boundary conditions, make it possible to limit the experimental artefacts and thus to test the capacity of the models to reproduce the hydro-mechanical behaviour during hydration. Taking into account the discrepancies observed between the modelling and the experimental results, the EARB believes it is important to continue this strategy in future R&D (within or outside of the current BEACON project).

More specifically, some analyses have shown the sensitivity of the results to some parameters such as retention curve or swelling pressure dry density relationship. The EARB therefore agrees with the BEACON conclusion identifying the need to determine more precisely a set of basic but essential data for a better representation of the physical processes that develop within bentonites during hydro mechanical solicitations.

The EARB recommends to take these comments into account in next synthesis reports D3.3 and D5.7.

EARB's Comments to D6.2

The EARB recommends to the Coordination Team might to revise the titles of all WP6 deliverables since Civil Society perspectives seem to fall outside the objectives of the redirected grant agreement.

It is not clear to the EARB to which extent the use of language close to "plain English" effectively increases comprehensibility. The EARB recommends to develop a glossary which could be interactive for web version.

Since the report is intended for dissemination of the work and results of the Beacon project to the civil society/public, the EARB recommends producing sections explaining the project context:

- the role and importance of bentonite in safety concepts for radioactive waste repositories,
- the need to understand its characteristics and long-term behaviour,
- the need to model this behaviour for demonstration purposes, together with an explanation why experiments and observations alone are not sufficient for safety assessments.

The EARB is of the opinion that four points should be addressed in WP6 deliverables:

1. A description of the overall aims of the project, its structure and the role the single WPs should fulfil.
2. A description of the results achieved.
3. Conclusions based on the results: Lessons learnt, achieving (or otherwise) project objectives and actors' expectations.

4. Outlook: Further research needs and expectations

While points 1 and 2 were addressed in D6.2, work on points 3 and 4 remains to be done. Indeed, the documents ends rather abruptly after a description of modelling the Canister Retrieval Test.

Appendix 1: Detailed EARB's Review D5.4/D.5.2.2

Context and objective deliverable D5.4/D.5.2.2

Deliverable D5.4/5.2.2 [1] concerns the modelling of three large-scale experiments studying the hydration process of bentonite backfill materials consisting in bentonite compacted blocks and/or pellets.

- Engineered Barrier Emplacement Experiment (EB) at Mont Terri clay laboratory,
- Canister Retrieval Test (CRT) at Äspö hard rock laboratory,
- Full-scale Engineered Barrier Experiment (FEBEX) at Grimsel hard rock laboratory.

The experiments have been selected based on their relevance to highlight the role of heterogeneities in bentonite component. The interest of these experiments is that they are well described and that post-mortem data have been obtained during their dismantling. The specifications of these tests have been collected in deliverable D5.3/5.2.1 [2].

The objective is to revisit and compare approaches to model these experiments considering the heterogeneities inherent to the installation and evolution of such structure. Theses heterogeneities can be induced by the initial installation of the material (in EB or CRT pellets + blocks) or induced by boundary conditions (local water supply for CRT). This highlights the added value of the work performed in BEACON compared to previous projects such like DECOVALEX [3].

EARB review

The EARB acknowledge the significant efforts made by the modelling teams. The report is well structured and written. The models and the modelling results are clearly presented comparative tables summarizing the differences in models, boundary conditions and initial state would have been useful to facilitate the comparison of the different approaches.

The EARB understands that the modelling of the selected experience is quite complex considering the uncertainties related to the real knowledge of the boundary conditions, the initial state and to the monitored data.

The effective initial dry density of the emplaced bentonite pellets were not well mapped during the installation of the experiments. These heterogeneities can significantly impact the transient hydro-mechanical behaviour of the backfill material during the hydration process. In the case of low initial dry density, the final state can also be impacted since homogenisation does not seem to occur completely (at least considering the timeframe of the experiments).

The hydration process is not well controlled in the experiments leading to non-uniform saturation in the transient phase. The lack of controllability of the hydration process is linked to the hydration system design but also to the hydration governing processes itself. Indeed, at the moment the hydration is initiated, the existing voids and gaps represent as many hydration preferential paths. During hydration these preferential paths will close progressively as the result of swelling and disaggregation of the bentonite blocks and pellets and will lead to non continuous hydration pathways. The dynamic of the hydration process will therefore highly depends of the hydraulic injection rate, the initial saturation and dry density of the blocks, and the technological voids.

The EARB thinks that the observed sensitivity of the hydro-mechanical evolution of the backfill material to the boundary conditions and the initial state is an important feed-back for the implementation of an actual disposal. Indeed this finding could lead to design provisions in order to facilitate the emplacement of the backfill materials in a more uniform way and to increase quality controls to ensure that the effective characteristics of the emplaced material meet the specifications.

Despite the complexity of modelling the experiments, the EARB considers that the dispersion of the results obtained by the partners, which are sometimes quite important, should be more in-depth discussed in order to better highlight the added value of one modelling approach over another. The results obtained by the different teams and the comparison with the experimental data could also be more investigated in particular to identify areas for improvement in the understanding and modelling of the impact of the heterogeneities in the evolution of such structure. For example, it would be interesting to compare the way to take into account heterogeneities and interfaces between different types of materials in the model and to investigate how it influences the numerical results.

The report point out the sensitivity of the models to the micro-macro interaction functions, the retention curve and the swelling pressure dry density relationship. The EARB thinks that these findings are quite relevant for further investigations in the project.

The EARB suggest to consider also the following issues:

- the general model overestimation of the swelling pressure (even for the final state): swelling pressure prediction is indeed particularly important when we are considering EDZ reconsolidation;
- the difficulties to predict the bentonite behaviour in the transient hydration phase: trends can be reproduced but not the qualitative results;
- the coupling terms between hydraulic parameters and mechanical behaviour: they seem to introduce dispersion in the numerical results obtained by the different modelling teams;
- the dynamics of the hydration process and of its non-uniform character: this is particularly important when we are considering the differences between natural and artificial hydration in terms of rate and pathways;
- the non-homogenisation of zone with low initial dry density: Why homogenisation is not reached? Is it a permanent situation or homogenisation would occurred at longer term? To what extent it could be a problem for safety?
- the reached prediction level in terms of project objectives and performance assessments: Do the models take into account heterogeneities in a sufficiently appropriate way? Is the prediction level sufficient to determine the required characteristics of the emplaced bentonite material for a detailed design?

EB experiment

The Engineered Barrier Emplacement Experiment (EB experiment – Mont Terri clay laboratory) is designed according the Swiss concept consisting in placing the canister on a bed of compacted bentonite blocks while the rest of the buffer is made of bentonite pellets. The objective of the experiment was to study the hydration and the homogenisation process of a mixed bentonite backfill material composed of blocks and pellets (see fig. 1). The experiment was dismantled after almost eleven years of operation.

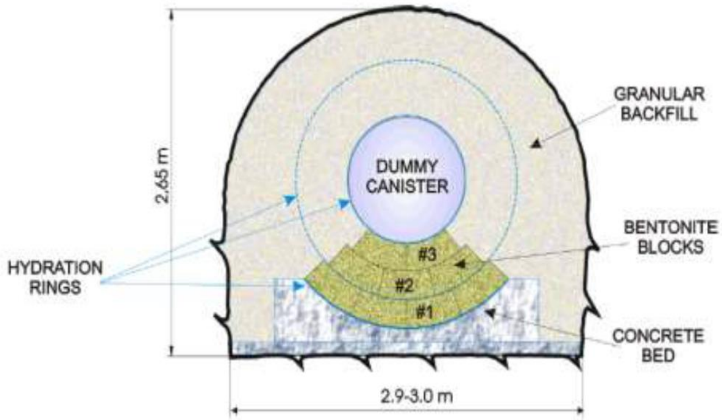


Figure 1 Schematic experimental EB layout

Two modelling teams UPC and ULG made numerical simulations. Difficulties for the modellers are the bad mapping of the initial inhomogeneities in terms of initial dry densities and the lack of close hydration control of the test during the saturation phase.

Differences in the approaches were noted e.g.:

- UPC took into account the excavation of the gallery and the time until the emplacement of the experiment, ULG not
- ULG used a corrected hydration process to take into account observed leakages, UPC not
- ULG considered alternative study cases taking into account heterogeneities in the dry densities and the hydration process
- initial suction of the blocks: 150 MPa for UPC & 120 MPa for ULG; how is this difference justified?

The conclusion made in the synthesis section 3.4 "*The results obtained by the two partners are in good agreement with the measures. The trend and the amplitude of the measured quantities are in most cases well reproduced*." does not reflect the results discussions made by UPC and ULG and should therefore be nuanced. Indeed even if both teams allows to reproduce homogenization of the dry density of blocks and pellets, important discrepancies were also noted (see comparative table 1).

Observed from monitoring	**UPC (base case)**	**ULG**
Re-saturation (suction drop & RH increase)	Much faster Effective injected volume probably < 6.7m3 considered in the model	Average re-saturation can be reproduced probably because the water injection in the compacted blocks has been calibrated in order to reproduce the average experimental

		suction decrease in the compacted blocks.
Desaturation episode observe close to the tunnel by sensors	Reproduced but not only close the tunnel phase. Relation of this phenomena with natural saturation is not clear.	Not reproduced
Desaturation in the host rock near field due to tunnel drainage (excavation and EB saturation) followed by re-saturation	Suction and RH: tendencies are reproduced but underestimated Porewater pressure: tendencies are reproduced but quantitative discrepancies	Not computed
Horizontal movement (6 to 1=7mm) of the canister during the buffer hydration	Not reproduced due to model symmetry It would be interesting to investigate what has been the impact of this horizontal displacement (not reproduced in the model) on the homogenisation process.	Not reproduced due to model symmetry
Vertical movement (~10 mm) of the canister during the buffer hydration	The tendency is reproduced but the steady value is largely overestimated (60-70 mm)	
Total stresses	Overestimated in the transient phase Steady state values are in agreement	The non-monotonic increase of the total pressure in the buffer but not the steady value which is largely underestimated
Final degree of saturation 90-100%	Overestimated: (due to model strategy) 100%	
Final dry density pellets	Steady state values are generally in agreement	Steady state values are overestimated
	The low dry density measured at the lower corners of the section is not reproduced by the model. The reason why we do not have homogenisation everywhere should be further investigated (how it will evolve at longer term?)	
Final dry density blocks	Steady state values are overestimated	
Water content	Not computed	Steady values well reproduced (could be the result of the overestimation of the saturation and the dry density

Table 1: Results comparison of modelling result obtained by UPC and ULG

2D modelling seems to be a limitation for the simulation of such tests. Need for 3D modelling to simulate such tests should be pointed out.

The overestimation of the vertical movement of the canister during the buffer hydration (60-70mm modelled compared to ~10 mm measured) should be deeper investigated because:

- displacements are key in the understanding of the HM behaviour
- the uplift of the canister is supposed to participate to the homogenisation process

The conclusion made in the synthesis "*This highlights the important role of the interaction functions on the results and specially to estimate the variation of these quantities during the transient phase. On the other hand, introducing a distribution of dry density of bentonite in the initial state or modification of the hydration scheme lead only to slight differences in the results*" suggests that micro-macro interaction functions have more impact than initial dry density heterogeneities on the modelling results. This would need to be further investigated. The low impact of initial dry density heterogeneities seems contradictory with the experimental observations.The potential impact of the non-uniform hydration process and of the heterogeneities in terms of dry densities on the final state should be discussed (e.g. the mechanisms explaining that homogenisation is not complete in the zone of low initial dry density).

CRT experiment

Canister Retrieval Test (CRT - Äspö Hard Rock Laboratory) is a full-scale field experiment simulating a deposition hole in a high level radioactive waste repository of KBS-3V. It was designed to demonstrate the ability to retrieve a deposited canister at full buffer saturation. The canister was surrounded by rings made by compacted bentonite. The gap between the host rock and the compacted bentonite was filled with pellets (see layout in figure 2). This in-situ experiment was carried out from 1999 to 2006 and dismantled after 5 years of heating and artificial hydration.

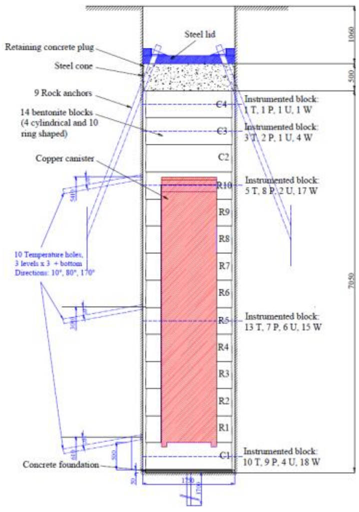


Figure 2: Schematic CRT experiment layout

Some differences in terms of boundary conditions and initial state were noted between modelling teams (e.g. initial temperature and porosity of the pellet filled gap). The EARB thinks that the rationale behind these difference should be explained.

A good agreement between the measurements and the models is assessed for the development of total pressure at different locations in the buffer. However the dispersion of the results between the partners is significant. The trends is to overestimate the swelling pressure.

Dispersion of the results between the partners is also significant for the suction evolution. Such dispersion should be discussed more in depth.

The final state in terms of dry density seems to be captured by the different modelling teams. The compression of the outer part of the pellet domain simulated by some modelling teams is however not observed on the measurement results.

FEBEX experiment

The Full-scale Engineered Barrier Experiment FEBEX (GRIMSEL hard rock laboratory) aims to study the behaviour of near-field components. The gaps between the bentonite blocks and at the bentonite-granite interface can be considered as initial heterogeneities in the system.

This in-situ experiment was carried out from 1995 to 2015 and partially and totally dismantled respectively after 5 and 13 years of heating and artificial hydration.

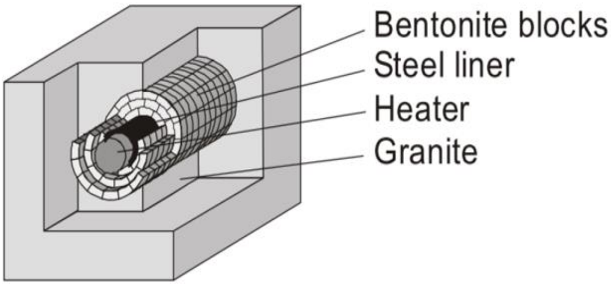


Figure 3: Schematic experimental FEBEX layout

The report indicates that numerical results reproduce the rapid increase of relative humidity in agreement with the measurements. However the results obtained by the modelling teams are dispersed. Dispersion of results are also observed in the simulation of water contents and radial stresses. These dispersion are explained by the importance of the coupling terms between hydraulic parameters and mechanical behaviour. The EARB thinks that the approaches followed to introduce the hydro-mechanical coupling in the models should be compared in order to identify the best approach or areas for improvement.

The report concludes from the comparison between the post-mortem measured quantities and the numerical results presented on Figure 5-106 and 5-107 for S56, that the models give a good estimation of final state. The good assessment of the water content seems however contradictory with the dispersion observed on Figure 5-102.

The EARB considers very interesting that the models are able to reproduce the persisting gradient of density in the material due to the way of hydration happened from the periphery of the bentonite blocks. It would be interesting to investigate if this gradient is persisting on longer period of time.

References

[1] D5.4/D5.2.2 Synthesis of the results obtained of test cases from task 5.2

[2] D5.3/D5.2.1 Testing, verification and validation of models, Step 2

[3] Response message No 3 to the EARB regarding comments in the third EARB report D8.9 with the title EARB second annual project review report, produced after the 2nd Annual Meeting of Beacon, M24

Appendix 2: Detailed EARB’s Review D5.6/D.5.3.2

Context and objective deliverable D5.6/D.5.3.2

D5.6/5.3.2 [1] concerns the comparison of numerical simulation with the results of three oedometer tests (MGR22, MGR23, MGR27) performed on bentonite cylinders composed of two layers of bentonite materials: one layer is a compacted bloc, the other layer is made of bentonite pellets and powder. The schematic layout of the experimental set-up is given on figure 1. The three tests are performed with the same conditions except the layer configuration and boundary conditions concerning the water supply (see table 1). Hydration takes place through the bottom for the three tests. MGR27 test has been selected for predictive modelling.

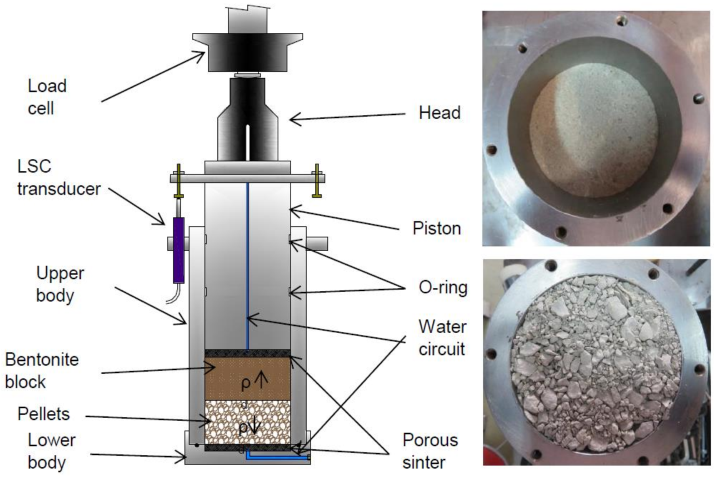


Figure 1: Schematic view of the experimental set-up

	Layers configuration	Water supply	Duration (days)
MGR22	Pellets in the lower part	Constant flow: 0.05 cm3/h	266
MGR23		Constant pressure: 15 kPa	210
MGR27	Pellets in the upper part		~280

Table 1: tests configuration and boundary conditions

Test MGR23 has been repeated two times with early stops at 14 (MGR24) days and 34 days (MGR21) allowing the analysis of transient hydro-mechanical states.

EARB review

Experimental issues

The grant agreement refers to the NSC in-situ experiment at Andra’s URL consisting of a 5 meter long bentonite plug with a diameter of 4.6 meter as candidate for predictive simulations. The reason why this test was finally not retain could be explained.

The preparation methods (pouring and shaking) of the pellets parts might induce some structural heterogeneities, which could affect the initial permeability.

It would be interesting to provide the water injection pressure evolution in MGR22 to maintain the constant flow.

The measured axial stress is much lower for MGR27 than MGR22 and MGR23. It would be interesting to investigate if this is an effect of the layers configuration.

The experimental artefact related to the plateau of water intake at 150 cm3 observed in MGR23 (stop of water intake) should be explained.

Modelling

The models , the model parameters used and the modelling results are clearly presented. The results obtained by the different modelling teams are clearly compared in light of the differences between modelling approaches. It is not clear, why in chapter 3 the teams were indicated by the name of their institutes (ULG, CU/CTU,…) and in chapter 4 the naming Team A, Team B, … has been used.

The EARB considers that the reason of the large range of permeability used in the simulations by the different teams should be explained. The EARB wonders why it was not possible to characterise more precisely the permeabilities of the bentonite materials. Data on permeability of Febex bentonite at various dry densities is well documented in the literature. For the pellets the initial average permeability could be deduced based on the initial average dry density. The observation that globally good prediction results are obtained despite this dispersion should be more in depth discussed. This is particularly important since the hydraulic conductivities of the bentonite materials are key in the dynamic of the saturation process. The reason of the large difference in mechanical parameters of the material should also be explained. Why it was not possible to characterise these parameters more precisely? It would have been worthwhile to have a comparison of all models using the identical parameter for the modelling of the experiments – as far as possible – knowing that different model concepts use different parameter sets.

Could the globally good prediction results obtained despite permeability dispersion be an indicator of the existence of initial dry density heterogeneities of the pellets parts (induced by the preparation protocol: pouring and shaking)?

The EARB notices that the final state in terms of water intakes, dry densities and water content can be predicted satisfactorily by most of modelling teams), whereas the model results showed a wide spreading for the transient phase. The plateaus in figure 4.1 were reproduced quite well (except by teams A, C, H&I (MGR23) and D (MGR27)). The same applies to water intake (figures 4.2 and 4.3).

The EARB points out that considering complete saturation and homogenization the final water content can be estimated from analytical solution (see appendix 4).

The predictions are however strongly dependent of the initial state and the boundary conditions. This means that in a real repository it would be important to control the initial state and the boundary conditions with sufficient precision. Prediction of the transient behaviour during hydration looks more challenging.

The EARB notices the large dispersion in the prediction of both axial and radial stresses between the modelling teams both during the transient and the final state. Adequate prediction of stress is however important since in some concept swelling pressure is a parameter supporting safety functions. Areas for improvement should be identified.

Another point is the use of friction in the models, which yielded a better prediction of the axial stress in MGR27. Would friction also be relevant for repository conditions?

The EARB notices that in ULG's BBM modelling the total stress formulation, instead of the widely used effective stress formulation, is selected for the mechanical constitutive model of the interface element (page 16 in D5.6). The reason is that using effective stress formulation, the interface presents a resistance during the unsaturated phase, which is proportional to the negative pore water pressure, suction. The EARB agrees with the authors that suction during the unsaturated phase is physically different from the positive pore water pressure developing after water saturation. The EARB thinks that the differences of the hydro-mechanical mechanisms and their effects to the homogenisation process under unsaturated and saturated conditions should be discussed.

The EARB notices that calculation with CT/CTU's THM double-structure hypoplastic model may sometimes lead to an unreasonably high suction value (up to the orders of GPa) when the calculation is bounded to experimental water retention curves (page 32 in D5.6). The EARB thinks that a discussion for the rationale behind this overestimation needs to be given as well as the reason why another calibration approach leading to more realistic suction and initial water content was not selected.

The EARB has the opinion that the presentation of "balance equations" for Clay Tech's HBM in Section 3.3.3 page 41 in D5.6 could be improved by either supply a list of symbols or a reference with more detailed explanation of the various terms and equations. Also, it is stated that "Radial homogeneity has been assumed and wall friction is not accounted for, which results in a one-dimensional model". The EARB thinks that the impact of this assumption should be discussed. Results from ULG seems to indicate that the influence of wall friction could be significant during later stages of saturation.

In the LEI model, "it was assumed that wetting pellets will swell into the void space around pellets, but there will be no overall swelling induced stress of a pellets zone as a whole" (page 69 in D5.6). The assumption could be more applicable during the early stage of evolution but probably is less obvious in the later stage of evolution after the pellets has swollen a lot. However, the agreement seems better for the later stage in the case of MGR22 (Figure 3-67 P 65).

It is impressive to the EARB that Quintessa, by using a relative concise model with only two fitting parameters in the respective equations, is so capable in predicting experimental results with much calibration with the experimental work. The underlying mechanical mechanisms for the relatively successful predictions are worth exploring.

It is unclear to the EABR how the suction mechanism during saturation is treated hydraulically and mechanically in BGR's hydro-mechanical model. As the negative potential of suction in the bentonite is the driving force for water uptake during saturation and plays a dominating role for the two-phase transport of water and vapour, it is probably worth explaining the treatment of suction in the model from a hydraulic perspective. As ULG has discussed in its presentation, the treatment of suction in the effective stress representations could be subtle and it is likely the treatment in BGR's model even need to be discussed from a mechanical perspective.

References

[1] D5.6/D5.3.2 Specifications for Beacon WP5: Testing, verification and validation of models. STEP 3 – predictive cases, section 4.2

Appendix 3: Detailed EARB's Review D6.2

Context and objective deliverable D6.2

D6.2 "CS perspectives with a focus on verification and validation of models, and comparing models with situations close to disposal conditions (task 5.1 and 5.2 of WP5)" [1] is meant to document and to communicate the work carried out in BEACON tasks 5.1 and 5.2 with a non-specialised audience as the target group. In the course of the project, BEACON WP6 work had been re-orientated to this type of "dissemination" tasks. This had been communicated at the 2019 Annual Meeting in Prague, cf. also [2]. The current version of the Grant Agreement reads:

"The overall aim of WP6 is to give civil society the opportunity to be informed of the research conducted in the project by supporting the Projects dissemination to the civil society. The work package will facilitate the translation of scientific results and other output from WP1-5 to the public and create the conditions for civil society local and national representatives be informed of the research results and other information made available by the project. This will enhance the possibilities of civil society participation in future situations where there are consultation processes as a part of safety case review."

In relation to D6.2 it states:

"Task 2. The WP working Group, with the support of the scientific expert(s) will then continuously take part of the project and its results, and translate the results to the public. Since WP5 is the core component of the Beacon project, and its tasks in a way are the essence of the project, the WP6 group will give special focus to the WP5 tasks and deliverables, and deliver an elucidation of the work and results targeted at civil society."

In its second review report, the EARB provided comments [3] on the old temporary version of D6.2 [4]. The BEACON coordinator suggested to leave these comments unresponded [5]because the draft D6.2 had been prepared in the middle of the re-orientation process and had to undergo major changes in any case.

Tasks 5.1 and 5.2 are part of BEACON's WP5 "Testing, verification and validation of models", task 5.1 being devoted to laboratory tests and task 5.2 to large-scale experiments. D6.2 is referring to deliverables D5.1.2 "Synthesis of results from task 5.1" and D5.2.2 "Synthesis of the results obtain of test cases from task 5.2", the latter also being subject of this EARB review.

EARB review

Given the rather complex situation of WP6 (cf. above), this review will be presented in stages: First, deliverable D6.2 in its present version [1] will be addressed. Then, the earlier EARB comments [2] on the draft version [4] will be revisited in order to derive general conclusions concerning WP6.

After having explained the situation concerning WP 6 (cf. above), D6.2 briefly describes all BEACON WPs. This is followed by a more detailed description of tasks 5.1 and 5.2 – first, all experiments are described for each task, followed by a description of modelling results.

At a first glance, two observations can be made:

(i) The text does not deliver what the title promises. The document provides descriptions but hardly perspectives. Apparently, the title was changed in the course of the changes explained above (documented in the current version of the Grant Agreement). However, in the view of the EARB it does not meet the intentions. The Coordination Team might, in consent with the WP 6 beneficiaries, consider revising the titles of all WP6 deliverables.

(ii) The documents ends rather abruptly after a description of modelling the Canister Retrieval Test. By the document's author, it was explained to the EARB this was done by intention but the rationale remains unclear to the EARB. In the introduction, it is stated that the deliverable was delayed since "the finalisation of this report has awaited the deliverable D5.2.2". D5.2.2 was finalised in July 2020. Therefore, the abrupt end cannot be explained by the timing. The EARB assumes from the author's reply that the intention of the text was more factual description but nevertheless sees the issue as a deficiency and recommend producing a summary section.

In chapter 2.1, it is explained that the text is "intended for use in the development of the dissemination of the work and results of the Beacon project to the civil society/public." It remains unclear to the EARB whether thus the deliverable is merely intended to provide "building blocks" for a later, more comprehensive document (which might explain point (ii) above). However, https://www.beacon-h2020.eu/deliverables/ indicates that D6.2 is going to be published. Consequently, and given the target group described above, it should be digestible on its own for the target group "civil society/public". Therefore, the EARB recommends producing sections briefly and understandably explaining

- the role and importance of bentonite in safety concepts for radioactive waste repositories, therefore
- the need to understand its characteristics and long-term behaviour, and
- the need to model this behaviour for demonstration purposes, together with an explanation why experiments and observations alone are not sufficient for understanding and safety assessments.

This can lead to an explanation of the BEACON philosophy as it is being provided in chapter 2.2.1 (which is devoted to WP1 but goes beyond the scope of this WP).

Another general impression is that the authors apparently attempted to use language similar or close to "plain English" (https://en.wikipedia.org/wiki/Plain_English) in order to make the text better understandable. It is not clear to the EARB to which extent this indeed increases comprehensibility and feels that some phrases might sound patronising ("The next thing that the work package did …") without achieving better understandability. The authors might consider seeking professional advice concerning language issues.

This use of language is in contrast to the widespread usage of rather technical terms (bentonite, assessment cases, verification, validation, pellets, swelling pressure, axial stress, …) which need explanation. This is even the case for the word "model" since it can have various meanings. The EARB recommends to develop an interactive glossary which can also be used for deliverables to come. It also recommends establishing a 1:1 relationship between terms and their meaning, i. e. it might be confusing for the target audience that the terms "bentonite" and "clay" are used interchangeably. Also, terms like "large-scale" will immediately lead to the question "how large?". Similarly, using terms such as "Febex bentonite" versus "MX-80" requires an explanation that there are various bentonite types and why this is important for the project. Along the same lines: Sentences like “The canister was not heated.” without further explanation will immediately raise the question “Why should it be heated?” since for non-specialists the image of a heat-emitting canister is perhaps not intuitionally connected with the issue of HLW (as it is for specialists).

Apart from these problems, the EARB acknowledges the efforts to make issues understandable. Section 3.1.1. can serve as an example for these efforts. Unfortunately, several figures, including the first one in section, suffer from low resolution. Other examples are the figures on pp. 13 (top), 14 (second from top) as well as almost all the figures provided in section 3.2. Another example for good communication is the paragraph beginning with “The tests were chosen …” on p. 20: The language is understandable but not simplifying, and the rationale behind choices is well explained.

Editorial notes:

- p. 8 “sixcountries”: space missing
- p. 8 “From the results of WP 2 with the long list of previous experiments on clay, two list of experiments that the modellers should test their models on were made.”: Hard to comprehend, in this case an easier grammar appears more appropriate.
- P. 17 “Even though all the models do not reach the same swelling pressure it can be said that they are in a good range as there are some uncertainties about how much water was in the pellets to start with.”: same comment. Also, one or two additional sentence might clarify things.

Hereinafter, excerpts from the EARB’S review [3] of the draft deliverable [4] are summarised in order to conclude about their further validity.

EARB comments in [3]	**Remark**
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 comment did not directly relate to D6.2 but to overall planning. The EARB consider it still valid.
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.	Related to D6.1 but in accordance with the recommendation made in this document (bulleted list after “Therefore, the EARB recommends producing sections

	briefly and understandably explaining …”)
… 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).	Relates to the remarks on the choice of title(s) made above.
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…)	In part addressed in the present version of D6.2 (“civil society/public”) but more differentiation is needed in the communication concept mentioned above.
final version should perhaps start by giving an overview of all the WPs and their roles	addressed
Note that GRS is not a WMO but a research and consultant organization	not addressed
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.	This is still the case.
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.	Still an issue to be considered.
… 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.	Still an issue to be considered.
it would be better to verbally explain ssues and also to explain that WP 5 is addressing reasons for the variation of results	Addressed, the combination of figures and verbal explanation appears in general appropriate. But

	higher-resolution figures are needed.
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.	addressed
… some sketches of repository components as well as photos from experiments are probably more useful.	in part addressed

In summary, the EARB sees (still) a need to improve and specify the general strategy for the revised objective of WP 6. The recommendation made in the second EARB report [3] remains valid:

"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"

Moreover, the role of the single WP6 deliverables should be clarified: Are these documents for the target audience on their own, or just building blocks for something to come?

Given the scope of WP6 according to the current version of the grant agreement, the EARB is of the opinion that four point should be addressed in WP6 deliverables:

1. A description of the overall aims of the project, its structure and the role the single WPs should fulfil.
2. A description of the results achieved.
3. Conclusions based on the results: Lessons learnt, achieving (or otherwise) project objectives and actors' expectations.
4. Outlook: Further research needs and expectations.

While points 1 and 2 were addressed in D6.2 (with the limitations named above), work on points 3 and 4 remains to be done.

References

[1] D6.2 CS perspectives with a focus on verification and validation of models, and comparing models with situations close to disposal conditions (task 5.1 and 5.2 of WP5)

[2] Grant Agreement 745942 – requested amendments to Annex 1, parts A & B, 28 March 2019

[3] D8.9 EARB second annual project review report

[4] D6.2 Report from first annual meeting, draft as of 15/4/19

[5] Response message No 3 to the EARB regarding comments in the third EARB report D8.9 with the title EARB second annual project review report, produced after the 2nd Annual Meeting of Beacon, M24

Appendix 4: Final water content assessing full saturation and perfect homogenisation

Full saturation ➔ $Sr_f = 100\%$

Perfect homogenisation ➔ $\rho_{df} = \rho_{dit} = 1.45\ g/cm^3$

W_f can be calculated as follows

$$W_f = W_i \underbrace{\frac{W_i \rho_{di} \rho_{df} + (\rho_{di} - \rho_{df})(Sr_i - W_i)\rho_w}{W_i \rho_{di} \rho_{df}}}_{\text{Layer volume change coefficient}} \underbrace{\frac{Sr_f}{Sr_i}}_{\text{Saturation change coefficient}}$$

$$= \frac{W_i \rho_{di} \rho_{df} + (\rho_{di} - \rho_{df})(Sr_i - W_i)\rho_w}{\rho_{di} \rho_{df}} \frac{Sr_f}{Sr_i} \qquad (1)$$

with

- i: initial
- f: final
- t: total
- w: water

Colour legend in the next tables:

- green: data given in D5.5
- orange: values deduced from full saturation and homogenisation hypothesis
- red: calculated values with (1)

Characteristics pellets layer

	Initial			Final estimation		
	W_i%	ρ_{di} (g/cm^3)	Sri (%)	W_f (%)	ρ_{df} (g/cm^3)	Sr_f (%)
MGR22	9.9	1.28	25	34.07	1.45	100
MGR23	3.5	1.3	9	34.03	1.45	100
MGR27	3.5	1.3	9	34.03	1.45	100

Characteristics block layer

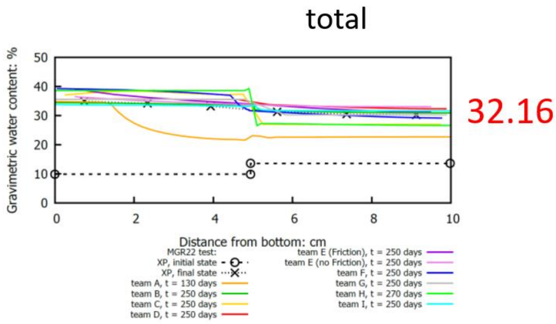
	Initial			Final estimation		
	W_i%	ρ_{di} (g/cm^3)	Sri (%)	W_f (%)	ρ_{df} (g/cm^3)	Sr_f (%)
MGR22	13.6	1.61	55	29.89	1.45	100
MGR23	14.2	1.6	56	30.18	1.45	100
MGR27	14.2	1.6	56	30.18	1.45	100

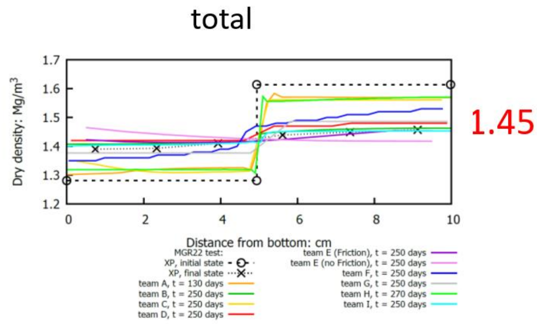
Characteristics total

	Initial			Final estimation		
	W_i%	ρ_{di} (g/cm^3)	Sri (%)	W_f (%)	ρ_{df} (g/cm^3)	Sr_f (%)
MGR22	11.9	1.45	37	32.16	1.45	100
MGR23	9.4	1.45	29	32.41	1.45	100
MGR27	9.4	1.45	29	32.41	1.45	100

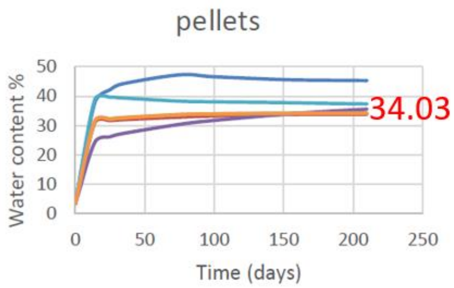
Comparison with Beacon modelling results - in red the above final state calculated values

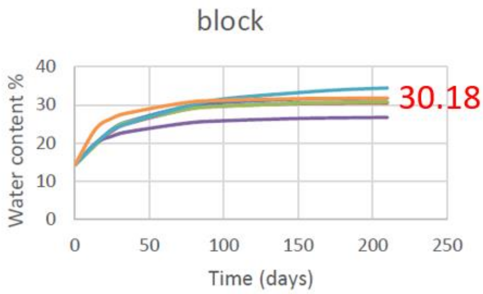
MGR22

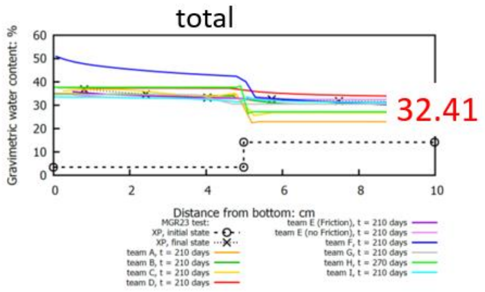


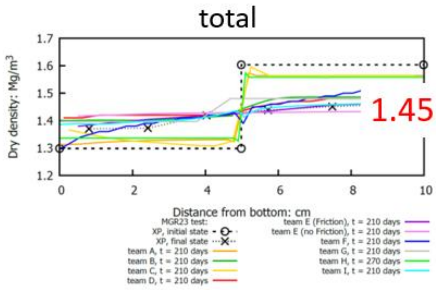


MGR23









MGR27