Doctoral Thesis Review

Student/author: Haiquan Sun

Title: Investigation of thermo-hydro-mechanical behavior of Czech bentonite used as a model material for planning of high level nuclear waste disposal

University: Charles university

Faculty: Faculty of Science

Study programme: Applied Geology

Supervisor: doc. RNDr. David Mašín, Ph.D.

Reviewer: Ing. Lucie Hausmannová, Ph.D. (hausmannova@surao.cz)

The doctoral thesis focuses on the testing of the thermo-hydro-mechanical behaviour of Czech bentonite with respect to its application in the planned Czech deep geological repository for radioactive waste. The thesis is based on three papers, all of which have been accepted by international journals and 2 of which have already been printed. Thus, the writing of the review was made easier since these papers had already been reviewed by the respective journals prior to their being accepted for publication. With respect to the style and structure, the thesis is written in the form of a standard scientific report with embedded papers of which Mr. Haiquan Sun is the first author. The style of the thesis is acceptable.

Composition of the Thesis

The thesis is organised in the form of 7 main chapters:

1. Chapter – Introduction – presentation of the research background and the organisation of the thesis
2. Chapter – Aim of the thesis
3. Chapter – Materials and methods – presentation of descriptions of: the tested material, i.e. Czech bentonite B75 and the methods employed – the vapour equilibrium method, the mercury intrusion porosimeter (MIP), the environmental scanning electron microscope (ESEM), oedometer tests and the testing programme
4. Chapter – Results and discussions – this part is divided into 3 subchapters:
   - 4.1 Water retention curves – this research was presented in one of the attached papers (Sun et al., 2018a)
   - 4.2 Microstructure evaluation – part of this research was presented in one of the attached papers (Sun et al., 2019), which is currently in print
   - 4.3 Mechanical behaviour – part of this research was presented in one of the attached papers (Sun 2018)
5. Chapter - Conclusions
6. Chapter – References
7. Chapter – Attached publications – Sun et al., 2018a; Sun 2018 and Sun et al., 2019 - in print

General comments

- The paper is well arranged, all the references are shown in the reference list, the thesis meets all the relevant formal requirements.
- Grammar errors – since the author is not a native Czech or English speaker, the grammar correction of the text by a native speaker would be beneficial (including with concern to the title of the thesis).
- Description of the parameters applied – the inclusion of a description and equations for the assessment of the following parameters is missing: the void ratio, water content, degree of saturation, thermal fractal dimension.

Factual comments

- Pg. 11 – vitrification is a different process; I assume that the author meant sodium activation
- Pg. 11– the content of montmorillonite is very low (the limit for bentonite is 65%) and the reference document cannot be traced.
- Pg. 27-29 – chapter 4.2.3 should be written in a more understandable way; it is very difficult to follow the text
- Pg. 31 – the explanation to Figure 12 b – it is written that the swelling pressure of the constant volume test is lower than the swelling pressure determined by "swell-consolidation". However, this appears not to be the case, i.e. the figure shows the perfect fit of the data

Questions:

1. Pg. 17 Chapter 3.3 Test programme. Why do the densities used for WRC, ESEM and MIP not correspond to those determined by the oedometric dry density tests? Why were these densities chosen?
2. Pg. 12 The vapour equilibrium method – did you perform the control measurement of the relative humidity in a desiccator?
3. Pg.14 The ESEM method – it is written that the vapour pressures were changed at 15-minute intervals; was this enough to attain equilibrium? How did you control it? (compared to the vapour equilibrium method concerning which it takes 2-3 months to attain equilibrium)
4. Article 1 - Fig. 4, the degree of saturation results are worthy of note. The degree of saturation at the same relative humidity is significantly lower than at higher densities. Can you offer a hypothesis for this? And concerning water density (higher than 1000 in denser bentonite)? If we accept this phenomenon, it might explain the difference. What is the author´s opinion?
5. Article 1 - Fig. 8, there is a significant difference between the 2 methods at higher density compared to lower density. What might the reason be for this difference?
6. Article 1 - Pg. 21 (4.1.2 Water retention curves at high temperatures) - the significant influence of temperature on the water content for all the tested samples with differing densities (at lower suctions) is indicated in the text. Does that mean that there would be such a significant difference in the water content at differing temperatures even for fully saturated samples? So, the saturated water content differs in relation to temperature with respect to the heated samples? If yes, the approach to the calculation of the degree of saturation concerning heated in-situ experiments will have to be modified.
7. Article 2, Table 3. Could you please explain why the pore diameter seems 1000 times smaller at higher magnifications? Is it a well-known fact?

Conclusion

I would like to conclude the review by stating that the submitted thesis is well written and fulfils all the demands required of a doctoral thesis. The thesis is based on papers of significant quality. The comments and questions herein are not intended to detract from the overall quality of the thesis.

In conclusion, I recommend the acceptance of the thesis and, following its successful defence, the awarding of the title PhD.

Prague, 3 September 2019