European Joint Programme on Radioactive Waste Management

MOBILITY MISSION REPORT

This work has been partially supported by the EURAD project that has received funding from H2020-EURATOM 1.2 under grant agreement ID 847593.

KLIKNĚTE NEBO KLEPNĚTE SEM A ZADEJTE TEXT.

MISSION TITLE

Research stage at Politecnico di Milano (Italy)

DESCRIPTION

Concerned organisations

Following requirements of the EURAD Project (the European Union's Horizon 2020 Research and Innovation Programme 'European Joint Programme on Radioactive Waste Management' EURAD (2019-2024) WP GAS 'Mechanistic understanding of gas transport in clay materials' under grant agreement No. 847593), numerous laboratory experiments on granular bentonite (a key component of engineering barrier systems to isolate radioactive waste) were conducted at the Geotechnical Laboratory of UPC. For better interpreting and exploiting these experimental results, constitutive modelling and numerical simulations are required. The experimental results in combination with the numerical ones are expected to enhance the contribution of technical reports for the EURAD Project in understanding the geotechnical properties of granular bentonite within a multi-scale perspective. The concerned organizations were:

- The EURAD Project
- Waste management organisations
- Research entities (International Center for Numerical Methods in Engineering (CIMNE) (Spain))
- Universities (Universitat Politècnica de Catalunya (Spain) and Politecnico di Milano (Italy))

Concerned infrastructures or facilities

Not applicable

Concerned phases

Phase 3: Facility construction

Phase 4: Facility operation and closure

Phase 5: Post-closure

Themes and topics

Theme 3: Engineered barrier system (EBS) properties, function and long-term performance

- Clay-based backfills, plugs and seals
- EBS system understanding

Keywords

Granular-type bentonite, Hydro-mechanical modelling; Microstructure; Constitutive model

EXECUTIVE SUMMARY

My work during the research stage was devoted to the development of a constitutive model for describing and predicting granular bentonite behaviour. The obtained experimental results have shown that different initial compaction conditions of the bentonite samples altered the pore microstructure and further affected the subsequent hydro-mechanical behaviour, including gas and water transport properties. Therefore, it is required a theoretical description of the processes within an elasto-plastic framework related to the microstructural evolution of the bentonite. To this end, during the stay period, I conducted a comprehensive review of pertinent literature in the field of saturated and unsaturated soil mechanics. This enabled a systematic examination of existing constitutive models for their theoretical applicability in explaining my experimental data about granular bentonite's hydro-mechanical behaviour within multi-physics and multi-scale processes. Besides, I was introduced to the basic principles of hydro-mechanical modelling of granular bentonite using a constitutive framework developed at Politecnico di Milano by Prof. Cristina Jommia and Prof. Della Vecchia. The model was able to capture some relevant aspects of multiscale/multiphase hydro-mechanical coupling in unsaturated soils. The experimental results on the water retention curve, produced within the experimental campaign of EURAD, were successfully simulated for granular bentonite subjected to various hydro-mechanical paths. Also, the modelling effort was exploited to indicate future improvement directions of the current model. This also inspires one of the topics for my future research, as the development of modelling tools suitable for studying the hydro-mechanical behaviour of granular-type bentonite is of importance for academic and industrial fields. Hence, I think that I acquired substantial knowledge with fruitful outcomes, particularly in the theoretical aspects of unsaturated soil, which aligned with the original purpose of launching this research stage.

1. MISSION BACKGROUND

1.1. R&D background

Supported by the EURAD Project, many laboratory experiments on granular bentonite were conducted at the Geotechnical Laboratory of UPC. The results demonstrated that different initial compaction conditions altered the pore microstructure of the bentonite and further affected the subsequent hydro-mechanical behaviour. Therefore, a theoretical description of the processes within an elasto-plastic framework related to the microstructural evolution is required to advance an understanding of the geotechnical properties of this material.

1.2. Mission objectives

To enhance the theoretical analysis of the hydro-mechanical behaviour of granular bentonite

1.3. Mission request

To examine existing constitutive models for their theoretical applicability in predicting the hydro-mechanical behaviour of granular bentonite produced within the experimental campaign of EURAD

To indicate future improvement directions of the current model

1.4. Mission composition

Host organisation

Department of Civil and Environmental Engineering at Politecnico di Milano (Italy)

Host facility

Department of Civil and Environmental Engineering at Politecnico di Milano (Italy)

Mission dates

From 11 October 2023 to 11 November 2023

2. MAJOR PRACTICES, TECHNIQUES, METHODS, TOOLS OR SYSTEMS OPERATED OR STUDIED

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2.1. Practice, technique, method, tool or system operated or studied during the mission

Research stage at Politecnico di Milano (Italy)

Description

During this research stage, I was introduced to the basic principles of hydro-mechanical modelling of granular bentonite using a constitutive framework developed at Politecnico di Milano by Prof. Cristina Jommia and Prof. Della Vecchia. The experimental results on the water retention curve, produced within the experimental campaign of EURAD, were successfully simulated for granular bentonite subjected to various hydro-mechanical paths. Also, the modelling effort was exploited to indicate future improvement directions of the current model.

Usage

Enhancing the theoretical analysis of the hydro-mechanical behaviour of granular bentonite

Simulating the water retention curve for granular bentonite subjected to various hydro-mechanical paths

Benefits

Checking existing constitutive models for their theoretical applicability in explaining the experimental data about granular bentonite's hydro-mechanical behaviour within multi-physics and multi-scale processes

Pointing out future improvement directions of the current model for better application in granular bentonite

Limitations

Although the improvement direction of the current constitutive model was ensured, the short research stage of one month was not enough to complete this mission. Therefore, the second stage is required to continue this work.

Applicability

The outcomes during this research stage enhanced an understanding of the hydro-mechanical behaviour of granular bentonite and indicated the improvement directions of the current constitutive model.

2.2. Practice, technique, method, tool or system operated or studied during the mission

Klikněte nebo klepněte sem a zadejte text.

Description

Not applicable

Usage

Not applicable

Benefits

Not applicable

Limitations

Not applicable

Applicability

Not applicable

2.3. Practice, technique, method, tool or system operated or studied during the mission

Klikněte nebo klepněte sem a zadejte text.

Description

Not applicable

Usage

Not applicable

Benefits

Not applicable

Limitations

Not applicable

Applicability

Not applicable

2.4. Practice, technique, method, tool or system operated or studied during the mission

Klikněte nebo klepněte sem a zadejte text.

Description

Not applicable

Usage

Not applicable

Benefits

Not applicable

Limitations

Not applicable

Applicability

Not applicable

3. MISSION FINDINGS AND CONCLUSIONS

3.1. Lessons learned and conclusions

During this research stage, I commenced by reading the book ‘Geotechnical modelling’ to enhance my theoretical understanding of saturated soil. In particular, I focused on several chapters such as 'Introduction to modelling', 'Characteristics of soil behaviour' and 'Constitutive modelling', thereby advancing my insight into the current constitutive models widely employed in saturated soil mechanics. While primarily proposed for saturated soils, their modifications were also applicable to unsaturated soils. Consequently, the acquired knowledge was valuable for my subsequent modelling of the hydro-mechanical behaviour of granular bentonite. Afterwards, I conducted a literature review and learned a fully coupled elastic-plastic hydro-mechanical model for compacted soil accounting for clay activity. This model incorporated multiphase and multiscale couplings, probably suitable for simulating granular bentonite's hydro-mechanical behaviour subjected to a multi-porosity network. To use this model, I must learn how to define the critical pore size to separate micropores and macropores. Through repeat tries, 8000 nm was finally determined as the critical pore size to evaluate the evolution of micropores with wetting, giving the results comparable to those from other investigations on bentonite-based materials. The difference among these results was analyzed, associated with the special microstructure of granular bentonite. The pore size of 8000 nm corresponded to a peak of the large pore range in the pore size distribution curve of the sample after saturation under constant volume. The reason for selecting the key pore size was that smaller pores were relatively insensitive to the change in net stress. At this moment, I realized the current model remained unconsidered a triple-porosity model observed in granular bentonite's microstructure. After defining the key pore size, I simulated water retention behaviour for granular bentonite. During this process, we found the water density of the bentonite was changed towards higher than 1 Mg/m3 along with continually wetting after the air entry value. If the water density of 1 Mg/m3 was assumed constant along wetting, the water ratio was higher than the total void ratio in the condition of full saturation. Therefore, this assumption led to a 'faked' water ratio, so that beyond the air entry value, the current model lost the macropore/total void ratio-dominant water retention curve. To address this issue, the linear relationship between suction and water density was assumed within the suction range smaller than the air entry value to scale the water ratio from the experiment. As a result, the water retention curve obtained at the laboratory level on granular bentonite was successfully simulated. However, an increase in water density was linked to the second development of swelling pressure for granular bentonite. Although the scaling of the water ratio made the water retention curve more previous to be captured by the current model, its flaw was foreseen in predicting the double-period feature of swelling pressure development for granular bentonite. In the future, we will try to improve this aspect. Furthermore, the mechanical response of granular bentonite will be simulated. For this purpose, several experiments and microstructure observations need to be supplemented to determine key parameters that will be used to modify the current constitutive model. We expect to reproduce the rotation-hardening effect on the mechanical response of granular bentonite, the stress-dependent evolution of micropores and so on.

3.2. Relevant findings and conclusions for home organisation

The experimental results in combination with the numerical ones are expected to enhance the contribution of technical reports for the EURAD Project in understanding the geotechnical properties of granular bentonite within a multi-scale perspective.

3.3. Relevant findings and conclusions for host organisation

Not applicable

3.4. Relevant findings and conclusions for other organisations

Not applicable

4. POTENTIALS FOR IMPROVEMENT OR DEVELOPMENT

4.1. Generic potentials

Not applicable

4.2. Potentials for home organisation

Not applicable

4.3. Potentials for host organisation

Not applicable

APPENDICES

Mission journal

10/10/2023

Travel from Barcelona (Spain) to Milan (Italy)

11/10/2023-18/10/2023

Reading the book 'Geotechnical modelling' to enhance the theoretical and modelling knowledge about soil mechanics

19/10/2023-26/10/2023

Reviewing pertinent literature to learn constitutive formulations and their physical meaning and to define the delimited pore size for incorporating the multi-porosity network into the model

27/10/2023-31/10/2023

Simulating the water retention curve of granular bentonite

01/11/2023-10/11/2023

Defining and addressing issues in the simulation, as well as preparing to simulate the mechanical response of granular bentonite

11/11/2023

Coming back to Barcelona

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MISSION BENEFICIARY

HAO ZENG
PhD candidate
Division of Geotechnical Engineering and Geosciences, Department of Civil and Environmental Engineering / Geomechanics Group
Universitat Politècnica de Catalunya, Barcelona, Spain /International Center for Numerical Methods in Engineering (CIMNE)

PARTNER EXPERTS CONTRIBUTING TO THE MISSION

Host organisation experts

Prof. Dr. Cristina Jommi

Head of the Section of Structures and Environment, Department of Civil and Environmental Engineering at Politecnico di Milano (Italy)

Home organisation experts

Prof. Dr. Enrique Romero

Full Research Professor CIMNE

Professor of Geotechnical Engineering Universitat Politècnica de Catalunya UPC

Head of the Geotechnical Laboratory UPC

Other organisations experts

Dr. Laura Gonzalez-Blanco

International Centre for Numerical Methods in Engineering (CIMNE)

Department of Civil and Environmental Engineering at Universitat Politècnica de Catalunya (UPC)

Prof. Dr. Della Vecchia

Department of Civil and Environmental Engineering at Politecnico di Milano (Italy)

REPORT APPROVAL

Date	Beneficiary	Home mentor/supervisor	Host mentor/supervisor
	Hao Zeng	Enrique Romero	Cristina Jommi

Firmato digitalmente
da:CRISTINA JOMMI
Organizzazione:
POLITECNICO DI
MILANO/800579301
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Date of last signee	Visa	Visa	Visa
	Hao Zeng	Enrique Romero Morales DNI 42067387L Barcelona, 07/12/2023	