MOBILITY MISSION REPORT

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MISSION TITLE

Joining the 2nd GAS/HITEC Joint training course – Liège (Belgium) – August 28th to September 1st 2023.

DESCRIPTION

Concerned organisations

- European Joint Programme on Radioactive Waste Management (eurad)
- University of Liege (the host organisation of this training course)
- University of Lorraine (the home organisation of this applicant)

Concerned infrastructures or facilities

- Thermo-hydro related experimental facilities of geomaterials
- Multiphysics experimental facilities of geomaterials
- In situ THM and gas experimental facilities
- HADES underground research laboratory

Concerned phases

- Phase 0: The basics of thermo-hydro-mechanical processes and the basics of experimental testing of geomaterials were introduced on the first day of this training course.
- Phase 1: Constitutive modelling of thermo-hydro-mechanical processes in geomaterials and the development, validation and maintenance of numerical codes were presented.
- Phase 2: Poster sessions and pitches were held and then advanced multiphysics experimental testing and imaging of geomaterials were presented.
- Phase 3: Advanced multiphysics modelling of geomaterials and in situ THM and gas experiments were shown.
- Phase 4: A visit to the HADES Underground Research Laboratory was organised on the last day of this training course.

Themes and topics

- Theme 1: Basics of thermo-hydro-mechanical processes in geomaterials and basics of experimental testing of geomaterials
- Theme 2: Constitutive modelling of thermo-hydro-mechanical processes in geomaterials and the development, validation and maintenance of numerical codes
- Theme 3: Advanced multiphysics experimental testing and imaging of geomaterials
- Theme 4: Advanced multiphysics modelling of geomaterials including multiscale approaches and heterogeneities
- Theme 5: In situ THM and gas experiments

Keywords

thermos-hydro-mechanical processes; constitutive modelling of THM processes; multiphysics experiments; multiphysics modelling; in situ THM experiments.

EXECUTIVE SUMMARY

Geomechanics plays a significant role in the understanding of the multiphysics and multiscale processes taking place in a geological disposal facility for radioactive waste. The objective of the training course is to introduce state-of-the-art understanding, concepts and methods related to thermo-hydro-mechanical coupled processes, the physical impacts of thermal loading and the mechanistic understanding of gas migration in geomaterials. Basics of thermo-hydro-mechanical processes in geomaterials were introduced first. Many valuable methods and skills on the numerical modelling of thermo-hydro-mechanical processes were presented in detail. For example, the appropriate order of conducting thermo-hydro-mechanical modelling was shown in the presentation. Then the basics of experimental testing of geomaterials was presented. Some basic elastic and plastic theories were introduced at the beginning, and then many experimental facilities and results related to thermo-hydro-mechanical coupled processes were shown. The procedures of some geomaterial experiments were presented in detail. The constitutive modelling of thermo-hydro-mechanical processes in geomaterials was introduced on the second day, and the topic is focused on the theories of thermodynamics and poromechanics. The presentation about the development, validation and maintenance of

numerical codes introduced many helpful methods and skills to us, such as how to use Gitlab to store numerical codes and how to use Paraview to visualize simulation results. The Advanced multiphysics modelling of geomaterials including multiscale approaches and heterogeneities was then presented. A number of simulation results, such as the thermo-hydro-mechanical coupled modelling using FEM and the gas migration inside geomaterials using the FEM + Z approach were shown. Besides, the presentation of in situ THM and gas experiments introduced a very long-term barrier experiments including thermos-hydro-mechanical processes, which also introduced the procedure of monitoring long-term experimental data and showed the analysis of the experimental data.

1. MISSION BACKGROUND

1.1. R&D background

The mobility action that I am going to perform is the 2nd GAS/HITEC Joint training course – Liège (Belgium) – August 28th to September 1st 2023. Its topic is on Multiphysics and multiscale coupled processes in geomaterials with a particular focus on thermal effects and gas transfer impact on the behaviour of geomaterials. The objective of this training course is to introduce state-of-the-art understanding, concepts and methods related to thermo-hydro-mechanical coupled processes, the physical impacts of thermal loading and the mechanistic understanding of gas migration in geomaterials. Results from the EURAD project will be integrated to the course.

1.2. Mission objectives

The objective of the training course is to introduce state-of-the-art understanding, concepts and methods related to thermo-hydro-mechanical coupled processes, the physical impacts of thermal loading and the mechanistic understanding of gas migration in geomaterials. Results from the EURAD project will be integrated to the course. Half day will be dedicated to presentations by early-career researchers. A visit to the HADES Underground Research Laboratory (EURIDICE, Mol, Belgium) will be organised on the last day of the course.

1.3. Mission request

The mobility action that I am going to perform is the 2nd GAS/HITEC Joint training course – Liège (Belgium) – August 28th to September 1st 2023. Its topic is on Multiphysics and multiscale coupled processes in geomaterials with a particular focus on thermal effects and gas transfer impact on the behaviour of geomaterials. The objective of this training course is to introduce state-of-the-art understanding, concepts and methods related to thermo-hydro-mechanical coupled processes, the physical impacts of thermal loading and the mechanistic understanding of gas migration in geomaterials. Results from the EURAD project will be integrated to the course.

The topic of this training course is very interesting, which is highly related to my PHD research. It will be very helpful to improve my geomechanics knowledge and skills. Therefore, I want to join this training course.

1.4. Mission composition

Host organisation

University of Liege

Host facility

Mathematics Institute at University of Liege

Mission dates

28 August 2023 – 1 September 2023

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

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

Constitutive modelling of thermo-hydro-mechanical processes in geomaterials

Description

Constitutive modelling of thermo-hydro-mechanical processes in geomaterials was introduced by Professor Jean-Michel Pereira from ENPC during the mission. The topic was related to the theories of poromechanics proposed by Coussy. Geomaterials are a typical kind of porous materials, which is composed of skeleton (i.e. porous solid) and fluid phases under saturated or unsaturated conditions. The primary aim of poromechanics is to study the mechanical behaviors of porous materials. The underlying idea of poromechanics consists in regarding the porous materials as the superimposition of the skeleton continuum and the fluid continuum. By making some continuity hypothesis, we assume the existence of representative elementary volumes that are infinitesimal and related to all the physical phenomena at the macroscopic scale. Moreover, the physical quantities are supposed to vary continuously from one to another of these infinitesimal volumes whose connection forms the porous materials.

Usage

This presentation of “constitutive modelling of thermo-hydro-mechanical processes in geomaterials” is related to my PHD subject, and therefore it was very helpful and impressive for me. This constitutive modelling was focused on the Poromechanics proposed by Coussy. The theory in Poromechanics proposed by Coussy involves thermodynamics. Thermodynamics analyses the transformations affecting all the forms of energy involved in the evolution of a system. The natural extension of thermostatics is composed of thermodynamics. Thermostatics is restricted to reversible and infinitely slow evolutions between successive states of equilibrium of homogeneous systems. Based upon the postulate of the local state, thermodynamics extends thermostatics to any system, discrete or continuous, and to any evolution, reversible or irreversible, irrespective of its time scale.

Benefits

Poromechanics is the study of porous materials whose mechanical behaviors are considerably affected by pores and pore fluid. Poromechanics involves a large range of materials, from rocks and soils to gels and biological tissues. The primary benefit of implementing and studying poromechanics is that we can obtain a unified and systematic continuum approach of porous materials, which is very helpful to research the mechanical behaviors of porous materials.

Limitations

The constitutive modelling in this presentation is highly related to the theory of poromechanics proposed by Coussy. Some concepts in the theory of poromechanics are not easy to understand, and learners need to have comprehensive understanding of continuum mechanics before learning the theory of poromechanics.

Applicability

This presentation of "Constitutive modelling of thermo-hydro-mechanical processes in geomaterials" is related to my home context and my PHD subject since my subject is also related to poromechanics. Therefore, I can implement the constitutive modelling and theories of poromechanics in my research and use numerical codes to achieve them in simulations.

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

Development, validation and maintenance of numerical codes

Description

The development, validation and maintenance of numerical codes were presented by Professor Olaf Kolditz from UFZ during this mission. This presentation introduced many valuable methods and skills, such as the operation of the simulation program "OpenGeoSys" developed by UFZ, the usage of Gitlab to store numerical codes and the usage of Paraview to visualize simulation results, which were very impressive and helpful.

Usage

The presentation of "development, validation and maintenance of numerical codes" during the mission is related to my subject since my subject is about numerical codes and numerical simulations. Therefore, the skills and methods in this presentation are very helpful for me. For example, program "OpenGeoSys" can be used to validate simulation results, Gitlab can be used to store numerical codes and Paraview can be used to visualize simulation results.

Benefits

The major benefit of this presentation of "development, validation and maintenance of numerical codes" is that it provides a number of useful tools, such as "OpenGeoSys", Gitlab and Paraview, which are very helpful for us to develop numerical codes and visualize simulation results.

Limitations

It would be better if other useful tools for development, validation and maintenance of numerical codes were presented during the mission.

Applicability

The skills and methods in the presentation of “development, validation and maintenance of numerical codes” are related to my home context and my subject. For example, Gitlab can be used to store numerical codes and Paraview can be used to visualize simulation results.

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

Description

Usage

Benefits

Limitations

Applicability

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

Description

Usage

Benefits

Limitations

Applicability

3. MISSION FINDINGS AND CONCLUSIONS

3.1. Lessons learned and conclusions

Geomechanics plays a significant role in the understanding of the multiphysics and multiscale processes taking place in a geological disposal facility for radioactive waste. This training course was focused on introducing state-of-the-art understanding, concepts and methods related to thermo-hydro-mechanical coupled processes, the physical impacts of thermal loading and the mechanistic understanding of gas migration in geomaterials, which is very valuable and helpful. Basics of thermo-hydro-mechanical processes in geomaterials were introduced first by Professor F. Collin from ULiège. Many valuable methods and skills on the numerical modelling of thermo-hydro-mechanical processes were presented in detail. For example, the appropriate order of conducting thermo-hydro-mechanical modelling was shown in the presentation, which left a deep impression on me. Then the basics of experimental testing of geomaterials was presented by Professor Alessio Ferrari from EPFL. Some basic elastic and plastic theories were introduced at the beginning, and many experimental facilities and results related to thermo-hydro-mechanical coupled processes were shown. The procedures of some geomaterial experiments were presented in detail. The constitutive modelling of thermo-hydro-mechanical processes in geomaterials was introduced by Professor Jean-Michel Pereira from ENPC on the second day, and the topic was related to the theories of thermodynamics and poromechanics proposed by Coussy. The Advanced multiphysics modelling of geomaterials including multiscale approaches and heterogeneities was then introduced. A number of simulation results, such as the thermo-hydro-mechanical coupled modelling using FEM and the gas migration inside geomaterials using the novel FEM + Z approach were shown, which were very impressive. The presentation of in situ THM and gas experiments introduced the process of a very long-term barrier experiments involving thermo-hydro-mechanical coupled processes, which also introduced the method of monitoring long-term experimental data and showed the analysis of the experimental data. In addition, the presentation of the development, validation and maintenance of numerical codes presented by Professor Olaf Kolditz from UFZ introduced many valuable methods, such as the usage of Gitlab to store numerical codes and the usage of Paraview to visualize simulation results, which were very impressive and helpful.

3.2. Relevant findings and conclusions for home organisation

3.3. Relevant findings and conclusions for host organisation

3.4. Relevant findings and conclusions for other organisations

4. POTENTIALS FOR IMPROVEMENT OR DEVELOPMENT

4.1. Generic potentials

4.2. Potentials for home organisation

4.3. Potentials for host organisation

APPENDICES

Mission journal

Monday 28 August:

9.00 – 12.30: “Basics of thermo-hydro-mechanical processes in geomaterials” presented by Professor F. Collin from ULiège.

13.30 – 17.00: “Basics of experimental testing of geomaterials” presented by Professor Alessio Ferrari from EPFL.

Tuesday 29 August:

9.00 – 12.30: “Constitutive modelling of thermo-hydro-mechanical processes in geomaterials” presented by Professor Jean-Michel Pereira from ENPC.

13.30 – 17.00: “Development, validation and maintenance of numerical codes” presented by Professor Olaf Kolditz from UFZ.

Wednesday 30 August:

9.00 – 12.30: A visit to the geomaterials laboratory in University of Liege and then poster sessions and pitches were held.

13.30 – 17.00: “Advanced multiphysics experimental testing and imaging of geomaterials” presented by Laura Gonzalez-Blanco (UPC), Dragan Grigc (U Lorraine), Jiri Svoboda (CTU) and Andrew Wiseall (BGS).

Thursday 31 August:

9.00 – 12.30: “Advanced multiphysics modelling of geomaterials: multiscale approaches and heterogeneities” presented by Pierre Bésuelle (UGA), Frédéric Collin (ULiège), Anne-Catherine Dieudonné (TU Delft) and Sebastià Olivella (UPC).

13.30 – 17.00: “In situ THM and gas experiments” presented by Arnaud Dizier (Euridice), Emiliano Stopelli (TBC), Carlos Plua (ANDRA) and Maria Victoria Villar (CIEMAT).

Friday 1 September:

Departure to Mol at 8.00 to visit the Tabloo expositions and EURIDICE_HADES underground research laboratory.

MISSION BENEFICIARY

Yifan Xu
PHD student
Georessources at University of Lorraine
University of Lorraine, France

PARTNER EXPERTS CONTRIBUTING TO THE MISSION

Host organisation experts

- Frédéric Collin (Professor, Department of Architecture, Geology, Environment & Constructions (ArGEnCo) at University of Liege)

Home organisation experts

- Fabrice Golfier (Professor, Georessources at University of Lorraine)
- Long Cheng (Associate Professor, Georessources at University of Lorraine)

Other organisations experts

- Anne-Catherine Dieudonné (Assistant Professor, the section of Geo-Engineering at Delft University of Technology)
- Séverine Levasseur (Scientific Project Manager, ONDRAF/NIRAS Belgian Agency for Radioactive Waste and Enriched Fissile Materials)

REPORT APPROVAL

Date	Beneficiary	Home mentor/supervisor	Host mentor/supervisor
22 Sept. 2023	Yifan Xu	Fabrice Golfier	Frédéric Collin
	Yifan Xu