Laboratory of Soil Mechanics – Chair « Gaz Naturel » Petrosvibri

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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

YEARLY REPORT 2012

Soil Mechanics Laboratory - Chair "Gaz naturel" Petrosvibri

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INTRODUCTION

Several important things happened in 2012 at the LMS. First of all, the new chair "Gaz Naturel" has been integrated in our laboratory. The chair aims at extending and combining the state-of-art research capacities developed in recent years at the LMS to understand the complex geo-mechanical behaviour in CO2 geological injection. Two PhD works started in 2012 in the context of the activities of the chair.

Teaching activities have continued. A new course (Experimental Geomechanics) has been activated within the EDME program. Two PhD students, Suzanne Fauriel and John Eichenberger, concluded successfully their works. Several semester projects have been carried out at the LMS. Eight students outside the EPFL choose to spend time in our laboratory for their PhD, master or internship activities.

Research work continued well. Ten PhD works are currently running in our laboratory. I was awarded at the University of Minnesota and invited to deliver the Vardoulakis lecture 2012. The scientific life of the laboratory was also animated by the presence of several visiting professors. Efforts have been made to communicate to the general public the outcomes of our research activities by means of papers and interviews for national media.

The collaborations with our industrial partners have been strengthened. New relevant research contracts have been signed with our consolidated partners (e.g. the National Cooperative for the Disposal of Radioactive Waste, the Mont Terri consortium). Also contacts with a new important industrial partner (Chevron, USA) have been established and an important contract is about to be signed.

I would like to thank all the LMS staff for their efforts in making the 2012 a successful year.

January 2013,
Lyesse Laloui

A. TEACHING

Bachelor level courses delivered at the EPFL, 2011 – 2012

- Soil Mechanics and Groundwater Seepage
  Taught by Prof. L. Laloui and Prof. L. Vulliet in the 4th semester in the Civil Engineering Section – 87 students

Master level courses delivered at the EPFL, 2011 - 2012

- Geology for environment
  Taught by Dr. L. Tacher in the 5th and 7th semesters in the Civil Engineering Section – 49 students

Doctoral courses delivered at the EPFL, 2011 – 2012

- Experimental geomechanics
  Taught by Dr. A. Ferrari and Prof. L. Laloui in the Doctoral Program in Mechanics – 7 students

- Mechanics of porous media
  Taught by Prof. L. Laloui in the Doctoral Program in Mechanics – 3 students

Master level courses delivered at the EPFL, 2012 – 2013

- Geomechanics
  Taught by Prof. L. Laloui and Dr. A. Koliji in the 5th and 7th semesters in the Civil Engineering Section – 17 students

- Risk analysis
  Taught by Prof. L. Vulliet and Prof. P.-A. Haldi in the 3rd semester in the Civil Engineering Section – 57 students

Courses delivered outside the EPFL

- Adanced Experimental Geomechanics
  Taught by Dr. A. Ferrari during the International Workshop "Advances in Multiphysical Testing of Soils and Shales", Lausanne, September 3-5, 2012.

- Engineering geology
  Taught by Dr L. Tacher, MAS in hydrogeology, Neuchâtel University

- Geological modeling
  Taught by Dr L. Tacher, master level, Lausanne University

Appointments as Professor at other high schools

- Prof. L. Laloui, Adjunct Professor at Duke University, Durham, NC, USA

PhD students (2012)

Two PhD works were successfully completed in 2012:

- Fauriel S. (L. Laloui advisor), Title: Multiphysical modelling of soils with a focus on microbially induced calcite precipitation

- Eichenberger J, (L. Laloui advisor), Title: Geomechanical modelling of rainfall-induced landslides in partially saturated slopes

Ongoing PhD works:

- Rizzi M. (L. Laloui advisor), Title: Characterization and constitutive modelling of the behaviour of granular bentonite during thermo-hydro-mechanical processes (candidacy exam passed, in progress, to be completed in 2013)

- Seiphoori A. (L. Laloui and A. Ferrari advisors), Title: Coupled Thermo-Hydro-Mechanical-Chemical processes in active clay (candidacy exam passed, in progress, to be completed in 2013)

- Di Donna A. (L. Laloui advisor), Title: Constructive recommendations for optimized and reliable heat exchanger pile system (candidacy exam passed, in progress, to be completed in 2014)

- Mimouni T. (L. Laloui advisor), Title: Energy pile foundations: group effects and long term behaviour (candidacy exam passed, in progress, to be completed in 2014)

- Manca D. (L. Laloui advisor), Title: Gas flow propagation and related Themo-Hydro-Mechanical response of sand bentonite mixtures (candidacy exam passed, in progress, to be completed in 2014)

- Li C. (L. Laloui advisor), Title: CO2 sequestration (candidacy exam passed, in progress, to be completed in 2014)

- Favero V. (L. Laloui and A. Ferrari advisors), Title: Thermo-Hydro-Mechanical characterization of shales (in progress, to be completed in 2015)

- Gonzalez Maceda S. (L. Laloui advisor), Title: Experimental investigation on the mechanical behaviour of reservoir materials as a result of CO2 injection and storage (in progress, to be completed in 2015)

- Parisio F. (L. Laloui advisor), Title: Hydro-mechanical damage model for anisotropic shales (Opalinus Clay): Constitutive modelling and numerical implementation (in progress, to be completed in 2015)

- Aili A. (L. Laloui advisor), Title: Numerical modeling of landslides (in progress, to be completed in 2016)

Master students (2012)

- Baudet G., UNIGE, Title: Assessment of soil collapsibility. Completed in June 2012

- Pigeon M., UNIGE, Title: Effects of wetting and drying cycles on landslide activity. Completed in June 2012

EPFL semester projects

- Kirci Mervegül - Analytical Analysis of CO2 Geological Sequestration
- Serge Goumas - Experimental investigation on the effect of temperature on clay-concrete interface
- Olivia Kuenzli - Microstructural investigations in geomechaincs
- Mélanie Baehler - Thermo-piles behaviour with underground water flow
- Baddour Soumaya - Review of interfacial tension tests of CO2-brine-geomaterial system
- Amchikak Marwan - Hydromechanical behaviour of geo-materials during CO2 sequestration process
- Goekok Timur - Technology and environmental impact of CO2 sequestration
- Rabenatoandro Elia - Behaviour of Geo-materials during unconventional gas exploration and CO2 sequestration
- Olivia Kuenzli - Estimation of hydraulic characteristics of a sand/bentonite mixture
- Davide Wüthrich - Estimation of water retention properties of a sand/bentonite mixture

Students outside the EPFL

- Annalisa Galeandro, PhD student at Politecnico di Bari, spent 1 month at the LMS
- Bonifetto Giovanni, Università Degli Studi di Padova, Master thesis "F.E.M. analysys of the coupled Thermo-Hydro-Mechanical behaviour of an elasto-plastic porous media with fluid phase change", September 2012 – February 2013
- Kusumawardani Rini, Gadjah Mada University Indonesia, visiting PhD student "Effect of matric suction of the liquefaction potential of soils", September 2012 - May 2013
- Lingxi Lei, Ecole Nationale des Ponts et Chaussées, Internship: "Thermo-mechanical behaviour of a piled raft with energy piles", April-July 2012
- Laurence Pouthas, Ecole Nationale des Ponts et Chaussées, Internship: "Experimental study of the hydro-mechanical behaviour of sand-bentonite mixtures", April-July 2012
- Swann Veyret, Ecole Nationale des Ponts et Chaussées, Internship: "Experimental analysis of a shale in the context of nuclear waste disposal", April-July 2012
- Paul Barès, École des Ponts ParisTech, Internship: "The semi-analytical solution of CO2 injection into geological formation", October 2012-January 2013
- Bénédicte Chapot, Institut polytechnique de Grenoble, Internship: "Volume change behaviour and retention behaviour of Mx80 bentonite", June-August, 2012

Apprentices

- 4 apprentices have been trained at the LMS in 2012: Julien Wahid Nocera and Bastien Pasquier, laboratory assistant; Jessica Garcia, commercial employee; Clémence Birbaum, office employee.

B. Publications and presentations (2012)

Journal papers

- S. Salager, B. François, M. Nuth and L. Laloui. Constitutive analysis of the mechanical anisotropy of Opalinus Clay, in Acta Geotechnica -Springer Verlag-, 2012. (http://infoscience.epfl.ch/record/180949)

- H. Péron, L. Laloui, l. hu and T. Hueckel. Formation of drying crack patterns in soils: a deterministic approach, in Acta Geotechnica -Springer Verlag-, 2012. (http://infoscience.epfl.ch/record/180187)

- S. Fauriel and L. Laloui. A bio-chemo-hydro-mechanical model for microbially induced calcite precipitation in soils, in Computer and Geotechnics, vol. 46, p. 104–120, 2012. (http://infoscience.epfl.ch/record/177606)

- L. Hu, H. Péron, T. Hueckel and L. Laloui. Desiccation shrinkage of non-clayey soils: a numerical study,accepted in International Journal for Numerical and Analytical Methods in Geomechanics, 2012. (http://infoscience.epfl.ch/record/176496)

- L. Laloui and A. Di Donna. Response to Comment on "Understanding the Thermo-Mechanical Behaviour of Energy Piles", in ICE Civil engineering, vol. 165, num. CE1, 2012. (http://infoscience.epfl.ch/record/175380)

- Z. Boukria, P. Perrotin, A. Bennani, F. Dupray and A. Limam. Structural monitoring: identification and location of an impact on a structurally dissipating rock-shed structure using the inverse method, in European Journal Of Environmental And Civil Engineering, vol. 16, p. 20-42, 2012. (http://infoscience.epfl.ch/record/177931)

- B. Matti, L. Tacher and S. Commend. Modelling the efficiency of a drainage gallery work for a large landslide with respect to hydrogeological heterogeneity, in Canadian Geotechnical Journal, vol. 49, num. 8, p. 968-985, 2012. (http://infoscience.epfl.ch/record/180281)

- A. Binod, S. Kenichi, B.-W. Peter J., a. Tony and L. Laloui. Thermo-mechanical Behaviour of Energy Piles, in Geotechnique-London, vol. 62, num. 6, p. 503–519, 2012. (http://infoscience.epfl.ch/record/167354)

- D. Fäh, J. R. Moore, J. Burjanek, I. Iosifescu, L. Dalguer, F. Dupray, …, A. Ferrari, L. Laloui, et al. (2011), Coupled seismogenic geohazards in Alpine regions, in Bollettino di Geofisica Teorica ed Applicata, vol. 53, num. 4, p. 485-508, 2012. (http://infoscience.epfl.ch/record/183067)

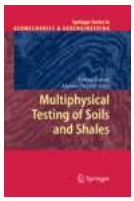
- S. Salager, M. Nuth, A. Ferrari and L. Laloui. An investigation into the water retention behaviour of deformable soils, accepted in Canadian Geotechnical Journal (in press). (http://infoscience.epfl.ch/record/183002)

- P. J. Witteveen, A. Ferrari and L. Laloui. An experimental and constitutive investigation on the chemo-mechanical behaviour of a clay, accepted in Geotechnique –London (in press). (http://infoscience.epfl.ch/record/181824)

- Hu L.B., Péron H., Hueckel T., Laloui L. "Desiccation shrinkage of non-clayey soils: multi-physics mechanisms and a microstructural model". International Journal for Numerical and Analytical Methods in Geomechanics (in press) (http://infoscience/record/176495?ln=fr)

Books

- L. Laloui and A. Ferrari (Eds.) Multiphysical Testing of Soils and Shales. Springer Series in Geomechanics and Geoengineering, 2012. (http://infoscience.epfl.ch/record/180950)



Chapters in books

- A. Ferrari and L. Laloui. Advances in the Testing of the Hydro-mechanical Behaviour of Shales, in Multiphysical Testing of Soils and Shales, Springer Series in Geomechanics and Geoengineering, p. 57-68, 2012. (http://infoscience.epfl.ch/record/181063)
- B. François and L. Laloui. Modelling the thermo-plasticity of unsaturated soils, in Constitutive Modeling of Geomaterials, Springer Series in Geomechanics and Geoengineering, p. 535-540. (http://infoscience.epfl.ch/record/181062)
- Dupray F., François B., Laloui L. "Numerical modeling of a real-scale nuclear waste engineering barrier experiment"; Chapter of the book "Bytes and Science", pp. 71-84, Eds. G. Zavatise & D. Boso, CIMNE, 2012. ISBN: 978-84-940243-2-0 (http://infoscience/record/183276?ln=fr)
- Sanavia L., Luison L., Passarotto M., Laloui L. "Finite element modeling of thermo-elasto-plastic multiphase porous material"; Chapter of the book "Bytes and Science", pp. 99-118, Eds. G. Zavatise & D. Boso, CIMNE, 2012. ISBN: 978-84-940243-2-0 (http://infoscience/record/124852?ln=fr)

Papers in Proceedings

- A. Ferrari, J. Eichenberger, J. Fern, P. Ebeling and L. Laloui. Experimental and numerical analysis of an unsaturated volcanic ash deposit for the establishment of an early warning system in a quarry in Costa Rica. Geocongress 2012: State of the Art and Practice in Geotechnical Engineering, Oakland, 2012. (http://infoscience.epfl.ch/record/175948)
- L. Laloui, A. Ferrari and S. Salager. Testing the Thermo-Hydro-Mechanical Behaviour of a Shale. 3rd EAGE Shale Workshop, Barcelona, 2012. (http://infoscience.epfl.ch/record/174656)
- A. Koliji, T. Bussard, A. Wohnlich and J. Zhao. Abutment stability assessment of the Hongrin arch dam using 3D distinct element method. Published in: Harmonising Rock Engineering and the Environment. Taylor & Francis Group, 2012 (http://infoscience.epfl.ch/record/170483)

Other publications

- A. Di Donna and L. Laloui. Pieux énergétiques, in TRACE, p. 6-10, 2012. (http://infoscience.epfl.ch/record/174934)

Course notes

- Tacher L. "*Géologie de l'environnement*". New course notes – Master level, EPFL, 100 pages

Important Presentations

- L. Laloui "Geomechanics and Shales". 3rd UNECE Gas Centre Industry Forum 2012 "International experience with unconventional gas resources", October 2012
- L. Laloui "Hydro-mechanically Coupled Processes in Rainfall-induced Landslide Modelling" Warren Lecture Series at the University of Minnesota, October 26
- A. Ferrari. Advances in the Testing of the Hydro-mechanical Behaviour of Shales. Theme lecture at the International Workshop "Advances in Multiphysical Testing of Soils and Shales", Lausanne, September 3-5, 2012.
- L. Tacher, "Deep geothermics", Fribourg University, November 15, 2012, conference.
- L. Tacher L., "Géothermie profonde, le projet Eclépens", Journée romande de géothermie, Yverdon, November 27, 2012, conference

Key publications
We were active in various strategic fields like (for each field a representative publication is cited):

- **Environmental geomechanics:**
  S. Fauriel and L. Laloui. A bio-chemo-hydro-mechanical model for microbially induced calcite precipitation in soils, in Computer and Geotechnics, vol. 46, p. 104–120, 2012. (http://infoscience.epfl.ch/record/177606)
- **Energy geomechanics:**
  L. Laloui and A. Ferrari (Eds.) Multiphysical Testing of Soils and Shales. Springer Series in Geomechanics and Geoengineering, 2012. (http://infoscience.epfl.ch/record/180950)
- **Nuclear waste storage:**
  S. Salager, B. François, M. Nuth and L. Laloui. Constitutive analysis of the mechanical anisotropy of Opalinus Clay, in Acta Geotechnica -Springer Verlag-, 2012. (http://infoscience.epfl.ch/record/180949)

Media

- "Des villes à l'assaut des profondeurs" interview to Dr. Laurent Tacher (Le temps, 14.01.2013)
- "Nos études de stockage du CO2 devraient limiter la micro-séismicité" interview of Prof. Laloui by the Swiss Engineering Magazine (December 2012).
- Dr. Ferrari was invited to talk about the Swiss concept for nuclear waste disposals (RSI, October 10, 2012) (http://reteuno.rsi.ch/modem/welcome.cfm?IDc=43321&IDd=1349737200)
- An article published in Tracés about energy piles by A. Di Donna and L. Laloui (15 February 2012).
- Prof. Laloui gave a public conference about nuclear waste storage in Sion on 19 January 2012 (http://www.mediatheque.ch/valais/podcast-confrence-lyesse-laloui-dchets-suisses.html)
- Extracting the heat from the ground (La Regione Ticino, 2.2.2012)
- Prof. Laloui was interviewed about nuclear waste storage solution investigated in Switzerland (19/01/2012)

C. Researches (2012)

New major research projects

Title: Triggering of Rapid Mass Movements in Steep Terrains
PI/Project Manager: L. Laloui and A. Ferrari
Sponsor: Competence Center Environment and Sustainability (CCES)
Period: March 2012 - February 2014

Title: GEOTHERM2 Geothermal Reservoir Processes: Towards the implementation of research into the creation and sustainable use of Enhanced Geothermal Systems
PI/Project Manager: L. Laloui and L.Tacher
Sponsor: Competence Center Environment and Sustainability (CCES)

Title: Modélisation de la sensibilité des systèmes hydrogéologiques de types alpins et périalpins aux changements climatiques.
PI/Project Manager: L. Tacher
Sponsor: Office Fédéral de l'Environnement (OFEV/BAFU) - Division Hydrologie - Section Hydrogéologie

Title: Experimental analysis of gas and water transport of Opalinus Clay
PI/Project Manager: L. Laloui and A. Ferrari
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)

Title: THM modeling of the FE experiment
PI/Project Manager: L. Laloui and A. Ferrari
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)

Title: Sensitivity of THM evolution of the SF/HLW near-field after waste emplacement
PI/Project Manager: L. Laloui
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)

Title: Evaluation of an advanced geomechanical model for the simulation of Opalinus Clay.
PI/Project Manager: L. Laloui
Sponsor: Swiss Federal office of topography - Swisstopo

Title: Geo-mechanical investigations of bio-improved soils.
PI/Project Manager: L. Laloui and Rizlan Bernier-Latmani
Sponsor: National Science Foundation.

Research prizes and awards

Prof. L. Laloui, 2012 Vardoulakis Lecture - University of Minnesota

Prof. L. LaLoui, MTS Distinguished Visiting Professorship, USA

Invited professors or academic hosts

- Prof. Wu Wei from Univ. für Bodenkultur, Vienna (January 2012)
- Prof. Mark Randolph from University of Western Australia (3 months)
- Prof. Oka from University of Tokyo (Japan), July 2012
- Mr. Hiromasa Iwai from University of Kyoto (Japan) (3 weeks)
- Prof. Antonio Bobet, from Purdue University (USA), November 2012
- Prof. Tomasz Hueckel from Duke University USA (1 month)
- Dr Dr Hossein Nowamooz from INSA-Strasbourg (1 month)

Organization of workshops or other international events at EPFL or outside

- The international workshop "Advances in Multiphysical Testing of Soils and Shales", organized by Prof. Laloui and Dr. Ferrari under the auspices of the International Society for Soil Mechanics and Geotechnical Engineering, was held at the EPFL between 3-5 September 2012 (http://amtss.epfl.ch/) (80 participants)

- A one-day workshop titled "CO2 State of Expertise" was organised by Prof. Laloui on 14.06.2012 at the EPFL.

- A one-day session organized by Lyesse Laloui on "Geomechanics for Energy Production" on October 3rd, 2012, in the context of the 23rd ALERT Geomaterials Workshop, Aussois, France (220 participants)

- The 5th Low Carbon Energy University Alliance workshop, gathering groups from the Massachusetts Institute of Technology (MIT), Cambridge University, Tsinghua University and EPFL, was organized by the LMS on the EPFL campus on November 16, 2012 (30 participants)

D. Valorization, collaborations & networks (2012)

New collaborations within ENAC, EPFL, EPF domain, other universities, governmental agencies, industry

Partners	Topic/Context/kind of collaboration
Chevron	Experimental characterization of gas shales
SHARC international consortium : CISRO Perth	Thermo-hydro-mechanical behaviour of shales/Industrial project

Innovative products, patents, spin-offs/startups

- Commercial software (ThermoPile) for the design of geothermal foundations (http://lms.epfl.ch/thermopile)

LMS seminars, 2012 series

Date: 14.05.2012
Title: Oshore geotechnical engineering in deepwater soft sediments
Speaker: Mark Randolph, Professor Professor of Civil Engineering in the Centre for Offshore Foundation Systems at the University of Western Australia

Date:17.05.2012
Title: Introduction to CCS monitoring
Speaker: Lukas Schaerer

Date: 18.06.2012
Title: Contribution of advanced geomechanical modelling to nuclear waste storage design
Speaker: Fabrice Dupray, post-doc researcher at LMS EPFL

Date: 03.07.2012
Title: A Chemo-Thermo-Mechanically Coupled Behaviour during Gas Hydrate Dissociation and its Numerical Analysis
Speaker: Prof. OKA, Kyoto University

Date: 06.07.2012
Title: Multiphysical modelling of soils with a focus on microbially induced calcite precipitation
Speaker: Suzanne Fauriel, Ph.D student at LMS EPFL

Date: 07.09.2012
Title: Preliminary concept for a carbon storage test site in Switzerland
Speaker: Markus Häring, Geo Explorers Ltd

Date: 04.10.2012
Title: Hydromechanical analyses of partially saturated slopes for the establishment of landslide early warning thresholds
Speaker : John Eichenberger, Ph.D student at LMS EPFL

Date: 08.11.2012
Title: Advances in the geotechnical design of energy pile foundations
Speaker: Alice Di Donna, Ph.D student at LMS EPFL

Date: 09.11. 2012
Title: Large deformation finite element modeling (LDFEM) of offshore foundation installation/penetration
Speaker: Mr Lars Andersen, director of the Norwegian Geotechnical Institute (NGI)

Date: 29.11. 2012, Civil engineering seminar series
Title: Propagation of Frictional Discontinuities
Speaker: Prof. Antonio Bobet, Purdue University

Date: 11.12. 2012
Title: Advances in characterization of water retention behaviour of highly expansive clays
Speaker: Ali Seiphoori, Ph.D student at LMS EPFL

Presentation of the laboratory to companies

- EGO (Erdgas Ostschweiz), August 18
- Petrosvibri /gaznat, September 12

E. Administrative efforts (2012)

Participation on boards, committees at EPFL (e.g. faculty search committees, promotion etc.)

Name	Board / committee, etc.	EPFL / External	Role in funding allocation yes/no
Prof. L. Laloui	EPFL Research Committee	EPFL	No
Prof. L. Laloui	ENAC Research Committee	EPFL	No
Prof. L. Laloui	Search committee for professor position	External (Uni. Grenoble)	No
Prof. L. Vulliet	Member, Foundation Council "Les Bois Chamblard"	EPFL	No
Prof. L. Vulliet	Member, Foundation Council PPUR	EPFL	No

Leadership responsibilities (e.g. sections, institutes, doctoral school)

Name	Board / committee, etc.	EPFL / External	Role in funding allocation yes/no
Prof. L. Laloui	Director of the doctoral program in Mechanics (until March 2012)	EPFL	Yes
Prof. L. Laloui	Director of the Civil Engineering Section	EPFL	Yes

Faculty or professional societies outside school including the EPF domain

Name	Board / committee, etc.	EPFL / External	Role in funding allocation yes/no
Prof. L. Laloui	Member of the Board of Directors	External	Yes
Prof. L. Laloui	Core member of the TC101 "Laboratory Stress Strain Strength - Testing of Geomaterials" of the International Society for Soil Mechanics and Geotechnical Engineering	External	No
Dr L. Tacher	SWISSTOPO, 3D geological modeling commission	External	No
Prof. L. Vulliet	Vice-President, Swiss Society of Engineers and Architects	External	No

Editorial work for journals or books

Name	Board / committee, etc.	EPFL / External	Role in funding allocation yes/no
Prof. L. Laloui	Book Series Editor Geomechanics and Geomaterials – Hermes science publishing limited (WILEY-ISTE, London)	External	No
Prof. L. Laloui	Member of editorial board of the following journals: - Acta Geotechnica - Chinese Journal of Geotechnical Engineering - Computer and Geotechnics	External	No

	- European Journal of Environmental and Civil Engineering - Géotechnique		
Dr A. Ferrari	Panel for the Géotechnique journal	External	No
Prof. L. Vulliet	Adjunct Editor-in-Chief, European Journal of Environmental and Civil Engineering, Hermes	External	No
Prof. Laloui and Dr A. Ferrari	Editors for the Springer Series in Geomechanics and Geoengineering, 2012	External	No

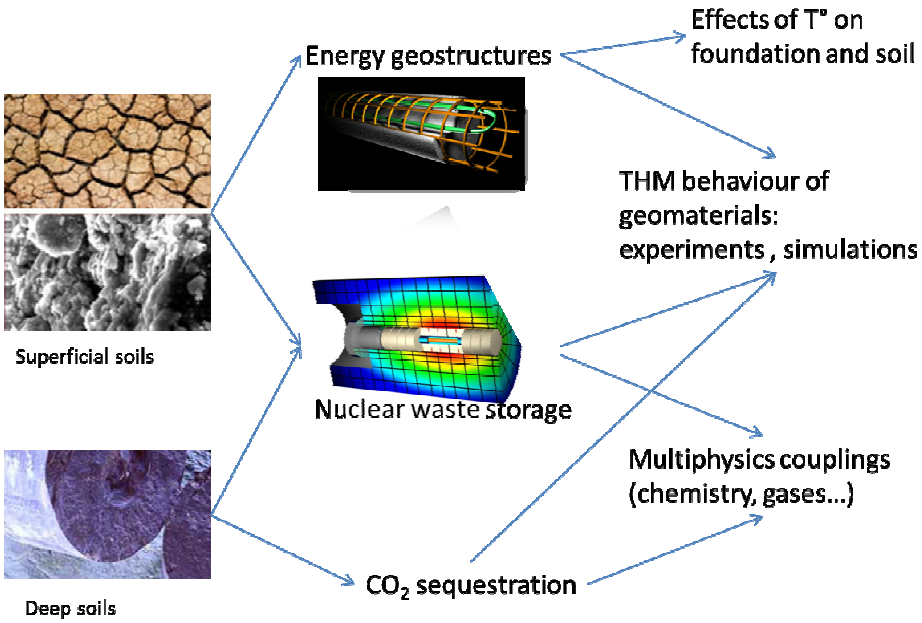
F. Key directions for the lab and plans for the future

Since January 2012, and the new appointment of Prof. L. Laloui, the Laboratory of Soil Mechanics is extending its activities to include Geo-engineering and CO2 storage. The LMS activities are now designed to promote engineering solutions in the field of the alternative sources of energy, including nuclear waste disposal, geothermal energy and CO sequestration.

The LMS activities will continue to cover education, research and technology transfer in the large field of Geomechanics. My vision aims at contributing to a sustainable development of our built and natural environment by addressing selected key questions with the highest possible academic standard, within transdisciplinary internal and international collaborations and through contacts with industry with long-term research focuses.

The research activities will focus on problems involving a variable environment and new and advances in existing technologies of energy production. These two areas: environment and energy are expected to dominate technological agenda for forthcoming years. The reason for that is two-fold: first there is world-wide crisis of environment endangerment related to the geosphere: soil and groundwater pollution by accidental spills, CO2 emission driven reduction of fossil fuel usage and/or inadequate isolation of pollutants, and second there is a host of new sources of energy related to geosphere. In both cases, there is an emerging new fundamental research concerning the effects of chemical, thermal and biological variables on mechanical properties and mechanical variables of soils and shales, and vice versa the effects of mechanical variables as stress, strain, damage affecting chemical and biological, physical or thermal processes and properties that require a multi-disciplinary approach. The levels of these couplings are multiple and often poorly recognized.

Especially with nascent technologies related to the energy production it is rational to include the environmental considerations early in the phase of development rather than seek remedies post factum, or after the damage has been induced. This clearly may refer to production of natural gas from shales, the techniques of hydraulic and chemical fracturing, CO2 sequestration technologies, nuclear waste isolation (long and short term), heat and fuel storage in the underground and under structures, geothermal fluid energy, energy from methane hydrates, oil production from high temperature, high pressure deposits, and many others. Effects of chemical and biological pollution on isolation geo-structures constitute a separate class of problems. Finally, technologies of chemical and biological improvement of mechanical and hydraulic quality of soils and shales involve knowledge and methods based on the same principles. The figure below indicates the link between some of those topics.



The intrinsic nature of coupling of chemical, biological, thermal and mechanical properties, variables and fields distinguishes the related problems from those in classical geomechanics. It is believed that continuing and establishing new research activities dedicated to these issues of Energy and Environmental Geomechanics is a great opportunity for LMS and ENAC.

Some examples of activities for the coming years would be in the following areas:

Geothermal Energy

Advanced theoretical, experimental and computational knowledge was developed in the recent years at the LMS for assessing and predicting the behaviour of geomaterials subjected to changes in temperature and at different states of saturation. This state of the art expertise has been mainly applied in the fields of underground nuclear waste storage as well as the geothermal use of the building foundations. The research activities are now devoted to (i) the enhancement of the understanding of the thermo-hydro-chemical-mechanical behaviour of shales (including gas shales and host rock formations for waste disposal) and bentonites and the prediction of their long term behaviour, and (ii) the development of computational design tools for geo-energy structures.

Several highly sophisticated and unique experimental tools were developed at the lab in the recent three years with an investment of about 1000.- Kfrs (from FNS, EPFL and industry). It is planned to develop the knowledge and the understanding on the behaviour of soils and shales in the light of the extreme loading conditions that the equipment allows. There is a huge room for fundamental research on the running of coupled thermo (until 150°C) –hydro (until 400 MPa of suction)-mechanical (until 30 MPa) testing as well as on the behaviour of the materials in such conditions. I would like also to extend the laboratory facilities serving the research to micro scale observations (i.e. neutron tomography) for a better insight on the fundamental physical mechanism governing the thermo-hydro-mechanical behaviour of the involved materials.

Also an effort will be developed in the area of deep geothermal energy.

Environmental Geomechanics

Efforts will be devoted to maintain the current research activities in the area of multi-physical coupling processes in soils at leading edge of knowledge with expertise in the fundamentals of Soil Mechanics. The developments of early warning systems for large landslides as well as the climate change effects on the soil stability constitute the major applications.

CO2 storage

The financial support of Petrosvibri to the Chair allows the development of a deep knowledge in the area of CO2 storage. Experimental facilities devoted to this topic are developed. Also computational tools at the basin scale will be introduced for the analysis of the various scenarios.

These objectives would help the ENAC to strengthen its research and teaching profile and to play an important national and an international role in the most advanced and strategically important areas of research in Energy and Environmental Geomechanics.

Prof. L. Laloui
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