Laboratory of Soil Mechanics

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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

YEARLY REPORT 2011

Laboratory of Soil Mechanics

A. TEACHING

Bachelor level courses delivered at the EPFL, 2010 – 2011

- **Soil Mechanics and Groundwater Seepage**
  Taught by Prof. L. Laloui and Prof. L. Vulliet in the 3th semester in the Civil Engineering Section – 112 students

Master level courses delivered at the EPFL, 2010 - 2011

- **Geomechanics**
  Taught by Prof. L. Laloui in the 5th or 7th semester in the Civil Engineering Section – 10 students

- **Risk analysis**
  Taught by Prof. L. Vulliet and Dr. P.-A. Haldi in the 5th or 7th semester in the Civil Engineering Section – 63 students

MAS level courses delivered at the EPFL, 2010 - 2011

- **Soil Mechanics**
  Taught by Prof. L. Vulliet and Dr. A. Ferrari in the Master of Advanced studies (MAS) on Tunneling – 15 students

Doctoral courses delivered at the EPFL, 2010 – 2011

- **Mechanics of Porous Media**
  Taught by Prof. L. Laloui in the Doctoral Program in Mechanics – 8 students

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 – 78 students

Master level courses delivered at the EPFL, 2011 – 2012

- **Geomechanics**
  Taught by Prof. L. Laloui in the 5th or 7th semester in the Civil Engineering Section – 10 students

- **Risk analysis**
  Taught by Prof. L. Vulliet and Prof. P.-A. Haldi in the 5th or 7th semester in the Civil Engineering Section – 57 students

- **Geology for construction**
  Taught by Dr. L. Tacher in the 1st semester or 3rd semester in the Civil Engineering Section – 41 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.

Courses delivered outside the EPFL

- **Risk management**
  Taught by Prof. L. Vulliet, Alert PhD course, Aussois, France

Appointments as Professor at other high schools

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

PhD students (2011)

- Fauriel S. (L. Laloui advisor), Title: Advanced modelling of the behaviour of clays: Time-dependency, chemical reactions and bacterial activities (in progress, to be completed in 2012)
- Rizzi M. (L. Laloui advisor), Title: Characterization and constitutive modelling of the behaviour of granular bentonite during thermo-hydro-mechanical processes (in progress, to be completed in 2012)
- Eichenberger J, (L. Laloui advisor), Title: Computational methods for slope stability analysis (in progress, to be completed in 2012)
- Di Donna A. (L. Laloui advisor), Title: Constructive recommendations for optimized and reliable heat exchanger pile system (in progress, to be completed in 2013)
- Seiphoori A. (L. Laloui advisor), Title: Coupled Thermo-Hydro-Mechanical-Chemical processes in active clay (in progress, to be completed in 2013)
- Manca D, (L. Laloui advisor), Title: Gas flow propagation and related Themo-Hydro-Mechanical response of sand bentonite mixtures (in progress, to be completed in 2014)
- Mimouni T. (L. Laloui advisor), Title: Energy pile foundations: group effects and long term behaviou (in progress, to be completed in 2014)
- Witteveen P. (L. Laloui, A. Ferrari advisors), Title: Thermo-Hydro-Mechanical characterization of shales (in progress, to be completed in 2014)
- Li C. (L. Laloui advisor), Title: CO2 sequestration (in progress, to be completed in 2014)
- Cornelia Broennimann (A. Parriaux & L. Tacher advisors), “Effect of Groundwater on Landslide Triggering“ PhD dissertation held on December 2011

Master students (2011)

- Fern J., EPFL Ms. Student, Title: Establishment of an early-warning system in the Llano Grande Mine (Costa Rica), concluded in June 2011
- Witteveen P., EPFL Ms. Student, Title: Chemo-osmotic processes as a part of the constitutive laws of clays, concluded in June 2011
- Vernay D., EPFL Ms. Student, Title: Energy pile foundations as sustainable source of energy: long-term effects induced by cyclic thermal loading, concluded in June 2011

- Nidegger V., EPFL Ms. Student, Title: Design of an energy pile foundation: group effects and long time behavior, concluded in June 2011

- Chao L., EPFL Ms. Student, Title: Study on the possible seismically triggered landslides in Matter Valley, concluded in June 2011

- Lamure E., ENTPE Lyon student, Title : Le modele ACMEG : etude theorique des lois constitutives et de leur implementation - Application à la modélisation numérique d'un ouvrage souterrain de stockage des déchets nucléaires, concluded in August 2011

- Baer JR., EC Nantes Ms student, Title: Validation of the fluid flow propagation model in sand-bentonite mixture, concluded in June 2011

- Fatnassi I., ENIT Tunis Ms student, Title: Study of energy geostructure for thermal regulation of road infrastructure, concluded in June 2011

- Baudet G., UNIGE Ms student, Title: Assessment of soil collapsibility, to be completed in June 2012

- Pigeon M., UNIGE Ms student, Title: Effects of wetting and drying cycles on landslide activity, to be completed in June 2012

Master students trip (2011)

The 5th year civil engineering students trip was organized to Shanghai this year. Prof. Laloui organized and leaded this trip from September 4th to September 9th during which visits of construction sites were organized.

Bachelor students

- Y. Zhao, Ecole Nationale des Ponts et Chaussées, "Experimental analysis of a shale in the context of nuclear waste disposal", 18.04-08.07.2011.

- R. M. Schudel, Ecole Nationale des Ponts et Chaussées,18.04-08.07.2011, 1ère année stage "Experimental study of the hydro-mechanical behaviour of bentonite".

B. Publications and presentations (2011)

Journal papers

- L. Laloui, A. Koliji and A. Ferrari. Review of the book 'Unsaturated soils: A fundamental interpretation of soil behaviour' by E. J. Murray and V. Sivakumar, in Geotechnique -London-, 2011. (http://infoscience.epfl.ch/record/168284)
- R. F. Obrzud, A. Truty and L. Vulliet. Numerical modeling and neural networks to identify model parameters from piezocone tests: I. FEM analysis of penetration in two-phase continuum, in International Journal For Numerical And Analytical Methods In Geomechanics, vol. 35, p. 1703-1730, 2011. (http://infoscience.epfl.ch/record/170801)
- R. F. Obrzud, A. Truty and L. Vulliet. Numerical modeling and neural networks to identify model parameters from piezocone tests: II. Multi-parameter identification from piezocone data, in International Journal for Numerical and Analytical Methods in Geomechanics, 2011. (http://infoscience.epfl.ch/record/164560)
- A. Koliji, T. Bussard, T. Wohnlich and T. Leroy. Abutment stability assessment at the Hongrin arch dam, in The international Journal on Hydropower & Dams, vol. 18, num. 3, p. 56-61, 2011. (http://infoscience.epfl.ch/record/170485)
- F. Dupray, B. François and L. Laloui. Analysis of the FEBEX multi-barrier system including thermo-plasticity of unsaturated bentonite, accepted in International Journal for Numerical and Analytical Methods in Geomechanics, 2011. (http://infoscience.epfl.ch/record/168627)
- S. Salager, M. Rizzi and L. Laloui. An Innovative Device for Determining the Soil Water Retention Curve Under High Suction at Different Temperatures, in Acta Geotechnica -Springer Verlag-, vol. 6, num. 3, p. 135-142, 2011. (http://infoscience.epfl.ch/record/167567)
- A. Binod, S. Kenichi, B.-W. Peter J., a. Tony and L. Laloui. Thermo-mechanical Behaviour of Energy Piles, in Geotechnique -London-, 2011. (http://infoscience.epfl.ch/record/167354)
- L. Laloui and A. Di Donna. Understanding the Thermo-Mechanical Behaviour of Energy Piles, in Civil Engineering, vol. 164, p. 184–191, 2011. (http://infoscience.epfl.ch/record/167204)
- L. Laloui and A. Di Donna. Advances in energy piles analysis. Swiss Geotechnical Society, 2011.(http://infoscience.epfl.ch/record/167173)
- A. Seiphoori, S. M. Haeri and M. Karimi. Three-dimensional nonlinear seismic analysis of concrete faced rockfill dams subjected to scattered P, SV, and SH waves considering the dam-foundation interaction effects, in Soil Dynamics and Earthquake Engineering -Southampton-, vol. 31, num. 5-6, p. 792-804, 2011. (http://infoscience.epfl.ch/record/163768)
- T. Hueckel, B. François and L. Laloui. Temperature-dependent internal friction of clay in a cylindrical heat source problem, in Geotechnique -London-, vol. 61, num. 10, p. 831-844, 2011. (http://infoscience.epfl.ch/record/163454)
- A. Tarantino, D. Gallipoli, C. E. Augarde, V. De Gennaro and R. Gomez et al. Benchmark of experimental techniques for measuring and controlling suction, in Geotechnique -London-, vol. 61, num. 4, p. 303–312, 2011. (http://infoscience.epfl.ch/record/163244)
- F. D'onza, D. Gallipoli, S. Wheeler, F. F. Casini and J. Vaunat et al. Benchmarking of constitutive models for unsaturated soils, in Geotechnique -London-, vol. 61, num. 4, p. 283–302, 2011. (http://infoscience.epfl.ch/record/163243)
- C. Knellwolf, H. Péron and L. Laloui. Geotechnical analysis of heat exchanger piles, in Journal of Geotechnical and Geoenvironmental Engineering, vol. 137, num. 10, p. 890-902, 2011. (http://infoscience.epfl.ch/record/163018)
- A. Ferrari, A. Ledesma, D. González and J. Corominas. Effects of the foot evolution on the behaviour of slow-moving landslides, in Engineering Geology -Amsterdam-, vol. 117, p. 217-228, 2011. (http://infoscience.epfl.ch/record/162296)
- S. Plumey, A. Muttoni, L. Vulliet and V. Labiouse. Analytical and numerical analyses of the load-bearing capacity of retaining walls laterally supported at both ends, in International

Journal for numerical and analytical methods in geomechanics, vol. 35, num. 9, p. 1019-1033, 2011. (http://infoscience.epfl.ch/record/150407)

- 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 e Applicata, accepted

Papers in Proceedings

- S. Fauriel and L. Laloui. Biogrout propagation in soils. international workshop on Multiscale and Multiphysics Processes in Geomechanics, Stanford, USA, 2011. Published in: Multiscale and Multiphysics Processes in Geomechanics, vol. 1, p. 77-80. Borja, Ronaldo (ed.) Berlin Heidelberg: Springer-Verlag, 2011. (http://infoscience.epfl.ch/record/170513)

- S. Fauriel and L. Laloui. Modelling transport of biogrout in soils. International Symposium on Deformation Characteristics of Geomaterials, Seoul, Korea, 2011. Published in: Deformation Characteristics of Geomaterials, vol. 2, p. 801-807. (http://infoscience.epfl.ch/record/168626)

- A. Seiphoori, A. Ferrari and L. Laloui. An advanced calibration process for a thermo-hydro-mechanical triaxial system. International Symposium on Deformation Characteristics of Geomaterials, Séoul, 2011. Published in: Deformation Characteristics of Geomaterials, vol. 1, p. 396-403. (http://infoscience.epfl.ch/record/168576)

- F. Dupray, B. François and L. Laloui. Numerical analysis of a near-to-real scale in-situ experiment of a deep geological repository. 2nd International Symposium on Computational Geomechanics, Dubrovnik, Croatia, 2011. (http://infoscience.epfl.ch/record/165430)

- S. Fauriel and L. Laloui. Modelling of biogrout propagation in soils. 2nd International Symposium on Computationel Geomechanics, Dubrovnik, Croatia, 2011. (http://infoscience.epfl.ch/record/165429)

- J. Eichenberger, M. Nuth and L. Laloui. Hydromechanically coupled analysis of transient phenomena in a rainfall-induced landslide. 2nd International Symposium on Computationel Geomechanics, Dubrovnik, Croatia, 2011. (http://infoscience.epfl.ch/record/165427)

- T. Hueckel, B. François and L. Laloui. Thermal variability of the internal friction in clay in a cylindrical thermo-mechanical problem. Com-Geo, Dubrovnic, Croatia, 2011. (http://infoscience.epfl.ch/record/165426)

- A. Ferrari and L. Laloui. Coupled hydrogeological and geomechanical modelling for the analysis of slowly-moving landslides. Geo-Frontiers 2011, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164424)

- L. Laloui. In-situ testing of a heat exchanger pile. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164229)

- L. hu, H. Péron, L. Laloui and T. Hueckel. A multi-scale multi-physics model of soil drying. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164228)

- S. Fauriel and L. Laloui. A Bio-hydro-mechanical Model for Propagation of Biogrout in Soils. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164227)

- M. Nuth and L. Laloui. A model for the water retention behavior of deformable soils including capillary hysteresis. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164226)

- J. Eichenberger, M. Nuth and L. Laloui. Modeling the Onset of Shallow Landslides in Partially Saturated Slopes Subjected to Rain Infiltration. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164224)

- H. Péron, C. Knellwolf and L. Laloui. A method for the geotechnical design of heat exchanger piles. Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011. (http://infoscience.epfl.ch/record/164223)

Course notes

- Laloui L., Koliji, A. "*Mechanics of Porous Media with a focus on geomaterials*". Course notes - Doctoral programme in Mechanics - EPFL, 225 pages, 2011.

Important Presentations

Prof. Laloui's presentations:

- "Multiphysical Coupled Processes in Underground Nuclear Waste Disposal Problems". Plenary lecture, Computational Methods for Coupled Problems in Science and Engineeing IV, Kos (Greece), June 2011.

- "Evidences on the deformation mechanisms of a Shale". Theme lecture, 5th International Symposium on Deformation Characteristics of Geomaterials (IS-Seoul 2011) IV, Seoul (Korea), September 2011.

- "Geotechnical design of energy piles". Feature lecture, 2nd International Symposium on Computational Geomechanics, Cavtat-Dubrovnik (Croatia), April 2011.

Dr. Ferrari's presentations:

- Thermo-Hydro-Mechanical behavior of a shale. Theme lecture at Geo-Frontiers 2011 Conference, ASCE, Dallas, Texas, USA, 2011.

- Linking hydrogeological and geomechanical landslide modeling. Keynote Lecture, European Geosciences Union General Assembly, Vienna, 2011. (http://infoscience.epfl.ch/record/167142)

- Assessment of structural changes in double-structured materials under HM loading conditions. Invited lecture, International Workshop "Characterisation of materials with inherent micro structure: Towards modelling of hydro-mechanical behaviour", Bochum, 2011. (http://infoscience.epfl.ch/record/164522)

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

- **Energy piles:**
  C. Knellwolf, H. Péron and L. Laloui. Geotechnical analysis of heat exchanger piles, in Journal of Geotechnical and Geoenvironmental Engineering, vol. 137, num. 10, p. 890-902, 2011. (http://infoscience.epfl.ch/record/163018)

- **Landslides:**
  Ferrari, A. Ledesma, D. González and J. Corominas. Effects of the foot evolution on the behaviour of slow-moving landslides, in Engineering Geology -Amsterdam-, vol. 117, p. 217-228, 2011. (http://infoscience.epfl.ch/record/162296)
- **Nuclear waste storage:**
  F. Dupray, B. François and L. Laloui. Analysis of the FEBEX multi-barrier system including thermo-plasticity of unsaturated bentonite, accepted in International Journal for Numerical and Analytical Methods in Geomechanics, 2011. (http://infoscience.epfl.ch/record/168627)

C. Researches (2011)

New major research projects

Title: Geotechnical REliability of Thermo-piles Energy storage in soiLs, Part II
PI/Project Manager: L. Laloui and F. Dupray
Sponsor: EOS Holding
Period: Apr 2011 – Apr 2014

Title: Analysis of Opalinus Clay behaviour in THM framework
Advanced experimental work along with innovative constitutive modeling is developed for a comprehensive assessment of the THM behavior of the Opalinus Clay, host rock material for the Swiss nuclear waste disposal concept.
PI/Project Manager: L. Laloui and A. Ferrari
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)
Period: June 2011- October 2013

Title: Laboratory test programme on core samples from the Schlattingen borehole
Experimental testing of shale materials in the context of the selection for a nuclear waste disposal system in Switzerland
PI/Project Manager: L. Laloui and A. Ferrari
Sponsor: Nagra
Period: June 2011 – Sept 2012

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: Engineering Barriers System- Task Force
PI/Project Manager: L. Laloui, F. Dupray
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)
Period: June 2011- October 2012

Title: In-situ analysis of the behavior of energy piles
PI/Project Manager: L. Laloui
Sponsor: EPFL
Period: May 2011- September 2011

Title: Study of the second phase of the real-scale in-situ test FEBEXe
PI/Project Manager: L. Laloui, F. Dupray
Sponsor: National Cooperative for the Disposal of Radioactive Waste (NAGRA)
Period: June 2011- October 2012

Research prizes and awards

Alice Di Donna, PhD candidate, got the first runner-up position from the US Deep Foundation Institute (DFI) Educational Trust 2011 Young Professor Paper Competition for her paper "Design of Piles with Dual Role of Structural Stability and as a Sustainable Source of Energy for the Heating and Cooling of Buildings. She received her award plaque at the awards ceremony that was organized by the DFI on October 20th in Boston.

Invited professors or academic hosts who visited your lab

- Prof. Alexandre Puzrin from ETHZ (3 months)
- Prof. Tomasz Hueckel from Duke University USA (1 month)

Organization of workshops or other international events at EPFL or outside

- Prof. Laloui: Organiser of the Geotechnique Symposium in Print 2013 on Bio- and Chemo-Mechanical processes in geotechnical engineering, London.

- Prof. Laloui: Member of the International Advisory Committee of the 2nd international symposium on constitutive modelling, Beijing (China), October 2012.

- Prof. Laloui: Member of the International Advisory Committee of the 1st international Pan-American Conference on Unsaturated soils, Cartagena (Colombia), February 2013.

- Prof. Laloui: Member of the Technical Advisory Panel of the 4th conference on Computational Methods for Coupled Problems in Science and Engineering (Coupled Problems 2011), Kos (Greece), June 2011.

- Prof. Laloui: convener for 2 sessions at Geo-Frontiers, Dallas 2011

- Prof. L. Vulliet: World Engineers Convention, Geneva, 5-7 September 2011 (member of the Organizing Committee)

D. Valorization, collaborations & networks (2011)

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

Partners	Topic/Context/kind of collaboration
Prof. Rizlan Bernier-Latmani	Bio-mechanics of soils/NSF proposal/ENAC
SHARC international consortium : CISRO Perth	Thermo-hydro-mechanical behaviour of shales/Industrial project
HOLCIM	Establishment of an early-warning system in the Llano Grande Mine (Costa Rica)/Industrial project
EOS holding	Geotechnical REliability of Thermo-piles Energy storage in soiLs

Innovative products, patents, spin-offs/startups

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

E. Administrative efforts (2011)

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	Faculty search committee for professor position	EPFL	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	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	Vice-Director, Alliance of European Research Laboratories (ALERT), and 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

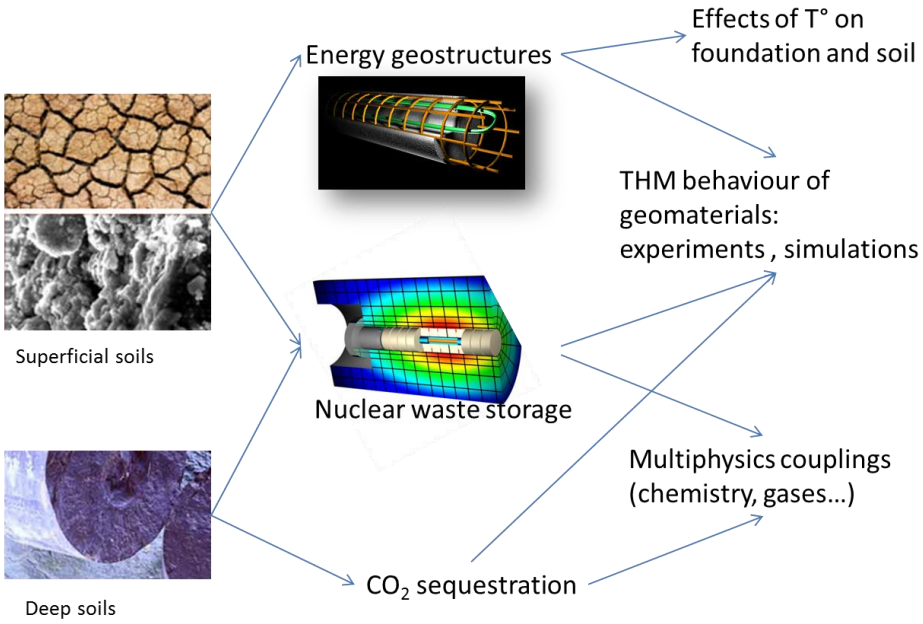
F. Key directions for the lab and plans for the future

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 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 will allow the development of a deep knowledge in the area of CO2 storage. Experimental facilities devoted to this topic will be developed. Also computational tools at the basin scale will be introduced for the analysis of the various scenarios. A group of three PhD students and one post-doc will be constituted to deal with this topic.

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
January 2012