

YEARLY REPORT 2009

Laboratory of Soil Mechanics (LMS)

0. Introduction

At the request, we have addressed below the six questions concerning the activities of the Laboratory of Soil Mechanics (LMS) in 2009.

1. Teaching

1.1 Bachelor, Master, Doctoral School and Continuing Education at EPFL

1.1.1 List of courses offered and student numbers

- 2008-2009 (based on information provided by IS-Academia)

Course Title	Instructor	Section ; number of hours	Level, semester	Number of students
Geomechanics	L. Laloui	Génie civil, 42h	Ms, 1&3	12
Ecoulements souterrains	L. Laloui	Génie civil, 28h	Bs, 4	54
Mécanique des sols	L. Laloui	ELSTE (Uni. Lausanne & Genève), 21h	Ms, 2	8
Environmental geomechanics	L. Laloui	Doctoral school, 28h	Ph.D	1
Soil Mechanics 2	L. Laloui	MAS Tunnelling, 9h	MAS	7
Mécanique des sols	L. Vulliet	Génie civil, 42h	Bs, 3	58
Soil Mechanics	L. Vulliet	MAS Tunnelling, 9h	MAS	7
Projets Master	L. Laloui	Génie civil, 420h	Ms 4	4
Projet de construction	L. Laloui	Génie civil, 35h	Ms 3	1
Pré-étude projet Master	L. Laloui	Génie civil, 42h	Ms 3	3
Projet ENAC	L. Laloui	Génie civil, 70h	Ms 1	1
Stage de Génie civil	L. Laloui	Génie civil, 28h	Ms 1,3	2
Mechanics of porous media	L. Laloui	Doctoral school, 28h	Ph.D	3

- 2009-2010 (based on information provided by IS-Academia)

Course Title	Instructor	Section ; number of hours	Level, semester	Number of students
Geomechanics	L. Laloui	Génie civil, 42h	Ms, 1&3	10
Mécanique des sols et Ecoulements souterrains	L. Laloui & L. Vulliet	Génie civil, 112h	Bs, 3	67
Analyse du risque	L. Vulliet	Génie civil, 42h	Ms, 1&3	55

1.1.2 Ms Students and PhD Students (academic years 2008-2009 and 2009-2010)

- Ms students

1. Planchat J., Ms student (L. Laloui advisor), Title: La Frasse Landslide: analysis of the hydro-mechanical behavior of the instability and of the associated risks (successful exam in July 2009)
2. Meynet T., Ms student (L. Laloui advisor), Title: A field and constitutive study on the bacterially induced calcite precipitation in granular soils (successful exam in July 2009).
Awarded the Zanelli prize
3. Minon S., Ms student (L. Laloui advisor), Title: Identification tests and rheological analysis on two facies of Opalinus clay (successful exam in July 2009).
4. Diogo H., Ms student (L. Laloui advisor), Title: Thermo vertical drains for in-situ consolidation of soils (successful exam in July 2009).
5. Dura A., Ms student (L. Laloui advisor), Title: Post-thermal aging of soils (successful exam in January 2009)
6. Adel Y., Ms student (L. Laloui advisor), Title: Etude du comportement mécanique des matériaux granulaires compactés non saturés sous chargements cycliques soils (successful exam in June 2008)
7. Passarotto M., Ms student (L. Laloui co-advisor), Title: Coupled hydro-thermo-mechanical analysis of deep radioactive waste disposals (successful exam in June 2008)
8. Akry A., Ms student (L. Laloui co-advisor), Title: Recharge de nappes en afrique du nord - barrages collinaires de rétention de crue, barrages infero-flupx – souterrains à travers le lit d'un oued (successful exam in June 2008)
9. Eichenberger J., Ms student (L. Laloui co-advisor), Title: dimensionnement de galeries en charge en milieu anisotrope (successful exam in June 2008)

- PhD students

(Completed PhD thesis)

1. Péron H., PhD student (L. Laloui advisor), Title: Desiccation cracking of soils (successful exam in January 2008)
Nominated for the EPFL award of best thesis 2008
2. Koliji A., PhD student (L. Vulliet advisor), Title: Mechanical behaviour of unsaturated aggregated soils (successful exam in January 2008)
Nominated for the EPFL award of best thesis 2008
Awarded best European thesis in Geomechanics in 2008
3. François B., PhD student (L. Laloui advisor), Title: Constitutive modelling of unsaturated soils and hydro-mechanical couplings (successful exam in September 2008)
Awarded best European thesis in Geomechanics in 2009
4. Nuth M., PhD student (L. Laloui advisor), Title: Advanced modelling of unsaturated soils, constitutive and hydro-mechanically coupled finite element analysis (successful exam in March 2009)
Nominated for the EPFL award of best thesis 2009
Awarded the Chorafas prize 2009
Awarded the best thesis in Civil Engineering 2008 from the "Association universitaire de génie civil" in France

5. Obrzud R., PhD student (L. Vulliet co-advisor), Title: Numerical modeling and neural networks to identify constitutive parameters from in situ tests (successful exam in July 2009)
Nominated for the EPFL award of best thesis 2009
6. Shokri N., PhD student (L. Laloui, co-advisor), Title: Pore scale analysis of evaporation from porous media (successful exam in August 2009)
Nominated for the EPFL award of best thesis 2009
7. Rascol E., PhD student (L. Vulliet advisor), Title: Cyclic Properties of Sand: Dynamic Behaviour for Seismic Applications (successful exam in December 2009)

(Current PhD students - names and stage of progress indicating expected date of completion)

1. Chalindar S., PhD student (L. Laloui advisor), Title: Advanced modelling of the behaviour of clays: Time-dependency, chemical reactions and bacterial activities (in progress, to be completed in 2011)
2. Rizzi M., PhD student (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 2011)
3. A. Battiato, PhD student (L. Laloui advisor), Title: Characterization and modelling of effects of wheeling on topsoil (in progress, to be completed in 2012)
4. J. Eichenberger, PhD student (L. Laloui advisor), Title: Behaviour of large landslides (in progress, to be completed in 2012)

1.2 Additional teaching (academic years 2008-2009 and 2009-2010)

1.2.1 List of courses offered outside EPFL

1. L. Laloui L. & Nuth M.: "Stabilité des digues et des barrages en terre". 3 hours - Annual meeting of the Fachleute Naturgefahren Schweiz, Lugano, September 17, 2008, 80 participants
2. L. Laloui: "Geomechanical modeling of a natural slope affected by multiple slip surface failure mechanisms". 3 hours teaching at the European Intensive course on Quantitative Risk Assessment and Risk management, Barcelona (Spain), September 2008, 70 students
3. H. Péron, "Mécanique des sols avancée - Sols non saturés: Phénomène de dessiccation des sols". 3 hours teaching at ENSG Nancy (Ecole Nationale Supérieure de Géologie, 3ème Année - option Géotechnique), June 2008, 28 students
4. Organiser (and lecturer) of the European Doctoral School of the ALERT-Geomaterials on Failure in multiphase materials, Aussois (France), 15-17 October 2009, 102 students.
5. Co-organiser of a European intensive course on Multi-technique landslide investigation, Les Diablerets, June 21-26, 2009, 40 students.
6. Co-organizer of a training course on THM behaviour of clays in deep excavation with application to underground radioactive waste disposal, EPFL, July 7-9, 2008, 50 students.

1.2.3 Appointments as Professor at other high schools

Adjunct professor, School of Civil and Environmental Engineering, Duke University, Durham, NC, USA, 2007-2012.

2. Publications and Presentations (2009)

2.1 Journal Articles accepted and published in 2009

1. Castelli, M., Scavia, C., Bonnard, C., Laloui, L., "Mechanics and velocity of large landslides", In *Engineering Geology*, vol. 109, pages 1-4, 2009
<http://infoscience.epfl.ch/record/141811>
2. Péron, H., Hueckel, T., Laloui, L., Hu, LB., "Fundamentals of desiccation cracking of fine-grained soils: experimental characterisation and mechanisms identification", In *Canadian Geotechnical Journal*, vol. 46, pages 1177-1201, 2009
<http://infoscience.epfl.ch/record/141895>
3. Laloui, L., Leroueil, S., Chalindar, S., "Reply to the discussion by G. Qu on Modelling of the combined effect of strain rate and temperature on one-dimensional compression of soils", In *Canadian Geotechnical Journal*, vol. 46, number 9, page 1102–1102, 2009
<http://infoscience.epfl.ch/record/140680>
4. Laloui, L., Nuth, M., "Response to Comment on "On the use of generalised effective stress in the constitutive modelling of unsaturated soils", In *Computer and Geotechnics*, vol. 36, pages 1362-1363, 2009
<http://infoscience.epfl.ch/record/140377>
5. Klubertanz, G., Laloui, L., Vulliet, L., "Identification of mechanisms for landslide type initiation of debris flows", In *Engineering Geology*, vol. 109, pages 114-123, 2009
<http://infoscience.epfl.ch/record/140319>
6. Laloui, L., de Gennaro, V., "Geomechanics of structured materials", In *Soils and Foundations*, vol. 49, number 3, pages 351-390, 2009
<http://infoscience.epfl.ch/record/139228>
7. Koliji, A., Laloui, L., Vulliet, L., "Behavior of Unsaturated Aggregated Soil in Oedometric Condition", In *Soils and Foundations*, vol. 49, num. 3, pages 369-380, 2009
<http://infoscience.epfl.ch/record/133587>
8. Charlier, R., Dizier, A., Laloui, L., Collin, F., "Multi-physical processes in geomechanics. An introduction to constitutive modeling and coupling aspects", In *European Journal of Environmental and Civil Engineering*, vol. 13, num. 7-8, pages 803-830, 2009
<http://infoscience.epfl.ch/record/141893>
9. Péron, H., Laloui, L., Hueckel, T., Hu, LB., "Desiccation cracking of soils", In *European Journal of Environmental and Civil Engineering*, vol. 13, num. 7-8, pages 869-888, 2009
<http://infoscience.epfl.ch/record/141892>
10. Laloui, L., François, B., "ACMEG-T: Soil Thermo-Plasticity Model", In *Journal of Engineering Mechanics*, vol. 135, num. 9, pages 932-944, 2009
<http://infoscience.epfl.ch/record/134820>
11. Hueckel, T., François, B., Laloui, L., "Explaining thermal failure in saturated clays", In *Géotechnique*, vol. 59, num. 3, p. 197-212, 2009
<http://infoscience.epfl.ch/record/129017>
12. Obrzud, R.F., Vuillet, L., Truty, A., "A combined neural network/gradient-based approach for the identification of constitutive model parameters using self-boring pressuremeter tests" In *International Journal for Numerical and Analytical Methods in Geomechanics*, vol. 33, num. 6, p. 817-849, 2009
<http://infoscience.epfl.ch/record/128547>

13. Obrzud, R.F., Vulliet, L., Truty, A., "Optimization framework for calibration of constitutive models enhanced by neural networks", In *International Journal for Numerical and Analytical Methods in Geomechanics*, vol. 33, num. 1, p. 71-94, 2009
<http://infoscience.epfl.ch/record/121378>
14. François, B., Laloui, L., Clément L., "Thermo-hydro-mechanical simulation of ATLAS in-situ large scale test in Boom Clay", In *Computers and Geotechnics*, vol. 36, p. 626-640, 2009
<http://infoscience.epfl.ch/record/126460>
15. Péron, H., Delenne, J.-L., Laloui, L., El Youssofi, S., "Discrete element modelling of drying shrinkage and cracking of soils", In *Computers and Geotechnics*, vol. 36, p. 61-69, 2009
<http://infoscience.epfl.ch/record/118741>
16. Laloui, L., Nuth, M., "On the use of the generalised effective stress in the constitutive modelling of unsaturated soils", In *Computer and Geotechnics*, vol. 36, num. 1-2, p. 20-23, 2009
<http://infoscience.epfl.ch/record/118500>
17. Ferrari, A., Laloui, L., Bonnard, C., "Hydro-mechanical modelling of a natural slope affected by a multiple slip surface failure mechanism", In *Computer Modeling in Engineering & Sciences*. In press.
<http://infoscience.epfl.ch/record/142579>
18. François, B., Laloui, L., "An oedometer for studying combined effects of temperature and suction on soils", In *Geotechnical testing journal*. In press.
<http://infoscience.epfl.ch/record/142846>
19. Koliji, A., Laloui, L., Vuillet, L., "Constitutive modeling of unsaturated aggregated soils", In *International Journal of Numerical and Analytical Methods in Geomechanics*. In press.
<http://infoscience.epfl.ch/record/142804>
20. Cekerevac, C., Laloui, L., "Experimental analysis of the cyclic behaviour of Kaolin at high temperature", In *Geotechnique*, 2009. In Press.
<http://infoscience.epfl.ch/record/140963>
21. Holzer, L., Münch, B., Rizzi, M., Wepf, R., Marschall, P., Graule, T., "3D-microstructure analysis of hydrated bentonite with cryo-stabilized pore water", In *Applied Clay Science*. In press.
<http://infoscience.epfl.ch/record/142688>

2.2 Proceedings (2009)

1. Ferrari, A., Laloui, L., Bonnard, C., "Geomechanical modelling of a natural slope affected by a multiple slip surface failure mechanism", In *Proceedings of the 1st international symposium Com-Geo* (Computational methods in Geomechanics), Juan-Les-Pins, France, April 29-May 1st, 2009
<http://infoscience.epfl.ch/record/138772>
2. Silvani, C., Nuth, M., Laloui, L., Peron, H. "Understanding the thermo-mechanical response of heat exchanger piles", In *Proceedings of the First International Symposium on Computational Geomechanics*, pages 589-596, Juan-les-Pins (France), April 29 - May 1st, 2009.
<http://infoscience.epfl.ch/record/138685>

3. Peron, H., Laloui, L., Bo Hu, L., Hueckel, T. "Prediction of the spacing and patterns of drying cracks in soils", In *Proceedings of the First International Symposium on Computational Geomechanics*, pages 623-629, Juan-les-Pins (France), April 29 - May 1, 2009.
<http://infoscience.epfl.ch/record/138684>
4. François, B., Laloui, L., "Behaviour of an engineered clay barrier involved in a prospective nuclear waste isolation system", In *Proceedings of the 1st international symposium Com-Geo (Computational methods in Geomechanics)*, Juan-Les-Pins, France, April 29-May 1st 2009.
<http://infoscience.epfl.ch/record/139043>
5. Laloui, L., Ferrari, A., Bonnard, C., "Geomechanical modeling of the Steinernase landslide (Switzerland) ", presented at 1st Italian workshop on Landslides. In *Rainfall-induced landslides*, pages 186-195, Naples, June 8-10, 2009.
<http://infoscience.epfl.ch/record/138759>
6. Hu, LB., Hueckel, T., Péron, H., Laloui, L., "Desiccation shrinkage and its controlling properties: multiphysics", In *Proceedings of the Int. Conf. on Computational Methods for Coupled Problems in Science and Engineering, Coupled Problems'09*, Ischia, Italy, June, 8-10, 2009
<http://infoscience.epfl.ch/record/138723>
7. François, B. Laloui, L. "Behaviour of an engineered clay barrier for A nuclear waste isolation system", In *Proceedings of the Int. Conf. on Computational Methods for Coupled Problems in Science and Engineering, Coupled Problems'09*, Ischia, Italy, June, 8-10, 2009.
<http://infoscience.epfl.ch/record/138722>
8. Rascol, E., Vuillet, L., "Characterization of natural sand under complex dynamic loading", In *Proceeding of the International Conference on Performance-Based Design in Earthquake Geotechnical Engineering*, pages 1505-1513 London: Taylor & Francis Group, Tsukuba, Japan, June 15-18, 2009.
<http://infoscience.epfl.ch/record/138971>
9. Rizzi, M., Salager, S., Marschall, P., Laloui, L. "Design of a complete characterization of bentonite behaviour under high pressure and high temperature", In *Proceedings of the 2nd Int. Conf. on Fault and top seals*, pages 68-71, Montpellier, France, September 21-24, 2009.
<http://infoscience.epfl.ch/record/141368>
10. Péron, H., Salager, S., Nuth, M., Marschall, P., Laloui, L., "Analysis of the swelling pressure development in opalinus clay – experimental and modelling aspects", In *Proceedings of the 2nd Int. Conf. on Fault and top seals*, pages 56-58, Montpellier, France, September 21-24, 2009.
<http://infoscience.epfl.ch/record/141367>
11. Planchat, J., Bonnard, C., Peron, H., Laloui, L. "After 10'000 years of movements, is the La Frasse landslide stabilized? Numerical modeling of the crises of a large landslide and of its mitigation measures", In *proceedings of the VII Simposio Nacional sobre Taludes y Laderas Inestables*, vol. 1, pages 95-126, Barcelona, Spain, October 27-30, 2009.
<http://infoscience.epfl.ch/record/142309>

3. Research (2009)

3.1 New major research projects

1. European program FP7 - ENV. Amount: CHF 260'000.- (Duration: 1/05/09 to 30/04/12)
Title: SafeLand - Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies. Applicant : L. Laloui
2. Swiss Federal Office of Energy (OFEN). Amount: CHF 237'000.- (Duration: 1/01/10 to 30/06/14)
Title: "Optimized and reliable heat exchanger pile systems". Applicant : L. Laloui
3. Swiss Federal Office of Road (OFROU). Amount: CHF 88'814.- (Duration: 1/01/10 to 30/09/10)
Title: "Heat exchanger anchors for thermo-active tunnels". Applicant : L. Laloui
4. National Cooperative for the Disposal of Radioactive Waste (NAGRA). Amount: CHF 140'000.- (Duration: 1/11/09 to 31/08/10)
Title: Description of the geomechanical response of granular bentonite on THM perturbations. Applicant : L. Laloui
5. National Cooperative for the Disposal of Radioactive Waste (NAGRA). Amount: CHF 143'000.- (Duration: 1/07/09 to 31/12/09)
Title: Laboratory work for initial phase of the European project FORGE. Applicant : L. Laloui
6. National Science Foundation. Amount: CHF 213'525.- (Duration: 1/07/09 to 30/06/11)
Title: Assessment of soil damage induced by drying". Applicant : L. Laloui
7. Swiss Competence Center Environment and Sustainability. Amount: CHF 290'000.- (Duration: 1/02/09 to 30/01/12)
Title: Coupled GeoHazards in Alpine Regions. Applicant : L. Laloui

3.2 Research Prizes and awards

1. Dr. Bertrand François has been awarded the ALERT 2009 PhD Prize (best European thesis in geomechanics) for his PhD thesis entitled "Constitutive modelling of unsaturated soils and hydro-mechanical couplings" under the supervision of Prof. L. Laloui
2. Dr. Mathieu Nuth has been awarded the Chorafas 2009 Prize in the category "Sustainable development" for his PhD thesis entitled "Constitutive modelling of unsaturated soils with hydro-geomechanical couplings" under the supervision of Prof. L. Laloui.
3. The paper "Effective stress concept in unsaturated soils: Clarification and validation of a unified framework" by Mathieu Nuth & Lyesse Laloui is the top most-cited article in the International Journal for Numerical and Analytical Methods in Geomechanics (since June 2009).
4. Prof. L. Laloui got the "Fondazione Cassa di Risparmio di Padova e Rovigo" award for Visiting Professorship, Doctoral School in Civil and Environmental Engineering, University of Padova, Italy, 2009.

3.3 New research facilities

We received the two Thermo-hydro-mechanical triaxial cells funded in the context of the National Science Foundation R'Equip programme (Total Amount: CHF 500'000.- matching fund EPFL (230KCHF; 230KCHF NSF and the rest LMS funds)

We are currently creating new testing facilities for the analysis of the gas propagation in soils (financial support of 90'000.- CHF provided by Nagra – industrial partner).

3.4 Invited professors or academic hosts

1. Prof. Tomasz Hueckel, invited professor, Duke University, June and July 2009.
2. Prof. Bernhard A. Schrefler, invited professor, University of Padova, November 2009.

4. Valorization, collaboration and networks (2009)

No information to communicate under this theme

5. Administrative efforts at ENAC or EPFL (2009)

Name	Board / committee, etc.	EPFL / External	Role in funding allocation yes/no
Prof. L. Laloui	Director of the doctoral programme in Mechanics.	EPFL	
Prof. L. Laloui	Member of the research committee for the School of Architecture, Civil and Environmental Engineering of the EPFL (ENAC)	EPFL	
Prof. L. Vulliet	Member, Foundation Council, Foundation "Les Bois Chamblard", financing research in Environmental Sciences at EPFL (focusing on bio-diversity)	EPFL	
Prof. L. Vulliet	Member, Foundation Council of the Presses Polytechniques et Universitaires Romandes (PPUR), Lausanne	EPFL	

6. Goals

Vision

The Soil Mechanics Laboratory (LMS) focuses its activities of education, research and technology transfer in the field of Geomechanics. Its 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 collaborations and through contacts with industry.

Activities

LMS offers courses from Bs to PhD level in soil mechanics, mechanics of porous media, geomechanics and groundwater seepage.

Research activities will mainly concentrate on:

- **mechanics of geomaterials**, including constitutive modelling, mechanics of porous media and mixtures, cemented, fissured and structured soils, unsaturated soils, multiphase flow in deformable porous media, cyclic loading, elasto-visco-plasticity, laboratory testing, image processing for mechanical testing;

- **environmental geomechanics** applied to geological disposal of nuclear and hazardous waste, as well as energetic geostructures; thermo-hydro-mechanical coupling effects, clay barriers, desiccation cracking;
- **numerical modelling of geomaterials** using finite differences and finite elements, algorithms for non-linear coupled problems, optimization procedures, back- and inverse analysis, modelling of landslides;
- **management of natural hazards**, including monitoring, analysis of landslides and debris flow, risk management.

LMS will continue to be active in technology transfer and outreach by offering laboratory tests, numerical modelling and expertise work.

For 2010, the aim is to developing a unique scientific way of thinking in the rapidly expanding field of multi-physics coupled processes in porous materials. This concerns the study of the behaviour of geomaterials with all the complexity of their multi-physical and often multi-scale nature and of their environment. Our framework might be extended to biological processes in the context of an ERC proposal that Prof. L. Laloui will submit in Feb. 2010.

We intend to form a strong scientifically competent group of interest in Environmental Geomechanics with a distinct modern focus. Such a group could be an international leader in the area that is gaining momentum worldwide.

Prof. Lyesse Laloui, director of LMS

Lausanne, January 8th 2010