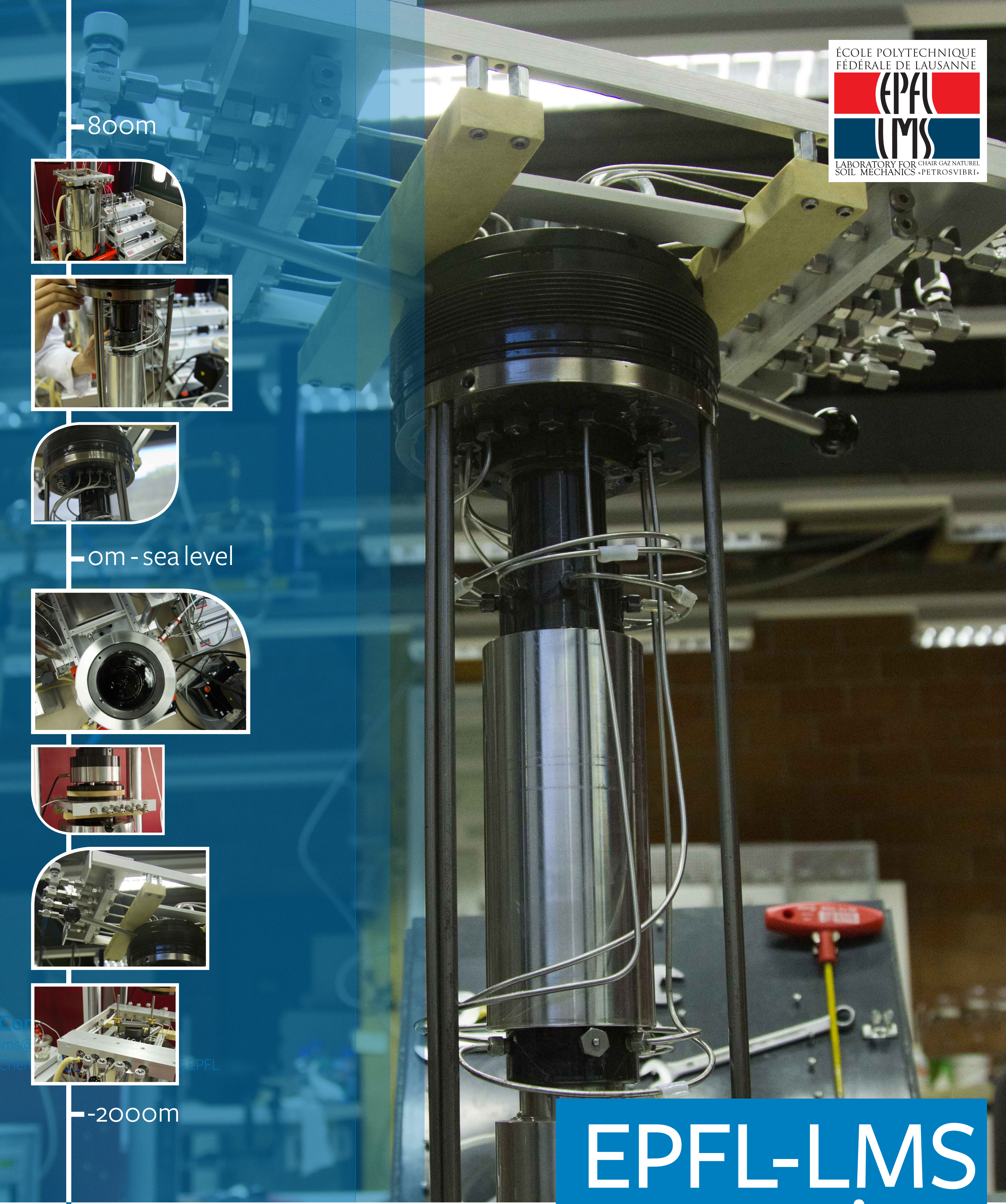


ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

EPFL LMS

LABORATORY FOR SOIL MECHANICS

CHAIR GAZ NATUREL «PETROSVIBRI»

EPFL-LMS Testing Service

The LMS/EPFL offers more than 600 m2 of testing surface . http://lms.epfl.ch

Our services are devoted to assess the behaviour of geomaterials in many fields such as civil engineering, oil industry and environmental geomechanics.

I. Conventional testing
II. Advanced geotechnical testing
III. Deep geo-engineering applications

EPFL Laboratory of Soil Mechanics

The Laboratory of Soil Mechanics (LMS) is among the first-established laboratories of the Swiss Federal Institute of Technology, Lausanne (EPFL), Switzerland. As a result of our extended experience over the years, the laboratory offers today a wide range of first-class testing facilities for geomaterials to cope with various issues in the areas of geotechnical engineering, oil industry, protection from geo-hazards and industrial damage to the environment, landforms and structures.

Beside the conventional geomechanical testing, our experimental facilities also allow us to perform complex investigations related to waste disposal, petroleum and gas exploitation, transportation and storage, methane hydrate technology, CO_2 geological sequestration, and energy technologies.

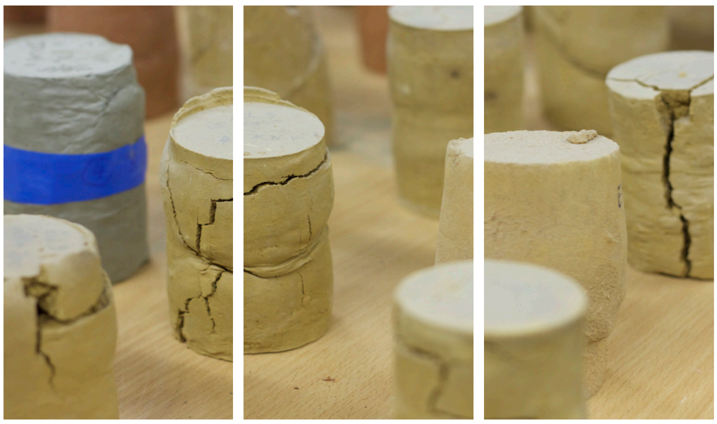
Our expertise in various fields allows us to work with national and international companies, from the public to industrial sectors, providing key support to strategic projects.

Prof. Lyesse Laloui - Director of the LMS/EPFL

Our basic services include:

- Geotechnical identification tests following the highest Swiss Standards. On request other national standards can be applied.
- Swelling characteristics of soils and rocks in terms of swelling pressure (constrained swelling) and swelling strain (free swelling) as a function of the degree of saturation.
- Permeability determination for geomaterials.
- Stress-path controlled triaxial testing. Our triaxial cells offer precise control/measurement of the pore water pressure. They can operate across a range of articulated stress paths, from conventional tests (UU, CD, CIU), to tensile strength determination.
- Consolidation and compaction behaviour of soils in oedometric and isotropic conditions, for a variety of sample dimensions (from few centimetres to one meter scale)
- Shear strength assessment through direct shear and simple shear testing.
- Dynamic compaction and CBR for infrastructure geomaterials.

All test results are analysed by our engineers to guarantee the maximum accuracy of the delivered results.



Advanced Geotechnical Testing

Sounded geotechnical practice often requires the assesment of the behaviour of geomaterials through complex testing. We have developed apparatuses and techniques to perform a large variety of advanced tests.

- Triaxial and oedometric tests on unsaturated geomaterials
- Non-isothermal testing of soils and soil-concrete interface
- Dynamic triaxial testing with articulated stress paths
- Gas and water permeability in unsaturated conditions

Unsaturated soil testing

To consider the partial saturation of soils is a fundamental requirement in many geotechnical applications such as the assessment of the stability of natural slopes and embankments, operations involving collapsible soils or foundations in partially saturated soils. Our laboratory offers a variety of equipment to perform testing and characterization of unsaturated soils.

We have conventional and in-house developed apparatuses for characterizing the water retention behaviour of soils, also in non-isothermal conditions.

Our triaxial and oedometric cells can operate with suction control to assess the effects of the partial saturation on the hydro-mechanical response of soils (shear strength, stiffness, volume change, relative permeability). The technical capacities of our controlled-suction devices are the following:

- Specimen dimensions: 38/50 mm in diameter, 76/100 mm in height for the triaxial systems; 50 mm in diameter, 20 mm in height for the oedoemtric cells.
- Confining stress: up to 2 MPa
- Suction control: up to 1.5 MPa (axis translation technique) and up to 400 MPa (vapour equilibrium technique).

Non-isothermal testing of soils

Controlled-temperature devices are available at the LMS/EPFL that cover temperature and stress ranges found in civil and environmental engineering problems such as energy geo-structures, waste deposits, temperature-enhanced drains. Our unique devices include triaxial and oedometric cells operating in non-isothermal conditions that allow to assess the influence of temperature on the shear strength and deformations. The technical capacities of the device are the following:

- Specimen dimensions: 38/50 mm in diameter, 76/100 mm in height for triaxial system, 55 mm in diameter, 20 mm in height for the oedometric cells
- Temperature: between -5°C and +85 °C
- Confining stress: up to 1.8 MPa
- Pore water pressures control up to 1.5 MPa with independent control of the pore water temperature

A special direct shear box allows us to perform soil-concrete interface tests at different temperatures. Technical capacities of the device are the following:

- Specimen Dimensions: 60X60 mm2
- Temperature: between -50 °C and +85 °C
- Max horizontal and vertical load: 5 kN

Dynamic testing of soils

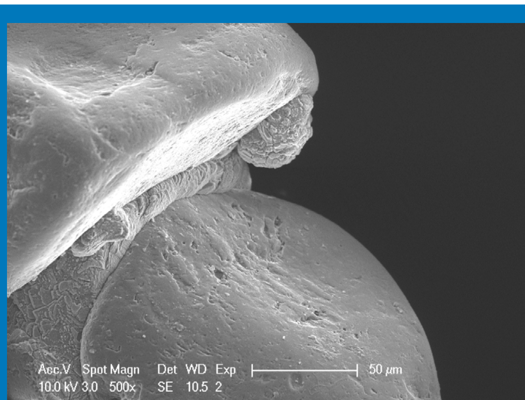
A special triaxial cell has been designed for dealing with dynamic load conditions as in the cases of earthquake engineering and transport infrastructure design. The cell can operate with three different cyclic motions (axial loading, confining pressure and rotation along the vertical axis) by a unique feedback control system. The device is also equipped with a specifically designed system with non-contact laser sensors to capture strains at high frequencies. The equipment can operate under the following conditions:

- Cyclic force-displacement control (0.01 to 50 Hz)
- Complex stress paths thanks to cyclic confining pressure
- Undrained and dry loading at medium to large strain amplitudes

Microstructural analyses

Microstructural analyses enhance the understanding of the complex behaviour of geomaterials. We offer a series of observational tools including:

- High Pressure Mercury Intrusion Porosimetry (MIP) up to 400 MPa to quantify the pore size distribution and anticipate transport and retention properties of the material
- High-resolution Scanning Electron Microscopy (SEM) observations up to the scale of hundreds of nanometres
- X-ray Diffractometry and Energy Dispersive X-ray analysis (EDX) that provide information on the chemical and mineralogical composition of the material.



SEM analysis of a bio-cemented sand sample. A bridge of precipitated calcite is observed between two silica sand grains.

Deep Geo-engineering Testing

Our experimental facilities allow us to reproduce in the laboratory the complex conditions of geo-materials found in oil industry applications and geological waste disposals

- High-pressure and high-temperature triaxial and oedometric testing
- Simultaneous Independent control of different pore fluid pressures including CO_2
- Multiphyiscal testing of shales and gas shales

High-pressure and high-temperature testing

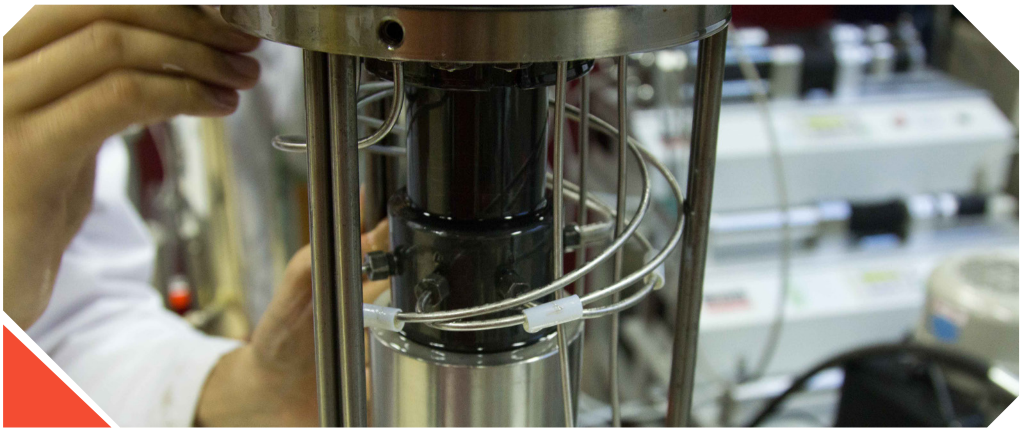
Deep geo-engineering application require the assessment of the behaviour of geomaterials in special conditions such as high temperature and high confining stresses. Our thermo-hydro-mechanical (THM) triaxial, oedoemetric and UCS systems allow the assessment of stiffness and strength of geomaterials in such special conditions. The systems are also equipped with a gas pressure/volume controller operating at a maximum pressure of 20 MPa to perform gas injection tests in low-porosity geomaterials. Technical capacities of the devices are the following:

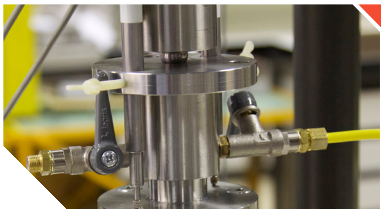
- Specimen Dimensions: 50 mm in diameter and 100 mm in height for the triaxial system; 35 mm in diameter for the oedometric system
- Max. vertical stress: 100 MPa (in the oedometric cell)
- Max. confining pressure: 30 MPa (in the triaxial systems)
- Independent control of liquid and gas pressures at the two bases of the specimen (pore water pressure up to 10 MPa)
- Max. temperature: 150 °C
- Suction control: up to 400 MPa can be integrated in the systems
- Direct control of the pore fluid chemical composition to reproduce brine characteristics

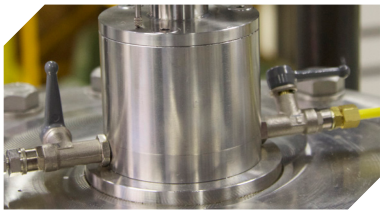
Hydro-mechanical testing of gas shales

Advanced experimental set-ups have been developed to test gas shales under different fluid saturation conditions. The apparatus allows assessing the impact of fluid saturation on the mechanical parameters (elastic and strength properties). Saturation changes at constant vertical stresses are performed to investigate the volumetric response of shales as a consequence of the exploitation. Technical capacities of the device are the following:

- Specimen dimensions: 20mm in diameter and 40mm in height
- Max. vertical stress: 150 MPa
- Sample deformation is assessed by a system of biaxial strain gauges + external LVDTs







Advanced triaxial cell for CO_2 injection

The device is used for injection of liquid and supercritical CO_2 in rock and measurements of its mechanical and petrophysical properties. Poroelastic, inelastic and strength characteristics, as well as permeability to different fluids are investigated at pressures and temperatures corresponding to deep geologic carbon dioxide storage conditions. Technical capacities of the device are the following:

- Specimen dimensions: 50 mm in diameter and 100 mm in height
- Max. vertical stress & confining pressure: 500 & 70MPa
- Max. brine pressure & CO_2 pressure: 32 & 26 MPa
- Max. temperature: 50 °C

Contact

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