

12TH IACMAG  
1-6 OCTOBER, 2008, GOA, INDIA

## **'MUSE' WORKSHOP**

### ***Benchmarking experimental techniques, and constitutive and numerical models in unsaturated soil mechanics***

#### **SPEAKERS**

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#### **OBJECTIVES**

The workshop will present the results of four benchmarking activities carried out within the MUSE ("Mechanics of Unsaturated Soils for Engineering") project, which is a major research and training network funded by the European Union. Details about the project can be found at <http://muse.dur.ac.uk>. The project's research programme encompasses a wide-ranging investigation of the engineering behaviour of unsaturated soils that is classified according to four broad tasks: Laboratory Testing (Task A), Constitutive Modelling (Task B), Numerical Analysis (Task C) and Application to Practical Problems (Task D).

Benchmarking activities have been undertaken under all four tasks of the MUSE project and have involved 8 European universities: Glasgow University (UK), Durham University (UK), Università di Trento (Italy), Universitat Politècnica de Catalunya (Spain), Ecole Nationale des Ponts et Chaussées (France), Università di Napoli Federico II (Italy), Ecole Polytechnique Fédérale Lausanne (Switzerland), and University of Innsbruck (Austria).

The objective of the workshop is twofold, i) sharing the results of these benchmarks with unsaturated soil specialists to demonstrate advantages and limitations of current experimental techniques, constitutive and numerical models; ii) introducing basic experimental and theoretical approaches in unsaturated soil mechanics to academics and practitioners not having a specific unsaturated soil background.

## **THE BENCHMARK ACTIVITIES**

### ***Laboratory Testing***

Different experimental techniques have been used at different institutions to determine of the water retention characteristics of a reconstituted soil under zero total stress along a drying path. The soil was prepared by mixing sand (70%), kaolin (10%), and bentonite (20%). All the ingredients are commercially available so that tests can be replicated by laboratories outside the network. In this exercise, samples were prepared by a single partner and distributed to the benchmark participants. Techniques investigated in this exercise include high-capacity tensiometer, pressure-plate, axis-translation oedometer, and osmotic technique. At least two institutions have used the same measuring/control device to determine the same water retention curve. This overlapping was aimed at cross-checking the experimental data.

### ***Constitutive Modelling***

Two benchmark exercises have been carried out a) to compare the procedures for determining parameter values in the Barcelona Basic Model (BBM) by Alonso, Gens & Josa (1990), with the objective of assessing the robustness and uniqueness of the calibration of such model and b) to compare the performance of different constitutive models in reproducing the response of triaxial tests on partly saturated samples at constant water content.

In the first benchmarking exercise, a set of data from laboratory tests on high plasticity clay has been circulated to all teams. Each team has independently determined the parameter values in BBM on the basis of this data set. The sets of parameter values from different teams, together with a description of the methodology for their calibration, have been forwarded to the coordinating institution. The sensitivity of parameter values to the chosen calibration procedure has been assessed by the coordinating institution, which has also produced a comparison of the predictions obtained by BBM for each parameter set along a number of different stress paths.

In the second exercise, a set of data from laboratory tests on silty soil has been circulated to all teams. This data set includes a number of oedometer tests and triaxial tests at constant suction with measurement of degree of saturation as well as soil-water retention curves. Each team has chosen a different constitutive model and has calibrated it on the basis of the circulated data. Network teams have forwarded to the coordinating institution the comparison between model predictions and experimental data for the tests used for calibration together with one blind prediction of an undisclosed laboratory test involving triaxial shearing of a sample subjected to constant

water content. This information has been analysed by the coordinating institution to identify strengths and weaknesses of the modelling approaches chosen from the different teams.

### ***Numerical Analysis***

Different finite element codes were benchmarked against each other by analysing a specified fictitious boundary value problem with different codes (using the same constitutive relationships, parameter values, initial conditions and boundary conditions for all codes). Four exercises have been carried out: 1) one-dimensional water infiltration in a unsaturated rigid column with numerical results compared with an analytical solution of the problem; 2) one-dimensional collapse of a unsaturated deformable column under stress increase and suction decrease with numerical results compared with an analytical solution of the problems; 3) two-dimensional displacement controlled loading of a rigid footing at constant suction with numerical results compared with a reference numerical solution; 4) two-dimensional displacement and load controlled loading of a rigid footing compared with a physical model run for this purpose in a centrifuge. Numerical codes tested include commercially available and home-made finite element codes.

### ***Application to Practical Problems***

An instrumented case history was selected to perform a Class A prediction. This is a river embankment in Northern Italy instrumented with piezometers, extensometers, geo-thermometers, heat flux sensor, multi-capacitance water content probe, and a meteorological station. Each research group have been provided with the soil profile derived from boreholes and dynamic probing testing and a preliminary assessment of saturated hydraulic conductivity of the foundation soils derived from field testing and the unsaturated hydraulic conductivity of the embankment soil derived from laboratory testing.

A first set of field monitoring data including the river level variation over a period of one month has been provided to refine the saturated hydraulic conductivities of the foundation soils and the make reasonable assumptions about the boundary conditions on the country-side which are unknown. A second period of observation has then been selected and each group has only been provided with the river level variation to perform a class A prediction. The results of the numerical simulations have been compared with piezometer data.