# MODELLING OF UNSATURATED CHALK: FROM EXPERIMENT TO RESERVOIR

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**ABSTRACT.** Chalk is the constituent material of numerous oil reservoirs in North Sea. The mechanical behaviour of a saturated chalk has been largely studied and different mechanical models have been proposed. However, different aspects of its behaviour are not yet well understood: one of them is the water-sensitivity of material characteristics. On one hand, an oil saturated chalk is stiffer and stronger than a water saturated one. On the other hand, during water injection in reservoir, compaction of production layers is observed implying seabed subsidence. The paper presents the different models developed in the framework of the “Pasachalk I” EC “Thermie” Project.

## 1. Introduction

As chalk in oil reservoir is generally saturated by two or more different fluids (oil, connate water, gas), the basic idea of this project is to apply some approaches of the unsaturated soil mechanics to the study of chalk, especially during waterflooding (Delage *et al.*, 1996).

A constitutive law is proposed for the modelling of the mechanical behaviour of chalk. The effects of the suction (related to some specific forces, including capillary pressure) are taken into account. They are considered as an independent variable, as in the Barcelona’s basic model developed for unsaturated clay (Alonso *et al.*, 1990). In the model, the experimental results have lead to consider internal friction and pore collapse as independent mechanisms.

The experimental work is focused on one hand on tests with different suction levels and on the other hand on the determination of the parameters of the failure mechanisms, including the hardening, for the two extreme saturation conditions (oil and water).

Validation of the numerical models is achieved thanks to waterflooding experiment. Finally results of an academic reservoir model are presented to show the ability of the numerical tools to reproduce the *in situ* observations.

## 2. Chalk behaviour: experimental evidences

The experiment on water and oil saturated sample shows clearly two plastic mechanisms: the pore collapse for high mean stress and a frictional rupture for high deviatoric stress (Figure 1). Few results allow determination of traction strength but the yield limit for extension path predicted by a frictional model usually overestimates actual value.

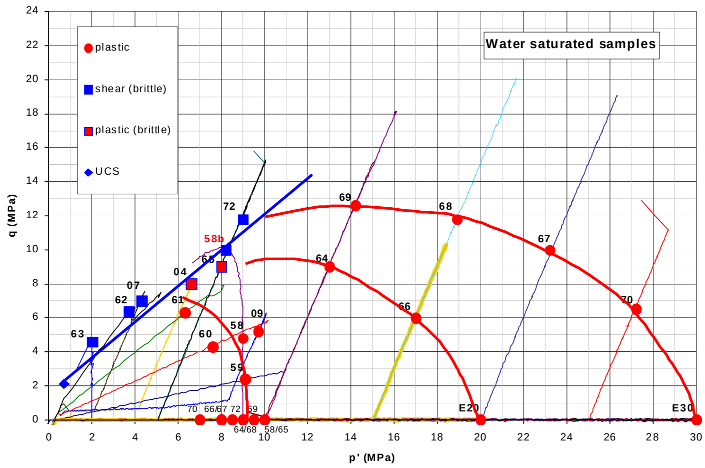


*Figure 1. Yield points for water saturated samples (Schroeder, 2000).*

In soils mechanics, two fluids are present in the pores: air (non-wetting fluid) and water (wetting fluid). In the reservoir chalk, suction effects develop between oil (non-wetting) and water (wetting). Suction controlled oedometer tests confirm the strengthening influence of the suction: results show the evolution of preconsolidation pressure from a water saturated chalk to an oil quasi-saturated one which is stronger and stiffer.

In order to better understand the compaction phenomenon during water injection in the reservoir, waterflooding experiment are achieved in pressure and stresses reservoir conditions. Experimental results show that compaction appears in the direction of the major stress and deformations follow the water front displacement.

## 3. Finite element modelling

In the CONVILAG finite element code, we develop on one hand a cap model with influence of suction and on the other hand a multiphasic flow model [Collin & al, 2002]. The used coupled finite elements allow us to carry out fully coupled simulation.

The parameters of the models are determined using results of experiment performed on the Lixhe chalk, which is an outcroup chalk belonging to the same formations as the reservoir layers.

### *Saturated chalk sample & waterflooding experiment*

In a first part of simulations, the goal is the validation of our models. Experiment on saturated chalk are modeled in order to check the ability of the constitutive laws to reproduce the different plastic mechanisms of the material.

The computations of waterflooding tests in iso- and anisotropic stress state are presented. Comparisons between numerical and experimental results are made in terms of fluid volume exchanges and local and global deformations measurements.

### *Academic reservoir simulation*

In the second part, a simplified reservoir model is used in order to simulate the production and injection phases. The fully coupled model allows us to reproduce the fluids flows and the compaction observed during the reservoir history.

These computations show the ability of the numerical models to reproduce the observations. They confirm also the validity of the assumptions we made to better understand compactions during water injections in the reservoir.

## 4. Perspectives

An important aspect of chalk behaviour is not taken into account in the model: the time-dependency response of the material. This is one of the topics of the currently running second PASACHALK project.

In the future, reservoir simulations will deal with more complex formations properties and a fully coupled 3D model will be developed.

## 5. References

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