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MODELLING OF TEMPERATURE-CONTROLLED TRIAXIAL COMPRESSION TESTS TO SUPPORT ANALYSIS OF CALLOVO-OXFORDIAN ARGILLITE BEHAVIOR

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Introduction

For certain time period the host rock of the geological repository for high level radioactive waste will be under elevated temperature conditions. Therefore, predictions of disposal system evolution in time requires deep knowledge of material properties and its behaviour under different temperature and mechanical conditions.

Description of the research problem

As a part of research activities within European joint programme EURAD work package HITEC, LEI modelled laboratory experiments which had been performed by Universite de Lorraine (France). These triaxial tests of Callovo-Oxfordian (COx) rock were carried out at different temperatures (20°C, 40°C, 60°C and 80°C) and at different confining pressures (0 MPa, 4 MPa and 12 MPa). In the experiments, the samples were loaded mechanically in two directions: when the direction of the applied load is parallel to the bedding direction and when it is perpendicular to the bedding direction in the sample [1].

Methodology

The purpose of modelling laboratory experiments was to derive the values of the numerical model parameters such as initial yield stress (σ_{01}), hardening modulus (h) used in developed elastoplastic model based on Drucker-Prager soil plasticity model. Temperature dependency of these parameters was analysed too (Fig. 1).

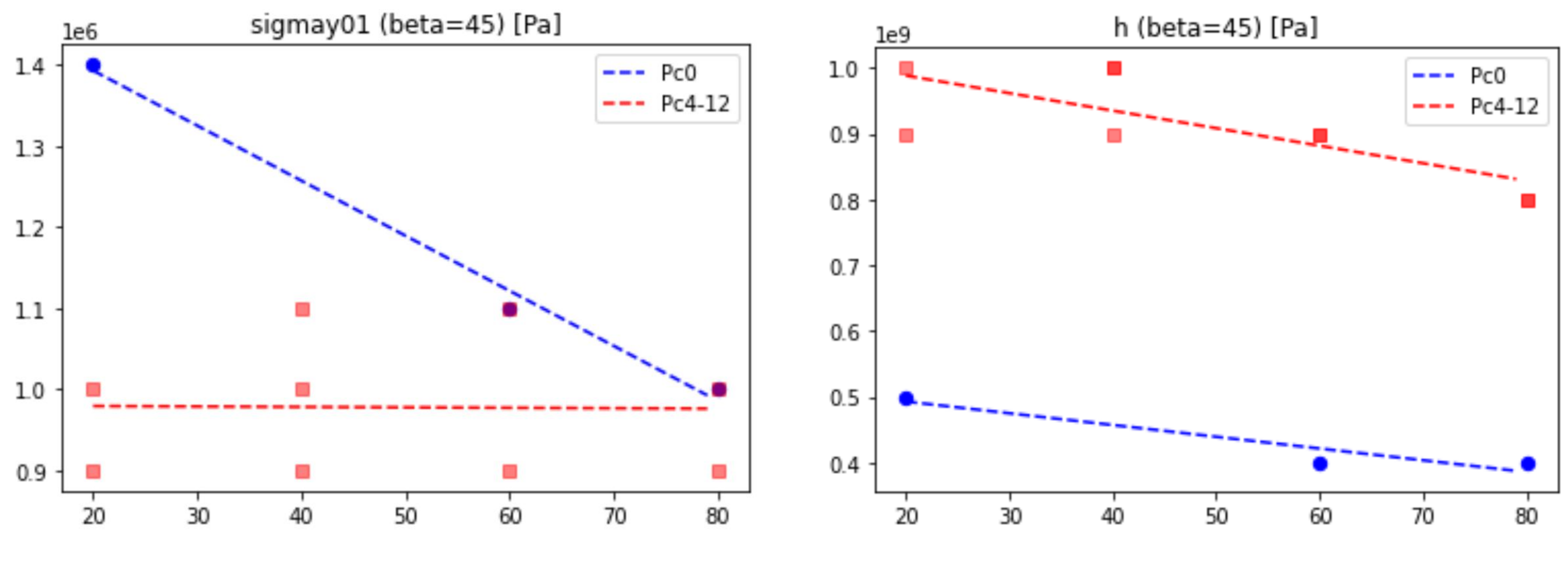

Fig. 1. Fitted initial yield stress (σ_{01}) and hardening modulus (h) against temperature

Yield function definition:

$$F_y = \sqrt{J_2} + \alpha_{DP} I_1 - \left(1 - w\left(\overline{\epsilon_{pm}}\right)\right)\sigma_y(\epsilon_p) \le 0$$

I_1, J_2 - stress tensor invariants, α_{DP}, k - Drucker-Prager model parameters related to friction angle and cohesion, $\sigma_y(\epsilon_p)$ – yield stress, $w(\overline{\epsilon_{pm}})$ – damage variable.

Material softening representation:

$$w\left(\overline{\epsilon_{pm}}\right) = \alpha_p\left[1 - \exp\left(-\beta\overline{\epsilon_{pm}}\right)\right]$$

Hardening controlled via hardening parameter *h*:

$$\sigma_y(\epsilon_p) = \left(\sigma_{y0} + h\epsilon_p\right), h > 0$$

Here $\overline{\epsilon_{pm}}$ – equivalent plastic strain, α_p, β- material parameters. The material parameter β controls the shape of the softening curve, and α_p controls the maximum degradation of the yield stress. The value of α_p typically ranges from 0.96 to 1.0.

For modelling of COx mechanical behaviour numerical 2D axisymmetric models in COMSOL Multiphysics were developed.

Results

Using fitted parameters, the COx specimen was modelled and compared to experimental stress-strain curves obtained with 0, 4 and 12 MPa confining pressure in the maximum load direction perpendicular to the bedding. Comparison of experimental and modelling results for 12 MPa confining pressure at different temperatures is provided in Fig. 2.

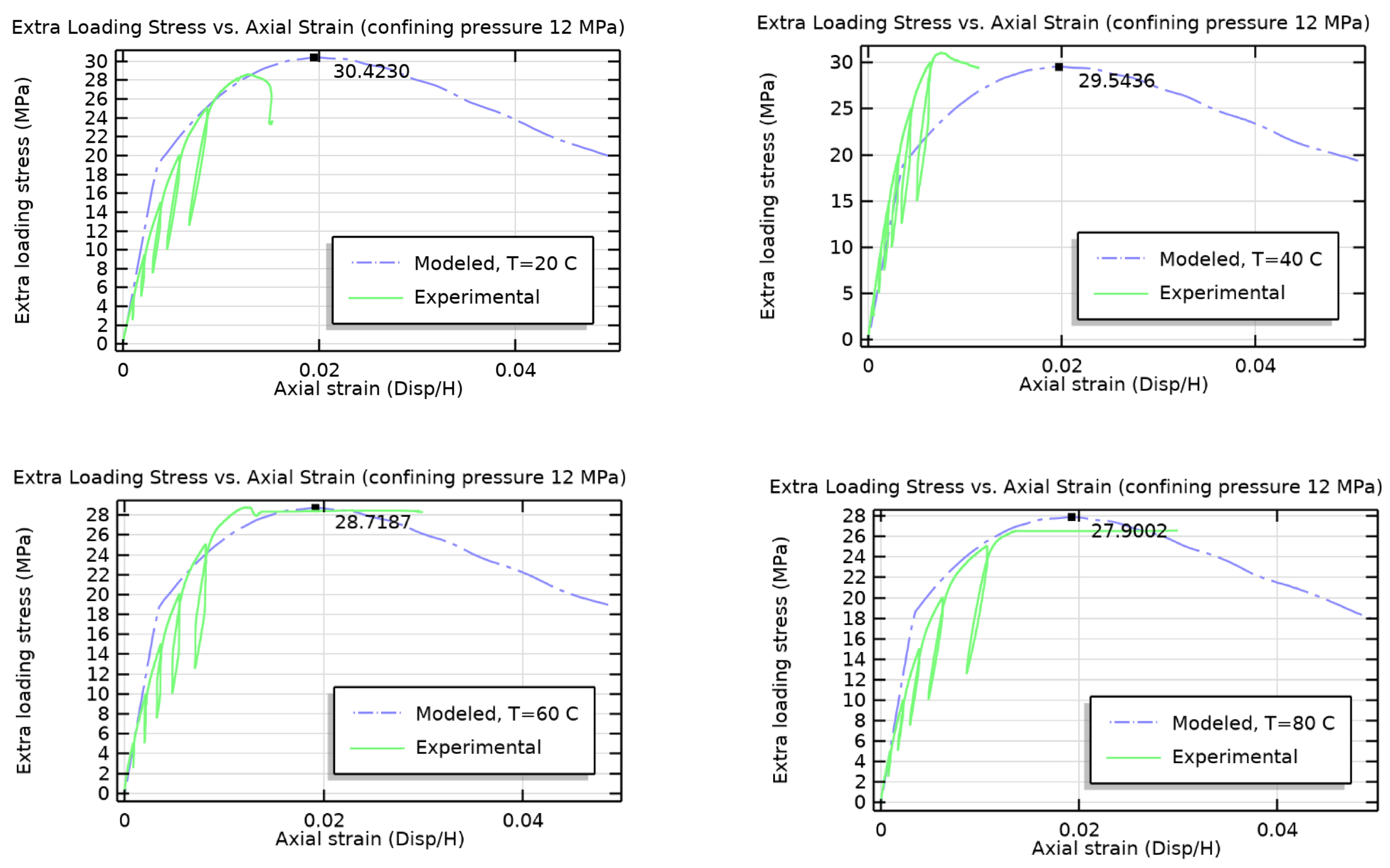

Fig. 2. Comparison of experimental and modelled stress vs axial strain for 12 MPa confining pressure at different temperatures

Experimentally determined peak strength decrease with temperature was successfully modelled considering linear decrease of the hardening modulus with temperature (Fig. 3).

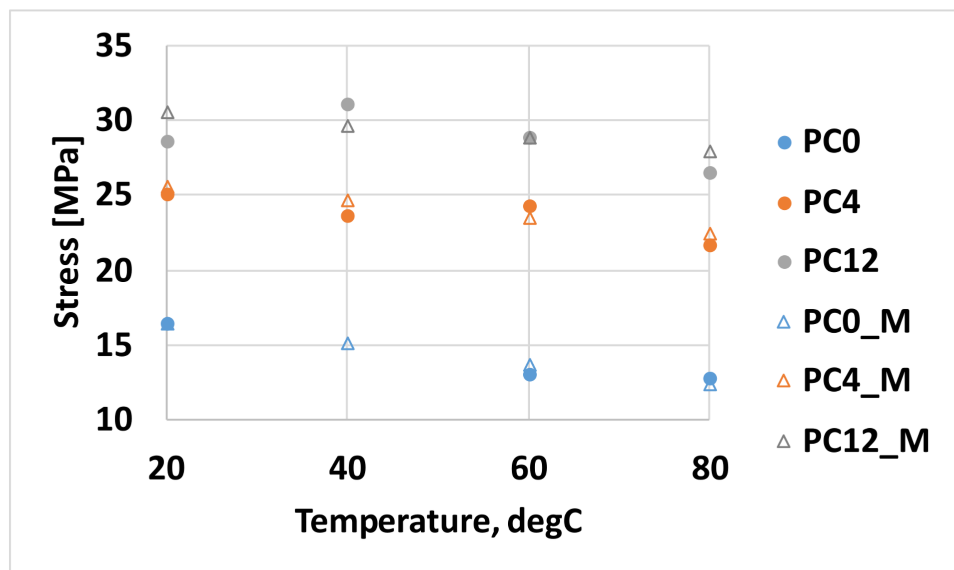

Fig. 3. Comparison of experimental (PC0, PC4, PC12) and modeled peak stress data (PC0_M, PC4_M, PC12_M)

Conclusions

Based on the modelling results, a set of parameters for elastoplastic model (σ_{01}, h, β) was compiled for modelling of thermo-hydro-mechanical response of COx material in-situ experiment ALC1605.

References:

1. C. de Lesquen et al.: Modelling report on the effect of temperature on clay host rocks behaviour. Final version as of 06/06/2024 of deliverable 7.6 of the HORIZON 2020 project EURAD.

Acknowledgments

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