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Thermal strain response of saturated clays in 1D condition

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Thermo-elastoplastic modelling

Total strain increment

$$\mathrm{d}\varepsilon = \mathrm{d}\varepsilon^{\mathrm{me}} + \mathrm{d}\varepsilon^{\mathrm{mp}} + \mathrm{d}\varepsilon^{\mathrm{Te}} + \mathrm{d}\varepsilon^{\mathrm{Tp}}$$

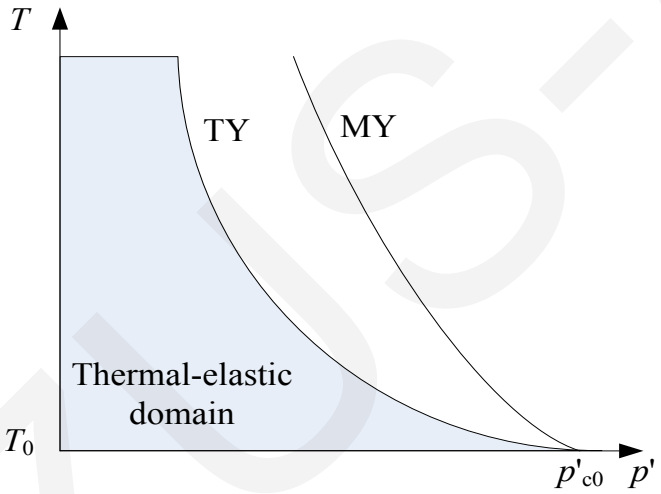
Elastic behavior

$$\mathrm{d}\varepsilon^{\mathrm{e}} = \mathrm{d}\varepsilon^{\mathrm{me}} + \mathrm{d}\varepsilon^{\mathrm{Te}}$$

$$\mathrm{d}\varepsilon_{\mathrm{v}}^{\mathrm{e}} = \frac{\kappa}{1+e}\frac{\mathrm{d}p}{p} - \alpha \mathrm{d}T$$

$$\mathrm{d}\varepsilon_{\mathrm{d}}^{\mathrm{e}} = \frac{2(1+\mu)}{9(1-2\mu)}\frac{\kappa}{1+e}\frac{\mathrm{d}q}{p}$$

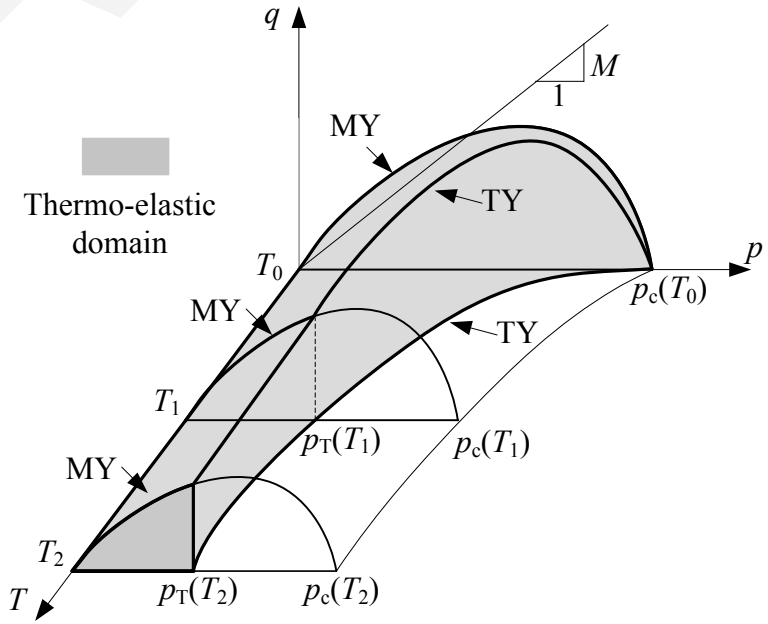
T-p plane



TY

$$\frac{p_{\mathrm{c}(\mathrm{T}_0)}}{p_{\mathrm{T}(\mathrm{T})}} = \beta\sqrt{\ln\frac{T}{T_0}} + 1$$

T-p-q plane



MY

$$\left(\frac{q}{Mp}\right)^{n} = -\frac{\ln(p / p_{\mathrm{c}(\mathrm{T})})}{\ln r_{(\mathrm{T})}}$$

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Thermal plastic strain increments

$$\mathrm{d}\varepsilon_{\mathrm{v}}^{\mathrm{tp}} = \omega\left(T - T_0\right)\left(\frac{p}{p_{\mathrm{c}(T_0)}}\right)^2 \mathrm{d}T$$

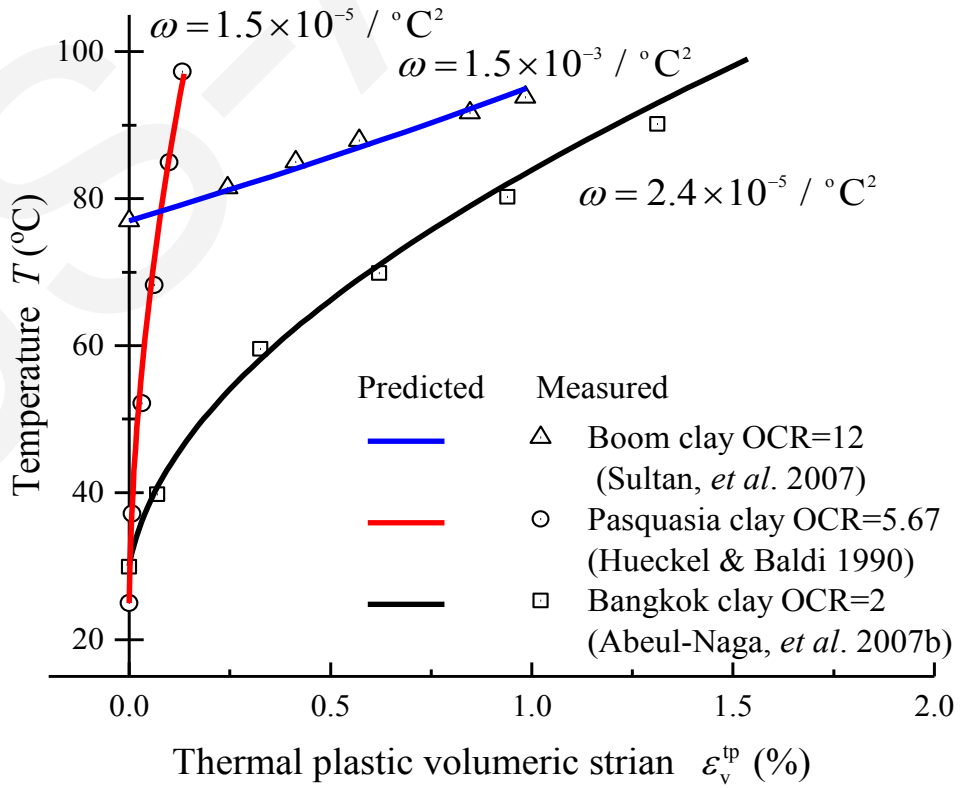
Mechanical plastic strain increments

$$\mathrm{d}\varepsilon_{v}^{\mathrm{mp}} = \mathrm{d}\lambda_{\mathrm{m}} \frac{\partial g^{\mathrm{MY}}}{\partial p}$$

$$\mathrm{d}\varepsilon_{\mathrm{d}}^{\mathrm{mp}} = \mathrm{d}\lambda_{\mathrm{m}} \frac{\partial g^{\mathrm{MY}}}{\partial q}$$

$$g^{\mathrm{MY}} = k \ln\left[1 + (k-1)\left(\frac{\eta}{M}\right)^2\right] + 2(k-1)\ln\left(\frac{p}{C}\right)$$

Temperature effects on the volumetric strain



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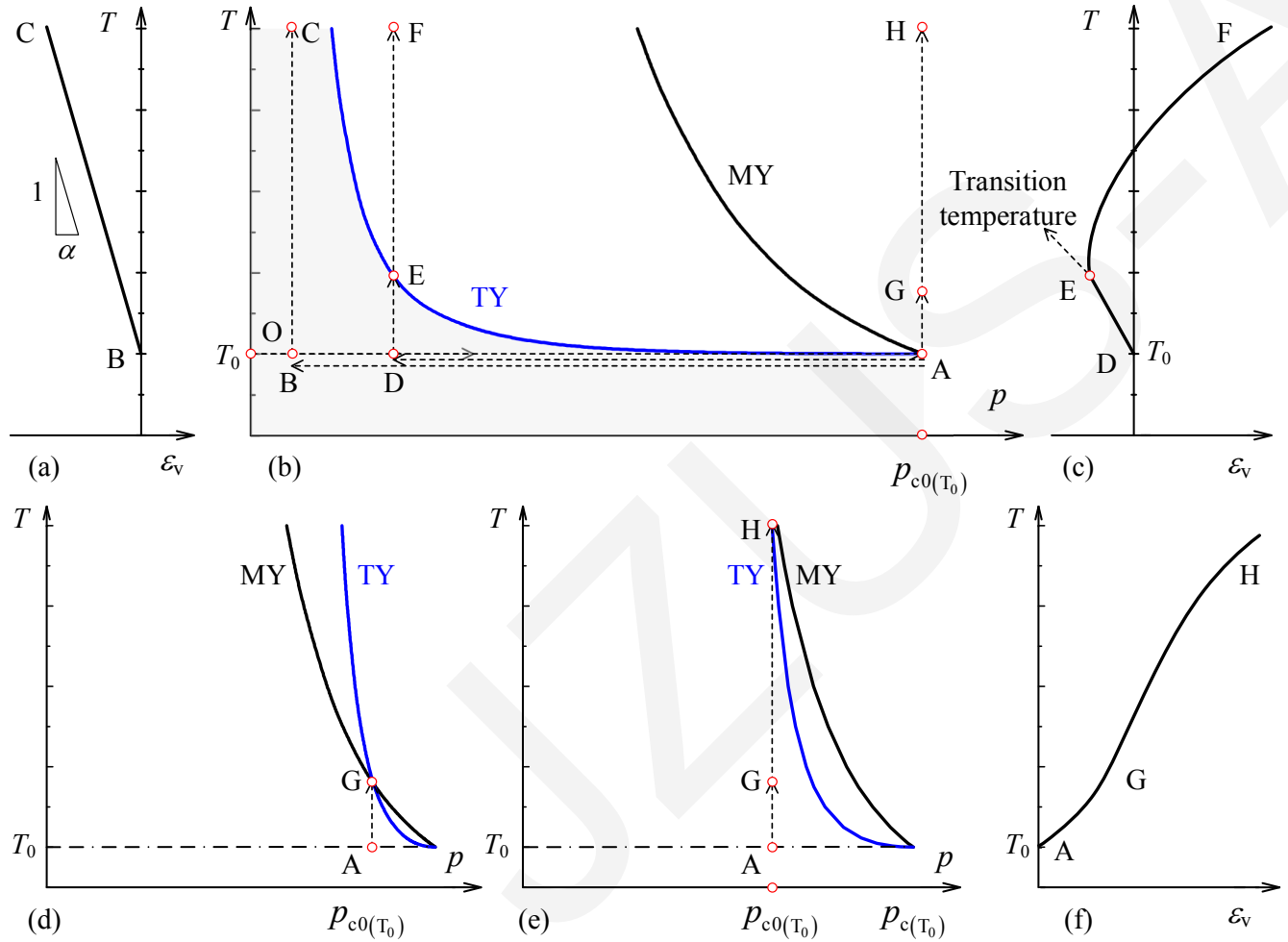
Thermo-elastoplastic modelling

Thermal evoluations of the MY and TY curves in the p-T plane



Explanation of model responses subjected to heating at three typical OCR values

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Model Performance

Thermal volumetric deformation

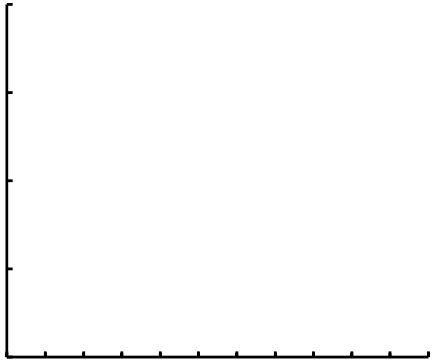

Fig. 3 Thermal volumetric deformation under multiple heating and cooling cycles
(a) OCR=1; (b) OCR=2; (c) OCR=4; (d) OCR=8

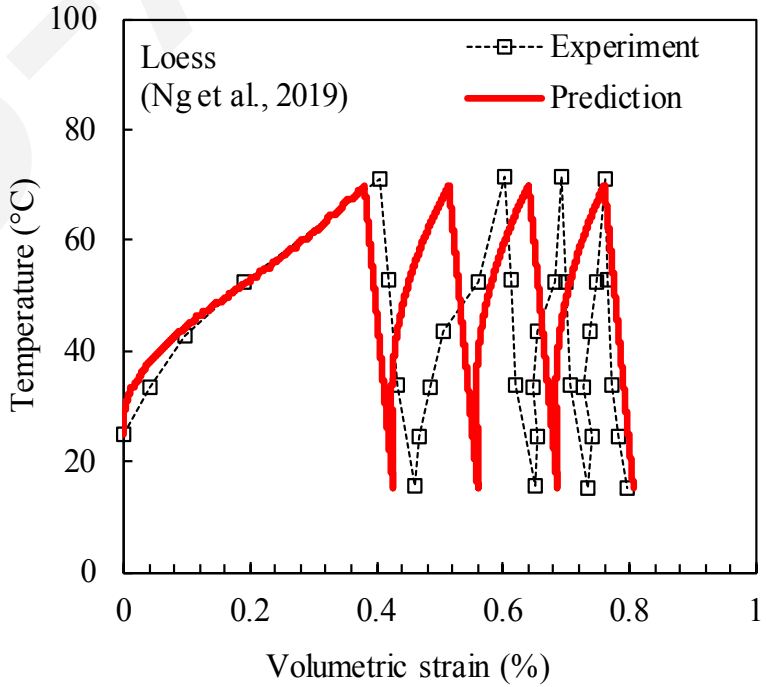

Fig. 5 Modelling the thermal strain of normally consolidated loess under multi-cycles

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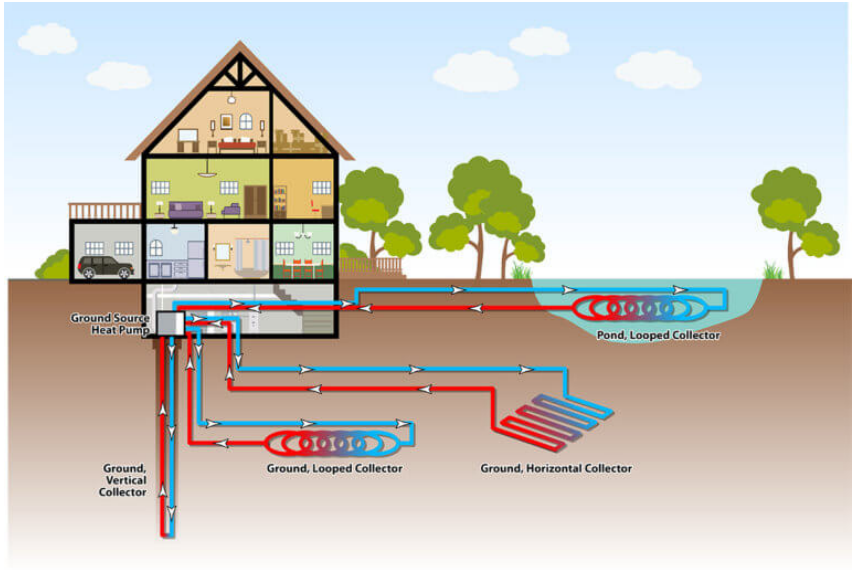
Conclusions

- A thermomechanical two surfaces constitutive model based on the elastoplastic theory is proposed;
- The performance of the model in reproducing the main features of clay thermomechanical volumetric behavior was studied by a set of synthetic tests examined by comparing with the selected temperature-controlled experimental results on illite clay and loess.



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