AD FALCON API Manual

SANICLAY Model (Saturated)

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Contents

1 SANICLAY Model (Saturated)

SANICLAY is an anisotropic critical-state constitutive model for saturated clays. In FALCON it is used as a user-defined mechanical material with evolving anisotropy tensors, a pressure-dependent elastic law, and non-associated plastic flow.

This page gives the compact manual view of the model: input syntax, parameter tables, required custom variables, initialization rules, and the single-point validation set used for the supplied example inputs.

1.1 Syntax

Configure SANICLAY in `% Materials` with `@UMAT:` and category `Mechanical`.

Example:

```
@UMAT: path/to/SANICLAYModelUMAT.cpp path/to/SANICLAYModelUMAT.hpp
Mechanical \
    Nu=0.20 Kappa=0.009 Lambda=0.63 Mc=1.18 Me=0.86 N=0.91 x=1.56 C=16.0 \
    P_min=1e-6 STOL=1e-3 FTOL=1e-8 LTOL=1e-6 \
    CustomVariable=P0,Pa,OCR,initialvoidratio,AlphaXX,AlphaYY,AlphaZZ,
AlphaZY,AlphaZX,AlphaXY,BetaXX,BetaYY,BetaZZ,BetaZY,BetaZX,BetaXY
```

Write the full `@UMAT:` command on one line in the actual input file. For readability it is wrapped here.

Example inputs used on this page:

Case family	Input
K0-consolidated undrained triaxial compression/extension	CK0UC.txt, CK0UE.txt
Isotropically consolidated undrained triaxial compression/extension	CIUC.txt, CIUE.txt
Drained triaxial compression	CK0DC.txt, CIDC.txt
Baseline single-element verification input	input.txt

1.2 Material parameters

1.2.1 Core model parameters

Symbol	Keyword in input	Required	Role
nu	Nu	Yes	Poisson ratio.
kappa	Kappa	Yes	Swelling or reloading index.
lambda	Lambda	Yes	Virgin compression index.
M_c	Mc	Yes	Critical-state stress ratio in triaxial compression.
M_e	Me	Yes	Critical-state stress ratio in triaxial extension.
N	N	Yes	Yield-surface shape parameter.
x	x	Yes	Anisotropy saturation parameter linking the two anisotropy tensors.
C	C	Yes	Rotational hardening rate parameter.

1.2.2 Numerical controls

Keyword in input	Required	Role
P_min	Yes	Positive floor for pressure-dependent terms.
STOL	Yes	Local stress-integration tolerance.
FTOL	Yes	Yield-surface tolerance.
LTOL	Yes	Load-unload detection tolerance.

The SANICLAY page focuses on the production parameters and required history variables. Debug-only diagnostics are intentionally omitted here.

1.3 Custom state variables

Declare SANICLAY history variables with `CustomVariable=`.

Name	Required	Role
`P0`	Yes	Isotropic yield-surface size or preconsolidation variable.
`Pa`	Recommended	Plastic-potential size used by the non-associated formulation.
`OCR`	Yes	Initialization multiplier used to keep the current stress state on or inside yield after conditioning.
`initialvoidratio`	Yes	Initial void ratio used in the elastic and hardening laws.
`AlphaXX`, `AlphaYY`, `AlphaZZ`, `AlphaZY`, `AlphaZX`, `AlphaXY`	Recommended	Components of the anisotropy tensor `alpha`.
`BetaXX`, `BetaYY`, `BetaZZ`, `BetaZY`, `BetaZX`, `BetaXY`	Recommended	Components of the anisotropy tensor `beta`.

Recommended practice:

- Initialize `initialvoidratio` to the same value as the starting void ratio.
- Always provide the full `alpha` and `beta` tensors for staged or restarted analyses.
- Keep `OCR >= 1`.

1.4 Model summary

1.4.1 Elastic law

SANICLAY uses a pressure-dependent elastic bulk modulus with the initial void ratio held as a stored history variable:

$$K = \frac{(1 + e_{\text{in}})\, p}{\kappa}, \qquad G = \frac{3(1 - 2\nu)}{2(1 + \nu)} K$$

where `initialvoidratio` supplies `e_in`.

1.4.2 Yield surface

With the shifted deviatoric stress

$$\mathbf{t} = \mathbf{s} - p\, \mathrm{dev}(\boldsymbol{\beta}),$$

the yield function is written as

$$f = \bar{q}^2 - (N^2 - \beta^2)\, p\, (P_0 - p), \qquad \bar{q}^2 = \tfrac{3}{2}\, \mathbf{t} : \mathbf{t}.$$

1.4.3 Plastic potential

With

$$\mathbf{u} = \mathbf{s} - p\, \mathrm{dev}(\boldsymbol{\alpha}),$$

the non-associated plastic potential is

$$g = u^2 - (M^2 - \alpha^2)\, p\, (P_a - p), \qquad u^2 = \tfrac{3}{2}\, \mathbf{u} : \mathbf{u}.$$

1.4.4 Hardening variables

SANICLAY evolves:

- `P0` for isotropic hardening,
- `alpha` for the plastic-potential anisotropy,
- `beta` for the yield-surface anisotropy.

The model therefore needs both scalar and tensor history to be initialized consistently.

1.5 Initialization and conditioning

Before stress integration, SANICLAY conditions the history so the current state is admissible and consistent with the stored anisotropy.

Key points:

- `P0` is enlarged if required so the current stress point lies on or inside the yield surface.
- `Pa` is recomputed so the plastic potential passes through the current stress point.
- `OCR` provides an interior offset so the conditioned state is not placed exactly on the yield boundary unless intended.
- `alpha` and `beta` are kept within their admissible bounds so denominator terms remain positive.
- `initialvoidratio` should remain consistent with the elastic compression law when `P0` is reset during conditioning.

For staged analyses, define the initial stress field and custom variables consistently before the first constitutive update.

1.6 Validation inputs

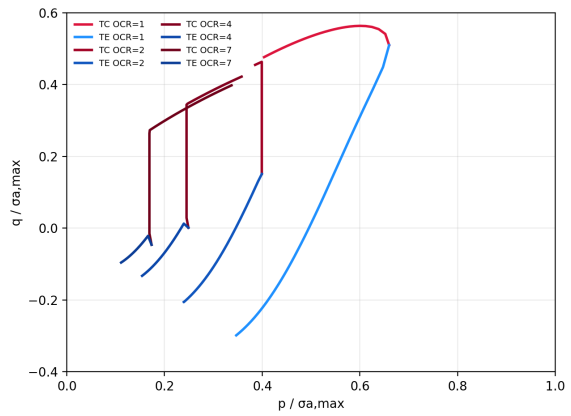
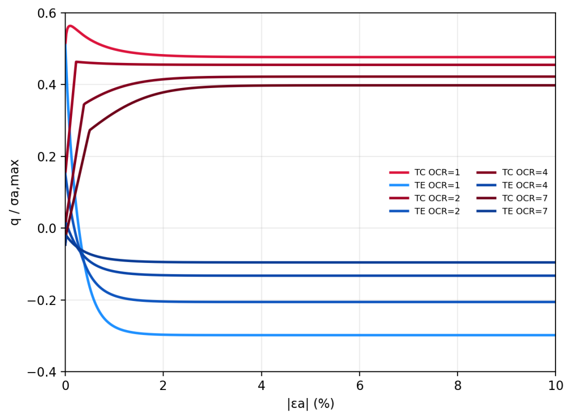
The supplied single-point validation set covers:

Family	Consolidation	Drainage	Sweep
CKo undrained triaxial compression and extension	Ko	Undrained	OCR
CI undrained triaxial compression and extension	Isotropic	Undrained	OCR
Anisotropic consolidation response	Anisotropic	Undrained	Kc
Plane-strain compression	Ko	Undrained	OCR
Drained triaxial compression	Ko and isotropic	Drained	OCR
Drained anisotropic triaxial compression	Anisotropic	Drained	Kc
Probe tests	Ko	Drained	Loading path

The validation plots below use paired layouts so the stress-path and stress-strain views for each benchmark family are read together.

1.7 Single-Point Validation

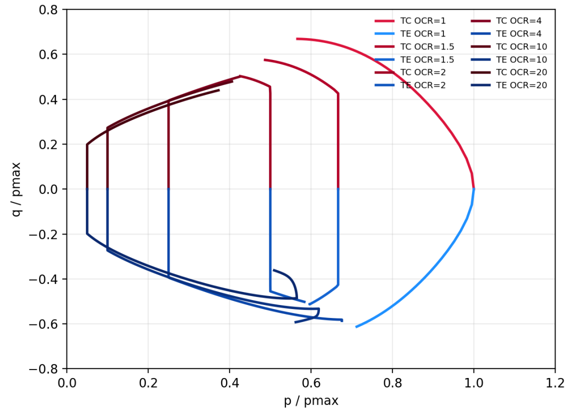
1.7.1 CKo-consolidated undrained triaxial compression and extension

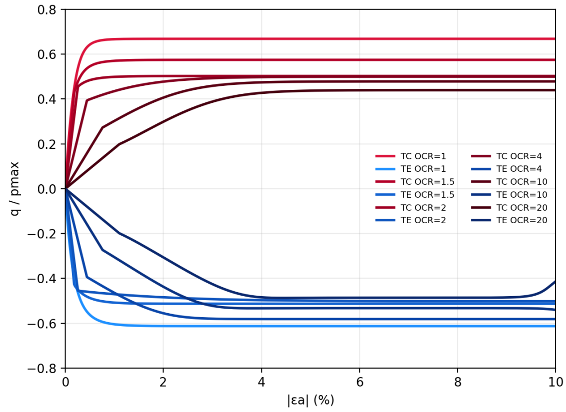
Stress path	Stress-strain
	

1.7.2 Isotropically consolidated undrained triaxial compression and extension

Stress path

Stress-strain

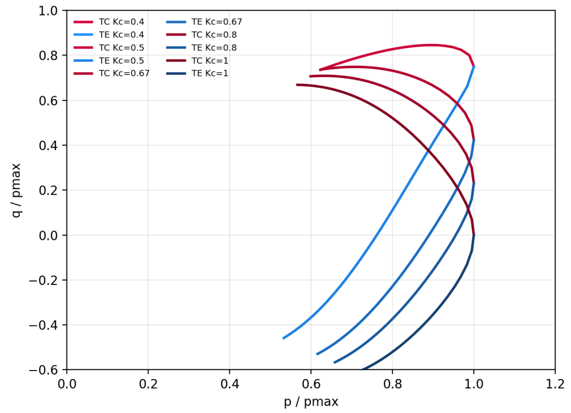


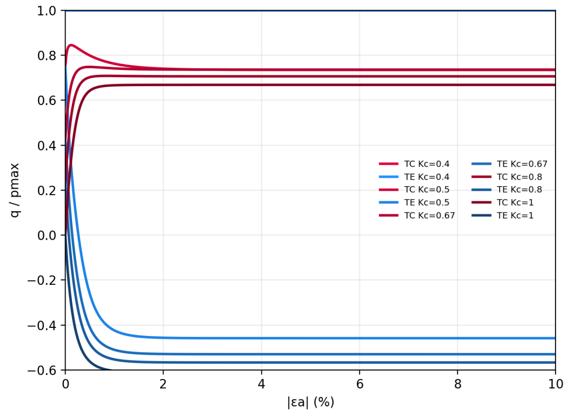


1.7.3 Anisotropic consolidation effect

Stress path

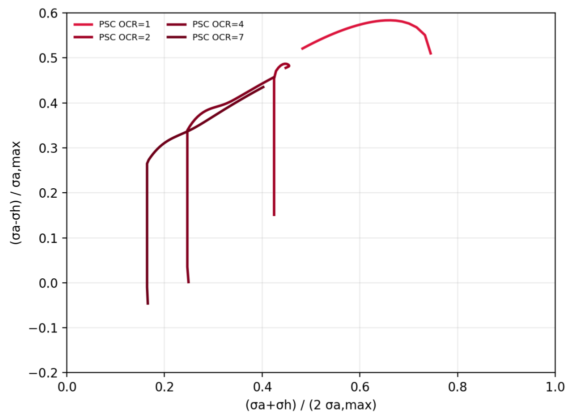
Stress-strain



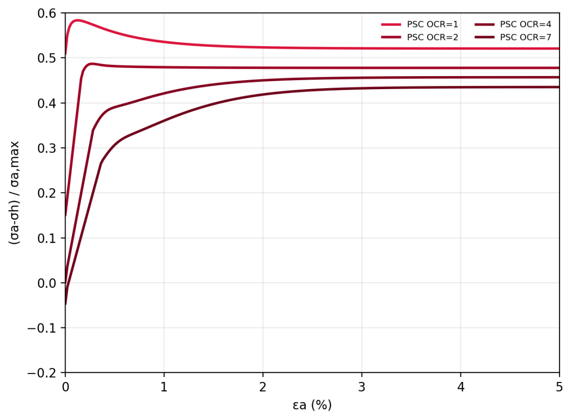


1.7.4 Plane-strain compression

Stress path

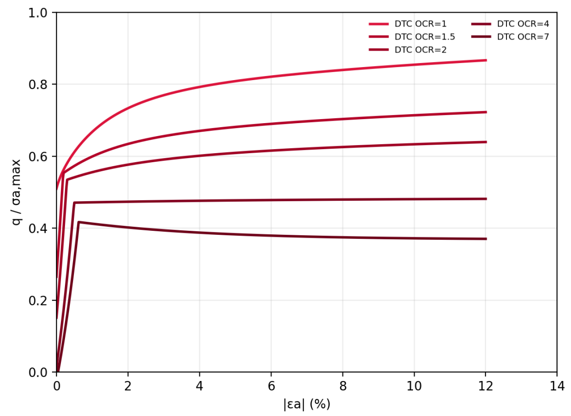


Stress-strain

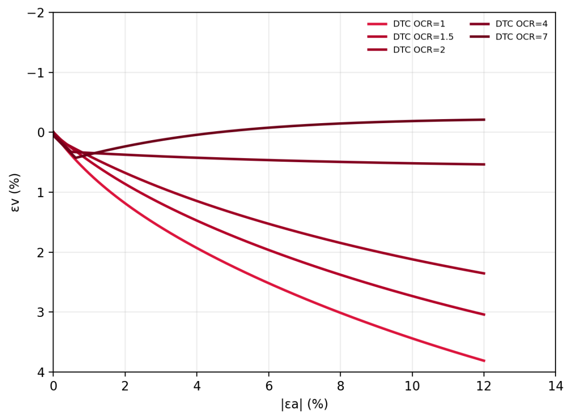


1.7.5 K0-consolidated drained triaxial compression

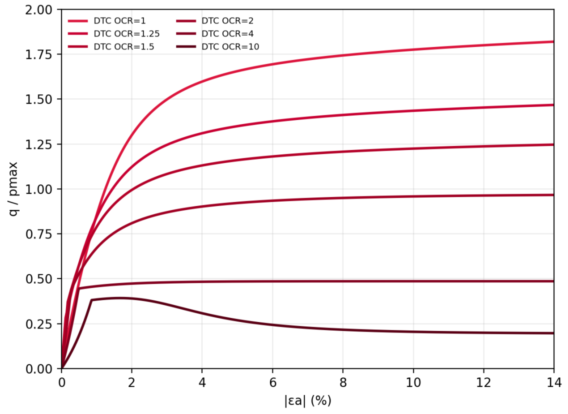
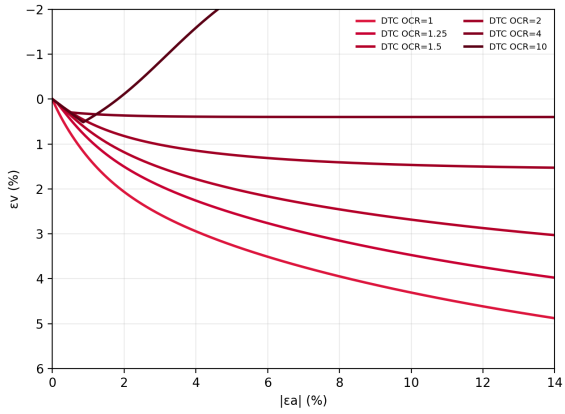
Stress-strain



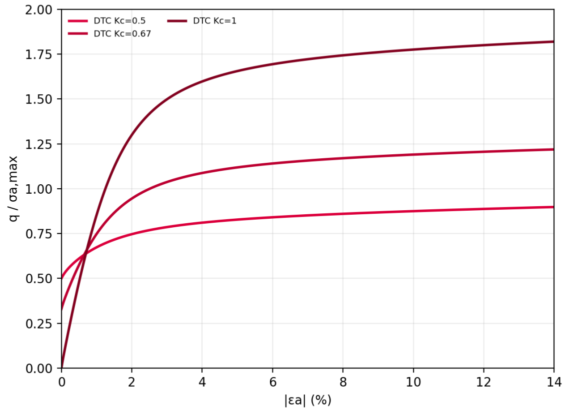
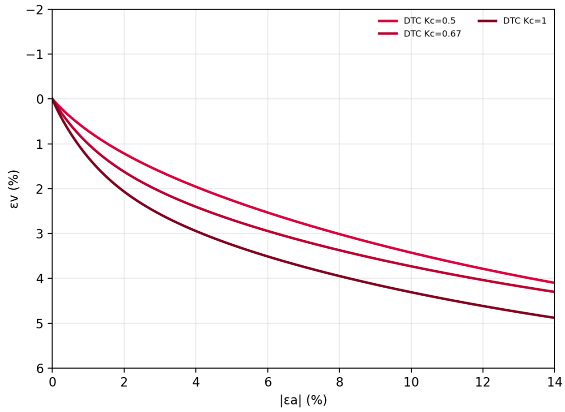
Volumetric strain



1.7.6 Isotropically consolidated drained triaxial compression

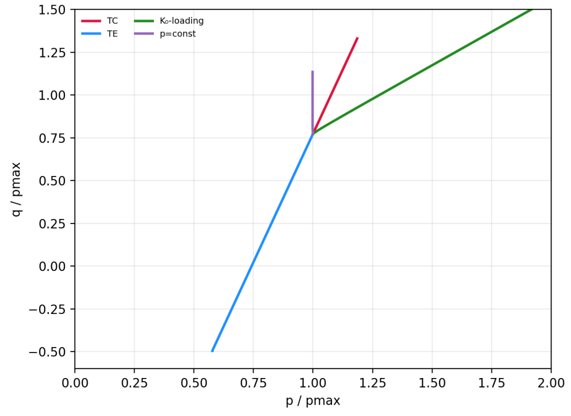
Stress-strain	Volumetric strain
	

1.7.7 Anisotropic drained triaxial compression

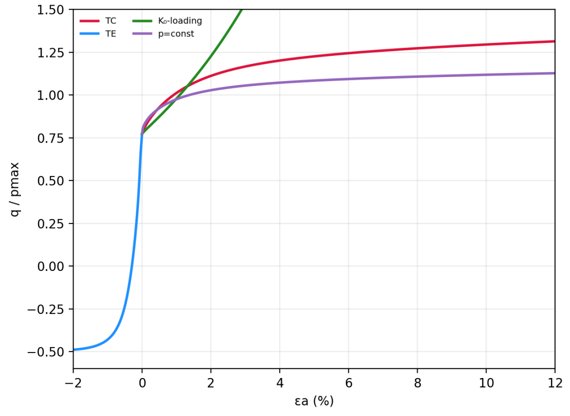
Stress-strain	Volumetric strain
	

1.7.8 Probe tests

Stress path



Stress-strain



1.8 References

- Dafalias, Y. F., Manzari, M. T., and Papadimitriou, A. G. (2006). Simple anisotropic clay plasticity model. *International Journal for Numerical and Analytical Methods in Geomechanics*, 30, 1231-1257.