AD FALCON API Manual

1D Soil Column under Top Pressure: Small- vs Large-Deformation

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March 26, 2026

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1 1D Soil Column under Top Pressure: Small- vs Large-Deformation

1.1 Input File Name

fem_Meroi.txt

1.2 Problem Description

We model an **axisymmetric soil column** of height $10\,\mathrm{m}$ and radius $1\,\mathrm{m}$ subjected to a uniform surface pressure.
The soil is treated as **linear elastic** and the analysis is fully coupled (pore-pressure–deformation).
We compare the classical small-strain formulation against an updated-Lagrangian (large-deformation) approach to investigate the effects of geometric nonlinearity under large deformations.

1.3 Geometry & Mesh

- **Domain**:
  - Radial extent: $0 \leq r \leq 1\,\mathrm{m}$
  - Vertical extent: $0 \leq z \leq 10\,\mathrm{m}$
- **Mesh**: 6-node triangular elements (40 elements, 123 nodes)
- **Analysis type**: AXCoupled (axisymmetric, fully coupled consolidation)

1.4 Material & Hydraulic Properties

- **Linear elastic** UMAT
  - Young's modulus: $E = 1 \times 10^{6}\,\mathrm{kPa}$
  - Poisson's ratio: $\nu = 0.01$
- **Intrinsic permeability**: $k_{\mathrm{sat}} = 1.0 \times 10^{-7}\,\mathrm{m}^2$
- **Hydraulic conductivity**:

$$k\ (\mathrm{m/s}) = \frac{k_{\mathrm{sat}}\,\gamma_w}{\mu} \tag{1}$$

- **Fluid**: density $\rho_w = 997\,\mathrm{kg/m^3}$, dynamic viscosity $\mu = 1 \times 10^{-6}\,\mathrm{Pa \cdot s}$

1.5 Boundary Conditions

- **Axis of symmetry** at $r = 0$: radial displacement fixed ($u_r = 0$)
- **Lateral boundary** at $r = 1\,\mathrm{m}$: radial displacement fixed ($u_r = 0$), impermeable
- **Bottom boundary** at $z = 0$: fully fixed ($u_r = u_z = 0$), impermeable
- **Top surface** at $z = 10\,\mathrm{m}$: drained ($p_w = 0$, $p_a = 0$), applied normal pressure ramped from 0 to $1.0 \times 10^6\,\mathrm{kPa}$

1.6 Loading & Time Stepping

- **Applied pressure** on top surface: $p = 1.0 \times 10^6\,\mathrm{kPa}$ (ramped linearly from 0)
- **Total time**: $T = 10{,}000\,\mathrm{s}$
- **Time increments**: 50 equal steps of $\Delta t = 200\,\mathrm{s}$
- **Solver**: Direct (SparseLU)

1.7 Formulations Compared

1. **Small-strain** (linearized geometry; strains assumed infinitesimal)
2. **Large-deformation** (updated-Lagrangian; geometry updated each increment)

1.8 Results

Figure: Normalized surface settlement under the applied pressure, comparing the small-strain formulation to the updated-Lagrangian (large-deformation) solution. The analytical solution is from Meroi et al. (1995).

1.9 References

1. Meroi, E.A., Schrefler, B.A., & Zienkiewicz, O.C. (1995). Large strain static and dynamic semisaturated soil behaviour. *International Journal for Numerical and Analytical Methods in Geomechanics*, 19(2), 81-106.

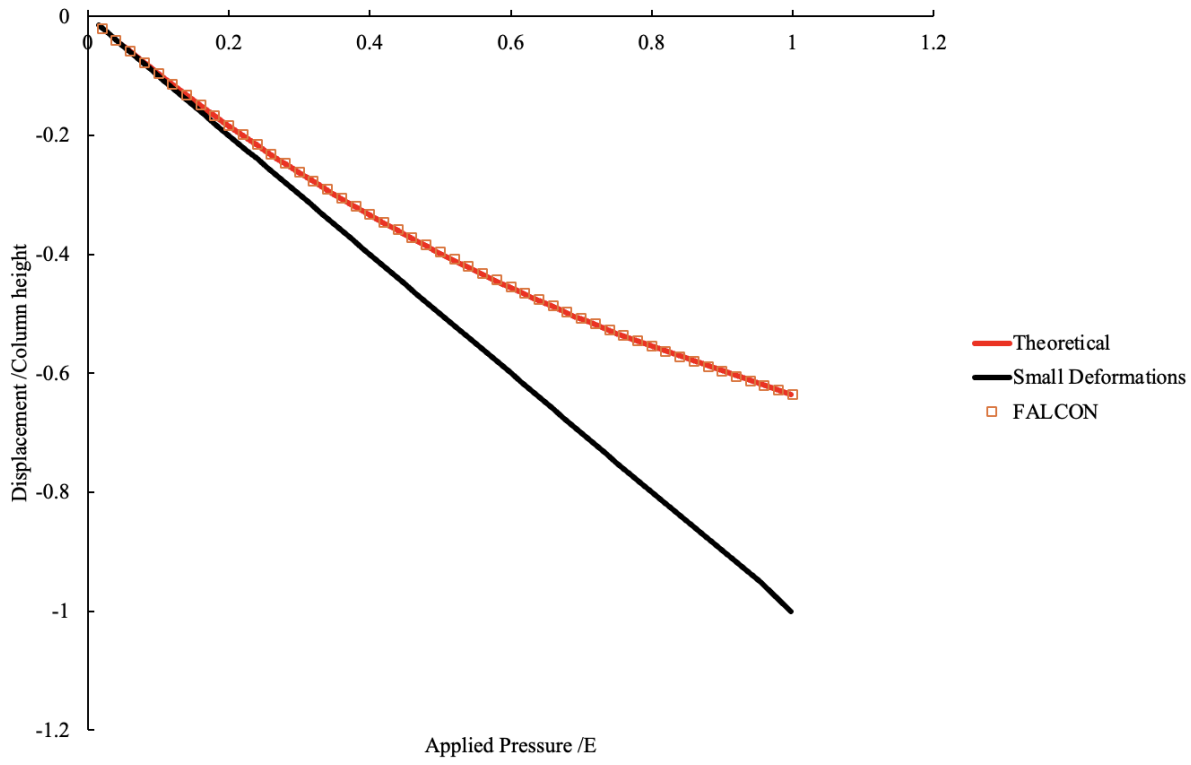

Figure 1: Figure: Top settlement – small vs large deformation