Simulation of Complex Stress-Paths Using the Manzari-Dafalias Bounding Surface Model

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Constitutive Modeling Issues

• General 3D constitutive models offer the possibility to capture the response of the soil to multiple loading conditions, but, require the calibration of several parameters.

• Stress paths in 3D-FEM simulations are very variable and impose severe conditions to constitutive models. These stress paths are sometimes beyond what is observed in laboratory stress paths.

• Accurate solutions are only possible if the constitutive model is robust and its implementation efficient.
Soil-Structure Interaction Problems
Manzari-Dafalias Model (1997)

Yield surface
\[ f = \eta - \alpha + m \]

Bounding surface
\[ M_c^b = \alpha_c^b + m = M_c + k_c^b (-\psi) \]
\[ M_e^b = \alpha_e^b + m = M_e + k_e^b (-\psi) \]

Dilatancy surface
\[ M_c^d = \alpha_c^d + m = M_c + k_c^d \psi \]
\[ M_e^d = \alpha_e^d + m = M_e + k_e^d \psi \]

Critical surface
\[ M_c = \alpha_c^c + m \]
\[ M_e = \alpha_e^c + m \]
Manzari-Dafalias Model (1997)

Yield surface

\[ f(\sigma, \alpha, m) = \partial E_\sigma \]

Surface in \( \pi \) plane

\[ f(\sigma, \alpha, m) = \|r\| - \sqrt[3]{2m}\rho \]

where, \( r = s - p\alpha \)

\[ L = n - \frac{1}{3}N1 \]
\[ m = n + \frac{1}{3}D1 \]
\[ \dot{\varepsilon}^p = \gamma m(\sigma, \alpha, m) \]

\[ D = A(\alpha_d^d - \alpha) : n = Ad : n \]
\[ A = A_o(1 + \langle F : n \rangle) \]
\[ \dot{F} = -\langle \gamma \rangle C_f (-D)(F_{\text{max}}n + F) \]
Experimental Program: Stress Paths in the Deviatoric Plane

Specimen Preparation Direction

DT and DR stress paths

CCT stress path

UCTC stress path

UCSS\textsubscript{30} stress path

UCSS\textsubscript{90} stress path
Yamada and Ishihara (1983) studied liquefaction behavior of material under similar stress path.

- Identify volumetric-stress-strain response under a complex loading.
- Identify effect of Lode angle.
- Understand precise phase transformation behavior.
- a to b (TC) and b-e-c ($\theta = 0^\circ \rightarrow 360^\circ$).
- Oscillation between c and e.
• Rotational Stress Path Test Example
• Rotational Stress Path
Test Example
CCT Model Simulation

Circular cyclic test

- Experiment
- Simulation