The TzSimple1 Material

uniaxialMaterial TzSimple1 matTag? tzType? tult? z50? <c>

The above command constructs a simple uniaxial t-z material for use with a zeroLength element. The argument matTag is used to uniquely identify this uniaxialMaterial object among uniaxialMaterial objects in the BasicBuilder object. The argument tzType currently can be:

tzType = 1   Backbone of t-z curve approximates Reese & O'Neill (1987) relation.

tzType = 2   Backbone of t-z curve approximates Mosher (1984) relation.

The argument tult is the ultimate capacity of the t-z material. Note that "t" or "t_{ult}" are shear stresses [force per unit area of pile surface] in common design equations, but are both loads for this uniaxialMaterial [i.e., shear stress times the tributary area of the pile].

The argument z50 is the displacement at which 50% of tult is mobilized during monotonic loading.

The optional argument c is the viscous damping term (dashpot) on the far-field (elastic) component of the displacement rate (velocity). This argument defaults to zero. Nonzero c values are used to represent radiation damping effects.

The equations for TzSimple1 and a few examples of its cyclic loading response are given in an attached document.

Appendix: Equations and Example Responses for the TzSimple1 Material

The equations describing TzSimple1 behavior are similar to those for p-y elements in Boulanger, R. W., Curras, C. J., Kutter, B. L., Wilson, D. W., and Abghari, A. (1999). "Seismic soil-pile-structure interaction experiments and analyses." Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 125(9): 750-759.

The nonlinear t-z behavior is conceptualized as consisting of elastic (t-z^e) and plastic (t-z^p) components in series. Radiation damping is modeled by a dashpot on the "far-field" elastic component (t-z^e) of the displacement rate. Note that $z = z^e + z^p$, and that $t = t^e = t^p$.

The plastic component is described by:

$$t^p = t_{ult} - \left(t_{ult} - t_o^p\right)\left[\frac{c \cdot z_{50}}{c \cdot z_{50} + \left|z^p - z_o^p\right|}\right]^n$$

where t_{ult} = the ultimate resistance of the t-z material in the current loading direction, $t_o^p = t^p$ at the start of the current plastic loading cycle, $z_o^p = z^p$ at the start of the current plastic loading cycle, and c = a constant and n = an exponent that define the shape of the t-z^p curve.

The elastic component can be conveniently expressed as:

$$t^e = C_e \cdot \frac{t_{ult}}{z_{50}} \cdot z^e$$

where C_e = a constant that defines the normalized elastic stiffness. The value of C_e is not an independent parameter, but rather depends on the constants c & n (along with the fact that $t = 0.5t_{ult}$ at $z = z_{50}$).

The flexibility of the above equations can be used to approximate different t-z backbone relations. Reese and O'Neill's (1987) recommended backbone for drilled shafts is closely approximated using c = 0.5, n = 1.5, and $C_e = 0.708$. Mosher's (1984) recommended backbone for axially loaded piles in sand is closely approximated using c = 0.6, n = 0.85, and $C_e = 2.05$. TzSimple1 is currently implemented to allow use of these two default sets of values. Values of t_{ult} and z_{50} must then be specified to define the t-z material behavior.

Viscous damping on the far-field (elastic) component of the t-z material is included for approximating radiation damping. For implementation in OpenSees the viscous damper is placed across the entire material, but the viscous force is calculated as proportional to the component of velocity (displacement rate) that developed in the far-field elastic component of the material. In addition, the total force across the t-z material is restricted to t_{ult} in magnitude so that the viscous damper cannot cause the total force to exceed the near-field soil capacity. Users should also be familiar with numerical oscillations that can develop in viscous damper forces under transient loading with certain solution algorithms and damping ratios. In general, an HHT algorithm is preferred over a Newmark algorithm for reducing such oscillations in materials like TzSimple1.

Examples of the cyclic loading response of TzSimple1 are given in the following plots. Note that the response for tzType = 2 has greater nonlinearity at smaller displacements (and hence greater hysteretic damping) and that it approaches t_{ult} more gradually (such that t/t_{ult} is still well below unity at $4z_{50}$).

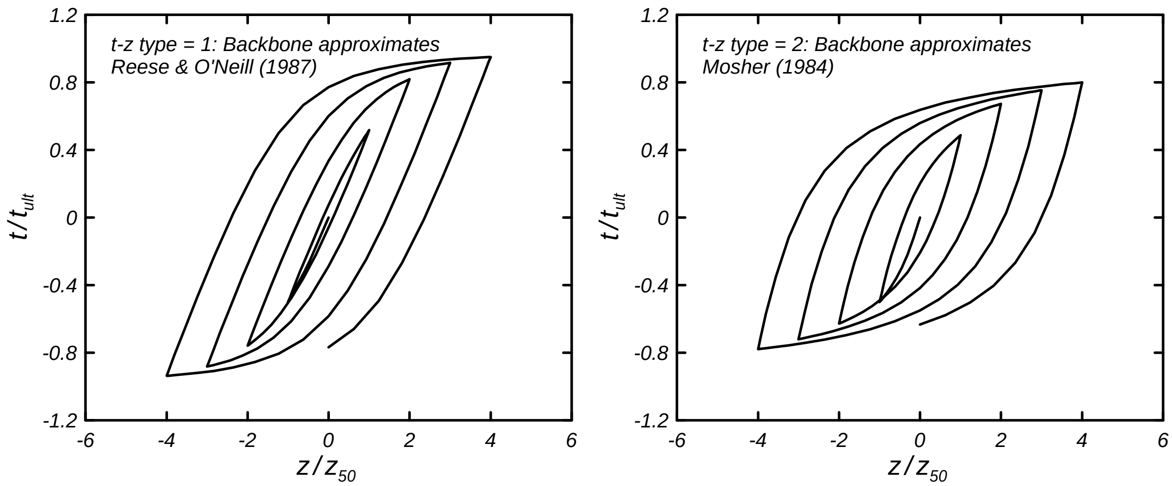

FIG. Examples of cyclic loading response for tzType = 1 and tzType = 2.