CycLiq - A Unified Plasticity Model for Large Post-liquefaction Shear Deformation of Sand

(DLL for FLAC^{3D} 5.0)

Description

CycLiq is a unified constitutive model for large post-liquefaction shear deformation of sand (Wang et al, 2014; Wang 2014/2016). The model provides a unified description of sand of different conditions from pre- to post-liquefaction under monotonic and cyclic loading, based on mechanisms proposed by Zhang and Wang (2012).

During undrained/partially drained cyclic shearing of sand, accumulation of shear strain has been observed at the zero effective stress state of liquefaction. This accumulation increases with loading cycle numbers but is bounded to a limited value. The CycLiq model provides physically based computation of the generation and accumulation of shear strain at zero effective stress.

Through the appropriate formulation of two dilatancy components, namely reversible and irreversible, the model explicitly links the phenomenon of cyclic mobility to soil dilatancy, providing excellent modelling capabilities for both monotonic and cyclic response of sand.

The state parameter Ψ was incorporated into the model for compatibility with the critical state soil mechanics concept. The model was unified to allow the simulation of sand at different relative densities and confining pressures with a same set of parameters.

Using a cutting-plane algorithm with substepping as the stress integration scheme, and the Pegasus procedure to locate the projection of current stress state on the maximum stress ratio surface, the model is implemented in FLAC3D (Version 5.0) (Zou et al, 2018), making it openly available to the technical community.

The constitutive model and its numerical implementation have been validated against drained and undrained triaxial experiments, undrained cyclic torsional experiments and centrifuge experiments, and used to analysis on structures in liquefiable ground (Wang, 2014; Wang et al, 2016, 2017; Chen et al, 2018; Zou et al, 2019)，showing the great capabilities of the model in simulating sand response of a wide range of densities and confining pressure, and highlighting its advantage in simulating large post-liquefaction shear deformations.

A detailed description and applications may be found in the following publications:

[1] WANG Rui, ZHANG Jian-min, WANG Gang. A unified plasticity model for large post-liquefaction shear deformation of sand[J]. Computers and Geotechnics, 2014, 59(3): 54－66.

[2] Wang R., Zhang J.M., Wang G., 2014. A unified plasticity model for large post-liquefaction shear deformation of sand. Computers and Geotechnics. 59, 54-66. 10.1016/j.compgeo.2014.02.008

[3] Zhang J.M., Wang G., 2012. Large post-liquefaction deformation of sand, part I: physical mechanism, constitutive description and numerical algorithm. Acta Geotechnica, 7(2): 69-113.

[4] ZOU You-xue, WANG Rui, ZHANG Jian-min. Implementing a plasticity model for large post-liquefaction deformation of sand into the FLAC^{3D} program. Rock and Soil Mechanics, 2018, 39(4): 1525—1534. (in Chinese)

[5] Wang R., Liu X., Zhang J.M. 2017. Numerical analysis of the seismic inertial and kinematic effects on pile bending moment in liquefiable soils. Acta Geotechnica, 12 (4), 773-791. 10.1007/s11440-016-0487-z

[6] Wang R., Fu P, Zhang J.M. 2016. Finite Element Model for Piles in Liquefiable Ground. Computers and Geotechnics. 72, 1-14. 10.1016/j.compgeo.2015.10.009

[7] ZOU You-xue, WANG Rui, ZHANG Jian-min. Analysis for the seismic response of stone columns composite foundation in liquefiable soils . Rock and Soil Mechanics, 2019,40(6): DOI：10.16285/j.rsm.2017.0852. (in Chinese)

[8] Chen R.R., Taiebat M., Wang R., Zhang J.M. 2018. Effects of layered liquefiable deposits on the seismic response of an underground structure. Soil Dynamics and Earthquake Engineering, 113: 124-135. 10.1016/j.soildyn.2018.05.037

Input parameters

Table 1 Model parameters and Description

Type	Parameter Name	Physical meaning	FLAC3D property name
Elastic modulus constants	G_o	Shear modulus index	G01
	κ	Rebound modulus index	kappa1
Plastic modulus parameter	h	Plastic modulus index	h1
Critical state parameters	M	Critical state stress ratio	Mc1
	λ_c	Critical state line parameters in the *e*-*p* space	lamdac1
	e_0		e01
	ξ		ksi1
State parameter constants	n^p	Plastic modulus state constant	nb1
	n^d	Reversible dilatancy state constant	nd1
Reversible dilatancy paramters	$d_{re,1}$	Reversible dilatancy generate rate	dre11
	$d_{re,2}$	Reversible dilatancy release rate	dre21

Type	Parameter Name	Physical meaning	FLAC3D property name
Irreversible dilatancy paramters	d_{ir}	Irreversible dilatancy rate	dir1
	α	parameter controlling the decrease rate of irreversible dilatancy	eta1
	$\gamma_{d,r}$	reference shear strain length	rdr1

Table 2 Material parameters and Description

Type	Parameter Name	Physical meaning	FLAC3D property name
Material parameter	e	Void ratio	ein1

Practical hints

1. Controlling variables
   - mElastFlag1 – controlling variable for Elastic or plastic calculation
     - prop mElastFlag1=1 ; plasticity model (CycLiq)
     - prop mElastFlag1=2 ; nonlinear elastic calculation for initial stress and balance
   - initializeState1 – controlling variable for initializing CycLiq internal parameters
     - prop initializeState1 = 0 ; initialize internal parameters of CycLiq model in the first calculation step
     - prop initializeState1 = 1 ; skip initialization
2. If calculation breaks, recovery calculation should reinitialize internal parameters.
3. The default value of variable 'pmin_' is assigned as 0.2 kpa.
   ** The unit for stresses and pore pressure is kpa.

Documents/files

Name	Type	Description
modelPost_sandliq005_64__v190122_.dll	DLL file	DLL file of CycLiqCP model for $FLAC^{3D}$ 5.0
Undrained_cyclic_torsional_test.rar	programs	Example for unit test
VELACS_No_01_test.rar	programs	Example for Centrifuge dynamic test
articles for reference.rar	pdf	Detailed description and applications

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