CONSTITUTIVE MODELING OF GEOMATERIALS

PRINCIPLES AND APPLICATIONS

TERUO NAKAI



CRC Press is an imprint of the Taylor & Francis Group, an **informa** business A SPON PRESS BOOK EL35-86571.458

vinterite Teylor & Francie S http://www.tayloca.odfn.ee

and the CFC Press Wile she http://www.com

Contents

		rdinary modeling of the s-dimensional sou behavior	<u>4 0</u>
	Pref		xi
	List	of symbols	xv
1	Intr	oduction	1
	1.1	Background 1	
	1.2	Contents of this book 3	
		adtanced elegendatio medeling of 1993.093 from no base	
	RT		
Mo	odeli	ng of geomaterials	7
2	Fun	damentals of conventional elastoplasticity	9
	2.1	Introduction 9	
	2.2	One-dimensional modeling of elastoplastic materials 9	
	2.3	Multidimensional modeling of elastoplastic materials 13	
3	Moo	deling of one-dimensional soil behavior	19
	3.1	Introduction 19	
	3.2	Modeling of normally consolidated soils—	
		conventional elastoplastic modeling 20	
	3.3	Modeling of overconsolidated soils—	
		advanced elastoplastic modeling at stage I 22	
	3.4	Modeling of structured soils (naturally deposited	
		soils)—advanced elastoplastic modeling at stage II 28	
	3.5	Modeling of other features of soils—advanced	
		elastoplastic modeling at stage III 34	
	3.6	Loading condition using increment of total	
		change of void ratio and explicit expression	
	3.7	in advanced elastoplastic modeling 39 Application of the advanced model (stage III)	
	3+/	to time-dependent behavior of soils 40	
		to mile acpendent behavior of sous to	

Contents vii

211

3.8 Meaning of present time-dependent modelcommon and different points to Sekiguchi model 43 3.9 Simulation of time-dependent behavior of soil in one-dimensional conditions 47 3.10 Application of advanced methods to modeling of some other features 61 3.10.1 Temperature-dependent behavior 61 3.10.2 Unsaturated soil behavior 66 4 Ordinary modeling of three-dimensional soil behavior 4.1 Introduction 73 Outline of ordinary elastoplastic models 4.2 such as the Cam clay model 73 Discussion on applicability of Cam clay type model 4.3 in three-dimensional conditions based on test results 94 5 Unified modeling of three-dimensional soil behavior based on the t_{ii} concept 5.1 Introduction 99 Concept of modified stress t_{ii} 99 5.2 Definition of t_{ij} and stress and strain increment 5.2.1 invariants based on the t_{ii} concept 99 Explicit expression of a_{ii} 107 5.2.2 5.2.3 Meaning of the t_{ii} concept 109 Three-dimensional modeling of normally 5.3

- consolidated soils based on the t_{ij} concept 112 5.3.1 Formulation of model 112
- 5.3.1 Formulation of model 112 5.3.2 Explicit expressions of equa
- Explicit expressions of equations used in the t_{ij} concept 120
 - 5.3.2.1 Partial derivatives of yield function and stress variables 120

73

99

135

- 5.3.2.2 Derivation of X_{CS} and Y_{CS} 123
 5.3.3 Validation by test data for remolded normally consolidated clay 124
- 6 Three-dimensional modeling of various soil features based on the t_{ij} concept
 - 6.1 Introduction 135
 - 6.2 Three-dimensional modeling of overconsolidated soils—advanced elastoplastic modeling at stage I 135

	6.2.1	Formulat	ion of model 135		
	6.2.2	Description	on of dependency of plastic flow		
			path in constitutive modeling 139		
	6.2.3		lidation using test data for remolded		
		normally	consolidated and overconsolidated clays	150	
		6.2.3.1	Conventional triaxial tests under		
			monotonic and cyclic loadings 151		
		6.2.3.2	True triaxial tests under cyclic loadings	153	
		6.2.3.3	Plane strain tests on Ko consolidated clay	y 155	
		6.2.3.4	Torsional shear tests on isotropically and anisotropically consolidated clays	158	
	6.2.4	Modelva	lidation using test data for sand 161		
	0.2.7		Conventional triaxial tests under		
		0.2	monotonic and cyclic loadings 161		
		6.2.4.2	True triaxial tests under		
		0.2.1.2	monotonic loading 171		
6.3	Three-	dimension	al modeling of structured soils—		
0.5		advanced elastoplastic modeling at stage II 177			
	6.3.1		tion of model 177		
	6.3.2		alidation through		
	0.0.2		on of structured clays 178		
	6.3.3		native formulation of the model 183		
6.4	0.0.0		al modeling of other features of		
0.1	soils-	-advanced	elastoplastic modeling at stage III 185		
	6.4.1	General	formulation of model 185		
	6.4.2	Applicat	ion of model to time-dependent behavior	r 187	
	6.4.3	Model v	alidation using simulations of		
			bendent behavior of clays 189		
	6.4.4	Modelin	g of some other features of soil behavior	194	
			Temperature-dependent behavior 195		
		6.4.4.2			
Co	nclusion	s of Part 1	10.1.2 Outline of sumerical analysis	205	
ART	1777		10.1.3.1 Series (influence of the most		
ume	rical a	nd physic	al modeling of geotechnical	1.19	
oble	ems			209	

- 8 Introduction to numerical and physical modeling
 - 8.1 Introduction to Part 2 211

P/

N

pr

vi Contents

Contents	İX
----------	----

291

viii Contents

10

8.2	Mode	ling the Interface Behavior	
0.2		en Soil and Structure 213	
8.3		naterials used in 2D and 3D model	
	tests a	and their material parameters 216	
	8.3.1	2D model ground 217	
	8.3.2	3D model ground 219	
7 Tun	neling		223
9.1	Two-a	limensional trapdoor problems 223	
	9.1.1	Outline of model tests 223	
	9.1.2	Outline of numerical analyses 225	
	9.1.3	Results and discussion 227	
		9.1.3.1 Series I (single block excavation) 227	
		9.1.3.2 Series II (excavations with	
		combination of three blocks) 231	
9.2	Three-	dimensional trapdoor problems 235	
	9.2.1	Outline of model tests 235	
	9.2.2	Outline of numerical analyses 237	
		Results and discussion 239	
9.3		ar tunneling 243	
		Outline of model tests 244	
	9.3.2	Outline of numerical analyses 248	
	9.3.3	Results and discussion 249	
		9.3.3.1 Series I (greenfield ground) 249	
		9.3.3.2 Series II (ground with	
		nearby building load) 255	
		neuroy building (bad) 255	
Eart	h pressi	ire of retaining walls and bearing	
capa	city of f	foundations	261
10.1	Active	and passive earth pressure behind retaining walls 2	61
	10.1.1	Outline of model tests 261	
	10.1.2	Outline of numerical analyses 264	
	10.1.3	Results and discussion 264	
		10.1.3.1 Series I (influence of deflection	
		process of the wall) 264	
		10.1.3.2 Series II (influence of deflection	
		mode of the wall) 270	

10.2 Braced open excavation 272

10.2.1 Outline of model tests 274 10.2.2 Outline of numerical analyses 277 10.2.3 Results and discussion 278 10.3 Strip foundation and piled raft foundation 284 10.3.1 Outline of model tests 284 10.3.2 Outline of numerical analyses 286

10.3.3 Results and discussion 287

11 Reinforced soils

11.1 Reinforced foundation under uplift loading	3 291
---	-------

- 11.1.1 Outline of model tests 291
- 11.1.2 Outline of numerical analyses 294
- 11.1.3 Results and discussions 296
 - 11.1.3.1 Series I (influence of
 - reinforcement direction) 296
 - 11.1.3.2 Series II (reinforcements stemming from bottom of the foundation) 300
- 11.2 Reinforcing for increasing bearing capacity 303
 - 11.2.1 Outline of model tests 304
 - 11.2.2 Outline of numerical analyses 305
 - 11.2.3 Results and discussion 306
 - 11.2.3.1 Influence of installation depth of reinforcement 306
 - 11.2.3.2 Influence of reinforcement length 309
 - 11.2.3.3 Influence of friction angle

of reinforcement 310

12 Localization and shear band development in element tests 315

- 12.1 Introduction 315
- 12.2 Outline of analyses 315
- 12.3 Results and discussion 316

13	Conclusions	of Part 2	

References Index

325 329

339