

# Contents

<b>1</b>	<b>Introduction, overview and basic notation</b>	<b>1</b>
1.1	Overview . . . . .	1
1.2	Basic notation . . . . .	2
1.2.1	Stress, strain and stretching . . . . .	2
1.2.2	Dilatancy . . . . .	3
1.2.3	Rendulic plane . . . . .	5
<b>2</b>	<b>The role of constitutive models</b>	<b>7</b>
2.1	About the Failure . . . . .	8
2.1.1	The role of dilatancy at failure . . . . .	10
2.1.2	Mathematical-mechanical description of failure . . . . .	10
2.1.3	Initial boundary value problems . . . . .	11
2.2	Validations of numerical simulations . . . . .	11
2.2.1	Measurements . . . . .	11
2.2.2	Comparison between different calculations . . . . .	11
2.3	Influence of constitutive model . . . . .	13
2.3.1	Infinite slope . . . . .	13
2.3.2	Undrained conditions . . . . .	14
2.4	When do material models mater? . . . . .	16
<b>3</b>	<b>Barodesy</b>	<b>19</b>
3.1	Notations used in Barodesy . . . . .	20
3.2	Soil behaviour and Barodesy . . . . .	21
3.2.1	Non-linear behaviour . . . . .	22
3.2.2	Asymptotic states . . . . .	22
3.2.3	Critical state . . . . .	28

3.2.4	Stress-dilatancy relations . . . . .	32
3.2.5	Pyknotropy and Barotropy . . . . .	33
3.3	Barodesy for clay . . . . .	37
3.4	Barodesy for sand . . . . .	40
<b>4</b>	<b>Further developments for Barodesy</b>	<b>43</b>
4.1	New formulation for the $\mathbf{R}$ -function . . . . .	43
4.1.1	The function of Chu and Lo . . . . .	44
4.1.2	New $\mathbf{R}$ -function . . . . .	47
4.1.3	Numerical experiments . . . . .	52
4.2	Implementing Ohde's compression law . . . . .	56
4.3	Summary of material parameters and constants . . . . .	64
4.4	Numerical experiments . . . . .	65
4.4.1	Isotropic compression . . . . .	66
4.4.2	Triaxial tests . . . . .	68
4.4.3	Oedometric tests . . . . .	69
4.4.4	Response envelopes and proportional strain paths . . . . .	72
<b>5</b>	<b>Principal stress rotations</b>	<b>79</b>
5.1	Introduction . . . . .	79
5.2	Models . . . . .	79
5.2.1	Hardening Soil with small-strain stiffness . . . . .	80
5.2.2	Sanisand . . . . .	81
5.2.3	Hypoplasticity . . . . .	84
5.2.4	Hypoplasticity with intergranular strain . . . . .	86
5.2.5	Calibration . . . . .	87
5.3	Kinematic analysis of the deformations . . . . .	90
5.3.1	Plane strain . . . . .	90
5.3.2	Analysis in a plane stress state (three dimensions) . . . . .	91
5.4	Calculation of the stress and strain rates . . . . .	93

<i>Contents</i>	xv
5.4.1 Newton's method for Hypoplasticity and Barodesy . . .	94
5.4.2 Newton's method for Sanisand . . . . .	95
5.4.3 Integration of the rate of deformation . . . . .	95
5.5 Tests with a $1\gamma 2\varepsilon$ apparatus . . . . .	96
5.5.1 Testing device . . . . .	97
5.5.2 Stress path . . . . .	97
5.5.3 Results . . . . .	100
5.6 Tests with a hollow cylinder apparatus . . . . .	102
5.7 Conclusions . . . . .	106
<b>6 Stability of infinite slopes</b>	<b>107</b>
6.1 Friction angle and angle of dilatancy of soil . . . . .	107
6.2 Mohr-Coulomb – elastoplastic . . . . .	108
6.3 Limit state function . . . . .	117
6.4 Matsuoka-Nakai – elastoplastic . . . . .	119
6.5 Matsuoka-Nakai – kinematic . . . . .	122
6.6 Hypoplasticity . . . . .	123
6.7 Barodesy . . . . .	127
6.8 Triaxial test versus simple and direct shear test . . . . .	132
6.9 Impact on limit state analyses . . . . .	133
6.10 Conclusion . . . . .	134
<b>7 Conclusion</b>	<b>135</b>
7.1 Summary . . . . .	135
7.2 Limitations . . . . .	136
7.3 Outlook . . . . .	136
<b>A Glossary</b>	<b>153</b>
<b>B Recalculation of a triaxial test</b>	<b>159</b>

<b>C Constitutive Models</b>	<b>163</b>
C.1 Barodesy . . . . .	163
C.1.1 Version of Medicus <i>et al.</i> for clay . . . . .	163
C.1.2 Version of Kolymbas for sand . . . . .	164
C.1.3 Improved version for sand . . . . .	165
C.2 Hypoplasticity . . . . .	167
C.2.1 Version of von Wolffersdorff for sand . . . . .	167
C.2.2 Intergranular strain concept . . . . .	168
C.3 Sanisand . . . . .	168
<b>D Matlab Code for Constitutive models</b>	<b>171</b>
D.1 Barodesy . . . . .	171
D.1.1 Version of Medicus <i>et al.</i> for clay . . . . .	171
D.1.2 Version of Kolymbas for sand . . . . .	172
D.1.3 Improved version for sand . . . . .	173
D.2 Hypoplasticity . . . . .	175
D.2.1 Version of von Wolffersdorff for sand . . . . .	175
D.2.2 Intergranular strain for the version of von Wolffersdorff	178
D.3 Sanisand . . . . .	183
<b>E Matlab Code for Stress rotation</b>	<b>189</b>
E.1 Stress dependant . . . . .	189
E.2 Strain dependant . . . . .	191