

# Numerical Models in Geomechanics

## NUMOG III

*Edited by*

**S. Pietruszczak**

*McMaster University, Hamilton, Ontario, Canada*

and

**G. N. Pande**

*University College of Swansea, Swansea, UK*



**ELSEVIER APPLIED SCIENCE**  
LONDON and NEW YORK



## Contents

<i>Preface</i> .....	v
----------------------	---

### 1. CONSTITUTIVE MODELS OF GEOLOGICAL MATERIALS

#### 1.1 Models for Granular Media

An elastoplastic model for granular material using three yielding mechanisms .....	1
<i>B. Cambou, K. Jafari and K. Elamrani</i>	
Plastic flow and stability of granular materials .....	9
<i>D. Pradel and P. V. Lade</i>	
A multilaminar model for sands .....	17
<i>S. A. Sadrnejad and G. N. Pande</i>	
A new double hardening model for soils under cyclic loading .....	28
<i>Y. Meimon and C. H. Tan</i>	
Kinematic extension of an isotropic hardening model for sand .....	36
<i>T. Nakai, J. Fujii and H. Taki</i>	
Shearing deformation of sand under three different principal stress .....	46
<i>N. Moroto</i>	
A plasticity model for the deformation of sand during rotation of principal stress directions .....	53
<i>M. Gutierrez, K. Ishihara and I. Towhata</i>	
<b>1.2 Models for Clays</b>	
Description of clay anisotropy employing the concept of directional variation of porosity .....	61
<i>S. Pietruszczak and S. Krucinski</i>	

Development of an anisotropic soil model for the stability analysis of a vertical cut .....	71
<i>P. K. Banerjee, A. S. Kumbhojkar and N. B. Yousif</i>	
Modeling of thermal failure of saturated clays .....	81
<i>T. Hueckel and R. Pellegrini</i>	
An experimentally based 'bubble' model for clay .....	91
<i>A. Al-Tabbaa and D. M. Wood</i>	
Viscoplastic modelling of time-dependent behaviour of clays .....	100
<i>T. Matsui, N. Abe and K. Hayashi</i>	
General elastic viscous plastic constitutive relationships for 1-D straining in clays .....	108
<i>J.-H. Yin and J. Graham</i>	
<b>1.3 Models for Soils and Reinforced Soils</b>	
Modelling of cyclic behaviour of soils on proportional and non-proportional paths .....	118
<i>F. Darve, H. El Gamali and J. P. Touret</i>	
Tangential plasticity .....	129
<i>K. Hashiguchi</i>	
Microplane model for triaxial deformation of soils .....	139
<i>P. C. Prat and Z. P. Bazant</i>	
Comparison of single and double hardening constitutive models for frictional materials .....	147
<i>P. V. Lade and D. Pradel</i>	
A constitutive model for soils evaluating principal stress rotation and its application to finite element analysis .....	155
<i>H. Matsuoka, Y. Suzuki and T. Murata</i>	
Elastoplastic modelling of partially saturated soils .....	163
<i>A. Gens, E. E. Alonso and A. Josa</i>	
Analysis of creep effects in frozen soils .....	171
<i>B. B. Budkowska and Q. Fu</i>	
A viscoelastic constitutive model for creep of frozen soil .....	179
<i>Q.-X. Sun, L. Domaschuk, D. H. Shields and M. Rahman</i>	

Performance of a numerical algorithm based on a thermodynamic constitutive theory in solving elasto-plastic boundary value problems .....	187
<i>A. Sengupta and S. K. Saxena</i>	
Characteristics and integration of undrained response of silty soils .....	195
<i>K. Axelsson, K. Runesson, S. Sture, Y. Yu and H. Alawaji</i>	
Modelling stone column reinforced soil—a modified Voigt approach .....	204
<i>H. F. Schweiger and G. N. Pande</i>	
Numerical modelling of a circular foundation over vibrofloted sand .....	215
<i>G. Canetta and R. Nova</i>	

#### **1.4 Models for Other Geological Materials and Soil-Structure Interfaces**

A continuum model for plastic-brittle materials with application to a reinforced concrete structure .....	223
<i>J. Jiang and S. Pietruszczak</i>	
Mechanical behaviour of asphalt concrete .....	233
<i>E. Troost</i>	
A consistent model for soil structure interface behaviour .....	241
<i>M. Boulon and P. Marchina</i>	

### **2. EXPERIMENTAL BEHAVIOUR AND EVALUATION OF CONSTITUTIVE MODELS**

Analysis of non-monotonic cubical triaxial tests with an elasto-plastic kinematic hardening constitutive model .....	248
<i>R. C. Velloso, R. F. Azevedo and H. B. Poorooshab</i>	
Simulations of Prevost's pressure sensitive model .....	256
<i>A. Derradji-Aouat and E. Evgin</i>	
A parametric study of Cam-clay .....	264
<i>H. K. Tam and R. I. Woods</i>	
Determination of hyperbolic soil model parameters for sand using a multi-axial device .....	272
<i>A. F. Rauch, S. M. Sargand and G. A. Hazen</i>	
Effective stress analysis of undrained behaviour of peat .....	281
<i>M. Yamada and M. Akaishi</i>	

- Bearing capacity of shallow foundations on granular trench in weak clay ..289  
*B. M. Das and V. K. Puri*

### 3. LIMIT ANALYSIS AND MODELLING OF INSTABILITIES

- Limit load in steady 3-D plastic flow around obstacles ..... 297  
*M. Lin and A. Drescher*
- Periodic patterns of granular flow through a plane container ..... 305  
*R. L. Michalowski*
- Numerical modeling of rockburst ..... 311  
*J. P. Bardet*
- The numerical modelling of the development of shear bands in  
 geomechanics ..... 319  
*R. G. Wan, D. H. Chan and N. R. Morgenstern*

### 4. SOIL DYNAMICS

- Comparative assessment of methods for dynamic effective stress  
 analysis ..... 330  
*W. D. L. Finn and M. Yogendrakumar*
- Blast loading of buried structures ..... 340  
*C. J. Shin, H.-Y. Ko and S. Sture*
- Dynamic analysis of pile foundations using transfer matrix methods .... 349  
*V. Chandrasekaran and C. V. G. Vallabhan*
- Failure of slopes under dynamic loading ..... 358  
*N. C. Koutsabeloulis*

### 5. FLUID FLOW AND CONSOLIDATION

- Analysis of groundwater flow through revetments ..... 367  
*K. J. Bakker*
- Numerical modelling of seepage erosion in shore bluffs consisting of  
 glaciolacustrine silts ..... 375  
*A. J. Zeman*
- Analysis of contaminant transport through fractured rock at an Ontario  
 landfill ..... 383  
*R. K. Rowe and J. R. Booker*

Numerical modelling for the flow of compressible fluids in systems of deformable fractured rocks .....	391
<i>H. Modaressi and D. Aubry</i>	
Behaviour of a heat source in a fully coupled saturated thermoelastic soil ..	399
<i>J. R. Booker and D. W. Smith</i>	
Wave-induced stresses in a layered seabed in relation to the liquefaction potential .....	407
<i>S. E. J. Spierenburg</i>	
Numerical simulation of the 3-D propagation of parametric hydraulic fractures in nonlinear layered grounds .....	415
<i>S. Ben Ammou</i>	

## 6. NUMERICAL METHODS AND SOFTWARE DEVELOPMENTS

An automatic step size correction scheme for non-associated plasticity problems .....	423
<i>H. van Langen and P. A. Vermeer</i>	
Viscoplasticity and plasticity—numerical stability revisited .....	431
<i>D. F. E. Stolle and J. E. Higgins</i>	
Viscoplasticity and vector processing .....	439
<i>W. Haas and H. F. Schweiger</i>	
Higher order displacement discontinuities in complex variable: application to the description of crack path with friction .....	447
<i>R. Miguez, Y. Belkacemi and J. P. Henry</i>	
A rational approach to the analysis of construction filling or excavation ..	455
<i>D. Aubry and Z. Modaressi</i>	
Some aspects of non-linear interfaces in geomechanics: boundary element modelling .....	463
<i>A. S. P. Selvadurai</i>	
A parallel solution of some groundwater flow problems .....	472
<i>H. R. Thomas and C. L. W. Li</i>	
The use of supercomputers for predicting three-dimensional ground deformations due to tunnelling in soft soils .....	481
<i>K. M. Lee and R. K. Rowe</i>	

- A micro-computer system for the verification of soils constitutive models ..489  
*W. Chehade, R. Chehade and I. Shahrour*

## 7. APPLICATIONS OF NUMERICAL TECHNIQUES TO PRACTICAL PROBLEMS

### 7.1 Tunnels and Excavations

- Theoretical and experimental studies of a tunnel face in a gravel site. Part I:  
 Basic theoretical approaches ..... 497  
*J. Monnet, S. Chaffois, C. Chapeau and M. Mohkam*
- Theoretical and experimental studies of a tunnel face in a gravel site. Part II:  
 Experimental and numerical analysis ..... 505  
*J. Monnet, S. Chaffois, C. Chapeau and M. Mohkam*
- Finite element modelling of tunnelling in jointed rocks ..... 515  
*J. M. Debaty, A. Monjoie, M. El Kiri and R. Charlier*
- Circular tunnel in reinforced jointed rockmass ..... 524  
*K. G. Sharma, A. Varadarajan and A. B. Pandya*
- Three dimensional numerical models to simulate tunnel excavation ..... 536  
*G. Swoboda, W. Mertz and A. Schmid*
- Ground surface settlements due to shield tunnelling with face pressure .. 549  
*M. Hisatake, H. Nakano, T. Sakakibara and Y. Tanaka*
- Prediction of surface subsidence caused by underground mining using a non-linear finite element procedure ..... 557  
*Y. Najjar, M. Zaman and J. Ahern*
- Finite element analyses of the Homestake Mine study slope: an update ... 566  
*W. G. Pariseau and F. Duan*
- Finite element modelling of a strutted excavation ..... 577  
*F. H. Lee, K. Y. Yong, S. L. Lee and C. T. Toh*
- Excavation in cohesive soils: modelling the effects of creep on long-term performance ..... 585  
*R. I. Borja, S. R. Lee and R. B. Seed*
- An elasto-viscoplastic constitutive model for clay and FEM analysis of the time-dependent behavior of clay deposits in tunneling ..... 593  
*T. Adachi, T. Hirata, T. Hashimoto, F. Oka and M. Mimura*

- Comparison of a finite-difference code to a finite-element code in modeling an excavation in an underground shaft pillar ..... 608  
*T. M. Brady and J. C. Johnson*
- Stability analysis of high salt domes ..... 620  
*R. Pöttler*

## 7.2 Embankments and Slopes

- Finite element studies of an embankment on soft ground ..... 628  
*A. R. Pickles and R. I. Woods*
- Numerical modelling of saturation shrinkage ..... 636  
*D. J. Naylor, S.-L. Tong and A. A. Shahkarami*
- 3-D FE modeling of crack development in earth dam subjected to fault movement ..... 649  
*J. Sohn, C. K. Shen and L. R. Herrmann*
- Modelling of embankments on near surface reinforced soft soils ..... 657  
*M. R. Madhav and H. B. Poorooshab*
- Plastic collapse analysis of slopes of strain softening materials ..... 667  
*T. Tanaka and O. Kawamoto*

## 7.3 Piles

- Comparison of an elastoplastic quasi three-dimensional model for laterally loaded piles with field tests ..... 675  
*A. P. Kooijman*
- P*-*Y* curves for laterally loaded piles derived from three-dimensional finite element model ..... 683  
*D. A. Brown, C.-F. Shie and M. Kumar*
- Analysis on the preventive mechanism of landslide stabilizing piles ..... 691  
*T. Adachi, M. Kimura and S. Tada*

## 7.4 Other Applications

- Numerical modelling of reinforced unpaved roads ..... 699  
*H. J. Burd and G. T. Houlsby*
- The experimental and finite element analysis of non-square raft type concrete pavements ..... 707  
*J. W. Bull and Y. B. Luheshi*



Geometrically nonlinear analysis of buried cylinders .....	716
<i>I. D. Moore and J. R. Booker</i>	
Comparison of rheological models in view of predicting the behaviour of a deep clay host rock during the construction of a radwaste repository .....	724
<i>D. de Bruyn, D. Aubry and G. Rousset</i>	
Bridge abutment reinforced with skew tie-backs .....	732
<i>S. Bang and S. D. Schelske</i>	
An effective stress approach to undrained analysis .....	740
<i>D. H. Chan and N. R. Morgenstern</i>	
Crack prediction of masonry panels subject to ground movement .....	751
<i>J. Middleton and R. P. Thomas</i>	
Effect of soil modulus on the depth of shrinkage cracks .....	759
<i>M. Picornell</i>	
Optimum design of the shape of cantilever quay using a decision-making process .....	767
<i>E. Dembicki and T. Chi</i>	
<i>Index of Contributors</i> .....	779