

Proceedings of

ICADD-4

Fourth International Conference on
Discontinuous Deformation Analysis

Edited by
Nenad Bićanić



UNIVERSITY
of
GLASGOW

Glasgow, Scotland, UK
6th-8th June 2001

Proceedings **ICADD-4**
Discontinuous Deformation Analysis
Edited by Nenad Bićanić
Published by University of Glasgow, June 2001, pp 494
ISBN 0-85261-735-6

Cover Photo - Basaltic columns of the discontinuous geological formation at the island of Staffa, off the West Coast of Scotland. The island houses Fingal's Cave, which was an inspiration for Mendelssohn's Hebrides Symphony

Preface

Modelling of discontinuous behaviour is a subject of intensive research among scientists and engineers in widely differing disciplines. The restrictions imposed by continuum framework are often difficult to reconcile when dealing with fracturing, granular and discontinuous media and possibilities of alternative discontinuous frameworks are explored. Recent developments are accompanied with an increased mathematical rigour and algorithmic robustness in the implementations for DDA, DEM, Keyblock Analysis, Lattice Modelling, Combined FEM/DEM, DG and Manifold Method. These developments have helped the discontinuum based methodologies to become more readily recognised and more frequently applied in engineering practice.

The **ICADD-4** conference follows in the footsteps of the three earlier **ICADD** conferences held in Taipei, ROC in 1995, Kyoto, Japan in 1997 and Vail, Colorado in 1999 and it is the first time that the conference is held in Europe. The intention is for the series will continue at regular two year intervals and **ICADD-5** is already scheduled for 2003 in Capetown, South Africa. The conference also draws on the two discrete element conferences held in Golden 1990 and Boston 1993, covering a more comprehensive range of related computational frameworks dealing with discontinuous behaviour.

The main objective is to bring together researchers and practising engineers involved in computational modelling of complex problems concerned with discontinuous behaviour in rock mechanics, structural engineering, geology, geophysics, and solid mechanics in general – e.g. jointed rock, fracturing media, fragmentation, granular and particulate media, bulk solids, glacier movements, plate tectonics and structural masonry.

ICADD-4 Proceedings comprise over 40 contributions, which discuss new developments and more complex applications within a whole range of discontinuous computational frameworks. The real value of the conference appears to lie in the fact that many contributions consider similar physical problems, but simulate them using different frameworks. We can look forward to fruitful discussions and a very stimulating conference.

The University of Glasgow is very proud of its engineering heritage. We are delighted to welcome you in Scotland and to act as the host for the conference in the **ICADD** Series.

Nenad Bićanić
ICADD-4 Chairman

ICADD-4

Glasgow, Scotland, UK

Technical Advisory Panel

Bernard Amadei
Josip Dvornik
Max Ma
Jeen-Shang Lin
Ante Munjiza
Graham Mustoe
Yuzo Ohnishi
Roger Owen
Ekkehard Ramm
Friedrich Scheele
Gen-Hua Shi
John Tinucci
Jan van Mier
Chung-Yue Wang
John Williams

Local Organising Committee

Nenad Bićanić
Chris Pearce
Barbara Grant

Supported by American Rock Mechanics Association (ARMA)

PROCEEDINGS ICADD-4

4th International Conference on Discontinuous Deformation Analysis University of Glasgow, 6th-8th June 2001

Table of Contents

Three Dimensional Discontinuous Deformation Analysis	<i>1</i>
<i>Gen-lua Shi</i>	
Transient Motion of Irregular 3D Discrete Elements	<i>23</i>
<i>A. Munjiza, J.P.Latham, N.W.M.John</i>	
The Influence of Tunnel Shape on Damage and Fracture Propagation at Ultra Depth	<i>35</i>
<i>D. P. Roberts</i>	
Deformation Analysis Considering Water Effect by Manifold Method	<i>47</i>
<i>Y. Ohnishi, H. Ohtsu, S. Nishiyama, T. Koyama, J.H. Wu</i>	
Modelling of Continuum to Discontinuum Transitions for Deep Level Mining	<i>63</i>
<i>E. J. Sellers</i>	
Investigation of Discontinuous Deformation Analysis Using Physical Laboratory Models	<i>73</i>
<i>A. McBride, F. Scheele</i>	
Study of Constant Force Distributions on the Bottom Plate of a Caisson resting on Rubble Rock Foundation	<i>83</i>
<i>M. Miyata, T. Sugano, G. G. W. Mustoe, M. Nakagawa</i>	
A Comparative Evaluation of Two Approaches to Discrete Element Modelling of Particulate Media	<i>97</i>
<i>C. O' Sullivan, J. D. Bray</i>	
Discrete Element Analysis of a Mine Stope in Blocky Rock: A Comparison of DDA and UDEC Results	<i>111</i>
<i>M. MacLaughlin, R. D. Langston</i>	
Three Dimensional Lattice Model for Fracture Analysis of Particle Composites	<i>121</i>
<i>J. van Mier, G. Lilliu</i>	
Fracture Simulations of Cohesive Frictional Materials by Discrete Element Models	<i>135</i>
<i>G. A. D'Adetta, E. Ramm, F. Kun</i>	

Grain Cracking, Grain Sliding and Volumetric Strains in Deforming Sandstones – DDA Simulations of the Behaviour of Porous, Granular Materials	159
<i>G. Couples, S. Bourlange, P. Bartolome, H. Lewis</i>	
DDA Analysis of the Couplet/Heyman Minimum Thickness Arch Problem	165
<i>N. Bićanić, C. Stirling</i>	
Domain Analysis for the Programming Library for Meshless Methods in Fracturing Solids	171
<i>K. Fresl</i>	
Selective Time Steps in Predictor/Corrector Methods Applied to Discrete Dynamic Models of Granular Assemblies	193
<i>J. Dvornik, D. Lazarević</i>	
On the choice between discrete or smeared approach in practical structural FE analyses of concrete structures	203
<i>L. Jendele, V. Cervenka, V. Saouma, R. Pukl</i>	
A Spatial Digital Tree Based Contact Detection Algorithm	221
<i>Y. T. Feng, D. R. J. Owen</i>	
Filling Domains with Disks	239
<i>Y. T. Feng, K. Han, D. R. J. Owen</i>	
From discontinuous to continuous Modelling of Granular Materials	251
<i>S. Diebels, W. Ehlers, T. Micheltisch</i>	
Different Microstructural Strain Tensors for Granular Assemblies	261
<i>K. Bagi, I. Bojtar</i>	
A study of time dependency of granular materials with DDA	271
<i>T. Ishikawa, Y. Ohnishi</i>	
Delaunay Triangulation of Granular Media	281
<i>J. D. Goddard</i>	
Reconnaissance of Vaults and Domes in Granular Material	293
<i>J. Dvornik, D. Lazarević</i>	
Parallel processing strategies for particulates and multi-fracturing solids	299
<i>D. R. J. Owen, Y. T. Feng</i>	
Simulation of Granular Assemblies by Discontinuous Deformation Analysis	315
<i>G. X. Zhang, G. X. Li, Y. Sugiura, H. Hasegawa</i>	
The Arching Mechanism on the Micro Level Utilizing Photoelastic Particles	317
<i>H. S. Tien, S. G. Paikowsky</i>	
Discontinuous Deformation Analysis in Ball Milling	337
<i>V. Balden, F. Scheele, G. Nurick</i>	

Effects of Small Particles on the Shear Strength of a Particulate System of Binary Mixtures	349
<i>T. Sugano, M. Miyata, M. Nakagawa, G. G. W. Mustoe</i>	
An application of key block analysis to large section tunnel excavation	357
<i>Y. Ohnishi, H. Niida, M. Ryu, T. Nakai</i>	
Two Extensions to Key theory	367
<i>G. X. Wang, W. Shiulin, Z. Guang, G. Xiurun</i>	
Analysis of the Discontinuous Rock Mass by four node iso-parametric Manifold Method	369
<i>T. Sasaki, Y. Ohnishi</i>	
A Coupled DDA and Boundary Element Analysis	379
<i>J. S. Lin, R. M. Al-Zahrani</i>	
Evolution of Systems Made of Rigid Bodies	389
<i>E. Dimnet, M. Fremond</i>	
Hydraulic Fracturing Simulation with Numerical Manifold Method	391
<i>M. Lu, B. Boström, G. Svanø</i>	
Hydraulic Fracturing with Lattice Models	401
<i>C. Davie, N. Bićanić</i>	
A Study on Coupling Calculation of Manifold Method and Saturated-Unsaturated Flow Analysis	407
<i>Y. Sun, S. Miki</i>	
HYDRO-DDA modelling of fractured mudrock seals	413
<i>M. Rouainia, C. Pearce, N. Bićanić</i>	
Coupled Hydro-mechanical Analysis of Jointed Rock Masses by Manifold Method	425
<i>G. X. Zhang, X. F. Wu, Y. Sugiura, H. Hasegawa</i>	
CGrid: Neighbor Searching for Many Body Simulation	427
<i>E. Perkins, J. Williams</i>	
Extensions of Manifold Method and Its Application	439
<i>G. Chen, K. Zen, Y. Ohnishi, K. Kasama G. Chen, K. Zen, Y. Ohnishi, K. Kasama</i>	
A new Method for simulating discontinuities using finite elements	451
<i>G. N. Wells, L. J. Shyys, R. de Borst</i>	
A simulation of the process of slope failure	461
<i>J. S. Lin, C. Y. Koo, J. C. Chern</i>	
Fundamental Study of Mechanical Behaviors of Rockfalls by Imaging Analysis	473
<i>T. Shimauchi, N. Sakai, Y. Ohnishi</i>	
An Educational Simulator for Multi Body Physics	483
<i>J. R. Williams, E. Perkins, B. Cook, D. Preece</i>	