

Research Article

Discontinuous Deformation Analysis Enriched by the Bonding Block Model

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The discontinuous deformation analysis (DDA) has been extensively applied in geotechnical engineering owing to its salient merits in the modeling of discontinuities. However, this method assumes a constant stress field within every block and hence cannot provide reliable estimation for block deformations and stresses. This paper proposes a novel scheme to improve the accuracy of the DDA. In our method, advanced subdivision is introduced to represent a block as an assembly of triangular or quadrilateral elements, in which overlapped element edges are separated from each other and are glued together by bonding springs. The accuracy and the effectiveness of the proposed method are illustrated by three numerical experiments for both continuous and discontinuous problems.

1. Introduction

The discontinuous deformation analysis (DDA) [1, 2] is developed for the modeling of the statics and dynamics problems in geological engineering. This method represents a jointed rock mass as an assembly of blocks with constantly changing deformations and contact status. At every contact point, a normal spring and a shear spring are applied. Such contact springs must satisfy no tension in an open contact and no penetration in a close contact, which are fulfilled through repeated open-close iterations. In the literature [3–8], the augmented Lagrangian method is also introduced into the DDA to increase the accuracy for contact computation. The DDA uses an incremental procedure to solve block movements and deformations on a given time mesh. In every time step, the simultaneous equilibrium equations are formed by the submatrices derived from minimizing all sources of potential energies. Due to the above unique merits, this method has been extensively applied in the analysis of seismic landslides [9–11], crack propagations [12–14], and hydraulic fractures [15, 16].

However, the DDA employs the first-order polynomial to approximate block displacements, and hence the stress within every block keeps invariable. Such assumption leads to the difficulty to implement this method to simulate block cracks, which require accurate stress estimation. In order to improve the accuracy of the DDA, a multitude of methods have been developed. A direct way is to use second- or higher-order polynomial functions to approximate block displacements [17–22]. But the accuracy of this method is only adequate for regularly shaped blocks. Another way is the so-called subblock DDA [3, 13, 16, 23], which subdivides blocks into smaller ones by preassumed artificial joints and applies contact springs along the interfaces to prevent the relative movements. Since contact detections and open-close iterations are also required for the contacts between subblocks, the computational burden of this method is very heavy, especially when adopting finer subdivisions.

The accuracy of the DDA can also be improved by coupling with the FEM. In the literature [24, 25], the DDA and the FEM codes are integrated into a computer program to alternately figure out block deformations and contact forces.

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Block System Modeling by Discontinuous Deformation Analysis Gen-hua Shi,1993 **Block System Modeling by Discontinuous Deformation Analysis** Gen-hua Shi,1993 Tunnel Design Methods Antonio Bobet,Herbert H. Einstein,2023-09-12 Tunnel Design Methods covers analytical numerical and empirical methods for the design of tunnels in soil and in rock The material is intended for design engineers looking for detailed methods for graduate students who are interested in tunnelling and for researchers working on various aspects of ground support interaction under static and seismic loading The book is divided into seven chapters covering fundamental concepts on ground and support behavior and on ground excavation support interaction and provides detailed information on analytical and numerical methods used for the design of tunnels with applications and on the latest developments on empirical methods The principles and formulations included are used throughout the book to provide insight into the response of tunnels under both simple and complex loading conditions thus providing the reader with fundamental understanding of tunnel behavior Both authors have experience in tunnelling and have worked extensively in practice designing tunnels both in the United States and abroad and in research

Advances in Rock Dynamics and Applications Yingxin Zhou,Jian Zhao,2011-05-25 The study of rock dynamics is important because many rock mechanics and rock engineering problems involve dynamic loading ranging from earthquakes to vibrations and explosions The subject deals with the distribution and propagation of loads dynamic responses and processes of rocks and rate dependent properties coupled with the physical environm **Development and Application of Discontinuous Modelling for Rock Engineering** Ming Lu,2021-07-28 The thirty papers published in this book represent the latest developments in Discontinuous Deformation Analysis DDA The Numerical Manifold Method NMM and other numerical methods and their applications are also covered as are the theoretical contributions of 3D DDA modelling and visualization of 3D joint systems and high order NMM Applications of these advances include the stability of underground works rock slopes and boreholes **Behaviour of Granular Materials** Bernard Cambou,2014-05-04 This book presents a complete and comprehensive analysis of the behaviour of granular materials including the description of experimental results the different ways to define the global behaviour from local phenomena at the particle scale the various modellings which can be used for a D E M analysis to solve practical problems and finally the analysis of strain localisation The concepts developed in this book are applicable to many kinds of granular materials considered in civil mechanical or chemical engineering

Fundamentals of Discrete Element Methods for Rock Engineering: Theory and Applications Lanru Jing,Ove Stephansson,2007-07-18 This book presents some fundamental concepts behind the basic theories and tools of discrete element methods DEM its historical development and its wide scope of applications in geology geophysics and rock engineering Unlike almost all books available on the general subject of DEM this book includes coverage of both explicit and implicit DEM approaches namely the Distinct Element Methods and Discontinuous Deformation Analysis DDA for both rigid

and deformable blocks and particle systems and also the Discrete Fracture Network DFN approach for fluid flow and solute transport simulations The latter is actually also a discrete approach of importance for rock mechanics and rock engineering In addition brief introductions to some alternative approaches are also provided such as percolation theory and Cosserat micromechanics equivalence to particle systems which often appear hand in hand with the DEM in the literature Fundamentals of the particle mechanics approach using DEM for granular media is also presented Presents the fundamental concepts of the discrete models for fractured rocks including constitutive models of rock fractures and rock masses for stress deformation and fluid flow Provides a comprehensive presentation on discrete element methods including distinct elements discontinuous deformation analysis discrete fracture networks particle mechanics and Cosserat representation of granular media Features constitutive models of rock fractures and fracture system characterization methods detailing their significant impacts on the performance and uncertainty of the DEM models *Understanding the Discrete Element Method*

Hans-Georg Matuttis, Jian Chen, 2014-06-23 Gives readers a more thorough understanding of DEM and equips researchers for independent work and an ability to judge methods related to simulation of polygonal particles Introduces DEM from the fundamental concepts theoretical mechanics and solidstate physics with 2D and 3D simulation methods for polygonal particles Provides the fundamentals of coding discrete element method DEM requiring little advance knowledge of granular matter or numerical simulation Highlights the numerical tricks and pitfalls that are usually only realized after years of experience with relevant simple experiments as applications Presents a logical approach starting with the mechanical and physical bases followed by a description of the techniques and finally their applications Written by a key author presenting ideas on how to model the dynamics of angular particles using polygons and polyhedral Accompanying website includes MATLAB Programs providing the simulation code for two dimensional polygons Recommended for researchers and graduate students who deal with particle models in areas such as fluid dynamics multi body engineering finite element methods the geosciences and multi scale physics *Computational Electromagnetics Using Boundary Elements* Jinxing Shen, 1995

Structural Analysis of Historic Construction: Preserving Safety and Significance, Two Volume Set Dina D'Ayala, Enrico Fodde, 2008-06-02 The successful preservation of an historic building complex or city depends on the continued use and daily care that come with it The possibility of continued use depends on the adaptation of the building to modern standards and practice of living requiring changes in constructional or structural features Conservation engineering is the process

Frontiers of Discontinuous Numerical Methods and Practical Simulations in Engineering and Disaster Prevention Guangqi Chen, Yuzo Ohnishi, Lu Zheng, Takeshi Sasaki, 2013-08-12 Analysis of large deformation rigid body movement and strain or stress for discontinuous materials is often required for project designs and plans in the fields of engineering and disaster prevention Many numerical simulation and analysis methods have been developed for the requirement from science and technology people since 1970s Among them D **Marine Engineering** T. K. S. Murthy, C. A.

Brebbia,1994 Boundary Elements in Nonlinear Fracture Mechanics V. M. A. Leitão,1994 *Knowledge Processing for Structural Design* B. Kumar,1995 This text describes an implementation of artificial intelligence techniques such as non monotonic reasoning and knowledge based techniques as encountered in structural design A conceptual model for integrated structural design is presented which suggests a number of enhancements to the models proposed by earlier researchers It provides a practical study of the applications of some of the state of the art tools and techniques to various stages of structural design *Mechanics of Deformation and Flow of Particulate Materials* Ching S. Chang,1997 Proceedings of a Symposium sponsored by the Engineering Mechanics Division of ASCE Committee on Properties of Materials and Committee on Fluid Mechanics and the Applied Mechanics Division of American Society of Mechanical Engineers Committee on Geomechanics Evanston IL June 29 July 2 1997 Presenting a collection of recent advances in the areas of granular solids and granular fluids these proceedings examine a variety of theoretical approaches including micromechanical methods with the consideration of particle interactions and conventional continuum mechanics methods Complementary computational and experimental techniques that have been developed that study phenomena ranging from particle level to bulk behavior are also covered **XAFS for Everyone** Scott Calvin,2013-05-20 XAFS for Everyone provides a practical thorough guide to x ray absorption fine structure XAFS spectroscopy for both novices and seasoned practitioners from a range of disciplines The text is enhanced with more than 200 figures as well as cartoon characters who offer informative commentary on the different approaches used in XAFS spectroscopy The book covers sample preparation data reduction tips and tricks for data collection fingerprinting linear combination analysis principal component analysis and modeling using theoretical standards It describes both near edge XANES and extended EXAFS applications in detail Examples throughout the text are drawn from diverse areas including materials science environmental science structural biology catalysis nanoscience chemistry art and archaeology In addition five case studies from the literature demonstrate the use of XAFS principles and analysis in practice The text includes derivations and sample calculations to foster a deeper comprehension of the results Whether you are encountering this technique for the first time or looking to hone your craft this innovative and engaging book gives you insight on implementing XAFS spectroscopy and interpreting XAFS experiments and results It helps you understand real world trade offs and the reasons behind common rules of thumb Advanced Computational Methods and Geomechanics Shenghong Chen,2023-01-01 The aim of this book is intended through parallel expounding to help readers comprehensively grasp the intrinsic features of typical advanced computational methods These methods are created in recent three decades for the understanding of the post failure of geo materials accompanied with discontinuous and finite deformation dislocation as well as the violent fluid structure interaction accompanied with strong distortion of water surface The strong points and weak points of the formalisms for governing equations the discretization schemes the nodal interpolation approximation of field variables and their connectivity via support domains covers or enrichments the basic algorithms etc are clarified Being

aware of that the differences in these methods are not so large as at the first glance this book will help readers to select appropriate methods to improve the methods for their specific purpose and to evaluate the reliability applicability of the outcomes in the hazard evaluation of geotechnical hydraulic structures beyond extreme work situation This book may be looked at as an advanced continuation of Computational Geomechanics and Hydraulic Structures by the author 2018 Springer Verlag ISBN 978 981 10 8134 7 which elaborates the fundamental computational methods in geomechanics for the routine design of geotechnical hydraulic engineering **Applied Mechanics Reviews** ,1988 *Anisotropic Analysis Using Boundary Elements* N. A. Schlar,1994 **Data Processing Techniques and Applications for Cyber-Physical Systems (DPTA 2019)** Chuanchao Huang,Yu-Wei Chan,Neil Yen,2020-02-03 This book covers cutting edge and advanced research on data processing techniques and applications for Cyber Physical Systems Gathering the proceedings of the International Conference on Data Processing Techniques and Applications for Cyber Physical Systems DPTA 2019 held in Shanghai China on November 15 16 2019 it examines a wide range of topics including distributed processing for sensor data in CPS networks approximate reasoning and pattern recognition for CPS networks data platforms for efficient integration with CPS networks and data security and privacy in CPS networks Outlining promising future research directions the book offers a valuable resource for students researchers and professionals alike while also providing a useful reference guide for newcomers to the field

Block System Modeling By Discontinuous Deformation Analysis Topics In Engineering: Bestsellers in 2023 The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous captivating novels captivating the hearts of readers worldwide. Lets delve into the realm of popular books, exploring the fascinating narratives that have captivated audiences this year. Block System Modeling By Discontinuous Deformation Analysis Topics In Engineering : Colleen Hoover's "It Ends with Us" This touching tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover skillfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can succeed. Block System Modeling By Discontinuous Deformation Analysis Topics In Engineering : Taylor Jenkins Reid's "The Seven Husbands of Evelyn Hugo" This captivating historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reid's compelling storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Discover the Magic : Delia Owens' "Where the Crawdads Sing" This captivating coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens crafts a tale of resilience, survival, and the transformative power of nature, captivating readers with its evocative prose and mesmerizing setting. These popular novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of captivating stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is an exceptional and gripping novel that will keep you wondering until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

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