

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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**Jianchun Li,Xiaozhao Li,Minghe
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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 **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 *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 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 **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

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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

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

Marine Engineering T. K. S. Murthy,C. A. Brebbia,1994 *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

Innovative Numerical Modelling in Geomechanics Luis Ribeiro e Sousa,Eurípedes Vargas Jr.,M.M. Fernandes,Roberto Azevedo,2012-05-03 Since the 1990s five books onApplications of Computational Mechanics in Geotechnical Engineering have been published Innovative Numerical Modelling in Geomechanics is the 6th and final book in this series and contains papers written by leading experts on computational mechanics The book treats highly relevant topics in the field of geotechnic

Rock Dynamics: Progress and Prospect, Volume 2 Jianchun Li,Xiaozhao Li,Minghe Ju,Fengqiang Gong,Yingxin Zhou,2023-05-28 Rock Dynamics Progress and Prospect contains 153 scientific and technical papers presented at the Fourth International Conference on Rock Dynamics and Applications RocDyn 4 Xuzhou China 17 19 August 2022 The two volume set has 7 sections Volume 1 includes the first four sections with 6 keynotes and 5 young scholar plenary session papers and contributions on analysis and theoretical development and experimental testing and techniques Volume 2 contains the remaining three sections with 74

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Dynamic Web Programming and HTML5 Paul S. Wang, 2012-11-21 With organizations and individuals increasingly dependent on the Web the need for competent well trained Web developers and maintainers is growing Helping readers master Web development Dynamic Web Programming and HTML5 covers specific Web programming languages APIs and coding techniques and provides an in depth understanding of the underlying concepts theory and principles The author leads readers through page structuring page layout styling user input processing dynamic user interfaces database driven websites and mobile website development After an overview of the Web and Internet the book focuses on the new HTML5 and its associated open Web platform standards It covers the HTML5 markup language and DOM new elements for structuring Web documents and forms CSS3 and important JavaScript APIs associated with HTML5 Moving on to dynamic page generation and server side programming with PHP the text discusses page templates form processing session control user login database access and server side HTTP requests It also explores more advanced topics such as XML and PHP MySQL Suitable for a one or two semester course at the advanced undergraduate or beginning graduate level this comprehensive and up to date guide helps readers learn modern Web technologies and their practical applications Numerous examples illustrate how the programming techniques and other elements work together to achieve practical goals Online Resource Encouraging hands on practice the book's companion website at <http://dwp.softpower.com> helps readers gain experience with the technologies and techniques involved in building good sites Maintained by the author the site offers Live examples organized by chapter and cross referenced in the text Programs from the text bundled in a downloadable code package Searchable index and appendices Ample resource listings and information updates

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