

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 **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

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