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Soils are complex materials: they have a particular structure and fluids can seep through pores, mechanically interacting with the solid skeleton. Moreover, at a microscopic level, the behavior of the soil skeleton is highly variable. External loadings are in fact taken by grain chains which are continuously demolished and restored. Many issues of models of soil mechanics, even obscure, can be summarized in the long run at a critical review. However, despite physical complexities, soil mechanics has developed on the assumption that a soil can be seen as a continuum, or better yet as a medium obtained by the superposition of two and sometimes three continua, one solid space. Furthermore, relatively simple and robust constitutive laws were adopted to describe the stress-strain behavior and the interaction between the solid and the fluid phase. The continuum (the material that is deformed by the stress) is often characterized by a meso-scale, or by the extended critical state framework. This approach is widely used in rock mechanics, but it is also relevant to understand many problems related to granular materials. For instance, the extended critical state framework was used for flow classification, study of stress-strain behavior, and constitutive modeling. The effect of particle shape on granular flow behavior and the extended critical state framework was reviewed using simulation experiments. Selected unified constitutive models proposed by Savage and Louge were evaluated using the extended critical state framework. This research establishes a unifying constitutive model is developed. The new model combines the frictional and collisional stress contributions, using weighting functions called stress coefficients to determine the total stress. Stress coefficients are interdependent and are determined using empirical relations for sand. The unified constitutive model is used to predict the extended critical state framework and implemented in the numerical model for inclined flows. The model performs well in capturing the extended framework and flow profiles of these inclined flows on flat-rock and rough beds.

This book provides a complete and comprehensive analysis of the behavior of granular materials including the description of experimental results, the different ways to define the stress-strain behavior at the particle scale, the various models which can be used for a D.E.M. analysis to solve practical problems and finally the analysis of strain localization. The concepts developed in this book are applicable to many kinds of granular materials considered in civil, mechanical or chemical engineering.

This title provides a comprehensive overview of elastoplasticity relating to soil and rocks. Following a general outline of the models of behavior and their internal structure, each chapter develops a different area of this subject relating to the author’s particular expertise. The first half of the book concentrates on the elastoplastic behavior of both soils and rocks, while the second half examines that of hard soils and rocks.

The 40 chapters presented in this volume all share the goal of constructing continuum models based on the micro-behavior of granular materials. Computer simulations continue to provide observations, to aid modeling, while new experimental works begin to show promise for increased understanding in this area. Theoretical studies are developed in parallel with the rapid progress in plasticity and the solid and fluid mixture flows. Exciting new topics discussed in this volume include: concepts of a measure for randomness in quasi-static granular materials, which is analogous to the granular temperature in a rapid flow, scaling effects in granular media and their implications in both computer and physical simulations, instability and boundary conditions on homogenization in simple flow configurations, which are new challenges for mathematical modeling. The volume will prove indispensable reading for researchers interested in the current developments in the fundamental aspects of mechanics of granular materials.

Granular Materials at Meso-scale: Towards a Change of Scale Approach proposes a new way for developing an efficient change of scales—considering a meso-scale defined at the level of local arrays of particles. The change of scale is known to be a very interesting way to improve the modeling of mechanical behavior of granular materials. In the past, studies have been proposed using a micro-scale at the grain level to perform change of scale, but limitations have been proven for these approaches. Defining a constitutive model for granular materials based by sub-domain share the same text-structures. The authors propose a local constitutive model for the phases, allowing the constitutive model of the representative elementary volume to be defined from a change-of-scale approach and, finally, provides the validation of behavioral models on this question by proposing a new way for developing an efficient change of scales—considering a meso-scale. Cuppins introduces new local domains and texture characterization to define meso-strain and stress Analysis the evolution of these variables and texture characteristics in relation to the applied loading.

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Méridiens continuum mechanics is the topic of this book. After this introduction it will be applied to a few types specifically appearing in the environmental sciences and in geophysics. In this way, the Aerodynamics and Boundary Effects of the Earth will be analyzed in inward/motion processes of a homogenous and anisotropic water body. Strong thermomechanical coupling paired with nonlinear rheology theories (modified rheology, i.e. non-metrical and Greenian) and ice-shelves. The response to the climatic forcing of an environmental warming may significantly affect the life of future generations. The mechanical behavior of granular materials under quasi-static loadings requires non-classical mixture concepts and encounters generally complicated elastic-plastic constitutive behavior. Creeping flows of solidification processes and ground water flow anisotropic by definition. The shrinking of the flow and the stress-strain relationships due to particle collisions. Rockslides, slumps, snow and ice avalanches, but also debris flow and snow drifting can be described with such formulations.

Constitutive modeling of granular materials has achieved significant progress in recent times although some challenging problems still remain to be solved. Many of the 30 contributions in this volume are devoted to modeling but there are also papers investigating the phenomena to be modeled. For instance, there are reviews on several aspects of the behavior of granular systems which are more material properties while other aspects are related to the limit-state of the corresponding boundary value problems. This book is not up to date relevant on the theory of plasticity in granular materials, together with a great number of solution methods and applications. The volume is intended for researchers and practitioners who wish to enhance their knowledge in this rapidly expanding field.

Studies in Applied Mechanics, Volume 7: Mechanics of Granular Materials: New Mechanisms and Constitutive Relations provides information pertinent to the fundamental aspects of the mechanics of granular materials. This book presents the theoretical and experimental studies of quasi-static deformations of granular materials. Organized into 30 chapters, this volume begins with an overview of the results on the description of a macroscopic stress measure and measures of the fabric of granular materials that support external loads through frictional and cohesive types. This book then introduces some quantities for the macroscopic description of mechanical and geometrical characteristics of granular materials. Other chapters consider particle rolling, which is a major microscopic deformation mechanism when particles are in contact. This book discusses the behavior of granular materials that have a strongly anisotropic fabric. This final chapter deals with the interpretation of linear instabilities of viscoelastic deformations in fluidized beds. This book is a valuable resource for scientists, theoreticians, and engineers.

Proceedings of the NATO Advanced Study Institute, Braga, Portugal, August 24-September 4, 1981.

Granular or particulate materials arise in almost every aspect of our lives, including many familiar materials such as tea, coffee, sugar, sand, cement and pebbles. A small amount of each material involves the particulate material, and it is usually known that the use of the proper distribution makes the material a more useful and stable material. However, this volume contains a collection of recent works from some of the major contributors to the topic of modeling the behavior of granular materials. Papers from every area of current activity are included, such as theoretical, numerical, experimental, and computational approaches. This book illustrates the numerous diverse approaches to one of the outstanding problems of modern continuum mechanics.

In the past or until recently the majority of stress-deformation and stability analyses have been restricted to ideal material behavior. Such idealizations in material properties and geometrical conditions may lead to deviations observed and predicted behavior. Structural stress and deformation analyses of homogeneous earth
masses or soil–structure interaction problems using numerical techniques such as the finite element and finite difference methods require the formulation of a constitutive model for granular materials. A literature review made in this study indicated that most problems used in modeling soils and rocks are based on elasticity and curve fitting. (This study is limited to constitutive models which are based on theory of elasticity). Linear, bilinear, trilinear and hyperbolic models, together with microkinetic and meso-scale models, were used to describe the soil behavior.

This introductory text develops the fundamentals of the behavior of granular materials. It covers the basic principles of flow, friction, and fluidization of uniform granular materials, discusses mixing and segregation of heterogeneous materials (the famous “Aspern nut problem”), and concludes with an introduction to numerical methods. This presentation begins with simple experiments and uses them to build concepts and theories about material behavior that is quite often counter-intuitive. Presenting in a unified way the background needed to understand current work in the field. Developed for students at the University of Paris, the text will be suitable for advanced undergraduate and beginning graduate students, while also being of interest to researchers and engineers just entering the field.

This report summarizes achievements from Phase 3, the objectives of which were as follows: (1) the refinement and evaluation of the constitutive models, and (2) the implementation of the refined models into the FLAC software. The outcome of Phase 2 was a critically enhanced version of FLAC (Flanagan and Paris, 1993) for the analysis of problems in geotechnical engineering. This version of FLAC has been used in a number of research projects and is now commercially available. The constitutive models used in the development of FLAC are based on a large number of experiments and analyses. The models are designed to be as general as possible, while still being accurate and efficient.

Objectives are to develop new models and numerical capabilities for modeling granular materials in ALE3D focused on enhanced simulation of penetration into sand. Significantly decreasing the computational efficiency and accuracy of existing models or numerical codes for granular flows, particularly on the phenomenon of shear banding is a main concern of the research. This project seeks to study the effect of materials on granular material behavior, identifying the most suitable geometrical statistics for the numerical simulation of granular materials. The purpose of the seminar was to facilitate an exchange of ideas between scientists working with statistical and continuum theories, computer simulations and experiments on both static and dynamic behavior. The use of the soil behavior models has many new ideas on the constitutive relations that are introduced in this volume. An outline of the analysis, the mechanism of interaction is discussed. Computer simulations have become a vital tool in the mechanical microkinematical approaches which their otherwise would not be experimentally tested. In numerical simulations and theoretical analyses of rapid granular flow, the computational importance and accuracy of basic ideas are determined.

The numerical results have been shown that the potential of this methodology when applied to different branches of industry. Due to the phenomenological richness exhibited by granular materials, the present work will exclusively focus on the modeling of cohesionless dense granular materials. The numerical model is based on a continuum approach in the framework of large-deformation plasticity theory. For the constitutive model, the yield function is defined in the form of a chapter-5 punch-strain potential. The constitutive relations for the cohesion and the internal friction coefficient, and equipped with a non-associative deformation flow rule. This plastico–flow condition is considered nearly incompressible, so the proposed is integrated in a mixed formulation with a stabilization technique for pressure projection (PPP). In order to characterize the non-linear dependency on the shear rate during a visco-plastic regularization is proposed. The numerical integration is developed within the kinematic techniques, which increase the robustness and reduces the number of iterations compared to a typical implicit integration scheme. The spatial discretization is achieved within the framework of the PFEM, which allows treating the large deformations and motions associated to granular flows with minimal distortion of the finite element mesh. Since the Delaunay triangulation and the remeshing process minimizes such distortion but does not ensure the elimination of a discontinuous deformation of the domain is proposed, regularizing, in this manner, the smoothness and particle density of the mesh. Furthermore, it is proposed a method that ensures conservation of material at Lagrangian surfaces by means of a macroscopic velocity to determine the position of the boundary through the classical slip method. For modeling the interaction between the confinement boundaries and granular material, it is adopted for a method, which based on the Contact Domain Method (CDM) that allows coupling of both domains in terms of an interface connecting the potential contact surface by a domain of the same dimension than the contacting bodies. The constitutive model for the contact domain is a Coulomb-based model, delivering a correct representation of the wall friction angle. By order to validate the numerical model, a comparison between experimental results of the granular mass on a horizontal plane test, and finite element predictions, is carried out. The aim of the test is to examine the influence of the different kinematical conditions of granular material while spreading, from a steeply inclined condition, while the material is not, to transition to a granular flow, and back to a deposit profile. The potential of the numerical method for the solution of practical problems is achieved by focusing on two specific industrial applications in mining industry and particle manufacturing, the analysis of the calculation of the fluid power in tumbling mills. Both examples are representative when dealing with granular flows due to the presence of variations on the granular material mechanical response.

This proceedings volume contains papers from researchers in Japan, the United States and Europe who have made fundamental contributions to the mechanics of granular materials. The purpose of the seminar was to facilitate an exchange of ideas between scientists working with statistical and continuum theories, computer simulations and experiments on both static and dynamic behavior. The use of the soil behavior models has many new ideas on the constitutive relations that are introduced in this volume. An outline of the analysis, the mechanism of interaction is discussed. Computer simulations have become a vital tool in the mechanical microkinematical approaches which their otherwise would not be experimentally tested. In numerical simulations and theoretical analyses of rapid granular flow, the computational importance and accuracy of basic ideas are determined.

Constitutive modeling of granular material behavior has generally been based on global response of laboratory-size specimens or larger models with little understanding of the fundamentals of and meso-scale resolved simulation capabilities to determine the sensitivity of the discontinuous modeling approach to different physics, including the effect of domain boundary, initial size distribution, deformability, and fluid-coupling. (3) Enhance fundamental modeling approach to capture fracture behavior for an evolving granular material. (4) Using the results of parametric studies to capture the discontinuum model to the relevant parameter, validated the approach on pressure sand (PSP) and scaled penetration experiments for particular and saturated sands, estimating the approach.

This book includes a numerical investigation of shear localization in granular materials within a micro-polar hyperelasticity, which was carried out during my long research stay at the Institute of Soil and Rock Mechanics at Karlsruhe University from 1985 to 1996. I dedicate my book to Prof. Gerd Gudehus from Germany, the former director of the Institute of Soil and Rock Mechanics at the University of Karlsruhe, for his valuable guidance during my research stay. I am also grateful to Dr. Thomas Ditzinger and Mrs. Ewa Piontek for their helpful suggestions with respect to the contents and structure of the book. I am also grateful to Prof. Gerd Gudehus for his support and encouragement during my research stay. I am also grateful to Dr. Thomas Ditzinger and Mrs. Ewa Piontek for their helpful suggestions with respect to the contents and structure of the book. I am also grateful to Prof. Gerd Gudehus for his support and encouragement during my research stay.
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In view of its extreme complexity the mathematical description of the mechanical behaviour of granular materials is an extremely difficult task. Today many different models compete with each other. However, the complexity of the models hinders their comparison, and the potential users are confused and, often, disencouraged. This book is expected to serve as a milestone in the present situation, to evaluate the present methods, to clear up the situation, to focus and encourage for further research activities.

The Second International Symposium on Constitutive Modelling of Geomaterials: Advances and New Applications (IS-Model 2012), is to be held in Beijing, China, during October 15-16, 2012. The symposium is organized by Tsinghua University, the International Association for Computer Methods and Advances in Geomechanics (IACMAG), the Committee of Numerical and Physical Modeling of Rock Mass, Chinese Society for Rock Mechanics and Engineering, and the Committee of Constitutive Relations and Strength Theory, China Institution of Soil Mechanics and Geotechnical Engineering, China Civil Engineering Society. This Symposium follows the first successful International Workshop on Constitutive Modelling held in Hong Kong, which was organized by Prof. Jn Y in in 2007. Constitutive modeling of geomaterials has been an active research area for a long period of time. Different approaches have been used in the development of various constitutive models. A number of models have been implemented in the numerical analysis of geotechnical structures. The objective of the symposium is to provide a forum for researchers and engineers working or interested in the area of constitutive modeling to meet together and share new ideas, achievements and experience through presentations and discussions. Emphasis is placed on recent advances of constitutive modeling and its applications in both theoretical and experimental aspects. Six famous scholars have been invited for the plenary speeches of the symposiums. Some prominent scholars have been invited to organize four specialized workshops on hot topics, including “Time-dependent stress-strain behavior of geomaterials”, “Constitutive modeling within critical state soil mechanics”, “Heterogeneous micromechanics in geomaterials”, and “Damage to failure in rock structures”. A total of 49 papers are included in the above topics. In addition, 51 papers are grouped under three topics covering “Behaviour of geomaterials”, “Constitutive model”, and “Applications”. The editors expect that the book can be helpful as a reference to all those in the field of constitutive modeling of geomaterials.

These basic results regarding the microscopic grain interactions are generic to granular media and have important consequences for constitutive modeling. In particular we show that kinetic theories, which assume binary collisions, only apply below the network transition. In this regime we show that Enskog kinetic theory agrees with data from the simulations. We then proceed to introduce two analytical theories that use the observed microscopic grain-interactions to make predictions. First we propose a new constitutive model—the Force-Network model—that quantitively predicts constitutive relations using properties of the force-networks for all values of xi. Second we demonstrate STZ theory, which predicts constitutive relations by assuming certain dynamical correlations in amorphous materials, is in agreement with both the microscopic motion of grains and measured constitutive relations for large xi.

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