

Abaqus For Oil Gas Geomechanics Dassault Syst Mes

This book comprises select proceedings of the annual conference of the Indian Geotechnical Society. The conference brings together research and case histories on various aspects of geotechnical engineering and geoenvironmental engineering. The book presents papers on geotechnical applications and case histories, covering topics such as (i) shallow and deep foundations; (ii) stability of earth and earth retaining structures; (iii) rock engineering, tunneling, and underground constructions; (iv) forensic investigations and case histories; (v) reliability in geotechnical engineering; and (vi) special topics such as offshore geotechnics, remote sensing and GIS, geotechnical education, codes, and standards. The contents of this book will be of interest to researchers and practicing engineers alike.

The book introduces the reader to the fundamentals of rock mechanics and to its application to economic construction in rock. Models describe the mechanical properties and the permeability of rock. Numerical methods for evaluating the stability of structures in rock are given to solve special problems related to tunnels, caverns, pressure tunnels, dam foundations and slopes. Methods for testing the rock mechanical properties are described. A number of case histories enable the reader to make use of the content in his or her own work.

Analytical Methods in Petroleum Upstream Applications CRC Press

Modelling and predicting how porous media deform when subjected to external actions and physical phenomena, including the effect of saturating fluids, are of importance to the understanding of geophysics and civil engineering (including soil and rock mechanics and petroleum engineering), as well as in newer areas such as biomechanics and agricultural engineering. Starting from the highly successful First Edition, Coussy has completely re-written Mechanics of Porous Continua/Poromechanics to include: New material for: Partially saturated porous media Reactive porous media Macroscopic electrical effects A single theoretical framework to the subject to explain the interdisciplinary nature of the subject Exercises at the end of each chapter to aid understanding The unified approach taken by this text makes it a valuable addition to the bookshelf of every PhD student and researcher in civil engineering, petroleum engineering, geophysics, biomechanics and material science.

This interdisciplinary book encompasses the fields of rock mechanics, structural geology and petroleum engineering to address a wide range of geomechanical problems that arise during the exploitation of oil and gas reservoirs. It considers key practical issues such as prediction of pore pressure, estimation of hydrocarbon column heights and fault seal potential, determination of optimally stable well trajectories, casing set points and mud weights, changes in reservoir performance during depletion, and production-induced faulting and subsidence. The book establishes the basic principles involved before introducing practical measurement and experimental techniques to improve recovery and reduce exploitation costs. It illustrates their successful application through case studies taken from oil and gas fields around the world. This book is a practical reference for geoscientists and engineers in the petroleum and geothermal industries, and for research scientists interested in stress measurements and their application to problems of faulting and fluid flow in the crust.

This book presents selected papers from the 7th International Field Exploration and Development Conference (IFEDC 2017), which focus on upstream technologies used in oil & gas development, the principles of the process, and various design technologies. The conference not only provides a platform for exchanging lessons learned, but also promotes the development of scientific research in oil & gas exploration and production. The book will benefit a broad readership, including industry experts, researchers, educators, senior engineers and managers.

In geomechanics, existing design methods are very much dependent upon sophisticated on-site techniques to assess ground conditions. This book describes numerical analysis, computer

simulation and modelling that can be used to answer some highly complex questions associated with geomechanics. The contributors, who are all international experts in the field, are associated with commercially significant amounts of crude oil and natural gas lying under the continental shelf of the United States. Advances in locating deposits, and improvements in drilling and recovery technology, have made it technically and economically feasible to extract these resources under harsh conditions. But extracting these offshore petroleum resources involves the possibility, however remote, of oil spills, with resulting damage to the ocean and the coastline ecosystems and risks to life and limb of those performing the extraction. The environmental consequences of an oil spill can be more severe underwater than on land because sea currents can quickly disperse the oil over a large area and, thus, cleanup can be problematic. Bolted connections are an integral feature of deep-water well operations. High-Performance Bolting Technology for Offshore Oil and Natural Gas Operations summarizes strategies for improving the reliability of fasteners used in offshore oil exploration equipment, as well as best practices from other industrial sectors. It focuses on critical bolting—bolts, studs, nuts, and fasteners used on critical connections.

Geologists, engineers, and petrophysicists concerned with hydrocarbon production from naturally fractured reservoirs will find this book a valuable tool for obtaining pertinent rock data to evaluate reserves and optimize well location and performance. Nelson emphasizes geological, petrophysical, and rock mechanics to complement other studies of the subject that use well logging and classical engineering approaches. This well organized, updated edition contains a wealth of field and laboratory data, case histories, and practical advice. A great how-to-guide for anyone working with fractured or highly anisotropic reservoirs. Provides real-life illustrations through case histories and field and laboratory data.

The Encyclopedia of Maritime and Offshore Engineering (EMOE) provides an unparalleled major reference work covering the design, construction and operation of ships, offshore installations and other marine structures used for transportation, exploration and the exploitation of ocean-based resources including oil, gas and renewable energy. It embraces all of the disciplines of engineering and naval architecture that are found in the complementary marine and offshore industries. Advances in ship technology, the growth of the offshore energy sector, and increasing activities in arctic and ultra-deepwater environments all highlight the need for an up-to-date reference work on the proposed scale. Operational and regulatory aspects of maritime industries will also be included. The technical sections are supported by the appropriate theoretical background information: for example, hydrodynamics and numerical analysis methods of fluid and stress analysis. The full editorial team and contributing authors is drawn worldwide from renowned engineers, scientists and practitioners in both the academic and industrial sectors.

Design practice in offshore geotechnical engineering has grown out of onshore practice, but the two application areas have tended to diverge over the last thirty years, driven partly by the scale of the foundation and anchoring elements used offshore, and partly by fundamental differences in construction and installation techniques. As a consequence offshore geotechnical engineering has grown as a speciality. The structure of Offshore Geotechnical Engineering follows a pattern that mimics the flow of a typical offshore project. In the early chapters it provides a brief overview of the marine

environment, offshore site investigation techniques and interpretation of soil behaviour. It proceeds to cover geotechnical design of piled foundations, shallow foundations and anchoring systems. Three topics are then covered which require a more multi-disciplinary approach: the design of mobile drilling rigs, pipelines and geohazards. This book serves as a framework for undergraduate and postgraduate courses, and will appeal to professional engineers specialising in the offshore industry.

Hydraulic Fracture Modeling delivers all the pertinent technology and solutions in one product to become the go-to source for petroleum and reservoir engineers. Providing tools and approaches, this multi-contributed reference presents current and upcoming developments for modeling rock fracturing including their limitations and problem-solving applications. Fractures are common in oil and gas reservoir formations, and with the ongoing increase in development of unconventional reservoirs, more petroleum engineers today need to know the latest technology surrounding hydraulic fracturing technology such as fracture rock modeling. There is tremendous research in the area but not all located in one place. Covering two types of modeling technologies, various effective fracturing approaches and model applications for fracturing, the book equips today's petroleum engineer with an all-inclusive product to characterize and optimize today's more complex reservoirs. Offers understanding of the details surrounding fracturing and fracture modeling technology, including theories and quantitative methods Provides academic and practical perspective from multiple contributors at the forefront of hydraulic fracturing and rock mechanics Provides today's petroleum engineer with model validation tools backed by real-world case studies

The book explores the theoretical background of one of the most widespread activities in hydrocarbon wells, that of hydraulic fracturing. A comprehensive treatment of the basic phenomena includes: linear elasticity, stresses, fracture geometry and rheology. The diverse concepts of mechanics are integrated into a coherent description of hydraulic fracture propagation. The chapters in the book are cross-referenced throughout and the connections between the various phenomena are emphasized. The book offers readers a unique approach to the subject with the use of many numerical examples.

Proceedings of the Fifth International Conference on Geotechnical and Geophysical Site Characterisation (ISC'15) held from September 5th to 9th 2016, Gold Coast, Australia

Core Analysis: A Best Practice Guide is a practical guide to the design of core analysis programs. Written to address the need for an updated set of recommended practices covering special core analysis and geomechanics tests, the book also provides unique insights into data quality control diagnosis and data utilization in reservoir models. The book's best practices and procedures benefit petrophysicists, geoscientists, reservoir engineers, and production engineers, who will find useful information on core data in reservoir static and dynamic models. It provides a solid understanding of the core analysis procedures and methods used by commercial laboratories, the details of lab data reporting required to create quality control tests, and the diagnostic plots and protocols that can be used to identify suspect or erroneous data. Provides a practical overview of core analysis, from coring at the well site to laboratory data acquisition and interpretation Defines current best practice in core analysis preparation and test procedures, and the diagnostic tools used to quality control core data Provides essential information on design of core analysis programs and to judge the quality and reliability of core analysis data ultimately used in reservoir evaluation Of specific interest to

those working in core analysis, porosity, relative permeability, and geomechanics
Petroleum Rock Mechanics: Drilling Operations and Well Design, Second Edition, keeps petroleum and drilling engineers centrally focused on the basic fundamentals surrounding geomechanics, while also keeping them up-to-speed on the latest issues and practical problems. Updated with new chapters on operations surrounding shale oil, shale gas, and hydraulic fracturing, and with new sections on in-situ stress, drilling design of optimal mud weight, and wellbore instability analysis, this book is an ideal resource. By creating a link between theory with practical problems, this updated edition continues to provide the most recent research and fundamentals critical to today's drilling operations. Helps readers grasp the techniques needed to analyze and solve drilling challenges, in particular wellbore instability analysis Teaches rock mechanic fundamentals and presents new concepts surrounding sand production and hydraulic fracturing operations Includes new case studies and sample problems to practice

The expansion of unconventional petroleum resources in the recent decade and the rapid development of computational technology have provided the opportunity to develop and apply 3D numerical modeling technology to simulate the hydraulic fracturing of shale and tight sand formations. This book presents 3D numerical modeling technologies for hydraulic fracturing developed in recent years, and introduces solutions to various 3D geomechanical problems related to hydraulic fracturing. In the solution processes of the case studies included in the book, fully coupled multi-physics modeling has been adopted, along with innovative computational techniques, such as submodeling. In practice, hydraulic fracturing is an essential project component in shale gas/oil development and tight sand oil, and provides an essential measure in the process of drilling cuttings reinjection (CRI). It is also an essential measure for widened mud weight window (MWW) when drilling through naturally fractured formations; the process of hydraulic plugging is a typical application of hydraulic fracturing. 3D modeling and numerical analysis of hydraulic fracturing is essential for the successful development of tight oil/gas formations: it provides accurate solutions for optimized stage intervals in a multistage fracking job. It also provides optimized well-spacing for the design of zipper-frac wells. Numerical estimation of casing integrity under stimulation injection in the hydraulic fracturing process is one of major concerns in the successful development of unconventional resources. This topic is also investigated numerically in this book. Numerical solutions to several other typical geomechanics problems related to hydraulic fracturing, such as fluid migration caused by fault reactivation and seismic activities, are also presented. This book can be used as a reference textbook to petroleum, geotechnical and geothermal engineers, to senior undergraduate, graduate and postgraduate students, and to geologists, hydrogeologists, geophysicists and applied mathematicians working in this field. This book is also a synthetic compendium of both the fundamentals and some of the most advanced aspects of hydraulic fracturing technology.

This book contains the Proceedings of EUROCK 2013 - The 2013 ISRM International Symposium, which was held on 23-26 September 2013 in Wroclaw, Poland. The Symposium was organized by the ISRM National Group POLAND and the Institute of Geotechnics and Hydrotechnics of the Wroclaw Institute of Technology. The focus of the Symposium was on recent develo

Basic level textbook covering concepts and practical analytical techniques of reservoir engineering.

Scientific understanding of fluid flow in rock fractures--a process underlying contemporary earth science problems from the search for petroleum to the controversy over nuclear waste storage--has grown significantly in the past 20 years. This volume presents a comprehensive report on the state of the field, with an interdisciplinary viewpoint, case studies of fracture sites, illustrations, conclusions, and research recommendations. The book addresses these

questions: How can fractures that are significant hydraulic conductors be identified, located, and characterized? How do flow and transport occur in fracture systems? How can changes in fracture systems be predicted and controlled? Among other topics, the committee provides a geomechanical understanding of fracture formation, reviews methods for detecting subsurface fractures, and looks at the use of hydraulic and tracer tests to investigate fluid flow. The volume examines the state of conceptual and mathematical modeling, and it provides a useful framework for understanding the complexity of fracture changes that occur during fluid pumping and other engineering practices. With a practical and multidisciplinary outlook, this volume will be welcomed by geologists, petroleum geologists, geoengineers, geophysicists, hydrologists, researchers, educators and students in these fields, and public officials involved in geological projects.

The purpose of this book is to bridge the gap between the traditional Geomechanics and Numerical Geotechnical Modelling with applications in science and practice. Geomechanics is rarely taught within the rigorous context of Continuum Mechanics and Thermodynamics, while when it comes to Numerical Modelling, commercially available finite elements or finite differences software utilize constitutive relationships within the rigorous framework. As a result, young scientists and engineers have to learn the challenging subject of constitutive modelling from a program manual and often end up with using unrealistic models which violate the Laws of Thermodynamics. The book is introductory, by no means does it claim any completeness and state of the art in such a dynamically developing field as numerical and constitutive modelling of soils. The author gives basic understanding of conventional continuum mechanics approaches to constitutive modelling, which can serve as a foundation for exploring more advanced theories. A considerable effort has been invested here into the clarity and brevity of the presentation. A special feature of this book is in exploring thermomechanical consistency of all presented constitutive models in a simple and systematic manner.

Stress Field of the Earth's Crust is based on lecture notes prepared for a course offered to graduate students in the Earth sciences and engineering at University of Potsdam. In my opinion, it will undoubtedly also become a standard reference book on the desk of most scientists working with rocks, such as geophysicists, structural geologists, rock mechanics experts, as well as geotechnical and petroleum engineers. That is because this book is concerned with what is probably the most peculiar characteristic of rock – its initial stress condition. Rock is always under a natural state of stress, primarily a result of the gravitational and tectonic forces to which it is subjected. Crustal stresses can vary regionally and locally and can reach in places considerable magnitudes, leading to natural or man-made mechanical failure. Pre-existing stress distinguishes rock from most other materials and is at the core of the discipline of "Rock Mechanics", which has been developed over the last century. Knowledge of rock stress is fundamental to understanding faulting mechanisms and earthquake triggering, to designing stable underground caverns and productive oil fields, and to improving mining methods and geothermal energy extraction, among others. Several books have been written on the subject, but none has attempted to be as all-encompassing as the one by Zang and Stephansson.

Engineers and geologists in the petroleum industry will find Petroleum Related Rock Mechanics, 2e, a powerful resource in providing a basis of rock mechanical knowledge - a knowledge which can greatly assist in the understanding of field behavior, design of test programs and the design of field operations. Not only does this text give an introduction to applications of rock mechanics within the petroleum industry, it has a strong focus on basics, drilling, production and reservoir engineering. Assessment of

rock mechanical parameters is covered in depth, as is acoustic wave propagation in rocks, with possible link to 4D seismics as well as log interpretation. Learn the basic principles behind rock mechanics from leading academic and industry experts Quick reference and guide for engineers and geologists working in the field Keep informed and up to date on all the latest methods and fundamental concepts

The theory of linear poroelasticity describes the interaction between mechanical effects and adding or removing fluid from rock. It is critical to the study of such geological phenomena as earthquakes and landslides and is important for numerous engineering projects, including dams, groundwater withdrawal, and petroleum extraction. Now an advanced text synthesizes in one place, with one notation, numerous classical solutions and applications of this highly useful theory. The introductory chapter recounts parallel developments in geomechanics, hydrogeology, and reservoir engineering that are unified by the tenets of poroelasticity. Next, the theory's constitutive and governing equations and their associated material parameters are described. These equations are then specialized for different simplifying geometries: unbounded problem domains, uniaxial strain, plane strain, radial symmetry, and axisymmetry. Example problems from geomechanics, hydrogeology, and petroleum engineering are incorporated throughout to illustrate poroelastic behavior and solution methods for a wide variety of real-world scenarios. The final chapter provides outlines for finite-element and boundary-element formulations of the field's governing equations. Whether read as a course of study or consulted as a reference by researchers and professionals, this volume's user-friendly presentation makes accessible one of geophysics' most important subjects and will do much to reduce poroelasticity's reputation as difficult to master.

Modern petroleum and petrotechnical engineering is increasingly challenging due to the inherently scarce and decreasing number of global petroleum resources. Exploiting these resources efficiently will require researchers, scientists, engineers and other practitioners to develop innovative mathematical solutions to serve as basis for new asset development designs. Deploying these systems in numerical models is essential to the future success and efficiency of the petroleum industry. Multiphysics modeling has been widely applied in the petroleum industry since the 1960s. The rapid development of computer technology has enabled the numerical applications of multiphysics modeling in the petroleum industry: its applications are particularly popular for the numerical simulation of drilling and completion processes. This book covers theory and numerical applications of multiphysical modeling presenting various author-developed subroutines, used to address complex pore pressure input, complex initial geo-stress field input, etc. Some innovative methods in drilling and completion developed by the authors, such as trajectory optimization and a 3-dimensional workflow for calculation of mud weight window etc, are also presented. Detailed explanations are provided for the modeling process of each application example included in the book. In addition, details of the completed numerical models data are presented as supporting material which can be downloaded from the website of the publisher. Readers can easily understand key modeling techniques with the theory of multiphysics embedded in examples of applications, and can use the data to reproduce the results presented. While this book would be of interest to any student, academic or professional practitioner of engineering, mathematics and natural science, we believe those professionals and academics working in civil engineering, petroleum engineering and

petroleum geomechanics would find the work especially relevant to their endeavors. *Underground Excavations in Rock* deals with the geotechnical aspects of the design of underground openings for mining and civil engineering processes.

This single-volume thoroughly summarizes advances in the past several decades and emerging challenges in fundamental research in geotechnical engineering. These fundamental research frontiers are critically reviewed and described in details in lights of four grand challenges our society faces: climate adaptation, urban sustainability, energy and material resources, and global water resources. The specific areas critically reviewed, carefully examined, and envisioned are: sensing and measurement, soil properties and their physics roots, multiscale and multiphysics processes in soil, geochemical processes for resilient and sustainable geosystems, biological processes in geotechnics, unsaturated soil mechanics, coupled flow processes in soil, thermal processes in geotechnical engineering, and rock mechanics in the 21st century.

A comprehensive overview of the key geologic, geomechanical and engineering principles that govern the development of unconventional oil and gas reservoirs.

Covering hydrocarbon-bearing formations, horizontal drilling, reservoir seismology and environmental impacts, this is an invaluable resource for geologists, geophysicists and reservoir engineers.

This book provides a comprehensive guide for the analysis and design of anchor systems used for mooring offshore floating structures. Much of the experience is based on applications toward the offshore oil and gas industry, but the substantial potential for offshore renewable energy systems is addressed. The major types of anchors are described with respect to their basic design concept, advantages and limitations, appropriate framework for analysis, and observed performance. This book addresses all aspects of anchor behaviour related to anchor design including the installation performance, load capacity, deformation, and structural integrity of the anchor itself. Coverage is also provided of appurtenant components of anchor systems, in particular of anchor line/chain mechanics in the soil and water columns. Much of the material presented represents relatively new developments, including several new anchors which have been developed within the last decade, so the book will provide a useful compendium of information is largely scattered in journals and conference proceedings. This book is intended for engineers engaged in offshore geotechnics and marine engineers involved in mooring system and floating structure design. While the analytical methods presented in this text have a strong theoretical basis, the emphasis is on simplified computational formats accessible to design engineers.

Geotechnical Safety and Risk IV contains the contributions presented at the 4th International Symposium on Geotechnical Safety and Risk (4th ISGSR, Hong Kong, 4-6 December 2013), which was organised under the auspices of the Geotechnical Safety Network (GEOSNet), TC304 on Engineering Practice of Risk Assessment and Management and TC205 on Safety an

A simplified approach to applying the Finite Element Method to geotechnical problems. Predicting soil behavior by constitutive equations that are based on experimental findings and embodied in numerical methods, such as the finite element method, is a significant aspect of soil mechanics. Engineers are able to solve a wide range of geotechnical engineering problems, especially inherently complex ones that resist traditional analysis. *Applied Soil Mechanics with ABAQUS® Applications* provides civil engineering students and practitioners with a simple, basic introduction to applying the finite element method to soil mechanics problems. Accessible to someone with little background in soil mechanics and finite element analysis, *Applied Soil Mechanics with ABAQUS® Applications* explains the basic concepts of

soil mechanics and then prepares the reader for solving geotechnical engineering problems using both traditional engineering solutions and the more versatile, finite element solutions. Topics covered include: Properties of Soil Elasticity and Plasticity Stresses in Soil Consolidation Shear Strength of Soil Shallow Foundations Lateral Earth Pressure and Retaining Walls Piles and Pile Groups Seepage Taking a unique approach, the author describes the general soil mechanics for each topic, shows traditional applications of these principles with longhand solutions, and then presents finite element solutions for the same applications, comparing both. The book is prepared with ABAQUS® software applications to enable a range of readers to experiment firsthand with the principles described in the book (the software application files are available under "student resources" at www.wiley.com/college/helwany). By presenting both the traditional solutions alongside the FEM solutions, Applied Soil Mechanics with ABAQUS® Applications is an ideal introduction to traditional soil mechanics and a guide to alternative solutions and emergent methods. Dr. Helwany also has an online course based on the book available at www.geomilwaukee.com. Effective measurement of the composition and properties of petroleum is essential for its exploration, production, and refining; however, new technologies and methodologies are not adequately documented in much of the current literature. Analytical Methods in Petroleum Upstream Applications explores advances in the analytical methods and instrumentation that allow more accurate determination of the components, classes of compounds, properties, and features of petroleum and its fractions. Recognized experts explore a host of topics, including: A petroleum molecular composition continuity model as a context for other analytical measurements A modern modular sampling system for use in the lab or the process area to collect and control samples for subsequent analysis The importance of oil-in-water measurements and monitoring The chemical and physical properties of heavy oils, their fractions, and products from their upgrading Analytical measurements using gas chromatography and nuclear magnetic resonance (NMR) applications Asphaltene and heavy ends analysis Chemometrics and modeling approaches for understanding petroleum composition and properties to improve upstream, midstream, and downstream operations Due to the renaissance of gas and oil production in North America, interest has grown in analytical methods for a wide range of applications. The understanding provided in this text is designed to help chemists, geologists, and chemical and petroleum engineers make more accurate estimates of the crude value to specific refinery configurations, providing insight into optimum development and extraction schemes.

Progressive failure has been a classical problem in the field of geotechnical engineering and has attracted considerable attention in connection with slope stability and foundation problems. It is associated with strain localization or shear banding and is also related to damage in material structures. As knowledge of the progressive failure mechanism increases, it is now necessary to establish effective communications between researchers and engineers. The International Symposium on Deformation and Progressive Failure in Geomechanics provided an opportunity for discussing recent advances in this area. A total of 136 papers were contributed from 22 countries. As well as these, the symposium proceedings also contain 8 interim technical reports on the subject by the members of the Asian Technical Committee of the International Society for Soil Mechanics and Foundation Engineering and the Japanese Geotechnical Society National Committee on Progressive Failure in Geo-structures. In this edited volume on advances in forensic geotechnical engineering, a number of technical contributions by experts and professionals in this area are included. The work is the outcome of deliberations at various conferences in the area conducted by Prof. G.L. Sivakumar Babu and Dr. V.V.S. Rao as secretary and Chairman of Technical Committee on Forensic Geotechnical Engineering of International Society for Soil Mechanics and Foundation Engineering (ISSMGE). This volume contains papers on topics such as guidelines,

evidence/data collection, distress characterization, use of diagnostic tests (laboratory and field tests), back analysis, failure hypothesis formulation, role of instrumentation and sensor-based technologies, risk analysis, technical shortcomings. This volume will prove useful to researchers and practitioners alike.

Rock masses are initially stressed in their current in situ state of stress and to a lesser natural state. Whether one is interested in the extent on the monitoring of stress change. formation of geological structures (folds, faults, The subject of paleostresses is only briefly intrusions, etc.), the stability of artificial struc discussed. tures (tunnels, caverns, mines, surface excava The last 30 years have seen a major advance our knowledge and understanding of rock tions, etc.), or the stability of boreholes, a in the in situ or virgin stress field, stress. A large body of data is now available on knowledge of along with other rock mass properties, is the state of stress in the near surface of the needed in order to predict the response of rock Earth's crust (upper 3-4km of the crust). masses to the disturbance associated with those Various theories have been proposed regarding structures. Stress in rock is usually described the origin of in situ stresses and how gravity, within the context of continuum mechanics. It is tectonics, erosion, lateral straining, rock fabric, defined at a point and is represented by a glaciation and deglaciation, topography, curva second-order Cartesian tensor with six compo ture of the Earth and other active geological nents. Because of its definition, rock stress is an features and processes contribute to the current enigmatic and fictitious quantity creating chal in situ stress field.

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