Asymptotic Analysis For Periodic Structures Ams Chelsea Publishing

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Advances in Mechanics: Theoretical, Computational and Interdisciplinary Issues covers the domain of theoretical, experimental and computational mechanics as well as interdisciplinary issues, such as industrial applications. Special attention is paid to the theoretical background and practical applications of computational mechanics.This volume
Materials science is an area of growing research as composite materials become widely used in such areas as civil engineering, electrotechnics, and the aerospace industry. This mathematically rigorous treatment of lattice-type structures will appeal to both applied mathematicians, as well as engineers looking for a solid mathematical foundation of the methodology.
This unique volume presents the state of the art in the field of multiscale modeling in solid mechanics, with particular emphasis on computational approaches. For the first time, contributions from both leading experts in the field and younger promising researchers are combined to give a comprehensive description of the recently proposed techniques and the engineering problems tackled using these techniques. The book begins with a detailed introduction to the theories on which different multiscale approaches are based, with regards to linear Homogenisation as well as various nonlinear approaches. It then presents advanced applications of multiscale approaches applied to nonlinear mechanical problems. Finally, the novel topic of materials with self-similar structure is discussed. Sample Chapter(s). Chapter 1: Computational Homogenisation for Non-Linear Heterogeneous Solids (808 KB). Contents: Computational Homogenisation for Non-Linear Heterogeneous Solids (V G Kouznetsova et al.); Two-Scale Asymptotic Homogenisation-Based Finite Element Analysis of Composite Materials (Q-Z Xiao & B L Karihaloo); Multi-Scale Boundary Element Modelling of Material Degradation and Fracture (G K Sfantos & M H Aliabadi); Non-Uniform Transformation Field Analysis: A Reduced Model for Multiscale Non-Linear Problems in Solid Mechanics (J-C Michel & P Suquet); Multiscale Approach for the Thermomechanical Analysis of Hierarchical Structures (M J Lefik et al.); Recent Advances in Masonry Modelling: Micro-Modelling and Homogenisation (P B Louren o); Mechanics of Materials with Self-Similar Hierarchical Microstructure (R C Picu & M A Soare). Readership: Researchers and academics in the field of heterogeneous materials and mechanical engineering; professionals in aeronautical engineering and materials science.
Boundary element methods relate to a wide range of engineering applications, including fluid flow, fracture analysis, geomechanics, elasticity, and heat transfer. Thus, new results in the field hold great importance not only to researchers in mathematics, but to applied mathematicians, physicists, and engineers. A two-day minisymposium Mathematical Aspects of Boundary Element Methods at the IABEM conference in May 1998 brought together top rate researchers from around the world, including Vladimir Maz'ya, to whom the conference was dedicated. Focusing on the mathematical and numerical analysis of boundary integral operators, this volume presents 25 papers contributed to the symposium. Mathematical Aspects of Boundary Element Methods provides up-to-date research results from the point of view of both mathematics and engineering. The authors

detail new results, such as on nonsmooth boundaries, and new methods, including domain decomposition and parallelization, preconditioned iterative techniques, multipole expansions, higher order boundary elements, and approximate approximations. Together they illustrate the connections between the modeling of applied problems, the derivation and analysis of corresponding boundary integral equations, and their efficient numerical solutions.

This is a reprinting of a book originally published in 1978. At that time it was the first book on the subject of homogenization, which is the asymptotic analysis of partial differential equations with rapidly oscillating coefficients, and as such it sets the stage for what problems to consider and what methods to use, including probabilistic methods. At the time the book was written the use of asymptotic expansions with multiple scales was new, especially their use as a theoretical tool, combined with energy methods and the construction of test functions for analysis with weak convergence methods. Before this book, multiple scale methods were primarily used for non-linear oscillation problems in the applied mathematics community, not for analyzing spatial oscillations as in homogenization. In the current printing a number of minor corrections have been made, and the bibliography was significantly expanded to include some of the most important recent references. This book gives systematic introduction of multiple scale methods for partial differential equations, including their original use for rigorous mathematical analysis in elliptic, parabolic, and hyperbolic problems, and with the use of probabilistic methods when appropriate. The book continues to be interesting and useful to readers of different backgrounds, both from pure and applied mathematics, because of its informal style of introducing the multiple scale methodology and the detailed proofs.

Asymptotic Analysis for Periodic StructuresElsevier

Numerous applications of rod structures in civil engineering, aircraft and spacecraft confirm the importance of the topic. On the other hand the majority of books on structural mechanics use some simplifying hypotheses; these hypotheses do not allow to consider some important effects, for instance the boundary layer effects near the points of junction of rods. So the question concerning the limits of applicability of structural mechanics hypotheses and the possibilities of their refinement arise. In this connection the asymptotic analysis of equations of mathematical physics, the equations of elasticity in rod structures (without these hypotheses and simplifying assumptions being imposed) is undertaken in the present book. Moreover, a lot of modern structures are made of composite materials and therefore the material of the rods is not homogeneous. This inhomogeneity of the material can generate some unexpected effects. These effects are analysed in this book. The methods of multi-scale modelling are presented by the homogenization, multi-level asymptotic analysis and the domain decomposition. These methods give an access to a new class of hybrid models combining macroscopic description with "microscopic zooms".

An area at the intersection of solid mechanics, materials science, and stochastic mathematics, mechanics of materials often necessitates a stochastic approach to grasp the effects of spatial randomness. Using this approach, Microstructural Randomness and Scaling in Mechanics of Materials explores numerous stochastic models and methods used in the mechanics of random media and illustrates these in a variety of applications. The book first offers a refresher in several tools used in stochastic mechanics, followed by two chapters that outline periodic and disordered planar lattice (spring) networks. Subsequent chapters discuss stress invariance in classical planar and micropolar elasticity and cover several topics not yet collected in book form, including the passage of a microstructure to an effective micropolar continuum. After forming this foundation in various methods of stochastic mechanics, the book focuses on problems of microstructural randomness and scaling. It examines both representative and statistical volume elements (RVEs/SVEs) as well as micromechanically based stochastic finite elements (SFEs). The author also studies nonlinear elastic and inelastic materials, the stochastic formulation of thermomechanics with internal variables, and wave propagation in random media. The concepts discussed in this comprehensive book can be applied to many situations, from micro and nanoelectromechanical systems (MEMS/NEMS) to geophysics.

Shell Structures. Theory and Applications, Volume 2 contains 77 contributions from over 17 countries, reflecting a wide spectrum of scientific and engineering problems of shell structures. The papers are divided into six broad groups: 1. General lectures; 2. Theoretical modeling; 3. Stability; 4. Dynamics; 5. Numerical analysis; 6. Engineering design, and will be of interest to academics, researchers, designers and engineers dealing with theoretical modelling, computerized analyses and engineering design of thin-walled structures and shell structural elements.

This book discusses recent findings and advanced theories presented at two workshops at TU Berlin in 2017 and 2018. It underlines several advantages of generalized continuum models compared to the classical Cauchy continuum, which although widely used in engineering practice, has a number of limitations, such as: • The structural size is very small. • The microstructure is complex. • The effects are localized. As such, the development of generalized continuum models is helpful and results in a better description of the behavior of structures or materials. At the same time, there are more and more experimental studies supporting the new models because the number of material parameters is higher.

This is the first book on the subject of the periodic unfolding method (originally called "éclatement périodique" in French), which was originally developed to clarify and simplify many questions arising in the homogenization of PDE's. It has since led to the solution of some open problems. Written by the three mathematicians who developed the method, the book presents both the theory as well as numerous examples of applications for partial differential problems with rapidly oscillating coefficients: in fixed domains (Part I), in periodically perforated domains (Part II), and in domains with small holes generating a strange term (Part IV). The method applies to the case of multiple microscopic scales (with finitely many distinct scales) which is connected to partial unfolding (also useful for evolution problems). This is discussed in the framework of oscillating boundaries (Part III). A detailed example of its application to linear elasticity is presented in the case of thin elastic plates (Part V). Lastly, a complete determination of correctors for the model problem in Part I is obtained (Part VI). This book can be used as a graduate textbook to introduce the theory of homogenization of partial differential problems, and is also a must for researchers interested in this field.

In the last few decades, metamaterials have revolutionized the ways in which waves are controlled, and applied in physics and practical situations. The extraordinary properties of metamaterials, such as their locally resonant structure with deep subwavelength band gaps and their ranges of frequency where propagation is impossible, have opened the way to a host of applications that were previously unavailable. Acoustic metamaterials have been able to replace traditional treatments in several sectors, due to their better performance in targeted and tunable frequency ranges with strongly reduced dimensions. This is a training book composed of nine chapters written by experts in the field, giving a broad overview of acoustic metamaterials and their uses. The book is divided into three parts, covering the state-of-the-art, the fundamentals and the real-life applications of acoustic metamaterials.

In this volume, a result of The CIME Summer School held in Cetraro, Italy, in 2006, four leading specialists present different aspects of quantum transport modeling. It provides an excellent basis for researchers in this field.

This book gives a systematic and comprehensive presentation of the results concerning effective behavior of elastic and plastic plates with periodic or quasiperiodic structure. One of the chapters covers the hitherto available results concerning the averaging problems in the linear and nonlinear shell models. A unified approach to the problems studied is based on modern variational and asymptotic methods, including the methods of variational inequalities as well as homogenization techniques. Duality arguments are also exploited. A significant part of the book deals with problems important for engineering practice, such as: statical analysis of highly nonhomogeneous plates and shells for which common discretization techniques fail to be efficient, assessing stiffness reduction of cracked [00n/900m]s laminates, and assessing ultimate loads for perfectly plastic plates and shells composed of repeated segments. When possible, the homogenization formulas are cast in closed form expressions. The formulas presented in this manner are then used in constructing regularized formulations of the fundamental optimization problems for plates and shells, since the regularization concepts are based on introducing the composite regions for which microstructural properties play the role of new design variables. Contents:Mathematical Preliminaries:Function Spaces, Convex Analysis, Variational ConvergenceElastic Plates:Three-Dimensional Analysis and Effective Models of Composite PlatesThin Plates in Bending and StretchingNonlinear Behavior of PlatesModerately Thick Transversely Symmetric PlatesSandwich Plates with Soft CoreElastic Plates with Cracks:Unilateral Cracks in Thin PlatesUnilateral Cracks in Plates with Transverse Shear DeformationPart-Through the Thickness CracksStiffness Loss of Cracked LaminatesComments and Bibliographical NotesElastic–Perfectly Plastic Plates:Mathematical Complements, Homogenization of Functionals with Linear GrowthHomogenization of Plates Loaded by Forces and MomentsComments and Bibliographical NotesElastic and Plastic Shells:Linear and Nonlinear Models of Elastic ShellsHomogenization and Stiffnesses of Thin Periodic Elastic Shells. Linear ApproachHomogenized Properties of Thin Periodic Elastic Shells Undergoing Moderately Large Rotations Around TangentsPerfectly Plastic ShellsApplication of Homogenization Methods in Optimum Design of Plates and Shells:Mathematical ComplementsTwo-Phase Plate in Bending. Hashin-Shtrikman BoundsTwo-Phase Plate. Hashin-Shtrikman Bounds for the In-Plane ProblemExplicit Formulae for Effective Bending Stiffnesses and Compliances of Ribbed PlatesExplicit Formulae for Effective Membrane Stiffnesses and Compliances of Ribbed PlatesThin Bending Two-Phase Plates of Minimum ComplianceMinimum Compliance Problem for Thin Plates of Varying Thickness: Application of Young MeasuresThin Shells of Minimum ComplianceTruss-Like Michell ContinuaComments and Bibliographical Notes Readership: Applied mathematicians and specialists in plate, shell theory and optimization of structures. keywords:Linear and Nonlinear Plates and Shells;Cracked Plates and Laminates;Perfectly Plastic Plates and Shells;Asymptotic Analysis;Homogenization;Topology Optimization "… the level of mathematical accuracy is very high. The authors present a representative selection of known results, including some of their extensive research, and experts in the field will find a lot of information … the methods used here are of broader significance and thus may provide inspiration for readers interested in quite distant fields of applied mathematics." European Mathematical Society

Asymptotic Analysis for Periodic Structures

Shells are basic structural elements of modern technology and everyday life. Examples are automobile bodies, water and oil tanks, pipelines, aircraft fuselages, nanotubes, graphene sheets or beer cans. Also nature is full of living shells such as leaves of trees, blooming flowers, seashells, cell membranes, the double helix of DNA or wings of insects. In the human body arteries, the shell of the eye, the diaphragm, the skin or the pericardium are all shells as well. Shell Structures: Theory and Applications, Volume 3 contains 137 contributions presented at the 10th Conference “Shell Structures: Theory and Applications” held October 16-18, 2013 in Gdansk, Poland. The papers cover a wide spectrum of scientific and engineering problems which are divided into seven broad groups: general lectures, theoretical modelling, stability, dynamics, bioshells, numerical analyses, and engineering design. The volume will be of interest to researchers and designers dealing with modelling and analyses of shell structures and thin-walled structural elements.

This second part of the work on creep modeling offers readers essential guidance on practical computational simulation and analysis. Drawing on constitutive equations for creep in structural materials under multi-axial stress states, it applies these equations, which are developed in detail in part 1 of the work, to a diverse range of examples.

Computational Analysis of Structured Media presents a systematical approach to analytical formulae for the effective properties of deterministic and random composites. Schwarz’s method and functional equations yield for use in symbolic-numeric computations relevant to the effective properties. The work is primarily concerned with constructive topics of boundary value problems, complex analysis, and their applications to composites. Symbolic-numerical computations are widely used to deduce new formulae interesting for applied mathematicians and engineers. The main line of presentation is the investigation of two-phase 2D composites with non-overlapping inclusions randomly embedded in matrices. Computational methodology for main classes of problems in structured media Theory of Representative Volume Element Combines exact results, Monte-Carlo simulations and Resummation techniques under one umbrella Contains new analytical formulae obtained in the last ten years and it combines different asymptotic methods with the corresponding computer implementations

Addressing algebraic problems found in biomathematics and energy, Free and Moving Boundaries: Analysis, Simulation and Control discusses moving boundary and boundary control in systems described by partial differential equations (PDEs). With contributions from international experts, the book emphasizes numerical and theoretical control of moving boundaries in fluid structure couple systems, arteries, shape stabilization level methods, family of moving geometries, and boundary control. Using numerical analysis, the contributors examine the problems of optimal control theory applied to PDEs arising from continuum mechanics. The book presents several applications to electromagnetic devices, flow, control, computing, images analysis, topological changes, and free boundaries. It specifically focuses on the topics of boundary variation and control, dynamical control of geometry, optimization, free boundary problems, stabilization of structures, controlling fluid-structure devices, electromagnetism 3D, and inverse problems arising in areas such as biomathematics. Free and Moving Boundaries: Analysis, Simulation and Control explains why the boundary control of physical systems can be viewed as a moving boundary control, empowering the future research of select algebraic areas.

The mechanics of structures with initial stresses is a traditional part of structural mechanics. It is closely related to the important problem of stability of structures. The basic concepts of elastic stability of structures go back to works by Euler (1759) and Bryan (1889). Later, it was found that the problem of deformation of solids with initial stresses is related to variational principles and nonlinear problems in elasticity; see Trefftz (1933), Marguerre (1938), Prager (1947), Hill (1958), Washuzu (1982). Historical detail up to the 1940s can be found in the book by Timoshenko (1953). Observing the basic concepts of the traditional mechanics of stressed structures, we agree that these are suitable for uniform structural elements (plates, beams, and so on) made of homogeneous materials, but not for complex structures (such as a network plate or a lattice mast) or structures made of composite materials (such as fiber reinforced or textile materials). Many concepts of the classical theory, such as a cross section or neutral plane (axis), correspond to no mechanical objects if we consider an inhomogeneous structure. As a result, we come to the conclusion that it would be useful to have a theory of thin inhomogeneous structures developed on the basis of 3-D elasticity theory with no simplifying assumptions (with no a priori hypothesis).

It was mainly during the last two decades that the theory of homogenization or averaging of partial differential equations took shape as a distinct mathe matical discipline. This theory has a lot of important applications in mechanics of composite and perforated materials, filtration, disperse media, and in many other branches of physics, mechanics and modern technology. There is a vast literature on the subject. The term averaging has been usually associated with the methods of non linear mechanics and ordinary differential equations developed in the works of Poincare, Van Der Pol, Krylov, Bogoliubov, etc. For a long time, after the works of Maxwell and Rayleigh, homogeniza tion problems for· partial differential equations were being mostly considered by specialists in physics and mechanics, and were staying beyond the scope of mathematicians. A great deal of attention was given to the so called disperse media, which, in the simplest case, are two-phase media formed by the main homogeneous material containing small foreign particles (grains, inclusions). Such two-phase bodies, whose size is considerably larger than that of each sep arate inclusion, have been discovered to possess stable physical properties (such as heat transfer, electric conductivity, etc.) which differ from those of the con stituent phases. For this reason, the word homogenized, or effective, is used in relation to these characteristics. An enormous number of results, approximation formulas, and estimates have been obtained in connection with such problems as electromagnetic wave scattering on small particles, effective heat transfer in two-phase media, etc.

Eleven chapters, written by experts in their respective fields, on topics ranging from control of the Navier-Stokes equations to nondestructive evaluation - all of which are modeled by distributed parameter systems.

This book is devoted to researchers and teachers, as well as graduate students, undergraduates and bachelors in engineering mechanics, nano-mechanics, nanomaterials, nanostructures and applied mathematics. It presents a collection of the latest developments in the field of nonlinear (chaotic) dynamics of mass distributed-parameter nanomechanical structures, providing a rigorous and comprehensive study of modeling nonlinear phenomena. It is written in a unique pedagogical style particularly suitable for independent study and self-education. In addition, the book achieves a good balance between Western and Eastern extensive studies of the mathematical problems of nonlinear vibrations of structural members.

Provides a comprehensive introduction to the dynamic response of lattice materials, covering the fundamental theory and applications in engineering practice Offers comprehensive treatment of dynamics of lattice materials and periodic materials in general, including phononic crystals and elastic metamaterials Provides an in depth introduction to elastostatics and elastodynamics of lattice materials Covers advanced topics such as damping, nonlinearity, instability, impact and nanoscale systems Introduces contemporary concepts including pentamodes, local resonance and inertial amplification Includes chapters on fast computation and design optimization tools Topics are introduced using simple systems and generalized to more complex structures with a focus on dispersion characteristics

Analytical and Numerical Approaches to Asymptotic Problems in Analysis

The focus of this is on the latest developments related to the analysis of problems in which several scales are presented. After a theoretical presentation of the theory of homogenization in the periodic case, the other contributions address a wide range of applications in the fields of elasticity (asymptotic behavior of nonlinear elastic thin structures, modeling of junction of a periodic family of rods with a plate) and fluid mechanics (stationary Navier?Stokes equations in porous media). Other applications concern the modeling of new composites (electromagnetic and piezoelectric materials) and imperfect transmission problems. A detailed approach of numerical finite element methods is also investigated.

This volume is a collection of articles in memory of Jacques-Louis Lions, a leading mathematician and the founder of the Contemporary French Applied Mathematics School. The contributions have been written by his friends, colleagues and students. The book concerns many important results in analysis, geometry, numerical methods, fluid mechanics, control theory, etc.

The Institute for Mathematical Sciences at the National University of Singapore hosted a two-month research program on "Mathematical Theory and Numerical Methods for Computational Materials Simulation and Design" from 1 July to 31 August 2009. As an important part of the program, tutorials and special lectures were given by leading experts in the fields for participating graduate students and junior researchers. This invaluable volume collects four expanded lecture notes with self-contained tutorials. They cover a number of aspects on multiscale modeling, analysis and simulations for problems arising from materials science including some critical components in computational prediction of materials properties such as the multiscale properties of complex materials, properties of defects, interfaces and material microstructures under different conditions, critical issues in developing efficient numerical methods and analytic frameworks for complex and multiscale materials models. This volume serves to inspire graduate students and researchers who choose to embark into original research work in these fields.

This monograph is intended to provide a snapshot of the status and opportunities for advan cement in the technologies of dynamics and control oflarge flexible spacecraft structures. It is a reflection ofthe serious dialog and assessments going on all over the world,across a wide variety of scientific and technical disciplines, as we contemplate the next major milestone in mankind's romance with space: the transition from exploration and experimentation to commercial and defense exploitation. This exploitation is already in full swing in the space communications area. Both military and civilian objectives are being pursued with increasingly more sophisticated systems such as large antenna reflectors with active shape control. Both the NATO and Warsaw pact alliances are pursuing permanent space stations in orbit: large structural systems whose development calls for in-situ fabrication and/or assembly and whose operation will demand innovations in controls technology. The last ten years have witnessed a fairly brisk research activity in the dynamics and control oflarge space structures in orderto establish a technology base forthe development of advanced spacecraft systems envisioned for the future. They have spanned a wide spectrum of activity from fundamental methods development to systems concept studies and laboratory experimentation and demonstrations. Some flight experiments have also been conducted for various purposes such as the characterization of the space enviroment, durability of materials and devices in that environment, assembly and repair operations, and the dynamic behavior of flexible structures. It is this last area that has prompted this monogram.

The two volumes contain 65 chapters, which are based on talks presented by reputable researchers in the field at the Tenth International Conference on Integral Methods in Science and Engineering. The chapters address a wide variety of methodologies, from the construction of boundary integral methods to the application of integration-based analytic and computational techniques in almost all aspects of today's technological world. Both volumes are useful references for a broad audience of professionals, including pure and applied mathematicians, physicists, biologists, and mechanical, civil, and electrical engineers, as well as graduate students, who use integration as a fundamental technique in their research.

The first edition of the Encyclopedia of Optical and Photonic Engineering provided a valuable reference concerning devices or systems that generate, transmit, measure, or detect light, and to a lesser degree, the basic interaction of light and matter. This Second Edition not only reflects the changes in optical and photonic engineering that have occurred since the first edition was published, but also: Boasts a wealth of new material, expanding the encyclopedia’s length by 25 percent Contains extensive updates, with significant revisions made throughout the text Features contributions from engineers and scientists leading the fields of optics and photonics today With the addition of a second editor, the Encyclopedia of Optical and Photonic Engineering, Second Edition offers a balanced and up-to-date look at the fundamentals of a diverse portfolio of technologies and discoveries in areas ranging from x-ray optics to photon entanglement and beyond. This edition’s release corresponds nicely with the United Nations General Assembly’s declaration of 2015 as the International Year of Light, working in tandem to raise awareness about light’s important role in the modern world. Also Available Online This Taylor & Francis encyclopedia is also available through online subscription, offering a variety of extra benefits for researchers, students, and librarians, including: Citation tracking and alerts Active reference linking Saved searches and marked lists HTML and PDF format options Contact Taylor and Francis for more information or to inquire about subscription options and print/online combination packages. US: (Tel) 1.888.318.2367; (E-mail) e-reference@taylorandfrancis.com International: (Tel) +44 (0) 20 7017 6062; (E-mail) online.sales@tandf.co.uk

This book provides an introduction to the theory and numerical developments of the homogenization method. It's main features are: a comprehensive presentation of homogenization theory; an introduction to the theory of two-phase composite materials; a detailed treatment of structural optimization by using homogenization; a complete discussion of the resulting numerical algorithms with many documented test problems. It will be of interest to researchers, engineers, and advanced graduate students in applied mathematics, mechanical engineering, and structural optimization.

Insights and Innovations in Structural Engineering, Mechanics and Computation comprises 360 papers that were presented at the Sixth International Conference on Structural Engineering, Mechanics and Computation (SEMC 2016, Cape Town, South Africa, 5-7 September 2016). The papers reflect the broad scope of the SEMC conferences, and cover a wide range of engineering structures (buildings, bridges, towers, roofs, foundations, offshore structures, tunnels, dams, vessels, vehicles and machinery) and engineering materials (steel, aluminium, concrete, masonry, timber, glass, polymers, composites, laminates, smart materials).

This is the second supplementary volume to Kluwer's highly acclaimed eleven-volume Encyclopaedia of Mathematics. This additional volume contains nearly 500 new entries written by experts and covers developments and topics not included in the previous volumes. These entries are arranged alphabetically throughout and a detailed index is included. This supplementary volume enhances the existing eleven volumes, and together these twelve volumes represent the most authoritative, comprehensive and up-to-date Encyclopaedia of Mathematics available.

Plate and shell theories experienced a renaissance in recent years. The potentials of smart materials, the challenges of adaptive structures, the demands of thin-film technologies and more on the one hand and the availability of newly developed mathematical tools, the tremendous increase in computer facilities and the improvement of commercial software packages on the other caused a reanimation of the scientific interest. In the present book the contributions of the participants of the EUROMECH Colloquium 444 "Critical Review of the Theories of Plates and Shells and New Applications" have been collected. The aim was to discuss the common roots of different plate and shell approaches, to review the current state of the art, and to develop future lines of research. Contributions were written by scientists with civil and mechanical engineering as well as mathematical and physical background.