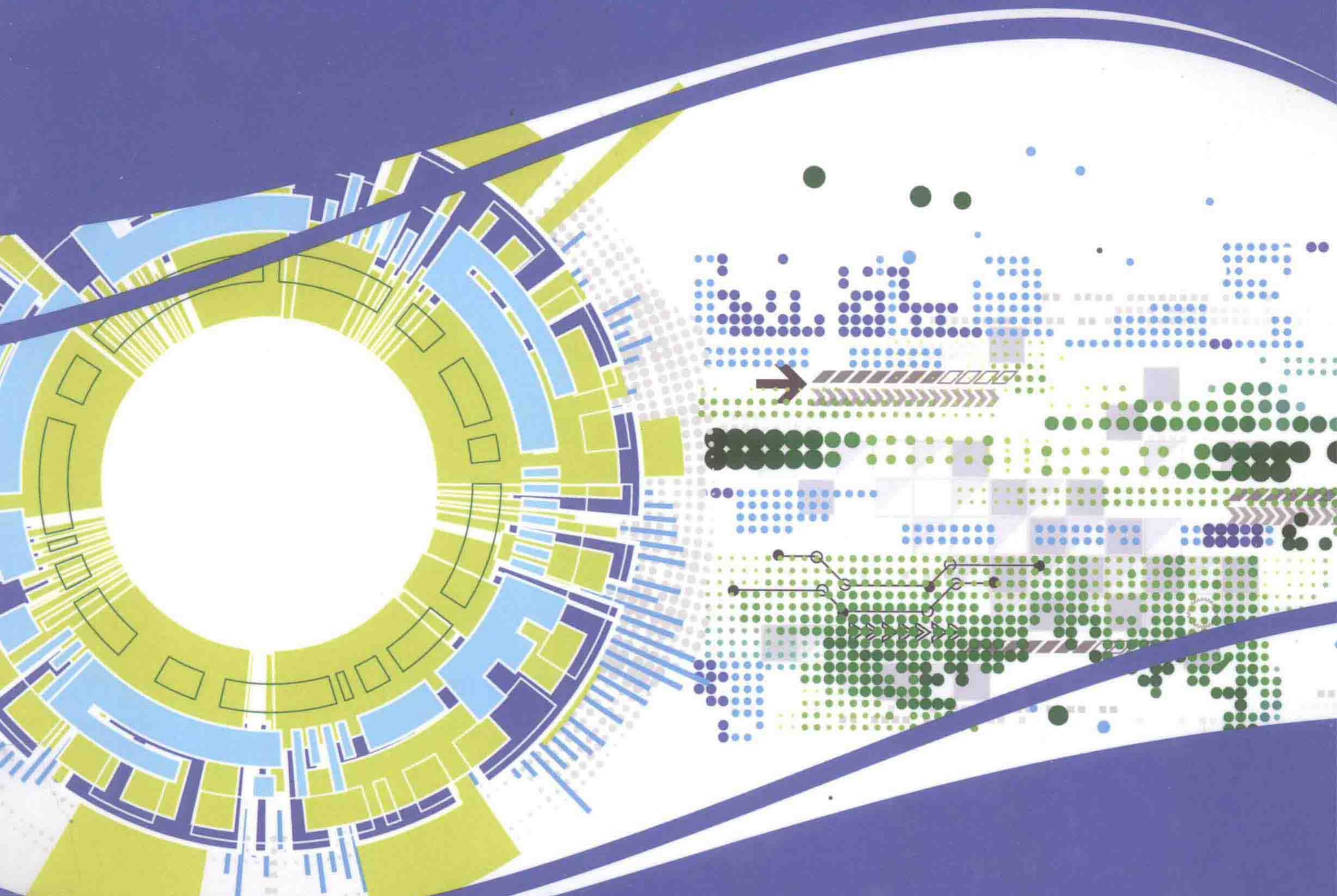
Modeling and Simulation Techniques in Structural Engineering



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Modeling and Simulation Techniques in Structural Engineering

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Dedicated to Amitava Pal

Preface

The performance of structure is assessed through conducting experiment or analysis of mechanical model. Experimental techniques are time consuming and expensive. Engineering community always prefer model for determination of performance of structure over experimental technique. Thus, the development of analytical and numerical model is the major focus for understanding performance of structure. The rapid advance in information processing systems in recent decades directed engineering and research towards the development of various computational methods that can model engineering phenomena realistically. The accuracy of the different models will be different. Therefore, it is necessary to develop the best possible model for a particular problem in structural engineering. Therefore, the development of new model is an imperative task for better understanding of behavior of structure. This book is an attempt to present various computational techniques for application in structural engineering. It consists of 16 chapters, and aims to present the developments in advanced computational techniques and new research areas in the diverse field of structural engineering.

In Chapter 1, the close relationship between noise and vibration is reviewed and analyzed for the suppression of noise and vibration in structures. For the first, an analysis is carried out by representing noise by monopoles and higher harmonics, and to devise a straight-forward method to counter their influence by selective secondary acoustic source. The second problem is analyzed using a methodology developed earlier for the computational scheme for the calculation of the acoustic disturbance to the aeroelasticity of structures. The generic approach of the latter consists of three parts. The first is the formulation of the acoustic wave propagation governed by the Helmholtz equation by using boundary element approach, to allow the calculation of the acoustic pressure on the acoustic-structure boundaries. The structural dynamic problem is formulated using finite elements. The third part involves the calculation of the unsteady aerodynamics loading on the structure using generic unsteady aerodynamics computational method. Chapter 2 opens the field of agent based modelling and simulation (ABMS) to civil engineers. ABMS offers a wide range of tools for implementing simulation models of systems with high degrees of interconnectivity and a large number of component subsystems. The ease of use for specialized engineers and the capabilities of integration with existent technologies and infrastructures, make agent based models a very attractive way to incorporate the social system in the design process of buildings. Moreover, ABMS allows for the testing and validation of structure wide control and automation systems. Chapter 3 presents the past and current efforts of using agent based modelling for smart structures, as well as the main challenges brought by this new interdisciplinary research domain. The chapter presents in one hand the definition of the pushover procedure based on Eurocode 8, and displacement based and force base elements which will be used in this study, in another hand the application of the pushover procedure based to Eurocode 8 to nonlinear framed structure model and comparison with time history analysis. As test-bed application, a two-story reinforced concrete building in Bonefro, Italy is considered. It is representative of typical residential building construction in Italy in the 1970's and 1980's. In chapter 4, the authors present the ring-tensile tests on specimens of Zircaloy pressure tubes of Indian pressurized heavy water reactor in order to carry out integrity assessment of these tubes. Determination of transverse mechanical properties from ring specimens machined from tubular components is not straightforward due to presence of combined tension and bending stresses. Zircaloy tubes as used in nuclear reactors are manufactured through a complicated process of pilgering and heat-treatment and hence, the properties need to be determined in the as-manufactured condition. As the loading condition in this test imposes both membrane and bending stresses in the cross-section of the ring, 3-D finite element analysis of the test setup was carried out in order to determine material stress-strain curve using an iterative technique. The effect of the design of the loading mandrel on the experimental stress-strain data has been investigated in detail. To validate the methodology, miniature tensile specimens have been tested and the data has been compared to those of ring specimens. Chapter 5 reviews the theories used for dynamic analysis of a modern day offshore wind turbine structure and applies these theories in analyzing realistic situations for offshore turbines under wave and wind action. The first half of the chapter provides a broad overview on the concepts of structural dynamics of wind turbine structures with illustrative examples that will enable the user to understand the methodology used to analyze these structures. The latter half of the chapter deals with the computational aspect of the analysis and focuses on the use of finite element software ANSYS 14 to model these critical structures. In chapter 6, a comparative study of various metamodelling approaches namely the least squares method (LSM), moving least squares method (MLSM) and artificial neural network (ANN) based response surface method (RSM) are presented to demonstrate the effectiveness to approximate the nonlinear dynamic response of structure required for efficient seismic reliability analysis (SRA) of structures. The seismic response approximation by the LSM, MLSM and ANN based RSMs are explained with a brief note on the important issue of ground motion bin generation. The procedure adopted herein for SRA is based on a dual response surface approach. In doing so, the repetition of seismic intensity for SRA at different intensity levels is avoided by including this as one of the predictors in the seismic response prediction model. A nonlinear SDOF system has been taken up to elucidate the effectiveness of various metamodels in SRA. In chapter 7, the major studies on pipe bends by various researchers are explored thoroughly through extensive literature survey. Pipelines are being used to convey different sorts of fluids from hazardous and toxic substances to high pressure steam. Piping systems are subjected to various external loads leading to major failures with gross plastic deformation. Pipe bends are incorporated into piping systems not only to change the direction of flow but also to provide flexibility, hence they are considered to be critical components and its safe design under various loads becomes important. Earlier studies of pipe bends utilized analytical methods to determine the plastic loads. The evolution of FEM and the advancements in computational capabilities have enabled analysts to generate large number of data which is expensive and time consuming with experimental investigations. Different studies on pipe bends namely stress analysis, creep analysis, fatigue analysis, analysis with cracks and the influence of geometric shape imperfections on pipe bends are also presented. Chapter 8 presents a practical approach based on High Dimensional Model Representation (HDMR) for analyzing response of structures with fuzzy parameters. The exponential growth of computational power during the last few decades has enabled the finite element analysis of many real-life engineering systems which are too complex to be analytically solved in a closed form. In the traditional deterministic finite element analysis, system parameters such as mass, geometry and material properties are assumed to be known precisely and defined exactly.

However, in practice most of the data used in the solution process of many practical engineering systems are either collected from experiments or acquired as empirical data from the past, which are usually ill defined, imprecise and uncertain in nature. The proposed methodology involves integrated finite element modelling, HDMR based surrogate model, and explicit fuzzy analysis procedures. In chapter 9, the nonlocal version of the Rousselier's damage model has been used to predict the fracture resistance behavior of double-edged-notched-tensile specimens made from Zircaloy-4 material. For investigation of fracture behavior and assessment of remaining life of critical thin-walled tubular components in industry, the transverse mechanical property and the axial fracture properties are essential. However, evaluation of these properties by machining suitable standard specimens from these components directly and subjecting them to standard tests is usually not feasible. Initially, the micro-mechanical parameters have been determined from the testing of ring-type specimens. Subsequently, these parameters were used in finite element analysis of the double-edged-notched-tensile specimen in order to predict the crack growth behavior and the crack path under applied displacement-controlled loading conditions. The fracture resistance behavior obtained in terms of J-R curve was also compared with the corresponding J-R curves of axially-cracked pin-loading-tension specimens. Chapter 10 explores the use of MARS and BPNN approaches to build predictive peak shear strength models of squat walls based on an extensive experimental database from the literature. Squat walls are widely used in structural engineering. The empirical equations currently used to calculate the peak shear strength of squat walls do not correlate well with the experimental results. Another limitation is the reliance on the use of many assumed intermediate parameters. First the MARS methodology and its associated procedures will be explained in detail. Analyses of the database are then carried out to verify the MARS's capacity in modelling the non-linear interactions between variables without making any specific assumptions. The performances of the built MARS and BPNN models are compared in terms of predictive accuracy, parameter relative importance, parametric analysis and model interpretability. Design charts are also proposed based on parametric studies using the developed models. In chapter 11, a system identification method for modeling nonlinear behavior of smart buildings is discussed that has a significantly low computation time. To reduce the size of the training data used for the adaptive neuro-fuzzy inference system (ANFIS), principal component analysis (PCA) is used, i.e., PCA-based adaptive neuro-fuzzy inference system: PANFIS. The PANFIS model is evaluated on a seismically excited three-story building equipped with a magnetorheological (MR) damper. The PANFIS model is trained using an artificial earthquake that contains a variety of characteristics of earthquakes. The trained PANFIS model is tested using four different earthquakes. It was demonstrated that the proposed PANFIS model is effective in modeling nonlinear behavior of a smart building with significant reduction in computational loads. In chapter 12, a fully equivalent operational model, referred as, Polynomial Correlated Function Expansion (PCFE) has been discussed. Uncertainty quantification of civil engineering structures are often time consuming. Hence, one has to rely on equivalent models (EM) that represent the original functions with a specific level of accuracy PCFE facilitates a systematic mapping between the input and output by expressing the output as a ranked order of component functions, with higher order component functions representing higher-order cooperative effect. The component functions are expressed in terms of extended bases and the unknown coefficients associated with the bases are determined by employing homotopy algorithm (HA). HA determines the unknown coefficients by minimizing the least-squared error and imposing an additional criteria defined as an objective function. Implementation of PCFE has been illustrated with two large scale problems. Results obtained have been compared with other popular techniques. For both the problems, PCFE outperforms popular EMs available in literature. In chapter 13, a mathematical model for rate of formation of chromium carbides near the grain boundary, which is a pre-cursor to chromium depletion and corresponding sensitization behavior in stainless steels, has been presented. This model along with the diffusion equation for chromium in the grain has been used to obtain chromium depletion profiles at various time and temperature conditions. Finite difference method has been used to solve the above equations in the spherical co-ordinate system and the results of time-temperature-sensitization diagrams of four different types of alloys have been compared with those of experiment from literature. For the problem of low temperature sensitization and corresponding inter-granular corrosion in austenitic stainless steel, it is very difficult to carry out experiment at higher temperatures and justify its validity at lower operating temperatures by extrapolation. The development of predictive models is highly useful in order to design the structures for prevention of corrosion of the material in aggressive environments. Chapter 14 introduces the basic concepts of Bayesian inference and illustrated through three problems in structural engineering, how it can be useful. Engineering phenomena described through models come with uncertainties arising out of the modelling assumptions and observational statistical discrepancies. A probabilistic framework helps in quantifying the uncertainties involved. Conventional statistics are not very useful for any inferring from a limited amount of data which is often the case for many real life engineering problems. Bayesian inference tackles this issue by integrating past experience with current information. The emphasis is in showing how Markov chain Monte Carlo (MCMC) simulation is used in Bayesian inference. Chapter 15 is to investigate the effects of Post-earthquake fire (PEF) loads on partially damaged RC buildings located in urban regions. To do that, a methodology named sequential analysis is introduced here via which the structural performance at various performance levels is evaluated under fire and PEF scenarios. PEF is one of the most complicated problems resulting from earthquake, presenting a serious risk to urban buildings. As most standards and codes ignore the possibility of PEF, buildings are too weak under PEF loads. Numerically, in order to simulate the earthquake loads, conventional pushover analysis is employed, with an explanation presented in the chapter to introduce the pushover analysis, its advantages and its limitations. To simulate the fire loads, standard fire curve (ISO 834) is used for simplicity. Chapter 16 presents potential simulation approaches that are possible to utilize for SIA&C in relation to prioritization as well as evaluation of current status of a SIA&C organization. Structural integrity assessment and control (SIA & C) are vital for existing ageing as well as newly built offshore and onshore structures. The SIA & C becomes highly sensitive to interventions under a potential loss of structural integrity (SI) especially when there are inherent constraints present in carrying out engineering work in hazardous environments such as petroleum production and process facilities (P&PFs). The challenges have been further exacerbated by the constantly ageing onshore and offshore structures whilst it is the necessity of carrying out life extension at the verge of their design service lives. Local and international regulations demand the implementation of appropriate strengthening, modification and repair (SMR) plans when significant changes in the SI have been revealed.

All the chapters are written by more than fifteen experts in the subjects with a hope that the book will give impetus for application of new modeling techniques for assessing performance of structure. We are deeply indebted and wish to thank all the authors for their valuable contributions. We thank all reviewers and editorial board members for their helpful supports. A special thanks goes to the staff members of IGI Global. We would also like to acknowledge the support of our institutions during preparation of this edited book.

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The close relationship between noise and vibration is reviewed and analyzed for the suppression of noise and vibration in structures. The suppression of noise and vibration by acoustic means are addressed. For the first, an analysis is carried out by representing noise by monopoles and higher harmonics, and to devise a straight-forward method to counter their influence by selective secondary acoustic source. The second problem is analyzed using a methodology developed earlier for the computational scheme for the calculation of the acoustic disturbance to the aeroelasticity of structures. The generic approach of the latter consists of three parts. The first is the formulation of the acoustic wave propagation governed by the Helmholtz equation by using boundary element approach, to allow the calculation of the acoustic pressure on the acoustic-structure boundaries. The structural dynamic problem is formulated using finite elements. The third part involves the calculation of the unsteady aerodynamics loading on the structure using generic unsteady aerodynamics computational method.

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