

Preface

The book provides an insight on advanced methods and concepts for design and analysis of structures against earthquake loading. It consists of 25 chapters covering a wide range of timely issues in Earthquake Engineering. The goal of this Volume is to establish a common ground of understanding between the communities of Earth Sciences and Computational Mechanics towards mitigating future seismic losses. Due to the great social and economic consequences of earthquakes, the topic is of great scientific interest and is expected to be of valuable help to the large number of scientists and practicing engineers currently working in the field. The chapters of this Volume are extended versions of selected papers presented at the COMPDYN 2009 conference, held in the island of Rhodes, Greece, under the auspices of the European Community on Computational Methods in Applied Sciences (ECOMASS).

In the introductory chapter of Lignos et al. the topic of collapse assessment of structures is discussed. The chapter presents the analytical modeling of component behaviour and structure response from the early inelastic to lateral displacements at which a structure becomes dynamically unstable. A component model that captures the important deterioration modes, typically observed in steel members, is calibrated using data from tests of scale-models of a moment-resisting connection. This connection is used for the two-scale model of a modern four-story steel moment frame and the assessment of its collapse capacity through analysis.

The work of Adam and Jäger deals with the seismic induced global collapse of multi-story frame structures with non-deteriorating material properties, which are vulnerable to the $P-\Delta$ effect. The initial assessment of the structural vulnerability to $P-\Delta$ effects is based on pushover analyses. More information about the collapse capacity is obtained with the Incremental Dynamic Analyses using a set of recorded ground motions. In a simplified approach equivalent single-degree-of-freedom systems and collapse spectra are utilized to predict the seismic collapse capacity of the structures.

Sextos et al. focus on selection procedures for real records based on the Eurocode 8 (EC8) provisions. Different input sets comprising seven pairs of records (horizontal components only) from Europe, Middle-East and the US were formed in compliance with EC8 guidelines. The chapter deals with the study of the RC bridges of the Egnatia highway system and also with a multi-storey RC building that was damaged during the 2003 Lefkada (Greece) earthquake. More specifically,

the bridge was studied using alternative models and accounting for the dynamic interaction of the deck-abutment-backfill-embankment system as well as of the superstructure-foundation-subsoil system. The building was studied in both the elastic and inelastic range taking into consideration material nonlinearity as well as the surrounding soil. The results permit quantification of the intra-set scatter of the seismic response for both types of structures, thus highlighting the current limitations of the EC8 guidelines. Specific recommendations are provided in order to eliminate the dispersion observed in the elastic and the inelastic response through appropriate modifications of the EC8 selection parameters.

Assimaki et al. study how the selection of the site response model affects the ground motion predictions of seismological models, and how the synthetic motion site response variability propagates to the structural performance estimation. For this purpose, the ground motion synthetics are computed for six earthquake scenarios of a strike-slip fault rupture, and the ground surface response is estimated for 24 typical soil profiles in Southern California. Next, a series of bilinear single-degree-of-freedom oscillators is subjected to the ground motions computed using the alternative soil models and the consequent variability in the structural response is evaluated. The results show high bias and uncertainty in the prediction of the inelastic displacement ratio, when predicted using the linear site response model for periods close to the fundamental period of the soil profile.

The chapter of Kappos et al. addresses the issue of pushover analysis of bridges sensitive to torsion, using as case-study a bridge whose fundamental mode is purely torsional. Parametric analyses were performed involving consideration of foundation compliance, and various scenarios of accidental eccentricity that would trigger the torsional mode. An alternative pushover curve in terms of abutment shear versus deck maximum displacement (that occurs at the abutment) was found to be a meaningful measure of the overall inelastic response of the bridge. It is concluded that for bridges with a fundamental torsional mode, the assessment of their seismic response relies on a number of justified important decisions that have to be made regarding: the selection and the reliable application of the analysis method, the estimation of foundation and abutment stiffnesses, and the appropriate numerical simulation of the pertinent failure mechanism of the elastomeric bearings.

Pardalopoulos and Pantazopoulou investigate the spatial characteristics of a structure's deformed shape at maximum response in order to establish deformation demands in the context of displacement-based seismic assessment or redesign of existing constructions. It is shown that the vibration shape may serve as a diagnostic tool of global structural inadequacies as it identifies the tendency for interstorey drift localization and twisting due to mass or stiffness eccentricity. This chapter investigates the spatial displaced shape envelope and its relationship to the three-dimensional distribution of peak drift demand in reinforced concrete buildings with and without irregularities in plan and in height. A methodology for the seismic assessment of rotationally sensitive structures is established and tested through correlation with numerical results obtained from detailed time history simulations.

The chapter of Cotsovos and Kotsovos summarises the fundamental properties of concrete behaviour which underlie the formulation of an engineering finite element

model that is capable to realistically predict the behaviour of (plain or reinforced) concrete structural forms for a wide range of problems from static to impact loading, bypassing the problem of re-calibration. The already published evidence that support the proposed formulation is complemented by four typical case-studies. For each case-study, the numerical predictions are computed against experimental data revealing good agreement.

The chapter of Wijesundara et al. investigates the local seismic performances of fully restrained gusset plate connections through detailed finite element models of a single storey single-bay frame that is located at the ground floor of the four storey frame. The chapter presents a design procedure, proposing an alternative clearance rule for the accommodation of brace rotation. Local performances of FE models are compared in terms of strain concentrations at the beams, the columns and the gusset plates.

Vielma et al. propose a new seismic damage index and the corresponding damage thresholds. The seismic behavior of a set of regular reinforced concrete buildings designed according to the EC-2/EC-8 prescriptions for a high seismic hazard level are studied using the proposed damage index. Fragility curves and damage probability matrices corresponding to the performance point are then calculated. The obtained results show that the collapse damage state is not reached in the buildings designed according the prescriptions of EC-2/EC-8 and that the damage does not exceed the irreparable damage limit-state for the buildings studied.

The application of discrete element models based on rigid block formulations to the analysis of masonry walls under horizontal out-of-plane loading is discussed in the chapter of Lemos et al. The problems raised by the representation of an irregular fabric as a simplified block pattern are addressed. Two procedures for creating irregular block systems are presented. One using Voronoi polygons and another based on a bed and cross joint structure with random deviations. A test problem provides a comparison of various regular and random block patterns, showing their influence on the failure loads.

Papaloizou and Komodromos discuss the computational methods appropriate for simulating the dynamic behaviour and the seismic response of ancient monuments, such as classical columns and colonnades. Understanding the behaviour and response of historic structures during strong earthquakes is useful for the assessment of conservation and rehabilitation proposals for such structures. Their seismic behaviour involves complicated rocking and sliding phenomena that very rarely appear in modern structures. The discrete element method (DEM) is utilized to investigate the response of ancient multi-drum columns and colonnades during harmonic and earthquake excitations by simulating the individual rock blocks as distinct rigid bodies.

The study on the seismic behaviour of the walls of the Cella of Parthenon when subjected to seismic loading is presented in the chapter of Psycharis et al.. Given that commonly used numerical codes for masonry structures or drum-columns are unable to handle the discontinuous behaviour of ancient monuments, the authors adopt the discrete element method (DEM). The numerical models represent in detail the actual construction of the monument and are subjected to the three components

of four seismic events recorded in Greece. Time domain analyses were performed in 3D, considering the non-linear behaviour at the joints. Conclusions are drawn based on the maximum displacements induced to the structure during the ground excitation and the residual deformation at the end of the seismic motion.

The chapter of Dolsek studies the effect of both aleatory and epistemic (modelling) uncertainties on reinforced concrete structures. The Incremental Dynamic Analysis (IDA) method, which can be used to calculate the record-to-record variability, is extended with a set of structural models by utilizing the Latin Hypercube Sampling (LHS) to account for the modelling uncertainties. The results showed that the modelling uncertainties can reduce the spectral acceleration capacity and significantly increase its dispersion.

The chapter of Taflanidis discusses the problem of the efficient design of additional dampers, to operate in tandem with the isolation system. One of the main challenges of such applications has been the explicit consideration of the nonlinear behavior of the isolators or the dampers in the design process. Another challenge has been the efficient control of the dynamic response under near-field ground motions. In this chapter, a framework that addresses both these challenges is discussed. The design objective is defined as the maximization of the structural reliability. A simulation-based approach is implemented to evaluate the stochastic performance and an efficient framework is proposed for performing the associated design optimization and for selecting values of the controllable damper parameters that optimize the system reliability.

Mitsopoulou et al. study a robust control system for smart beams. First the structural uncertainties of basic physical parameters are considered in the model of a composite beam with piezoelectric sensors and actuators subjected to wind-type loading. The control mechanism is introduced and designed to keep the beam in equilibrium in the event of external wind disturbances and in the presence of mode inaccuracies using the available measurement and control under limits.

Panagiotopoulos et al. examine through simple examples the performance and the characteristics of a methodology previously proposed by the authors on a variationally-consistent way for the incorporation of time-dependent boundary conditions in problems of elastodynamics. More specifically, an integral formulation of the elastodynamic problem serves as basis for enforcing the corresponding constraints, which are imposed via the consistent form of the penalty method, e.g. a form that complies with the norm and inner product of the functional space where the weak formulation is mathematically posed. It is shown that well-known and broadly implemented modelling techniques in the finite element method such as “large mass” and “large spring” techniques arise as limiting cases of this penalty formulation.

Sapountzakis and Dourakopoulos study the nonlinear dynamic analysis of beams of arbitrary doubly symmetric cross section using the boundary element method. The beam is able to undergo moderate large displacements under general boundary conditions, taking into account the effects of shear deformation and rotary inertia. The beam is subjected to the combined action of arbitrarily distributed or

concentrated transverse loading and bending moments in both directions as well as to axial loading. To account for shear deformations, the concept of shear deformation coefficients is used. Five boundary value problems are formulated and solved using the Analog Equation Method. Application of the boundary element technique yields a nonlinear coupled system of equations of motion. The evaluation of the shear deformation coefficients is accomplished from the aforementioned stress functions using only boundary integration.

The chapter of Papachristidis et al. presents the fiber method for the inelastic analysis of frame structures when subjected to high shear. Initially the fiber approach is presented within its standard, purely bending, formulation and it is then expanded to the case of high shear deformations. The element formulation follows the assumptions of the Timoshenko beam theory, while two alternative formulations, a coupled and a decoupled are presented. The numerical examples confirm the accuracy and the computational efficiency of the element formulation under monotonic, cyclic and dynamic/seismic loading.

A simplified procedure to estimate base sliding of concrete gravity dams induced by an earthquake is proposed in the chapter of Basili and Nuti. A simple mechanical model is developed in order to take into account the sources that primarily influence the seismic response of such structures. The dam is modelled as an elastic-linear single-degree-of-freedom-system. Different parameters are considered in the analysis such as the dam height, foundation rock parameters, water level, seismic intensity. As a result, a simplified methodology is developed to evaluate base residual displacement, given the dam geometry, the response spectrum of the seismic input, and the soil characteristics. The procedure permits to assess the seismic safety of the dam with respect to base sliding, as well as the water level reduction that is necessary to render the dam safe.

Papazafeiropoulos et al. provided a literature review and results from numerical simulations on the dynamic interaction of concrete dams with retained water and underlying soil. Initially, analytical closed-form solutions that have been widely used for the calculation of dam distress are outlined. Subsequently, the numerical methods based on the finite element method, which is unavoidably used for complicated geometries of the reservoir and/or the dam, are reviewed. Numerical results are presented illustrating the impact of various key parameters on the distress and the response of concrete dams considering the dam-foundation interaction.

Motivated by the earthquake response of industrial pressure vessels, Karamanos et al. investigate the externally-induced sloshing in spherical liquid containers. Considering modal analysis and an appropriate decomposition of the container-fluid motion, the sloshing frequencies and the corresponding sloshing (or convective) masses are calculated, leading to a simple and efficient method for predicting the dynamic behavior of spherical liquid containers. It is also shown that considering only the first sloshing mass is adequate to represent the dynamic behavior of the spherical liquid container within a good level of accuracy.

Jha et al. introduce a bilevel model for developing an optimal Maintenance Repair and Rehabilitation (MR&R) plan for large-scale highway infrastructure elements, such as pavements and bridges, following a seismic event. The maintenance

and upkeep of all infrastructure components is crucial for mobility, driver safety and guidance, and the overall efficient functioning of a highway system. Typically, a field inspection of such elements is carried out at fixed time intervals to determine their condition, which is then used to develop optimal MR&R plan over a given planning horizon.

Frangopol and Akiyama present a seismic analysis methodology for corroded reinforced concrete (RC) bridges. The proposed method is applied to lifetime seismic reliability analysis of corroded RC bridge piers, and the relationship between steel corrosion and seismic reliability is presented. It is shown that the analytical results are in good agreement with the experimental results regardless of the amount of steel corrosion. Moreover, after the occurrence of crack corrosion, the seismic reliability of the pier is significantly reduced.

Life cycle cost assessment of structural systems refers to an evaluation procedure where all costs arising from owning, operating, maintaining and ultimately disposing are considered. Life cycle cost assessment is considered as a significant assessment tool in the field of the seismic behaviour of structures. Therefore, in the chapter by Mitropoulou et al. two test cases are examined and useful conclusions are drawn regarding the behaviour factor q of EC8 and the incident angle that a ground motion is applied on a multi-storey RC building.

Bal et al. examine vulnerability assessment procedures that include code-based detailed analysis methods together with preliminary assessment techniques in order to identify the safety levels of buildings. Their chapter examines the effect of four essential structural parameters on the seismic behaviour of existing RC structures. Parametric studies are carried out on real buildings extracted from the Turkish building stock, one of which was totally collapsed in 1999 Kocaeli earthquake. Comparisons are made in terms of shear strength, energy dissipation capability and ductility. The mean values of the drop in the performance are computed and factors are suggested to be utilized in preliminary assessment techniques, such as the recently proposed P25 method that is shortly summarized in the chapter.

The aforementioned collection of chapters provides an overview of the present thinking and state-of-the-art developments on the computational techniques in the framework of structural dynamics and earthquake engineering. The book is targeted primarily to researchers, postgraduate students and engineers working in the field. It is hoped that this collection of chapters in a single book will be a useful tool for both researchers and practicing engineers.

The book editors would like to express their deep gratitude to all authors for the time and effort they devoted to this volume. Furthermore, we would like to thank the personnel of Springer Publishers for their kind cooperation and support for the publication of this book.

Athens
June 2010

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Computational Methods in Earthquake Engineering

Papadrakakis, M.; Fragiadakis, M.; Lagaros, N.D. (Eds.)

2011, XIV, 586 p., Hardcover

ISBN: 978-94-007-0052-9