International Journal for Multiscale Computational Engineering, 7(2) vii (2009)

SPECIAL ISSUE

Homogenization in Civil Engineering Applications

Guest Editor
M. Šejnoha

PREFACE

Although a variety of composite systems appear in civil engineering applications since the dawn of civilization, it is only recently when micromechanical modeling has been sufficiently promoted to provide better understanding of thermomechanical behavior of traditional civil engineering materials such as concrete, cement pastes, asphalts, masonry, jointed rocks, soft and hard soils, etc.

Microstructures of these material systems often show a certain degree of disorder, which needs to be properly addressed. Reliable predictions of the behavior of such complex structures usually call for a variant of nonlinear multiscale analysis. Whereas detailed information on local fields at all scales are of considerable interest to understand the basic mechanisms triggering the local failure, their application to the prediction of macroscopic failure declines in importance if fully coupled analysis comprising all relevant scales is not executed. Mostly nested but even totally uncoupled multiscale solution strategies then allow for bridging individual scales to span increasingly large size differences all the way up to the structural level. Full scale analysis of Charles Bridge in Prague presents an extraordinary example of this endeavor.

Inspired by traditional composite materials a notable amount of contributions with emphasis on proper micromechanical modeling have emerged only recently in many disciplines of civil engineering. The everlasting popularity of classical mean field or effective mediummicromechanical models is evident from a variety of their applications in the fields of geotechnical, road construction and building engineering. While certainly more efficient when compared to extensive finite element simulations, these models cannot provide detailed distribution of local stress and strain fields in individual constituents. This becomes an important modeling aspect when localization of strains, promoted either by underlying microstructure or caused by evolving damage, is expected. Such objectives can be achieved only by performing a numerical analysis on a representative element with specific microstructural configuration. The complexity of actual microstructures does not, however, allow direct numerical treatment of large samples of real world materials. Here, the elements of periodic homogenization developed over the last few decades offer a suitable alternative. While often used in hierarchical approaches, the issue of applicability of periodic boundary conditions when applied in the nested "coupled" analysis of quasibrittle materials (a typical material product in civil engineering applications) motivates new research directions in the field of homogenization and scale bridging.

Although unable to cover all major areas of civil engineering, the present special issue offers a collection of diverse papers addressing various demands currently at the forefront of civil engineering interests. These include challenges in design of radioactive waste storage, evaluation of structure safety subjected to blast loading, understanding the behavior of novel civil composite systems such as textile reinforced concrete brought to light by the need for high-strength light-weight structural components, modeling of concrete at early stages of hydration which may translate, if properly controlled, into an exceptional long-term performance of this most common building material, characterization of the damage behavior of both regular and irregular masonry structures motivated by increasing public interest in conservation of the most vivid civil engineering heritage. It is now generally recognized that the effective resolution of even this narrow range of civil engineering problems requires departure from traditional solution strategies. A sample of modern solution techniques that incorporate the increased knowledge in both material imaging and material characteristics in the framework of multiscale computational modeling is offered through the following list of selected contributions.

Despite a significant progress in strong coupling procedures for multiphysics and multiscale phenomena in recent decades a fully coupled analysis is feasible only if limiting the attention to very simple geometries. Real engineering structures of considerable complexity thus naturally invite a number of simplifying assumptions. The resulting computational scheme is then termed as fully uncoupled meaning that the output of an independent study performed on lower scale serves as the input for the analysis on the contiguous upper scale. In other words, only the bulk response on each scale derived from the application of a certain homogenization scheme is relevant and practically exploitable. This particular solution methodology is explored in the first two papers.

Severe requirements imposed on nuclear waste play a central role in search for reliable predictive computational strategies. A very efficient micromechanics based approach is offered in the paper by Pichler, Cariou and Dormieux to study evolution of drying induced damage of a rock mass surrounding a deeply seated underground opening. While damage analysis is understood as a stand-alone macroscopic problem, the homogenized effective properties and the macroscopic load driving the cracking process is derived from an independent three-scale continuum micromechanics approach.

Application of uncoupled multiscale procedure to the blast analysis of enclosure masonry walls is discussed in the paper written by Milani and Lourenço. The authors present a limit state analysis of out-of-plane loaded masonry wall starting from the derivation of homogenized failure surfaces which then serve as macroscopic yield criteria in an independent dynamic study of the homogeneous wall.

While sufficient in some applications purely hierarchical approaches may prove too conservative suggesting the need for more detailed fully coupled multiscale modeling with reasonable resolution of geometrical details on a lower scale. Several distinct applications of nested multiscale computational strategy are discussed in the following papers.

An example of an enabling role of advanced experimental methods and modern computational strategies in the development of reliable constitutive models of new civil engineering materials is presented in the paper by Konrad and Chudoba addressing the tensile behavior of cementitious composite reinforced by epoxy impregnated multifilament yarns.

The ever increasing resolution of observation drives the research effort in virtually all engineering disciplines towards better understanding of the thermomechanical behavior of materials at very low scales. Even traditional civil engineering materials such as concrete may benefit from new trends in the computational modeling based on multiscale concept. A particular example is presented in the paper by Šmilauer and Krejčí studying the evolution of both microstructure and temperature at early stages of concrete hydration and their impact on macroscopic response.

Progressive damage in localized form observed in quasibrittle materials has been an active research area of the last few decades. This topic deserves particular attention in problems of periodic geometries, particularly if periodic boundary conditions are utilized in the solution on fine scale resolution. This issue is addressed in the paper by Mercartoris and Massart in conjunction with novel scale-bridging strategy based on displacement-discontinuity enhanced continuum to tackle the localized failure at macroscopic level.

In the last 10 or so years there has been a considerable effort in the study of heterogeneous, often disordered or random, materials to reflect essential details of real world material systems through images of their actual microstructures. Disordered microstructures have been observed not only in classical composite materials but also in traditional civil engineering structures such as historical masonry bridges or cathedrals. The reliable predictions of the macroscopic response will then largely depend on reasonably accurate quantification of all microstructural details. Feasible approach then usually requires intervention with the field of material statistics accepting a random nature of distribution of individual constituents in the masonry structures. Statistical descriptors such as one- and two-point probability functions or lineal path function then become the most viable measures of relevant microstructural details. The issue has received considerable attention in the literature and is now widely accepted in problems of this kind.

Elastic homogenization of disordered masonry structures with moderate meso/macro length scale is discussed in the paper by Lombardo, Zeman, Šejnoha and Falsone. Attractiveness of low-order statistical descriptors is demonstrated in the study of three numerical approaches that comprise a variant of perturbation methods, the Karhunen-Loève expansion technique and the solver based on the Hashin-Shtrikman variational principles proving a lively interest in classical micromechanical models.

In conclusion, I wish to thank all the authors for their valuable contributions. All manuscripts underwent technical peer review. I therefore also wish to thank all the reviewers for their critical comments which undoubtedly improved the original technical value of all contributions. Finally, I would like to extend my personal thanks to Professor Jacob Fish for inviting me to organize this Special Issue.

Czech Technical University in Prague,
Faculty of Civil Engineering,
Department of Mechanics Thákurova 7,
166 29, Prague 6, Czech Republic