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Preface to special issue on modelling and assessment of soil-structure interaction effects on the dynamics of structures

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The topic of Soil-Structure Interaction (SSI) can be considered midway between geotechnical and structural engineering. Historically, geotechnical engineers were primarily interested in the seismic performance of soil-foundation systems and consequently their attention mainly focused on aspects related to the non-linear behaviour of soils or to liquefaction problems. On the other hand, structural engineers were traditionally interested in the seismic response of structures that they conventionally assumed to be fixed at the base. However, SSI problems are complex, and oversimplified approaches may lead to results that do not faithfully reproduce the actual behaviour of the system being analysed. As a result, to produce technically sound and reliable results, a multidisciplinary approach that bridges both disciplines is needed. Such approach would ideally combine the expertise of structural and geotechnical engineers and could produce results that are theoretically robust and can be applied in practise. In recent years, SSI issues were tackled implementing different approaches by experts with a remarkable variety of expertise. Such diversity of backgrounds is clearly reflected in the composition of the Guest Editors team and the Authors of this Special Issue, which includes experts in disciplines such as civil and mechanical engineers, with recognised experiences in various field, including structural mechanics and dynamics, earthquake engineering, soil dynamics, and analytical and numerical modelling.

The decision to work on this special issue stems from the Guest Editors' awareness of the aforementioned multidisciplinary nature of the problem in conjunction with the observation that SSI effects were historically neglected when performing routine structural design. This is due to the fact that, at least from a code's perspective, the concept that SSI can be neglected is still well rooted in the common engineering practice. This approach is traditionally justified by the wrong assumption that SSI always provides beneficial effects on the seismic performance of structures, reducing inertia forces and enhancing the dissipation capacity due to radiation damping of the soil-foundation system. However, theoretical, numerical, and experimental research has already largely proven that SSI is not always beneficial and that it may play an important role in the dynamic behaviour of structures (e.g., Stewart et al. 1999a, b; Mylonakis and Gazetas, 2000). This is especially so for medium or soft soil conditions and for existing structures, which are generally characterised by foundations with relatively low dynamic stiffnesses, mainly deriving from the adoption of dated codes. In this connection, an efficient modelling of SSI, site amplification phenomena, liquefaction problems, and soil-retaining wall interactions, is crucial for a reliable prediction of the structural dynamics, especially in the context of earthquake engineering. The inclusion of SSI phenomena in modern seismic risk assessment and mitigation frameworks is timely for a reliable risk reduction and an improvement of the community resilience. This requires an effort from the research community aimed at developing new and efficient numerical and/or analytical models for the analysis of the above phenomena, to validate procedures by performing real scale or reduced scale experimental programs, and to assess the significance of SSI effects through applications to real case studies.

When the call for abstract was publicized, we were both proud and impressed by the large number of replies obtained from the scientific community and by the number of candidate papers proposed for the inclusion in the collection, demonstrating that the above feelings are widely shared among researchers worldwide. This effort resulted in a collection of papers encompassing many aspects of SSI-related issues including: (1) outcomes of experimental investigations, (2) new analytical models or modelling approaches, (3) studies of liquefaction issues and the relevant effects on the response of both structures and industrial plants, (4) soil-retaining wall interaction analyses, (5) continuous pipelines crossing strike-slip faults, and (5) a variety of interesting case studies. Thus, this Special Issue of the Bulletin of Earthquake Engineering is a compilation of 19 works in which experimental, theoretical and applicative issues often intersect.

We believe that the variety of papers and approaches addressed in the special issue provides an up-to-date overview of the state of the art on the most relevant topics and methods of investigation pertaining to SSI. Ideally, this special issue will provide a benchmark for SSI research that can be used by researchers and practitioners as a starting point for future studies and/or applications.

Various papers of this Special Issue deal with SSI-related effects from an experimental perspective. Fayez et al. (2021) present a full-scale shake table testing to assess the performance of single and grouped helical piles in dry sands. Among other results, the natural frequencies of the piles were evaluated, investigating the effects of different pile configurations and successive shakings. Zafar et al. (2021) use experimental and numerical approaches to investigate the effect of soil and soil-pile interface nonlinearities on the vertical dynamic interactions of floating piles embedded in cohesionless soils. Karaman et al. (2022) present a physical model test setup to investigate the performance of tyre derived aggregates as a seismic mitigation technique for buried continuous pipelines crossing strike-slip faults, and carry out several tests to assess their performance. Vratsikidis et al. (2021) present results of free- and forced-vibration experiments on two structural configurations of EuroProteas prototype systems (i.e., structural systems part of a large-scale testing facility, located in Greece, on soil-foundation-structure interaction and wave propagation), investigating SSI effects on stiff and deformable structures founded on a soft soil. Such analyses are interpreted in terms of period lengthening, damping ratio, foundation stiffness, and strains developed in the soil.

Six papers analyse various SSI problems using analytical and/or numerical approaches. Galvín et al. (2021) propose a general sub-structuring approach to solve SSI problems in railway bridges applying modal superposition and exploiting the perfectly matched layers (i.e., special absorbing layers used in the numerical resolution of wave equations, used to reduce the analysis region and to speed up the computational time for large domain applications) to model arbitrary foundation geometries. Álamo et al. (2021) present a three–dimensional linear numerical model for the dynamic and seismic analysis of pile-supported structures. The use of advanced Green's functions leads to a very compact representation of the problem and to the possibility of accounting for any complex soil profiles in which the seismic excitation is represented as incident planar body waves propagating from an infinitely–distant source. Bharathi et al. (2022) investigate the behaviour of batter piles and pile groups using Finite Element (FE) models calibrated using results of an experimental campaign previously performed by the Authors. Cairo (2022) employs a linear and theoretically robust boundary element approach in conjunction with steady-state analyses to investigate the key features of SSI, identifying situations in which SSI may be relevant. The proposed framework is then applied to a large number of case studies from earthquakes in California. Cavalieri et al. (2022) present the verification analyses of a footing macro-element developed by the Authors through comparisons with results from 3D FE nonlinear applications, which are, in turn, verified through cross-checks and cross-modelling with linear-equivalent and fully nonlinear analyses. The macro-element accounts for the soil nonlinear behaviour in the near-field, as well as in the far-field, dynamic impedance and energy dissipation through radiation damping. Minnucci et al. (2021) investigate the dynamic behaviour of pile foundations in a probabilistic framework, assuming uncertainties as uncorrelated probabilistic distributions of the main parameters governing the soil-foundation dynamic response, and adopting a numerical model developed by the Authors. The approach uses a quasi-random sampling technique to limit the computational effort.

Liquefaction issues are addressed by Hussein and El Naggar (2022), who investigate the seismic behaviour of piles in non-liquefiable and liquefiable soil through nonlinear soil–pile–structure three-dimensional numerical models, verified with the results of large-scale shaking table tests. Ground motions with varying intensities are considered and both kinematic and inertial interactions are addressed in their study that, for technical reasons, was published in a regular issue although candidate by the Authors for the inclusion in this collection. Demirci et al. (2022) develop a FE model to investigate the effects of liquefaction on the natural frequency of offshore wind turbines with monopile foundations. The numerical model is firstly calibrated and then used to conduct a parametric investigation by varying the monopile length and diameter, the friction angle of the soil, and the liquefaction depths. Sharari et al. (2022) study the effect of the depth of liquefiable soil deposits on the seismic response of liquid natural gas tanks supported by pile foundation through three-dimensional FE analysis.

SSI effects on buildings are studied by Zhang X. and Far (2021), who investigate the seismic performance of frame-core tube structures, which is a structural typology generally used for high-rise buildings, through FE modelling, accounting for SSI effects and considering different heights of the building. Zhang W. et al. (2022) investigate the seismic vulnerability of a 20-story steel building equipped with tuned mass dampers by considering SSI effects, comparing the system fragility curves with and without dissipative devices. They also assess the performance of tuned mass dampers and investigate the importance of SSI effects for the investigated structural typology.

A wide set of analyses performed on real case studies are also included in the collection. Cacciola et al. (2021) address the seismic response of linearly-behaving structures resting on compliant soil, exploring the efficiency of the Preisach hysteresis formalism to model nonlinear soil-structure interaction problems. This methodology is applied to the bell tower of the Messina Cathedral in Italy, which hosts the largest and most complex mechanical and astronomical clock in the World. Sobhi and Far (2021) conduct a comprehensive review and comparison of past and present studies on structural pounding investigating the significance of SSI and the need of improved seismic design approaches. Karakostas et al. (2021) present an investigation of SSI effects on the seismic response of the Regional Administration building in the island of Lefkas, Greece. The investigation exploits earthquake recordings from accelerometric stations installed at the basement of the building and in the free-field area, making it possible to study the filtering effect of the foundation, as well as the kinematic and inertial effects through a FE modelling of the building. Durante et al. (2022) present the effects of the spatial variation of ground motion on semi-circular and V-shaped canyons, as well as on a real canyon over crossed by a long multispan bridge in Southern Italy (the Viadotto Italia crossing the Lao River in the Calabria region). Numerical simulations include wave passage and site effects due to topographic irregularities, and aim at exploring the role of the combination of these effects on the definition of the ground surface motion. The study also casts light on how the shape of canyon-like topographic features and the characteristics of the input motion influence the amplitude, shape, and frequency content of strong ground motions at the surface.

The special issues is closed by an interesting work by Psarropoulos et al. (2022) in which the seismic response of retaining walls is addressed. As stated by the Authors themselves, the dynamic response of retaining walls is a SSI problem in which the term *structure* is used to describe the retaining wall, while the term *soil* includes the retained soil layers and the soil layers of the wall foundation. The work is interesting from a practical point of view because the need for deep excavations in urban environments is quite frequent, leading to temporal or even permanent retaining walls close to existing structures. Such scenarios, which may be responsible to single or double resonance phenomena, are analysed in the paper, discussing possible mitigation strategies.

As a concluding remark, the Guest Editors would like to express their gratitude to the Authors, for their valuable contributions, and to the international board of reviewers, for their timely and efficient work, which led to improve the Authors' original submissions. Moreover, the Guest Editors would like to thanks the Editor in chief of the Bulletin of Earthquake Engineering, Prof. Atilla Ansal, for the opportunity to lead this Special Issue and the time spent in assessing their decisions on manuscripts, and Petra Van Steenbergen, for her patient and active assistance during the editorial process.

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