Uncertainty Quantification in Linear Structural Systems Applying a Reduced Basis Method

Javier I. Correa*, Marcos A. Valdebenito*

* Department of Civil Engineering, Santa Maria University
Casilla 110-V, Valparaíso, Chile
E-mail: javier.correa@alumnos.usm.cl, marcos.valdebenito@usm.cl

ABSTRACT

The Finite Element (FE) method is well established within the engineering community as a means for performing analysis of complex structural systems. For its practical application, it is required to define a number of input parameters such as loadings, structural properties, boundary conditions, etc. Usually, this definition involves a deterministic approach, where inherent variability on these parameters is taken into account by a unique, deterministic value selected considering, e.g. extreme or average values. However, such an approach may result in either overly conservative estimations of the structural response or (in extreme cases) unsafe predictions of the behavior of a system. In order to quantify the variability of the structural performance, it is possible to resort to probability theory. For example, a possible means to quantify the variability of structural response consists of applying special techniques for uncertainty propagation such as Monte Carlo Simulation (MCS, see e.g. [1]). This is a robust, widespread and versatile method to quantify the effects of uncertainty. Nonetheless, its main drawback is that it demands performing a large number of analyses for different realizations of the uncertain input parameters associated with the FE model. This can be a challenging task from the numerical viewpoint. Hence, this contribution examines the possibility of reducing numerical efforts required to apply MCS by using a reduced basis method for performing structural reanalysis ([2], [3], [4]). The main concept behind a reduced basis is performing a limited number of full structural analyses in order to construct a basis. Then, when evaluating the structural response for a particular realization of the uncertain input parameters, the structural problem is projected onto a space of much smaller dimension by means of the basis. Undoubtedly, this allows evaluating the structural response approximately but with reduced numerical costs. In addition to applying a reduced basis method, the application of the so-called intervening variables (see, e.g. [5]) is investigated as well in order to further increase numerical efficiency and the quality of the approximations involved. In order to illustrate the application of a reduced basis method involving intervening variables and MCS, problems of linear static structural analysis are studied. In particular, second order statistics and exceedance probabilities of uncertain structural systems are estimated using the suggested approach.

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