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A non-intrusive reduced basis method for elastoplasticity problems in geotechnics

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Abstract

This work aims at investigating the use of reduced basis (RB) methods to diminish the cost of numerical simulation of elastoplasticity problems arising from geotechnics modeling, and involving parameter-dependent partial differential equations (PDEs). Computation times for large three-dimensional analysis commonly take tens of hours, making optimization procedures or sensitivity analysis, relying on repeated simulations, hardly feasible. In many cases the geotechnical analysis requires very specific features such as highly non-linear constitutive laws, making the necessary modification of the FE calculation code for a standard RB method impossible. An approach making it possible to use the reduced basis framework without having to modify the code gives the so-called non-intrusive reduced basis method a versatility of great practical interest. Our approach involves the computation of less expensive (but less accurate) FE approximation during the online stage and improvement of those solutions using a RB-based rectification method.

Keywords : Reduced Basis method; Finite Element method; Parametric studies; Elastoplasticity; Soils.

1. Introduction

Numerical modeling has met growing success over the last decades, becoming indispensible in the field of geotechnical engineering, leading to the numerical simulation by finite elements of even larger nonlinear problems. This trend stems from the need to account for the influence of constructing new structures, such as deep foundations of high-rise buildings or shallow tunnels for transport infrastructures, on neighboring structures (e.g. sewers, existing buildings, etc.) in dense urban areas. Computation times for large three-dimensional analysis commonly take tens of hours, making sensitivity analysis relying on repeated simulations hardly feasible. A common approach is to develop simplified models, such as metamodels, to approximate the model without significant loss of accuracy. In [1] a metamodel based on Proper Orthogonal Decomposition (POD) with radial basis functions (RBF) was applied to test problems in material mechanics with the goal of illustrating the capability of these metamodels to reproduce mechanical responses to the loading of complex non-linear material systems. An extended version of the POD-RBF metamodel was proposed in [2] to surrogate a 3D finite element simulation of a tunnel using a Hardening Soil model.

Another approach to rapidly compute reliable approximations of solutions of complex problems with many parameters is the use of reduced basis (RB) methods [3]. These methods rely on the parametric structure of the model and that when the parameters vary, the manifold of all possible solutions can be approximated by n-dimensional spaces. The performance and efficiency of the reduced

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