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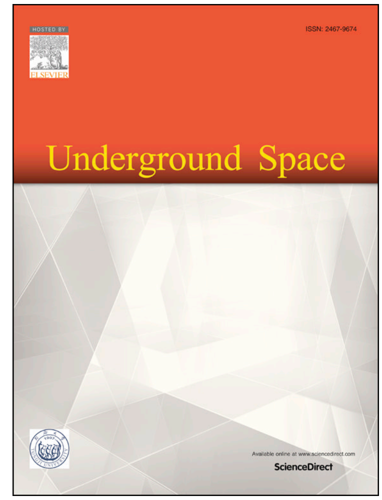

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Bubble-enhanced quadrilateral finite element formulation for nonlinear analysis of geotechnical problems

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Abstract: We investigate a new numerical procedure based on a bubble-enriched finite element formulation in combination with the implicit backward Euler scheme for nonlinear analysis of strip footings and stability of slopes. The soil body is modeled as a perfect plastic Mohr–Coulomb material. The displacement field is approximated by a 4-node quadrilateral element discretization enhanced with bubble modes. Collapse loads and failure mechanisms in cohesive frictional soil are determined by solving a few Newton–Raphson iterations. Numerical results of the present approach are verified by both analytical solutions and other numerical solutions available in the literature.

Keywords: Material nonlinear analysis; backward Euler scheme; bearing capacity; slope stability; bubble functions; finite elements

1. Introduction

At present, finite element methods (FEMs) are proven to be the most versatile tool for solving engineering problems. One major branch of FEM that has been dedicated for evaluating engineering results of geotechnical problems to date is the nonlinear analysis, in which the material behavior is nonlinear or being treated as elasto-plastic, where by nonlinear analysis, we refer to material nonlinearity. This is different from geometric nonlinearity, which is beyond the scope of our research. The history of material nonlinear analysis can be found from many sources [1-5] (we can also refer to the work of Potts and Zdravkovic [6] for further considerations on geotechnical engineering). Our method is related to the Newton–Raphson algorithm and the implicit backward Euler integration scheme. This combination has proven to be a robust and efficient nonlinear finite element (FE) scheme [7,8]. Although FEMs can solve elasto-plastic problems with high reliability, it, however, requires FEM practitioners to gain a detailed understanding and experience of nonlinear schemes, which also

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