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基于真实细观结构的岩土工程材料三维数值分析方法

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摘要 提出基于真实细观结构的岩土工程材料三维数值分析方法。运用数字图像技术，将岩土工程材料的表面图像转换为材料的真实矢量细观结构。然后通过一种简单变换，将该矢量结构转换为单层的三维结构。最后采用研磨及扫描循环系统，逐步扫描并生成每一层材料的表面细观结构，将这些沿深度方向连续的细观结构逐层逐层叠加起来，从而形成了整个试件的三维真实细观结构。该细观结构可以与传统数值计算方法耦合来分析非均质岩土工程材料的力学性能。以香港花岗岩为例，采用有限差分法软件FLAC3D，分析岩石在单轴受压情况下的三维应力分布及裂纹的产生及扩展过程。计算结果显示真实细观结构能显著影响材料的力学性能及破裂模式。

关键词 岩石力学 数值分析 非均质材料 花岗岩 数字图像处理 有限差分法

分类号

ACTUAL MESOSTRUCTURE BASED THREE-DIMENSIONAL NUMERICAL MODELING METHOD FOR HETEROGENEOUS GEOMATERIALS

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Abstract

This paper presents a three-dimensional numerical modeling method associated with actual mesostructures for heterogeneous geomaterials. Firstly，digital image techniques are used to extract two- dimensional material heterogeneity from material surface images. Secondly，the 2D square mesostructures are extrapolated to form 3D cuboidal mesostructures with the assumption that the material surface is a representation of the inner material distribution within a very small depth. Thirdly，an iterative milling and scanning system is set up to remove the material surface layer at a very small depth. The newly exposed surface is scanned to form the new digital representation of material heterogeneity. The milling and scanning process is repeated until the entire specimen can be represented by a series of layers of the cuboidal elements. These one-layer-thick 3D mesostructures are connected in series to form the actual 3D mesostructures. Finally，the 3D mesostructures are incorporated into traditional numerical methods to examine the mechanical behavior and fracture patterns of heterogeneous geomaterials under external loadings. A Hong Kong granite specimen is used to demonstrate the procedure of the 3D mesostructure establishment. The granite heterogeneity consists of three minerals：biotite，quartz and feldspar. A 40×118×10 cuboidal model is established. The actual size of the model is 15.00 mm×44.25 mm×3.56 mm. By adopting the commercial finite difference code FLAC3D，the 3D stress distribution，crack propagation process and failure model of rock under uniaxial compression loadings are simulated. Three homogenous cases and one heterogonous case are studied. The stress distribution and failure patterns associated with the three homogenous cases and a heterogeneous case are different. The load and displacement curves show that the compressive strength of the heterogeneous case is lower than those of the homogenous cases. The numerical results indicate that material heterogeneity can play an important role in the failure behavior as well as fracture patterns of geomaterials under external loading.

Key words rock mechanics numerical analysis heterogeneous geomaterials granite digital image processing finite difference method

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