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盾构隧道动力有效应力分析方法研究

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摘要 耦合场分割算法是求解Biot动力固结方程的一种有效的方法，它能够充分利用现有程序资源，并且在土介质渗透系数较小时能够有效地解决统一算法中容易出现的病态矩阵问题。然而，目前已经提出的Biot方程分割算法都是基于有限元离散方程形式的，难以直接应用于现在软件的二次开发。在对瞬态热传导方程和孔压消散方程的对比研究的基础上，推导一种能够在结构－温度耦合场分析软件(也可以在单独的结构场软件和温度场软件)上实现的Biot方程多次迭代串行分割算法，即在求解Biot方程的第n+1荷载步时，预先将孔压消散方程中的耦合项(未知量)用某种形式的预测值(已知量)代替，使孔压消散方程中的未知量只剩下节点孔压，从而可独立求解；再代入Biot方程的第1式，求出节点位移；如此循环迭代，即能以解耦的形式完成Biot方程的求解过程。这种方法对不同维数的问题、不同单元类型以及动力或静力问题都适用，并且额外编程量很少，十分便于推广应用和充分利用现有资源。数值算例结果表明，这种方法具有良好的精度和计算稳定性。最后，利用这种方法对武汉长江盾构隧道横断面进行动力有效应力分析，并对该工程地基的液化危险性进行评价。

关键词 隧道工程；地震响应分析；盾构隧道；耦合场分割算法；液化；有效应力原理

分类号

STUDY ON EFFECTIVE STRESS BASED ON DYNAMIC RESPONSE ANALYSIS METHOD FOR SHIELD TUNNEL

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Abstract

Partitioned solution procedures could be effectively used to solve Biot¢s equations，which can depict the coupled soil-pore fluid systems. With this method，the existing finite element analysis software could be utilized adequately，while the problem of ill-conditioned matrix，emerging in monolithical approach when the coefficient of permeability of the soil is comparatively small，can be settled successful. The partitioned approaches of Biot¢s equations are all based on the discrete form by finite element method，which will lead to the difficulties when employing them in the redevelopment of existing programs. After comparing

the transient heat conduction equation and the pore pressure dissipation equation，a new multi-iteration serial partitioned solution procedure is proposed，in which a certain predicted known value is substituted for the coupled unknown item in pore pressure dissipation equation. With the only one unknown parameter，the nodal pore pressure is left in the equation and could be figured out easily. Subsequently，the solution from the above step is incorporated into the second equation and the other variable，the nodal displacement could be calculated separately. And then，all the load steps could be solved in uncoupled form iteration. With little additional procedures，this method could be easily realized in thermo-structural analysis programme(or independent). This differential equation based method，suitable for two or three-dimensional problems and for static or dynamic problems as well as various element types，is proposed. As demonstrated with numerical examples，this approach could give comparatively precise results and has good computational stability. Subsequently，this approach was applied to the transverse dynamic response analysis of Wuhan Yangtze River Tunnel.

Key words tunneling engineering；seismic response analysis；shield tunnel；partitioned solution procedures of coupled mechanical systems；liquefaction；effective stress principle

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