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Introduction to Two Artificial Boundary Conditions for Transient Seepage Problems and Their Application in Geotechnical Engineering

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Abstract : Many problems in geotechnical engineering, such as foundation deformation, groundwater seepage, seismic wave propagation and geothermal transfer problems, may involve analysis in the ground which can be seen as extending to infinity. To that end, consideration has to be given regarding how to deal with the unbounded domain to be analyzed by using numerical methods, such as finite element method (FEM), finite difference method (FDM) or finite volume method (FVM). A simple artificial boundary approach derived from the analytical solutions for transient radial seepage problems, is introduced. It should be noted, however, that the analytical solutions used to derive the artificial boundary are particular solutions under certain boundary conditions, such as constant hydraulic head at the origin or constant pumping rate of the well. When dealing with unbounded domains with unsteady boundary conditions, a more sophisticated artificial boundary approach to deal with the infinity of the domain is presented. By applying Laplace transforms and introducing some specially defined auxiliary variables, the global artificial boundary conditions (ABCs) are simplified to local ones so that the computational efficiency is enhanced significantly. The introduced two local ABCs are implemented in a finite element computer program so that various seepage problems can be calculated. The two approaches are first verified by the computation of a one-dimensional radial flow problem, and then tentatively applied to more general two-dimensional cylindrical problems and plane problems. Numerical calculations show that the local ABCs can not only give good results for one-dimensional axisymmetric transient flow, but also applicable for more general problems, such as axisymmetric two-dimensional cylindrical problems, and even more general planar two-dimensional flow problems for well doublet and well groups. An important advantage of the latter local boundary is its applicability for seepage under rapidly changing unsteady boundary conditions, and even the computational results on the truncated boundary are usually quite satisfactory. In this aspect, it is superior over the former local boundary. Simulation of relatively long operational time demonstrates to certain extents the numerical stability of the local boundary. The solutions of the two local ABCs are compared with each other and with those obtained by using large element mesh, which proves the satisfactory performance and obvious superiority over the large mesh model.

Keywords : transient seepage, unbounded domain, artificial boundary condition, numerical simulation
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