International Conference on Contemporary Iran on Civil Engineering
Architecture and Urban Development
Iran Tehran - August 16, 2017

Determination of factor of safety against piping using scaled boundary finite-element method

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Abstract

Preventing piping is a prime consideration in the design of safe dams. Upward seepage at the toe of the dam on the downstream side causes local instability of soil in that region leading erosion. A process of gradual erosion and undermining of the dam may has been a common cause for the total failure of dams. In this research, a novel semi-analytical approach called the Scaled Boundary Finite-Element Method (SBFEM) is employed to determine the exit gradient and the factor of safety against piping. It utilizes the merits of boundary element method and Finite-Element Method (FEM). Anisotropic materials can be modeled without extra scrambles. Firstly, the two-dimensional steady state seepage flow problems beneath dams are analyzed. As the final product of seepage analysis the hydraulic heads are estimated on the boundary. The solution is extended for inside domain. The determined hydraulic heads are used to calculate the exit gradient and factor of safety against piping. The efficiency and accuracy of the proposed method is demonstrated by two numerical examples. The influence of impervious blanket on factor of safety against piping is investigated via examples. The SBFEM results are compared with the FEM and a great versatility is observed.

Key words: Seepage analysis, Scaled boundary finite-element method, Exit gradient, Factor of safety against piping.

1. Introduction

Seepage analysis has a vital importance in geotechnical engineering. The results of the seepage analysis allow the assessment of flow rates, exit gradients and factors of safety against piping which may be required for the safe design of various engineering structures such as dams and bridges. Several methods such as analytical and numerical methods were used to analyze the seepage problem. A short explanation and literature review of each method with own advantages and disadvantages is presented here.

The analytical methods have proven to be essential not only to gain a deeper conception of the basic physics, as well as for the parametric analysis of complex flow patterns and the optimization and estimation of the properties of seepage fields [1]. While problems with only