International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 28, No. 1, March 2018, pp. 80–86; https://doi.org/10.17736/ijope.2018.cl08

http://www.isope.org/publications/publications.htm

Three-Dimensional Seepage Characteristics of Reservoir Embankment Considering Interval of Horizontal Filter

Young-Hak Lee
Institute of Agricultural Science, Chungnam National University
Daejeon, Korea

Sung-Yong Park
National Disaster Management Research Institute, Ministry of Public Safety and Security
Ulsan, Korea

Ken-Ichi Tokida
Public Works Research Center
Tokyo, Japan

Dal-Won Lee
Department of Agricultural Engineering, Chungnam National University
Daejeon, Korea

Recently, the deterioration of reservoir embankments has progressed severely; thus, a more efficient design and construction method for deteriorated reservoir structures is required. For a fill-type reservoir embankment, a method that employs intervals between the horizontal filter and the embankment has been used and shown to achieve an efficient design. Since the horizontal filter is an important structure that provides stable drainage during an earthquake or concentrated leak, it is necessary to examine any change in the seepage characteristics depending on the filter intervals. In this study, the seepage characteristics of a reservoir embankment were examined according to the filter interval range via 3-D finite element analysis; additionally, potential risks such as those from piping were reviewed relative to the design interval of structurally stable filters. Consequently, results showed that the maximum filter intervals to yield efficient seepage characteristics were within 0–20.5 m for the pore water pressure of the core and the height of the seepage line. The piping evaluation results, as based on the range of the critical hydraulic gradient (I_{cr} : 0.8–1.4), demonstrated that the piping maintained stability within the filter interval range of 0–20.5 m; applying this range, stability was maintained when filters were installed throughout the embankment. However, when the filter interval exceeded 20.5 m, the piping was observed to fluctuate between stable and unstable conditions according to the range of the critical hydraulic gradient. Thus, to ensure structural stability, this study has proposed a decision method for the interval of horizontal filters based on the results of 3-D seepage analysis and the theoretical range of critical hydraulic gradient.

INTRODUCTION

Recently, because of the effects of climate change, concerns for functional degradation are rising for soil reservoirs vulnerable to seepage; moreover, the risk of disaster is expected to increase because risk factors for the collapse of embankment still exist. At present, 99.3% of all agricultural dams and reservoirs in South Korea are fill dams with the cross-sectional horizontal filter zone designed downstream of the embankment according to the relevant specifications (MAFRA, 2002). The interval of horizontal filters is designed to range between 10 and 40 m, and these filters regulate water drainage from the collected water inside the embankment. Since a filter has a coefficient of permeability higher than 1.0×10^{-5} m/s, the seepage characteristics of the embankment are expected to exhibit significant variation according to the interval range of the horizontal filters. Most previous studies related to the design of filters have been performed mainly at the particle size range of the filter material, considering control of seepage water and the minimum filter thickness capable of dissipating the pore water pressure (PWP) (e.g., USACE, 2004; Sherard et al., 1989; NRCS, 2007; US Bureau of Reclamation, 2007). However, studies on the safety of a reservoir embankment with a filter interval have not yet been reported. Chen and Zhang (2006) compared the seepage failure characteristics of rock-fill dams according to the 3-D analysis with that according to the 2-D analysis, taking into consideration the ground geometry. The 2-D analysis results, rather than the 3-D analysis results, suggested that the risk of seepage failure is underestimated. In the reservoir embankment with filter interval, since the horizontal filter interval is not considered in the 2-D seepage analysis, the horizontal filter zone is assumed to be installed throughout the embankment (z-axis direction).

As a result, the stability of the embankment can be underestimated, as the seepage line of the embankment drops more sharply than in the actual phenomenon. Thus, the seepage characteristics of the embankment should be evaluated with respect to the filter interval by 3-D analysis; furthermore, the results should be utilized to propose a practically applicable filter design interval.

Received April 19, 2017; revised manuscript received by the editors June 12, 2017. The original version was submitted directly to the Journal.
KEY WORDS: Seepage characteristics, 3-D analysis, filter interval, critical hydraulic gradient.