Analysis of Seepage Flow Through Homogeneous Earthen Dams Under Various Design Factors and Dynamic Reservoir Water Level Conditions

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Abstract

Earthen dams are susceptible to seepage losses, which pose a significant risk to their structural integrity. Seepage failures of these dams can occur due to piping and internal erosion, by gradual migration of soil particles and water towards coarser exits. Accurate prediction of seepage is essential for effective planning and design of hydraulic structures like dams. This study investigated the seepage behavior in a typical earthen dams under various dam design factors and reservoir water level conditions. The research employed both small-scale physical experiments and numerical modelling techniques using SEEP/W to investigate the seepage behavior. A series of small-scale physical model experiments of earthen dam were conducted with different materials and studied under controlled conditions. During the experiments, the seepage rate and total water pressure head were recorded for various upstream water level. Further, the numerical modelling for the developed physical setup was conducted using the SEEP/W simulator. The numerical model is then validated by comparing the observed seepage discharge rate and total water pressure head from the physical model for identical scenarios. The results exhibit a robust correlation between the observed and the simulated seepage discharge rate, with a high level of accuracy with a model efficiency of more than 90%. The seepage rates obtained from the both experimental study and the numerical modelling also exhibits a strong correlation, with an R2 value of 0.98. This confirms the reliability and effectiveness of the numerical model in predicting the seepage rates/ quantity accurately. Thereafter, impacts of various dam design parameters on seepage behavior were analyzed using the developed numerical framework. The investigated parameters included the height of the dam, upstream slope and the slope of downstream side. Steady-state analysis at different reservoir levels was the performed, to examine the impact of water level fluctuations on seepage patterns. Additionally, the influence of soil permeability on seepage discharge was investigated by considering a range

of permeability values for commonly used dam materials. This analysis provided valuable insights into the interplay between material properties and the behavior of seepage within the dam. Utilizing the data acquired through numerical modeling, a mathematical relationship was established to describe the seepage behavior across diverse parameter settings of dams. Finally, a sensitivity analysis was performed to investigate the impact of various factors on seepage flow in a homogeneous earthen dam. The results highlighted the permeability of the dam as a critical factor influencing seepage behavior. Moreover, the design parameter of dam height was identified as another significant factor affecting seepage characteristics. These findings emphasize the importance of considering both material properties and design parameters when assessing and managing seepage in earthen dams. In conclusion, this study provides a comprehensive understanding of the seepage behavior in earthen dams considering various parameters and water level conditions. These results can contribute to the manage seepage-related challenges in hydraulic structures for facilitating informed decision-making during the planning and design processes.