PERFORMANCE EVALUATION OF SELECTIVE CONTROL MEASURES OF FOUNDATION SEEPAGE FOR EMBANKMENT DAMS OVER PERMEABLE STRATA

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(2005-Ph.D-CEWRE-02)

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

WATER RESOURCES ENGINEERING

CENTRE OF EXCELLENCE IN WATER RESOURCES ENGINEERING

University of Engineering and Technology

LAHORE, PAKISTAN

(2012)

ABSTRACT

This research has addressed typical geological complexities through performance evaluation of selective foundation seepage control features for embankment dams on deep permeable strata. The study is based on an intricate case history of Satpara Dam Project founded over moraines. Seepage control measures for Satpara dam foundations included upstream extension of the dam core as an impervious blanket with a partial cutoff at its upstream end.

Seepage modelling was carried for 'as-designed' seepage mitigation measures under 2-D sectional flow model assumptions for different case scenarios using SEEP/W. In-situ permeability test results from pre-construction exploratory investigations of the project, ranging over several logarithmic orders of magnitude, were scrutinised for identification of a representative dataset for assignment of K-values while characterising spatial variability. Relative seepage sensitivity analyses were made using 'percentile' values from the two-layered 'pervious zone in homogeneous' foundation representation approach and computed values from the multi-zoned 'ROCKWORKS modelled' multi-zoned foundation representation approach. Comparative inferences considered theoretically acceptable limits in averting piping initiation for the adopted seepage control measures. The refinement in K-assumptions from the layered to the multi-zoned approach influenced and enhanced scale of magnitudes and rate of change of computed gradients and hydraulic heads along their distributions and trends at different points of consideration along the flow direction. The adopted seepage control scheme reduced the computed hydraulic gradients to 73.5% and the head potential to 72% at toe of core relative to no seepage control measures.

Available project data from five years of consecutive operation (for five impoundings during 2007-2011) showed that conservation level and consequently a steady state condition was not achieved. Effectiveness of the adopted seepage control measures at Satpara Dam was evaluated through comparative response of instruments installed across the cutoff wall, for upstream and downstream observations at two different depth zones, and along the flow path in the foundations upstream and downstream of the main dam axis. Piezometeric data from 27 selected responsive foundation piezometers covering the project area was used to develop percent potential contour plot plans, corresponding to selected pseudo-steady state reservoir levels and for a reservoir level common to the last three impounding stages. Evaluation of head differentials and percent potential distributions also provided evidence of cross flow influences, indicating 3-D flow in the dam foundation domain.

Pseudo-steady state reservoir levels defined new loading conditions, which were used to extend the 2-D 'as designed' SEEP/W model and additionally simulate a 3-D seepage model using FEFLOW. Simulated results based on the multi-zoned pre-construction foundation representation could not replicate the observed 'pseudo-steady' foundation response. It was assessed that applied heads had likely caused redistribution of unsupported fines, at probable locations associated with higher potential drops and concentrated potential contours. The cutoff wall proximity and foundations underlying the drainage blanket were accordingly identified to induce higher gradients susceptible for subsequently dislodging fines. An inverse 2-D modelling approach was implied to correspondingly re-adjust K-values in the sectional multi-zoned pre-construction foundation representation. This helped improve related subsurface perceptions of post-construction foundation behaviour.