Optimal Design of Hydraulic Structures Profiles under Uncertain Seepage Head

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Most of the hydraulic structures are founded on permeable foundation. There is, however, no procedure to fix the basic barrage parameters, which are depth of sheet piles/cutoffs and the length and thickness of floor, in a cost-effective manner. Changes in hydrological and climatic factors may alter the design seepage head of the hydraulic structures. The variation in seepage head affects the downstream sheet pile depth, overall length of impervious floor, and thickness of impervious floor. The exit gradient, which is considered the most appropriate criterion to ensure safety against piping on permeable foundations, exhibits non linear variation in floor length with variation in depth of down stream sheet pile. These facts complicate the problem and increase the non linearity of the problem. However, an optimization problem may be formulated to obtain the optimum structural dimensions that minimize the cost as well as satisfy the exit gradient criteria. The optimization problem for determining an optimal section for the weirs or barrages normally consists of minimizing the construction cost, earth work, cost of sheet piling, length of impervious floor etc. The subsurface seepage flow is embedded as constraint in the optimization formulation.

Statistical techniques have been traditionally used to deal with parametric variation in model inputs, but these require substantial hydrogeologic explorations data for estimates of probability distributions. In the presence of limited, inaccurate or imprecise information, simulation with fuzzy numbers represents an alternative tool to handle parametric uncertainty. Fuzzy sets offer an alternate and simple way to address uncertainties even for limited exploration data sets. In the present work, the optimal design is obtained assuming a deterministic value of seepage head, in optimization model. Uncertainty in seepage head is then characterized using fuzzy logic. The fuzzified nonlinear optimization formulation (NLOF) is then solved using GA.

The results indicate that there is more than 16 percent saving in cost for the barrage profile obtained by solution of NLOF compared to the profile obtained by conventional

design. As the safe exit gradient value decreases or seepage head increases, the cost increases. Uncertainty in design, and hence cost from uncertain seepage head are quantified using fuzzy numbers. Results show almost linear relationship between uncertainty in seepage head and uncertainty in design represented by overall design cost. The limited evaluation show potential applicability of the proposed method.

Keywords: barrage design; nonlinear optimization; fuzzy numbers; seepage head; exit gradient.