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Domain Knowledge Based Approach for Design Optimization of Arch Dams Using Genetic Algorithms

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Abstract

Concrete arch dams, unlike conventional concrete gravity dams, have thin arch-shaped cross sections and must be designed considering a three-dimensional shape. In particular, double-curvature arch dams, which have arch-shaped vertical and horizontal sections, require careful consideration during design due to their unique shape. Although stress analysis is complex, and various factors need to be considered during the design, these dams offer economic advantages as they require less material. Consequently, numerous double-curvature arch dams have been constructed worldwide, and ongoing research focuses on optimizing their shapes. In this study, an efficient optimization algorithm was developed for the shape optimization of concrete arch dams with double-curvature using genetic algorithms and improved population initializing technique. The developed technique utilized domain knowledge in the field of arch dams to generate an excellent initial population. To assess the relevance of domain knowledge, an investigation was conducted on the accumulated knowledge and empirical formulas from literature. Two pieces of domain knowledge can be gleaned from the iterative structural design experiences associated with arch dams. First, it concerns the thickness of the central cantilever of an arch dam. For minimum tensile stress, it is best to make the thickness as thin as possible at the dam crest and gradually become thicker as it goes down. The second aspect concerns the sliding stability of the arch dam, which depends on the central angle of the horizontal section. This angel is important for stability because the plane arch serves to transfer the hydraulic load from the reservoir to both abutments. Also, preliminary design formulas for arch dams from a manual written by the United States Bureau of Reclamation (USBR) were used. On the other hand, since domain knowledge is based on engineering experiences and data from existing dams, its usability should be verified by comparing it with the results of design optimization performed by classic genetic algorithms. To validate the performance of the optimization algorithm with the improved population initialization technique, a test site with an existing dam was selected, and algorithmic application tests were conducted. Stress analysis is performed for each design iteration, evaluating constraints and calculating fitness as the objective function. The results confirmed that the algorithm developed in this study exhibits superior performance in terms of average fitness and convergence rate compared to classic genetic algorithms.

Key words: design optimization, arch dam, domain knowledge, genetic algorithms

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