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Research Article

Predicting local scour depth of bridge piers using hybrid particle swarm optimization and gray wolf optimizer

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Abstract

Introduction

Bridge pier foundations are costly to construct, and local scour around them can lead to instability and, if not properly addressed, eventual structural failure. Therefore, a detailed study to understand this phenomenon and the factors influencing it is essential. This research proposes an equation to estimate local scour depth around bridge piers based on an extensive dataset of field measurements. An optimization model was defined, and its decision variables were estimated using a hybrid metaheuristic algorithm combining Grey Wolf Optimizer (GWO) and Particle Swarm Optimization (PSO) (HPSGWO). Various equations were evaluated, and the best-performing model was selected based on error metrics such as RMSE, RSR, NSE, PBIAS, and CC. The results indicate that the proposed equation is reliable and outperforms existing empirical methods. The equation shows that scour depth is directly proportional to the Froude number and the ratio of pier width to flow depth, and inversely proportional to the ratio of median sediment size to flow depth.

Materials and Method

The study utilized a dataset of 540 field measurements of local scour depth around bridge piers, collected under various hydraulic and sediment conditions. The dataset included parameters such as pier width, flow velocity, flow depth, sediment size, and Froude number. An optimization model was formulated to minimize the root mean square error (RMSE) between observed and calculated scour depths. The hybrid HPSGWO algorithm was employed to solve the optimization problem, combining the exploration capabilities of GWO with the exploitation strengths of PSO. The model was evaluated using error metrics, including RMSE, RSR, NSE, PBIAS, and CC, to ensure accuracy and reliability.

Results and Discussion

The results demonstrated that the proposed equation, derived using the HPSGWO algorithm, provided accurate estimates of local scour depth. The best-performing model (SF13) achieved an RMSE of 0.504 m, an NSE of 0.729, and a CC of 0.734, indicating a strong correlation between observed and predicted values. The model showed that scour depth increases with the Froude number and the ratio of pier width to flow depth, while it decreases with the ratio of median sediment size to flow depth. The proposed equation outperformed existing

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empirical methods, such as those by Sharafi et al. (2016), which achieved an RMSE of 0.507 m and an NSE of 0.711. The study highlights the importance of considering sediment characteristics and flow conditions in scour depth estimation.

Conclusion

This research presents a reliable equation for estimating local scour depth around bridge piers, derived from a comprehensive field dataset and optimized using the HPSGWO algorithm. The proposed model outperforms existing empirical methods, providing more accurate and robust predictions. The results underscore the significance of incorporating sediment size and flow parameters in scour depth calculations. The equation can be used as a practical tool for engineers and researchers to assess scour risk and design more stable bridge foundations. Future studies could explore the application of this approach to other hydraulic structures and under varying flow conditions to further validate its effectiveness.

Conflict of Interest

The author declares no conflict of interest regarding the authorship or publication of this article.

Data availability statement

The data and results used in this research will be available through correspondence with the author.