

ENSEMBLE MACHINE LEARNING AND HYPERSTATIC REACTION METHOD FOR THE DESIGN OF QUASI-RECTANGULAR TUNNELS

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ABSTRACT

Recently, the quasi-rectangular tunnel has been developed as a novel design concept, aimed at replacing traditional circular and rectangular tunnels. This work presents an integrated approach combining Hyperstatic Reaction Method (HRM) and ensemble machine learning methods to enable real-time design of quasi-rectangular tunnels. The HRM is employed to analyze the deformation and structural integrity of this innovative tunnel geometry [1]. To support the real-time design and optimization, three popular ensemble algorithms including Random Forest (RF), Gradient Boosting Decision Trees (GBDT), and Extreme Gradient Boosting (XGBoost) are evaluated to determine the best-performing model to efficiently substitute the HRM. It turns out that, XGBoost [2] proves to be the most reliable, achieving excellent accuracy with an R^2 of ~ 0.999 and a mean absolute percentage error (MAPE) of $\sim 1\%$. In addition to its precision, XGBoost demonstrates remarkable computational efficiency. The HRM-XGBoost hybrid model is integrated with Particle Swarm Optimization to enhance the design process of quasi-rectangular tunnels, enabling real-time optimization for both with and without the interior column. All the developed methods are integrated into a specialized software platform for real-time tunnel design, which contributes an important step towards the development of digital twin-assisted tunnel engineering.

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