Prediction of residual compressive strength of normal concrete exposed to elevated temperatures

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Predicting the residual compressive strength of concrete after exposure to elevated temperatures is essential for post-fire safety assessment. However, this task remains difficult because the degradation of concrete strength is nonlinear, scattered, and strongly affected by testing conditions. Existing empirical and design-code equations usually rely on simplified assumptions and limited datasets, which may restrict their accuracy when applied to broad experimental databases. This study presents a comparative data-driven framework for predicting the residual compressive strength of normal concrete exposed to elevated temperatures. A database of 700 experimental results collected from 67 published studies was used. Exposure temperature and compressive strength at ambient conditions were selected as input variables because they are widely reported in the literature and are commonly used in design-code formulations. Seven predictive models were developed and evaluated, including multiple linear regression (MLR), support vector regression (SVR), k-nearest neighbor (KNN), random forest (RF), extreme gradient boosting regression (XGBR), gene expression programming (GEP), and multi-expression programming (MEP). The models were assessed using statistical error metrics, regression analysis, sensitivity analysis, and comparison with existing empirical and code-based equations. The results showed that ensemble learning models such as RF and XGBR provided the most accurate and stable predictions. In particular, XGBR achieved the best testing performance, with a test RMSE of 3.57 MPa and R^2 of 0.914. RF also showed strong predictive capability and stable generalization. In contrast, MLR and several existing equations were less effective in capturing the nonlinear strength degradation at high temperatures. Among the symbolic models, GEP showed better generalization than MEP and provided an explicit analytical relation for practical estimation. Sensitivity analysis confirmed that exposure temperature was the dominant variable, while ambient compressive strength had a secondary influence. Overall, the findings indicate that ensemble models are suitable for accurate prediction, whereas GEP can support transparent engineering assessment through an explicit formulation.