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Machine learning enhanced modeling of steel-concrete bond strength under elevated temperature exposure

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Abstract
This study uses machine learning techniques to investigate the bond strength between steel and concrete under various elevated temperature scenarios. Five distinct machine learning algorithms, including Random Forest (RF), XGBoost, AdaBoost, Decision Tree, Linear Regression, and hyperparameteric optimisations, were used to predict changes in bond strength. The models underwent rigorous optimisation using GridSearchCV to achieve optimal performance. In this study, we evaluated several metrics such as Mean Squared Error, Root Mean Squared Error, Mean Absolute Error, and coefficient of determination (R^2) Score to compare and assess the models' prediction capabilities. After optimisation, results indicate that the RF model exhibited exceptional performance in estimating bond strength across different temperature conditions, demonstrating minimal errors and a high R^2 Score. Visual comparisons of actual and predicted values further confirmed the efficacy of the RF model in capturing complex fluctuations in bond strength. The findings of this study underscore the potential of machine learning models, particularly the optimized RF method, in accurately predicting bond strength under varying thermal conditions, with promising implications for engineering and construction practices.

1 | INTRODUCTION

The exposure of buildings and infrastructure to elevated temperatures remains a critical concern worldwide. The materials subjected to extreme temperatures lead to structural deterioration and potential collapse. Among the essential construction materials, concrete and steel play pivotal roles in ensuring structures' overall strength and stability. However, their behavior and performance under elevated temperatures differ significantly from their normal operating conditions. Understanding the effects of high temperatures on concrete and steel and the bond strength between them is essential for designing structures that can withstand high temperatures.[1]

Concrete is a composite material comprising aggregates bound together by a cement paste, resulting in diverse mechanical and thermal characteristics. Reinforced concrete, widely utilized in construction, involves incorporating steel reinforcing bars (rebar) to enhance its tensile strength and overall structural soundness.[2] A pivotal factor affecting reinforced concrete's performance is the adherence between the concrete and the reinforcing bars. This connection ensures the effective transfer of tensile forces between the materials, enabling them to function cohesively. This characteristic is crucial for concrete structures' overall stability and load-bearing capacity.[2] Despite the considerable volume of investigations, the intricacies of concrete's thermal and mechanical