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RESEARCH ARTICLE

Use of soft computing approaches for the prediction of compressive strength in concrete blends with eggshell powder

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Abstract

The present study showcases a prediction model for estimating the compressive strength of concrete combined with ESP utilizing machine-learning techniques. The models were created using 399 datasets that were sourced from published literature. The datasets included a range of input factors, including cement content, ESP content, fine aggregate content, coarse aggregate content, water content, and curing duration. The models used the compressive strength of ESP mixed concrete as the output variable. This research used a collection of seven machine learning algorithms, namely linear regression, artificial neural network, boosted decision tree regression, K nearest neighbors, random forest regression, support vector regression, and XGboost as statistical evaluation tools in order to determine the best accurate and dependable model for forecasting the compressive strength of ESP mixed concrete. Among the machine-learning models assessed in this investigation, the XGboost model has shown exceptional efficacy in forecasting compressive strength. It attained an R^2 value of 0.99 and an RMSE of 0.99 MPa for the training dataset while reaching an R^2 value of 0.82 and an RMSE of 4.48 MPa for the testing dataset. The sensitivity analysis results of the XGboost model indicate that the compressive strength of the material is mostly affected by the curing period. The compressive strength of a material is also significantly impacted by the amounts of cement and water in the mix.

Keywords Concrete · Eggshell powder · Compressive strength · Machine learning · SHAP analysis

1 Introduction

The production of building materials has a substantial influence on the natural environment. The demand for cement-based products has significantly increased due to the fast expansion of infrastructure construction. Cement is a highly used substance on a global scale. Cement production had significant expansion throughout the 2000s, resulting in a total output of 4000 million tons during the previous decade. The manufacture and use of cement have been identified as significant contributors, accounting for 8% of worldwide carbon dioxide (CO_2) emissions [1]. This emission breakdown reveals that clinker production is responsible for 50% of these emissions while burning fuel accounts for 40%. The remaining 10% is attributed to various activities such as transport, raw material preparation, cooling, grinding, and mixing [2]. There is a global prevalence of large-scale infrastructure projects now underway, and the geological distribution of raw materials necessary for cement production is extensive. Consequently, it is improbable that there will be a reduction in the use of cement in the foreseeable future. According to the cited source, an approximate emission of 0.9 kg of CO_2 per kilogram of cement production is anticipated. Furthermore, using nonrenewable resources in cement production has raised an additional environmental concern. Consequently, experts in the industry and scholars have collaborated to develop innovative strategies to address these escalating challenges [3, 4].

The existing published literature demonstrates that several investigations have been undertaken to explore substitute materials for cement. Using waste materials as substitutes for cement can decrease cement consumption and mitigate the environmental consequences associated with the indiscriminate disposal of waste [5, 6]. Waste materials may be classified into industrial byproducts and

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