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Prediction of damage evolution in carbonate building stones subjected to simulated acid rain using M5P model

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This study focuses on predicting the acid rain damage using machine learning techniques. First, a database containing 168 datasets was established based on laboratory experiments on seven types of carbonate building stones. Laboratory experiments were conducted at three different pH levels, using sulfuric acid (H_2SO_4) and nitric acid (HNO_3) to simulate acid rain conditions. Furthermore, during experiments, P-wave velocity was used to define the acid rain damage index (D). Then, to predict D efficiently and accurately, the M5 Prime (M5P) algorithm was employed as a white-box and interpretable machine learning technique. The predictive capability of developed M5P model was assessed by several performance assessment metrics. Based on obtained results, the suggested model predicted D with good accuracy and acceptable errors. The feature importance quantification results in M5P model demonstrated that stone's porosity is the most influential variable on acid rain damage. Finally, predictive capability of M5P model was compared with support vector regression (SVR) and random forest (RF) models. This comparison showed that the proposed M5P model outperforms other models in terms of D prediction accuracy, with a determination coefficient (R^2 of 0.891, a root mean square error (RMSE) of 0.021, and a mean absolute error (MAE) of 0.017. Thus, the proposed M5P model offers the construction industry a reliable framework for evaluating acid rain damage of building stones, reducing the need for extensive experimental testing, and facilitating the selection of durable stones for exterior cladding and floor coverings in acid rain-prone areas.

Keywords Carbonate building stones, Acid rain, Machine learning, M5P model, Damage prediction

Abbreviations

M5P	M5 Prime
C	Regularization parameter
RBF	Radial basis function
Optuna	A hyperparameter optimization framework
D	Acid rain damage index
D_{20}	Acid rain damage index after 20 cycles
d	Density
P	Porosity
WA	Water absorption
UCS	Uniaxial comprehensive strength
SVR	Support vector regression
RF	Random forest
R^2	Determination coefficient
RMSE	Root mean square error
MAE	Mean absolute error
MAPE	Mean absolute percentage error
RPD	Relative percent deviation
SD	Standard deviation
REC	Regression error characteristic

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