

Physics-assisted machine learning methods for predicting the cracking performance of recycled aggregate concrete

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Abstract

The poor cracking performance has become the obstacle for the application of recycled aggregate concrete (RAC). In this study, the physics-assisted machine learning methods are adopted to predict the cracking performance of RAC. Based on physics, 9 features are effectively selected as the inputting variables, while the splitting tensile strength is selected as characterization parameter of cracking. The classification and regression trees (CART), support vector regressor (SVR), adaptive boosting (Adaboost), and Random Forests algorithms are used to construct the predictive models, and the Firefly algorithm is used to search for the optimum hyperparameters. By comparing the predicted values and with the experimental data during the training and testing procedures, the Adaboost model is found to be the best one proved to be the excellent model for predicting the tensile strength of RAC. Combined with the physical mechanism, this important analysis proves that the contents of recycled aggregate, aggregate size, and water contents are the three most influential factors for the predictive models, and that these factors should be carefully considered during when designing the mixture of RAC. Moreover, the reliability of the predictive models is verified by physical experiments.

Introduction

Due to various outstanding characteristics, the concrete material is used widely in building construction. According to the reports of National Development and Reform Commission, the total production of commercial concrete exceeded 32 billion cubic meters in 2021. Hence, a large amount of cement, sand, natural gravel, and crushed stone are demanded every year. Meanwhile, with the demolition of old and abandoned buildings, more than 2 billion tons of concrete waste is produced annually. Hence, as a result, the recycled aggregate concrete (RAC), which uses recycled concrete waste to partly replace the coarse aggregates in concrete, has increasingly been used. This becomes a new trend in concrete production, development is also helping which will make contributions to reduce the carbon emissions related to concrete production.

During the production of the manufacturing procedure of recycled aggregates, the obtained recycled aggregate final product always typically consists of natural aggregates and hardened mortar. Hence, comparing with natural aggregates, the recycled aggregates exhibit low strength owing to the presence of the hardened mortar, which is weaker, and the interfaces that form between the mortar and natural aggregates. Furthermore, a large number of many cracks are generated inside within the recycled

I hyphenated "Physics-assisted" as a compound modifier before "machine learning methods," and dropped the article before "cracking performance" for

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I spelled out CART and SVR in full and removed the abbreviations, since each term appears only once in the abstract. The short form of Adaboost is retained because it

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"Due to" traditionally functions as an adjectival expression meaning "caused by" rather than "because of." Rule of thumb: if "due to" can be replaced with "caused

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Please consider mentioning a few of these characteristics to strengthen your claim.

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A serial comma is inserted, for clarity, before the conjunction that precedes the last element of a series (e.g., bread, eggs, and milk). In US English it is called

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I added "related to concrete production" to specify which carbon emissions are reduced. Please confirm this scope is what you intend.

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aggregates during the crushing process. As shown in Fig. 1, ~~various-several~~ weak regions ~~is-are~~ introduced into ~~the recycled aggregate concrete~~ RAC, and ~~making it such material is particularly~~ peculiarly prone to cracking when under suffering external loads and thus, which severely restricts its applicability. Hence ~~Consequently~~, compared with its other mechanical properties, the cracking ~~properties-characteristics~~ of RAC deserve more attention.

Once abbreviations are defined, they must be used uniformly throughout the manuscript.

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As a type of RAC, the ~~f~~Fiber-reinforced RAC, ~~which is a type of RAC, behaves better in~~ exhibits greater resisting-cracking resistance by virtue of ~~because of the~~ various-fibers present. Akca et al. applied-used polypropylene fibers to reinforce RAC; and ~~proved-showed~~ that both the flexural tensile strength and splitting tensile strength increased with the fiber contents. Ali et al. compared the mechanical properties of glass-fiber-reinforced RAC and plain RAC. ~~They, the-~~ observed that ~~obvious increase was witnessed on the~~ the splitting tensile strength of the fiber-reinforced ~~recycled aggregate concrete~~ RAC was markedly higher. Gao et al. studied the performance of steel-fiber-reinforced RAC and found that ~~the, the-~~ flexural strength was improved significantly with the ~~an~~ increase of ~~in the~~ steel fiber volume fraction. ~~It-Thus, it~~ can be concluded that the-fibers ~~could are~~ efficiently-effective in improving the cracking resistance of RAC. ~~H, but-oweever, their the mechanism of~~ reinforcement performance is affected by various factors.

For ~~the~~ plain concrete, various methods have been proposed to predict its cracking performance, such as fracture tests, numerical methods, and mechanical models. ~~In addition, different factors are have been studied to guarantee the~~ evaluated to test the reliability of its performance-prediction-reliability. ~~Even so-However, precisely it is still difficult to precisely-~~ describing its cracking characteristics ~~remains difficult. Considering-Given the influence-effect~~ of the recycled aggregates, ~~the prediction of predicting the~~ cracking behavior of RAC ~~become more comple, x, let alone the~~ especially that of fiber-reinforced RAC, ~~is even more complex with fibers. The-m~~ Machine learning (ML) methods are novel approaches for prediction ~~issuesproblems~~. Pan and Amin ~~tried to used~~ machine-learning (ML) to predict the cracking characteristics of RAC, and established several ML models with superior performance. However, during the construction of the ML models, the physical meaning of the models ~~is-was~~ neglected, ~~and the the influence-effect~~ of any reinforcing fibers ~~is-was~~ not considered.

In this study, the ~~existed-existing~~ mechanical models and the results of physical experiments are adopted to ~~assist-improve the the machine-learning~~ ML approaches; ~~with the aim of and try-to-~~ precisely-predicting the cracking behavior of RAC accurately. The ~~whole-rest of the~~ paper is arranged as follows: (1) Chap. Section 2 mainly describes the construction of a database ~~with the help of based on~~ physical theories; (2) Chap. Section 3 illustrates the ~~several-various~~ machine-learning ML algorithms used in ~~thise~~ current-study; (3) Chap. Section 4 mainly presents the construction process of predictive models; (4) Chap. Section 5 ~~tests the-describes the~~ results of tests performed using the performance-of predictive models and compares them with those of with-mathematical and physical methods; and- finally (5) Chap. Section 6 ~~drawslists the-~~ the conclusions.