

A Review of Research on Prediction Methods for Compressive Strength of Concrete

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Abstract

Concrete is one of the most widely used building materials in the world. The compressive strength of concrete is a crucial parameter in construction engineering as it directly affects the safety performance and stability of building structures. Therefore, accurately predicting the compressive strength of concrete has become a widely discussed issue across various fields. Both traditional prediction methods and machine learning techniques, which have gained popularity in recent years, play important roles in this field. Researchers have started applying these methods to predict the compressive strength of concrete. This article will introduce some methods used for predicting the compressive strength of concrete.

Keywords

Compressive Strength of Concrete; Prediction; Machine Learning.

1. Introduction

Concrete is the most widely used building material in the world[1]. At the same time, with the growth of the world's population and urbanization, the future demand for concrete will be more and more large. In order to cope with different concrete structure design, it is necessary to have a better understanding of the mechanical properties of concrete. The compressive strength of concrete is one of the key factors to evaluate the safety performance and stability of concrete. Therefore, how to accurately predict its compressive strength is very important for the safety and stability of structural design. At the same time, concrete is a complex system composed of different components, and these components are randomly distributed in the whole concrete matrix. This has a serious interference to the prediction of concrete compressive strength.

In recent years, with the development and progress of artificial intelligence, researchers have paid wide attention to the trend of using machine learning methods and integrated learning methods to predict the compressive strength of concrete. Compared with machine learning or ensemble learning methods, traditional concrete performance prediction methods are usually based on empirical formulas or basic properties of its materials to predict concrete performance. But these approaches will be limited in the face of changing and uncertain circumstances. The machine learning method has a different specificity, it can learn from the data and more accurate results are relatively direct output to the researcher.

This paper reviews the application of some machine learning methods[2] to the prediction of concrete compressive strength and the potential of these methods to improve the accuracy and intuitiveness of the prediction performance. In this paper, the advantages and limitations of different concrete compressive strength prediction methods are analyzed to compare the appropriateness and reliability of different methods. And by studying the appropriateness of different forecasting methods in the prediction of concrete compressive strength, to promote the use of each method in the design of concrete structure and to provide a certain practical and theoretical basis for its structural design.

2. Research Status at Home and Abroad

2.1. Traditional Prediction Method

In the past decades, scholars have found that the compressive strength of concrete is not only closely related to the material parameters in its mix ratio, but also closely related to the influence of external factors. How to design concrete suitable for the compressive strength of different buildings is a problem that researchers have always considered. In this regard, the researchers tested the compressive strength of concrete through many tests, and conducted regression analysis through the relevant data, so as to deduce the prediction relationship related to the compressive strength.

In 1918, foreign scholar Abrams[3] found from a large number of experimental data that the properties of different material content had different influences on the compressive strength of concrete. For example, the amount of water used in the material content shows an inverse trend in the compressive strength of concrete, and the compressive strength of concrete shows a proportional trend with the increase of the amount of cement. Based on the water-cement ratio, the researchers deduced the formula to predict the compressive strength of concrete by regression analysis.

$$f = \frac{A}{B^x} \quad (1)$$

Among them: f for 28 days compressive strength, A and B as cement quality, age, maintenance, test method and different constant, x as the water cement ratio.

In addition, there are Graff formula, Paulmie formula, etc.[4]. Although most of these formulas explore the relationship between the water-cement ratio and the compressive strength of concrete, these formulas can explore the prediction formulas of concrete compressive strength applicable to different situations according to the different test materials and environmental factors.

2.2. Machine Learning Prediction Methods

In the process of concrete preparation, its properties are affected by many factors such as raw materials, mix ratio and admixtures. Therefore, the application range of different concrete compressive strength prediction formulas is limited, and with the continuous development of machine learning technology. Researchers are gradually applying machine learning methods to the prediction of concrete compressive strength. The algorithms and models of machine learning methods are diverse, such as decision trees, support vector machines, neural networks and integrated learning methods, etc., and the degree of adaptation of different algorithms is also different. For example, decision trees are suitable for interpretable tasks, while neural networks are suitable for complex nonlinear relationships.

In recent years, foreign scholars have carried out a lot of work on the prediction of concrete compressive strength by machine learning. In 2006, Ahmet Oztahi et al., in order to predict the compressive strength and slump of high-strength concrete, collected the mix ratio data of 187 neutral concrete in this paper to construct the data set. In addition, the neural network method is used to predict these two properties of concrete, and the results show that the neural network has strong potential to predict the compressive strength and slump properties of concrete[5].

In 2012, Andreas F.V. Roy et al. wanted to use traditional empirical formulas to predict the compressive strength of high performance concrete. Due to the influence of mineral composition and admixtures used in HPC, the traditional empirical formula is not applicable. In

this regard, the researchers adopted the support vector machine combined method to predict the high performance concrete, and the results show that the support vector machine combined method has great potential for predicting the compressive strength of high performance concrete[6].

In 2013, Adriana Trocoli Abdon Dantas et al. predicted the compressive strength of concrete containing construction and demolition materials at 3, 7, 28 and 91 days. By collecting 1178 sets of data, the data set is constructed and the data set is predicted by neural network method. The results show that artificial neural network can be used to predict the compressive strength of concrete at different ages[7].

In 2016, S. Chithra et al. constructed multiple regression analysis and artificial neural network models to predict the compressive strength of high-performance concrete with different mineral content. The results show that the artificial neural network model has higher accuracy and higher correlation than the multiple regression analysis model[8].

In recent years, a lot of work has been carried out on machine learning to predict the compressive performance of concrete. In 2006, in order to predict the compressive strength of vibration-free fly ash concrete, Wang Jinli et al. adopted the neural network method to predict the compressive strength of concrete. Through analysis, it can be seen that the neural network method is feasible for predicting the compressive performance of this type of concrete[9].

In 2011, PI Wenshan et al. established a prediction model of concrete compressive strength based on neural network for the factors affecting strength. By taking different dosage and age as input and concrete compressive strength as output, the prediction is made. The results show that the prediction model has high prediction accuracy [10].

In 2015, Lin Yuezhong et al. established a dataset of test samples. The influence of water-reducing agent, age and other factors on the compressive strength of polymer concrete is explored, and a neural network prediction model is constructed. The results show that the neural network prediction method has high accuracy in predicting the compressive performance of this type of concrete[11].

In 2020, Feng Decheng et al. collected 1030 sets of concrete compressive strength test data and established a data set. The integrated learning method in the machine learning method is used to predict the compressive strength of concrete. The results show that ensemble learning has better prediction accuracy than single machine learning techniques such as neural network and support vector machine[12].

It can be seen that the machine learning method is relatively successful in the current research and application, mainly because the method reduces the test time and the amount of test materials to a certain extent, saving costs and time for researchers and construction personnel. At the same time, machine learning methods are more universal. It can predict the compressive strength of concrete under different conditions.

3. Major Problems

When the traditional prediction method is used to predict the compressive strength of concrete, the traditional prediction method usually relies on the traditional experience and empirical formula. First, these methods often rely on the experience and expertise of engineers and do not adequately reflect the complexity and variability of concrete materials. At the same time, because the traditional method may be too simplified, it is difficult to adapt to the change of different types of concrete and material characteristics. And these methods usually use empirical formulas, limited to limited experimental data and specific conditions, it is difficult to generalize to different situations.

Compared with traditional methods, machine learning prediction methods also face some problems in the prediction of concrete compressive strength. These methods require a large amount of data to train, and obtaining large-scale applicable data in concrete tests is equally challenging. Moreover, some machine learning models may lack explanatory power, and it is difficult to explain the influence of different factors on the strength of concrete, which will affect the research and discovery of some theories. At the same time, overfitting, model parameter adjustment and other problems are also the challenges machine learning methods need to face in practical applications.

4. Conclusion

With the continuous development of society, the existence of concrete buildings is only more and more. The wide application of concrete in construction engineering and the direct influence of its compressive strength on the safety and stability of structure are widely concerned by the society. Although the traditional concrete prediction method is widely used, it still cannot guarantee its accuracy and applicability for concrete under different conditions. The emergence of machine learning method provides a new idea for the prediction of concrete compressive strength. Although machine learning method has good applicability for the prediction of concrete compressive strength, how to improve the accuracy and accuracy of the prediction model is also a problem that will be faced in the research process. In general, the machine learning method has a great prospect and development space in the aspect of concrete performance prediction.

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