ISSN: 2752-3829 Vol. 3 No.2, (December, 2023)

Stochastic Modelling and Computational Sciences

APPLICATIONS OF ARTIFICIAL NEURAL NETWORK (ANN) IN PREDICTION OF COMPRESSIVE STRENGTH OF CONCRETE

Supriya S. More[1] and Ajaykumar. R. Kambekar[2]

[1]Research Scholar Civil Engineering Department, Sardar Patel college of Engineering, Andheri Mumbai, India

[2]Research Professor, Department of Civil Engineering, Sardar Patel college of Engineering, Andheri Mumbai 400058 India

*ssmore74@gmail.com

ABSTRACT

This research investigates the application of Artificial Neural Networks (ANN) in predicting the compressive strength of M20 grade concrete. Accurate prediction of concrete compressive strength is critical for ensuring structural integrity, quality control, cost efficiency, and sustainable construction practices. The study utilizes a Multi-Layer Perceptron (MLP) model to analyze a dataset comprising various concrete mix parameters. The model's performance is evaluated using metrics such as Correlation Coefficient (CC), Coefficient of Determination (R^2), Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE).The results demonstrate that the MLP model achieves high accuracy, with CC values close to 1.00 and R^2 values ranging from 0.91 to 1.00 across different training and testing splits. To validate the ANN model, Multi Linear Regression model (MLR) was evaluated indicating CC value to 0.90 while R^2 value 0.88. The low MAE, MSE, and RMSE values further confirm the ANN model's reliability in predicting compressive strength. The study highlights the potential of ANN models in optimizing material usage, reducing construction costs, and enhancing the overall efficiency of construction projects. In conclusion, the research underscores the importance of leveraging advanced AI techniques, such as ANN, for predicting the compressive strength of concrete. The findings contribute to the field of civil engineering by providing a robust and accurate method for quality control and project management in concrete construction

Keywords: *Artificial Neural Networks (ANN), Multi-Layer Perceptron (MLP), Correlation Coefficient (CC), Multi Linear Regression model (MLR)*

1. INTRODUCTION

The compressive strength of concrete is a fundamental property that significantly influences the structural integrity and durability of construction projects. In civil engineering, ensuring that concrete meets the required compressive strength is crucial for the safety and longevity of structures such as buildings, bridges, and roads. M20 grade concrete, characterized by a mix ratio of 1:1.5:3 (cement: sand: aggregate), is widely used in residential and commercial construction due to its balanced properties of strength and workability. Traditional methods of predicting the compressive strength of concrete often involve extensive laboratory testing, which can be time-consuming and costly. These methods typically require the preparation of concrete samples, curing them under controlled conditions, and conducting compressive strength tests at various ages. While these tests provide accurate results, they are not always feasible for large-scale projects or for situations where rapid decision-making is required. With the advent of advanced computational techniques, Artificial Neural Networks (ANN) have emerged as a powerful tool for modeling complex relationships between input variables and predicting outcomes with high accuracy. ANNs, inspired by the human brain's neural networks, are capable of learning from data and making predictions based on patterns and trends. This capability makes them particularly suitable for applications in civil engineering, where the relationships between concrete mix parameters and compressive strength can be highly nonlinear and complex. With the advent of advanced computational techniques, ANN have emerged as a powerful tool for modeling complex relationships between input variables and predicting outcomes with high accuracy. ANNs, inspired by the human brain's neural networks, are capable of learning from data and making predictions based on patterns and trends. This capability makes them particularly suitable for applications in civil engineering, where the relationships between concrete mix parameters and compressive strength can be highly nonlinear and complex. The findings of this research have significant implications for the construction industry, offering a reliable and efficient method for predicting concrete compressive strength. This can lead to improved safety, cost savings, and more sustainable construction practices. The study also contributes to the growing body of knowledge on the use of artificial intelligence in civil engineering, highlighting the potential of ANN models in addressing complex engineering challenges.

2. LITERATURE REVIEW

Artificial Intelligence (AI) has revolutionized various fields, including civil engineering, by providing advanced tools for predictive modeling. The use of AI, particularly ANN, in predicting the compressive strength of concrete has gained significant attention due to its ability to model complex, nonlinear relationships between input variables and outcomes. This section reviews the existing literature on the application of ANN models in predicting the compressive strength of concrete, with a focus on M20 grade concrete. Several studies have demonstrated the effectiveness of ANN models in predicting the compressive strength of concrete. For instance, Lin and Wu (2021) developed an ANN model using a Back Propagation (BP) network with one hidden layer to predict the compressive strength of concrete based on mix proportioning. Their model achieved high accuracy, indicating the potential of ANN in reducing the number of physical tests required for quality control. Similarly, Poorarbabi et al. (2020) combined ANN with non-destructive testing methods, such as rebound number and ultrasonic pulse velocity tests, to predict the compressive strength of concrete. Their study highlighted the reliability of ANN models in providing accurate predictions, thereby reducing the need for destructive testing methods. In addition to ANN, other machine learning models have been explored for predicting concrete compressive strength. Nikoopayan Tak et al. (2025) compared various machine learning techniques, including gradient boosting, random forest, and k-nearest neighbors, with ANN models. Their findings indicated that while gradient boosting regressor achieved the highest predictive accuracy, ANN models also performed exceptionally well, demonstrating their robustness and reliability. Research focusing specifically on M20 grade concrete has also shown promising results. Charhate et al. (2018) developed ANN models to predict the 7-day and 28-day compressive strength of M20 grade concrete. Their study concluded that ANN models outperformed traditional multiple linear regression models, providing more accurate predictions and highlighting the potential of ANN in optimizing concrete mix designs. Swetha and Rani (2022) investigated the use of ANN models for predicting the compressive strength of M20 grade self-compacting concrete made from agricultural wastes. Their research demonstrated that ANN models could effectively predict the compressive strength, even when using alternative materials, thus promoting sustainable construction practices. The reviewed literature underscores the significant potential of ANN models in predicting the compressive strength of concrete. These models not only enhance the accuracy of predictions but also contribute to more efficient and cost-effective construction practices.

3. METHODOLOGY

The dataset used in this study comprises various parameters that influence the compressive strength of M20 grade concrete. These parameters include cement content kg per cum, water cement ratio, Fine aggregate kg per cum, coarse aggregate kg per cum and admixture kg per cum which were taken as input data set for ANN model. The data was collected from multiple sources, including laboratory experiments and existing literature. Each data point represents a specific mix proportion, and its corresponding compressive strength measured at 28 days which was taken as output dataset. Before training the ANN model, the data underwent several preprocessing steps. All input features were normalized to a common scale to ensure that the model training process is not biased towards any particular dataset. Any missing values in the dataset were addressed using appropriate imputation techniques. The dataset was split into training and testing sets. Various splits were used to evaluate the model's performance, including 50-50, 60-40, 70-30, 80-20, and 90-10 splits. The ANN model used in this study is a Multi-Layer Perceptron (MLP) which consists of input layer, hidden layer and output layer. The model was trained using backpropagation where the weights and biases of the network were initialized randomly. The input data was passed through the network, and the output was computed. The error between the predicted and actual compressive strength values was calculated using Mean Squared Error (MSE) as the loss function. The gradients of the loss with respect to the weights and biases were computed, and the weights were updated using the Adam optimizer. The training process was repeated for a specified number of epochs until the model converged to a minimum loss. The performance of the ANN model was evaluated using Correlation Coefficient (CC), Coefficient of Determination (R^2), Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE). To validate the ANN model, Multi Linear Regression model (MLR) was evaluated, and statistical parameters were compared with ANN model statistics.

4. RESULTS AND DISCUSSION

The performance of the Multi-Layer Perceptron (MLP) model in predicting the compressive strength of M20 grade concrete was evaluated as mentioned in table 1. The CC values close to 1.00 across all splits indicate a strong positive correlation between the predicted and actual compressive strength value while at 10% testing split the value is almost 1. The R^2 values, ranging from 0.91 to 1.00, suggest that the model explains a significant portion of the variance in the compressive strength data. The ANN model effectively captures the complex, nonlinear relationships between these various factors and the compressive strength of concrete. By learning from a diverse dataset that includes different mix designs, curing conditions, and material properties, the model can accurately predict the compressive strength. The high R^2 values indicate that the model accounts for most of the variability in the data, reflecting its ability to generalize well across different scenarios and conditions. The factors that are affecting compressive strength of concrete are mix design proportions, water cement ratio, aggregate properties, curing conditions, admixtures and specimen preparations, curing and testing conditions. The low MAE values, particularly in the full training and different testing splits indicate that the model's predictions are very close to the actual values. While ANN

Table 1: ANN model statistical performance

Strength	Full Training	Testing				
		50%	40%	30%	20%	10%
CC	0.98	0.97	0.97	0.97	0.97	1.00
R^2	0.96	0.93	0.95	0.94	0.95	1.00
MAE (MPa)	0.04	0.09	0.06	0.07	0.03	0.04
MSE (MPa)	0.00	0.01	0.00	0.01	0.00	0.00
RMSE(MPa)	0.05	0.11	0.07	0.10	0.05	0.06

showed low MSE and RMSE values mean that the model can precisely predict the compressive strength based on the mix proportions. MLR model resulted with CC value 0.90 and R^2 0.88 with MAE 4.61 MPa, MSE 33.15 MPa and RMSE 4.76 MPa which is on much higher side as compared with ANN model statistics.

5. CONCLUSION

This research explored the application of Artificial Neural Networks (ANN), specifically a Multi-Layer Perceptron (MLP) model, in predicting the compressive strength of M20 grade concrete. The study demonstrated that the MLP model could accurately predict compressive strength based on various concrete mix parameters, achieving high performance metrics across different training and testing splits. The results indicated that the MLP model achieved a Correlation Coefficient (CC) close to 1.00 and a Coefficient of Determination (R^2) ranging from 0.91 to 1.00, suggesting a strong positive correlation and a significant portion of variance explained by the model. The low Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE) values further confirmed the model's accuracy and reliability as compared with Multi linear regression (MLR) model. The findings of this study have significant implications for the construction industry. Accurate prediction of compressive strength can enhance quality control, optimize material usage, and reduce construction costs. By leveraging the power of ANN models, engineers can make informed decisions, ensuring the safety and durability of concrete structures. Additionally, the use of AI in predicting concrete properties aligns with the industry's move towards more sustainable and efficient construction practices.

In conclusion, the MLP model demonstrates a high level of accuracy and reliability in predicting the compressive strength of M20 grade concrete. This research highlights the potential of ANN models in civil engineering applications and paves the way for further exploration of AI-based solutions in the construction industry. Future research should focus on expanding datasets, incorporating additional datasets , and exploring hybrid models to further improve predictive performance and generalizability.

REFERENCES

Lin, C.-J., & Wu, N.-J. (2021). An ANN Model for Predicting the Compressive Strength of Concrete. Applied Sciences, 11(9), 3798. This study establishes an ANN model using a Back Propagation network to predict the compressive strength of concrete based on mix proportioning

Poorarbabi, A., Ghasemi, M., & Moghaddam, M. A. (2020). Concrete Compressive Strength Prediction Using Neural Networks Based on Non-destructive Tests. Journal of Nondestructive Evaluation, 39, 78. This research combines ANN with non-destructive testing methods to predict the compressive strength of concrete2.

Nikoopayan Tak, M. S., Feng, Y., & Mahgoub, M. (2025). Advanced Machine Learning Techniques for Predicting Concrete Compressive Strength. Infrastructures, 10(2), 26. This study compares various machine learning techniques, including ANN, for predicting concrete compressive strength3.

Charhate, S., Subhedar, M., & Adsul, N. (2018). Prediction of Concrete Properties Using Multiple Linear Regression and Artificial Neural Network. Journal of Soft Computing in Civil Engineering, 2(3), 27-38. This research focuses on predicting the 7-day and 28-day compressive strength of M20 grade concrete using ANN models4.

Swetha, R. R., & Rani, M. S. (2022). Prediction of Compressive Strength Values Using ANN for M20 Grade of Self-Compacting Concrete Made from Agricultural Wastes. NeuroQuantology, 20(19), 1427-1435. This study investigates the use of ANN models for predicting the compressive strength of M20 grade self-compacting concrete made from agricultural wastes5.