Literature Review on Prediction of Compressive Strength of Concrete Using Artificial Neural Network

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Abstract **- The compressive strength of concrete is the mostly used criterion in producing concrete. Compressive strength of concrete is determined by destructive testing of control specimens in a Compression Testing Machine (CTM) but testing for these specimens is a complicated and tedious task. Also, the test specimens are not an exact representation of in-situ concrete. As the test is usually performed after 28 days of curing of concrete at the construction site, it is too late to make improvement if the results does not satisfy the required strength. Therefore, it is highly desirable to predict the strength of concrete before the placement. Application of Artificial Neural Network technique to predict the strength of concrete based on different parameters and characteristics of concrete is reliable and efficient. ANN makes the task easy and provides in-situ strength of concrete in very less time with reasonable accuracy.**

Index Terms **- Artificial Neural Network (ANN), Compressive Strength, Concrete, Prediction**

I.INTRODUCTION

Conventional concrete is a mixture of cement, water, and coarse and fine aggregates. Supplementary components such as chemical and mineral may be added to enhance its properties in fresh or hardened state. The development of tools to find the optimized mix proportion has been the subject of research during the last more than four decades [2]. Strength, in almost all cases, is considered as the most important property of concrete, as it usually indicates the overall quality of concrete [7]. Compressive strength of concrete is generally obtained after a standard curing of 28 days and testing using a Compressive Testing Machine (CTM). Conventional methods of predicting 28-day compressive strength are based on statistical analysis. These analysis have led to the development of many linear and some nonlinear equations to model such problem inaccurately [4].

Considering that concrete is a highly non linear material, modeling its behaviour would be highly difficult. An alternative method to estimate the strength of concrete is the artificial neural network (ANN) approach. ANNs may be trained on the available experimental data describing the behaviour of the material to predict its behaviour from the result of other experiments using that material [7].

ANN is a tool which is suitable for the association of many parameters, through which certain material or strength features, such as the strength of concrete are identified [6]. In recent years Machine learning approach is appealing for artificial intelligence since it is based on the principle of learning from training and experience. Connectionist models, such as neural networks, are well suited for machine learning where connection weights are adjusted to improve the performance of a network [7].

II. LITERATURE REVIEW

A brief review of the past literature carried by different researchers in Prediction of Compressive Strength of Concrete Using Artificial Neural Network is discussed below:

"Predicting the 28 Days Compressive Strength of Concrete Using Artificial Neural Network" Faezehossadat Khademi and Sayed Mohammadmehdi Jamal

Predicting the compressive strength of concrete has always been a difficulty since the concrete is sensitive to its mixture components, methods of mixing, compaction, curing condition, etc. Scientists have proposed different methods for predicting the compressive strength of concrete. Some of these methods have been successful, however, some others

were not suitable enough to predict the compressive strength of concrete. The aim of this study is to evaluate the capability of Artificial Neural Network Model (ANN) in predicting the 28 days compressive strength of concrete. Therefore, considering specific concrete characteristics as input variables, Artificial Neural Network Model is constructed and the compressive strength of concrete is predicted. Results show that ANN is a suitable model to predict the 28 days compressive strength of concrete.[1]

"Prediction of Compressive Strength of Concrete Using Artificial Neural Network and Genetic Programming" Palika Chopra, Rajendra Kumar Sharma and Maneek Kumar

An effort has been made to develop concrete compressive strength prediction models with the help of two emerging data mining techniques, namely, Artificial Neural Networks (ANNs) and Genetic Programming (GP). The data for analysis and model development was collected at 28-, 56-, and 91-day curing periods through experiments conducted in the laboratory under standard controlled conditions. The developed models have also been tested on the in situ concrete data taken from literature. A comparison of the prediction results obtained using both the models is presented and it can be inferred that the ANN model with the training function Levenberg-Marquardt (LM) for the prediction of concrete compressive strength is the best prediction tool. [2]

"Prediction of Compression Strength of Concrete by Using Artificial Neural Network" D.A. Sonawane and R.M. Jadhav

Concrete cubes strength determination tests are usually performed at three days to one year after pouring the concrete. The waiting period required to perform such test may delay the construction progress, decision making and neglecting such test would limit the quality control checks in large construction projects. Therefore, it becomes necessary that the rapid and reliable prediction of concrete strength is essential for pre-design or quality control of construction. Artificial Neural Network (ANN) is used to predict the compressive strength of concrete. Standard back propagation is used to train the networks. Networks are trained and tested at various learning rate and momentum factor and after many trials these were kept constant for this study. However, according to the standard test procedure, the results of a compressive strength test on cement can be known only after 7 or 28 days. To overcome this difficulty, artificial neural network for predicting the 28 days' compressive strength of cement is introduced. The results of artificial neural network are then compared with the available experimental results. The comparison shows the validity of the method. This report investigates the use of artificial neural network in evaluating the compressive strength of concrete. It is observed that artificial neural networks can predict compressive strength of concrete with 91 to 98 % accuracy. [3]

"Application of Artificial Intelligence to Predict Compressive Strength of Concrete from Mix Design Parameters: A Structural Engineering Application" M. A. Faruqi, R. Agarwala, J. Sai and A. Francisco

There are no fixed formulations for mixing concrete constituents to obtain the compressive strength. Concrete mixing is predominantly a qualitative knowledge-based approach subjected to variations. Reliance on such an approach compromises the precision and accuracy of concrete properties, and hence necessitates the development of a reliable mixing formulation. In this paper a Neural Network model for predicting the compressive strength of concrete for different mix-design parameters is developed. A neural network model based on five hidden layers was trained using the results of a series of previously conducted experiments. Each experiment consisted of five parameters and a corresponding compressive strength obtained from 28-days cylinders tests. It was observed that the neural network model performed with satisfactory results in predicting the 28-day compressive strength of concrete. [4]

"Application of artificial neural networks to predict compressive strength of high strength concrete" Seyed Jamalaldin Seyed Hakim, Jamaloddin Noorzaei, M. S. Jaafar, Mohammed Jameel and Mohammad Mohammadhassani

A method to predict 28-day compressive strength of high strength concrete (HSC) by using MFNNs is proposed in this paper. The artificial neural networks (ANN) model is constructed trained and tested using the available data. A total of 368 different data of HSC mix-designs were collected from technical literature. The data used to predict the compressive strength with ANN consisted of eight

input parameters which include cement, water, coarse aggregate, fine aggregate, silica fume, superplasticizer, fly ash and granulated grated blast furnace slag. For the training phase, different combinations of layers, number of neurons, learning rate, momentum and activation functions were considered. The training was terminated when the root mean square error (RMSE) reached or was less than 0.001 and the results were tested with test data set. A total of 30 architectures were studied and the 8-10-6-1 architecture was the best possible architecture. The results show that the relative percentage error (RPE) for the training set was 7.02% and the testing set was 12.64%.The ANNs models give high prediction accuracy, and the research results demonstrate that using ANNs to predict concrete strength is practical and beneficial. [5]

"Application Of Artificial Neural Networks To Determine Concrete Compressive Strength Based On Non-Destructive Tests" Jerzy Hola and Krzysztof Schabowicz

The paper deals with the neural identification of the compressive strength of concrete on the basis of non-destructively determined parameters. Basic information on artificial neural networks and the types of artificial neural networks most suitable for the analysis of experimental results are given. A set of experimental data for the training and testing of neural networks is described. The data set covers a concrete compressive strength ranging from 24 to 105 MPa. The methodology of the neural identification of compressive strength is presented. Results of such identification are reported. The results show that artificial neural networks are highly suitable for assessing the compressive strength of concrete. The neural identification of the compressive strength of concrete has been verified in situ. [6]

"Comparison of Concrete Strength Prediction Techniques with Artificial Neural Network Approach" Meltem Özturan, Birgül, Kutlu and Turan Özturan

Prediction of concrete strength is an important issue in ready-mixed concrete industry, especially, in proportioning new mixtures and for the quality assurance of the concrete produced. In this paper, it is aimed to illustrate that the artificial neural networks can be used for predicting the 28-day strength of low to medium strength concretes. The compositional, fresh concrete and early strength data obtained from different batching plants of a ready-mixed concrete company have been defined in terms of ten independent variables that are grouped in five different system models to which neural network and multiple linear regression models have been applied. The accuracies of prediction by artificial neural network and multiple linear regression models as well as by Abrams' law are compared on the basis of the coefficient of determination. It appears that the best results are obtained by the artificial neural network models using data for fresh concrete and early strength simultaneously. [7]

"Using the Artificial Neural Networks for Predicting Compressive Strength of Normally Concretes" Dr. Ibrahim Farouq Varouqa

In this study Artificial Neural Networks (ANNs) models were developed for predicting the compressive strength, at the age of 28 days, of normally concretes. The experimental results used to construct the models were gathered from laboratory of Isra University - Amman in 2019. Total of 15 experimental design used for modeling ANN models. 80% in the training set, and 10% in the testing set, and 10% in the validation set. To construct the model, three input parameters were used to achieve one output parameter, referred to as the compressive strength of normally concrete. The results obtained in both, the training and testing phases strongly show the potential use of ANN to predict 28 days' compressive strength of normally concretes with average accuracy 90% and correlation coefficient 95%. [8]

"Prediction of Compressive Strength of Concrete using Artificial Neural Network" Wankhade M W and Kambekar A R

Concrete cube strength determination tests are usually performed at three days to one year after pouring the concrete. The waiting period required to perform such test may delay the construction progress, decision making and neglecting such test would limit the quality control checks in large construction projects. Therefore it becomes necessary that the rapid and reliable prediction of concrete strength is essential for pre-design or quality control of construction. The early prediction of concrete strength is essential for estimating the desirable time for concrete form removal, project scheduling, quality control and estimating delay if any. Artificial Neural Network (ANN) is used to predict the compressive strength of concrete. Standard back propagation and Jordan–Elman algorithms are used to train the networks.

Networks are trained and tested at various learning rate and momentum factor and after many trials these were kept constant for this study. Performance of networks were checked with statistical error criteria of correlation coefficient, root mean squared error and mean absolute error. It is observed that artificial neural networks can predict compressive strength of concrete with 91 to 98 % accuracy. [9]

"Prediction of Concrete Compressive Strength by Evolutionary Artificial Neural Networks" Mehdi Nikoo, Farshid Torabian Moghadam and Lukasz Sadowski

Compressive strength of concrete has been predicted using evolutionary artificial neural networks (EANNs) as a combination of artificial neural network (ANN) and evolutionary search procedures, such as genetic algorithms (GA). In this paper for purpose of constructing models samples of cylindrical concrete parts with different characteristics have been used with 173 experimental data patterns. Water-cement ratio, maximum sand size, amount of gravel, cement, 3/4 sand, 3/8 sand, and coefficient of soft sand parameters were considered as inputs; and using the ANN models, the compressive strength of concrete is calculated. Moreover, using GA, the number of layers and nodes and weights are optimized in ANN models. In order to evaluate the accuracy of the model, the optimized ANN model is compared with the multiple linear regression (MLR) model. The results of simulation verify that the recommended ANN model enjoys more flexibility, capability, and accuracy in predicting the compressive strength of concrete. [10]

III. SUMMARY

Based on the above literature review it has been observed that in predicting the 28 days compressive strength of concrete Artificial Neural Network presents good accuracy. Therefore, ANN model can work efficiently for prediction of both experimental and in situ data within reasonable accuracy. ANN is more accurate than the model using regression analysis and conventional methods. It may also provide prefect and precise formulation for many civil engineering applications, although predictive pronouncements are required. This technique of ANN modeling can be a great boon to concrete technologies for decision purposes if there is any suspicion about concrete not having the required strength. It is a portable method and can be used in the field with relative use.

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