Prediction of Compression Strength of Concrete by Using Artificial Neural Network

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Abstract:
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. It is possible to facilitate the modification of the mix proportion if the concrete does not meet the required design stage, which may save time and construction costs. 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 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.
Key word: *concrete, Compression strength, Prediction, ANN*

I Introduction:

An ANN is extensive laterally distributed notification processing system that has certain performance characteristics resembling biological neural network of the human brain. ANN has been establishing as a generalization of mathematical models of human cognition or neural biology. In the brain each neuron is nominally its own self-contained actor and its wire to ultimate or all of the neuron that physically beleaguer in it extremely difficult and somewhat unreliable ways. Inspired by the neuron architecture and operation of the human brain an ANN consist of interconnected computing cells (neurons) linked by weighted connection strength. The topology of interconnection and the rules employed by a neural network are referred to as the architecture (or the model) of the network. Some of these require topologies with total interconnection between all the nodes and others require arrangement in layers with intermodal connections between (but not within) layers. There are many other possibilities. The selection of topology and the rule of operation depend on the application.

a) Objectives of work:

- To study the Artificial Neural Network.
- To check the feasibility of application of artificial neural network in developing the analytical model for structural problems.
- To check the variation of compression test at different percentage of material.
- To develop the analytical model by using ANN.
- To conduct literature survey

b) Advantages:

- The main advantage of using if ANN includes: It can handle large amount of data set; it has ability to implicitly detect complex nonlinear relationship between dependent and independent variables; it has ability to detect all possible interaction between predictor variables.
- ANN is nonlinear model that is easy to use and understand compared to statistical method. Ann is non-parametric model while most of statistical method is parametric model that need higher background of statistic. ANN with back propagation (BP) learning algorithm is widely used in solving various classifications and forecasting problem.
- Mathematical model are typically used to model a system when the system is not so complicated, but when the complexity of a system is increase other method should be used for modelling. Fuzzy theory is typically used when the behaviour of system is the most complicated or the linguistic rules are needed to define the behaviour of system. But in a condition between the above- mention ANN is good modelling which can produce good result.
- Ability to work with incomplete knowledge: After ANN training, the data may produce output even with incomplete information. The loss of performance here depends on the importance of the missing information.

c) Disadvantages:

- Needs lots of data, especially for architecture with many layers. This problem for more ML algorithm, of course, but is especially relevant for ANNs because of the vast number of weights and connection in ANN.

- Determination of proper network structure: There is no specific rule of ANN. Appropriate network structure is achieved through experience and trial and error.
- The duration of network is unknown: the network is reduced to certain value of the error on the sample means that training has been completed. This value does not give us optimum results.
- Hardware dependence: ANN required processor with parallel processing power, in accordance with their structure. For this reason, the realization of the equipment is dependent.

d) Development of ANN is based on the following rules:

- Signals are passed between nodes through connection links.
- Every network link has its join weight that can be represents its connection strength.
- Each node typically applies a nonlinear transformation called an activation function to its net input to determine its output signal.

Iiliterature Review

P.Muthupriya,K.Subramanian ,B.G.vishnuram have reported Neural networks have recently been widely used to model some of the human activities in many areas of civil engineering applications. In the present paper, artificial neural networks (ANN) for predicting compressive strength of cubes and durability of concrete containing metakaolin with fly ash and silica fume with fly ash are developed at the age of 3, 7, 28, 56 and 90 days. For building these models, training and testing using the available experimental results for 140 specimens produced with 7 different mixture proportions are used. The data used in the multi-layer feed forward neural networks models are designed in a format of eight input parameters covering the age of specimen, cement, metakaolin (MK), fly ash (FA), water, sand, aggregate and super plasticizer and in another set of specimen which contain SF instead of MK. According to these input parameters, in the multi-layer feed forward neural networks models are used to predict the compressive strength and durability values of concrete. It shown that neural networks have high potential for predicting the compressive strength and durability values of the concretes containing metakaolin, silica fume and fly ash.As a result, compressive strength values of concretes containing metakaolin and silica fume can be predicted in the multilayer feed forward artificial neural networks models without attempting any experiments in a quite short period of time with tiny error rates.

Vahid.K.Alilou, Mohammad.Teshnehlab have investigated artificial neural networks are known as intelligent methods for modeling of behavior of physical phenomena. In this paper, performance of an artificial neural network has been established for foresight of compressive strength of concrete. A MISO (Multi Input Single Output) adaptive system has been introduced which can model the proposed phenomenon. The data has been compile by experimenting on concrete samples and then the neural network has been trained using these data. From among 432 specimens, 300 data sample has been used for train, 66 data sample for validation and 66 data sample for the final test of the network. The 3-day strength parameter of concrete in the introduced structure also has been used as an important index for predicting the 28-day strength of the concrete. The simulations in this paper are based on real data obtained from concrete samples which indicate the validity of the proposed tool.

Palika Chopra, RajendrakumarSharma and ManeekKumar have studied an artificial neural network (ANN) model is proposed to predict the compressive strength of concrete. For developing the ANN model the data bank on concrete compressive strength has been taken from the experiments conducted in the laboratory under standard conditions. The data set is of two types; in one dataset 15% cement is replaced with fly ash and the other one is without any replacement. It is found that Levenberg–Marquardt (LM) with tan-sigmoid activation function is best for the prediction of compressive strength of concrete. In-situ concrete compressive strength data, based on varying mix proportions, have been taken from one of the research paper present in literature for the validation of the model. It is also recommended that ANN model with the training function, Levenberg–Marquardt (LM) for the prediction of compressive strength of concrete is one of the best possible tools for the purpose.

III Material And Work:

A)Preliminary testing on cement is done to check the quality of cement and these parameters are used for making the model using artificial neural network.

1) Cement: Cement used in the investigation was 53 Grade ordinary Portland cement confirming to Indian Standard (IS): 12269.The physical properties of cement are as given in table no 1

Table no 1: physical properties of cement

Properties	Results
Specific gravity	3.1
Standard consistency	35%
Initial setting time	56min
Final setting time	285min
Fineness	2%

2) Fine aggregate: The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In

our region fine aggregate, it conforms to IS 383 1970 comes under zone II. The physical properties of fine aggregate are given in table 2

Table no 2: physical properties of fine aggregate

Properties	Result
Type	Air cooled
Specific gravity	2.674
Water absorption	1.048%

3) Coarse aggregate: The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work.

B)How to Work? A neural network is characterized by its architecture that represents the pattern of connection between nodes, its method of determining the connection weights, and the activation function. A typical ANN consists of a number of nodes that are organized according to a particular arrangement.

One way of classifying neural networks is by the number of layers: single (Hopfield nets); bilayer (Carpenter/Gross berg adaptive resonance networks); and multilayer (most back propagation networks). ANN can also be categorized based on the direction of information flow and processing. In a feed forward network organised in layers, starting from a first input layer and ending at the final output layer.

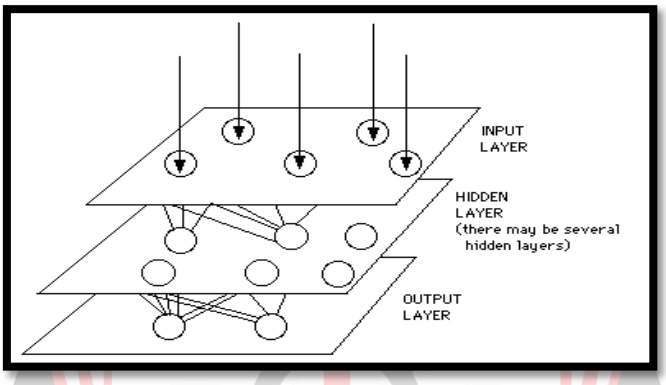

Figure 1: concept of annmodelling

In most networks, the input (first) layer receives the input variables for the problem at hand. This consists of all quantities that can influence the output. The input layer is thus, transparent and is a means of providing information to the network. The last or output layer consists of values predicted by the network and thus, represents model output. The number of hidden layers and the number of nodes in each hidden layer are usually determined by a trial-and-error procedure. The nodes within neighbouring layers of the network are fully connected by links. A synaptic weight is assigned to each link to represent the relative connection strength of two nodes at both ends in predicting the input-output relationship.

These kinds of ANN can be used in a wide variety of problems, such as storing and recalling data, classifying patterns, performing general mapping from input pattern (space) to output pattern (space), grouping similar patterns, or finding solutions to constrained optimization problems. In this figure, X is a system input vector composed of a number of causal variables that influence system behaviour, and Y is the system output vector composed of a number of resulting variables that represent the system behaviour.

1)Mathematical aspects:

A schematic diagram of a typical j^{th} node is displayed in Fig. 2 the inputs to such a node may come from system causal variables or outputs of other nodes, depending on the layer that the node is located in. These inputs form an input vector X = (x1. . . xi, . .xn). The sequence of weights leading to the node form a weight vector Wj = (w1j. . . wij, . . . , wnj), where wij represents the connection weight from the i^{th} node in the preceding layer to this node.

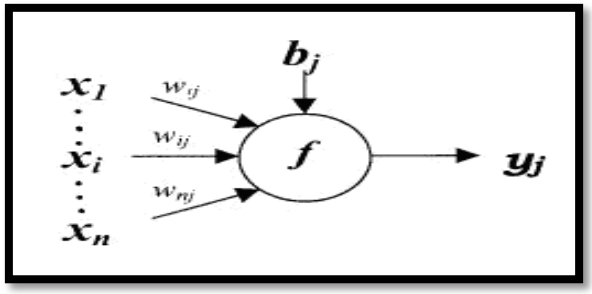

Figure 2: input data

The output of node j, yj, is achieved by figure out the value of function f with respect to the inner product of vector X and Wj minus bj, where bj is the threshold value, also called the bias, associated with this node. In ANN parlance, the bias bj of the node must be exceeded before it can be activated. The following equation defines the operation:

$$yj = f(X, Wj, -bj) \qquad \ldots\ldots(a)$$

The function f is called an activation function. Its functional form determines the response of a node to the total input signal it receives. The most commonly used form of f(t) in is the sigmoid function, given as

$$f(t) = 1/(1+e^{t}) \qquad \text{.....(b)}$$

2) The sigmoid function:

The sigmoid function is a bounded, monotonic, non-decreasing function that provides a graded, nonlinear response. This function enables a network to map any nonlinear process. The popularity of the sigmoid function is partially attributed to the simplicity of its derivative that will be used during the training process. Some researchers also employ the bipolar sigmoid and hyperbolic tangent as activation functions both of which are transformed from the sigmoid function. A number of such nodes are organized to form an Artificial Neural Network.

3) Feed forward network:

In a feed forward neural network, the artificial neurons are arranged in layers, and all the neurons in each layer have connections to all the neurons in the next layer. However, there is no connection between neurons of the same layer or the neurons which are not in successive layers. The feed forward network consists of one input layer, one or two hidden layers and one output layer of neurons. Associated with each connection between these artificial neurons, a weight value is defined to represent the connection weight. Figure shows a typical architecture of a multilayer feed forward neural network with an input layer, two hidden layer, and an output layer. The input layer receives input information and passes it onto the neurons of the hidden layer(s), which in turn pass the information to the output layer. The output from the output layer is the prediction of the net for the corresponding input supplied at the input nodes. There is no reliable method for deciding the number of neural units required for a particular problem. This is decided based on experience and a few trials are required to determine the best configuration of the network. In this study, the multilayer feed forward types of ANN, as shown in figure is considered. In a feed forward network, the inputs and output variables are normalized within the range of 0–1.

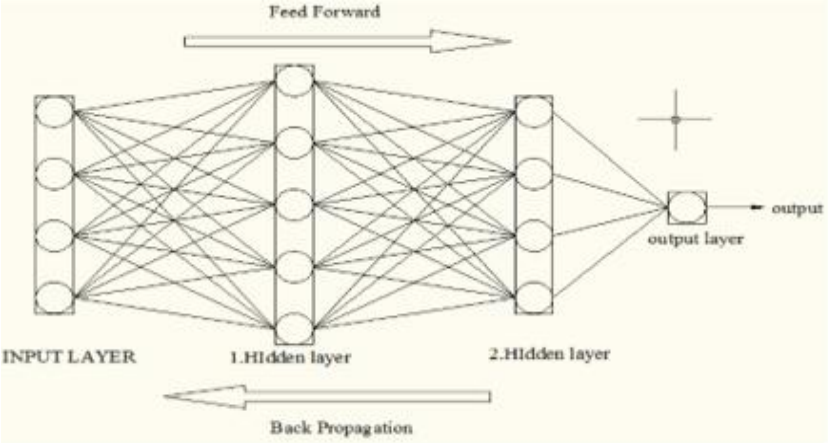

Figure 3: typical architecture of multilayer feed forward neural network

4)Back propagation algorithm:

Back propagation algorithm, as one of the biggest well-known training algorithms for the multilayer perception, is a gradient descent technique to minimize the error for a particular training pattern in which it adjusts the weights by a small amount at a time. The network error is passed backwards from the output layer to the input layer, and the weights are adjusted based on some learning strategies so as to reduce the network error to an Table acceptable level.

$$Er = \tfrac{1}{2} \sum (t_j - o_j)$$

Here tj is the output desired at neuron j and oj is the output predicted at neuron j. As presented in Eqs. (1) the output oj is a function of synaptic strength and outputs of the previous layer. The learning consists of changing the weights in order to minimize this error function in a gradient descent technique. In the back propagation phase, the error between the network output and the desired output values is calculated using the so-called generalized delta rule and weights between neurons are updated from the output layer to the input layer

$$W_{ij}(m+1) = w_{ij}(m) + \eta(\delta_j o_j) + \beta w_{ij}(t)$$

Here, δj is the error signal at a neuron j, oj is the output of neuron j, m is the number of iteration, and g, b is called learning rate and momentum rate, respectively.

C)Methods of ANN modelling: The manner in which the neurons of a neural network are structured is intimately linked with the learning algorithm used to train the network.

In general, there are four different classes of neural network architectures.

1. Single layer feed forward networks.
2. Multi-layer feed forward networks.
3. Recurrent networks.
4. Lattice structure.

1)**Single layer feed forward network:**A single layered neural network is a network of neurons organized in the form of layers. In the simple form of a layered network, we just have an input layer of the source nodes that projects into an output layer of neurons, but not vice versa.

2) **Multilayer feed forward layer:**The second class of a feed forward neural network distinguishes itself from the single layer network by the presence of one or more hidden layers; the network is enabled to extract higher order statistics. A feed forward network with source nodes as 'p' neurons in input layer, 'h1 'hidden nodes in the first hidden layer, 'h2'neurons in the second hidden layer, and 'q' neurons in the output layer, is referred to as p-hl-h2-q network.

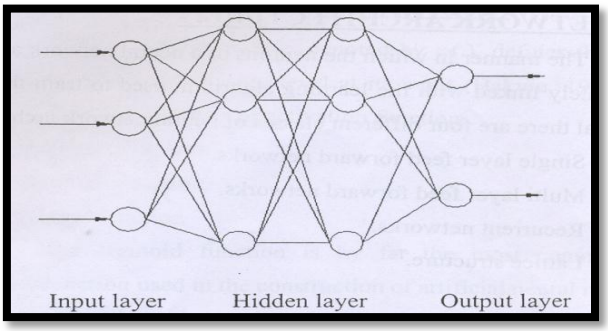

Figure 4: multilayer feed forward network

3) Recurrent networks: A recurrent neural network distinguishes itself from a feed forward neural network in that it has at least one feedback loop. For example, a recurrent network may consist of a single layer of neurons with each neuron feeding its output back to the inputs of all the other neurons.

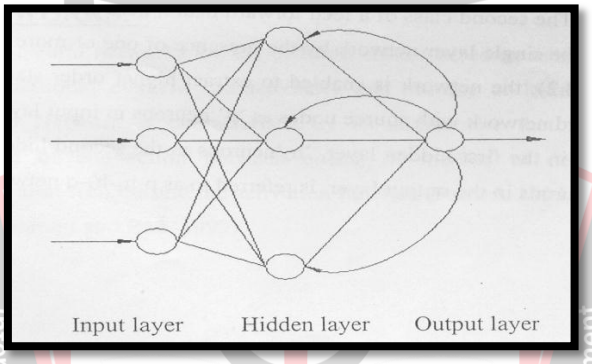

Figure 5: recurrent network

4) Lattice Structures: A lattice consists of a one-dimensional, two-dimensional or higher dimensional array of neurons with a corresponding set of source nodes that supplies the input signals to the array. A lattice network is really feed forward network Withoutput neurons arranged in rows and columns.

IV Result And Discussion:

The first step in the ANN modelling is to distribute the available results into groups: -

a. One group of result is used for the training of the network.
b. The second group is used for the testing purpose that is for the validation purpose.
c. The third group of readings is used as input in the form of the hidden layer.

For the distribution purpose from the total readings available 50% that is half of the total readings that are available is taken for the training purpose. The remaining readings are taken for the testing (Validation) purpose. Compressive strength at the end of 7 days is considered as input data. Table 3 shows input data.

Table 3: input value

Sr.no.	Grade of concrete	% of replacement of cooper slag	Strength of 7 days	Strength of 28 days
1	M 40	0%	26.45	40.70
2	M 40	10%	27.2675	41.95
3	M 40	20%	27.495	42.30
4	M 40	30%	27.69	42.6
5	M 40	40%	24.9305	42.97
6	M 40	50%	24.9145	38.33
7	M 40	60%	22.386	34.44
8	M 40	75%	20.9365	32.21
9	M 40	90%	18.993	29.22
10	M 40	100%	17.979	27.66

After the division of the data, next step is to normalize all the given values. For this purpose, various normalization functions are used. The normalization function used in this case is the Rajurkar's function which is given as: -

Normalized value = $0.1 + 0.8*(X_i/X_{imax})$

Where, X_i = the value of strength of that particular day in N/mm^2

X_{imax} = the maximum value of strength of that particular day in N/mm^2

After the normalization, the variables are created in the Matlab software

Table 4: comparison between experimental results and ann model results

Sr.no.	% of replacement of copper slag	Strength at 28 days	Strength obtained by ANN model	Correlation factor
1	0%	0.85774	0.8722	0.983646
2	10%	0.88101	0.88056	1.000
3	20%	0.88753	0.8821	1.00615
4	30%	0.89311	0.88322	1.0111
5	40%	0.9	0.88439	1.017
6	50%	0.81361	0.8335	0.976136
7	60%	0.74119	0.71996	1.029
8	75%	0.69967	0.68658	1.01906
9	90%	0.64401	0.67052	0.9604635
10	100%	0.61496	0.6674	0.921426

V Conclusion:

Compressive strength of concrete is the significant properties of concrete. But to find out these strengths, 28 days waiting period is required which consumes more time and may delay the projects. To avoid this problem, models are prepared to find the strengths by approach of Artificial Neural Network. Following conclusions are made from the developed:

1. As the result of compressive test is obtained concrete strength has found to be maximum at 40% replacement of copper slag.
2. Hence till 40% fine aggregate can be successfully replaced by copper slag and thus allows the safe.
3. ANN modeling gives more accurate results as compared to statistical method.
4. To get more accurate results, ANN requires huge data.
5. From the table no.4 we can specify experimental result of 28 days of compression strengthand ANN model result of 28 days of compression strength.
6. The results of models developed by ANN were validated with the experimental results and the correlation factors were developed which indicate the moderate fitting of experimental results with that of models.
7. Artificial neural networks are one typical example of a modern interdisciplinary subject that helps solving various different engineering problems which could not be solved by the traditional modeling and statistical methods.
8. From studies conducted in over two decades, there is a strong interest in using neural networks in solving problems in civil engineering, and demonstrated their usefulness for problems in building work
9. Neural networks do not replace conventional methods of calculation, but are complementary.
10. This study shows the feasibility of using the artificial neural network in replacement of copper slag for predicting compressive strength of concrete using material content of mixes, m40grade of concrete.
11. In constructing, early determination of compressive strength value is very important. Normally, determination of compressive strength takes 28 days but using the proposed model, the compressive strength values can be predicted in short time.

VI Acknowledgment:

It is an opportunity of immense pleasure for us to present the paper “prediction of compression strength of concrete by using artificial neural network” the credit goes to our project guide prof. R.M.Jadhav and H.O.D. of civil engineering prof. A.D. Hamigi. And I also like to thankful to our principal Dr. S.B. Bagal for the support and encouragement.

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