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REVIEW ARTICLE

PREDICTION OF CONCRETE MIX DESIGN USING DATA MINING TECHNIQUES - A REVIEW

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Abstract

Concrete mix proportioning is one of the critical process and it involves a lot of precautionary measures to arrive at the right proportions of ingredients like cement, aggregate, water, and admixtures. Even though there are technical specifications that are managed mix proportionating, the procedure is not totally in the realm of science. Due to imprecise codal provisions, impreciseness, and fuzziness involved in the various stages of mix proportioning. This paper reviews the various data mining and machine learning techniques developed by the researchers for making concrete mix design for various codal provisions more realistic and scientific.

Introduction:-

Concrete is one of the major construction materials being used worldwide. It is typically a mixture of cement, fine aggregate, coarse aggregate, water, chemical, and mineral admixture. Concrete mix design, also known as mix proportioning is the process of determining the required suitable ingredients and their proportions. The main objective of concrete mix design is to attain the required intended properties both in a fresh state like slump value etc. and hardened states like strength and durability.

In practice, it is very difficult to get desired strength and properties of concrete mix at the site. This may be due to unreliable performance of constituents, quality check at site, and estimations of materials in codal provisions [1-9]. Hence the process of concrete mix proportion is an approximate one. Therefore it is necessary to arrive at the process of mix proportioning in such a way that, it should be more regular and technically sound.

The neural networks are one of the power tools that are having the competence of understanding non-linear functions. The trained network has the capability of recognizing the examples of the outside set also. Therefore the fuzzy neuron networks are a worthy technique to develop suitable concrete mix proportioning.

Scope of Review:-

This review gives details on the different procedures applied in the design of concrete mix namely formulation, model generation, and solving the mix proportion using various optimizing techniques. In addition, the present review delivers a critical outline and argument of research and advancement needs that are essential to developments in the area of concrete mix proportioning optimization.

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Data Mining Models for Concrete Mix Design:-

In this section, the literature review has been made on various existing data mining models for Concrete Mix Design.

To improve the concrete mix design by using more components such as cement, gravel, sand, water, coal ash, and blast furnace slag with the approach of Artificial Neural Network (ANN) with genetic algorithm. The strategy is to find a solution and prove the proposed model by using the following steps as data gathering, experiment, evaluation, and validation. The ANN the RMSE value obtained is 6.084. On further experimentation, the lowest value obtained is 4.815 based on neurons. The ANN with the genetic algorithm produced an RMSE value between 1.389871 to 2.82618. The computational model that has been designed in the study has the components such as cement, sand, gravel, water, coal ash (fly ash), and blast furnace slag using ANN which is optimized by a Genetic Algorithm. This system proved that the proposed system has a lower error than the predicted model of ANN [10].

To reduce the time required to design concrete mix and the number of trails required to evaluate the mix the ANN is used. The learning processes use the previously obtained experimental mix data to predict the mix proportions. To predict the concrete mix proportions the neural network is trained based on the feed-forward back propagation technique. The outcomes obtained are very close to predicted results. The ANN model shows the maximum error of 0.7281% in predicting the mix proportions and it can be applied only for M25 grade proportions [11].

When the solution algorithm is not known the soft computing tools neural network and fuzzy logic can be used for the problems. Feature such as computer-aided soft computing tools can be used to get the perfect relationship between various design parameters of concrete mix and reduce the requirement of a large number of trails. Based on the environmental engineering method a concrete mix designed with five-layer. In estimating the design requirements of concrete the results of ANN has strong potential. The ANN helps in the selection of materials and the use of proper construction methods. ANN can provide reliable advice to the user in an ambiguous situation [12].

To correctly proportionate the ingredients in concrete to achieve the strength the ANN is used. The ANN is very helpful in saving a lot of time cost of materials as well as labor. To predict the properties of compressive strength for the given data set the trained model is used. ANN gives higher accuracy and can predict concrete mix for desired strength. A typical neural network and neural network block diagram for concrete mix design are shown in Figure 1 and Figure 2 respectively [13].

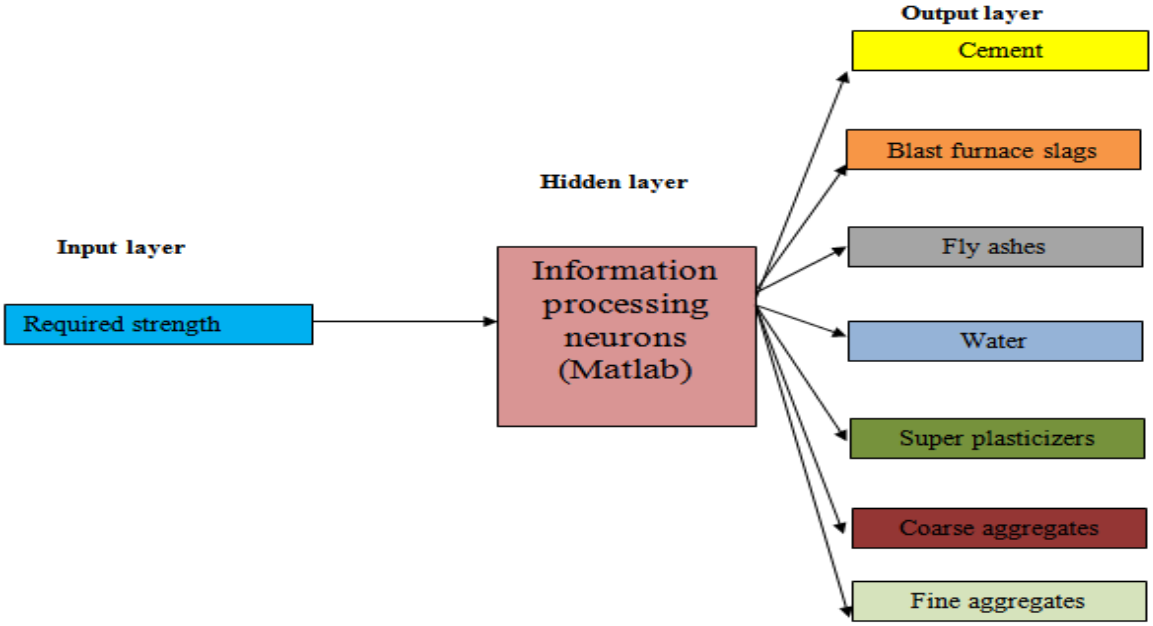

Fig. 1:- A typical neural network of concrete mix proportioning [13].

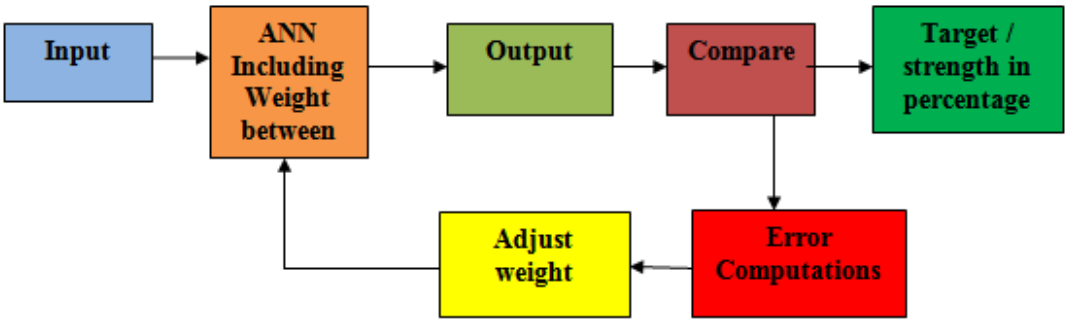

Fig. 2:- A typical neural network block diagram of concrete mix design [13].

To reduce the time required and irregularity in proportion the optimized quantitative model for proportioning concrete mixtures based on cement content, water-cement ratio according to preferred recycled brick aggregate concrete compressive strength is proposed. The method used is a multi-layer backpropagation network and it generally consists of layers with neurons, an input layer, an output layer, and one or more hidden layers. With adequate precision, the proposed network models can be used to predict concrete compressive strength [14].

To make concrete cost-effective and durable, fine and coarse aggregates must give the cement and water mixture. Having the past knowledge of the cement mixture constituents and hence making general predictions of the composition does not aid in guaranteeing the building structure its strength over time. The commonly used ANN model is that of backpropagation. The input weights are fed into the neural network layers and combined with a bias with target a certain output value. If the error is large the reweighting is performed using sigmoid, linear, or Gaussian functions. Once the error is generated less than ~0.5, the training model can be used for a real-time dataset sample. A typical architecture of ANN used to predict the slump of concrete is shown in Figure 3 [15].

Over time engineers and constructors have learned that incrementing the density of constituent materials used in making the cement concrete mixture yields many benefits in long term, both to man and the environment. Mainly a fuzzy logic system combined with Gaussian member functions is employed to deal with the non-linearity and continuous input functions or input curves. The various components of the fuzzy system are the strength of compression and water to cement proportion that enables us to design ideal graphs to be understood and analysed thoroughly for future structures. The output of the combined effect of different parameters is shown in Figure 4 [16].

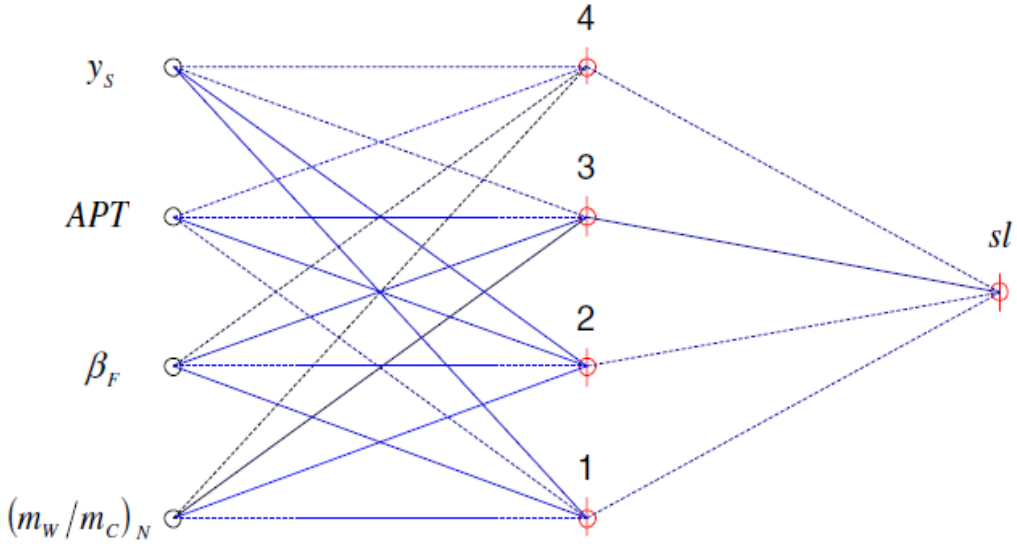

Fig. 3:- A typical architecture of ANN used to predict the slump of concrete [15].

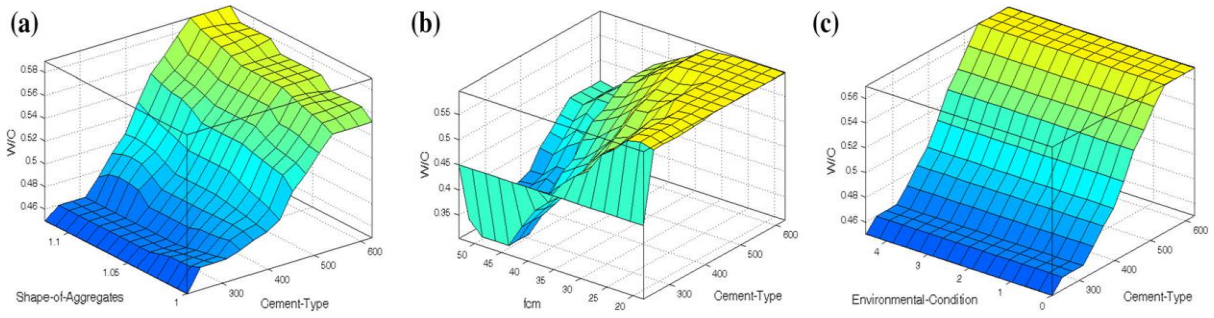

Fig. 4:- Output layers of WCRFS [16].

Precise predictions of the proportions of concrete mix proportions cannot be fully ensured due to changing properties of the constituent materials involved over time and their decreasing tolerance properties amidst the testing conditions of the environment. The design of the neural network consists of five layers that are passed through Gaussian functions and the experiment is carried out over a 28 day plan to test the changes in the ratio of cement to water.

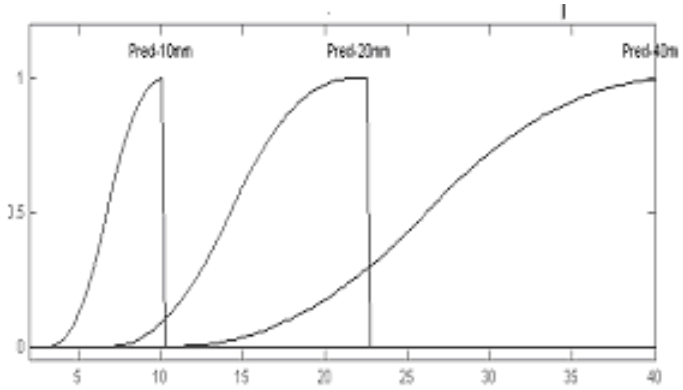

Fig. 5:- Fuzzy layer for the size of the aggregates [17].

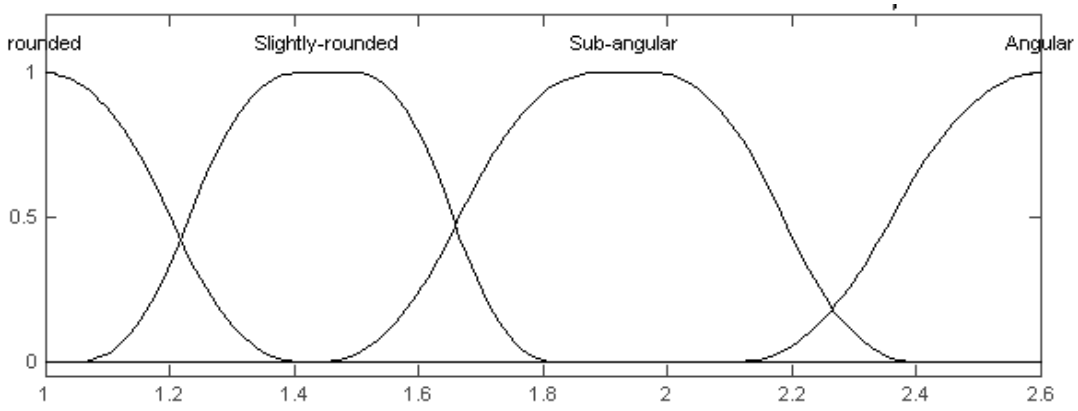

Fig. 6:- Fuzzy layer for the shape of the aggregates [17].

The size and shape of the aggregate layers used become crucial in the success of this training model. Typical fuzzy layers of parameters size and shape of the aggregates are shown in Figure 5 and 6 respectively [17].

The fuzzy logic system is one of the most popular techniques to predict and analyze uncertainty in a graphical approach. This method is hence applied for preparing the accurately quantified concrete mix. The role of the cement is to provide binding amidst the fine and coarse aggregates ensuring that the voids are kept to a bare minimum. As the ingredients and parameters are input to the fuzzy system, the various conditional rules of the fuzzy logic are followed to grant us a permissible belief in the proportions of the cement mix [18].

The desired concrete mix mainly infuses the fine and coarse aggregates in approximately the right proportions with the water and cement. This process is a trial and error method usually it takes into account the previous experience of the masons. To obtain a satisfactory mix various adjustments are done to the estimated quantities in the trial mix. The ingredients and quantitatively fed as weights into the neural network and the desired output is obtained after a thorough training of the input data set and validation of the test data set.

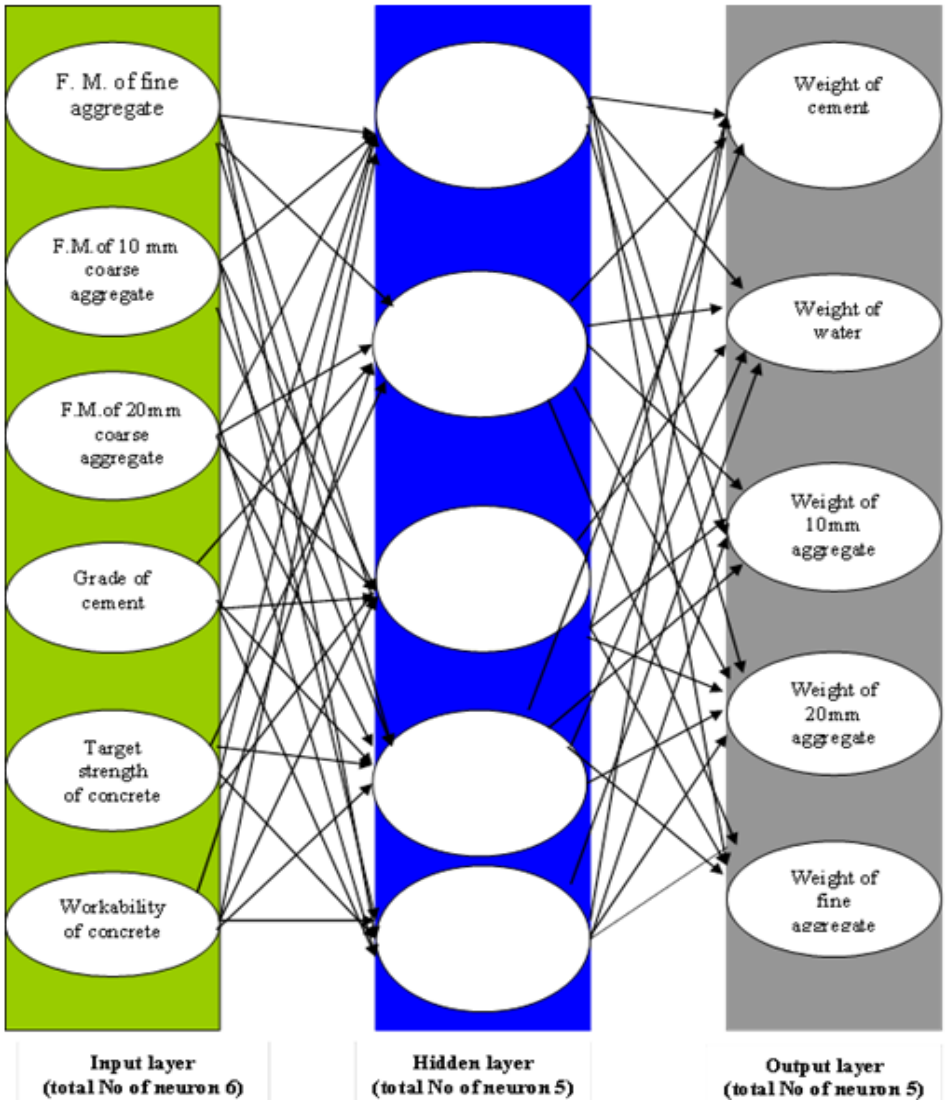

Fig. 7:- Configuration of ANN [19].

The comparisons were done and close agreement was found between the output of the neural network and the dataset fed initially. The configuration of ANN is shown in Figure 7 [19].

The performance of the models was evaluated based on their predictive accuracy, error rate, and time taken to build the model. This paper discussed the classifiers namely PLS-LDA, MLP, and RND algorithms, and found that MLP and Rnd have a minimum difference inaccuracy rate. Concerning error rate and time Rnd tree outperforms MLP,the result with the data set suggests that the tree-based modeling approach can effectively be used in predicting the compressive strength of high-performance concrete [20].

The two-stage fuzzy model can be effectively used for early strength prediction of concrete. The water-cement ratio is considered as the first stage and the water-cement ratio and aggregate-cement ratio were considered as the second stage. For generalized Abram's law is considered as the basic model. The results of defuzzification techniques are

excellent mainly with centroid and bisector methods. For different types of cement and aggregate types, the sensitivity of the model should be explored [21].

The optimization of high-volume fly ash concrete mixes can be done using elitism-based genetic algorithm (GA) models. By using GA models the number of trail samples, with intended properties can be reduced in the field. To start the trail mix for a new batch of high-performance concrete. The errors are not large in the GA model for usage of superplasticizers and fine aggregates since it shows a low standard deviation for all grades of concrete considered [22].

ANN model can be used as a very suitable model to solve concrete mix proportion problems. The ANN model can predict the strength of concrete with fewer minimal errors. The model validated and outputs predicted are fairly accurate in a range of 90-95%. To obtain a very appropriate mix of design proportions at a reasonable cost and less time the application of artificial intelligence can be used [23].

To save time, reduce wastage of materials during trail mix and overall design cost one has to go for the usage of ANN Artificial intelligence. The study was conducted on strength of concrete at different curing ages like 7, 14, and 28 days. The results show a marginal difference between predicted and actual values and this difference can be accepted as mix design is approximate. From the client (engineer) point of view, the model can be declared as an efficient model since it provides inherent fuzziness in the design. Overall the ANN model tool could be one of the effective techniques in the area of cement and concrete production [24].

The usage of machine learning concepts in a concrete mix design and other construction activities could be one of the effective techniques. The optimal ANN architecture is used for the study with a wide database of concrete mix design results. The model has fifteen equations and fourteen auxiliary variables in the initial conversion. Finally, one general equation for the calculation of compressive strength is obtained and this equation is used as a quick tool for concrete mix proportion check. The proposed method allows the checking of ingredients of concrete-like cement, water, both fine and coarse aggregate, for attaining the desired strength [25].

The proposed ANFIS model contains four models like model-1 for approximating the measure of water, model-2 for approximation of the value of cement, model-3 for calculation of the value of coarse aggregate, and model-4 for calculation of fine aggregate. The ANFIS model is trained using American Concrete Institute (ACI) concrete mix design code provisions. The final results of the ANFIS model in comparison to (ACI) results have the following average errors: average error of Water, Cement, C.A., and F.A. are in the orders of 9.5%, 27.6%, 96.5%, and 49% respectively [26].

Conclusion:-

This paper summarised feasibility studies of fuzzy neuro models application for examining non–linear relations between the various parameters involved in the concrete mix design. Always the accuracy of any model depends on several trained data sets and their wide variations. It has been concluded that the Artificial Neural Network technique provides better efficiency in making the concrete mix design. Further, intended to develop a suitable outperforming fuzzy neuro model for concrete mix design to a greater extent, along with the development of models which suit the maximum requirements and validation will be done for various types of concrete mixes.

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