Strength Prediction of Geopolymer Concrete using FUZZY

A. Siva Krishna, V. Ranga Rao

Abstract:--- Concrete being versatile material is widely used in almost all Civil engineering works. Mostly cement is used as the binder whose production is non-eco- friendly and resource consuming. Concrete varieties like geopolymer which does not involve cement usage (or) using less cement are slowly replacing conventional cement-based concrete. The strength and durability of geopolymer concrete depends on the concentration of geopolymer concrete is an upcoming area, this work involves such prediction to propose strength variation with reference to molar concentration by using FUZZY logic. Results show that predicting strength is possible by molar concentration data of the binder used.

Index Terms: FUZZY, Strength prediction, Molar concentration, Geo polymer concrete.

I. INTRODUCTION

Geopolymer is a well known cementitious material that is similar to the ordinary Portland Cement (OPC), and it is used as an alternative of OPC. Geopolymer cement is a special binding material which is a similar function that performs as OPC [1]. However, industrial waste can be utilized as the source materials for producing the Geopolymer cement, it is manufactured from Aluminum and silicon where as for preparation of OPC, calcium and silicon materials are used [2,23]. In the same manner to OPC, Geopolymer concrete is also the composite material which is a result obtained from the addition of Geopolymer cement to the aggregates. Nowadays the studies and investigations on Geopolymer material are widely increasing due to the conversion of the waste into the sustainability material as it becomes the eco-friendly material [4]. The production of normal cement or OPC leads to the production of 600Kg of carbon dioxide per metric ton of OPC.

It can be twice the normal carbon di oxide based on the manufacturing efficiency and the percentage of clinker [6]. According to a study done in Australia, the manufacturing of 1 metric ton of geo polymeric cement results in the emissions of carbon dioxides with a wide range between 271-425 kg. The geopolymers have many advantages when compared to the OPC in terms of strength, durability, temperature resistance and acid resistance [3]. Geo polymer concrete can be effectively utilized in the construction of pavements and also in the construction of retaining walls etc. In Australia, an aircraft pavement is constructed mainly by using the geopolymer concrete in the year of 2014 [5]. The major benefit of using geopolymer concrete lies in its ability of utilizing the waste materials as raw materials for concrete preparation [7].

Coal power plants produce fly ash as a byproduct having low calcium content which is termed to be class F fly ash. In general, it is an acidic material which contains highly reactive acidic oxides like Al_2O_3 and SiO_2, providing a very potential to form alumina silicate gel as geopolymers in an alkaline setting [9]. Due to the huge benefits of usage of Geopolymers, the studies are being gone on continuously where the conclusion will be decided when the experimental work will be completed. It consumes a large amount of time, money and material. There were many techniques employed for the prediction of the data by researchers where it becomes a huge Task for them to choose the best one [8].

To conquer these issues computational tools like Artificial Neural Network (ANN), Adaptive Neuro-fuzzy Interference Systems (ANFIS) and Genetic Programming (GP) have been effectively utilized to a wide extent of civil engineering issues. So far their application in the geopolymers field is extremely less as this is one of the best achieved material in construction and there are only few earlier works [10]. In the past work, compressive strength and tensile strength of geopolymers with various alumina silicate sources was displayed by utilizing ANN [11]. It was examined that ANN can foresee the compressive strength and tensile strength of geopolymers with precision. The current work deals with ANFIS which has been utilized to anticipate the compressive strength of concrete prepared busing geopolymers. Fuzzy sets were utilized properly in developing a linguistic model consisting of if-then principles.

ANFIS integrates the human- type thinking approach of fuzzy systems. Besides the capacity to petition for interpretable IF-THEN principles, being general approximates is the fundamental quality of ANFIS approximations [12]. To build the ANFIS display in the present work, percentage of concrete and the H_2O/NaOH molar proportion was considered as autonomous information parameters and the strength characteristics of researched geopolymers as an independent target esteem [14]. The test values were isolated into 80% preparing and 20% testing sets and demonstrated by the proposed ANFIS model which was built utilizing a sum of 9 rules

II. MATERIALS

A. Fly ash

Fly ash is also termed as pulverized fuel ash. It is the product of coal combustion product driven out of coal-fired boilers together with flue gases [16]. Fly ash includes Silicon dioxide (SIO_2), Calcium oxide (CaO) and Aluminum oxide (Al_2O_3) in a substantial amount [15]. If fly ash is

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A. Siva Krishna, Department of Civil Engineering, S R Engineering College, Warangal, India. And research Scholar, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Guntur, India.

V. Ranga Rao, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Guntur, India.

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released in the atmosphere it affects the environment, instead, it is recycled, and also it can be used as pozzolana to manufacture hydraulic cement and also as a replacement for Portland cement in concrete preparation.

B. Silica Sand

Silica sand is the one, which is a most commonly used sand, which is made either by crushing the sand stones or from naturally occurring river bed locations and beaches etc. [17]. Due to its great abundance and less cost, it is most common material. For industrial purposes, pure sand deposits containing 95% of silica are required. Very often it requires more purity may be needed.

C. Coarse Aggregate

Coarse aggregate is the portion of concrete which are made from crushing huge stones in different sizes.

III. METHODOLOGY

A. ANFIS

Fuzzy set hypothesis was created by Lotfi Zadeh in 1965 to manage the inexactness and vulnerability that's often gift within the universe applications [22]. In 1974 Mamdani, by applying Zadeh's speculations of linguistic approach and fuzzy reasoning, effectively used the 'IF-THEN' rule on the programmed operating management of the steam generator. It wants simply to line a simple dominant technique captivated with engineering background. So it's particularly useful in sophisticated structural systems. Mathematical logic has been making since 1965 and seems to be best in application

In this work, the created fuzzy logic based model was connected to foresee the compressive strength and split tensile strength, information acquired from trial work. The information and yield factors for the fuzzy logic model were isolated [19]. The fuzzy logic model has one info parameter (molarity proportion) and the yield parameter is (compressive strength). Inputs (molarity ratio) are fuzzified. Participation functions for information and yield parameters utilized for fuzzy demonstration are given in figures. The decision for enrollment capacities depends on the encounters picked up, and their base values are chosen with the goal that they are focused on sensitive regions [21]. The fuzzy principles were composed to anticipate compressive strength.

The basic architecture of the ANFIS network consisting of one input variables is shown in Figure 1 and the mechanism of the reasoning illustrates as follows.

Rule 1: IF x is A1 and y is B1 THEN f1+p1+q1+r1

Here Figure 2, 3, 4 shows the Membership functions for output parameters, Input and output model segregation and Surface view of the data.

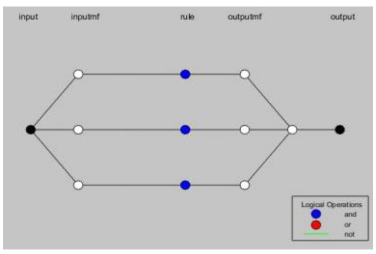

Figure 1: ANFIS model structure

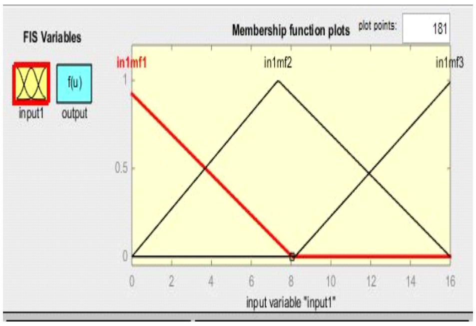

Figure 2: Membership functions for output parameters

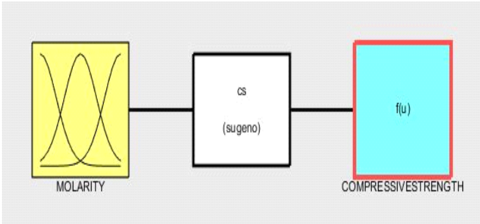

Figure 3: Input and output model segregation.

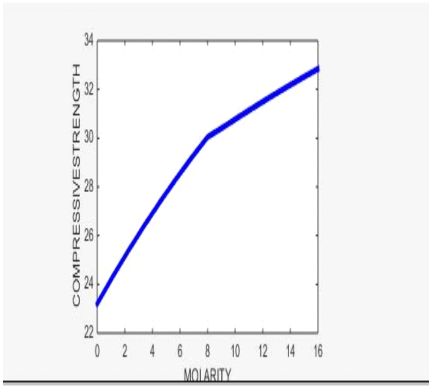

Figure 4: Surface view of the data

The function of each layer is described below:

Layer 1:

The very first layer in the architecture of ANFIS is called as fuzzy layer. Each node from the fuzzy layer. Each node from the fuzzy layer a membership grad of fuzzy set. Every node is an adaptive node with a node function.

$$O_i^1 = \mu_{A_i}(x)$$

Where, x be the node I input

Ai is a label incorporated with the function. The shape of the membership functions changes with the premise parameters.

Layer 2:

Each node in this layer will be having a fixed node, represented by a circle and labeled II, and then the node function has to be multiplied by the signals of input nodes serve as the output signal.

$$O_i^2 = \mu_{A_i}(x) \times \mu_{B_i}(y), i = 1,2$$

W_i represents the firing strength rule.

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Layer3:

Every node in third layer will be also same as layer 2 that is having a fixed node and represented with a circle and labeled as N. In this the ratios of node firing strength to sum of all firing strength were es6timated, which can be used for normalizing the firing strength.

$$O_i^3 = \overrightarrow{w_i} = \frac{W_i}{W_1 + W_2}, i = 1,2$$

Layer 4:

Each node in this layer is an adaptive node, marked by a square, with node function.

$$O_i^4 = \overrightarrow{w_i} f_{i=\overrightarrow{w_i}(p_i x + q_i y + r_i), i=1,2}$$

Layer 5:

Each node in this layer is circle node labelled sigma indicating the overall out as the summation of all incoming signals calculated that is

$$O_i^5 = \sum_i \overrightarrow{w_i} f_i = \frac{\sum_i W_i f_i}{\sum_i W_i}$$

The model architecture consists of 5 layers, including input, output, membership functions of input and output respectively and rules.

MATLAB ANFIS toolbox was employed for developing the model. There are mainly two methods of developing a model were available named subtractive clustering and grid portion. Grid portion method gives experimental growth with the growth in no. of inputs which paralyzed calculation system [20]. Whereas the subtractive method creates an input-output rule model without an exponential growth unless the parameters were arbitrary settled which further increases the workload. The fundamental training rule of ANFIS is its back propagation in which the error is estimated from the output layer and it will be back propagated to the input layer.

The fundamental learning rule of ANFIS is back propagation gradient descent which calculates error from the output layer and propagates back to the input node. The input node is similar to the general feed-forward neural networks. In recent times, a rapid learning method named hybrid learning was incorporated in ANFIS which uses least squares and gradient descent methods to calculate consequent and antecedent parameters. In this study hybrid method of learning is adopted for constructing models.

Table I: Showing the Results of Compressive Strength

Molarity	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Compressive Strength	33.5	32.4	32	31	31	31.1	30.1	30.2	29.4	28.82	28.5	28.3	28.12	27.67	26.55	24.16	20.6

IV. RESULTS

The compressive strength of the produced specimens has been illustrated for7, 14 and 28 days of curing, respectively. On the whole, samples made with FA particles have shown considerably higher strength than the other series. This may be due to the production of more compacted specimens in presence of finer FA particles rather than POC particles. Fine particles are capable to fill the vacancies and produce more densified specimens which make them stronger to the applied loads. This has been confirmed in some works done on concrete specimens due to the use of geopolymers.

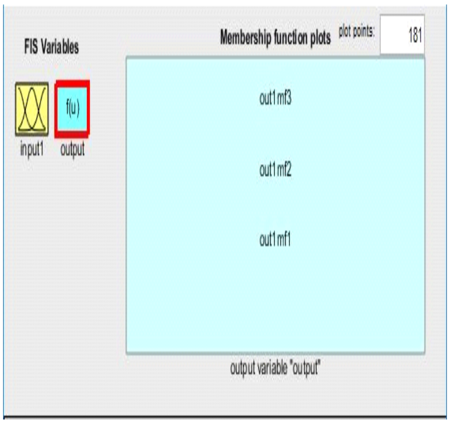

Figure 6: Membership functions for input and output parameters

The graph represents the prediction results of the split tensile strength of the samples with the comparison of experimental observations and predicted model values. The error can be also calculated by the following method.

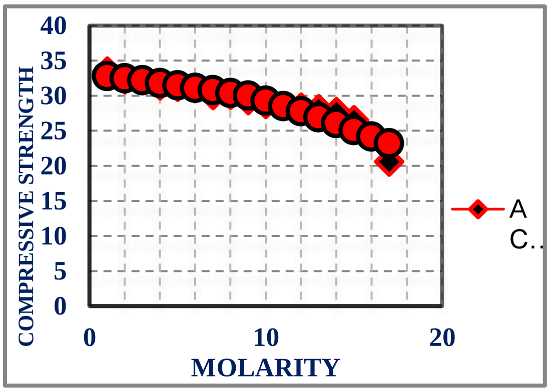

Figure 7: Comparison of Actual and predicted strength tests

V. CONCLUSION

In the present work, an appreciable attempt was made to use ANFIS, a sub division of Artificial Intelligence, to develop models which can predict the strength characteristics of concrete aided with geopolymers with respect to molar concentration. It was successfully demonstrated using this soft computing technique for

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prediction of pozzolana material and its properties with respect to changes in the compressive strength during curing. the samples which contain Fly ash particles have shown appreciable high amount of strength characteristics than others. For this, reason could be the manufacturing of more compacted specimens of finer Fly ash particles rather than the PCC particles. Finer particles are having the capability of occupying the vacant spaces and produce more densified specimens which will make them stronger to the application of loading conditions. Experimental investigation data was used to train and develop the model. The generated model is having high accuracy in predicting the strength characteristics of concrete.

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AUTHORS PROFILE

A. Siva Krishna completed his Post Graduation in Global Institute of Engineering &Technology, JNTU, Hyderabad. Now he is pursuing Ph.D in Koneru Lakshmaiah Education Foundation (Deemed to be University), Vijayawada. Presently, he is working as Assistant Professor in SR Engineering College, Warangal. He published 5 in International Journals.

Dr. V. Ranga Rao is working as Professor in Department of Civil Engineering at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur district, Andhra Pradesh, India. He is pursuing Doctorate from Ph. D. on "**Conventionally reinforced concrete columns with cement from industrial wastes under uniaxial bending**" from Andhra University, awarded in the year 1999, and M. E. on Structural Engineering from Annamalai university, awarded in the year 1990 with First class, and M. Tech. on C. S. C. from Vinaya Mission, awarded in the year 2007 with first class, and B. Tech on Civil Engineering from NIT-Bhopal, awarded in the year 1985 with first class. He published 20 journals in International and national. He is having 28-years of teaching experience. His research area is concrete Structures and Building materials.