



## **Development of Non Destructive Techniques in Nano Composite Concrete Specimen Using Software Analysis**

**A Jayaraman<sup>1\*</sup>, N Sathyakumar<sup>2</sup> and S Dhivyabharathi<sup>3</sup>**

<sup>1,2 and 3</sup> **Assistant Professor, Department of Civil Engineering, Bannari Amman Institute of Technology, Sathamangalam-638 401, India**

**Abstract :** This paper presents to study the strength of hardened concrete by software analysis and made comparison with the experimental result. Artificial Neural Network (ANN) and Fuzzy logic is one of the popular testing method used in recent days. The paper focuses on determination of strength of grade (M40) concrete of different mixes in which ordinary portland cement is replaced by Nano silica, Nano calcium carbonate and Nano calcium hydroxide of 2%, 4%, 6% and 8% using Artificial neural network and fuzzy. Artificial Neural Network Model and fuzzy model is constructed and the compressive strength of concrete is predicted by considering specific concrete properties as input variables. Experimental data result of these mixes were obtained by testing and is compared with software result. The result shows that ANN and fuzzy are suitable model and have high potential to predict compressive strength and predicts good result when compared to experimental result.

**Key words :** Fuzzy, Neural Network, Compressive Strength, Nano Silica, Nano calcium carbonate, Nano calcium hydroxide, Concrete.

### **Introduction**

Hardened concrete is a concrete which must be strong enough to withstand the structural and service loads which will be applied to it and must be durable enough to the environmental exposure for which it is designed. It will be the strongest and durable building material. With the development of hydration, concrete will change from a fluid to a plastic state, and finally to a solid hardened state. In the hardened state, concrete is ready to support external loads as a structural material. One of the motivations behind testing hardened concrete is to affirm that the concrete utilized at site has built up the required quality. As the hardening of the concrete requires some serious energy, one won't come to know, the real quality of cement for quite a while. Concrete is mostly used as construction materials in many structures such dams, building frames etc. 7, 14, 28days compressive strength is taken into consideration for any of result analysis. Strength performance is the most important of all other properties of concrete. In recent years there has been increasing interest in evaluating the

strength of concrete using software. Many researchers had carried out the ANN tool which can easily make the database for calculating compressive strength of concrete even from the imprecise ambiguous data. **Noorzaei et al (2007)**, concentrated and developed an ANN model for the datas that were collected from different literatures showed that ANN have strong potential in predicting compressive strength of concrete. **Vijay Pal Singh et al (2013)**, made an attempt to correlate the strength obtained by non destructive testing with experimental and ANN modelling result which showed that ANN can predict good result. **Sakshi Gupta et al (2013)**, developed an ANN model for predicting compressive strength by partially replacing cement with nano materials which showed that the strength increases to certain addition of nano materials and decreases gradually. **Rama Shanker et al (2015)**, proposed a design mix technique for standard grades using ANN and obtained a result with 4% to 5% error rates. **Jayaranjini et al(2016)**, developed ANN model for predicting the strength of concrete for 28 days by using silica fume, bottom ash, metakaolin which predicted the result with some error rates.

## II. Aim of the study

The main aim of the project is to predict the strength of concrete using software analysis.

## III Experimental Investigation

### 3.1 Nano silica:

It is one of the nanomaterial which improves the concrete workability and strength and also acts as filler material and activator to promote pozzolanic reactions.

### 3.2 Nano calcium carbonate:

It is commonly known as lime stone which is used to improve the properties of materials and also act as filler material and accelerate the hydration process.

### 3.3 Nano calcium hydroxide:

It is also called as slaked lime an inorganic compound obtained when calcium oxide mixed with water. It accelerates the hydration process.

### 3.4 Artificial Neural Network

ANNs are computing systems made up of a number of simple, highly interconnected processing elements, which processes information by their dynamic state response to external inputs. The fundamental concept of neural networks is the structure of the information processing system They are the establishments of Artificial Intelligence (AI) and take care of issues that would demonstrate outlandish or troublesome by human or measurable guidelines. ANN make them learn capacities that empower them to create better outcomes as more information data become available. In general, ANN contains three different steps of training, validation, and test. In the training step the epochs is repeated as long as it is not gotten into the desired output accuracy. The errors of the validation step is monitored during the training step. The test set error is the one which is used to compare different models. The ANN has been used in various engineering applications since it has the ability to generate the communications significant concepts in modeling the system. In present investigation, the ANN tool kit of the program MATLAB was utilized to play out the fundamental calculations. In these applications, modelling of material behaviour and characteristics plays an important role. This study is also about the determination of material characteristics of concrete specimens.

### 3.5 Fuzzy logic

Fuzzy logic is a way to make machines more intelligent, enabling them to reason in a fuzzy manner like humans. Fuzzy models “think” the way as humans do (human-like thinking) and include verbal expressions instead of numbers. It is preferable when the mathematical problem is hard to derive, and when decisions have to be made with estimated values under incomplete information. Fuzzy logic implements human experiences and preferences via membership functions and fuzzy rules. Fuzzy membership functions can have different shapes depending on the designers preference and/or experience. A general fuzzy inference system (FIS) has

basically four components: fuzzification, fuzzy rule base, fuzzy output engine and defuzzification. Fuzzification converts each part of the input data to degrees of membership by a look into one or more different membership functions. Fuzzy rule base encloses rules that include all feasible fuzzy relation between the inputs and the outputs. These rules are expressed in the IF– THEN format. There are basically two type of rule base 1) Sugeno type, 2) Mamdani type. Fuzzy inference engine takes into application all the fuzzy rules contained in the fuzzy rule base and understands and read how to transform a collection of inputs to the corresponding outputs.

#### IV. Experimental Procedure

M40 grade of concrete were used for the present investigation. Mix design was done based on IS 10262 – 2009. The concrete mix proportion 1:1.38:2.41 with w/c 0.45 considered in this study. Forty different trial mixes with various combinations were prepared. In this, Ordinary Portland cement is replaced by combination of nano silica, nano calcium carbonate and nano calcium hydroxide for different trial mixes. Concrete cubes were casted for all mixes. For each combination, trial mixes were carried out. In total 120 cubes were casted for all mixes. The specimens were demoulded after 24 hours and cured in water for 28 days. The test results were carried out to obtain compressive strength of concrete. The cubes were tested using compression testing machine (CTM) of capacity of 1000kN.

##### Mix design, casting and curing

- In this to examine, different mixes of nano materials as replacement of cement in hardened concrete are brought.
- The blend proportion of nano materials replacing cement for M40 grade of concrete is obtained by casting a specimen of size 150mm×150mm×150mm.
- Thorough mixing & adequate curing is most important to reach a hardened concrete.
- The specimen is de-moulded after 24hrs and kept for curing.
- The compressive strength obtained after 28 days of curing by testing is compared with software result.

##### 4.1 ANN Model

The results of ANN model network test shown in Figure 1, 2, 3 and 4. In this model the basic parameters which are used for making database consists of 24 input parameters which are the properties of cement, fine aggregate and coarse aggregate and one output parameter which is compressive strength at 28 days. The ANN model was designed using 120 pairs of input and output parameters. The predicted results obtained from the ANN model are compared with experimental values. The properties of input data are tabulated in table 1.

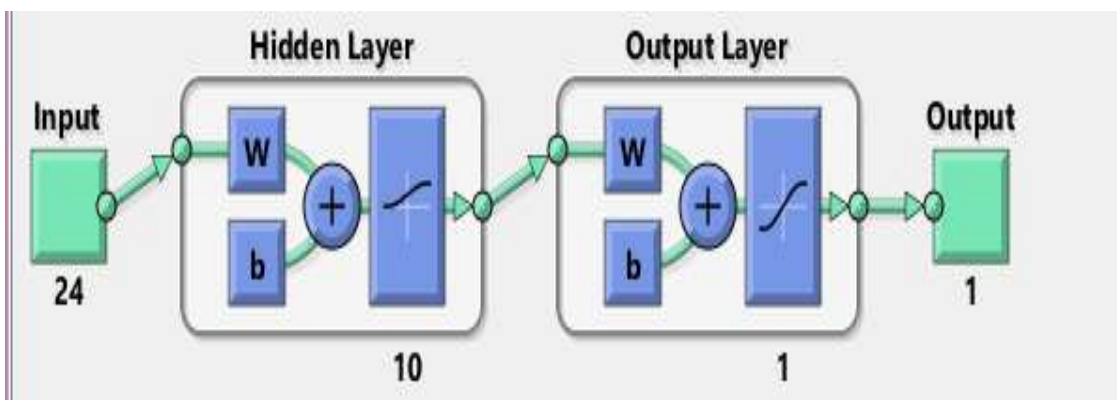


Figure 1: ANN model

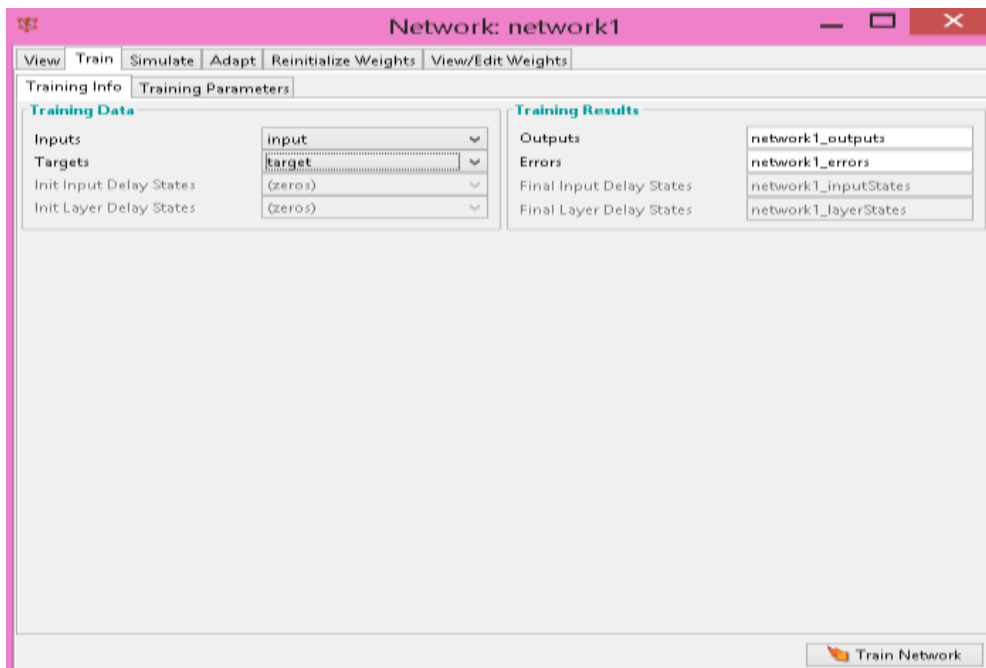


Figure 2: Training of network

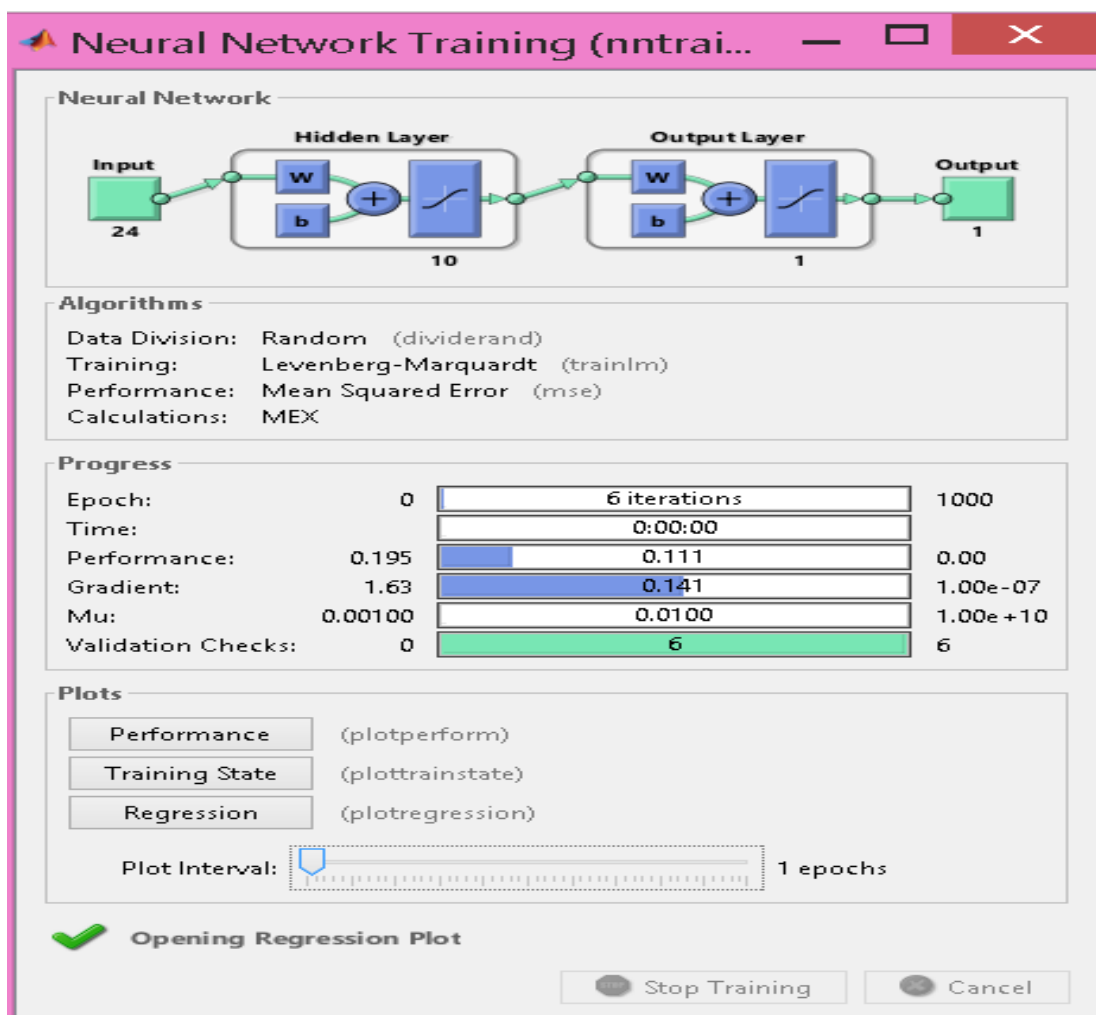


Figure 3: NN Training

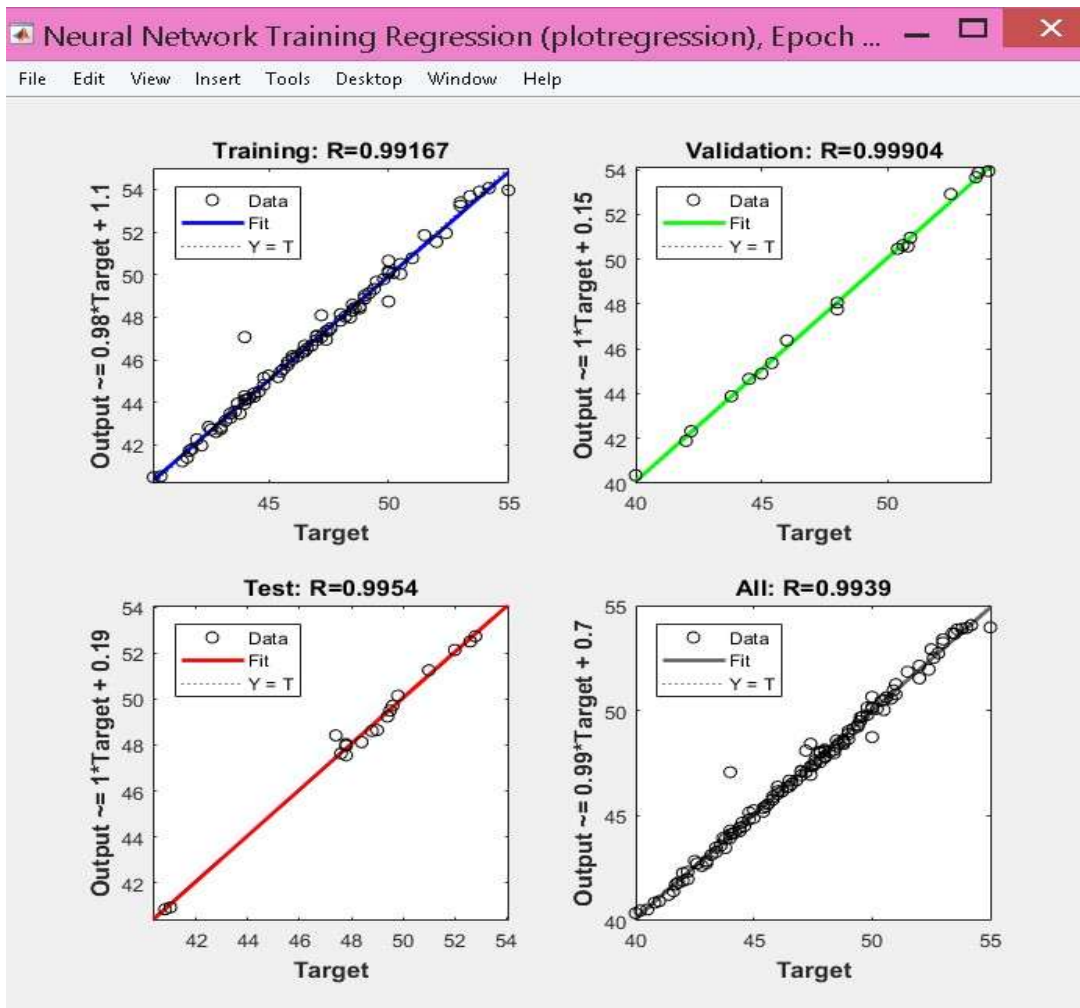


Figure 4: Regression plot

Table 1: Properties of input data

Properties	Cement	Nano SiO <sub>2</sub>	Nano CaCO <sub>3</sub>	Nano Ca(OH) <sub>2</sub>
CaO	63.81	0.27	96	83.3
SiO <sub>2</sub>	21.45	95.3	0.3	2.5
Al <sub>2</sub> O <sub>3</sub>	4.45	0.65	0.3	1.5
Fe <sub>2</sub> O <sub>3</sub>	3.07	0.28	0.3	1.8
Mgo	2.42	0.41	0.8	0.5
Alkalies	1.3	1.03	0.4	0.5
SO <sub>3</sub>	2.46	-	0.7	0.5
Loi	0.81	-	1.5	-
TiO <sub>2</sub>	0.22	-	-	-
CaCO <sub>3</sub>	-	-	-	10

#### 4.2 Fuzzy Logic Model

The results of **FUZZY LOGIC** model network test shown in Figure 5, 6a,6b,6c,6d, 6e ,6f, 6hand 6i.In this model the basic parameters which are used for making database consists of 24 input parameters which are the properties of cement, fine aggregate and coarse aggregate and one output parameter which is compressive strength at 28 days. The fuzzy logic model was designed using 60 pairs of input and output parameters. The predicted results obtained from the fuzzy logic model are compared with experimental

values. Fuzzy rules and Simulink representation shown in Figure 7: Figure 8

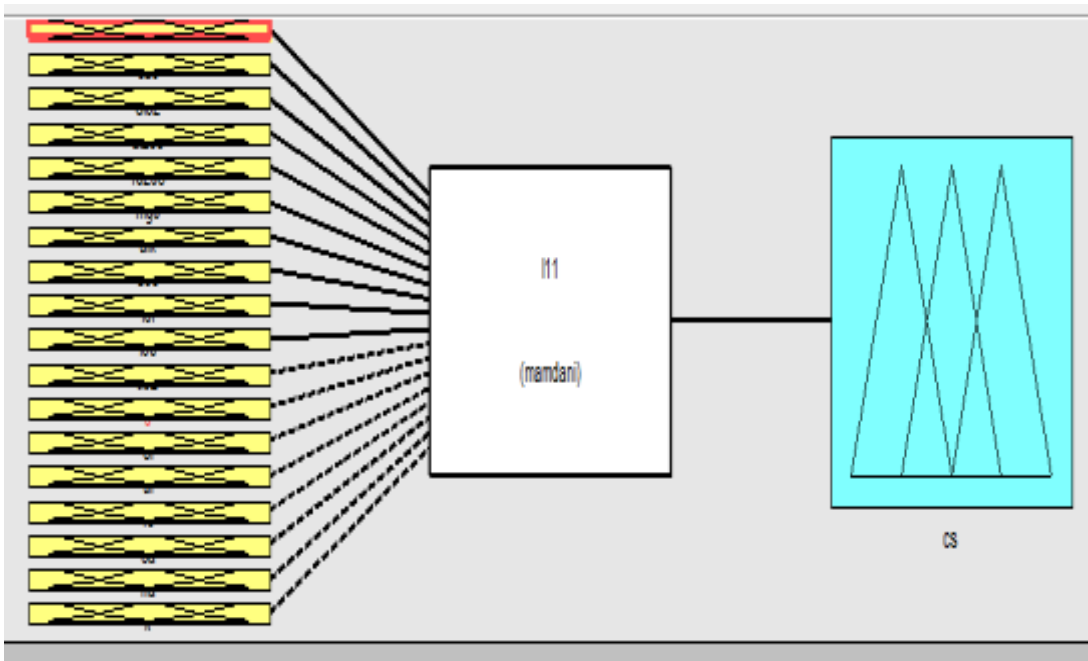


Figure 5: FL model

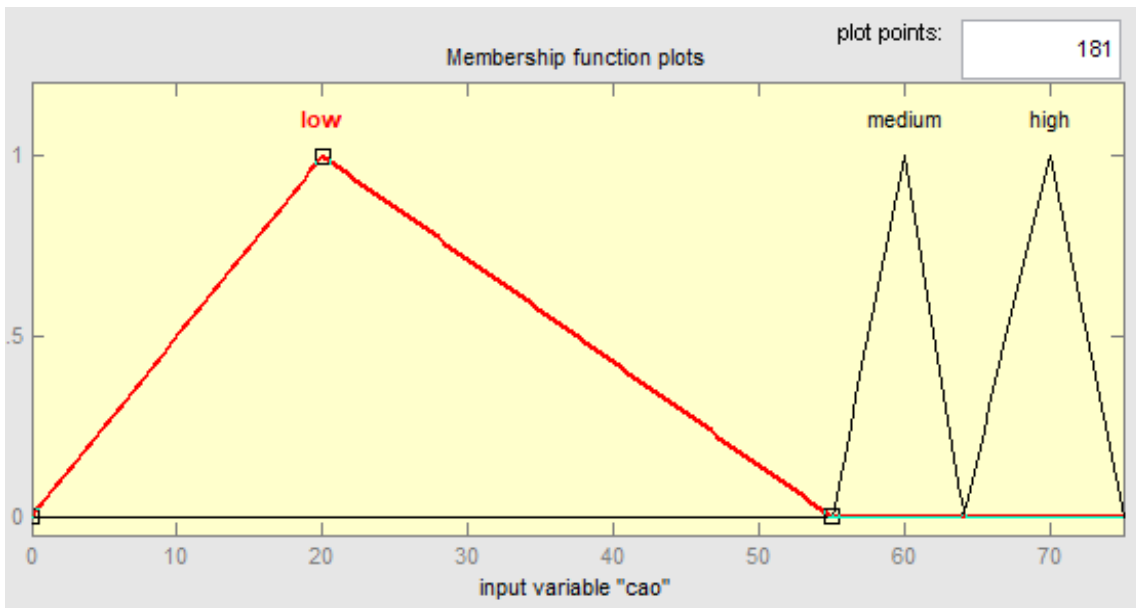


Figure 6a: Membership function for CaO

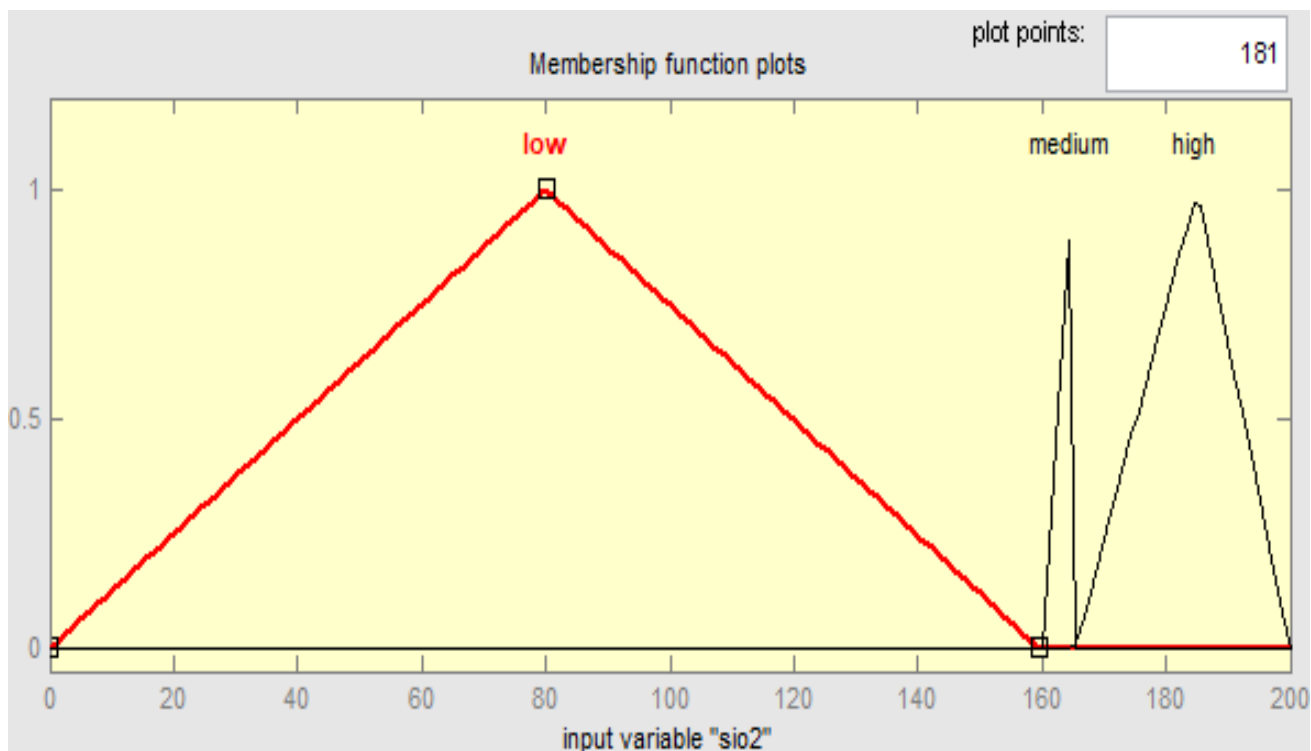


Figure 6b: Membership function for  $\text{SiO}_2$

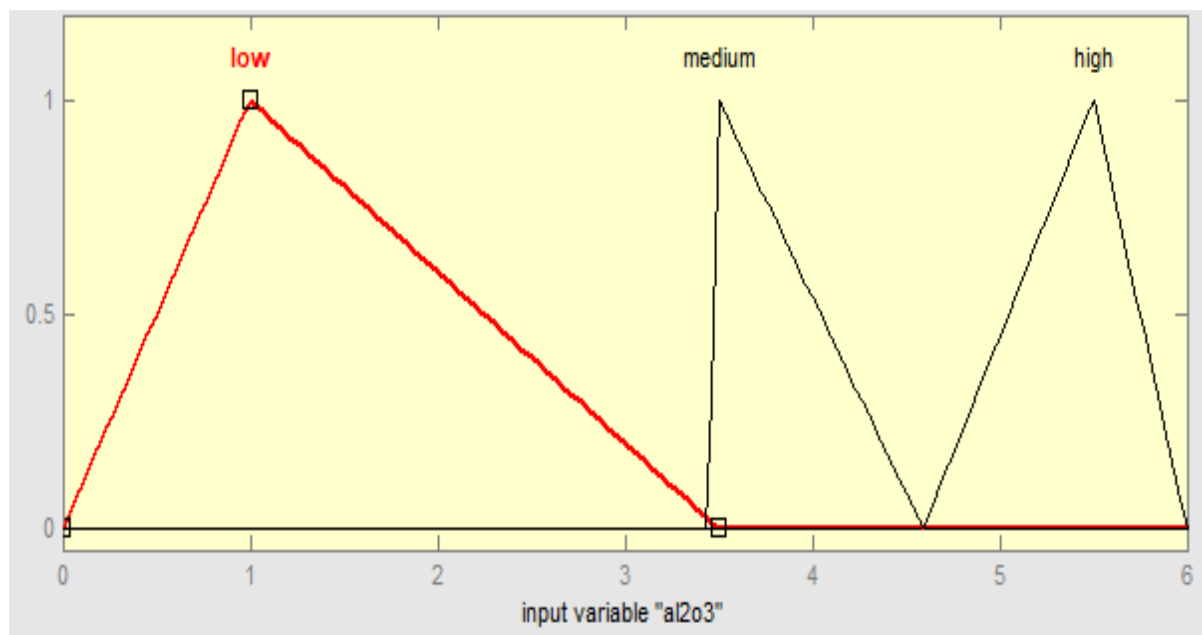


Figure 6c: Membership function for  $\text{Al}_2\text{O}_3$

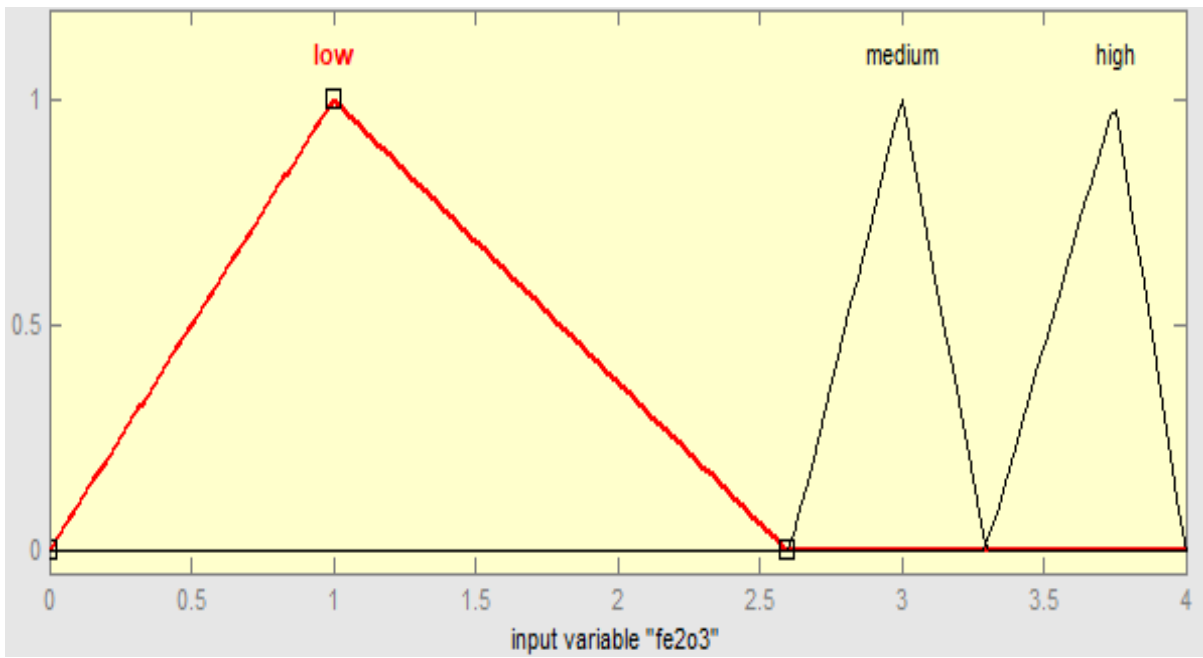


Figure 6d: Membership function for Fe<sub>2</sub>O<sub>3</sub>

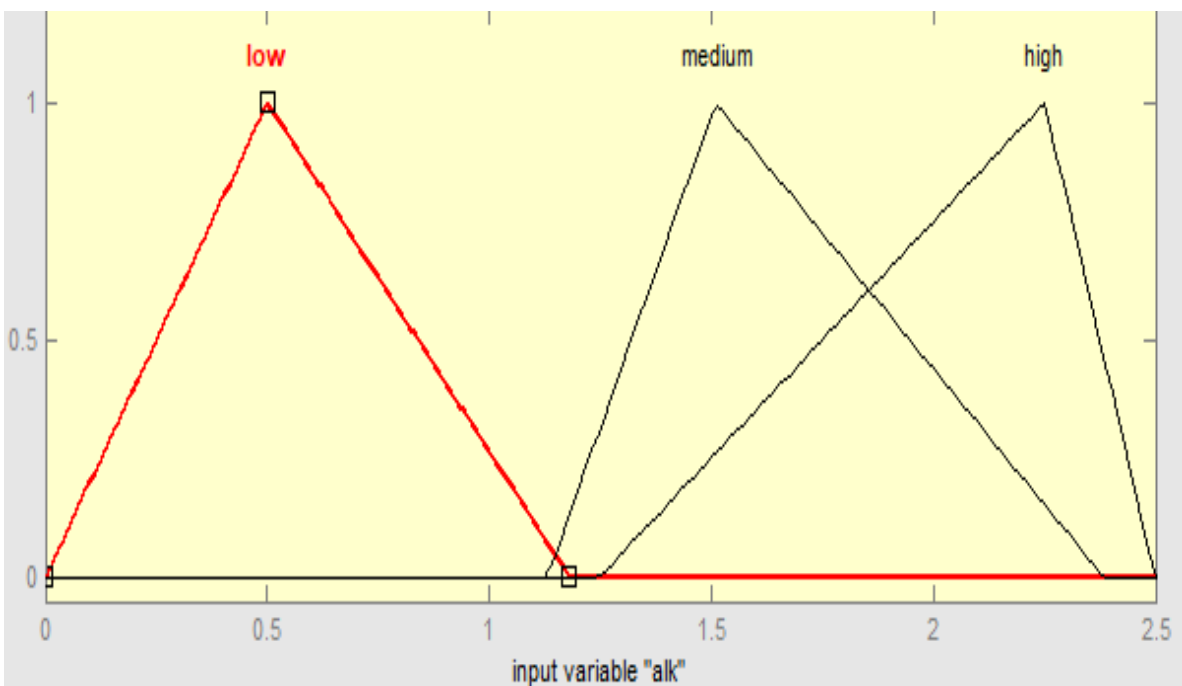


Figure 6e: Membership function for Alkalies



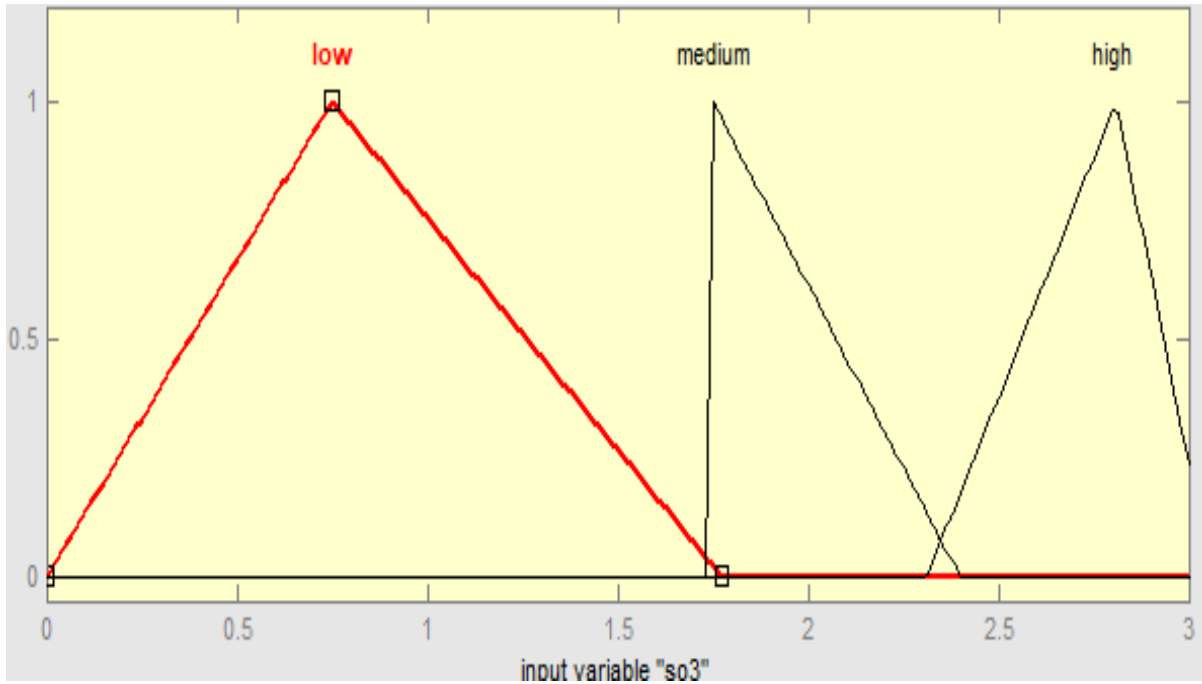


Figure 6f: Membership function forSO<sub>3</sub>

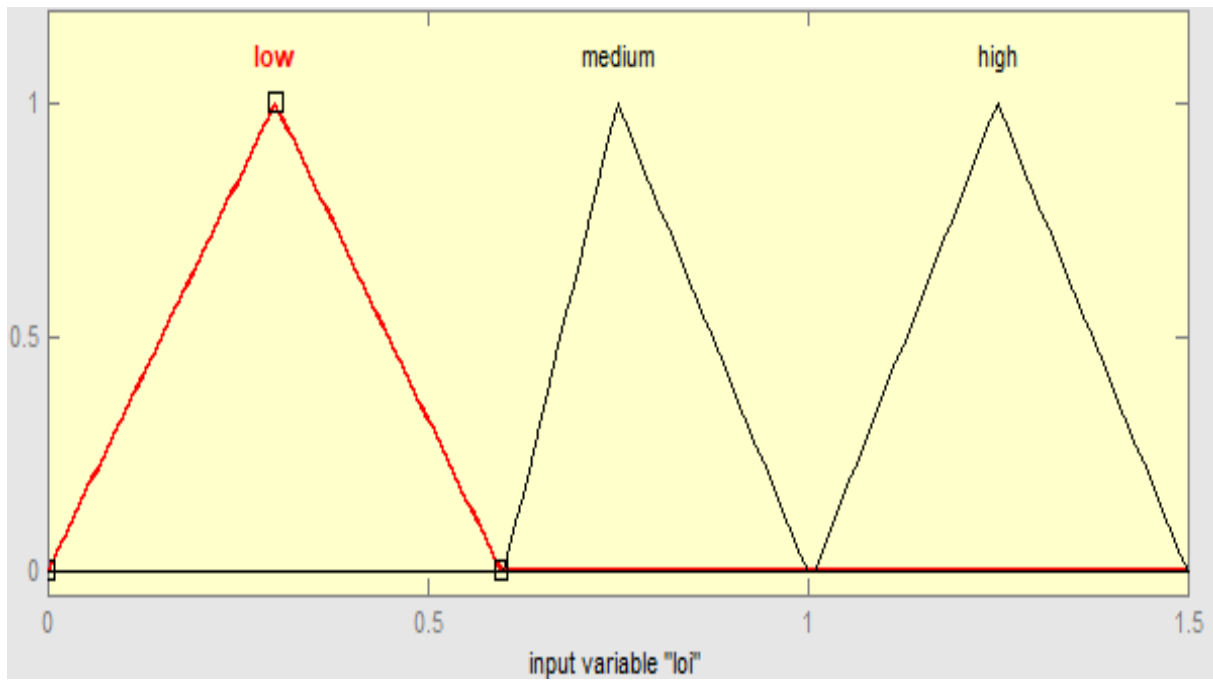


Figure 6g: Membership function forLoi

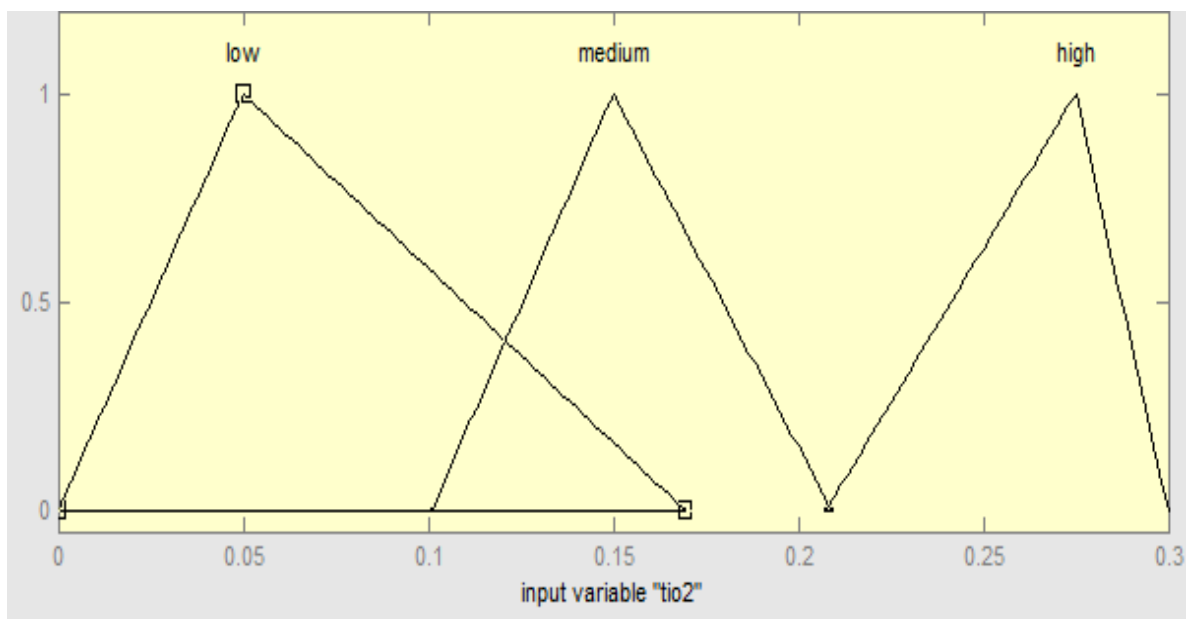


Figure 6h: Membership function for TiO<sub>2</sub>

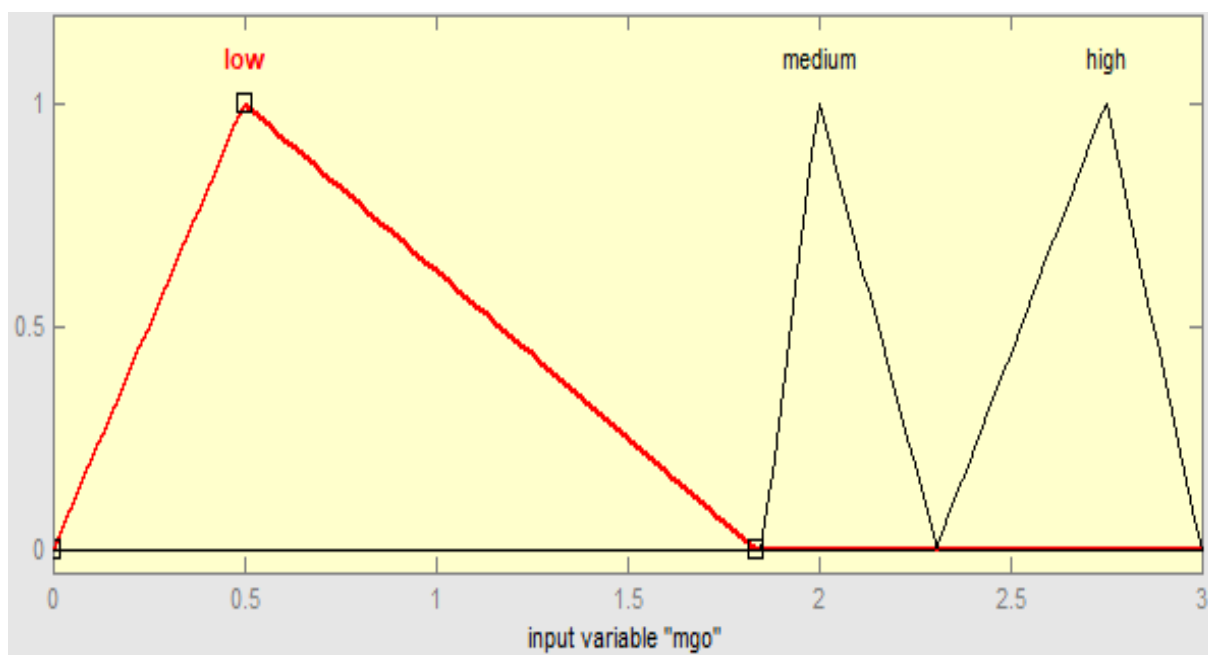


Figure 6i: Membership function for MgO

1. If (cao is high) and (sio2 is low) then (cs is veryhigh) (1)
2. If (cao is medium) and (sio2 is medium) then (cs is high) (1)
3. If (cao is medium) and (sio2 is high) then (cs is medium) (1)
4. If (al2o3 is high) and (fe2o3 is high) then (cs is veryhigh) (1)
5. If (al2o3 is medium) and (fe2o3 is medium) then (cs is high) (1)
6. If (al2o3 is low) and (fe2o3 is low) then (cs is medium) (1)
7. If (mgo is high) and (alk is medium) then (cs is veryhigh) (1)
8. If (mgo is medium) and (alk is medium) then (cs is high) (1)
9. If (mgo is low) and (alk is low) then (cs is medium) (1)
10. If (so3 is high) and (loi is medium) and (loe is medium) and (tio2 is high) then (cs is veryhigh) (1)
11. If (so3 is medium) and (loi is medium) and (loe is medium) and (tio2 is medium) then (cs is high) (1)
12. If (so3 is low) and (loi is medium) and (loe is medium) and (tio2 is low) then (cs is medium) (1)
13. If (o is medium) and (si is medium) then (cs is high) (1)
14. If (o is medium) and (si is medium) and (na is medium) and (k is medium) then (cs is high) (1)
15. If (al is medium) and (fe is medium) then (cs is high) (1)
16. If (ca is medium) and (na is medium) then (cs is high) (1)

Figure 7: Fuzzy rules

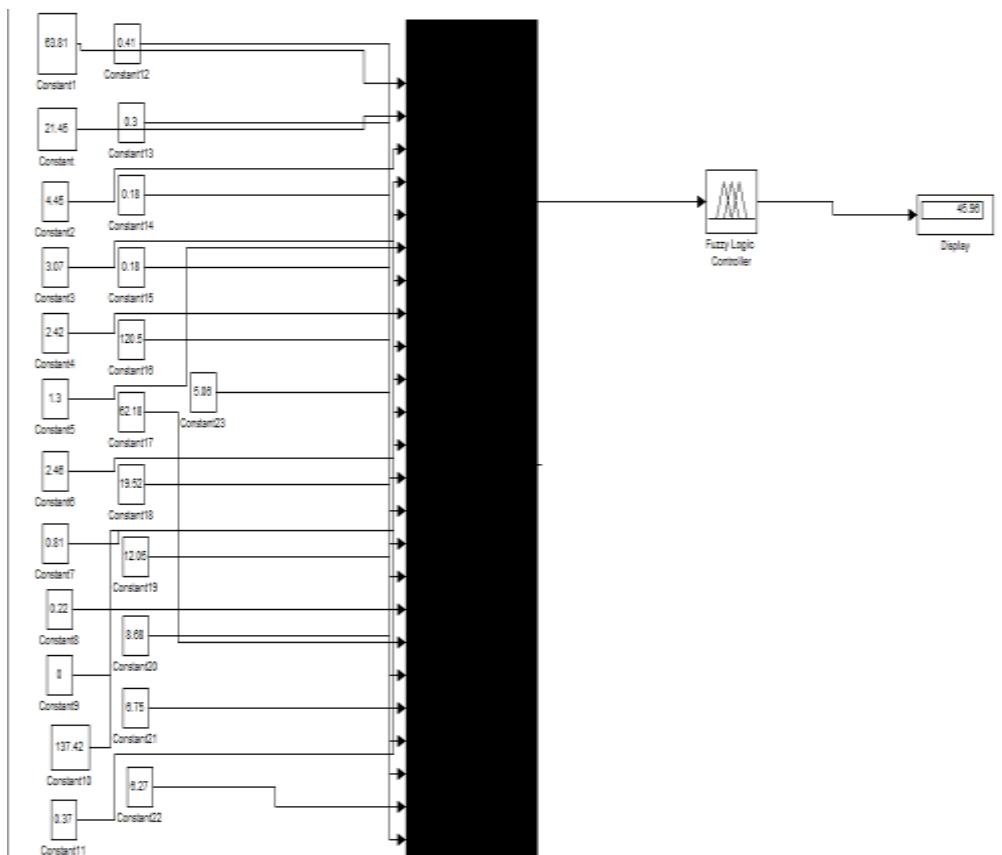
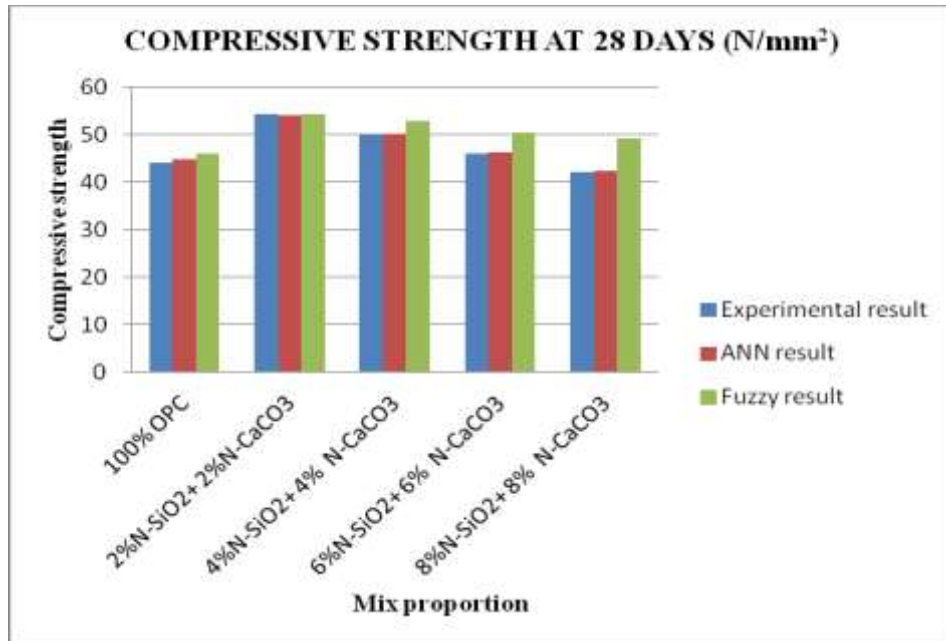


Figure 8: Simulink representation

**V. Result and Discussion**

**5.1 The comparisons Mix–**

A28 days compressive strength results (OPC +N- SiO<sub>2</sub>+ N-CaCO<sub>3</sub> ) in various percentage as shown in Figure.9 and Table 2. The 28 days compressive strength of concrete specimen experimental test results, ANN model and fuzzy model for 28-day compressive strength has been developed which was trained with different input and output data .The ANN model and fuzzy which developed showed a good relation between the experimental and predictedvalues.



**Figure 9: Graphical representation of compressive strength at 28 days**

**Table 2 Mix– A : 28 days compressive strength results (OPC +N- SiO<sub>2</sub>+ N-CaCO<sub>3</sub> ) in various percentage in different techniques**

Mix	Experimental result	ANN result	Fuzzy result
100% OPC	44.18	44.85	45.95
2%N-SiO <sub>2</sub> + 2%N-CaCO <sub>3</sub>	54.28	54.07	54.24
4%N-SiO <sub>2</sub> + 4% N-CaCO <sub>3</sub>	50.03	50.15	52.74
6%N-SiO <sub>2</sub> + 6% N-CaCO <sub>3</sub>	46.12	46.38	50.41
8%N-SiO <sub>2</sub> + 8% N-CaCO <sub>3</sub>	42.25	42.26	49.20

Compression between experimental, Fuzzy logic and ANN results shows that the strength increases when replacing cement with the combination of nano materials when compared to conventional concrete. The compressive strength increases the 2% replacement of cement with combination of nano materials and thereafter decreases slowly in all the results. In 2%N-SiO<sub>2</sub>+ 2%N-CaCO<sub>3</sub> ,the compressive strength is increased about 18.68% ,17.05% and 15.06 % compare with conventional concrete specimen in all the test results such as experimental ANN and Fuzzy logic.In replacement of 8%N-SiO<sub>2</sub>+ 8% N-CaCO<sub>3</sub> with replacement of cement, the compressive is decreased with compared to conventional concrete specimen.

**5.2 The comparisons Mix–**

**B**28 days compressive strength results (OPC +N-SiO<sub>2</sub>+ N-Ca(OH)<sub>2</sub>) in various percentage as shown in Figure.10 and Table 3. The 28 days compressive strength of concrete specimen experimental test results, ANN model and fuzzy model for 28-day compressive strength has been developed which was trained with different input and output data .The ANN model and fuzzy which developed showed a good relation between the experimental and predicted values.

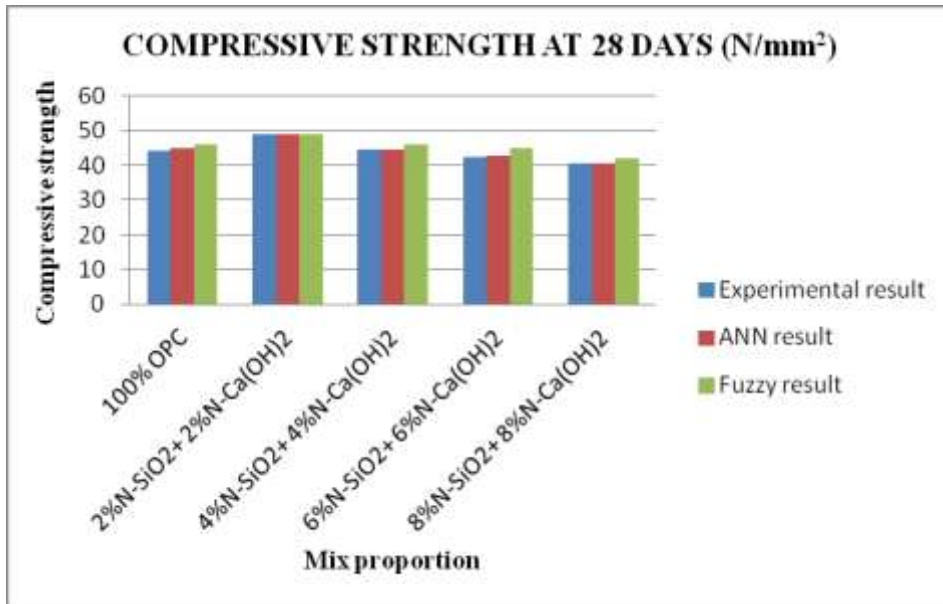


Figure 10: Graphical representation of compressive strength at 28 days

Table 3 Mix– B: 28 days compressive strength results (OPC +N-SiO<sub>2</sub>+ N-Ca(OH)<sub>2</sub>) in various percentage in different techniques

Mix	Experimental result	ANN result	Fuzzy result
100% OPC	44.18	44.85	45.95
2%N-SiO <sub>2</sub> + 2%N-Ca(OH) <sub>2</sub>	48.95	49.01	48.91
4%N-SiO <sub>2</sub> + 4%N-Ca(OH) <sub>2</sub>	44.52	44.66	46.15
6%N-SiO <sub>2</sub> + 6%N-Ca(OH) <sub>2</sub>	42.30	42.72	44.98
8%N-SiO <sub>2</sub> + 8%N-Ca(OH) <sub>2</sub>	40.65	40.53	42.12

Compression between experimental, Fuzzy logic and ANN results shows that the strength increases when replacing cement with the combination of nano materials when compared to conventional concrete. The compressive strength increases the 2% replacement of cement with combination of nano materials and thereafter decreases slowly in all the results. In 2%N-SiO<sub>2</sub>+ 2%N-Ca(OH)<sub>2</sub> ,the compressive strength is increased about 9.7 % ,8.46 % and 6.44 % compare with conventional concrete specimen in all the test results such as experimental ANN and Fuzzy logic. In replacement of 8%N-SiO<sub>2</sub>+ 8%N-Ca(OH)<sub>2</sub> with replacement of cement, the compressive is decreased with compared to conventional concrete specimen.

**5.3 The comparisons Mix–**

**C: 28 Days compressive strength results (OPC+ N-SiO<sub>2</sub>+ N-CaCO<sub>3</sub>+ N-Ca(OH)<sub>2</sub>)in various percentage** as shown in Figure.11 and Table 4. The 28 days compressive strength of concrete specimen experimental test results, ANN model and fuzzy model for 28-day compressive strength has been developed which was trained with different input and output data .The ANN model and fuzzy which developed showed a good relation between the experimental and predicted values.

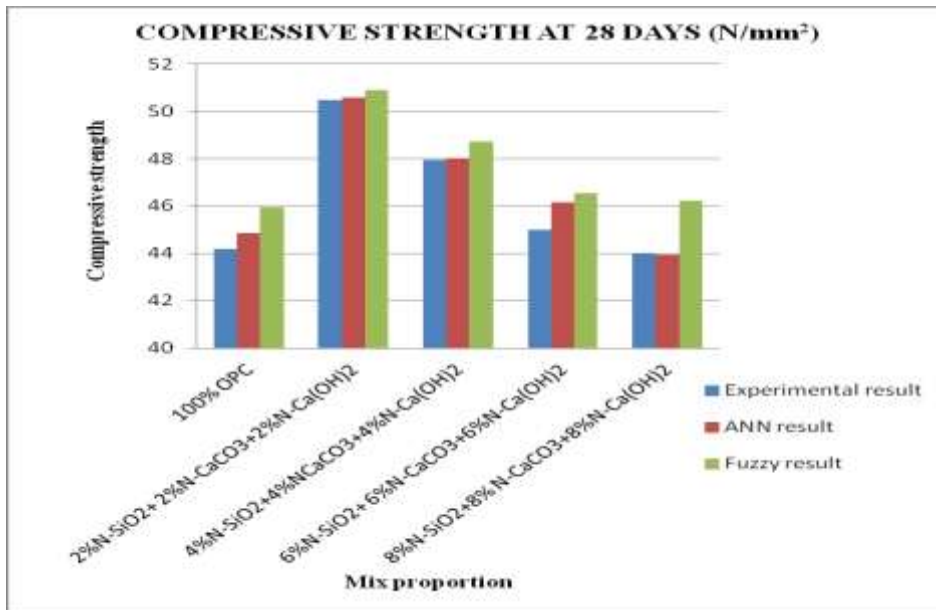


Figure 11: Graphical representation of compressive strength at 28 days

Table 4 Mix- C: 28 Days compressive strength results (OPC+ N-SiO<sub>2</sub>+ N-CaCO<sub>3</sub>+ N-Ca(OH)<sub>2</sub>) in various percentage in different techniques

Mix	Experimental result	ANN result	Fuzzy result
100% OPC	44.18	44.85	45.95
2%N-SiO <sub>2</sub> + 2%N-CaCO <sub>3</sub> +2%N-Ca(OH) <sub>2</sub>	50.49	50.57	50.88
4%N-SiO <sub>2</sub> +4%N-CaCO <sub>3</sub> +4%N-Ca(OH) <sub>2</sub>	47.96	48.02	48.70
6%N-SiO <sub>2</sub> + 6%N-CaCO <sub>3</sub> +6%N-Ca(OH) <sub>2</sub>	45	46.16	46.54
8%N-SiO <sub>2</sub> +8% N-CaCO <sub>3</sub> +8%N-Ca(OH) <sub>2</sub>	44.01	43.94	46.21

Compression between experimental, Fuzzy logic and ANN results shows that the strength increases when replacing cement with the combination of nano materials when compared to conventional concrete. The compressive strength increases the 2% replacement of cement with combination of nano materials and thereafter decreases slowly in all the results. In 2%N-SiO<sub>2</sub>+ 2%N-CaCO<sub>3</sub>+2%N-Ca(OH)<sub>2</sub>, the compressive strength is increased about 10.8 % ,11.45 % and 10.98 % compare with conventional concrete specimen in all the test results such as experimental ANN and Fuzzy logic. In replacement of 8%N-SiO<sub>2</sub>+8% N-CaCO<sub>3</sub>+8%N-Ca(OH)<sub>2</sub> with replacement of cement, the compressive is decreased with compared to conventional concrete specimen.

**VI Conclusions:**

- In the present study, the application of ANN and fuzzy logic model for 28-day compressive strength has been studied. The values were very closer to the experimental value which obtained from ANN model and fuzzy. As a result compressive strength values of concrete can be predicted in ANN models and fuzzy models without attempting any experiments in short period of time.
- In case of comparison of software analysis, the effect of 2% replacement of combination of nano silica, nano calcium carbonate and nano calcium hydroxide shows high strength and conventional concrete strength is achieved at 8% replacement in all grades.

**References**

1. J. Noorzaei, S.J.S. Hakim, M.S. Jaafar, and W.A.M.Thanoon, Development of artificial neural networks for predicting concrete compressive strength (2007), International Journal of Engineering and

- Technology, Vol. 4, No. 2, pp. 141153.
2. Vijay Pal Singh, Yogesh Chandra Kotiyal, Prediction of Compressive Strength Using Artificial Neural Network (2013), International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:7, No:12.
  3. Sakshi Gupta, Using Artificial Neural Network to Predict the Compressive Strength of Concrete containing Nano-silica (2013), Civil Engineering and Architecture 1(3): 96-102.
  4. Rama Shanker, Anil Kumar Sachan, Concrete Mix Design Using Neural Network (2014), International Journal of Computer and Information Engineering Vol:8, No:8.
  5. A. Jayaranjini Prediction of compressive strength of high performance concrete containing industrial by products using artificial neural networks, International Journal of Civil Engineering and Technology (IJCIET) Volume 7, Issue 2, March-April 2016, pp. 302–314.

\*\*\*\*\*