ISSN: 2345-3109

RCEE
Research in Civil and Environmental Engineering

www.jrcee.com
Research in Civil and Environmental Engineering 2014 2 (03) 120-132

USING FUZZY LOGIC APPROACH TO FIND THE COMPRESSIVE STRENGTH OF CONCRETE

Gupta Sakshi *

[a] Assistant Professor, Department of Civil Engineering, Dronacharya College of Engineering, Gurgaon, Haryana, India

Keywords

Fuzzy Logic

Compressive strength

Concrete

Supplementary materials

Correlation coefficient

A B S T R A C T

The paper presents the research work is carried out to predict the 28 days compressive strength of concrete with supplementary materials such as flyash, bottom ash, super plasticizers, silica fume using fuzzy logic technique It also help in optimizing constituents available and reducing cost and efforts in studying design to develop mixes by pre-defining suitable range for experimenting. The model developed using fuzzy logic consists of 7 input parameters which are contents of cement, fine aggregates, coarse aggregates, silica fume, ash, water to cement ratio, super plasticizers and one output parameter that is compressive strength at 28 days. The model developed is completely based on experimental data of research papers.

1 INTRODUCTION

Concrete is one of the oldest materials in the construction industry. It is a mixture of paste and aggregates. It is the most widely used construction material because of its flowability in most complicated form i.e. its ability to take any shape while wet, and its strength development characteristics when it hardens. Concrete production is a complex process that involves the effect of several processing parameters on the quality control of concrete pertaining to workability, strength etc. These parameters are all effective in producing a single strength quantity of compressive strength. Concrete is widely used as construction materials in many structures such dams, building frames etc. 7, 28, 56 and 90 days compressive strength is taken into consideration for any of result analysis. Strength performance is the most important of all other properties of concrete. But due to some circumstances if the resulting compressive strength may be not up to desired than whole of the process has to be repeated which in return may be very time consuming and costly.

Within last few decades, researchers had carried out the calibre of fuzzy logic (FL), tool which can easily make the database for calculating compressive strength of concrete even from the imprecise and

*Corresponding author (E-mail: *dceggnsakshigupta@gmail.com*).

ambiguous data. Fuzzy logic is not limited to a few inputs and outputs, any data that provides some indications of a system's action and reactions are sufficient. Moreover the system of fuzzy is user governed, such that it is very easy to add, improve and alter the system performance. The relation between mixture proportions and mechanical properties of concrete was based on data obtained experimentally.

2 FUZZY LOGIC

Constructions is the second most important thing in this ever-growing world of development and speed, first is time. So, to make the project least time consuming, various tools, techniques and softwares are developed and introduced to predict the result before implementing practically. The concept of ''fuzzy set'' was first introduced by Zadeh, who initiated the development of fuzzy logic (FL) replacing Aristotelian logic which has two possibilities only. FL concept provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria rather than the presence of random variables. Herein, uncertainties do not mean random, probabilistic and stochastic variations, all of which are based on the numerical data. Fuzzy set theory provides a systematic calculus to deal with such information linguistically. Fuzzy approach performs numerical computation using the linguistic labels stimulated by membership functions. Although FL was brought forward by Zadeh in 1965, fuzzy concepts and systems attracted attention after a real control application in 1975 conducted by Mamdani and Assilian. 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. There are basically two kinds of inference operators: minimization (min) and product (prod). Defuzzification is a process to produce the results in fuzzy logic, which converts the resulting fuzzy outputs from the fuzzy inference engine to a number. There are many defuzzification methods such as weighted average (wtaver) or weighted sum (wtsum). In the present study, the fuzzy model used is of Mamdani fuzzy rule type and the prod method was employed because of its more precise result methodology. For the defuzzification in the fuzzy model, weighted average method has been applied.

The major concept in fuzzy logic approach is the contribution of partial belongings of any object to various subsets of the universal set instead of belonging to a single set altogether. Partial belonging to set can be characterized numerically by a membership function which considers values between 0 and 1. All the possible inputs to a parameter are used to form their respective membership functions nominating a membership value of 1 to the crisp input in the database. The base of all the membership functions is chosen to be the integrated range of values to assure that no region is abandoned of the functions. For ease, the functions are assigned names on the basis of values of the nodal points for the functions.

3 DATABASE

The model successfully predicts the compressive strength of concrete depends on accuracy of experimental data. Availability of mass quantity of experimental data was used to develop the relation between the mix and properties of concrete. The basic parameters which are used for making database consists of 7 input parameters which are contents of cement (kg/m³), fine aggregates, coarse aggregates, silica fume, ash, super plasticizers, w/c ratio and one output parameter which is compressive strength at 28 days. A database of 129 mixes from different literature was chosen having mixture composition with comparable mechanical properties which is only compressive strength in this study. The fuzzy logic model was designed using 129 pairs of input and output parameters. The predicted results obtained from the fuzzy logic model are compared with experimental values. The parameters used in the prediction of compressive strength are listed in Table 1 and the details of the data used in modeling are given in Table 2.

Table 1 List of parameters with ranges

S.No	Input/ Output	Parameters (Units)	Ranges for compressive strength at 28 days		
			min-max	mean	Standard deviation
1	Input	Cement (Kg/m³)	10-500	344.69	111.20
2	Input	Water-Cement ratio	0.4-2.1	0.77	0.27
3	Input	Silica Fume (Kg/m³)	0-150	41.80	50.90
4	Input	Superplasticizer (Kg/m³)	0-6	4.0	2.23
5	Input	Coarse Aggregates	10-1283	953.82	256.06
6	Input	Fine Aggregates (Kg/m³)	0-990	246.49	345.64
7	Input	Ash (Kg/m³)	0-620	60.67	118.06
8	Output	Compressive strength at	3-62	36.80	8.35

Table 2 Details of the data used in modeling

Cement	W/C	Silica fume	Super plasticizer	C.A	F.A	Ash
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
360	0.86	40	4.8	1028	0	0
360	0.86	40	4.8	1028	0	0
360	0.86	40	4.8	1028	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
360	0.86	40	4.8	1028	0	0
360	0.86	40	4.8	1028	0	0
360	0.86	40	4.8	1028	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
400	0.77	0	4.8	1038	0	0
360	0.86	40	4.8	1028	0	0

Cement	W/C	Silica fume	Super plasticizer	C.A	F.A	Ash
360	0.86	40	4.8	1028	0	0
360	0.86	40	4.8	1028	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
320	0.96	80	4.8	1015	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
280	1.1	120	4.8	1005	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
500	0.77	0	6	820	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
450	0.86	50	6	805	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
400	0.96	100	6	790	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
350	1.1	150	6	775	0	0
390	0.47	0	2.6	1170	560	0
390	0.48	0	3.5	1170	510	50
390	0.49	0	3.6	1170	450	110
390	0.49	0	3.7	1170	390	170
390	0.49	0	3.7	1170	340	220
390	0.5	0	3.9	1170	380	280
426.7	0.43	0	2	1225	532.7	0
426.7	0.43	0	2.7	1225	426.7	106
426.7	0.43	0	2.8	1225	372.7	160
426.7	0.43	0	2.95	1225	319.7	213
426.7	0.43	0	3.2	1225	266.3	266.35
28.62	0.51	0	0	79.37	48.64	0
28.62	0.51	0	0	79.37	43.78	4.86
28.62	0.51	0	0	79.37	38.91	9.73

Cement	W/C	Silica fume	Super plasticizer	C.A	F.A	Ash
28.62	0.51	0	0	79.37	34.04	14.6
28.62	0.51	0	0	79.37	29.18	19.46
28.62	0.51	0	0	79.37	24.32	24.32
438	0.45	0	0	1096	620	0
438	0.45	0	0	1096	558	62
438	0.45	0	0	1096	496	124
438	0.45	0	0	1096	434	186
438	0.46	0	0	1096	372	248
438	0.47	0	0	1096	310	310
438	0.48	0	0	1096	248	372
438	0.5	0	0	1096	186	434
438	0.51	0	0	1096	124	496
438	0.52	0	0	1096	62	558
438	0.53	0	0	1096	0	620
380	0.4	0	0	1170	760	0
323	0.4	0	0	1170	760	57
266	0.4	0	0	1170	760	114
209	0.4	0	0	1170	760	171
152	0.4	0	0	1170	760	228
95	0.4	0	0	1170	760	285
354	0.5	0	1.75	822	986	0
339	0.53	0	1.7	825	990	18
320	0.55	0	1.68	819	983	35
302	0.59	0	1.58	816	978	53
335	0.52	0	1.7	817	980	18
317	0.55	0	1.77	813	976	35
301	0.59	0	1.93	815	978	53
337	0.53	0	1.81	823	987	18
319	0.55	0	1.95	819	983	35
300	0.58	0	2.07	813	976	53
342	0.46	0	5.7	1283	711	38
304	0.52	0	5.7	1283	711	76
266	0.6	0	5.7	1283	711	114
228	0.7	0	5.7	1283	711	152
190	0.84	0	5.7	1283	711	190
152	1.05	0	5.7	1283	711	228
304	0.52	76	5.7	1283	711	0
266	0.6	76	5.7	1283	711	38
228	0.7	76	5.7	1283	711	76
190	0.84	76	5.7	1283	711	114
152	1.05	76	5.7	1283	711	151
114	1.4	76	5.7	1283	711	190
76	2.1	76	5.7	1283	711	228

4 RESULTS AND DISCUSSIONS

The model developed using Fuzzy Logic showed a good correlation between the experimental and predicted values. The various surface diagrams are shown in Figure 1 (a)-(f) and the membership functions for different parameters is presented in Figure 2 (a)-(h). The MATLAB fuzzy logic toolbox is used in the modelling where it generates a plot of the output surface of a given fuzzy inference system (FIS) using the first two inputs and the output. The Correlation coefficient, RMSD was observed to be 0.94613 and 2.7037 respectively. The correlation coefficient being shows that the model is capable of predicting good values. Figure 3 represents Graph for experimental vs predicted compressive strength.

Table 3 Actual and Predicted Value of Compressive strength

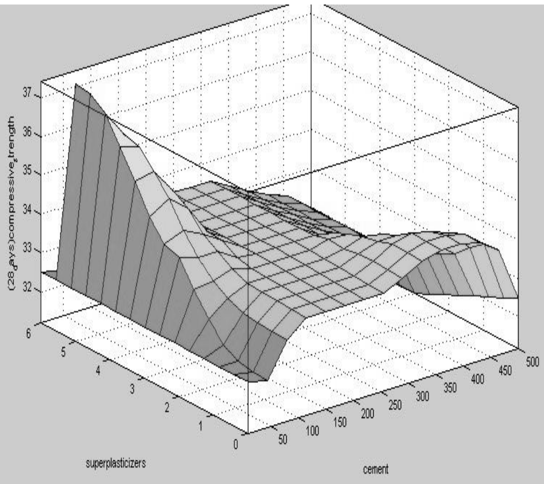
S.No.	Experimental / Actual Compressive Strength	Predicted Compressive strength (FL)
1	30	30.4
2	33.4	30.4
3	35.48	30.4
4	37.8	33
5	32	33
6	33.52	33
7	37.7	35.1
8	35.8	35.1
9	39.6	35.1
10	28.6	24.7
11	27.4	24.7
12	29.29	24.7
13	29.68	30.4
14	30.4	30.4
15	30.13	30.4
16	33.4	33
17	30	33
18	35.63	33
19	33.52	35.1
20	34.4	35.1
21	37.35	35.1
22	28.5	24.7
23	26.8	24.7
24	26.96	24.7
25	29.3	30.4
26	27.2	30.4
27	29.66	30.4
28	30.81	33
29	27.8	33
30	30.1	33
31	33.52	35.1
32	32.26	35.1
33	31	35.1
34	21	24.7
35	23.5	24.7
36	20	24.7
37	33.46	37.8
38	40	37.8
39	42.13	37.8
40	47.8	43.3
41	45.68	43.3
42	43.56	43.3
43	51.4	46.1
44	49.9	46.1
45	49.3	46.1
46	33.52	30
47	33.4	30
48	33.62	30
49	40.1	37.8
50	37.32	37.8
51	35.8	37.8
52	42.11	43.3
53	40.3	43.3
54	43.65	43.3
55	45.6	46.1
56	42.1	46.1
57	46.49	46.1

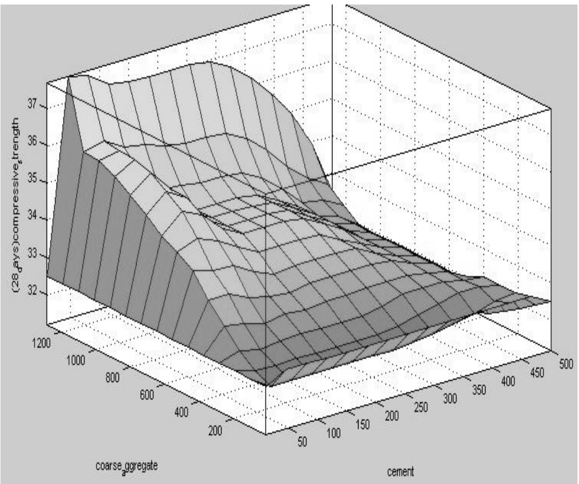
S.No.	Experimental / Actual Compressive Strength	Predicted Compressive strength (FL)
58	33.2	30
59	29.4	30
60	27.46	30
61	37.8	37.8
62	33.5	37.8
63	35.74	37.8
64	39.6	43.3
65	34.9	43.3
66	39.11	43.3
67	45.6	46.1
68	40.2	46.1
69	43.08	46.1
70	27.7	30
71	30.3	30
72	27.77	30
73	26.4	26.6
74	28.2	28.1
75	30.8	30.7
76	34.9	35.2
77	38.9	39.3
78	40	40
79	33.33	32.8
80	30.43	30.6
81	29.55	30.6
82	28	28.1
83	26.37	26.6
84	39.52	40
85	21.41	27.7
86	23.78	23.7
87	24.65	22.2
88	20	22.2
89	21.2	22.2
90	41.62	42.7
91	42	42.7
92	41.92	42.7
93	39.96	40.1
94	40	40.2
95	38.2	38.1
96	37.5	38.1
97	36.82	34.6
98	34.94	34.4
99	34.5	32.9
100	32	32.8
101	46.5	45.8
102	45.5	45.8
103	47.6	50.1
104	50.5	50
105	52.5	56.1
106	34	34.2
107	43.1	42.7
108	39.7	40.2
109	38.1	32.5
110	36.8	37.2
111	41.3	40.9
112	39.4	32.5
113	38.8	37.2
114	49.7	50.1
115	46.9	50

S.No.	Experimental / Actual Compressive Strength	Predicted Compressive strength (FL)
116	44.3	45.8
117	38	38.1
118	39	39.3
119	40	40.1
120	41	41
121	42.82	42.7
122	41	41
123	44.66	45.8
124	48	50.1
125	49	50.2
126	54	56.2
127	60.3	56.1
128	62.37	56.2
129	59.3	56.2

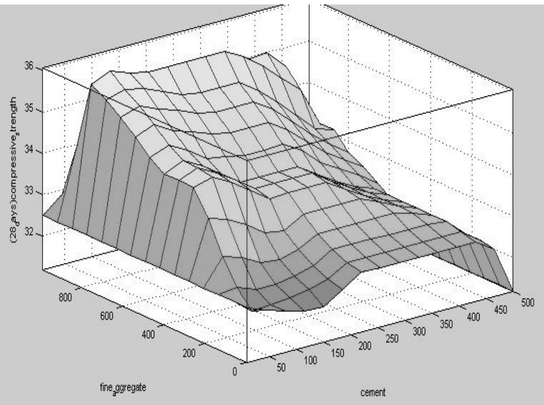
Table 4 Statistical parameters for the fuzzy logic model

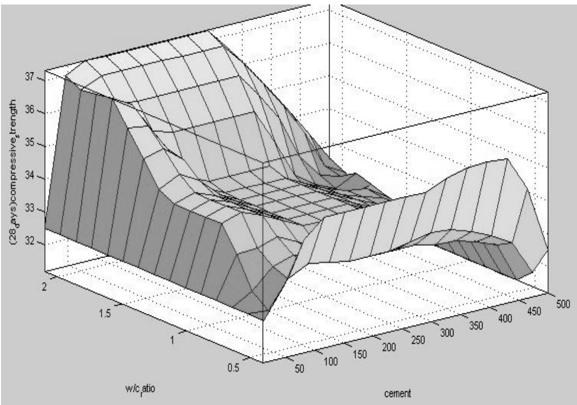
S.No.	Statistical parameter	Value
1.	Correlation coefficient	0.94613
2.	Root mean square error	2.70370



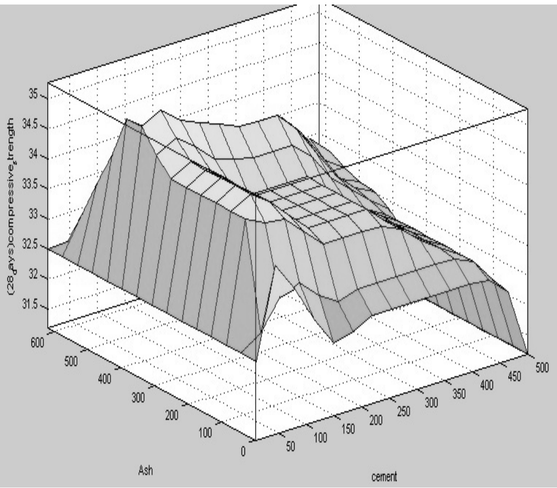


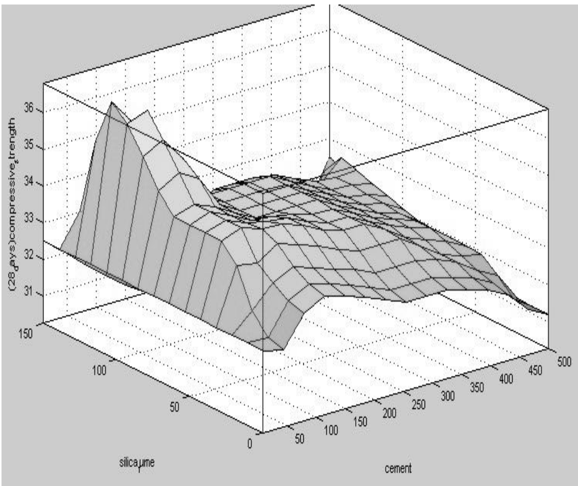
(a) (b)





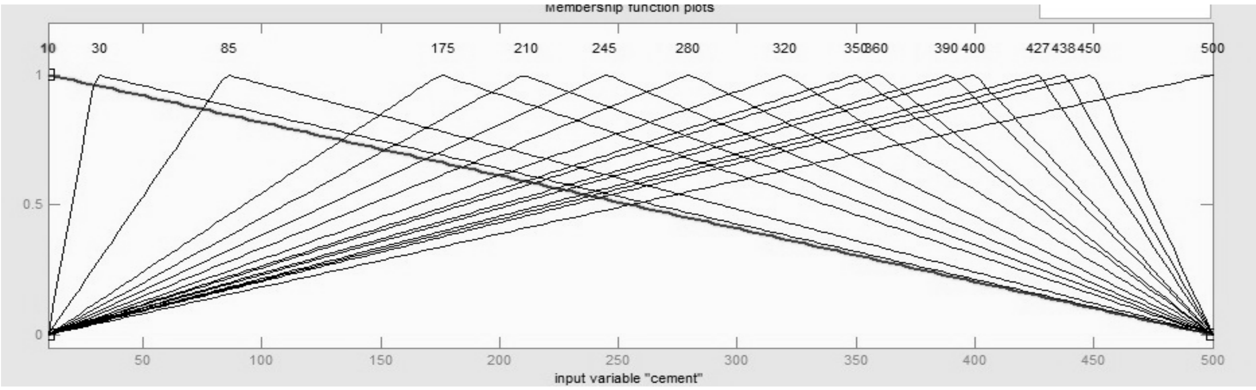
(c) (d)


(28 days)compressive strength
Ash
cement

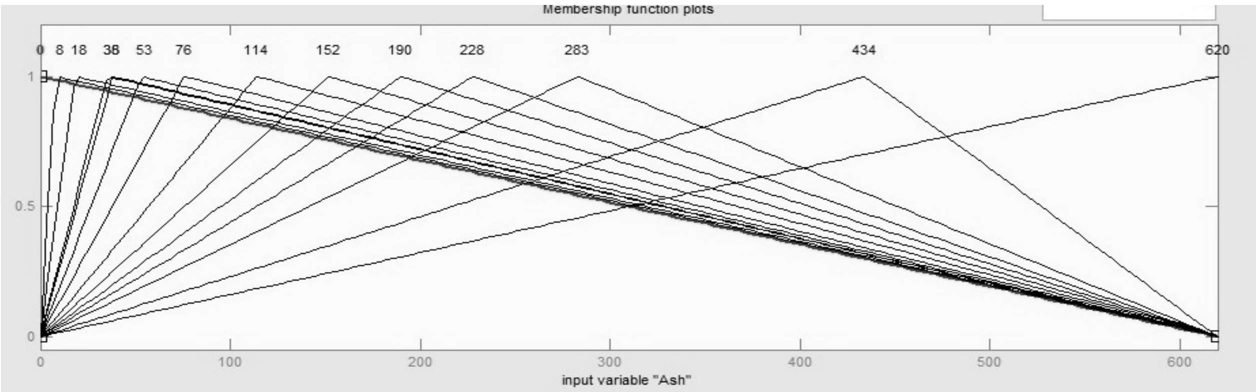

(28 days)compressive strength
silicafume
cement

(e) **(f)**

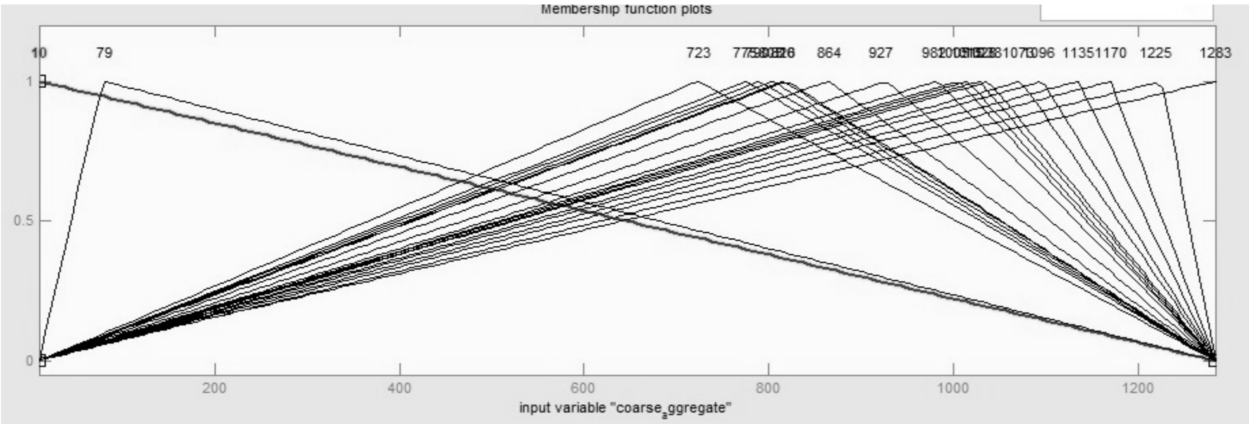
Fig.1

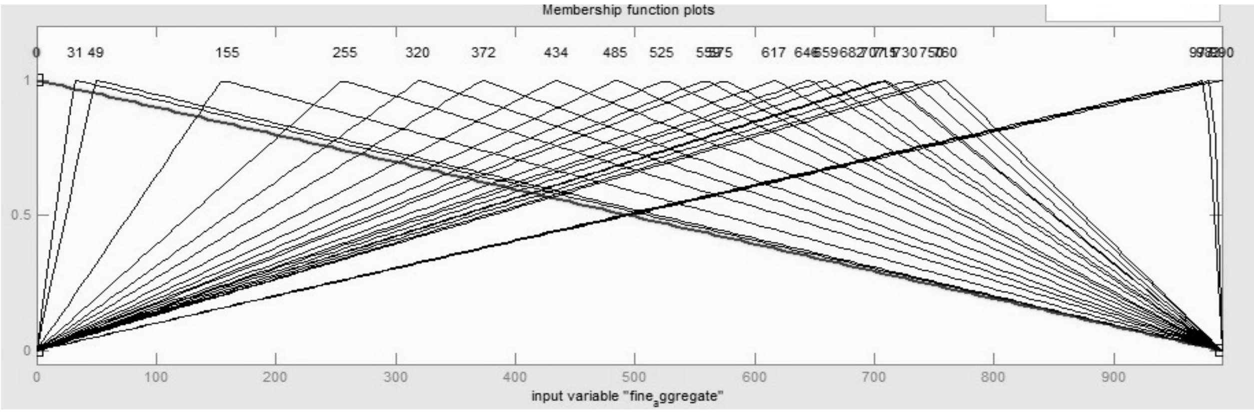

Membership function plots
10 30 85 175 210 245 280 320 350 360 390 400 427 438 450 500
input variable "cement"

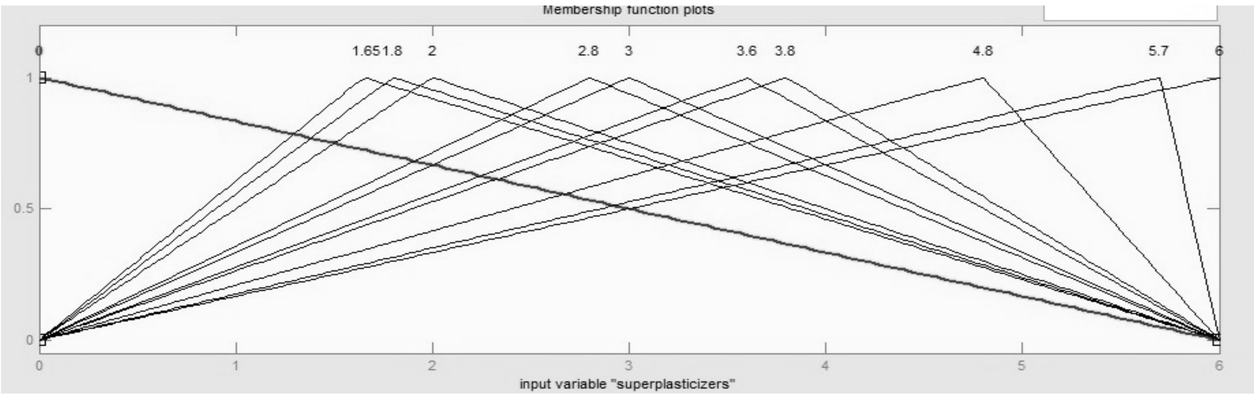
(a)

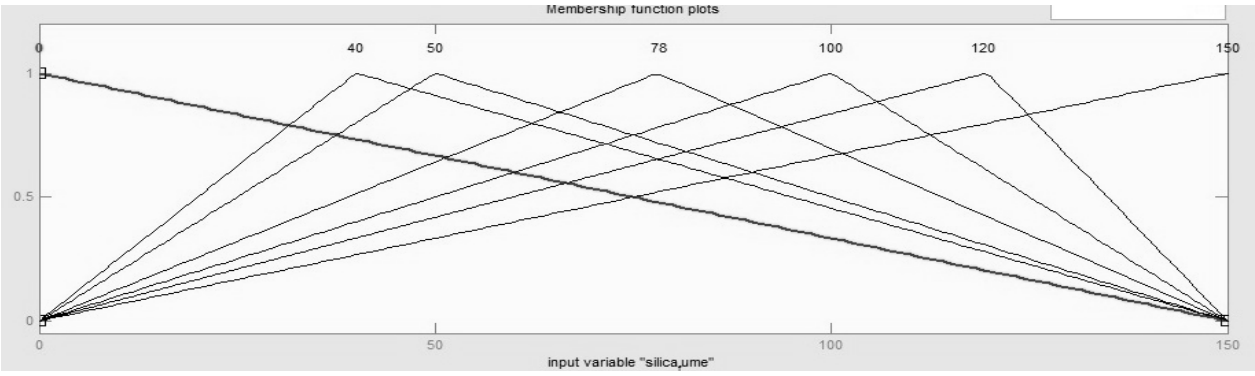

Membership function plots
0 8 18 38 53 76 114 152 190 228 283 434 620
input variable "Ash"

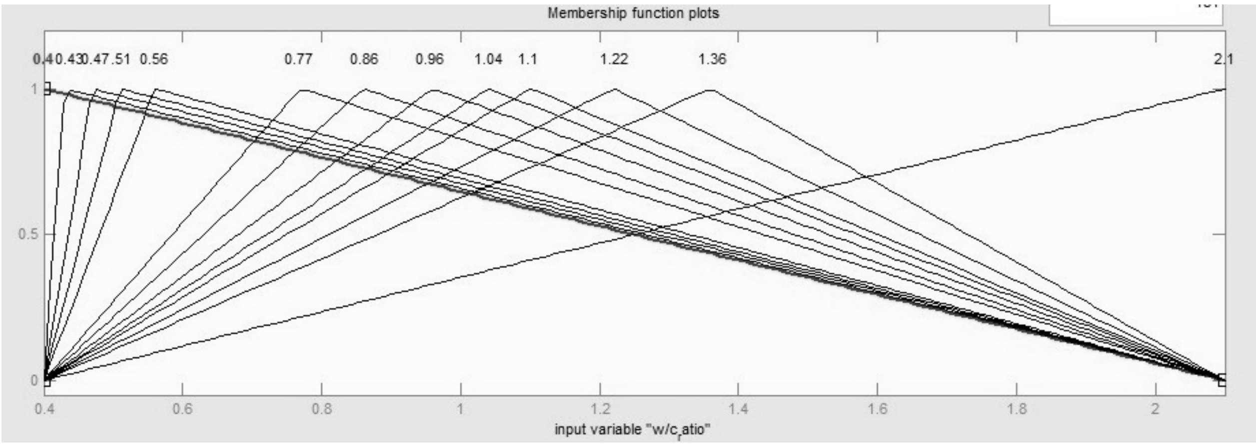
(b)


Membership function plots
input variable "coarse_aggregate"
200
400
600
800
1000
1200
(c)

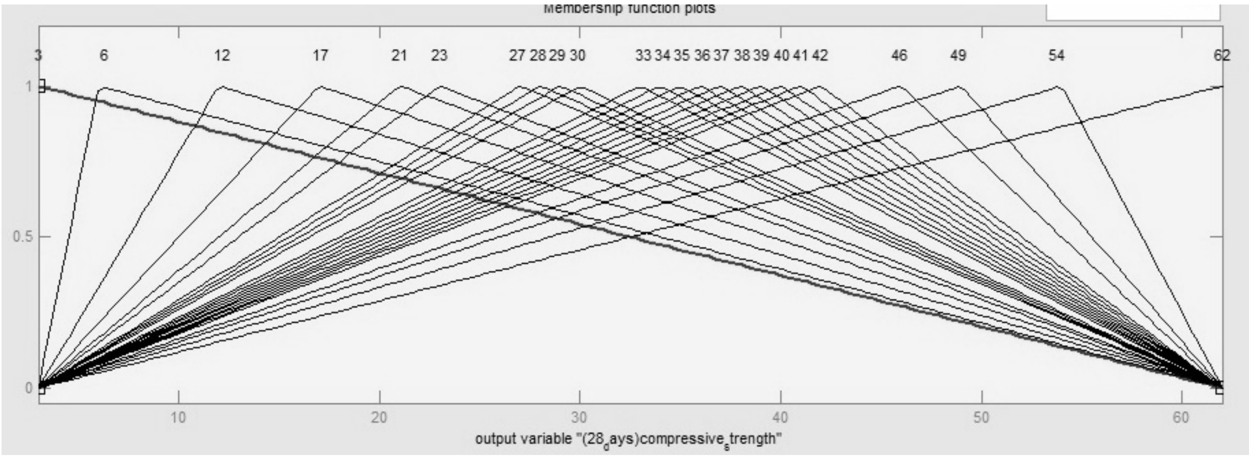

Membership function plots
input variable "fine_aggregate"
100
200
300
400
500
600
700
800
900
(d)


Membership function plots
1.65
1.8
2
2.8
3
3.6
3.8
4.8
5.7
input variable "superplasticizers"
(e)


Membership function plots
40
50
78
100
120
150
input variable "silica_fume"
(f)



(g)



(h)

Fig. 2

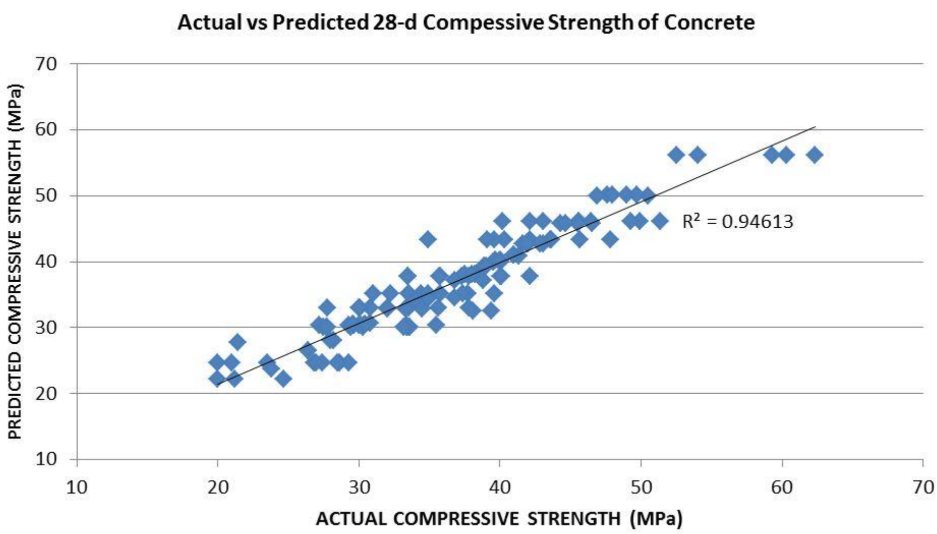


Fig. 3 Graph for experimental/actual vs predicted compressive strength

5 CONCLUSIONS

In the present study, a fuzzy logic prediction model for 28-day compressive strength has been developed. In order to predict the effects of supplementary materials on compressive strength values of concrete without attempting any experiments, the models were carried out in fuzzy logic system. The models were trained with input and output experimental data. The values are very closer to the experimental data obtained from fuzzy logic models. Correlation coefficient, RMSE and CC are statistical values that are calculated for comparing experimental data with fuzzy logic model. As a result, compressive strength values of concrete can be predicted in fuzzy logic models without attempting any experiments in a quite short period of time with tiny error rates. From the data and the results it is inferred that a) RMSE and CC lie in the category of better and good.

b) Model predicts the value is in between 0.9 to 1.

c) Fuzzy Logic can be conveniently used for the prediction of strength of concrete.

References

Abichou, T., Benson, C.H., and Edil, T.B. (1998). Database on beneficial reuse of foundry by-products, Recycled materials in geotechnical applications. *In: Vipulanandan C, Elton D, editors, Geotechnical Special Publication ASCE*, 79, 210–23.

Aggarwal.P, Aggarwal.P, Gupta.S.M, (2007). Effect of bottom ash as replacement of fine aggregates in concrete. *Asian Journal of Civil Engineering (building and housing)*, 8(1), 49-62.

Aitcin, P. C. Hershey, P.A. & Pinsonneault (1981). Effect of the addition of condensed silica fume on the compressive strength of mortars and concrete. *American Ceramic Society*, 22, 286-290.

F. Demir (2005). Prediction of compressive strength of concrete using ANN and Fuzzy logic. *Cement and Concrete Research*, 35, 1531–1538.

Khatib, J.M., and Ellis, D.J. (2001). Mechanical properties of concrete containing foundry sand, ACI special publication SP-200. *American Concrete Institute*, 733-748.

L.A. Zadeh (1965). Fuzzy Sets. *Information and Control*, 8, 338-353.

M. Passino (1998). Stable Fuzzy Logic design of point to point control for mechanical systems, S. Yurkovich, Fuzzy Control, *Addison-Wesley*.

Mohd.b Sani.M.S.H, Muftah.F, Muda.Z (2010). The Properties of Special Concrete Using Washed Bottom Ash(WBA) as Partial Sand Replacement. *International Journal of Sustainable Construction Engineering & Technology*, 1(2).

Muthupriya.P, Vishnuram.B.G, Subramanian.K (2011). Prediction of compressive strength and durability of high performance concrete by artificial neural networks. *International Journal of optimization in civil engineering Int. j. optim. Civil eng.,*1, 189-209.

Ozcan.F, Atis.C.D, Karahan.O, Uncuoglu.E, Tanyildizi.H (2009). Comparison of artificial neural network and fuzzy logic models for prediction of long-term compressive strength of silica fume concrete. *Advances in Engineering Software,* 40, 856-863.

Pathak.S.S, Sharma.S, Sood.H, Khitoliya.R.K (2012). Prediction of Compressive Strength of Self compacting Concrete with Flyash and Rice Husk Ash using Adaptive Neuro-fuzzy Inference System. (IJACSA) *International Journal of Advanced Computer Science and Applications*, 3(10).

S. Akkurt, G. Tayfur, and S. Can (2004). Fuzzy logic model for prediction of cement compressive strength. *Cement Concr Res*, 34(8), 1429-1433.

Siddique.R (2003). Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete. *Cement and Concrete Research*, 33, 539-547.

Sivalingam.K, Jayanthi.S, Jagadeesan.K and Samson.S (2012). Mechanical properties of concrete composites with replacement of class c fly ash and silica fume. *International Journal of Scientific & Engineering Research*, 3 (9), ISSN 2229-5518.

Tanyildizi.H (2009). Fuzzy logic model for prediction of mechanical properties of lightweight concrete exposed to high temperature. *Materials and Design*, 30, 2205-2210.

Tanyildizi.H, Cevik.A (2010). Modelling mechanical performance of lightweight concrete containing silica fume exposed to high temperature using genetic programming. *Construction and Building Material*, 24, 2612-2618.

Topcu I.B., Sarıdemir M. (2008). Prediction of mechanical properties of recycled aggregate concretes containing silica fume using artificial neural networks and fuzzy logic. *Comput Mater Sci*, 42(1), 74-82.

Topcu.I.B and Sarıdemir.M (2008). Prediction of rubberized concrete properties using artificial neural network and fuzzy logic. *Construction and Building Materials*, 22, 532-540.

Yazic.S and Hasan,S (2012). Effects of fly ash fineness on the mechanical properties of concrete. *Indian Academy of Sciences,* 37(3), 389-403.