International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 11, November 2017, pp. 245-255, Article ID: IJCIET_08_11_027
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

EVALUATION OF COMPRESSIVE STRENGTH, ULTIMATE LOAD AND DURABILITY CHARACTERISTICS OF HIGH PERFORMANCE CONCRETE BY ARTIFICIAL NEURAL NETWORKS

UmaMahendra Yadav. Ravulapalli
Assistant Professor, Department of Civil Engineering,
CMR College of Engineering & Technology, Medchal, India

Prasad Bollini
Associate Professor, Department of Civil Engineering,
CMR College of Engineering & Technology, Medchal, India

Narayana Maddela
Assistant Professor, Department of Civil Engineering,
CMR College of Engineering & Technology, Medchal, India

ABSTRACT

Neural networks have recently been widely used to model some of the human activities in many areas of Civil engineering applications. In the present project, the models in artificial neural networks (ANN) for predicting compressive strength of cubes, ultimate load of beams, columns and durability of concrete containing metakaolin with fly ash and silica fume with fly ash have been developed at the age of 3, 7, 28, 56 and 90 days. For purpose of building these models, training and testing using the available experimental results for required number of specimens produced with 7 different mixture proportions were used. The data used in the multilayer feed forward neural networks models are arranged in a format of eight input parameters that cover 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 multilayer feed forward neural networks models are used to predict the compressive strength and ultimate load values of beams and columns concretes. The training and testing results in the neural network models have shown that neural networks have strong potential for predicting 3, 7, 28, 56 and 90 days compressive strength values and ultimate load values of beams and columns of concretes containing metakaolin ,silica fume and fly ash..

Key words: Neural Networks, Metakaolin, Fly Ash, Compressive Strength and Ultimate Load Etc.

Cite this Article: UmaMahendra Yadav. Ravulapalli, Prasad Bollini and Narayana Maddela, Evaluation of Compressive Strength, Ultimate Load and Durability Characteristics of High Performance Concrete by Artificial Neural Networks, International Journal of Civil Engineering and Technology, 8(11), 2017, pp. 245-255.
http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=11

1. INTRODUCTION

High Performance Concrete is a term used to describe concrete with special properties. HPC was first known to be concrete with high strength for structural purpose. However, advances in concrete technology have generated a new (Super plasticizer, retarders, fly ash, blast furnace slag, silica fume, fumed silica and metakaolin) combined according to a selected mix design, properly mixed, transported, placed, consolidated and cured to give excellent performance, such as high compressive strength, high density, low shrinkage, high modulus of elasticity, low permeability, and good resistance to certain forms of attack.

Most ready-mixed concrete producers are familiar with the concept of “performance concrete.” performance concrete implies that specifications will stipulate minimum concrete strengths and leave the proportioning of the concrete mixture to the concrete producer .However, lately, another similar term, “high-performance concrete,” is being heard in the industry.

2. LITERATURE REVIEW

Mustafa saridemir (2009) In the present paper, the models in artificial neural networks (ANN) for predicting compressive strength of concretes containing metakaolin and silica fume have been developed at the age of 1, 3, 7, 28, 56, 90 and 180 days. The different mixture proportions were gathered from the technical literature. *Emre Sancak (2009)* In the scope of this study, concrete samples planned to be used as load-bearing concrete were produced by using pumice aggregate and silica fume. Cement was replaced by silica fume, as the mineral additive, by 5 and 10% of its weight. *R. Parichatprecha, P. Nimityongskul (2009)* the aim of this study is to construct an ANNs model to investigate the influence of mix proportion parameters on the resistance of chloride ion penetrability of high performance concrete. For this purpose, data for developing the neural network model are collected from the experiments and previous research.

B.K. Raghu Prasad, Hamid Eskandari, B.V. Venkatarama Reddy (2008) An artificial neural network (ANN) is presented to predict a 28-day compressive strength of a normal and high strength self compacting concrete (SCC) and high performance concrete (HPC) with high volume fly ash. Umesh *Pendharkar, Sandeep Chaudhary, A.K. Nagpal (2007)* A methodology using a neural network model has been developed for the continuous composite beams to predict the inelastic moments from the elastic moments. *A. Cladera , A.R. Mari(2004)* In this paper presents the current shear procedures of different codes of practice for normal-strength and high-strength beams with web reinforcement an extensive research study was performed. M.Y. *Mansour, M. Dicleli,_, J.Y. Lee, J. Zhang(2004)*

3. RESULTS AND DISCUSSION

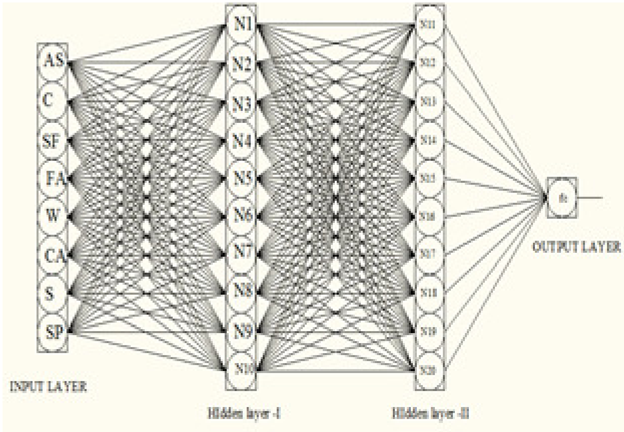

Figure 2 The system used in the ANN-II model

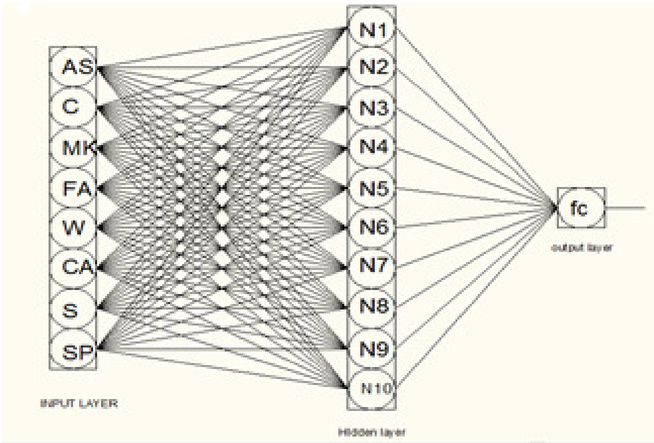

Figure 3 The system used in the ANN-II model

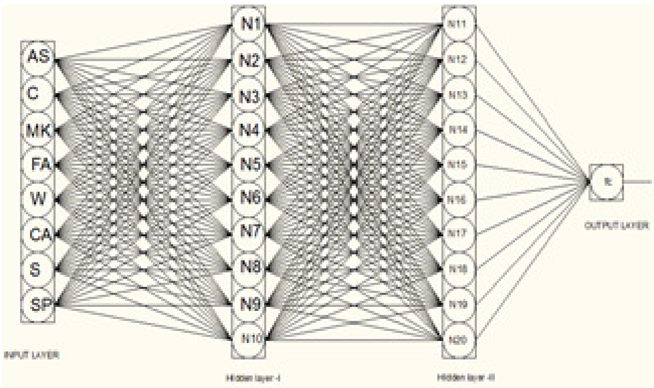

Figure 4 The system used in the ANN-II model

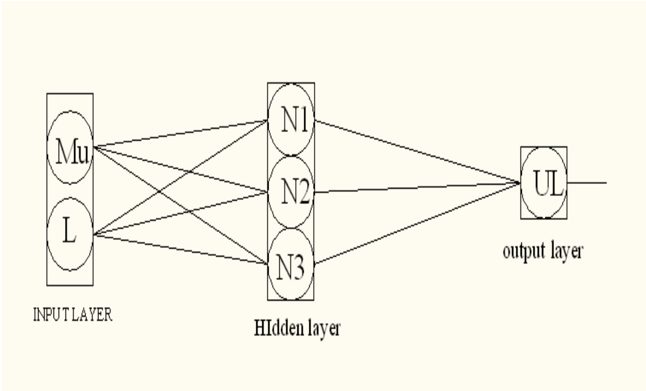

Figure 5 ANN architecture for beam

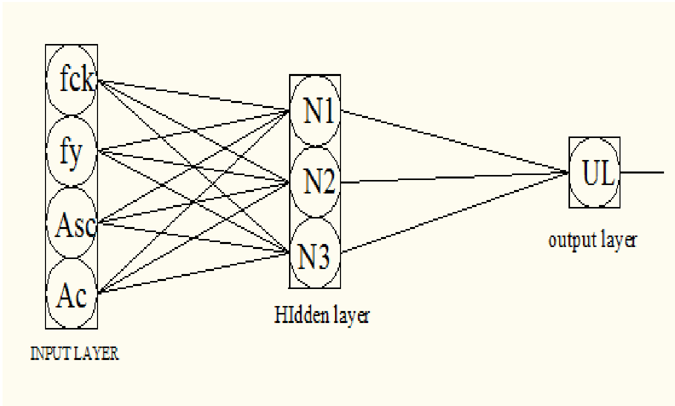

Figure 6 ANN architecture for column

1. Compressive strength of concrete mixes with and without mineral admixtures with water bonder ratio of 0.3 at various ages

Age in days	Compressive strength for 0.3 w/b (MPa)												
	NC	SF 5%	SF 7.5%	SF 10%	SF 5% FA 10%	SF 7.5% FA 10%	SF 10% FA 10%	MK 5%	MK 7.5%	MK 10%	MK 5% FA 10%	MK 7.5% FA 10%	MK 10% FA 10%
3	35.67	32	34.33	32.67	33.67	31.33	29	38	41	39.67	29.67	41.33	30.67
7	42.33	40.67	44.67	40.33	42.33	41	39.33	39.33	49.33	43.33	37.67	46.67	43.33
28	54.67	55	61.33	56.33	58.67	57.33	55.33	55.67	59	57.67	56	64	55.67
56	61.33	61.67	69.67	65.67	68.67	68.33	60.33	64.67	66.33	62.67	65.33	67	62
90	66.67	67.67	76.33	71.67	74.33	73.67	67.33	72.33	77.33	71	73.33	80.67	72.33

2. Compressive strength of concrete mixes with and without mineral admixtures with water bonder ratio of 0.32 at various ages

Age in days	Compressive strength for 0.32w/b (MPa)												
	NC	SF 5%	SF 7.5%	SF 10%	SF 5% FA 10%	SF 7.5% FA 10%	SF 10% FA 10%	MK 5%	MK 7.5%	MK 10%	MK 5% FA 10%	MK 7.5% FA 10%	MK 10% FA 10%
3	41	42	43	39	38	36.5	34.5	42.4	46	44.5	43	47.5	46.2
7	42.33	40.67	44.67	44.33	42.33	41	39.33	55.35	57.5	56.63	54.5	58.1	54.05
28	61	63	66	60	57	64	63.70	63.70	67	65.20	66	68.50	64.80
56	66	68	73.5	65	64	69	72.5	70.00	72.95	69.00	70.42	74.00	71.50
90	66.67	67.67	76.33	71.67	74.33	73.67	67.33	72.33	77.33	71	73.33	80.67	72.33

4. DURABILITY TEST RESULTS OF CONCRETE

3. Table Results of Saturated Water Absorption for Silica Fume

Replacement Percentage of Silica fume (%)	Replacement Percentage of Fly ash (%)	Wet weight (kg)	Dry weight (kg)	Water Absorption (%)
0	0	2.520	2.438	3.36
5	0	2.525	2.447	3.18
7.5	0	2.561	2.520	1.63
10	0	2.591	2.521	2.78
5	10	2.575	2.487	3.53
7.5	10	2.538	2.495	1.72
10	10	2.479	2.424	2.27

4. Table Results of Saturated Water Absorption for Metakaolin

Replacement Percentage of Metakaolin (%)	Replacement Percentage of Fly ash (%)	Wet weight (kg)	Dry weight (kg)	Water Absorption (%)
0	0	2.516	2.433	3.41
5	0	2.533	2.455	3.17
7.5	0	2.597	2.565	1.25
10	0	2.583	2.542	1.61
5	10	2.565	2.486	3.18
7.5	10	2.625	2.588	1.43
10	10	2.587	2.489	3.93

5. Table Results of Porosity for Silica fume

Replacement Percentage of Silica fume (%)	Replacement Percentage of Fly ash (%)	Dry weight (kg)	Saturated weight (kg)	Submerged weight (kg)	Porosity at 28 days (%)
0	0	2.483	2.516	1.3	2.71
5	0	2.497	2.525	1.3	2.29
7.5	0	2.530	2.561	1.3	2.46
10	0	2.561	2.591	1.3	2.33
5	10	2.546	2.586	1.3	3.11
7.5	10	2.556	2.594	1.3	2.93
10	10	2.596	2.635	1.3	2.92

6. Table Results of Porosity for Metakaolin

Replacement Percentage of Metakaolin (%)	Replacement Percentage of Fly ash (%)	Dry weight (kg)	Saturated weight (kg)	Submerged weight (kg)	Porosity at 28 days (%)
0	0	2.483	2.516	1.3	2.71
5	0	2.497	2.533	1.3	2.91
7.5	0	2.565	2.597	1.3	2.47
10	0	2.542	2.583	1.3	3.20
5	10	2.486	2.518	1.3	2.63
7.5	10	2.548	2.598	1.3	3.85
10	10	2.552	2.596	1.3	3.39

7. Table Results of Acid Attack for Silica fume

Replacement Percentage of silica fume (%)	Replacement Percentage of Fly ash (%)	Dry weight (kg)	weight after immersed in acid (kg)	Weight loss (%)
0	0	2.483	2.395	3.67
5	0	2.497	2.406	3.78
7.5	0	2.530	2.439	3.73
10	0	2.561	2.467	3.81
5	10	2.494	2.406	3.65
7.5	10	2.528	2.445	3.39
10	10	2.578	2.492	3.45

8. Table Results of Acid Attack for Metakaolin

Replacement Percentage of Metakaolin (%)	Replacement Percentage of Fly ash (%)	Dry weight (kg)	weight after immersed in acid (kg)	Weight loss (%)
0	0	2.483	2.395	3.67
5	0	2.497	2.409	3.65
7.5	0	2.565	2.494	2.84
10	0	2.542	2.447	3.88
5	10	2.568	2.486	3.29
7.5	10	2.592	2.526	2.61
10	10	2.496	2.417	3.26

9. Table Results of Permeability coefficient for concrete with mineral admixtures

Replacement Percentage (%)	Silica Fume	Silica Fume & 10%Fly ash
	Permeability coefficient x 10^{-7} cm/sec	
0	7.90	7.90
5	7.30	7.50
7.5	6.90	7.10
10	6.50	6.60

5. TEST RESULTS OF HPC CONCRETE BEAMS

11. Shear Test Results for Beam Specimen for W/b ratio 0.3

Description	**First Crack load(kN)**	**Ultimate Load (kN)**	**Deflection at Ultimate Load (mm)**
CB	30	61	8.54
SFB1	30	70	14.43
SFB2	**20**	**76**	**16.78**
SFB3	25	68	14.87
SFFB1	30	63	11.84
SFFB2	**20**	**69**	**13.33**
SFFB3	30	73	19.27
MKB1	30	74	13.5
MKB2	**35**	**90**	**24.5**
MKB3	35	85	22.85
MKFB1	30	72	20.50
MKFB2	**35**	**80**	**21.5**
MKFB3	30	68	11.5

12. Shear Test Results for Beam Specimen for W/b ratio 0.32

Description	**First Crack load(kN)**	**Ultimate Load (kN)**	**Deflection at Ultimate Load (mm)**
CB	20	29	6.83
SFB1	23	34	8.39
SFB2	**26**	**38**	**7.96**
SFB3	19	31	7.8
SFFB1	**22**	**35**	**8.12**
SFFB2	16	29	7.11
SFFB3	21	30	7.89
MKB1	22	35	8.11
MKB2	**24**	**38**	**8.63**
MKB3	21	33	7.31
MKFB1	22	34	7.98
MKFB2	**25**	**38**	**8.38**
MKFB3	20	33	7.72

13. Flexural Test Results for Beam Specimen (w/b=0.3)

Description of test specimens	First Crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
CB	30	72	15.65
SFB1	30	90	20.9
SFB2	35	95	23.6
SFB3	30	85	25.2
SFFB1	30	79.5	23.01
SFFB2	35	86	26.25
SFFB3	35	88	30.4
MKB1	35	86	15.20
MKB2	40	105	21.50
MKB3	35	95	19.85
MKFB1	35	84	19.50
MKFB2	35	93.50	18
MKFB3	40	69	9.3

14. Flexural Test Results for Beam Specimen (w/b=0.32)

Mix	First Crack load (kN)	Ult. load (kN)	Deflection at Ult.Load (mm)
CB	28	47	14.28
SFB1	37	63	17.87
SFB2	40	69	18.32
SFB3	32	58	18.59
SFFB1	39	66	16.88
SFFB2	33	64	18.65
SFFB3	30	54	17.24
MKB1	29	68	17.54
MKB2	35	70	19.69
MKB3	29	66	18.06
MKFB1	30	67	18.78
MKFB2	39	83	20.23
MKFB3	28	62	16.75

6. TEST RESULTS OF HPC CONCRETE COLUMNS

16. Short Column Testing Results (w/b ratio 0.3)

Specimen Details	% of SF/MK	% of Flyash	First Crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
SC	0	0	164	196	0.86
SSC1	5	0	147	192	0.90
SSC2	7.5	0	192	238	1.5
SSC3	10	0	168	225	1.01
SSFC1	5	10	187	230	1.34
SSFC2	7.5	10	170	223	1.05
SSFC3	10	10	156	189	0.65
SMKCI	5	0	186	238	0.98
SMKC2	7.5	0	216	252	1.16
SMKC3	10	0	189	245	1.03
SMKFC1	5	10	197	249	1.10
SMKFC2	7.5	10	224	263	1.60
SMKFC3	10	10	220	258	1.21

17. Short Column Testing Results (w/b ratio 0.32)

Specimen Details	% of SF/MK	% of Flyash	First Crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
SC	0	0	153	180	0.65
SSC1	5	0	167	225	0.86
SSC2	**7.5**	**0**	**183**	**232**	**0.98**
SSC3	10	0	160	223	0.8
SSFC1	**5**	**10**	**185**	**238**	**1.0**
SSFC2	7.5	10	180	237	1.12
SSFC3	10	10	**196**	**255**	**1.6**
SMKCI	5	0	193	245	1.32
SMKC2	**7.5**	**0**	201.5	252	2.45
SMKC3	10	0	**207**	**256.5**	**2.15**
SMKFC1	5	10	214	263	1.91
SMKFC2	**7.5**	**10**	220	265	2.04
SMKFC3	10	10	**224**	**271**	**2.26**

18. Table Long Column Testing Results (w/b ratio 0.3)

Description of Specimen	First crack load (kN)	Ultimate load (kN)	Ultimate mid-height deflection (mm)
LC	164	198	2.38
LSC1	171	195	2.35
LSC2	195	240	4.05
LSC3	185	218	3.30
LSFC1	189	220	3.45
LSFC2	178	213	3.25
LSFC3	159	191	2.20
LMKCI	188	207	2.76
LMKC2	**204**	**234**	**4.18**
LMKC3	191	223	3.42
LMKFC1	186	228	3.28
LMKFC2	**232**	**254**	**5.48**
LMKFC3	185	226	3.85

19. Table Long Column Testing Results (w/b ratio 0.32)

Description of Specimen	First crack load (kN)	Ultimate load (kN)	Ultimate mid-height deflection (mm)
LC	153	176	2.38
LSC1	165	195	2.78
LSC2	180	220	4.62
LSC3	162	213	3.62
LSFC1	160	218	3.71
LSFC2	158	204	3.85
LSFC3	178	232	5.70
LMKCI	162	218.5	10.58
LMKC2	168.5	223	11.2
LMKC3	186	237	11.5
LMKFC1	179	232	10.2
LMKFC2	181.4	236.5	12.02
LMKFC3	193	240	11.63

7. CONCLUSIONS

Artificial neural networks are capable of learning and generalizing from examples and experiences. This makes artificial neural networks a powerful tool for solving some of the complicated civil engineering problems. In this study, using these beneficial properties of artificial neural networks in order to predict the 3, 7, 14, 28, 56, and 90 compressive strength, durability, ultimate load of beams and columns of concretes containing metakaolin and silica fume along with fly ash without attempting any experiments were developed with two different multilayer artificial neural network architectures namely ANN-I and ANN-II. In the two models developed in ANN method, a multilayered feed forward neural network with a back propagation algorithm was used. In ANN-I model, one hidden layer was selected. In the hidden layer 10 neurons were determined. In ANN-II model, two hidden layers were selected. In the first hidden layer ten neurons and in the second hidden layer ten neurons were determined. The models were trained with input and output data. Using only the input data in trained models the 3, 7, 28, 56, and 90 days compressive strength, durability, ultimate load of beams and columns of concretes containing metakaolin and silica fume were found. The compressive strength, durability, ultimate load of beams and columns of concrete values predicted from training and testing, for ANN-I and ANN-II models are very close to the experimental results. Furthermore, according to the compressive strength, durability, ultimate load of beams and columns of concrete results predicted by using ANN-I and ANN-II models, the results of ANN-II model are closer to the experimental results. RMS, R^2 and MAPE statistical values that are calculated for comparing experimental results with ANN-I and ANN-II model results have shown this situation. As a result, compressive strength, ultimate load 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. The obtained conclusions have demonstrated that multilayer feed forward artificial neural networks are practicable methods for predicting compressive strength values of concretes containing metkaolin and silica fume.

REFERENCES

[1] Mustafa Sarıdemir, Prediction of compressive strength of concretes containing metakaolin and silica fume by artificial neural networks, Advances in Engineering Software 40 (2009) 350–355.

[2] Emre Sancak, Prediction of bond strength of lightweight concretes by using artificial neural networks, Scientific Research and Essay Vol. 4 (4), pp. 256-266, April, 2009.

[3] Vu DD, Stroeven P and Bui VB, Strength and durability aspects of calcined kaolinblended Portland cement mortar and concrete, Cement Concrete Compos 2001; 23 (6):471–8.

[4] Poon CS, Kou SC and Lam L, Compressive strength, chloride diffusivity and pore structure of high performance metakaolin and silica fume concrete, Constr Build Mater 2006; 20 (10):858–65.

[5] Parande AK, Babu BR, Karthik MA, Deepak Kumaar KK and Palaniswamy N, Study on strength and corrosion performance for steel embedded in metakaolin blended concrete/mortar, Constr Build Mater 2008; 22(3):127–34.

[6] FEMA 356 (2000), Pre standard and Commentary for the Seismic Rehabilitation of Buildings, American Society of Civil Engineers, Reston, VA.

[7] Mr. Supratip Mondal and Sulagno Banerjee High Strength & High Performance Concrete, International Journal of Civil Engineering and Technology, 8(6), 2017, pp. 782–786.

[8] R. Bhuvaneswari, M. Jagadeesh, E. Ezhilarasi, A. Thangadurai and P. Magudeaswaran, Microstructural Study on High Performance Concrete Made with M Sand. International Journal of Civil Engineering and Technology, 8(3), 2017, pp. 628–636

[9] Al-Amoudi OSB, Maslehuddin M, Shameem M and Ibrahim M., Shrinkage of plain and silica fume cement concrete under hot weather, Cement Concrete Compos 2007; 29 (9): 690–9.

[10] Curciol F, Deangelis BA. Dilatant "behavior of superplasticized cement pastes containing metakaolin"Cement Concrete Res 1998; 28(5):629–34.