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International Journal of Current Research
Vol. 9, Issue, 02, pp.47137-47143, February, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ASSESSMENT OF STRENGTH OF REINFORCED CONCRETE BEAMS SUBJECT TO CORROSION USING ARTIFICIAL NEURAL NETWORK

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ARTICLE INFO

Article History:

Received 23rd November, 2016
Received in revised form
10th December, 2016
Accepted 29th January, 2017
Published online 28th February, 2017

Key words:

Artificial Neural Network,
Back Propagation,
Electrochemical Test,
Ultrasonic Pulse Velocity Test and
Rebound Hammer Test.

ABSTRACT

Deterioration of structure is occur due to poor workmanship, poor maintenance, adverse atmospheric effects, natural calamities and etc. The aim of this paper is to assess strength of corroded reinforce concrete beams by using Non-Destructive Test (NDT) methods such as half shell potential test, Rebound hammer test, and ultrasonic pulse velocity test . These experimental results are compared with Artificial Neural Network. Total six reinforced concrete beams (150x150x1000) mm were considered. An impressed current was induced to beams with two different degree of corrosion (5%. &10%) in order to accelerate corrosion in reinforcement. Electrochemical measurements were carried out to obtain open circuit potential. Result show that the linear regression analysis is the best fit for the compressive strength prediction relationship by using Rebound hammer and Ultrasonic pulse velocity test at compression as well as tension side of reinforced concrete beam with two different degree of corrosion(5%, &10%) . In continuation with experimental, Artificial Neural Network (ANN) is used to predict corrosion, Four layered ANN pattern is selected, Back propagation algorithm has been used for training. A learning rate constant of 0.9, error tolerance 0.001, and 6000 cycles are used for training ANN. Delta rule is used for adjusting the weights. It is found that a four-layer network (6-8-8-2) consists of 6 input neurons , two hidden layers of 8 neurons each and two output neuron is efficiently converges almost close to experimental results with an allowable error range.

Citation: Jayaramappa, N. and Rekha, H.B.. 2017. "Assessment of strength of reinforced concrete beams subject to corrosion using artificial neural network", *International Journal of Current Research*, 9, (02), 47137-47143.

INTRODUCTION

Artificial neural networks (ANN) have emerged as a computationally powerful tool in artificial intelligence with the potential of mapping an unknown nonlinear relationship between the given set of inputs and outputs. Their application can be widely seen in Civil Engg field such as design, analysis, and optimization. The network consists of some layers of interconnected Neurons. In the computational model this is represented by an activation function. Which includes a set of weights associated with each input value. The learning process is used to determine the proper weights. An Artificial Neural network composes of a number of interconnected units (artificial neurons). Each unit has an input/output characteristic and implements a local computation or function. The output of any unit is determined by its Input / Output characteristics, its interconnection to the other unit and external input, the network uses supervised learning using generalized delta rule.

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The corrosion of reinforcing steel in concrete structure leads to the failure of structures. Rust products form on the bar, expanding its volume and creating stress in the surrounding concrete. This leads to cracking and sapling, both of which can severely reduce the strength of a member. Corrosion of reinforcing steel in concrete structures is one of the major expensive problems facing the Civil Engineers all around the world. There have been many tests reported in literature for the assessment of the corrosion of steel in concrete. Most of the earlier tests, primarily through field exposure could provide only qualitative information, while in the recent year researchers have been utilizing some of the techniques like electrochemical tests as well as non-destructive methods to establish precise and quantitative results. The non-destructive testing is the method to evaluate strength of hardened concrete, which is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is attained the designed strength, for its designed use. Ideally, such testing should be done without damaging the structure. The tests available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests where the surface has to be repaired after the test. Half cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete .Ultrasonic pulse velocity testing , mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.

Research Significance

Strength of structure is an important to take up the design load and design life of structure corrosion leads to failure of structure earlier to design life , hence to evaluation of strength of Structure suffered by corrosion, experiment was carried out to two different degree of corrosion (5%. &10%). This research illustrates the interactions among degree of corrosion rate with age in days, ultrasonic pulse velocity, rebound hammer number, concrete compressive strength of reinforced concrete beams. The objective of this study is to provide a reliable data base for effectiveness of different degree of corrosion on corrosion damage assessment of reinforced concrete beams and application of ANN Thus the results may provide researchers insight into corrosion damage evaluation of reinforced concrete beams by using NDT methods and compare with ANN. Use of ANN is to predict strength of structure in corroded RC beams.

Experimental Investigation

Basic Tests on Cement

In the present investigation ordinary Portland cement of grade 53 is used. Tests are conducted in accordance with the Indian standards confirming to IS-12269-1987.

Test on Fine Aggregate

It is desirable to use coarse sand having high fineness modulus. Generally, fractions passing through 4.75 mm sieves and entirely retained on 150u sieve are used. Locally obtained Natural River sand is used as the fine aggregate in the concrete mix. The test on fine aggregate was conducted in accordance with IS 650-1966 & IS 2386-1968 to determine the specific gravity and the fineness modulus. The sand is confirming to zone-II as per Indian standards.

Test on Coarse Aggregate

Crushed Granite stone with a Maximum nominal size 12mm and down was adopted as the coarse aggregate. The tests on coarse aggregate were conducted in accordance with IS 2386-1963 to determine specific gravity and fineness modulus and other tests are carried out as per IS codes.

Experimental Work

Six beams of 1000 mm span with cross section 150 mm x150 mm were cast , using 2 of 12mm bars (Fe- 415) as tension reinforcement, 2of 8 mm bars as compression reinforcement, and 6 numbers of 6 mm dia at 150 mm c/c stirrups are used . The mean compressive strength of concrete used for concrete beam is 35.21N/mm^2. The concrete mix used was 1:1.53.3.2 by weight with a water-cement ratio of 0.49. Out of six beams, two beams were subjected to different degree of corrosion under accelerated corrosion by constant current source (Dc= 5% and 10% of rebar mass loss). The details of reinforced concrete beam are shown in Fig.1.

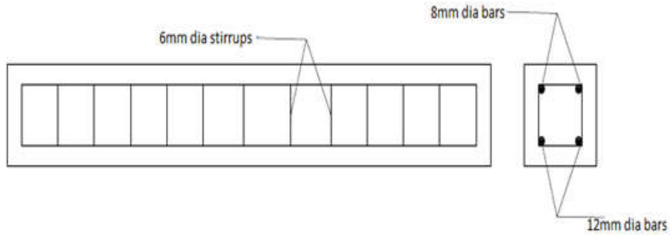

Fig.1. Reinforcement details of RC beam tested

Corrosion Process Induced in RC Beams

The RC beams were immersed to an accelerated corrosion process in an electrolytic cell by means of supply direct current. An electric current was passed to the main longitudinal bottom reinforcing bars of about 5000 m A by using converter. And this set up was placed in the 3.5% NaCl solution (solution is prepared as per experts suggestion), which acted as an electrolyte and the solution level in the tank was adjusted to slightly exceed the concrete cover plus rebar diameter. Fig.2 and fig .3 shows the experimental work carried out in Civil Engineering Department of Bangalore University.

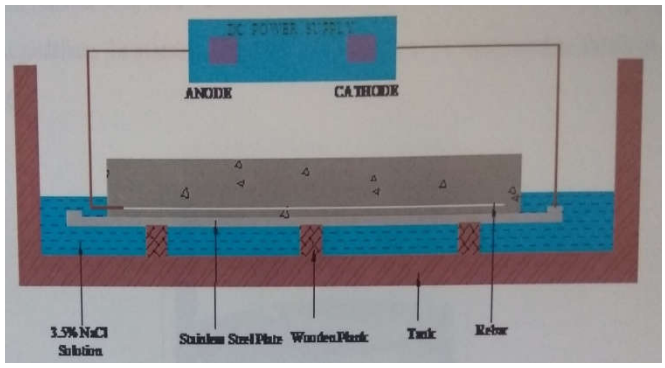

Fig. 2. Layout of Experiment

Fig.3. Layout of Experimental setup

As per Faraday's law, the time for accelerated corrosion was alculated as 18.30 hr, and 45.31 hr for 5%, &10% mass loss (corrosion) of tension steel. In order to evaluate strength of hardened concrete, rebound hammer test was carried out on compression as well as tension side, before and after corrosion induced in RC beams for different degree of corrosion at eleven different locations that are equally distributed along a beam to measure the surface hardness of concrete by releasing a spring loaded plunger which impacts the concrete and measures the rebound distance.

It is also well known fact that the test method of rebound hammer for normal concrete has been well documented by ASTM C 805 (10), in turn this code procedure was followed in the present study for the evaluation of the rebound hammer number. Fig. 4 shows the rebound hammer test carried out to evaluate the strength of hardened concrete and table 1 shows the results obtained from rebound hammer.

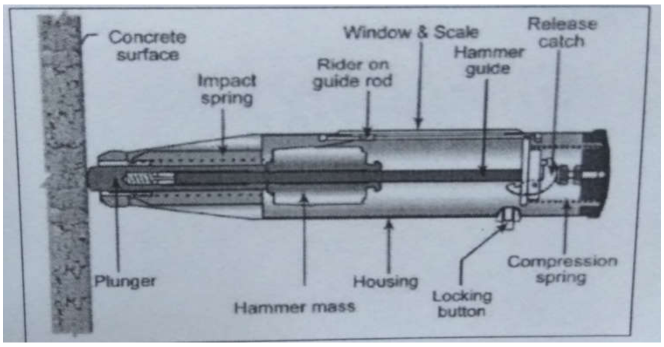

Fig.4. Layout of Rebound Hammer

Table 1. Average Rebound number and quality of concrete

Sl. No.	Average Rebound Number	Quality of Concrete
1	>40	Very good hard layer
2	30 to 40	Good layer
3	20 to 30	Fair
4	<20	Poor concrete
5	0	Delaminated

Ultrasonic pulse velocity (UPV) test is also carried out to evaluate with opposite faces (direct transmission) was carried out as per IS : 13311-Part (11) on corrosion damaged RC beams for different degree of corrosion (5% and 10%) at eleven different locations that are equally distributed along length of beam and ultrasonic pulse velocity reading are recorded both at compression as well as tension side. This test is conducted for assessing the quality and integrity of concrete by passing ultrasound waves through the specimen or RCC member under test. Ultrasonic pulse velocity test is also used to identify the honeycombs, voids and structural cracks developed in the concrete. This instrument consists of a transmitter and a receiver, transmitter and the receiver shall kept opposite to each other, to receive the signals, the time to travel of the wave to pass from the transmitter to the receiver will be measured, table 2 shows the results obtained from UPV.

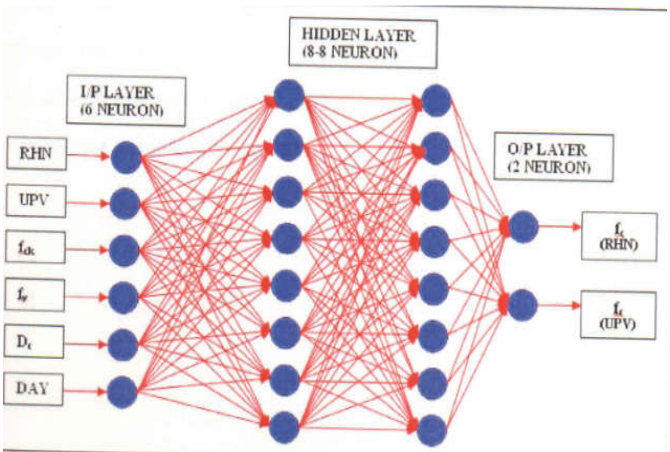

Fig. 5. Artificial Neural Network

Table 2. UPV value and concrete quality

Sl.No.	UPV value in km/sec (V)	Concrete quality
1	V greater 4.0	Very good
2	V between 3.5 and 4.0	Good, but may be porous
3	V between 3.0 and 3.5	Poor
4	V between 2.5 and 3.0	Very poor
5	V between 2.0 and 2.5	Very poor low integrity
6	V less than 2.0 and reading fluctuating	No integrity, large voids suspected

Artificial Neural Network

The second objective of this paper, is to predict the corrosion of reinforcement in beams using ANN. Proposed four-layer ANN is as shown in fig.5. The input data contains the normalized values of 12. Back propagation algorithm has been used for training. A learning rate constant of 0.9, error tolerance 0.001,and 6000 cycles are used for training. Delta rule is used for adjusting the weights. The network uses supervised learning using generalized delta rule.

Initially the weights are randomly regenerated and as the iterations continue, the weights get modified to approximate values. About 6 input values were used while training the net work. The final weights assigned byANN is shown in table-1. The table-2 shows the results obtained from ETABS and ANN, last column of the table -2 shows the percentage of error between ETABS results and ANN predicted values. Table 12 to 15 shows the comparison of results.

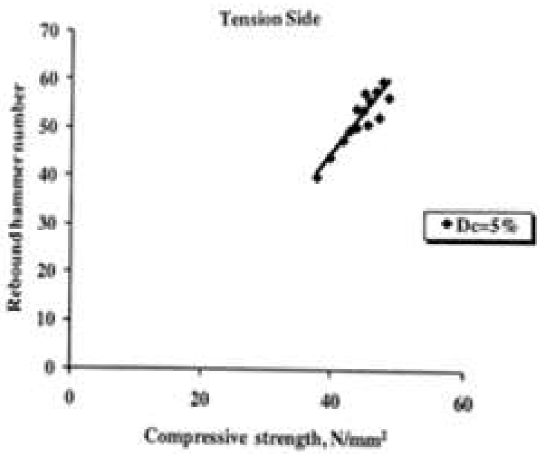

Fig. 6a. RHN Vs Compressive strength

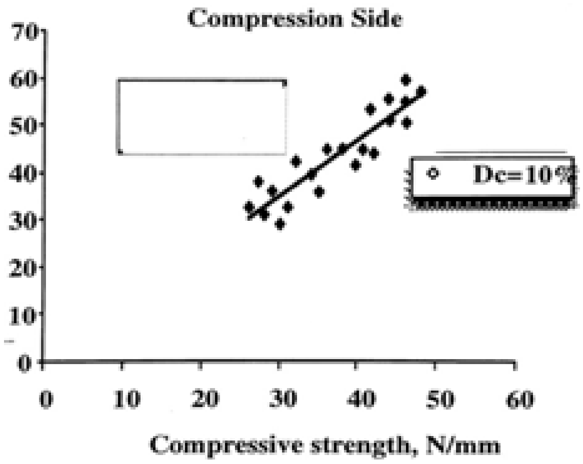

Fig. 6b. RHN Vs Compressive strength

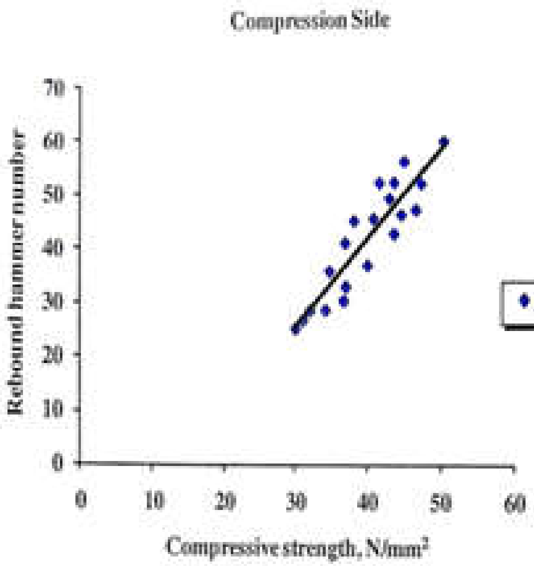

Fig . 7a. RHN Vs Compressive strength

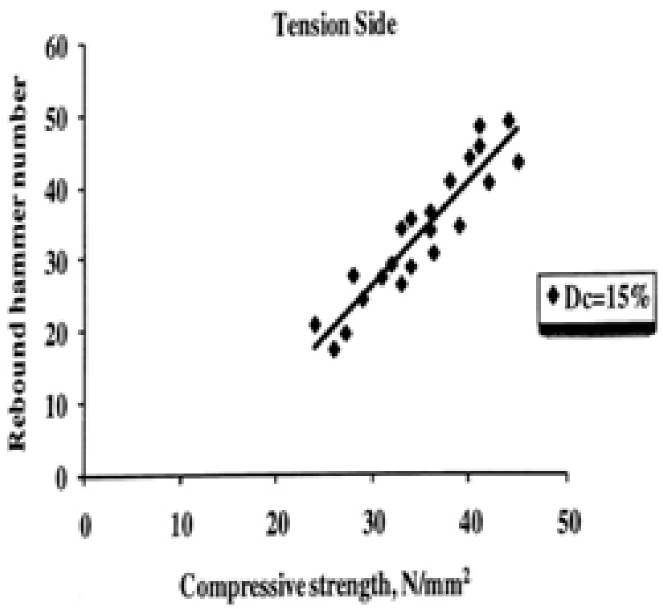

Fig. 7b. RHN Vs Compressive strength

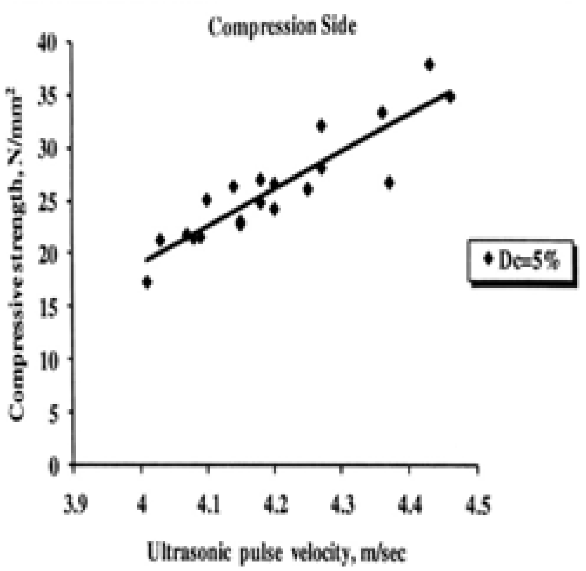

Fig.8a. Compressive strength Vs UPV

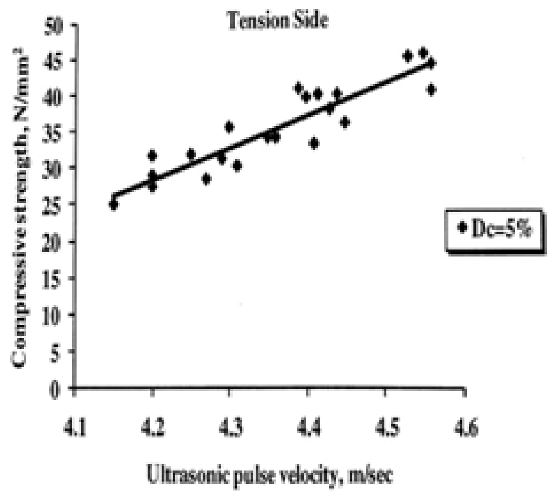

Fig. 8b. Compressive strength Vs UPV

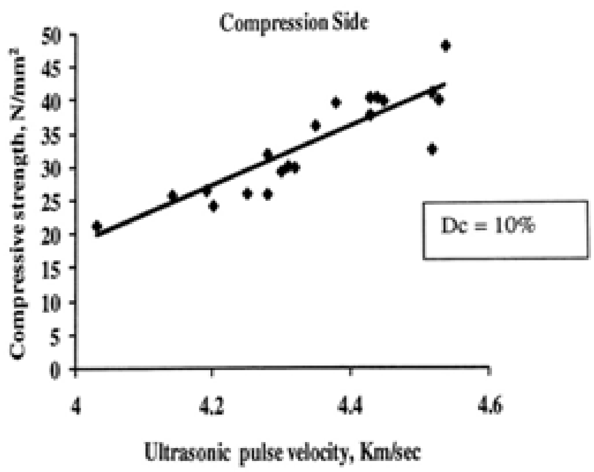

Fig.9a. Compressive strength Vs UPV

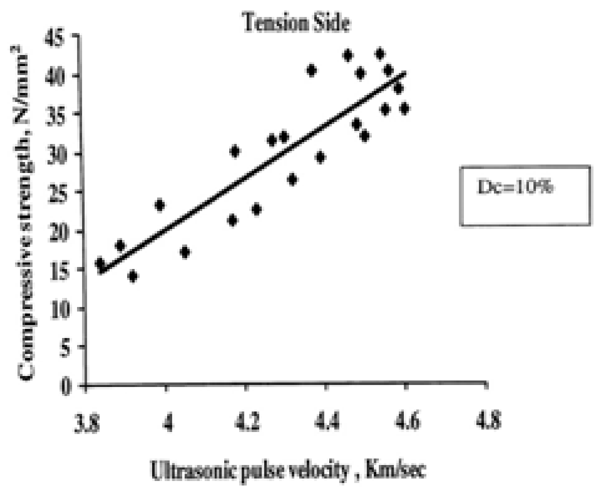

Fig. 9b. Compressive strength Vs UPV

Table 6 Results of beam 1

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	33	4.4	55	4.5
2	49	4.4	57	4.5
3	46	4.2	55	4.3
4	45	4.2	57	4.5
5	52	4.2	55	4.4
6	36	4.1	55	4.4

Table 7. Results of beam 2

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	51	4.4	33	4.4
2	50	4.2	45	3.9
3	44	4.3	40	4.3
4	44	4.4	40	4.5
5	41	4.4	36	4.4
6	55	4.3	43	4.5

Table 8. Results of beam 3 subjected to 5%

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	45	4.1	39	4.1
2	52	4.1	26	4.1
3	20	3.9	41	3.9
4	30	3.8	49	4.2
5	47	3.9	28	4.1
6	32	4.0	27	4.1

Table 9. Results of beam 4 subjected to 5%

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	50	3.8	46	3.9
2	55	3.8	51	3.8
3	48	3.9	50	3.9
4	50	3.9	54	4.1
5	27	3.7	53	4.0
6	34	3.8	51	4.1

Table 10. Results of beam 5 subjected to 10%

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	41	4.0	36	4.0
2	42	3.9	22	3.9
3	40	4.1	33	3.9
4	39	3.9	25	4.0
5	38	4.0	29	4.1
6	39	3.9	35	4.2

Table 11. Results of beam 6 subjected to 10%

Sl.No	Beam TOP (Compression)		Beam BOTTOM (Tension)	
	RHN	UPV	RHN	UPV
1	25	3.7	36	3.6
2	33	3.8	29	3.9
3	33	3.9	38	3.9
4	40	3.8	28	4.0
5	38	3.8	41	3.9
6	28	3.9	25	4.0

RESULTS AND DISCUSSION

Rebound Hammer Test

The Rebound Hammer (RH) results are provides a surface hardness strength. Rebound hammers test the surface hardness of concrete, which cannot be converted directly to compressive strength. There is a considerable amount of scatter in rebound numbers because of the heterogeneous nature of near surface properties. There are several factors other than concrete strength that influence rebound hammer test results. Including surface smoothness and finish, moisture content, aggregate type, and the presence of carbonation. In the present study Rebound hammer test was carried out both at compression side as well as tension side of the beam before and after the corrosion inducement in the beam with different degree of corrosion. Figs 6a, fig 6b,fig 7a, and fig 7b shows the results.

Ultrasonic Pulse Velocity Test

Another method of evaluating the strength of hardened concrete is Ultrasonic Pulse Velocity (UPV)test, this test involves measuring the velocity of sound through hardened concrete . This technique is applied to measurements of composition, strength estimation, homogeneity, elastic modulus, age, presence of defects and crack depth. In the present study UPV test was carried out both at compression side as well as tension side of the beam before and after the corrosion inducement in the beam with two different degree of corrosion (5%, 10%). The variations of Compressive strength versus Ultrasonic pulse velocity for compression side as well as tension side of beam with different degree of corrosion such 5% are plotted. Fig .8a, fig.8b, and for 10% fig.9a, and fig.9b. The results of Rebound hammer number (RHN) and Ultrasonic pulse velocity (UPV) before and after corrosion for few beams with different degree of corrosion are compared and tabulated in the tables 1 to 11.

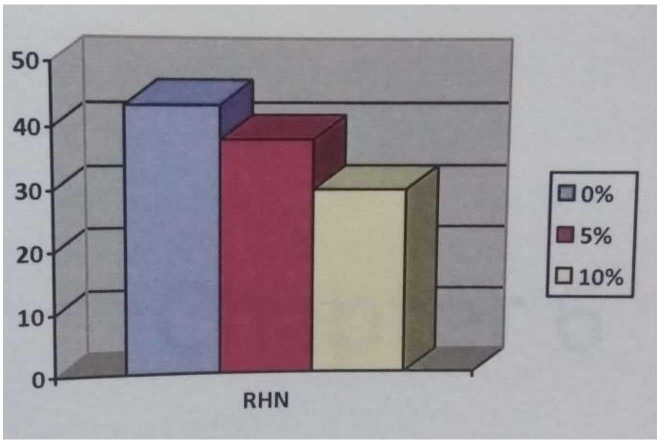

Fig 10. RHN variation with indusion of corrosion

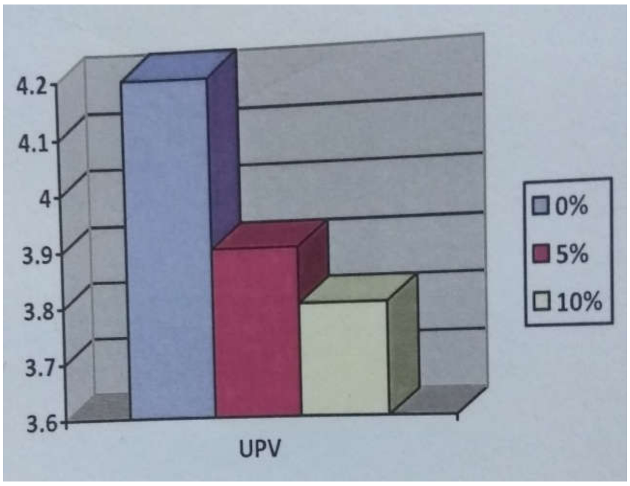

Fig 11.UPV value variation with indusion of corrosion

Results of Artificial Neural Network

Table 12 to 15 shows the results obtained for beam before and after the corrosion inducement in the beam with different degree of corrosion (5%, 10%) using ANN.

Table 12. Results of beam 6 subjected to 5% top surface strength

Sl No.	Input values						Results of ANN	
1	RHN	UPV	Fck	Fy	Dc	day	CR	CU
2	0.033	0.0044	0.025	0.415	0.00	0.00	0.036	0.039
3	0.049	0.0044	0.025	0.415	0.00	0.00	0.037	0.0365
4	0.046	0.0042	0.025	0.415	0.00	0.00	0.0359	0.0395
5	0.045	0.0042	0.025	0.415	0.00	0.00	0.0396	0.0389
6	0.052	0.0042	0.025	0.415	0.00	0.00	0.038	0.0379
7	0.036	0.0041	0.025	0.415	0.00	0.00	0.0361	0.0415
8	0.051	0.0044	0.025	0.415	0.00	0.00	0.039	0.0410
9	0.050	0.0042	0.025	0.415	0.00	0.00	0.0387	0.0396
10	0.044	0.0043	0.025	0.415	0.00	0.00	0.0376	0.0389
11	0.044	0.0044	0.025	0.415	0.00	0.00	0.040	0.0381
12	0.041	0.0044	0.025	0.415	0.00	0.00	0.039	0.0398
13	0.055	0.0043	0.025	0.415	0.00	0.00	0.040	0.0385

Table 13. Results of beam 6 subjected to 10% top surface strength

Sl No.	Experimental Results						Results of ANN	
1	HN	UPV	Fck	Fy	Dc	day	CR	CU
2	0.055	0.0045	0.025	0.415	0.00	0.00	0.0391	0.0385
3	0.057	0.0045	0.025	0.415	0.00	0.00	0.0410	0.0394
4	0.055	0.0043	0.025	0.415	0.00	0.00	0.038	0.0379
5	0.057	0.0045	0.025	0.415	0.00	0.00	0.0415	0.0359
6	0.055	0.0044	0.025	0.415	0.00	0.00	0.039	0.0389
7	0.055	0.0044	0.025	0.415	0.00	0.00	0.0395	0.0391
8	0.033	0.0044	0.025	0.415	0.00	0.00	0.0375	0.0398
9	0.045	0.0039	0.025	0.415	0.00	0.00	0.0386	0.0397
10	0.040	0.0043	0.025	0.415	0.00	0.00	0.039	0.0358
11	0.040	0.0045	0.025	0.415	0.00	0.00	0.0410	0.0387
12	0.036	0.0044	0.025	0.415	0.00	0.00	0.040	0.0398
13	0.043	0.0045	0.025	0.415	0.00	0.00	0.041	0.0395

Table 14. Results of beam 6 subjected to 5% bottom surface strength

Sl No.	Experimental Results							Results of ANN
1	0.042	0.0045	0.025	0.415	0.00	0.00	0.0395	0.0391
2	0.026	0.0045	0.025	0.415	0.00	0.00	0.0385	0.0392
3	0.045	0.0043	0.025	0.415	0.00	0.00	0.0375	0.0387
4	0.054	0.0045	0.025	0.415	0.00	0.00	0.0398	0.0385
5	0.029	0.0044	0.025	0.415	0.00	0.00	0.0395	0.0389
6	0.027	0.0044	0.025	0.415	0.00	0.00	0.0410	0.0379
7	0.049	0.0042	0.025	0.415	0.00	0.00	0.0401	0.0395
8	0.055	0.0041	0.025	0.415	0.00	0.00	0.0391	0.0391
9	0.055	0.0042	0.025	0.415	0.00	0.00	0.0393	0.0381
10	0.057	0.0043	0.025	0.415	0.00	0.00	0.0406	0.0391
11	0.059	0.0044	0.025	0.415	0.00	0.00	0.0396	0.0381
12	0.055	0.0044	0.025	0.415	0.00	0.00	0.0387	0.0391

Table 15. Results of beam 6 subjected to 10% bottom surface strength

Sl No.	Experimental Results							Results of ANN
1	HN	UPV	Fck	Fy	Dc	day	CR	CU
2	0.039	0.0041	0.025	0.415	0.005	0.002	0.0401	0.0398
3	0.026	0.0041	0.025	0.415	0.005	0.002	0.0398	0.0387
4	0.041	0.0039	0.025	0.415	0.005	0.002	0.0387	0.0376
5	0.049	0.0042	0.025	0.415	0.005	0.002	0.0386	0.0379
6	0.028	0.0041	0.025	0.415	0.005	0.002	0.0394	0.0398
7	0.027	0.0041	0.025	0.415	0.005	0.002	0.0386	0.0381
8	0.046	0.0039	0.025	0.415	0.005	0.002	0.0394	0.0379
9	0.051	0.0038	0.025	0.415	0.005	0.002	0.0376	0.0398
10	0.050	0.0039	0.025	0.415	0.005	0.002	0.0367	0.0389
11	0.054	0.0041	0.025	0.415	0.005	0.002	0.0395	0.0378
12	0.053	0.0040	0.025	0.415	0.005	0.002	0.0392	0.0374
13	0.051	0.0041	0.025	0.415	0.005	0.002	0.0367	0.0376

Conclusion

The following conclusions are drawn by observing the experimental and ANN results. It was observed from test that, the statistical risk of corrosion was around 40-50%, 50-75% in case of two different degree of corrosion (Dc 5%, 10%). It was observed from the Rebound hammer test that performed at the compression and tension side of the beam depicts 85%, 83%, rebound hammer number as well as compressive strength data was correlated on compression side as well as 87%, 85.7%, on tension side of the beam for different degree of corrosion (Dc 5%, 10%)

- It was confirmed from the Ultrasonic pulse velocity test that performed at the compression and tension side of the beam depicts 82.10%, 71.70
- It was observed from test result that Rebound hammer number as well as ultrasonic pulse velocity and compressive strength data values was vary (coefficient of correlation convergence) extensively both in compression and tension side of the beam for in case of lower degree of corrosion (Dc=5%) as when compared to higher degree of corrosion (Dc=10%) .
- ANN is able to predict the strength in corroded beams almost close to experimental results.

REFERENCES

Al-Sulaimani, G.J. 1990. Kaleemullah, M. Basunbul, I.A. and Rasheeduzzafar, "Influence of Corrosion and cracking on Bond Behaviour and Strength of Reinforced Concrete Members. ACI Structural Journal. V 87, No 2, pp 220-231

Carino. N.J. 1967. Non-destructive Test Methods, Concrete Construction Engineering Handbook, ed. E .G. Nawy, CRC Press, 19.1.

Deputat. J. 1997. "Non-destructive evaluation methods of material properties". Gamma(in Polish), Warszawa.

Mehta, P. K, and Gerwick, B. C. 1982. "Cracking-Corrosion Interaction in Concrete Exposed to Marine Environment," Concrete International, v. 4, No. 10, Oct. pp. 45-51.

Wang, K., and Monteiro, P. I. 1996. "Corrosion Products of Reinforcing Steel and their Effects on the Concrete Deterioration." Third CANMET/ACI international Conference on Performance of Concrete in Marine Environment, P. K. Mehta, ed. New Brunswick, Canada. Aug. 4-9, pp. 83-97.

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