APPLICATION OF ANN FOR ULTIMATE SHEAR STRENGTH OF FLY ASH CONCRETE BEAMS

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Abstract

The application of artificial neural networks (ANN) for ultimate shear strength of fly ash concrete beams with transverse reinforcement is investigated in this paper. An ANN model is built, trained and tested using the available test data of 216 RC beams collected from the literature also the experimental data of twenty seven fly ash concrete beams under shear. The experimental shear strength were also compared to those obtained using building codal equations and empirical equations proposed by various researchers. The ANN model was found to predict satisfactorily when compared to available analytical predictions.

***Keywords**: Artificial Neural Network (ANN), Building codes, Comparison, Charts, Empirical Equations, Fly ash Concrete, Shear Strength.*

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1. INTRODUCTION

Artificial neural networks are, by definition, interconnected networks of processing elements that have the ability to be trained to map a given input into the desired output. ANN's possess some distinctive properties not found in conventional computational models. In most cases however, there are only observational data of the problem, while the underlying rules relating the input variables to the output variables are either unknown or extremely difficult to discover. Under these circumstances, ANN's exhibit their superiorities over conventional computational techniques. ANN's are composed of many interconnected processing units. Each processing unit keeps some information locally, is able to perform some simple computations, and can have many inputs but can send only one output. The ANN's have the capability to respond to input stimuli and produce the corresponding response, and to adapt to the changing environment by learning from experience. Therefore, in order for researchers to use ANN's as a predictive tool, data must be used to train and test the model to check its successfulness.

The manner in which the neural elements (neurons, layers, biases, etc.,) are connected determines the network architecture and the number of neurons and layers determines the network size. Sometimes there is also a constant value, or bias, that is added to the input signals. The unit then calculates the net input, which is a weighted sum of its inputs plus the bias value:

$$net_i = \sum w_{ij} A_j + b_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (1)$$

2. NEURAL NETWORK MODEL

In this study, a computer programmed tool was used to develop an ANN model for predicting the ultimate shear strength of fly ash concrete beams. The program requires the following input data:

- The total number of data that is presented (in this case, 216 RC beams + 27 fly ash concrete beams were considered) under shear. The computer program uses 68.14% of the data for training, 15.93% for validation and 15.93% for testing.
- The number of input neurons (9 in this study) and the output neurons (1 in this study).
- In the current analysis a Levenberg-Marquardt[12] learning algorithm, an approximation to Newton's method more is used. The LM algorithm is efficient in terms of high speed of convergence and reduced memory requirements compared to the two previous methods. In general, with networks that contain up to several hundred weights, the LM algorithm has the fastest convergence.
- To determine the best performance network a trial and error search procedure was employed to determine the number of hidden layers in the network.
- For a given architecture and a fixed number of iterations say 500, the number of hidden layers was altered and the network which provides the least error (test data) is selected.

Table 1- The following nine variables are used as input parameters:

Input parameters	**B (mm)**	**D (mm)**	**a/d**	**f'_c (MPa)**	**ρ (%)**	**ρ_v (%)**	**f_y (Mpa)**	**f_{vy} (Mpa)**	**d_a (mm)**
Range (min-max)	64-356	140-575	1.1-2.5	13.79-120	0.16-3.77	0.074-2.7	320.6-931	250-1238	7-25

3. NETWORK TRAINING ANALYSIS

In the present work, the best architecture was 9-17-1 i.e. 9 inputs, 17 hidden layers and 1 output. The data of the 243 beams are grouped randomly into training, validating and testing set before presenting them to the network for analysis.

4. EXPERIMENTAL WORK ON FLY ASH CONCRETE BEAMS

To understand the behavior of fly ash concrete beams two cement replacement levels by fly ash are considered viz. 20% and 35%.Mix design of normal concrete (without fly ash) of grade M40 was obtained as per IS method as outlined in IS: 10262-1982.Mix proportion that arrived at for normal concrete itself was adopted for fly ash concrete, with only change in certain replacement of cement by fly ash (i.e 20% to 35%).

Table: 2 -Mix Proportions for Normal Concrete

Cement Kg/m^3	Water Kg/m^3	Fine Aggregates Kg/m^3	Coarse Aggregates Kg/m^3	Water/Cement ratio Kg/m^3
385	140	862	1097	0.364

Table.3 -Details of the tested beams with Failure loads

B (mm)	**D (mm)**	**a/d**	**f'_c (MPa)**	**P (%)**	**ρ_v (%)**	**f_y (Mpa)**	**f_{vy} (Mpa)**	**d_a (mm)**	**EXP V_u (KN)**
125	225	1.77	50.90	0.91	0.53	415	415	12	130
125	225	1.77	68.30	1.60	0.53	415	415	12	200
125	225	1.77	64.00	2.23	0.53	415	415	12	230
125	225	1.77	60.75	0.91	0.40	415	415	12	146
125	225	1.77	61.04	1.60	0.40	415	415	12	190
125	225	1.77	57.40	2.23	0.40	415	415	12	260
125	225	1.77	53.41	0.91	0.53	415	415	12	130
125	225	1.77	55.08	1.60	0.53	415	415	12	210
125	225	1.77	56.68	2.23	0.53	415	415	12	250
125	225	1.77	54.64	0.91	0.40	415	415	12	140
125	225	1.77	51.60	1.60	0.40	415	415	12	220
125	225	1.77	50.14	2.23	0.40	415	415	12	240
125	225	1.77	51.30	0.91	0.34	415	415	12	138
125	225	1.77	52.32	1.60	0.34	415	415	12	180
125	225	1.77	50.00	2.23	0.34	415	415	12	270
125	225	1.77	65.40	0.91	0.34	415	415	12	140

125	225	1.77	68.30	1.60	0.34	415	415	12	228
125	225	1.77	66.53	2.23	0.34	415	415	12	250
125	225	1.77	58.86	0.91	0.53	415	415	12	140
125	225	1.77	60.70	1.60	0.53	415	415	12	220
125	225	1.77	58.42	2.23	0.53	415	415	12	240
125	225	1.77	55.51	0.91	0.40	415	415	12	138
125	225	1.77	52.84	1.60	0.40	415	415	12	180
125	225	1.77	51.68	2.23	0.40	415	415	12	270
125	225	1.77	52.25	0.91	0.34	415	415	12	140
125	225	1.77	60.00	1.60	0.34	415	415	12	228
125	225	1.77	66.45	2.23	0.34	415	415	12	250

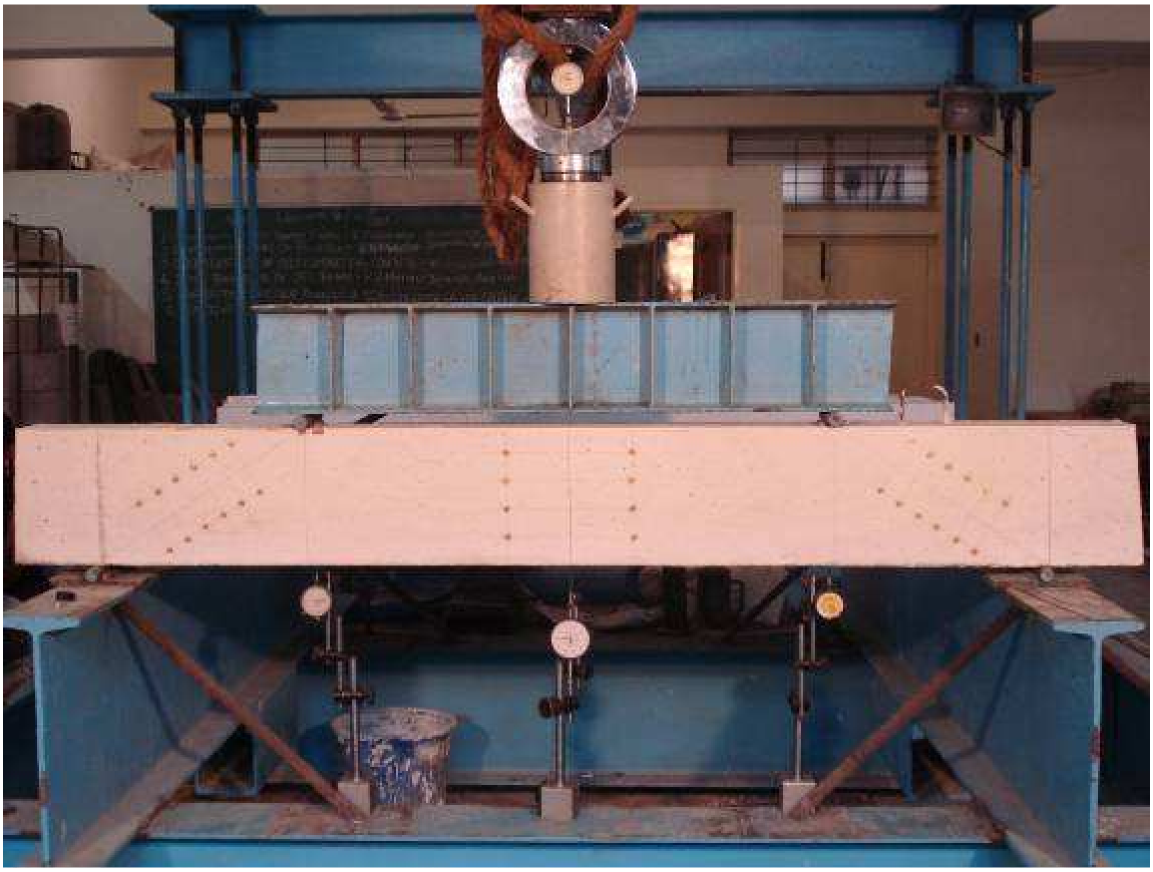

Fig: 1 Test Setup

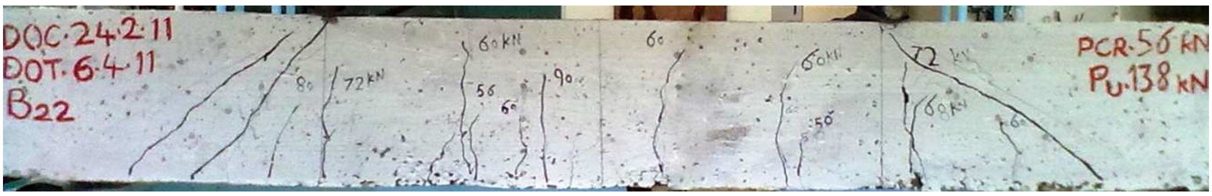

Fig.2 Crack Pattern of Fly ash Concrete Beam

5. THEORETICAL COMPUTATION OF ULTIMATE SHEAR STRENGTH

Ultimate Shear strength was computed using various codes of practices and various other researchers as listed below:

Codal Equations	Researchers Equation
ACI 318-12	Zsutty (1971)
CSA A23.3-94	Bazant and Kim (1984)
Euro code EN 1992-1-1	Kim and Park (1996)
German code DIN 1045-1	Rebeiz (1999)
Japanese Code	Collins and Kuchma (1999)
CEB-FIP model code	Sarkar et al. (1999)
British Standards BS-8110	Gastebled and May (2001)
New Zealand Code NZS	Kim et al. (2003)
Australian Code, AS 3600	Desai (2004)
Norwegian Code, NS 3473E	Cladera and Mari (2004)
Indian Code of practice	

6. RESULTS AND COMPARISIONS

The Ultimate Shear strength has been calculated by using the available analytical model and shear strength was predicted. The comparison between the predicted and the experimental data is shown in Fig 3 to Fig 24.

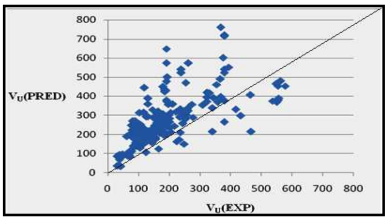

Fig. 3 ACI

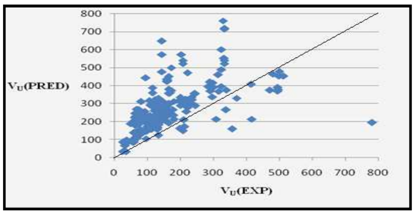

Fig.4 CSA

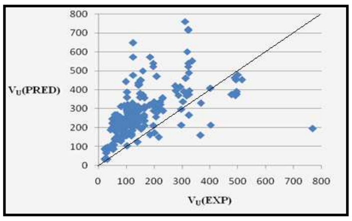

Fig.5 EURO

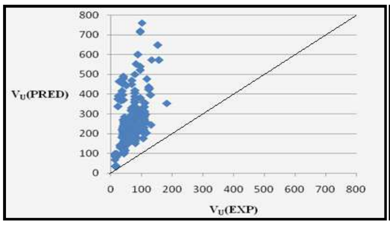

Fig.6 GERMAN

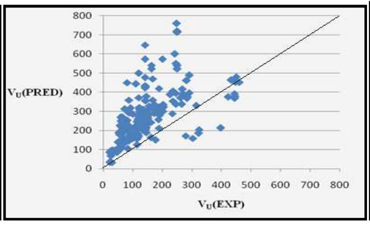

Fig.7 BRITISH

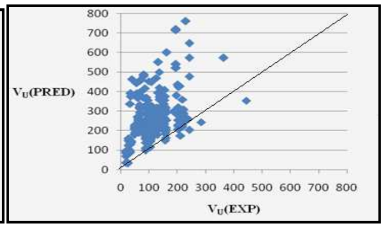

Fig.8 CEB-FIP

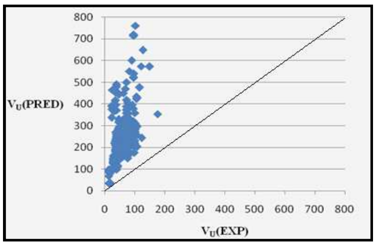

Fig.9 JAPANESE

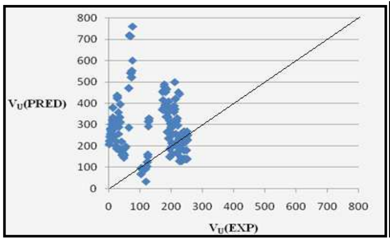

Fig.10 NEWZEALAND

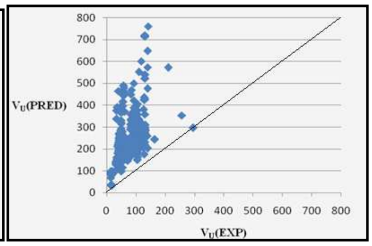

Fig.11 NORWEGIAN

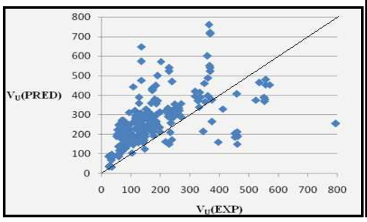

Fig.12 INDIAN

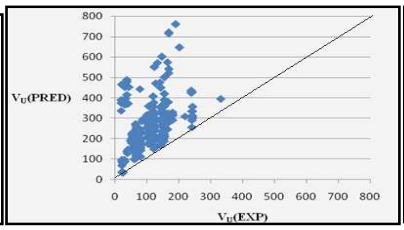

Fig.13 BAZANT

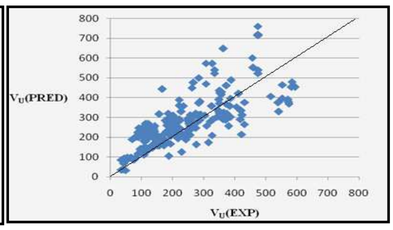

Fig.14 ZSUTTY

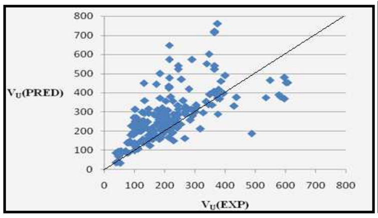

Fig.15 CLADERA

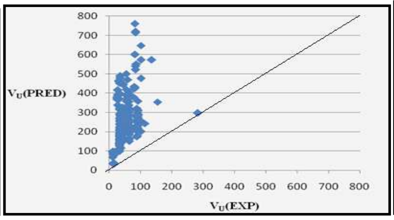

Fig.16 COLLINS

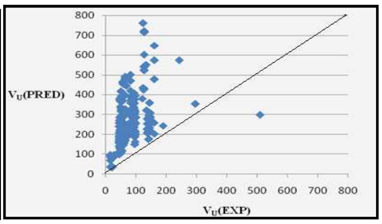

Fig.17 DESAI

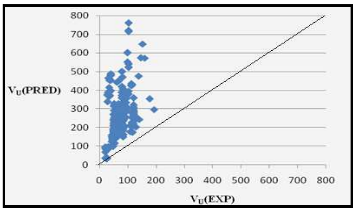

Fig.18 GASTEBLED

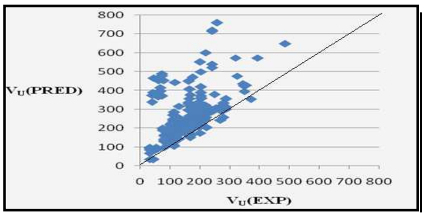

Fig.19 KIM & PARK

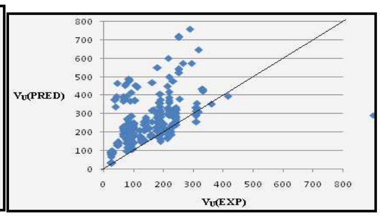

Fig.20 KIM et al

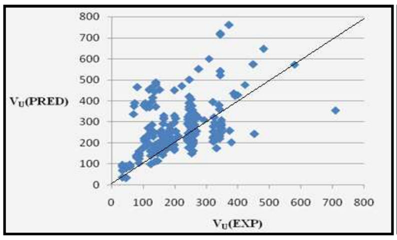

Fig.21 REBIZ

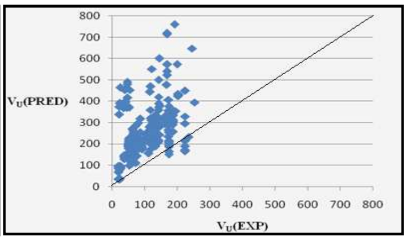

Fig.22 RUSSO

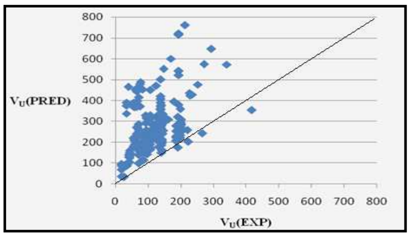

Fig.23 SARKAR

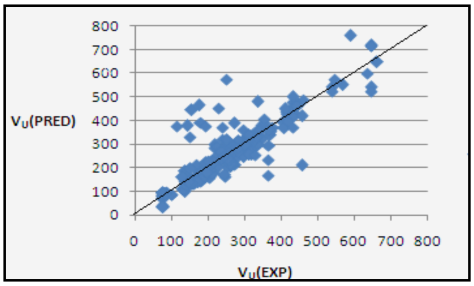

Fig.24 ANN

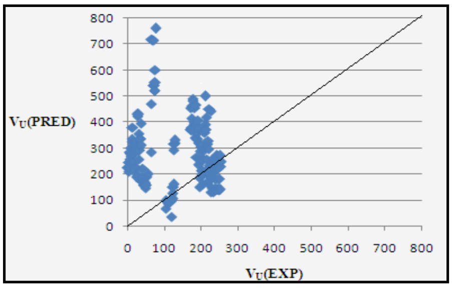

Fig.25 AUSTRALIAN

The comparison showed that the codal equations are not able to predict the experimental ultimate shear strength satisfactorily however the equation proposed by Zsutty [Fig.14] is able to predict the ultimate shear strength when compared to the other available methods.

Also the results of ANN [Fig.24] show a better prediction when compared to codal and empirical prediction, considering all the 10 equations and the codal provisions it is found that Zsutty results are found to be better than others.

SUMMARY AND CONCLUSIONS

An experimental program has been design to cast and test 27 fly ash concrete beams under shear. The shear strength of the tested beam were computed by using the available theoretical models , as a wide variation was observed for the predictions of ultimate shear strength of the tested beams and a attempt has made to apply the soft computing tool that is ANN. A large database of conventional reinforced concrete beams tested under shear as been used as an input to the ANN. It has found that ANN is able to predict satisfactorily the ultimate shear strength of conventionally reinforced concrete beams.

As no theoretical model is available exclusively for fly ash Concrete beams an attempt has been made to apply ANN which has been validated to fly ash beams.

- For the network model 9-17-1 used to predicting the shear strengths of fly ash concrete beams, the average of ratio of predicted value to experimental value of shear strength was 1.02 with Coefficient Of Variation (COV) of 0.3.
- For beams with shear reinforcement Zsutty's equation provided the least COV=0.05 and the ratio of predicted strength to experimental shear strength is 0.875.

Thus the Zsutty's prediction is better than the available close form solutions. The present investigation highlights an alternative method which is simply to apply ANN for the prediction of shear strength of GPC beams.

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