

Numerical Study on FRP Wrapped Concrete Columns Under Compression

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Abstract

Fiber Reinforced Plastic (FRP) wrapped concrete column shows better performance in terms of strength and ductility of the columns. **Objective:** Already published experimental results of the FRP wrapped concrete columns were used to analyse the same using Finite Element Software ANSYS and ANN. The comparison between the ANSYS and ANN results were made. **Methods/Analysis:** The cross sections of the concrete column varied in the study were square, circular and rectangular with different corner radius. The software stimulates the behaviour of the FRP wrapped concrete column properly if proper choice of elements from the ANSYS library were made. **Findings:** Results from the analysis of the specimens made from the quarter part of the model showed that confinement of the FRP over the concrete columns increases the strength and ductility by 25% when compared to unconfined columns. **Applications:** An artificial Neural Networks (ANNs) approach was also used to find the compressive stress of the confined and unconfined columns by using both experimental and analytical results.

Keywords: Compressive Strength, FRP Columns, Plies, ANSYS, ANN

1. Introduction

The retro fitting of the concrete columns has been used as technique to improve the structural and ductility behaviour of the concrete columns. In Japan, researcher reported that fiber wrapped concrete columns have been successful by using many fibers like glass, aramid fibers and carbon fibers over the structures like piers, columns, chimneys etc¹. Many researchers²⁻⁸ have proposed several models to strengthen the square and circular concrete columns with FRP fibers.

In⁹ have developed quarter finite element model of the confined and un confined columns to investigate the behaviour of the concrete columns wrapped with number of plies of carbon and aramid fibers. Sangeetha¹⁰⁻¹³ have analysed the FRP wrapped concrete columns and composite against published experimental results obtained

using finite element software ANSYS. In the recent years, Artificial Neural Network (ANN) has been used to predict the behaviour of various civil Engineering structures. The regression analysis using ANN approach is able to predict the stress developed in the FRP wrapped concrete columns under compression. This paper gives the comparison made between the predicted compressive strength of the confined and unconfined concrete columns using ANN approach with published experimental and analytical behaviour of the specimens with varying cross section, number of plies and corner radius of the column.

2. Analytical Model

Column model were made of plain cement concrete having compressive strength of M35, M40 & M45. The parameters varied in the study are cross sectional shape

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of the column (square-S, rectangle -R and circle - C), Types of fibers (Carbon-C and Aramid -A), Number of plies (0 - unconfined, 2, 3, 4, 5, 6, 9 & 12 plies confined), Compressive strength of concrete (35, 40 & 45 Mpa) and corner radius (5, 25, 38, 100 & 150 mm). Totally sixty five specimens were analysed using ANSYS. Only quarter model were used for analysis because of symmetry in order to reduce the memory required for analysis. SOLID 186 is used for modelling concrete portion and SHELL93 element is used for fibers. Bottom end of the columns was fixed and top surface was subjected to axial compressive load. Figure 1 shows the quarter mesh model of the specimen. Figure 2 shows the stress distribution along Y- direction of the square (S38-C3), rectangular (R25-C3) and circular column (C150-A12) obtained from the analysis using ANSYS.

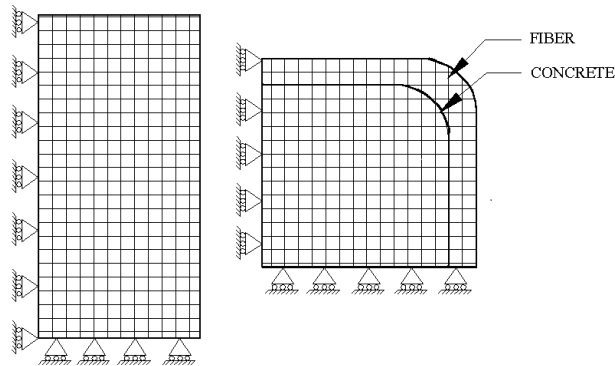
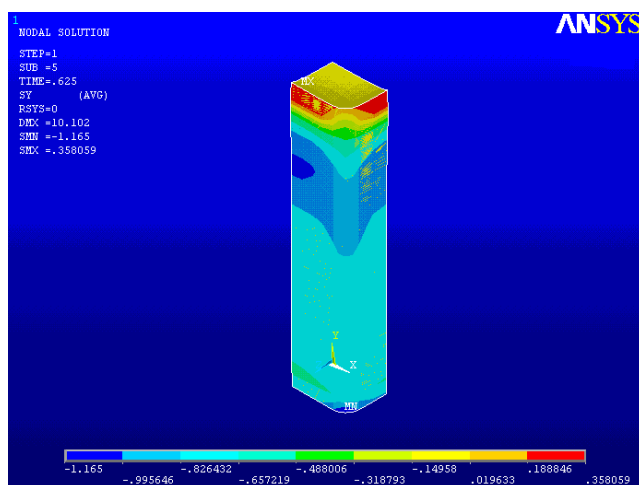
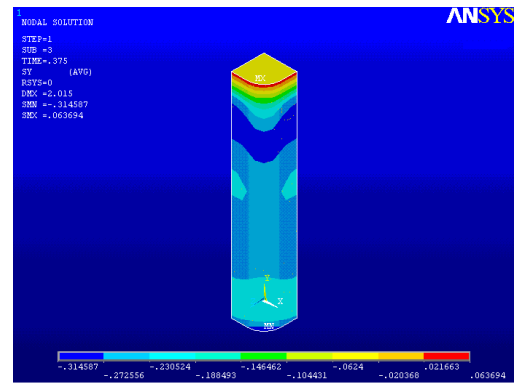


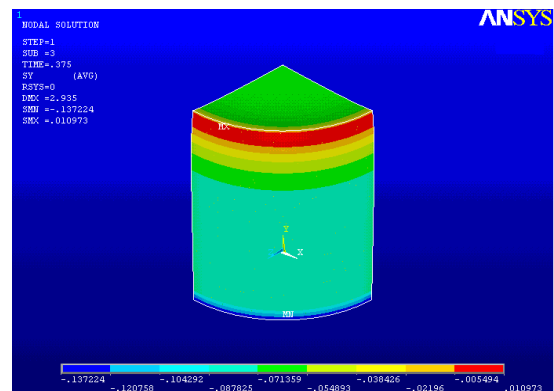
Figure 1. Meshed quarter model of the FRP wrapped column.



Square Column-S38-C3



Rectangular Column - R25-C3



Circular Column - C150-A12

Figure 2. Stress along Y- direction of FRP wrapped concrete column.

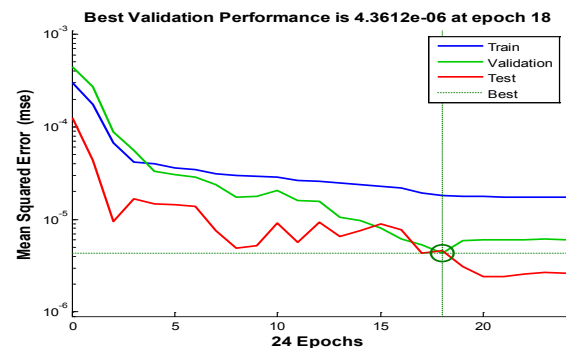


Figure 3. Performance of the Square and Rectangular columns confined with FRP sheets.

3. Result and Discussion

The results obtained from training the specimens using ANN are showed in Figure 3 to 7. Figure 3 and Figure 4 shows the error of the network starting from larger

value and getting decrease for the lower value in terms of mean square. From the Figure 4 it is observed that network being learned. The three coloured lines in the plot are because of the sixty four specimen results as input and targets were accordingly divided into three different sets. The training is continuous upto the training vector reduces the error and finally reaches the validation vectors and then the training is been stopped. Figure 5 and 6 shows the training of the specimens. Figure 7 shows the error stimulated by ANN for the specimens. Table 1 gives the comparison of the results between experimental, analytical and ANN results of the all specimens.

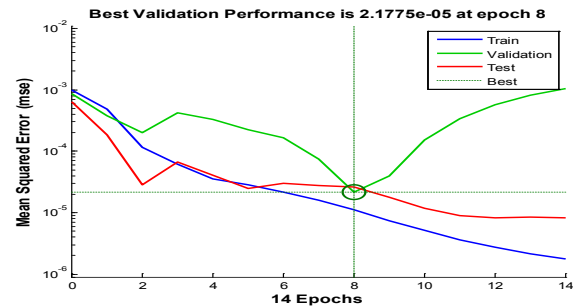


Figure 4. Performance of the circular columns confined with FRP sheets.

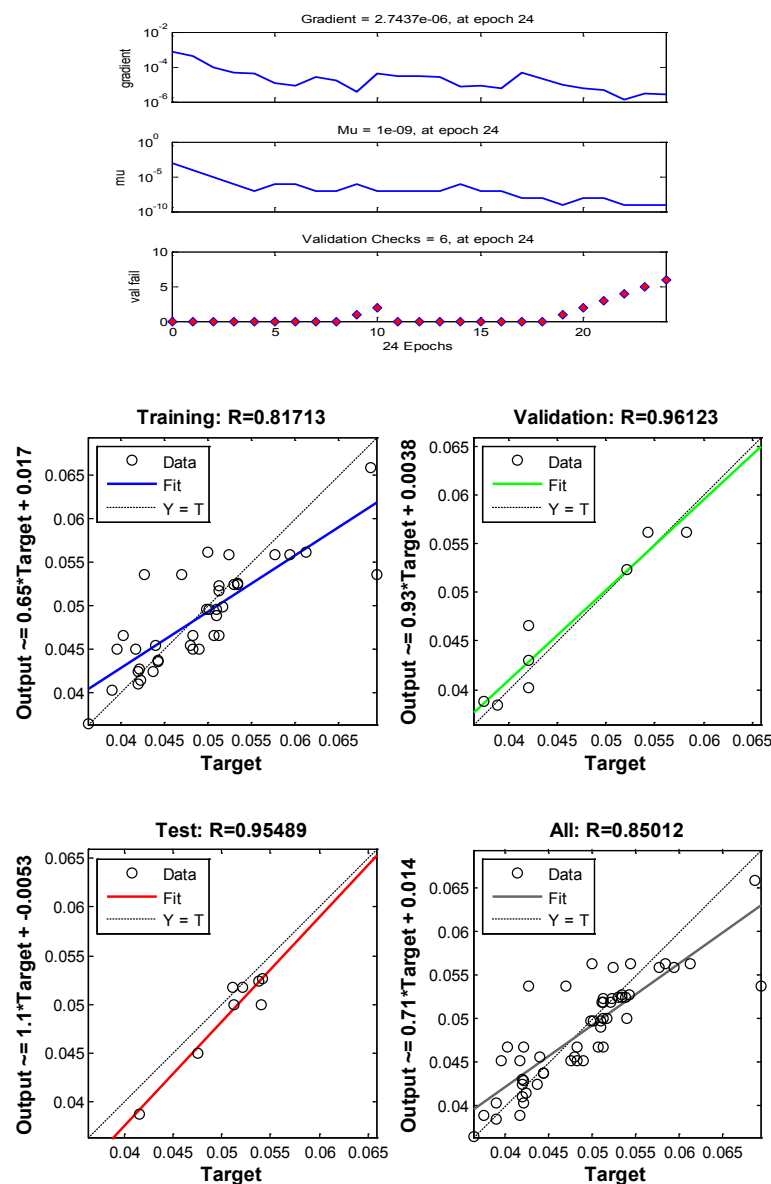


Figure 5. Regressions of training, validation and test data for square and rectangular shaped column.

Table 1. Comparison between experimental, analytical and ANN results and its error

Sl.No	Model	Geometry	No. of Plies	Concrete strength	Experimental Axial Stress	Analytical Axial Stress	ANN	Error
		$l \times b \times h$ (mm)		(Mpa)	(kN/mm ²)			
1	S - NC- 40	152´152×500	0	40	0.0416	0.0401	0.038789	0.002811
2	S - NC - 45	152´152×500	0	45	0.0423	0.0412	0.041391	0.000909
3	S5-C3 - 40	152´152×500	3	40	0.0395	0.0421	0.045052	-0.00555
4	S5-C4 - 45	152´152×500	3	45	0.0402	0.0416	0.046621	-0.00642
5	S25-C3 - 40	152´152×500	3	40	0.0416	0.0450	0.045052	-0.00345
6	S25-C3 - 45	152´152×500	3	45	0.0421	0.0470	0.046621	-0.00452
7	S38-C3 - 40	152´152×500	3	40	0.0475	0.0450	0.045052	0.002448
8	S38-C3 - 45	152´152×500	3	45	0.0482	0.0475	0.046621	0.001579
9	S5-C5 - 40	152´152×500	5	40	0.0427	0.0431	0.053632	-0.01093
10	S5-C5 - 45	152´152×500	5	45	0.0439	0.0461	0.045509	-0.00161
11	S25-C4 - 40	152´152×500	4	40	0.05	0.0510	0.056222	-0.00622
12	S25-C4 - 45	152´152×500	4	45	0.0509	0.0473	0.04894	0.00196
13	S25-C5 - 40	152´152×500	5	40	0.0469	0.0417	0.053632	-0.00673
14	S25-C5 - 45	152´152×500	5	45	0.0479	0.0427	0.045509	0.002391
15	S-NC - 35	152´152×500	0	35	0.0363	0.0367	0.036372	-7.25E-05
16	S-NC - 40	152´152×500	0	40	0.0375	0.0387	0.038789	-0.00129
17	S25-C4 - 35	152´152×500	4	35	0.0523	0.0529	0.055857	-0.00356
18	S25-C4 - 40	152´152×500	4	40	0.0543	0.0552	0.056222	-0.00192
19	S25-C4 - 35	152´152×500	4	35	0.0576	0.0595	0.055857	0.001743
20	S25-C4 - 40	152´152×500	4	40	0.0583	0.0597	0.056222	0.002078
21	S38-C4 - 35	152´152×500	4	35	0.0594	0.0502	0.055857	0.003543
22	S38-C4 - 40	152´152×500	4	40	0.0612	0.0623	0.056222	0.004978
23	S38-C5 - 35	152´152×500	5	35	0.0687	0.058	0.065866	0.002834
24	S38-C5 - 40	152´152×500	5	40	0.0693	0.062	0.053632	0.015668
25	R-NC - 35	203´152×500	0	35	0.0389	0.0401	0.038354	0.000546
26	R-NC - 40	203´152×500	0	40	0.042	0.0437	0.041014	0.000986
27	R25-C3 - 35	203´152×500	3	35	0.039	0.042	0.040239	-0.00124
28	R25-C3 - 40	203´152×500	3	40	0.042	0.0706	0.042401	-0.0004
29	R38-C3 - 35	203´152×500	3	35	0.0421	0.0501	0.040239	0.001861
30	R38-C3 - 40	203´152×500	3	40	0.0437	0.069	0.042401	0.001299

31	R5-C5 - 40	203'152×500	5	40	0.042	0.0482	0.043001	-0.001
32	R5-C5 - 45	203'152×500	5	45	0.0443	0.0584	0.04366	0.00064
33	R25-C4 - 40	203'152×500	4	40	0.0421	0.043	0.042742	-0.00064
34	R25-C4 - 45	203'152×500	4	45	0.0443	0.0449	0.043648	0.000652
35	S5-A3 - 40	152'152×500	3	40	0.0489	0.0501	0.045052	0.003848
36	S5-A3 - 45	152'152×500	3	45	0.0507	0.0462	0.046621	0.004079
37	S5-A6 - 44	152'152×500	6	40	0.0498	0.0412	0.049619	0.000181
38	S5-A6 - 40	152'152×500	6	45	0.0516	0.043	0.049941	0.001659
39	S5-A12 - 40	152'152×500	12	40	0.0522	0.0612	0.052299	-9.90E-05
40	S5-A12 - 45	152'152×500	12	45	0.0542	0.0714	0.052651	0.001549
41	S25-A3 - 40	152'152×500	3	40	0.0482	0.0467	0.045052	0.003148
42	S25-A3 - 45	152'152×500	3	45	0.0512	0.0466	0.046621	0.004579
43	S25-A6 - 40	152'152×500	6	40	0.0501	0.0485	0.049619	0.000481
44	S25-A6 - 45	152'152×500	6	45	0.0512	0.0495	0.049941	0.001259
45	S25-A9 - 40	152'152×500	9	40	0.0521	0.0461	0.051741	0.000359
46	S25-A9 - 45	152'152×500	9	45	0.0533	0.047	0.052436	0.000864
47	S25-A12 - 40	152'152×500	12	40	0.0512	0.0451	0.052299	-0.0011
48	S25-A12 - 45	152'152×500	12	45	0.0533	0.0463	0.052651	0.000649
49	S38-A6 - 40	152'152×500	6	40	0.051	0.0485	0.049619	0.001381
50	S38-A6 - 45	152'152×500	6	45	0.054	0.0495	0.049941	0.004059
51	S38-A9 - 40	152'152×500	9	40	0.0512	0.0452	0.051741	-0.00054
52	S38-A9 - 45	152'152×500	9	45	0.0529	0.0469	0.052436	0.000464
53	S5-A9 - 40	152'152×500	9	40	0.0511	0.05	0.051741	-0.00064
54	S5-A9 - 45	152'152×500	9	45	0.0538	0.0517	0.052436	0.001364
55	C100-C2 - 40	150'300	2	40	0.0734	0.0744	0.070843	0.002557
56	C100-C2 - 45	150'300	2	45	0.0742	0.0752	0.06949	0.00471
57	C150-A3 - 40	150'300	3	40	0.0463	0.0621	0.052827	-0.00653
58	C150-A3 - 45	150'300	3	45	0.0473	0.0728	0.051922	-0.00462
59	C150-A6 - 40	150'300	6	40	0.0552	0.0682	0.052083	0.003117
60	C150-A6 - 45	150'300	6	45	0.0589	0.0737	0.051756	0.007144
61	C150-A9 - 40	150'300	9	40	0.0683	0.0671	0.070838	-0.00254
62	C150-A9 - 45	150'300	9	45	0.0709	0.0706	0.071766	-0.00087
63	C150-A12 - 40	150'300	12	40	0.081	0.07	0.080127	0.000873
64	C150-A12 - 45	150'300	12	45	0.0844	0.0714	0.083661	0.000739

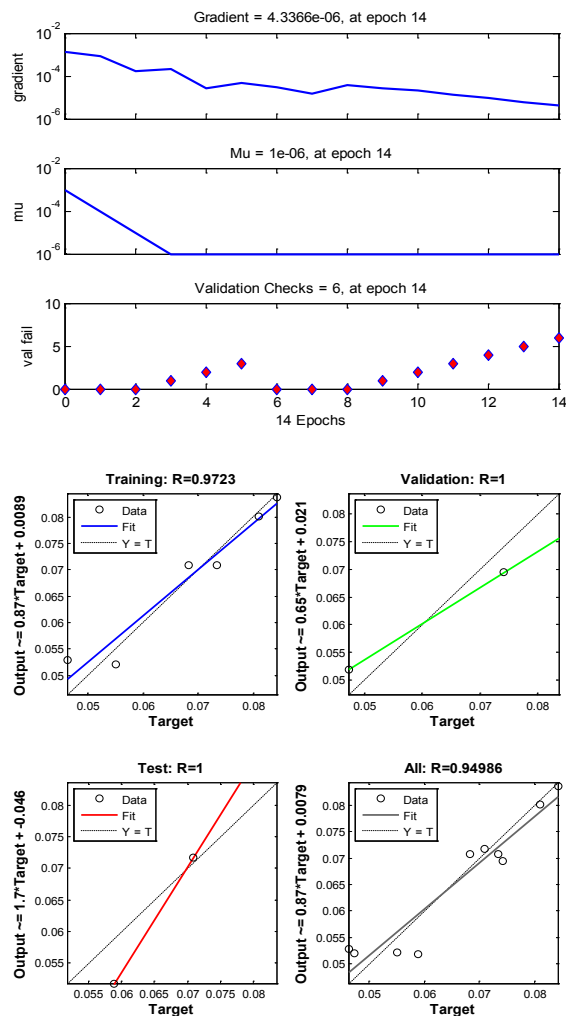


Figure 6. Regressions of training, validation and test data for circular shaped column.

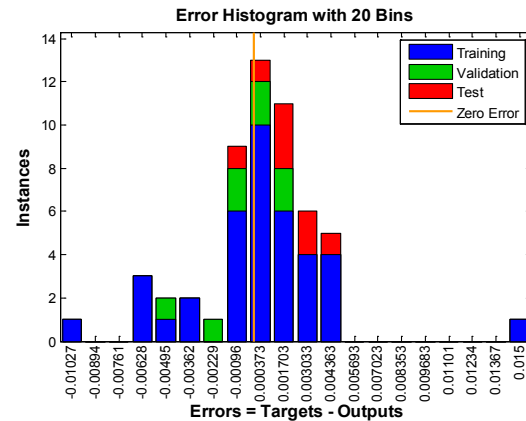
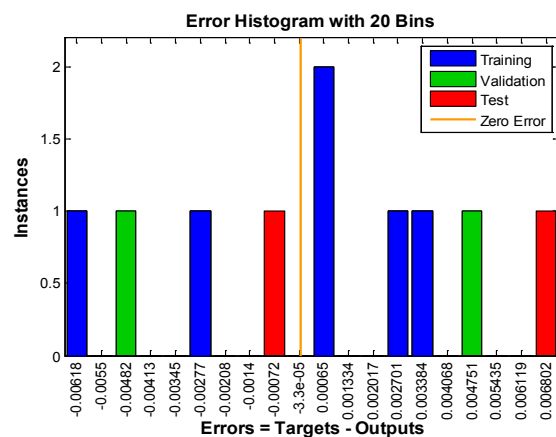


Figure 7. Error histogram data simulated by ANN for Square and rectangular and circular columns.

4. Conclusions

The compressive strength of FRP-confined concrete column was obtained using ANSYS and ANN for sixty four specimens. The effective neural network approach was selected in order to verify the performance of the network. The results from ANN simulations were compared with the compressive stress of specimens obtained from ANSYS output. The average error for the Artificial Neural Network model for predicting the experimental stress and analytical stress was lower by 4%. The error was very less in the order of $\pm 1\%$ of the experimental and analytical stresses. Also values simulated by the ANN model set spread around the 45° line which shows that the predicted values were neither over-estimated nor under-estimated. Thus ANN model is used to predict the compressive stress values of FRP wrapped concrete columns under compressive load.

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