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AXIAL COMPRESSION BEHAVIOUR OF REINFORCED SHORT COLUMNS –EXPERIMENTAL, ANALYTICAL AND ANN APPROACH

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Abstract

The main purpose of this study is to determine the behavior of reinforced short columnsmade up of different kinds of concrete subjected to axial compression. The study includes ultimateload carrying capacity of short columns made up of various kinds of concrete with different gradesand various percentages of longitudinal steel viz., 1.29%, 2.01%, 2.89% and 5.15%. In addition tothe experimental study, analytical investigation by using the codal equations from various codes of practices were used and the comparative was carried out by using ANN approach also. From theresults, it was clear that the results were very close as the percentage error is very less.

Keywords: Short Columns, Axial Compression

1. INTRODUCTION

Columns are the vertical compression component; it is carrying predominant axial concentric load.It is stiffer structural component compared over beams and slabs in the structure. Therefore, uniquesignificance must be specified in command to learn their structural reaction, ever since it also transmits load commencing superstructure to foundation structural elements below. They should be strong by both its intrinsic and extrinsic factors in order to achieve improved structural presentation in provisions of strength and durability During past decades many researchers have dealt with the investigations on the performance of compression behaviour of columns over identified parameters such as compression index, early spalling, stiffness degradation, maximum compressive strain, confining effect, failure behaviour and bond slip between concrete and steel. It has been observed over the past decade development neo concretes further created a need to study compression behaviour. However, these studies have been oriented mainly on strength investigations and very fewer investigations are being carried out experimentally on the above parameters.

2. LITERATURE REVIEW

By adding the normal force from concreteand the normal force from steel reinforcement the calculation of axial load capacity of RC columns may be done, separately for RC columns without strengthening.Also, by adding steel jacketing contributions directly to the normal force of the Reinforced Concrete column, the processes ACI Committee 318 and Euro code 4 match

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perfectly. As a result, in accordance with globally established protocols, the axial load capacity of a reinforced RC column is articulated asthe sum of three normal elements, as shown in equation.

Hany A. Kottb et al., (2014) the performance of HSC columns under eccentric compression was researched with the help of laboratory experiments and analytical methods; the key factors evaluatedwere the eccentricity of the applied load, column slenderness ratio, and longitudinal and transversereinforcement ratios. It was discovered that increasing the longitudinal steel ratio increases load capacity while decreasing column ductility. Increased load eccentricity reduces column load capacity while increasing mid-height displacement and concrete compression strain. Increasing the column slenderness ratio reduces load capacity while increasing mid-height displacement at failure and concrete compressive strain.

Vasumathi et al., (2014) have carried out an laboratory experimentations and evaluation to examine the usage of CFRP composite strips in the reinforcement of RC columns constructed of fiber reinforced concrete. The effective gap between the FRP strips and the number of CFRP layers were the experimental parameters. They discovered that CFRP strips spaced 20mm and 30mm apart improved the strength capacity of an RC column composed of FRC concrete under axial compression. Columns restricted with three layers in both spacing's demonstrated superior ductilityperformance.

The main objective of this research is to determine the ultimate compression strength of RC short columns made out of various kinds of concrete with different longitudinal steel ratio. We will be comparing the results of experimental ultimate load carrying capacity of columns with the theoretical values of ultimate load carrying capacity predicted using MATLAB by varying the parameters. Further the results obtained for NSC, SCC and GPC columns will be presented in theform of column-charts for various cases.

We will be using the formulae from IS, ACI, AS, BS, NZS codebooks to find the data and later compare those values with the predicted values obtained using MATLAB.

3. EXPERIMENTAL STUDY

The experimental investigation comprised of the examination of the material characteristics and axialbehavior of totally 36 RC short columns for each concrete type. Details of the experimental study are listed below. For the purpose of investigation totally thirty-six columns of dimension 125x125x1000 mm with slenderness ratio of 8 were casted and cured maintaining all the prescribed specifications as per IS codal provisions. This dimension of specimen is selected to maintain a slenderness ratio of 8 which is less than 12, so that we can group it as short column. The quantity of materials used are presented in Table1. Figure 2 depicts the strengthening features of the short columns. After drying, the columns were white washed before being mounted on the loading frame. All of the columns were tested in a 1000 KN loading frame. All columns were fixed on both ends, with a short column having an effective span of 0.96m. The load was applied in theaxial direction using a 1000 kN hydraulic jack, as indicated in Fig. 2. The axial deformations of the column were recorded at the top with a dial gauge. The initial measurements were taken

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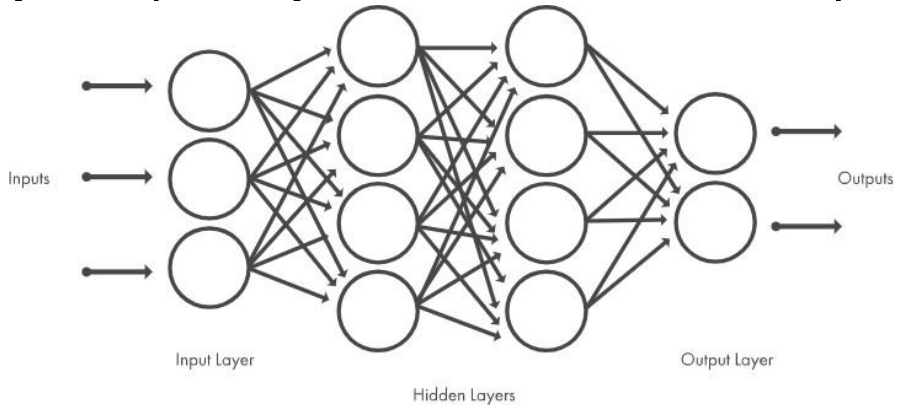
beforeto the application of the load, and the deflection in the dial gauge was recorded for each incrementof force. The column surface was inspected for apparent fractures after each load increment. The load at which the first visible crack emerged was designated as the "Cracking load (Pcr)," and theload at which the beam fully collapsed was designated as the "Ultimate load (Pu).

4. NEURAL NETWORK APPROACH (ANN APPROACH)

An Artificial Network is a user-friendly approach that learns by incorporating inter connected nodes or neurons in a layered structure that simulates a human brain. This network can learn from data, so it can be trained to recognize patterns, categorize data, and forecast upcoming events. Its behavior is defined by the way its individual elements are connected andby the strength, or weights of those connections. These weights are automatically adjusted during training according to a specified learning rule until the artificial neural network performs the desired task correctly.

This network merges many processing layers, using simple elements operating simultaneously and inspired by biological nervous systems. It consists of an input layer, one or more hidden layers, and an output layer. In each layer there are several nodes, or neurons, with each layer using the output of the previous layer as its input, so neurons interconnect the different layers. Each neuron



typically has weights that are adjusted during the learning process, and as the weight decreases orincreases, it changes the strength of the signal of that neuron With tools and functions for managing large data sets, MATLAB offers specialized toolboxes forworking with machine learning, artificial neural networks, deep learning, computer vision, and automated driving Ultimate strength of reinforced short columns made out of various kinds of concrete with different longitudinal steel ratio, under axial compression was experimentally calculated, and results obtained from experiment were used to develop the ANN model. A total of 144 results values were used to modeling formation, and from that 30% data record was used for testing purpose and 70%data record was used for training purpose.

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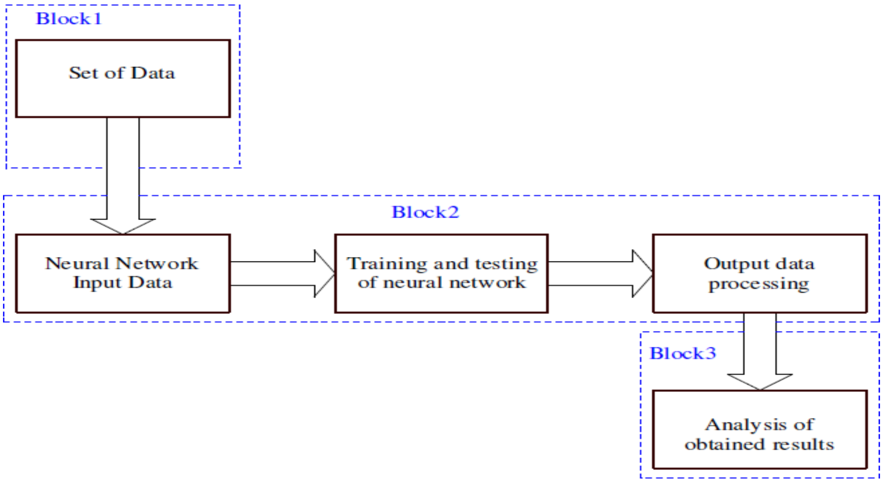

Fig.1: Block diagram of concrete compressive strength identification using neural networks

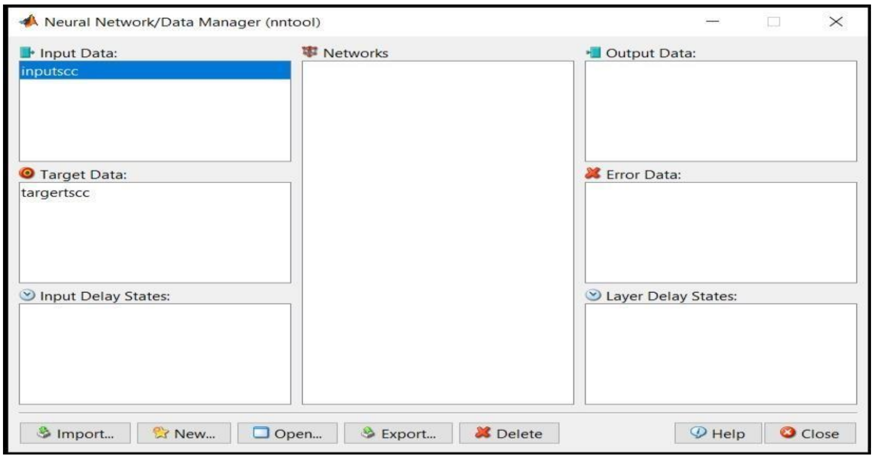

Fig. 2: ANN tool box for input and target data

This toolbox helps to predict input data for the predicted values. We need to extract the input andthe target data from the excel sheet in this particular step. A variable is created at first in the workspace as “Input” and another variable “Target” is also created. The extracted data is later added into these variables after transposing it respectively. A third variable is created for the machine to understand the input data. Later we select any column(s) from the input data added andis pasted it into the third variable created. We have all the data’s that needs to be predicted.

In the command window we type in the respective commands i.e., nntool and a pop up appears onthe screen. Select import and select the variable as input and import it. All the variables now havebeen imported into the Network/Data Manager. This same procedure is repeated with the sample data taken in the initial step. This step is repeated likewise with the target data.

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Later in the nntool, click on new and name the network according to preference. Choose the network type as feed-forward back propagation as it gives more accurate results and it consumes lesser memory for the prediction. After customizing the neural network, it can be viewed in a separate pop-up window as shown above. It is automatically generated by the software. We can get a clear picture on the number of hidden layers, the number of inputs added and the number of outputs.is gives an idea about the algorithm that has been used in the toolbox. The number of iterationsis 100 out of 1000.

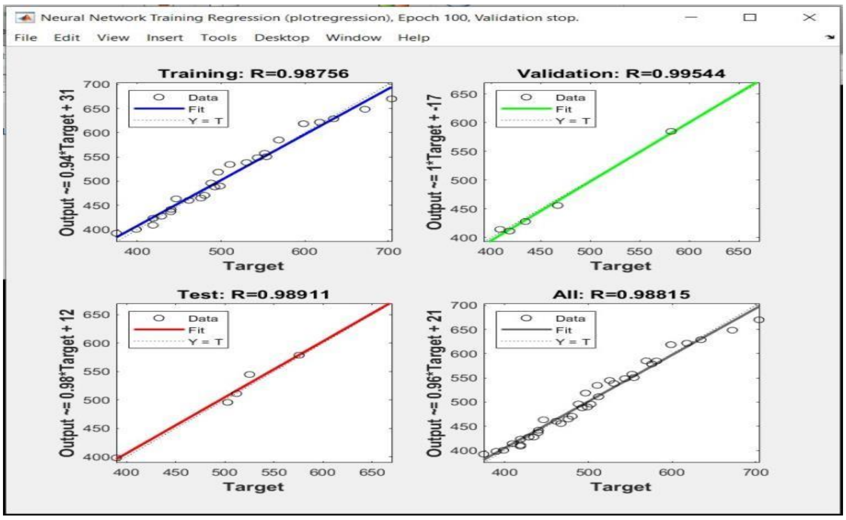

Fig.3: Training and validation data based on root mean square error

5. RESULTS AND DISCUSSION

In this chapter we have compared the results of experimental ultimate load carrying capacity of columns with the theoretical values of ultimate load carrying capacity predicted using MATLAB by varying the parameters. Further the results obtained for NSC columns are presented in the formof column-charts for various cases.

ISSN 1533-9211

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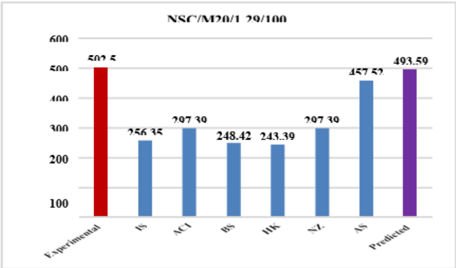
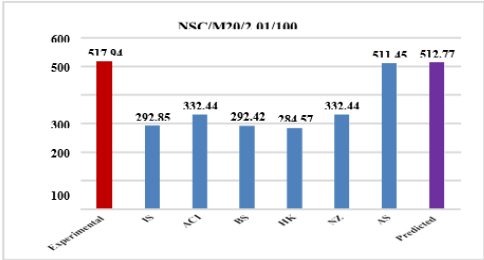
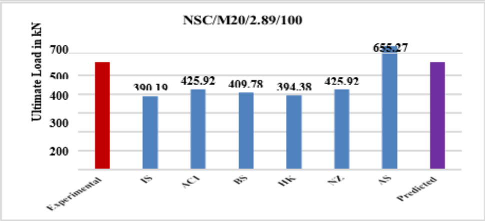
5.1 Ultimate load carrying capacity of Normal Strength Concrete columns



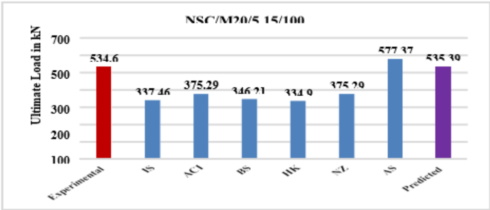
Graph 5.1- Ultimate load for 1.29% longitudinal steel



Graph 5.2- Ultimate load for 2.01% longitudinal steel



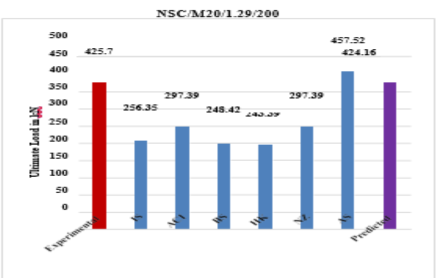
Graph 5.3- Ultimate load for 2.89% longitudinal steel



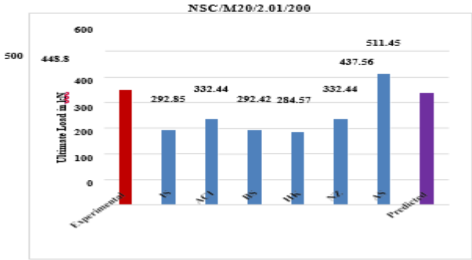
Graph 5.4- Ultimate load for 5.15% longitudinal steel

From the graphs 5.1, 5.2, 5.3 & 5.4, it was observed that, for M20 grade NSC columns with 100mmtransverse spacing. The experimental values of ultimate load carrying capacity for 1.29%, 2.01%,2.89% and 5.15% longitudinal steel were 502.5kN, 517.94kN, 534.6kN & 567.8kN respectively and the predicted values were near to the experimental values i.e., 493.59kN, 512.77kN, 535.39kN& 570.30kN.

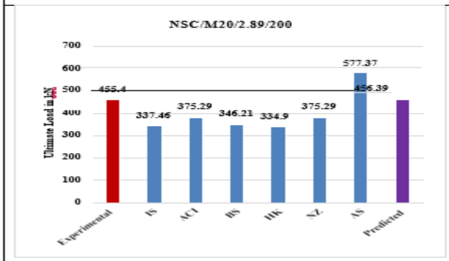
5.2 Ultimate load of normal strength concrete column with M20 grade and 200mmC/C



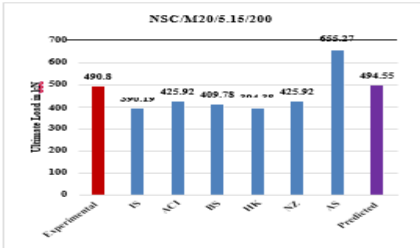
Graph 5.5- Ultimate load for 1.29% longitudinal steel



Graph 5.6- Ultimate load for 2.01% longitudinal steel



Graph 5.7- Ultimate load for 2.89% longitudinal steel



Graph 5.8- Ultimate load for 5.15% longitudinal steel

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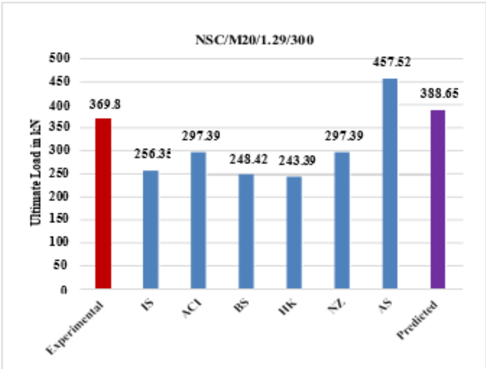
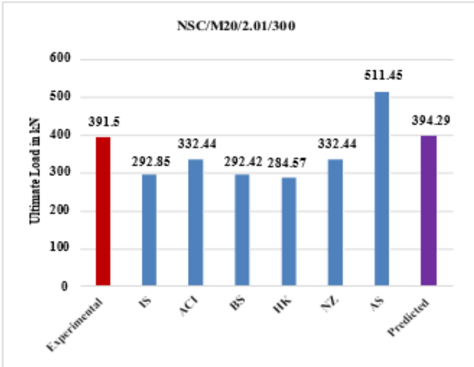
From the graphs 5.5, 5.6, 5.7 & 5.8, it was observed that, for M20 grade NSC columns with 200mm transverse spacing. The experimental values of ultimate load carrying capacity for 1.29%, 2.01%, 2.89% and 5.15% longitudinal steel were 425.7kN, 448.8kN, 455.4kN & 490.8kN respectively and the predicted values were near to the experimental values i.e., 424.16kN, 437.56kN, 456.39kN& 494.55kN.

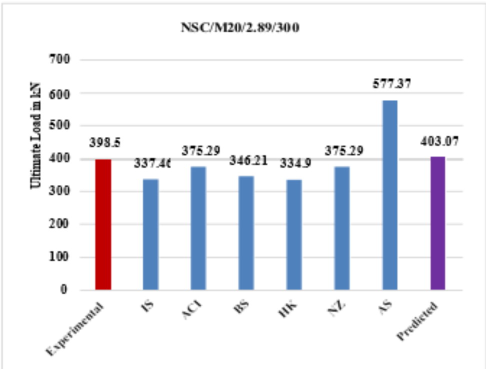
5.3 Ultimate Load of Normal Strength Concrete Column with M20 Grade and 300mmc/C



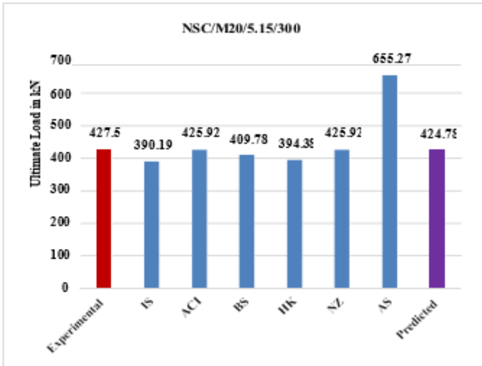
Graph 5.9-- Ultimate load for 1.29% longitudinal



Graph 5.10- Ultimate load for 2.01% longitudinal



Graph 5.11- Ultimate load for 2.89% longitudinal



Graph 5.12- Ultimate load for 5.15% longitudinal

From the graphs 5.9, 5.10, 5.11 & 5.12, it was observed that, for M20 grade NSC columns with 300mm transverse spacing. The experimental values of ultimate load carrying capacity for 1.29%, 2.01%, 2.89% and 5.15% longitudinal steel were 369.8kN, 391.5kN, 398.5kN & 427.5kN respectively and the predicted values were near to the experimental values i.e., 388.65kN,394.29kN, 403.07kN & 424.78kN.

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Table.1: Comparative results of Ultimate strength of columns for Self-compacting concrete

Specimen ID	Experimental	Theoretical – As per Code of practice						ANN Predicted
		IS	ACI	BS	HK	NZ	AS	
SCC/M20/1.29/100	492.4	275.09	320.4	265.08	260.05	320.4	466.7	488.17
SCC/M20/2.01/100	496.4	311.45	355.28	308.96	301.11	355.28	520.56	518.60
SCC/M20/2.89/100	552.15	355.9	397.92	362.6	351.29	397.92	586.4	557.55
SCC/M20/5.15/100	634.6	408.42	448.31	425.99	410.59	448.31	664.2	628.96
SCC/M20/1.29/200	418.7	275.09	320.4	265.08	260.05	320.4	466.7	423.33
SCC/M20/2.01/200	440.12	311.45	355.28	308.96	301.11	355.28	520.56	441.79
SCC/M20/2.89/200	480.3	355.9	397.92	362.6	351.29	397.92	586.4	470.74
SCC/M20/5.15/200	543.6	408.42	448.31	425.99	410.59	448.31	664.2	548.47
SCC/M20/1.29/300	374.6	275.09	320.4	265.08	260.05	320.4	466.7	392.45
SCC/M20/2.01/300	398.4	311.45	355.28	308.96	301.11	355.28	520.56	400.28
SCC/M20/2.89/300	408.9	355.9	397.92	362.6	351.29	397.92	586.4	414.04
SCC/M20/5.15/300	446.08	408.42	448.31	425.99	410.59	448.31	664.2	463.36
SCC/M30/1.29/100	512.04	337.56	397.09	320.6	315.57	397.09	610.91	511.06
SCC/M30/2.01/100	525.3	373.46	431.41	364.08	356.23	431.41	663.72	544.74
SCC/M30/2.89/100	581.4	417.35	473.37	417.22	405.91	473.37	728.26	584.86
SCC/M30/5.15/100	672.18	469.21	522.95	480.02	464.63	522.95	804.53	648.61
SCC/M30/1.29/200	439.75	337.56	397.09	320.6	315.57	397.09	610.91	436.93
SCC/M30/2.01/200	461.4	373.46	431.41	364.08	356.23	431.41	663.72	460.44
SCC/M30/2.89/200	502.9	417.35	473.37	417.22	405.91	473.37	728.26	495.81
SCC/M30/5.15/200	575.7	469.21	522.95	480.02	464.63	522.95	804.53	578.82
SCC/M30/1.29/300	389.5	337.56	397.09	320.6	315.57	397.09	610.91	398.15
SCC/M30/2.01/300	418.5	373.46	431.41	364.08	356.23	431.41	663.72	408.92
SCC/M30/2.89/300	428.5	417.35	473.37	417.22	405.91	473.37	728.26	427.68
SCC/M30/5.15/300	498.7	469.21	522.95	480.02	464.63	522.95	804.53	489.86
SCC/M40/1.29/100	554.4	398.01	471.32	374.34	369.31	471.32	725.1	550.61
SCC/M40/2.01/100	569	433.47	505.09	417.42	409.57	505.09	777.07	585.08
SCC/M40/2.89/100	617.9	476.82	546.38	470.08	458.77	546.38	840.59	621.70
SCC/M40/5.15/100	704.07	528.04	595.17	532.31	516.92	595.17	915.66	669.98
SCC/M40/1.29/200	475.8	398.01	471.32	374.34	369.31	471.32	725.1	465.06
SCC/M40/2.01/200	487.92	433.47	505.09	417.42	409.57	505.09	777.07	496.04
SCC/M40/2.89/200	530.4	476.82	546.38	470.08	458.77	546.38	840.59	538.50
SCC/M40/5.15/200	598.75	528.04	595.17	532.31	516.92	595.17	915.66	618.71
SCC/M40/1.29/300	418.5	398.01	471.32	374.34	369.31	471.32	725.1	411.18
SCC/M40/2.01/300	434.5	433.47	505.09	417.42	409.57	505.09	777.07	427.81
SCC/M40/2.89/300	467.1	476.82	546.38	470.08	458.77	546.38	840.59	455.72
SCC/M40/5.15/300	510.45	528.04	595.17	532.31	516.92	595.17	915.66	534.56

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Table.2: Comparative results of Ultimate strength of columns for Geopolymer concrete

Specimen ID	Experimental	Theoretical – As per Code of practice						ANN Predicted
		IS	ACI	BS	HK	NZ	AS	
GPC/M20/1.29/100	518.5	261.21	303.35	252.74	247.71	303.35	466.7	521.67
GPC/M20/2.01/100	542	297.67	338.36	296.71	288.86	338.36	520.56	542.32
GPC/M20/2.89/100	556	342.24	381.16	350.46	339.15	381.16	586.4	558.15
GPC/M20/5.15/100	593	394.92	431.73	413.98	398.59	431.73	664.2	585.53
GPC/M20/1.29/200	453.4	261.21	303.35	252.74	247.71	303.35	466.7	445.09
GPC/M20/2.01/200	467.5	297.67	338.36	296.71	288.86	338.36	520.56	462.83
GPC/M20/2.89/200	478.4	342.24	381.16	350.46	339.15	381.16	586.4	478.63
GPC/M20/5.15/200	512.5	394.92	431.73	413.98	398.59	431.73	664.2	513.78
GPC/M20/1.29/300	398.4	261.21	303.35	252.74	247.71	303.35	466.7	407.63
GPC/M20/2.01/300	429.4	297.67	338.36	296.71	288.86	338.36	520.56	421.50
GPC/M20/2.89/300	454.4	342.24	381.16	350.46	339.15	381.16	586.4	450.97
GPC/M20/5.15/300	479.5	394.92	431.73	413.98	398.59	431.73	664.2	477.45
GPC/M30/1.29/100	539.5	330.61	388.57	314.43	309.41	388.57	597.8	538.55
GPC/M30/2.01/100	561	366.57	422.96	357.95	350.1	422.96	650.7	568.25
GPC/M30/2.89/100	590	410.52	464.98	411.15	399.84	464.98	715.36	593.87
GPC/M30/5.15/100	642	462.46	514.65	474.02	458.62	514.65	791.78	643.98
GPC/M30/1.29/200	467.4	330.61	388.57	314.43	309.41	388.57	597.8	454.39
GPC/M30/2.01/200	485.3	366.57	422.96	357.95	350.1	422.96	650.7	487.21
GPC/M30/2.89/200	512.5	410.52	464.98	411.15	399.84	464.98	715.36	512.90
GPC/M30/5.15/200	534.6	462.46	514.65	474.02	458.62	514.65	791.78	535.92
GPC/M30/1.29/300	402.7	330.61	388.57	314.43	309.41	388.57	597.8	413.42
GPC/M30/2.01/300	435.3	366.57	422.96	357.95	350.1	422.96	650.7	430.26
GPC/M30/2.89/300	461.4	410.52	464.98	411.15	399.84	464.98	715.36	462.93
GPC/M30/5.15/300	490.4	462.46	514.65	474.02	458.62	514.65	791.78	485.05
GPC/M40/1.29/100	560.5	396.69	469.7	373.17	368.14	469.7	722.61	561.88
GPC/M40/2.01/100	589.4	432.16	503.49	416.26	408.4	503.49	774.6	603.41
GPC/M40/2.89/100	644.2	475.52	544.79	468.93	457.62	544.79	838.14	638.50
GPC/M40/5.15/100	686.78	526.76	593.6	531.17	515.78	593.6	913.23	672.55
GPC/M40/1.29/200	479.3	396.69	469.7	373.17	368.14	469.7	722.61	477.32
GPC/M40/2.01/200	506.3	432.16	503.49	416.26	408.4	503.49	774.6	510.11
GPC/M40/2.89/200	554.4	475.52	544.79	468.93	457.62	544.79	838.14	552.49
GPC/M40/5.15/200	589.75	526.76	593.6	531.17	515.78	593.6	913.23	598.93
GPC/M40/1.29/300	426.1	396.69	469.7	373.17	368.14	469.7	722.61	431.74
GPC/M40/2.01/300	449.76	432.16	503.49	416.26	408.4	503.49	774.6	451.41
GPC/M40/2.89/300	479.12	475.52	544.79	468.93	457.62	544.79	838.14	482.89
GPC/M40/5.15/300	509.89	526.76	593.6	531.17	515.78	593.6	913.23	507.37

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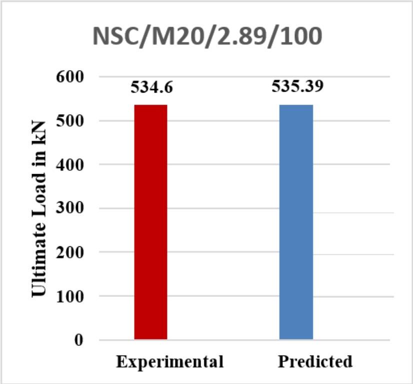
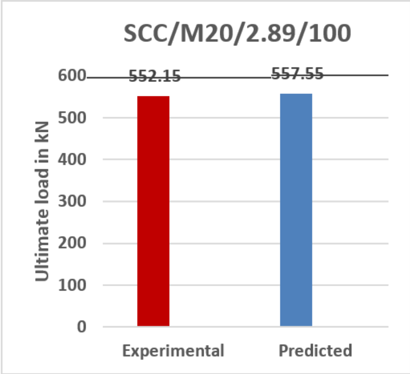
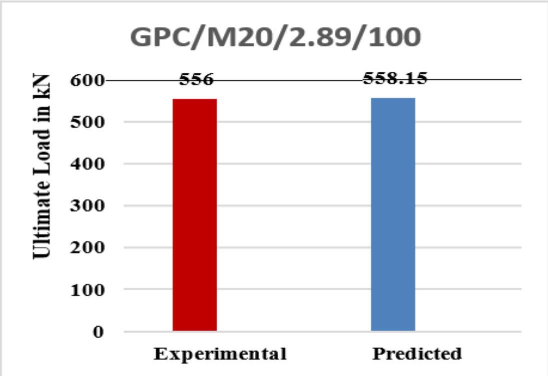
6. CONCLUSION



Graph 6.1:- Result comparison of normal strength concrete



Graph 6.2:- Result comparison of self-compacting concrete



Graph 6.3:- Result comparison of geopolymer concrete columns

The above graph 6.1, 6.2 and 6.3 shows the comparison between the predicted and the experimental values of ultimate load carrying capacity of NSC, SCC and GPC columns respectively. It is observed that, for M20 grade NSC, SCC and GPC columns with 100mm transverse spacing. The experimental values of ultimate load carrying capacity for 2.89% and longitudinal steel were 534.6kN, 552.15kN, & 556kN and the predicted values were near to the experimental values i.e., 535.39 kN, 557.55 kN and 558.15 kN. We used different parameters to analyze the compression behaviour of columns. After repeated number of training the input given and by changing the weights and the biases, we obtained a set of values which were close enough to the experimental values. We can analyze how the validation has been taken. The more the data is trained the more accurate the results will be. Once the network is integrated into a production system, it is used to predict the results for new parameters. By this we can conclude that it is easier to predict the values compared to other software. Comparing the experimental data with the predicted MATLAB values, we can see that the predicted values obtained are more accurate and closer to the experimental values obtained. Further the results obtained for NSC, SCC and GPC columns were presented in the form of column-charts for various cases.

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9. Conflicts Of Interest

The authors declare no conflict of interest.

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