Design of reinforced concrete structures using neural networks

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Abstract - *Optimization techniques play an important role in structural design. The purpose is to find the best ways so that a designer or a decision maker can derive maximum benefit from the available resources. In the present study a column, a beam and a G+4 storey model are modelled using STAAD PRO v8i software. Static analysis of the structure is carried out and the results like axial forces (P) , bending moments (M) , support reactions(R) are recorded. The results are tabulated along with other parameters like Area of steel(Ast), Breadth of beam (B), Depth of beam or slab (D) , Characteristic compressive strength of concrete (fck) , Characteristic strength of steel (fy) , Design bending moment (Mu) and percentage of steel (pt). The design of Reinforced concrete members under uni axial bending is done manually as per IS-456:2000 and SP 16 and percentage of steel is calculated and noted down. The results from the static analysis of the structure which are in tabulated form are tested and trained in MATLAB neural network toolbox. The predicted values for the percentage of steel by neural network toolbox are noted down. The percentages of error for the predicted values are almost negligible when compared to those obtained by conventional method for most of the cases and are in good agreement with one another.*

Key Words: **Optimization, Artificial Neural Network , STAAD PRO , MATLAB , IS-456 : 2000 etc...**

1. INTRODUCTION

The artificial neural network (ANN) was developed 50 years ago. ANNs are the simplifications of biological neural networks. The neural networks are very important tool for studying the structure of human brain. Due to the complexity and for complete understanding of biological neurons , many architectures of ANN have been reported in the present study.

1.1 Aim of neural networks

The aim of neural networks is to replicate the human ability to adapt to changes taking place in the current environment. This depends on the capability to learn from the events that have happened in the past and to be able to apply that to future situations.

For example : The decisions made by trainee doctors are rarely based on a single symptom due to complexity of human body. But an experienced doctor is far more likely to make a good and effective decision than a trainee , because from his past experiences he knows what to look out for and what not to worry about. Similarly it would be beneficial if machines too, could utilize past events as part of the criteria on which their decisions are based, and this is the role that neural networks seek to fill.

1.2 Artificial neural networks

ANNs consist of a number of processing units analogous to neurons in the brain called nodes. Each node has a function called node function which are associated with a set of local parameters . The local parameters determine the output of the node when input is given. If the local parameters are modified , the node functions may get altered. Hence, the artificial neural networks can be defined as the information-processing system in which the elements called neurons, process the information.

1.3. Structure of neural network

The neural networks can be single layered or multi-layered. A single layered neural network is composed of two input neurons and one output neuron. A multi-layered artificial neural network(MNN) consists of input layer, output layer and a hidden layer of neurons. The hidden layer of neurons is also called as intermediate layer of neurons. A three layered neural network is shown in the figure below.

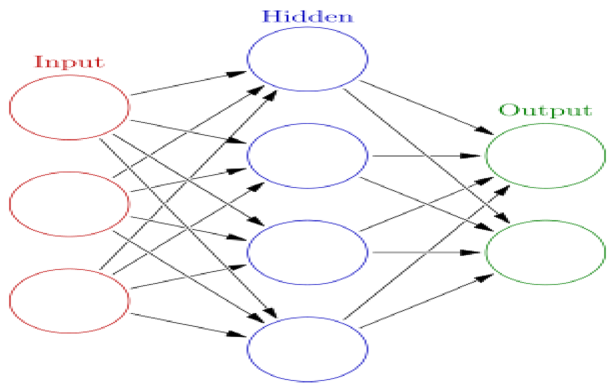


Fig -1:

The above figure shows densely interconnected three layered static neural network in which each circle represents an artificial neuron.

In a MNN, the input layer is connected to hidden layer and the hidden layers are inter-connected to layer of outputs. The neurons in the input layer represent the information that is fed into the network. The activity of neurons in the intermediate layer depends on the activity of neurons in input layer. Likewise, the activity of neurons in the output layer depends on the activity of neurons in the intermediate layer.

2. PARAMETERS IN THE STUDY

Pu Axial load

B Breadth of member

D Overall depth of member

Ast Area of steel

fck Characteristic compressive strength of concrete or grade of concrete

fy Characteristic strength of steel or grade of steel

Mu Design bending moment

Pt Percentage of steel

3. ANALYTICAL STUDY

From the analysis of G+4 storey structure carried out in STAAD PRO software results are taken. The design of columns loaded axially under uni-axial bending and the design of simply supported singly reinforced beams are done as per IS:456-2000 and SP-16 code books. The same design of columns and beams of the G+4 storey structure is carried out in neural network toolbox of MATLAB in the form of trained computer programme. Both the cases are compared with one another.

Table 1: Input values calculated for short columns using excel spread sheets for 10 sets

No. of sets	Pu (N)	Breadth (mm)	Depth (mm)	Moment (N-mm)	Cover (mm)	Factored load (N)	Grade of concrete	Grade of steel (N/mm^2)	% of steel
1	761967	230	600	5895000	40	761967	25	500	2
2	578928	230	600	8726000	40	578928	25	500	0.8
3	512476	230	600	8716000	40	512476	25	500	0.8
4	135530	230	380	1397000	40	135530	25	500	0.8
5	724123	230	600	87331000	40	724123	25	500	1.3
6	379050	230	600	75315000	40	379050	25	500	1.2
7	871473	230	600	74193000	40	871473	25	500	2.3
8	847200	230	600	82397000	40	847200	25	500	2
9	912968	230	600	64645000	40	912968	25	500	2.2
10	642114	230	600	25650000	40	642114	25	500	1.4

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Table 2 : Training data for short column for 10 sets

No. of sets	1	2	3	4	5	6	7	8	9	10
Pu (N)	761967	578928	512476	135530	724123	379050	871473	847200	912968	642114
Breadth (mm)	230	230	230	230	230	230	230	230	230	230
Depth (mm)	600	600	600	380	600	600	600	600	600	600
Moment (N-mm)	5895000	8726000	8716000	1397000	87331000	75315000	74193000	82397000	64645000	25650000
Cover (mm)	40	40	40	40	40	40	40	40	40	40
Factored load (N)	761967	578928	512476	135530	724123	379050	871473	847200	912968	642114
Grade of concrete (N/mm²)	25	25	25	25	25	25	25	25	25	25
Grade of steel (N/mm²)	500	500	500	500	500	500	500	500	500	500

Table 3 : Input values calculated for simply supported beams using excel sheets for 10 sets.

Beam No.	252	245	247	246	244	251	253	272	273	255
Cover	25	25	25	25	25	25	25	25	25	25
Depth (mm)	600	600	600	600	600	600	380	600	600	600
Span Moment (N-mm)	75400000	103000000	43500000	43000000	101000000	74800000	62600000	54500000	186000000	55400000
Left hand support moment (N-mm)	102000000	156000000	63200000	77200000	175000000	111000000	93300000	174000000	308000000	98400000
Right hand support moment	112000000	157000000	71400000	58300000	152000000	104000000	146000000	103000000	310000000	179000000
fck (N/mm²)	25	25	25	25	25	25	25	25	25	25
Fy	500	500	500	500	500	500	500	500	500	500
Percentage of steel at mid span	0.30	0.37	0.20	0.19	0.36	0.32	0.27	0.19	0.71	0.19
Percentage of steel at left hand support	0.36	0.58	0.22	0.27	0.66	0.39	0.38	0.65	1.22	0.35
Percentage of steel at right hand support	0.4	0.63	0.25	0.2	0.56	0.37	0.37	0.37	1.23	0.68

Table 4: Training data for simply supported beam for 10 sets

No. of sets	Beam no.	Breadth (mm)	Depth (mm)	Span Moment X10⁶ (N-mm)	Cover (mm)	Grade of concrete (N/mm²)	Grade of steel (N/mm²)
1	255	230	600	55.4	40	25	500
2	273	230	600	186	40	25	500
3	272	230	600	54.5	40	25	500
4	253	230	380	62.6	40	25	500
5	251	230	600	74.8	40	25	500
6	244	230	600	101	40	25	500
7	246	230	600	43	40	25	500
8	247	230	600	43.5	40	25	500
9	245	230	600	103	40	25	500
10	252	230	600	75.4	40	25	500

3.1 Optimized response spectrum results in MATLAB

The response spectrum analysis of the above mentioned G+4 storey structure is carried out in STAAD PRO software and the maximum results of nodal displacement, moments and base shear are taken.

Table 5 : Input data

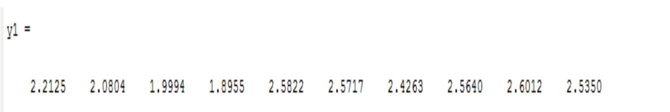
Total height of the structure	21 m
Maximum width of the structure	21.03 m
Zone	0.1
Number of storeys	7
Number of bays	5

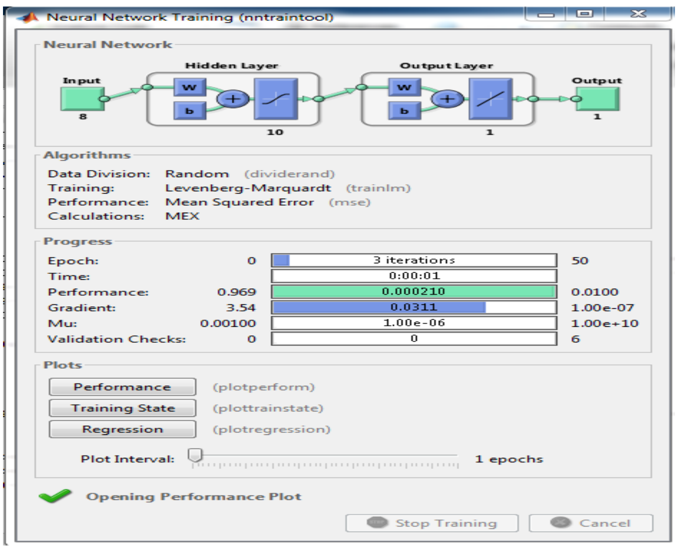
Table 6 : Target data obtained from Response spectrum analysis using STAAD PRO

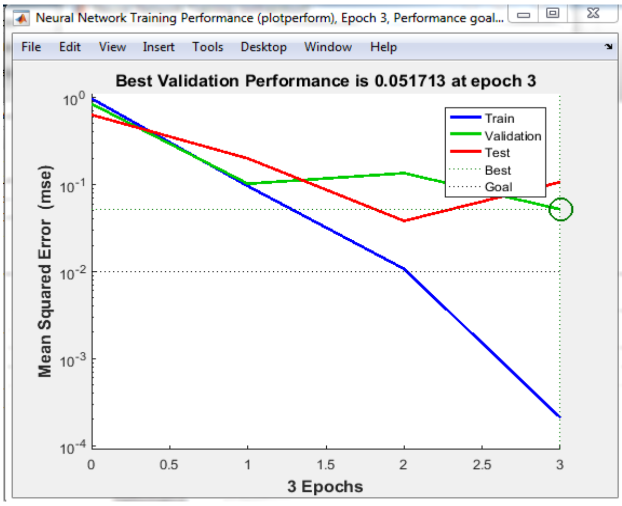
Maximum base shear	996.42 kN
Maximum nodal displacement in X direction	48.84 mm
Maximum nodal displacement in Y direction	3.733 mm
Maximum nodal displacement in Z direction	70.214 mm
Maximum moments in X direction	104.14 kNm
Maximum moments in Y direction	2.009 kNm
Maximum moments in Z direction	107.657 kNm

4. Results and discussions

4.1 Results for 10 sets of input of short columns







4.2 Results for 10 sets of input of simply supported beams

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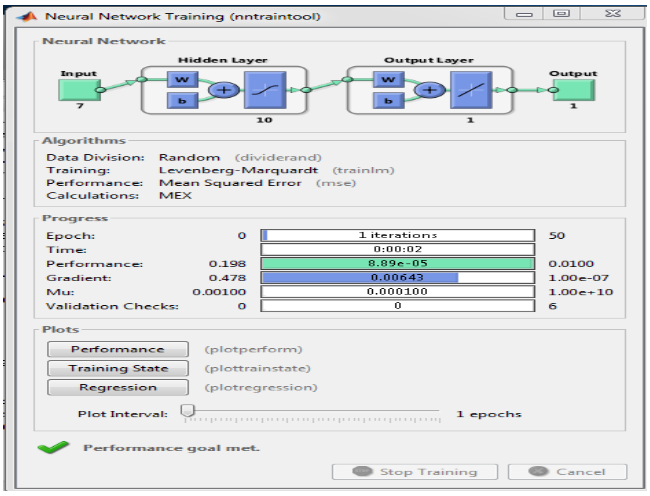
y1 =

0.5962 0.3129 0.3792 0.6414 0.6526 0.6183 0.9586 0.7797 0.6357 0.6342
```



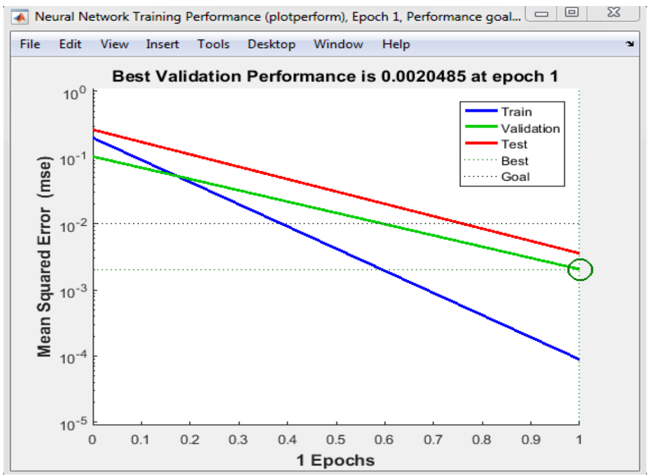


Table 7 : Percentage of errors in the design of short column

Pu (N)	642114	912968	847200	871473	379050	724123	135530	512476	578928	761967
B (mm)	230	230	230	230	230	230	230	230	230	230
D (mm)	600	600	600	600	600	600	380	600	600	600
Mu	25650000	64645000	82397000	74193000	75315000	87331000	1397000	8716000	8726000	5895000
Cover (mm)	40	40	40	40	40	40	40	40	40	40
Factored load (N)	642114	912968	847200	871473	379050	724123	135530	512476	578928	761967
Fck (N/mm²)	25	25	25	25	25	25	25	25	25	25
Fy (N/mm²)	500	500	500	500	500	500	500	500	500	500
Desired value of percentage of steel	1.4	2.2	2	2.3	1.2	1.3	0.8	0.8	0.8	2
Predicted value of percentage of steel	1.4030	2.588	2.003	2.305	1.1705	1.2893	0.7791	0.7960	0.9755	1.93
% error	0.002	0.176	0.002	0.002	-0.025	-0.008	-0.026	-0.005	0.219	-0.035

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Table 8 : Percentage of errors in the design of simply supported beam

Beam No.	252	245	247	246	244	251	253	272	273	255
Cover	25	25	25	25	25	25	25	25	25	25
Depth (mm)	600	600	600	600	600	600	380	600	600	600
Span Moment	75400000	103000000	43500000	43000000	101000000	74800000	62600000	54500000	186000000	55400000
Left hand support	102000000	156000000	63200000	77200000	175000000	111000000	93300000	174000000	308000000	98400000
Right hand support	112000000	157000000	71400000	58300000	152000000	104000000	146000000	103000000	310000000	179000000
fck (N/mm²)	25	25	25	25	25	25	25	25	25	25
Fy (N/mm²)	500	500	500	500	500	500	500	500	500	500
Percentage of steel at mid span	0.30	0.37	0.20	0.19	0.36	0.32	0.27	0.19	0.71	0.19
Percentage of steel at left hand support	0.36	0.58	0.22	0.27	0.66	0.39	0.38	0.65	1.22	0.35
Percentage of steel at right	0.4	0.63	0.25	0.2	0.56	0.37	0.37	0.37	1.23	0.68

5. Conclusion

Predicted values from the Artificial neural network (ANN) for the design of Reinforced concrete columns, beams are very close to those obtained from conventional design using IS:456-2000. The errors are quite low in the predicted values. Similarly, the maximum values of base shear, nodal displacements and moments from the analysis are compared with those from the predicted values using artificial neural network. The two are very close to one another. Therefore, it can be said such a well trained artificial neural network can be used to perform design.

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