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Technical Note

STUDY ON THICKNESS OF TWO-WAY SLAB BY ARTIFICIAL NEURAL NETWORK

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ABSTRACT

In this paper, an attempt has been taken to find out optimum thickness of edge-supported slabs. To arrive at optimum solution using artificial neural network based on back-propagation network, a number of architectures such as 5-15-25-35-45-55-5; 5-25-35-45-55-65-85-105-5 and 5-35-45-65-75-85-5 with different number of hidden layers and hidden nodes or neuron were tried. Among them, 5-25-35-45-55-65-85-105-5 is found to have the least errors.

1. INTRODUCTION

Edge-supported slabs are typically thin relative to their span, and may show large deflection even though strength requirements are met. The simplest approach to deflection control is to impose a minimum effective depth- span ratio. However, permissible value of this ratio depends on percentage of steel and stress under service load. Since these quantities are interrelated and depend upon slab thickness, the absolute determination of slab thickness becomes a tedious iterative process. Thus structural designer is left with only trial and error method in which designer has to start with tentative thickness of slab based on his judgment, then design the slab for strength, and check the design for serviceability. To solve the problem, Artificial Neural Network (ANN) is very useful. Many authors worked on applications of ANN in structural design [1, 2]. The objectives of the paper are to develop complex relationship among the design parameters of the two ways slab based on a back-propagation neural network algorithm developed in MATLAB7.0 software.

2. METHODOLOGY

An Artificial Neural Network is an information-processing paradigm that is inspired by the way biological nervous systems [3,4,5]. In error backpropagation, the gradient descent method searches for the minimum error surface along the steepest negative gradient in order to minimize the error or objective function. The objective function is minimized with respect to independent interconnecting weight variables as

$$\text{Error function (E)} = \frac{1}{2}\sum_{k=1}^{kk}\left[d_{(k)} - O_{(k)}\right]^2$$

Where, $d_{(k)}$ is the observed output at kth node of the node of the output layer.

The change in weights (Δw) in the direction of negative gradient is given by the equation

$$\Delta W_{(ij)} = -\alpha \frac{\partial E}{\partial W_{(ij)}}$$

Where, α is the learning rate such that $0<\alpha<1$. The learning rate governs the rate at which the weights are allowed to change [6,7]. Where $net_{(i)}$ is net input to the ith node, $W_{(ij)}$, is the interconnection weights of jth node with the ith node, $O_{(j)}$ is the output of jth node and $O_{(i)}$ is the output of ith node.

A method of minimum weight design of slab is used for the output data to prepare an ANN model for two-way slab, with opposite two sides continuous and another two opposite sides discontinuous. Training data have been collected from some reputed construction farms (EPCT and Universal Group) of Sylhet. These data were normalized between the range of 0 and 1. The learning rate was 0.05, 0.04 and 0.02. Different network configurations are used for training. The trained network is used for testing by new inputs data collected from construction farms of Dhaka (Concord, Sheltech). For network testing input data were normalized between the range of 0 and 1.

3. RESULTS AND DISCUSSION

3.1 Training data

A large training data set is required to train a neural network.

Input data: Five input nodes are considered for the training of Back Propagation Network (BPN).

Live load: 1500 N/m^2, 2000 N/m^2, 3000 N/m^2, 4000 N/m^2, and 5000 N/m^2; Finish load: 2850 N/m^2, 1000 N/m^2; Short span length (L_x): 2m, 2.5m, 3m, 3.5m, 4m, 4.5m, and 5m; Aspect ratio (L_y/L_x): 1, 1.2, 1.3, 1.4, 1.5, 1.75, 1.9, and 2; and Grade of steel: 250N/mm^2 and 415N/mm^2.

Output data: Five output nodes are considered: Total thickness of slab (T), Area of steel required at support in short direction (Ast 1); Area of steel required at mid-span in short direction (Ast 2); Area of steel required at support in long direction (Ast 3); Area of steel required at mid-span in long direction (Ast 4); Ref. [8].

Table 1. Training data set for two-way slab design

Input parameters					**Output parameters**				
Live load N/m^2	**Finish load N/m^2**	**Short span L_x m**	**Steel grade N/m^2**	**Aspect ratio L_y/L_x**	**Thick-ness of slab T, mm**	**Steel area,cm^2 along short direction**		**Steel area, cm^2 along long direction**	
						Support Ast 1	**Mid span Ast 2**	**Support Ast 3**	**Mid span Ast 4**
1500	2850	2.5	250	1.10	60	4.23	2.98	3.59	2.54
1500	2850	3	250	1.20	75	5.08	3.62	3.81	2.74
1500	2850	3.5	250	1.10	85	5.32	3.82	4.56	3.27
1500	2850	4	250	1.50	105	8.20	5.81	4.76	3.44
1500	2850	4.5	250	1.75	125	10.06	7.16	5.14	3.74
1500	1500	5	250	1.00	110	7.48	5.35	7.53	5.35
2000	1500	2.5	250	1.40	65	3.71	2.66	2.34	1.70
2000	1000	3	250	1.30	75	4.21	3.03	2.89	2.10
2000	1000	3.5	250	1.20	80	4.99	3.57	3.77	2.72
2000	1000	4	250	1.10	90	5.14	3.71	4.42	3.18
2000	1000	4.5	250	1.75	115	8.67	6.20	4.46	3.24
2000	1000	5	250	1.30	120	7.88	5.67	5.41	3.92
3000	1000	2.5	250	1.00	55	3.95	2.76	3.98	2.76
3000	1000	3	250	2.00	85	6.50	4.68	3.03	2.21
3000	1000	3.5	250	1.50	95	6.36	4.55	3.74	2.71
3000	1000	4	250	1.90	110	8.87	6.35	4.28	3.11
3000	1000	4.5	250	2.00	125	10.44	7.52	4.88	3.55
4000	1000	3	250	1.75	85	7.13	5.02	3.58	2.59
5000	1000	3	250	1.00	70	5.69	3.97	5.74	3.98
5000	1000	4.5	250	1.40	125	10.35	7.33	6.42	4.63
1500	2850	4	415	1.75	120	4.79	3.45	2.49	1.82
2000	1000	4	415	1.30	100	3.44	2.49	2.37	1.72
3000	1000	5	415	1.90	150	6.39	4.63	3.15	2.30

Table 1 shows the training data set for two-way slab design. Training data were collected from different construction farms of Sylhet (EPCT and Universal Group). Those data were used for design of four stories to fifteen stories building construction. Data was normalized. It was conducted because using in neutral network program. After training of the network for nonlinear relationship between thickness of the slab and live load, finish load, span length, grade of steel and aspect ratio, testing of the relationship was conducted by the data collected from construction farms of Dhaka (Concord, Sheltech). Table 2 shows the testing data. Those data was normalized.

Table 2. Testing data set for two-way slab design

Input parameters for testing						Expected output			
Live load N/m^2	Finish load N/m^2	Short span L_X m	Steel grade N/mm^2	Aspect ratio, Ly/Lx	Thickness of slab T, mm	Ast 1 cm^2	Ast 2 cm^2	Ast 3 cm^2	Ast 4 cm^2
1500	2850	3.5	250	1.5	95	6.79	4.84	3.96	2.87.
1500	1500	5.0	250	1.4	130	9.99	7.12	6.25	4.52
2000	1000	4.0	250	1.0	85	4.71	3.39	4.74	3.39
2000	1000	4.5	250	1.3	105	7.13	5.11	4.87	3.52
3000	1000	2.5	250	1.9	70	5.50	3.90	2.61	1.89
3000	1000	4.0	250	2.0	110	9.19	6.60	4.28	3.11
4000	1000	2.5	250	1.9	75	5.94	4.22	2.83	2.05
4000	1000	3.0	250	1.1	75	5.01	3.57	4.28	3.06
4000	1000	3.5	250	1.2	90	6.26	4.47	4.71	3.31
4000	1000	4.0	250	1.5	110	8.57	6.09	4.98	3.61
5000	1000	2.5	250	2.0	80	6.51	4.65	3.00	2.18
5000	1000	3.5	250	1.9	105	9.43	6.68	4.48	3.25
1500	2850	4.0	415	2.0	125	5.01	3.66	2.40	1.75
1500	1500	5.0	415	1.8	150	6.34	4.57	3.30	2.41
2000	1000	4.5	415	1.9	130	4.86	3.54	2.42	1.77
2000	1000	5.0	415	1.3	125	4.55	3.29	3.14	2.28
3000	1000	3.0	415	2.0	90	3.60	2.62	1.71	1.25
3000	1000	4.0	415	1.8	115	4.75	3.41	2.46	1.80
3000	1000	4.5	415	1.5	125	4.97	3.57	2.94	2.14
5000	1000	2.5	415	1.3	75	2.91	2.08	1.98	1.43
5000	1000	3.0	415	1.9	100	4.16	3.00	2.04	1.49
5000	1000	3.5	415	1.1	95	3.56	2.56	3.06	2.20
5000	1000	4.5	415	1.5	135	6.08	4.34	3.56	2.58

Output of testing data from network was found out at three different network architectures. Those network architectures are 5- 15-25-35-45-55-5; 5-25-35-45-55-65-85-105-5 and 5-35-45-65-75-85-5. The output for network architecture 5- 15-25-35-45-55-5 with the learning rate was 0.05 with 10-14% error. Table 3 shows the output for network architecture 5-25-35-45-55-65-85-105-5 and the learning rate was 0.02. This gives 3-5% error. The output for network architecture 5-35-45-65-75-85-5 with the learning rate was 0.04 with 7-10% error. It is clear from the above analysis that the network architecture 5-25-35-45-55-65-85-105-5 is best. It indicates that this network architecture show best convergence, because the number of hidden layers and neurons are more than other two network configurations. Thus, it is clear that learning rate, number of hidden layers and neurons have impact on network training.

Table 3. Outputs obtained from testing (for network architecture 5-25-35-45-55-65-85-105-5)

Thickness	**Ast 1 cm^2**	**Ast 2 cm^2**	**Ast 3 cm^2**	**Ast 4 cm^2**
92.42	5.01	3.47	3.12	2.68
120.68	4.93	4.21	4.78	2.66
125.06	3.03	5.14	4.90	4.07
119.94	9.04	5.54	5.77	4.30
126.86	10.00	5.16	5.36	4.43
131.96	5.90	7.37	7.38	5.10
69.54	2.55	2.68	1.52	1.71
108.95	6.92	4.16	4.76	3.98
115.29	4.37	3.30	2.20	1.95
90.02	6.91	2.67	2.69	2.09
62.79	8.77	4.57	5.88	3.67
143.10	8.53	5.60	3.42	3.42
95.73	3.00	4.47	5.12	3.07
79.64	7.70	3.03	2.16	2.22
92.69	4.31	4.99	5.20	3.72
120.26	7.04	5.54	3.99	3.77
129.02	9.11	6.56	5.20	4.92
101.85	7.62	4.55	4.53	3.38
112.34	2.27	6.02	6.46	4.43
87.69	9.88	6.89	6.86	5.08
104.72	9.12	2.60	2.42	1.93
86.57	6.74	2.79	2.31	1.52
124.76	8.14	5.13	5.76	3.81

Table 4 shows comparison between best testing output and expected output data, which were collected from construction farms of Dhaka (Concord, Sheltech). The network architecture 5-25-35-45-55-65-85-105-5 performed more perfect network training with 0.02 learning rate. This network gives 3-5% error on average. This error was found because of lack of large amount of training data during training session.

Table 4. Comparison between testing output and expected output data

Best testing output data					Expected output				
Thickness mm	**Ast 1 cm^2**	**Ast 2 cm^2**	**Ast 3 cm^2**	**Ast 4 cm^2**	**Thickness mm**	**Ast 1 cm^2**	**Ast 2 cm^2**	**Ast 3 cm^2**	**Ast 4 cm^2**
92.42	5.01	3.47	3.12	2.68	95	6.79	4.84	3.96	2.87.
120.68	4.93	4.21	4.78	2.66	130	9.99	7.12	6.25	4.52
125.06	3.03	5.14	4.90	4.07	85	4.71	3.39	4.74	3.39
119.94	9.04	5.54	5.77	4.30	105	7.13	5.11	4.87	3.52
126.86	10.00	5.16	5.36	4.43	70	5.50	3.90	2.61	1.89
131.96	5.90	7.37	7.38	5.10	110	9.19	6.60	4.28	3.11
69.54	2.55	2.68	1.52	1.71	75	5.94	4.22	2.83	2.05
108.95	6.92	4.16	4.76	3.98	75	5.01	3.57	4.28	3.06
115.29	4.37	3.30	2.20	1.95	90	6.26	4.47	4.71	3.31
90.02	6.91	2.67	2.69	2.09	110	8.57	6.09	4.98	3.61
62.79	8.77	4.57	5.88	3.67	80	6.51	4.65	3.00	2.18
143.10	8.53	5.60	3.42	3.42	105	9.43	6.68	4.48	3.25
95.73	3.00	4.47	5.12	3.07	125	5.01	3.66	2.40	1.75
79.64	7.70	3.03	2.16	2.22	150	6.34	4.57	3.30	2.41
92.69	4.31	4.99	5.20	3.72	130	4.86	3.54	2.42	1.77
120.26	7.04	5.54	3.99	3.77	125	4.55	3.29	3.14	2.28
129.02	9.11	6.56	5.20	4.92	90	3.60	2.62	1.71	1.25
101.85	7.62	4.55	4.53	3.38	115	4.75	3.41	2.46	1.80
112.34	2.27	6.02	6.46	4.43	125	4.97	3.57	2.94	2.14
87.69	9.88	6.89	6.86	5.08	75	2.91	2.08	1.98	1.43
104.72	9.12	2.60	2.42	1.93	100	4.16	3.00	2.04	1.49
86.57	6.74	2.79	2.31	1.52	95	3.56	2.56	3.06	2.20
124.76	8.14	5.13	5.76	3.81	135	6.08	4.34	3.56	2.58

Manual calculation of two-way slab thickness determination

For data used in network training, Short span length (L_x) = 2.5 m; Aspect ratio (L_y/L_x) =1.10; Long span length = 2.5*1.10= 2.75 m; Perimeter of the slab=2*(2.5+2.75) =10.5 m = 413.41 inch; According to ACI code [9], Thickness of two-way slab = $\frac{413.41}{180}$ = 2.3 inch = 58.42 mm. This is near about 60 mm.

The output data from the network testing is depending on network structure and the size, learning algorithm, learning rate, quality and quantity of training. For different network architectures and different learning rates error in outputs varies. If the amount of data used for network training is large, network gives more accurate results. This is why in this study some errors are found in testing output data.

4. CONCLUSION

Output of testing data from network was found out for three different network architectures. It is clear from the above analysis that the network architecture 5-25-35-45-55-65-85-105-5 is best. It indicates that this network architecture show best convergence, because the number of hidden layers and neurons are more than other two network configurations. Therefore, it is clear that learning rate, number of hidden layers and neurons have impact on network training.

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