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Forecast of Highway Subgrade Settlement Based on Improved BP Neural Network

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ABSTRACT

In order to improve the feasibility and accuracy of the roadbed settlement prediction model, the factor analysis method is combined with the BP neural network method, and an improved BP neural network roadbed settlement prediction model is proposed. Select example data to test the improved BP neural network roadbed settlement prediction model. The test results: The relative average error of the 10 sets of training samples' predicted and actual roadbed settlements was 4.287%, and the roads of five predicted samples The relative error of subgrade settlement is 1.79%, 1.93%, 6.62%, 7.19%, 4.05%, all less than 10%, which proves that the improved BP neural network prediction model has good prediction accuracy.

Keywords: Roadbed settlement; Factor analysis method; BP neural network; Simulation prediction

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1. Introduction

In recent years, my country's infrastructure has been gradually improved and achieved world-renowned achievements. Among them, the rapid development of railways and highways has provided strong support for my country's economic construction. Controlling the settlement of roadbed is a key issue in highway engineering, which directly affects the safety of people and vehicles. Therefore, the accurate prediction of the settlement of the roadbed plays a very important role in correct construction and saving project cost [1]. For the prediction of roadbed settlement, scholars at home and abroad have done a lot of research work. Based on the layered summation method, Hu Rongguang established a multiple nonlinear regression equation between subgrade settlement and filling height, elastic modulus, compression layer thickness and time [2]. Pan Linyou et al. analyzed different engineering examples through four different curve fittings and found that the settlement of roadbeds needs to be fitted with different curves according to the actual settlement-time curve [3]. Li Hongfeng et al. used the empirical formula method, the layered sum method, and the curve fitting method to calculate the settlement of the roadbed. Compared with the measured settlement of the roadbed, they found that the empirical formula method can effectively calculate the settlement of the roadbed [4]. Deng Chengfa et al. used the finite element method of Biot's consolidation theory based on the elastic nonlinear model to study the consolidation deformation, pore water pressure changes and dissipation process of the soft soil roadbed of the expressway, and analyzed the roadbed in the soft soil area. Settlement [5]. Su Xiaocheng et al. used the pseudo-static method to study the dynamic stability of subgrade structures and improved the pseudo-static formula [6]. Yu Huan et al. used FLAC3D to establish a numerical model, analyzed the dynamic characteristics of the widened embankment under asymmetric traffic loads, and studied the settlement of the embankment [7].

Based on the related principles of factor analysis, this paper proposes an improved highway subgrade settlement prediction model based on the combination of factor analysis and BP neural network.

2. Application of Factor Analysis and BP Neural Network in Prediction of Subgrade Settlement of Expressway

2.1 Data acquisition of main factors affecting the settlement of highway roadbed

According to practical analysis, the main influencing factors of highway subgrade settlement are: ground treatment method, soft soil layer thickness, soft soil layer compression modulus, embankment height, subgrade filling time and settlement at completion. See the original data for each influencing factor Table 1.

TABLE 1. ORIGINAL DATA OF INFLUENCING FACTORS

Experiment name	*Ground treatment method*	*Soft soil layer thickness /m*	*Soft soil layer compression modulus /MPa*	*Embankment height /m*	*Subgrade filling time / month*	*Settlement at completion / cm*	*Measured final settlement / cm*
1	0.0000	0.0000	0.0335	0.8058	0.4882	0.1333	0.1349
2	0.0000	0.0000	0.0332	0.8191	0.4235	0.4990	0.4973
3	0.1667	0.2250	0.0076	0.0290	0.0000	0.03443	0.0170
4	0.1667	0.6250	0.0000	0.0000	0.5882	0.0000	0.0000
5	0.1667	1.0000	0.0335	0.4930	0.7353	0.2556	0.2174
6	0.3333	0.5625	0.0150	0.3212	0.6059	0.3061	0.3381
7	0.3333	0.2500	0.0190	0.3345	0.4176	0.2758	0.3801
8	0.3333	0.5375	0.0092	0.1633	0.2706	0.1121	0.1624
9	0.3333	0.5000	0.0157	0.2226	0.4882	0.0737	0.0855
10	0.3333	0.7500	0.0157	0.0635	0.3118	0.1081	0.1432
11	0.3333	0.7500	1.0000	0.9177	1.0000	1.0000	1.0000
12	0.3333	0.8750	0.0136	0.4567	0.5882	0.5202	0.5439
13	0.3333	0.3750	0.0083	0.7423	0.8588	0.9525	0.9739
14	0.3333	1.0000	0.0116	0.3146	0.4529	0.6455	0.8998
15	0.3333	0.7000	0.0092	0.6509	0.7647	0.3838	0.3774

2.2 Factor Analysis of Influencing Factors of Highway Subgrade Settlement

The factor analysis function of SPSS software is used to carry out data preprocessing on the factors affecting the settlement of highway subgrade. The input layer parameters of BP neural network are selected as foundation treatment method, soft soil layer thickness, soft soil layer compression modulus, embankment height, roadbed filling time and settlement at the completion of filling, and the above input layer parameters are analyzed by factor analysis Dimensionality reduction processing, replacing the original input layer parameters with the obtained common factors as the new input layer parameters of the BP neural network.

Data preprocessing. Use SPSS software to calculate the variance contribution rate and cumulative contribution rate of each component (Table 2), the correlation matrix table of each factor (Table 3), the component matrix (Table 4), the component score coefficient matrix (Table 5) and the common factor Matrix table (table 6). Select the factor whose cumulative percentage of the first q eigenvalues is greater than or equal to 80% as the common factor. According to the results in Table 2, select 2 common factors.

TABLE 2. VARIANCE CONTRIBUTION RATE AND CUMULATIVE CONTRIBUTION RATE OF EACH COMPONENT

Total variance of interpretation									
Ingredient	*Initial eigenvalue*			*Extract square sum loading*			*Rotation square sum loading*		
	Total	*Variance %*	*Grand total %*	*Total*	*Variance %*	*Grand total %*	*Total*	*Variance %*	*Grand total %*
1	2.894	48.232	48.232	2.894	48.232	48.232	2.819	46.977	46.977
2	1.735	28.909	77.142	1.735	28.909	77.142	1.810	30.165	77.142
3	0.551	9.186	86.328						
4	0.481	8.021	94.349						
5	0.246	4.100	98.448						
6	0.093	1.552	100.000						

TABLE 3. CORRELATION MATRIX TABLE

	Ground treatment method	*Soft soil layer thickness*	*Soft soil layer compression modulus*	*Embankment height*	*Subgrade filling time*	*Settlement at completion*
Ground treatment method	1.000	0.583	0.150	-0.257	0.225	0.279
Soft soil layer thickness	0.583	1.000	0.166	-0.214	0.359	0.196
Soft soil layer compression modulus	0.150	0.166	1.000	0.469	0.521	0.565
Embankment height	-0.257	-0.214	0.469	1.000	0.655	0.703
Subgrade filling time	0.225	0.359	0.521	0.655	1.000	0.680
Settlement at completion	0.279	0.196	0.565	0.703	0.680	1.000

TABLE 4. COMPOSITION SCORE COEFFICIENT MATRIX TABLE

Component matrix a		
	Ingredient	
	1	*2*
Ground treatment method	0.298	0.833
Soft soil layer thickness	0.333	0.820
Soft soil layer compression modulus	0.747	-0.056
Embankment height	0.745	-0.601
Subgrade filling time	0.883	0.025
Settlement at completion	0.895	-0.060

TABLE 5. COMPONENT SCORE COEFFICIENT MATRIX

	Component score coefficient matrix	
	1	*2*
Ground treatment method	-0.023	0.491
Soft soil layer thickness	-0.009	0.486
Soft soil layer compression modulus	0.258	0.034
Embankment height	0.337	-0.269
Subgrade filling time	0.291	0.092
Settlement at completion	0.308	0.045

2.3 Prediction model of BP neural network based on factor analysis

Use F1 and F2 in Table 6 as the input layer parameters of the BP neural network, and final settlement of highway subgrade center as the output layer parameters. The number of hidden layer neurons calculated by the traditional formula of the number of hidden layer neurons [8] and the empirical formula [9] are substituted into the BP neural network prediction model for calculation. The final results show that when the hidden layer neurons When the number is 5, the improved BP neural network has the best convergence effect and the highest accuracy, that is, the empirical formula is used to calculate the number of hidden layer neurons. Finally, the topological structure of the BP neural network model is determined to be 2-5-1.

Use the BP neural network toolbox in Matlab software to create a BP neural network, use 2 common factors as input layer parameters, final settlement of highway subgrade center as output layer parameters, and select tansig function and logsig function as hidden layer neurons and input layer, respectively for the transfer function of the neuron, purelin function and trainlm function are selected as the output layer activation function and BP neural network training function respectively. Set the maximum number of training times to 5000, the training error is 1×10^{-15}, the learning rate is 0.01, and the rest of the training parameters are default values. Use the first 10 sets of data samples of public factors as training samples to learn and train the improved BP neural network prediction model. The prediction result of the training sample is shown in Figure 1. The average relative error between the predicted value of the training sample and the actual value is 4.287%.

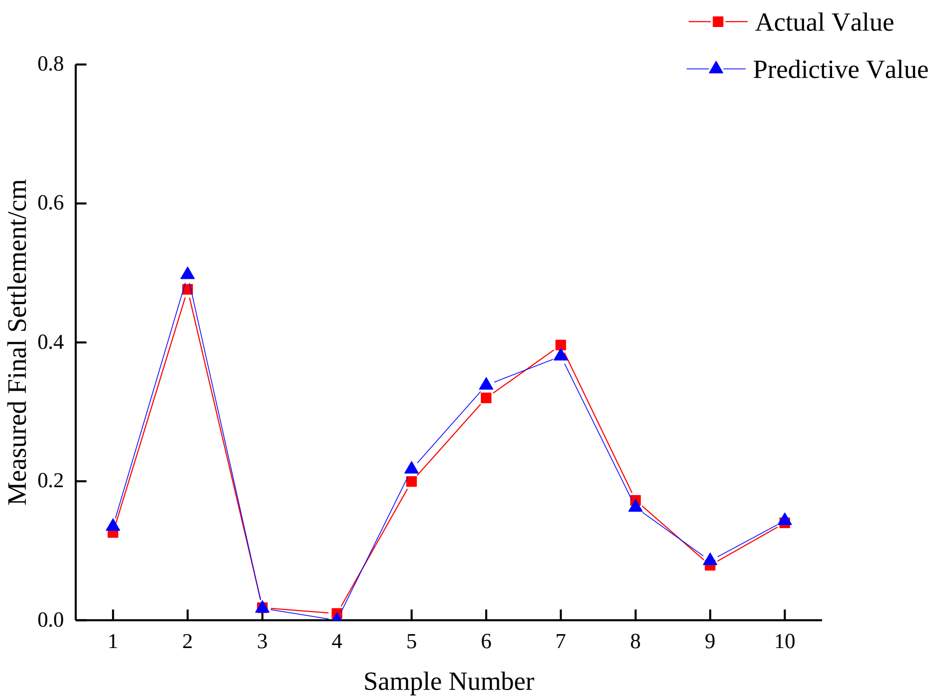

Fig.1 Training samples prediction results

TABLE 6. COMMON FACTOR MATRIX TABLE

F1	*F2*
0.17026	-2.22529
0.46472	-2.20849
-1.41738	-0.73840
-0.81340	0.10173
0.17442	0.32910
-0.15461	0.43722
-0.37694	-0.11944
-0.91511	0.38644
-0.62474	0.35313
-0.98022	0.81062
2.63370	0.57282
0.17213	0.81367
1.23314	-0.03180
-0.02656	1.09535
0.46059	0.42334

The last 5 sets of data samples of common factors are used as prediction samples to test the prediction performance of the improved BP neural network prediction model. The final settlement prediction result of the center of the highway subgrade is shown in Figure 2.

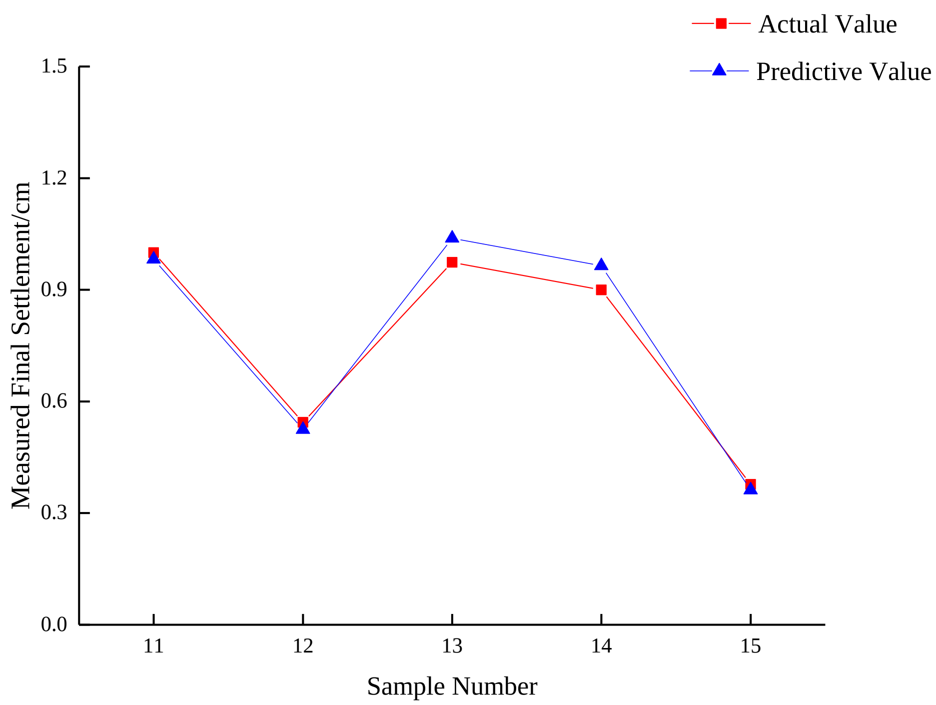

Fig.2 Improved BP model prediction sample Results comparison

TABLE 7. MEASURED FINAL SETTLEMENT PREDICTION RESULTS

Sample number	*Forecast result* /cm	*Desired result* /cm	*Relative error* /%
11	0.9821	1.0000	1.79
12	0.5246	0.5439	1.93
13	1.0384	0.9739	6.62
14	0.9645	0.8998	7.19
15	0.3621	0.3774	4.05

The last 5 sets of data samples of common factors are used as prediction samples to test the prediction performance of the improved BP neural network prediction model. Measured final settlement prediction results are shown in Table 7. The improved BP neural network model predicts the average relative error of the roadbed settlement of the sample is 4.316% respectively, and the model prediction has a small relative error. It has good roadbed settlement prediction accuracy and is suitable for highway roadbed settlement prediction research.

3. Conclusions

(1) Use the first 10 sets of training sample data to learn and train the improved BP neural network prediction model, and compare the predicted value with the actual value. The final settlement of the highway subgrade center has a relative average error of 4.287%, which proves the improvement completed by the training. The BP neural network model has a good fitting effect.

(2) The improved BP neural network prediction method is used to predict the final settlement of the highway subgrade center. The average relative errors of the final settlement of the highway subgrade center of the test prediction effect samples are 1.79%, 1.93%, 6.62%, 7.19%, 4.05%, respectively, both are less than 10%, which proves that the improved BP neural network roadbed settlement prediction model is finally feasible and has good prediction accuracy.

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