Research on an Analysis Method of Engineering Mechanics in Bridge Field based on Machine Learning

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Abstract
The identification of bridge cable force has a great influence on the safety and reliability of arch bridge structure, which is a difficult problem in bridge construction. According to a certain tension sequence, the required sample library of suspender cable force is obtained by establishing the finite element model by MIDAS software. The designed cable force of the bridge is taken as the input vector of the radial basis function method (RBF method), and the initial cable force obtained is the output vector. The solution accuracy is controlled by distributed density parameters, the nonlinear mapping relationship between them is approached, and the initial cable force of suspender is calculated directly. The experimental results show that the error between the calculated value and the design value of the cable force can be controlled within 5% by the RBF method, which meets the engineering requirements.

Keywords
Radial basis function (RBF) method; Arch bridge; The completed.

1. Introduction
The Paihe Bridge is located at the junction of Binhu New District and Fexi District in Hefei. It crosses Xipai River and is an important part of the planned Jianghuai Canal. The main bridge is 238m in length and 31.0m in width. It is a flying geese shaped steel box arch ring three-span bowstring arch bridge. The main arch ring is made of double-sheet steel box arch, the main span is made of orthotropic steel bridge panel, the side span is made of steel box girder section, the suspender is made of whole bundle of extruded steel strand, and the whole bridge constitutes a three-span continuous beam stress system. Among them, the main span is the bow-arch composite system bow-arch bridge, and the tie rod is the rigid and flexible combination tie rod. Calculated span (54+130+54) m, vector height 28m, the number of each side of the boom is 17, the whole bridge a total of 34 boom. The arch rib is made of steel box structure, with a height of 2.2m and a width of 1.5m. The i-type stiffening rib is used inside the arch rib, and the derrick stiffening separator is set at the derrick, which is consistent with the axis of the derrick. The main bridge structure is shown in Figure 1, and the steel box arch section is shown in Figure 2.

Figure 1. Diagram of main bridge structure
2. Analysis and Calculation

In this paper, the finite element software MIDAS Civil is used to establish the spatial beam element model for analysis and calculation, and the activation and passivation functions are used to simulate the whole construction process.

2.1. Model

Beam element is used to simulate the main beam and side span box beam, and thin-wall theory is used to calculate the section characteristics of element section. The suspender is simulated by the truss element with only tension. Considering that the flexible tie bar is simulated by prestressing tendons; the lower support of main beam is simulated by elastic element under compression only. The arch ring support is erected on the main beam, so the arch ring support point and the corresponding point of the main beam are connected by elastic compression only. The compression stiffness of the support is calculated according to the section and height of the actual construction support. When the length \( L \) of the derrick in the model is not equal to the length of the derrick in the structure, the elastic modulus \( E \) of the derrick in the model should be modified according to the principle that the elongation of the derrick after being stressed is equal \([3-4]\):

\[
E_{\text{model}} = \frac{L_{\text{model}}}{L_{\text{real}}} E_{\text{real}}
\]  

In the design of the steel girder grid system of the main span structure, it is considered that "the deck system does not participate in the force", but in the actual structure, the deck system and the web have certain contribution to the overall stiffness of the main bridge after being connected with the steel longitudinal beam through the transverse separation beam. Therefore, the girder element section of the main span section takes the steel bridge faceplate into account, and the transverse diaphragm is applied to the girder section of the main span with joint forces. The final structural model is shown in figure. 3.
2.2. The Calculation Scheme of Boom Tensioning Is Confirmed

The main problem of boom tensioning is that the subsequent boom has influence on the cable force of the previous boom tensioning. The closer the boom is, the softer the structure is and the greater the mutual influence is. Common tensile order: from the two ends to the middle, from the middle to both ends, from the 1/4 span to the middle and then to the two ends, etc. The main methods for the control of suspender cable force are reverse demolition, influence matrix, iteration and RBF. In this paper, the RBF method is used to analyze the tension of the arch bridge, and the process is shown in figure 4.

![Figure 4. RBF neural network](image)

![Figure 5. RBF calculation process](image)
RBF type neural network includes input layer, hidden layer and output layer (FIG. 4). The hidden layer uses radial basis function (such as Gaussian function) as the activation function, while the output layer uses linear function as the activation function [6]. When the tension control force of the suspender is calculated in a certain tension order, the cable force is designed as the input vector, and the initial cable force obtained is taken as the output vector. The test samples obtained by finite element calculation were input into RBF network for training and testing. By adjusting the distribution density parameter (Spread value) to control the prediction accuracy, the initial cable force of the boom is calculated, and the RBF calculation process is shown in Figure 5.

3. **Radial Basis Network Application**

![Figure 6. Arch bridge boom number](image)

In order to improve efficiency, the suspenders of The Paihe Bridge are tensioned into place in batches, each batch of which consists of 4 symmetrical suspenders. The sequence is HN4 (HS4) → HN5 (HS5) → HN3 (HS3) → HN6 (HS6) → HN2 (HS2) → HN1 (HS1) → HN7 (HS7) → H0 → HN8 (HS8). Considering that the shortest HN8 (HS8) cable is not easy to control, the last tension HN8 (HS8) is made.

![Figure 7. The network structure](image)

In this paper, a total of 20 groups of data were obtained by finite element calculation, among which 1 ~ 18 groups were selected as training samples and 19 ~ 20 groups as test samples. Newrbe function was used to construct RBF network, which contains two hidden layers. The network structure is shown in Figure 7.

There are 18 neurons in the radial base layer of the hidden layer, and the node function is the Gaussian function, and the output layer of the hidden layer has 17 neurons, and the node function adopts a simple linear function, in which the MATLAB code is: `net=newrbe(Pscore,T,spread value)`, where P is the input vector and T is the target vector.

The default spread value is 1, and the larger it is, the smoother the function is.

When the accuracy of the test sample is less than 5%, the Spread value is selected as the training network. For the trained RBF network, the prediction error is detected by testing the generalization characteristics of the samples. The prediction error of the network is calculated when the value of Spread is 1-15, and the result is shown in figure 8.
Figure 8. Take the forecasting errors of different Spread values

The results show that when the Spread value is 15 and 7, the prediction error is within 1% and 5% respectively, which meets the accuracy requirement. The distribution density parameters have a great influence on the accuracy of prediction. When the values are 15 and 7, the calculation and design cable forces are shown in Table 1 and Table 2.

Table 1. When the Spread value is 15, the cable force value and error calculated according to the output value

| Serial number | The completed/kN | Error / % |
|---------------|-----------------|-----------|
|               | To calculate    |           |
| HN8           | 554.1           | 557.5     | -0.6    |
| HN7           | 605.6           | 603.0     | 0.1     |
| HN6           | 613.6           | 610.0     | 0.6     |
| HN5           | 594.8           | 606.5     | -1.9    |
| HN4           | 505.0           | 535.0     | -5.6    |
| HN3           | 520.5           | 556.0     | -6.4    |
| HN2           | 549.4           | 581.5     | -5.5    |
| HN1           | 478.4           | 521.5     | -8.3    |
| H0            | 480.8           | 532.0     | -9.6    |
| HS1           | 480.1           | 521.5     | -7.9    |
| HS2           | 550.7           | 581.5     | -5.3    |
| HS3           | 520.5           | 556.0     | -6.4    |
| HS4           | 509.1           | 535.0     | -4.8    |
| HS5           | 594.5           | 606.5     | -2.0    |
| HS6           | 612.8           | 610.0     | 0.5     |
| HS7           | 604.9           | 603.0     | 0.3     |
| HS8           | 554.6           | 557.5     | -0.5    |
Table 2. When the Spread value is 15, the cable force value and error calculated according to the output value

| Serial number | The completed/kN  | Error / % |
|---------------|------------------|-----------|
|               | To calculate     | design    |           |
| HN8           | 554.3            | 557.5     | −0.6      |
| HN7           | 593.1            | 603.0     | −1.6      |
| HN6           | 598.6            | 610.0     | −1.9      |
| HN5           | 588.6            | 606.5     | −3.0      |
| HN4           | 511.7            | 535.0     | −4.4      |
| HN3           | 532.3            | 556.0     | −4.3      |
| HN2           | 556.9            | 581.5     | −4.2      |
| HN1           | 498.2            | 521.5     | −4.5      |
| H0            | 498.2            | 521.5     | −1.5      |
| HS1           | 557.1            | 581.5     | −4.5      |
| HS2           | 532.3            | 556.0     | −4.2      |
| HS3           | 511.5            | 535.0     | −4.3      |
| HS4           | 588.4            | 606.5     | −4.4      |
| HS5           | 598.6            | 610.0     | −3.0      |
| HS6           | 593.1            | 603.0     | −1.9      |
| HS7           | 554.1            | 557.5     | −1.6      |
| HS8           | 498.2            | 521.5     | −0.6      |

4. Conclusion

In this paper, through the application of the machine learning method of RSF neural network in the drainage bridge project, we verify the feasibility of this method to control the sling force, and the diffusion value of the distribution density parameter has a great influence on the accuracy of the prediction results. The experimental results show that when the diffusion values are 15 and 7, the prediction errors are less than 1% and 5% respectively, which can meet the requirements of engineering accuracy.

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