Research Article

Finite Element of Nanoscale Carbon Fiber-Reinforced Concrete Bridge Engineering Monitoring Based on Data Mining Technology

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The finite element method divides the existing solid structure into a finite number of elements. It integrates and analyzes the divided elements according to preset criteria, and then solves the equilibrium equation of the overall structure according to the corresponding boundary conditions. The problem is analyzed through a finite element model. A large amount of data from the experiment are derived, and then data mining technique is used to find out the data that are useful for the experiment. The purpose of this paper is to test bridge engineering through data mining technology, and then simulate different fiber-reinforced concrete models through finite element method. In this paper, three kinds of nanofibers, carbon fiber (CFRP), glass fiber (GFRP), and aramid fiber (AFRP) are used to make concrete bridges. Loading experiments are also carried out with different degrees of load on the bridge and 100 experiments on the error interval. The experimental results show that the displacement is proportional to the load to a certain extent. The carbon fiber concrete has a stronger positive correlation than the other two materials. Its finite element simulation experimental data have 78% error difference between 0 and 10, while the other two are around 40%.

1. Introduction

1.1. Background. Under the combined influence of nature and application environment, bridge concrete components are often accompanied by extreme environmental impacts, such as earthquakes and floods. Coupled with the adverse effects of early design and construction defects, as the application period increases, its application efficacy will inevitably weaken. Therefore, a lot of researchers started to study bridge engineering to find better bridge materials through the introduction of data mining and finite element methods. Therefore, it is extremely important to effectively monitor the quality of bridge engineering. However, the physical and chemical reactions of corrosive elements can easily cause steel corrosion in traditional reinforced concrete components in a specific corrosive environment, which leads to cracks along the bars of the concrete, the reduction of the bonding force between the steel and the concrete, the damage of the scattering section of the steel and the corrosion damage, etc. The durability, applicability and bearing capacity of the structure are greatly compromised. Therefore, it is very important to find a new metal material to make concrete.

1.2. Significance. A bridge project cannot be done casually in reality. The finite element analysis solves this problem perfectly, and it can directly simulate the bridge structure for experimental analysis. It is of great significance to promote the development of bridge engineering. Adding activated carbon fibers to ordinary cement can significantly control the expansion of cracks, thereby greatly increasing the tensile, flexural and shear hardness of the cement so that the impact resistance, fatigue resistance and elasticity after fracture of cement can be improved. A large number of important achievements have been obtained in the research on carbon fiber-reinforced concrete structures. Carbon fiber-reinforced concrete structures have been widely used in...
various construction engineering fields such as roads, civil engineering, and hydraulic engineering. Even in many developed countries, design and construction specifications or standards for carbon fiber-reinforced concrete structures have been formulated. The study of the finite element method of carbon fiber-reinforced concrete will further promote the application of carbon fiber in various fields, which is of great research significance. Therefore, it can be expected that the use of carbon fiber-reinforced concrete structures will become more common.

1.3. Innovation. In this paper, the carbon fiber (CFRP), glass fiber (GFRP), and aramid fiber (AFRP) are compared. These three materials are applied to concrete, and then the bridge of 2100 mm × 150 mm × 300 mm is made. The finite element analysis model is established, and the bridges are detected by using two data mining techniques, decision tree and neural network. Then the experimental data are obtained. Its data are also analyzed. The innovation of this paper include: (1) This paper introduces the relevant theories of data mining technology, and applies decision tree and neural network methods to the experiments. (2) This paper compares concrete bridges of three fiber materials, and establishes a finite element model to analyze the problem so as to make the experimental data more convincing. (3) This paper summarizes various indicators of concrete of various fiber materials, as well as introduces the differences between them and the solution of some indicators.

2. Related Work

At present, a large number of researchers conduct research on data mining technology. Among them, Lee et al. used data mining techniques, combining logistic regression, decision tree diagrams, neural network models, and partial least squares (PLS) models to predict customer churn in the mobile industry [1]. Zhang studied the definition of data mining technology, obtained the steps and methods of data mining technology, and analyzed its application in the badminton court tactical analysis system [2]. Huo et al. studied the value of data mining models in evaluating the therapeutic effect of acupuncture on cervical spondylosis and neck pain patients [3]. Song took the research and application of data mining technology in book copyright information management decision-making system as the theme, and studied the role of data mining technology in book copyright information management [4]. Liu et al. used 3D virtual reality and data mining technology to analyze the wearing comfort from the numerical pressure of clothing, which showed how different human body parts affect the wearing comfort of clothing [5]. But the feasibility is not very high.

There are also a large number of researchers on the finite element analysis of nanoscale carbon fiber-reinforced concrete bridge engineering monitoring. Elliott and Ranner investigated a new finite element method for numerical approximation of solutions to partial differential equations in the volume domain and surface partial differential equations proposed on the boundary of the volume domain [6]. Zhan studied the relationship between the phase-locked equation and the superconducting Ginzburg-Landau equation. He proposed the finite element analysis and calculation of the phase-locked equation, and established the existence of strong and weak solutions of the equation [7]. Sexton et al. investigated settlement prediction methods using finite element analysis and conducted a comprehensive review and evaluation to determine which method was most consistent with finite element prediction results for end-bearing columns from PLAXIS 2D axisymmetric analysis [8]. Yao et al. established a detailed finite element model of aircraft tires based on the actual geometry of the target tires for numerical simulation, and used CV and CPM methods to conduct finite element analysis for safety assessment of aircraft tires [9]. However, the experimental cost is relatively high, and further research is needed.

3. Bridge Engineering Monitoring Knowledge and Methods

3.1. Data Mining Technology. Data mining is to mine useful information for users from a large amount of data, and data mining is to find that information or knowledge that cannot be seen directly by human eyes [10]. It refers to the process of extracting hidden, unknown, but potentially useful information and knowledge from a large amount of incomplete, noisy, fuzzy, and random practical application data. In simple terms, it is the extraction or “mining” of knowledge from large amounts of data. Data mining is the use of various analytical tools to find relationships between models and data in datasets, and to obtain information technology predictions, which can help decision makers find possible connections between data and reasons for disregarding information. Therefore, it is regarded as an effective way to deal with the problem of insufficient information caused by data explosion in today’s information age. Data refers to a collection of relevant facts F, which is used to describe the information of relevant aspects of the transaction. It is the raw material for knowledge discovery, while data mining is the process of deeper processing of data, which is an advanced process of data processing. The model is shown in Figure 1 including the processes of problem definition, data selection, data preprocessing, data transformation, data mining, knowledge evaluation, and knowledge representation [11].

Data mining technology refers to the technology of data processing in the process of data mining. There are mainly decision trees, neural networks, and other commonly used data mining techniques. Decision tree is a supervised learning method. It mainly finds classification rules from some data without any rules.

Decision tree is a design method that operates slowly from the top to the bottom. After each iteration, a new cycle is required, and then a feature attribute is selected for bifurcation until it can no longer be bifurcated [12]. There are many indicators that can be used to measure this impurity, including entropy, exponent and error, these are relatively common. Their formulas are as formulas (1)–(3):
Entropy
\[ E(D) = -\sum_{i=1}^{n} p_i \log_2 p_i \] (1)

Gini Index
\[ G(D) = \sum_{i=1}^{n} p_i (1-p_i) \] (2)

Classification error
\[ 1 - \max \{p_i\} \] (3)

Among them, \( D \) represents each set of data, and the set is divided into \( n \) in total. \( p_i \) represents the sample rate of the \( i \)th category as formula (4):
\[ p_i = \frac{N_i}{N} \] (4)

In formula (4), \( N \) and \( N_i \) represent the total number of sample data in set \( D \) and the number of samples in the \( i \)th category respectively.

The activation function model commonly used in neural networks is a neuron called sigmoid. A neuron model can have three inputs, but it can also have other numbers of inputs, which are marked as \( x_1, x_2, x_3 \) here. A simple calculation output rule uses different weights to indicate how important each input is to the model. The output of the neuron is determined by a certain threshold after weighting, and the output of the neuron is usually 0 or 1. Thresholds, like weights, are also a parameter of neurons [13]. Strict algebraic form is used to represent the input in the graph and turned into a formula as formula (5):
\[ y = f(W^T X) = f \left( \sum_{i=1}^{3} \omega_i x_i + b \right) \] (5)

In formula (5), the function \( f(x) \) is the activation function; \( x_i, \omega_i (i = 1, 2, 3) \) correspond to the three inputs and weights respectively; \( b \) is a scalar called the bias parameter. Usually, the activation functions used by neural networks also usually have different types, and the use of different transfer functions may also affect the differences in the structure and function of neural networks.

Among them, the sigmoid function has the form as formula (6):
\[ f(z) = \frac{1}{1 + e^{-z}} \] (6)

The form of the hyperbolic tangent function is as formula (7):
\[ f(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}} \] (7)

The function image comparison of the two of them is shown in Figure 2.

In Figure 2, it can be seen that the sigmoid function has the interval \([0, 1]\), while the tanh function has the interval \([-1, 1]\). For multiple neurons, there is a mapping relationship between them, as shown in Figure 3.

The Bayesian classification method is obtained according to Bayes’ theorem, which is a very mature classification method. It is mainly used to predict the likelihood of relationships among class members. For example, the probability of a given observation belonging to a specific category is judged by its related properties [14].

3.2. Nanoscale Carbon Fiber Concrete. The shortcoming of ordinary concrete being easy to crack is a major direct reason that limits its application. In general, concrete members work with cracks. Cracks greatly reduce the ability of the structure to be lower than the external erosive substances, and the harmful substances in the environment penetrate into the interior of the components and directly corrode the steel bars, which ultimately reduces the durability of the components and even affects the bearing capacity of the structure [15]. The factors that affect the durability of concrete are shown in Figure 4.

Figure 1: Data mining model.
The most important role of fibers in concrete is to inhibit the crack propagation of the matrix under external loads. Nanomaterial refers to an ultrafine material whose particle size is defined in nanometer order (1 nm to 100 nm), and its size is in the transition region where atomic clusters interface with macroscopic objects. When the component is bent or stretched, deformation occurs, and the initial fiber and the matrix share the cross-sectional stress. At this time, since most of the fibers have not been “tightened,” the tensile stress cannot be effectively provided, so the matrix bears most of the stress. When the matrix is cracked, the fibers bridge the two ends at the cracks. At this time, the fibers exert their high tensile strength, and the fibers bear most of the tensile stress of the section. When the fiber volume content is greater than a certain critical value and the fiber length is long enough, the improvement effect on the composite material is great. When the deformation of the component is large enough, the fibers are pulled out or even broken so that the component can be destroyed. In the whole failure process, the pulling out and breaking of fibers can consume a lot of energy, so the incorporation of fibers can greatly improve the tensile strength and toughness of concrete, and improve various technical properties of concrete (such as impermeability properties, durability) [16]. Common fiber materials are shown in Table 1.

In general, the addition of fiber can be used in the following aspects: (1) Improve tensile strength. There are many internal defects in ordinary concrete, which cause good bonding between components. The incorporation of fibers can effectively enhance the bonding force inside the concrete so that the tensile strength of the material can be fully guaranteed. (2) Resist cracks. When the concrete is in the plastic stage, it is easy to produce fine cracks. Due to shrinkage during cement hydration or deformation during loading, these fine cracks will rapidly expand and transform into wide cracks. The incorporation of fibers into the matrix can prevent the propagation of the original microcracks and inhibit the propagation of the cracks. In addition, several main cracks with extremely large crack width and extremely fast extension often appear in the flexural and tensile members of concrete. The presence of these “dangerous cracks” can cause harmful substances in the environment to corrode the reinforcement and possibly lead to brittle failure of the member. The incorporation of fibers can improve the crack morphology, making the components more cracked, and multiple fine and dense cracks will be formed [17]. (3) Increase the deformation capacity. The fiber-reinforced concrete can continue to bear a certain load even if there are

Figure 2: Comparison of sigmoid function and tanh hyperbolic tangent function.

Figure 3: Simple diagram of multiple neuron transmissions.
many and dense cracks when it is bent and pulled. With false ductility, the impact resistance and toughness of components can be significantly improved. This function can effectively protect the steel bars in the reinforced concrete components from erosion, thereby improving the durability of the components and prolonging the life of the structure. In order to compare the differences of various fibers, Figure 5 shows the style diagrams of four fiber materials: carbon fiber, steel fiber, polypropylene fiber, and PVA fiber.

This paper mainly studies the CFRP fiber material in FRP. FRP is a new type of composite material with high-strength fiber as the increasing phase and resin as the matrix. With its high strength, high modulus, corrosion resistance, easy processing, and other characteristics, it is gradually being used more and more to reinforce the old buildings, bridge engineering, coastal engineering, etc. FRP short fibers are used in engineering as an admixture, which can be added during concrete grouting to effectively improve the impermeability and impact resistance of concrete structures. FRP bars can be used as a substitute for traditional steel bars and pre-stressed tendons in concrete structures. They can also be used in long-span cable suspension structures, support structures, and tension structures. FRP sheet is the most widely used in structural reinforcement and repair projects. When in use, it is infiltrated with resin and then pasted on the surface of the structure. The two are combined into a whole and bear the force together. The winding profile in the FRP profile can be used for filling concrete in the winding pipe to form piles, columns, etc. Its shear resistance and seismic performance of the reinforced components are better than those of ordinary steel tube concrete. According to the different types of fibers composed of FRP, fiber composite materials mainly used in engineering can be divided into carbon fiber-reinforced polymer (CFRP), glass fiber-reinforced polymer (GFRP), aramid fiber-reinforced polymer (AFRP) [18]. Table 2 shows their various indicators.

Table 2 gives a detailed comparison between the properties of three types of FRP materials and traditional steel. Since carbons in CFRP are distributed along the lattice axis in the form of covalent bonds, it can be seen that the tensile strength of CFRP not only far exceeds that of traditional steel, but also has the highest tensile strength and elastic modulus compared with the other three FRP materials. On the other hand, the density of CFRP is only about 1/6 of that of steel, so it has a specific strength far greater than that of other materials, which means that CFRP components have a strength reserve far exceeding that of steel components under the same quality as steel components. Taking a suspension bridge as an example, when the main cable is made of high-strength steel, its theoretical maximum span is 3,000 meters. When this theoretical span is exceeded, the load-bearing efficiency of the main cable of the steel cable is extremely low and can only bear its own weight. Moreover, CFRP has a small thermal expansion coefficient at room temperature and is dimensionally stable. CFRP material also has shortcomings. Because it has no yield point in the
traditional sense of steel and the fracture strain is small, it is characterized by brittle failure, so special attention should be paid in design and use.

CFRP is evaluated from many complex environmental factors such as temperature, humidity, dry-wet cycle, freeze-thaw cycle, water immersion environment, corrosion of chemical media (acid, alkali, salt, etc.), ultraviolet radiation and so on. It can be discovered that its mechanical properties are almost unchanged, showing its durability far superior to traditional steel. CFRP also has electrical conductivity. After external force, it has obvious piezoresistive effect. Its internal damage, such as fiber breakage or delamination, will lead to a decrease in the electrical conductivity of the composite material. Using this property, CFRP can be used to monitor the working state of concrete structures.

From the current point of view, carbon fiber-reinforced concrete is the most widely used in practical engineering, and the research is also the most complete. The application and theoretical research of fiber-reinforced concrete have gradually evolved and developed through the example of steel fiber. From the comprehensive consideration of performance requirements, economic applicability, and construction difficulty, the volume content of carbon fiber in engineering applications is mainly between 0.5% and 2%. According to existing research, it can be known that when the volume content of carbon fiber is 1%-2%, the tensile strength can be increased by 40%–60%, the flexural strength can be increased by 60%–120%, and the shear strength can be increased by 50%–120%. In addition, carbon fibers can be made into flat-end or end-bend forms according to requirements to enhance the anchorage between the fiber and the matrix.

The composite mechanics theory is usually applied to the matrix and its unidirectional uniform configuration of composite materials. For composites reinforced with long fibers in one direction, when the direction of tensile force is along the direction of the fibers, three assumptions are required to review the stress law of the material: The matrix is isotropic and homogeneous; The fibers are uniformly distributed along the direction of force; The deformation of the fiber matrix is coordinated. The force diagram is shown in Figure 6.

The composite stress laws are as formula (8):

\[
\sigma = \sigma_m(1 - \rho_f) + \sigma_f \rho_f.
\]  

(8)

In formula (8), \(\sigma\) represents the stress of the composite material; \(\sigma_m, \sigma_f\) represent the stress borne by the matrix and fibers, and \(\rho_f\) represents the fiber volume fraction. The elastic modulus of the composite material can be obtained from formula (8). The corresponding strains are derived on both sides at the same time as formulas (9) and (10):

\[
d\sigma = d\sigma_m(1 - \rho_f) + d\sigma_f \rho_f,
\]  

(9)

\[
E = E_m(1 - \rho_f) + E_f \rho_f.
\]  

(10)

In formulas (9) and (10), \(E, E_m, E_f\) are the elastic modulus of the composite material, the elastic modulus of the fiber and the elastic modulus of the matrix respectively.

The fiber spacing theory is based on linear elastic fracture mechanics to explain the constraining effect of fibers on the generation and development of cracks. In order to enhance the tensile strength of fiber-reinforced concrete with internal micro-cracks, it is necessary to minimize the size of the internal micro-cracks, improve its toughness, and reduce the stress field intensity factor at the tip of the micro-cracks. The existence of fibers can effectively constrain the development of cracks, reduce the intensity factor of the stress field at the tip, and ease the stress concentration at the tip.
3.3. Finite Element Analysis. The finite element method originated in the 1950s and 1960s. As a mechanical analysis method, the finite element method was first applied to the finite element dynamic analysis of bridges, and was gradually extended to the research of the entire civil engineering field. The finite element method divides the existing solid structure into a finite number of elements, integrates and analyzes the divided elements according to preset criteria. Then it solves the equilibrium equation of the overall structure according to the corresponding boundary conditions. On the basis of a reasonable comprehensive analysis, the engineering designers evaluate the strength and stiffness of the structure, and adjust the unreasonable design parameters to obtain a more optimal design scheme. With the rapid development of electronic computers, in order to solve complex problems in engineering, people develop and use finite element software to solve practical problems in reality. The use of finite element software has helped people to solve the problem of large amount of calculation for practical problems in different fields. In recent years, with the continuous maturity of computer programming technology and the continuous improvement of finite element theory, the development of finite element software is also very rapid. Its calculation modules continue to increase, such as static analysis, structural nonlinear analysis, dynamic analysis and so on. Its functions have also continued to increase, and the simulation of actual engineering has become more and more refined. In conclusion, finite element software has become a powerful calculation tool for engineers.

Its general analysis process mainly includes the following five aspects: Discrete structure—It can divide the model into discrete domains composed of finite units with multiple approximate shapes, finite sizes and connected to each other; Element analysis—Through studying the relationship between the single body and the internal force and shape parameters, the relationship between the internal force of the node and the displacement between the nodes is derived, and the rigidity matrix of the single body is established; Overall analysis—Through studying the assembled elements of equilibrium conditions and continuous conditions, the overall rigidity matrix is obtained, and the overall stiffness equation of the structure is established. The boundary conditions are also considered, and the overall rigidity matrix is partially adjusted; Problem solving—It first selects the unknowns (strain, stress) of the target, and solves the simultaneous equations by direct method, iterative method and random method; Comprehensive evaluation—Through comparing with the allowable value provided by the design criteria or related requirements, it can evaluate and determine whether there is a need for double counting.

It can be seen from its basic process that, compared with other analysis methods, the biggest feature of the finite element analysis method is normalization and standardization, which makes the analysis and calculation of large-scale complex problems possible. With the rapid improvement of the computing power of modern computers, engineering designers have the ability to solve large and complex engineering problems by using relevant compiled software.

The finite element model of CFRP concrete structure has three modeling methods: separated model, integral model and combined model. (1) Separate model: The simulation of CFRP concrete uses different elements, ignoring the transverse shear strength of CFRP. In ANSYS specific modeling, the Link8 space rod element is used to build the CFRP model. According to the test results in this test process, the bond between CFRP concrete is good. The slip is small, and the CFRP unit and the concrete unit can share the unit node. (2) Integral model: Concrete or CFRP materials are not considered separately when modeling, and CFRP is considered to be uniformly dispersed in the concrete. The model is convenient for modeling and is suitable for the macroscopic response of components under the action of external loads, but it is not suitable for the uneven distribution of CFRP materials. It is difficult to calculate the internal force of CFRP. (3) Combination model: The combined model is between the integral model and the separate model. The CFRP is embedded in the concrete unit, and it is considered that the bond with the concrete is good without slip, and the displacement or strain of the two are completely consistent. By comparing the characteristics of each model, this paper selects a plastic damage analysis model combining separate and integral models when conducting the flexural nonlinear finite element analysis of CFRP fiber high-strength concrete beams.

For this simulation, the calculation assumptions should be followed. Therefore, in the process of selecting the constitutive relationship of reinforced concrete in this simulation, the constitutive relationship provided by the relevant codes is mainly referred to. The stress–strain relationship of concrete under compression is as formulas (11) and (12):

\[
\sigma = (1 - d_t)E_c\varepsilon \\
d_t = \begin{cases} 
1 - \rho_t(1.2 - 0.2x^2) & x \leq 1 \\
1 - \frac{\rho_t}{\alpha_t(x - 1)^{1/2} + x} & x > 1
\end{cases}
\]  

Among them,

\[
x = \frac{\varepsilon}{\varepsilon_{t,r}}
\]  

\[
\rho_t = \frac{f_{s,r}}{E_c\varepsilon_{t,r}}
\]

In formulas (13) and (14), \(\sigma\) is the concrete stress; \(d_t\) is the concrete damage evolution parameter; \(\alpha_t\) is the parameter of the descending section of the uniaxial tensile stress–strain curve of the concrete, and \(f_{s,r}\) is the tensile strength of the concrete. To sum up, it is the stress–strain constitutive relationship of the referenced concrete. The stress–strain relationship of concrete is shown in Figure 7.

In Figure 7, A represents \(f_{s,r}\); B represents \(\varepsilon_{t,r}\); C represents \(f_{s,r}\); D represents \(\varepsilon_{t,r}\), and the ordinate of the curve point corresponding to E is half of A.
strength, the stress-strain relationship curve of the material increases linearly. The ultimate tensile strength of the material is reached, and the material is pulled apart.

4. Experiment of Nanoscale Carbon Fiber-Reinforced Concrete Bridge Engineering Monitoring Finite Element Analysis Based on Data Mining Technology

4.1. Finite Element Analysis of Nanoscale Carbon Fiber-Reinforced Concrete Bridge Engineering Monitoring Based on Data Mining Technology

The size of the bridge used in this experiment is $2100 \text{ mm} \times 150 \text{ mm} \times 300 \text{ mm}$. Three kinds of fibers, namely carbon fiber (CFRP), glass fiber (GFRP), and aramid fiber (AFRP), are prepared for comparative experiments. The test piece adopts a customized wooden formwork for pouring, assembling and disassembling, which is convenient for recycling, and the bottom of the formwork is sanded and leveled. Place spacers at the bottom and sides of the cage to ensure that the thickness of the protective layer meets the design requirements. According to the design mix ratio, the concrete mixing method of dry mixing first and then wet mixing is adopted, and the coarse and fine aggregates and cement are mixed evenly. Then the steel fiber is added while stirring. After a day and night, the concrete beams reaches a certain strength and the formwork is removed. It should be ensured that the specimen is maintained at least three times a day by watering, and then it should be covered with plastic film after each watering. After curing for 28 days, the specimens are moved to the laboratory for further work. Then the basic mechanical function of the bridge is tested. The decision tree and neural network in data mining are used to detect the bridge in real time, and the abnormal data are mined. Based on these experimental materials and methods, the finite element model is established, and the comparison of various materials is obtained through simulation. Figure 8 shows the different loads of concrete bridges with different fiber materials under different lateral displacements. Figure 8(a) is the experimental data, and Figure 8(b) is the simulation data obtained by using the finite element method.

It can be seen from Figure 8(a) that the greater the load is, the greater the lateral displacement of the concrete bridge of the three materials will be. Its maximum load is reached at 30 mm. Compared with other materials, the displacement of CFRP material is the same distance, and the concrete bridge of CFRP material is subjected to the largest load. The simulated data of the finite element model in Figure 8(b) are not much different from the experimental data with only a small error. The two figures have one thing in common. That is, when the displacement is 0–30 mm, the load is almost proportional to the displacement. But when the displacement continues to increase, the load is slowly decreasing, indicating that the bridge has a problem to a certain extent.

Then the longitudinal force of the experimental concrete bridge is given to see the longitudinal displacement. The experimental data are shown in Figure 9.
As can be seen from the two graphs in Figure 9, the longitudinal displacement of the bridge is proportional to the load received. The CFRP material receives the maximum load at the same displacement distance. Other data of carbon fiber are shown in Table 3.

It can be seen from Table 3 that the experimental data of carbon fiber-reinforced concrete bridges are in line with the standard data.

In order to make the experimental data more credible, two data mining methods are recorded in this experiment to record the strain of the experimental material. The experimental data are shown in Figure 10.

It can be seen from Figure 10 that the material strain is proportional to the mid-span load, and the concrete bridges made of GFRP and AFRP materials receive less mid-span load than CFRP under the same strain.

4.2. Experimental Results. In this experiment, the finite element model is used to simulate the strain of the three materials for a total of 100 times, and the difference between the data and the experimental data is determined, as shown in Table 4.

Combining all the data, it can be seen that the carbon fiber concrete has the best effect, which is more in line
Figure 9: Longitudinal displacement load comparison diagram of bridges with three materials. (a) Longitudinal displacement loads for three materials. (b) Longitudinal displacement load of finite element model of three materials.

Table 3: Carbon fiber-reinforced concrete bridge related data.

| Test items                        | Standard requirement | Test result |
|----------------------------------|----------------------|-------------|
| Standard value of tensile strength (MPa) | >3400                | 3500        |
| Tensile modulus of elasticity (MPa)   | ≥ 2.3 × 10^5         | 2.51 × 10^5 |
| Elongation (%)                    | >1.6                 | 1.63        |
| Bending strength (MPa)            | >700                 | 783         |
| Interlaminar shear strength (MPa)  | >45                  | 48.2        |
| Mass per unit area (g/m²)         | >300                 | 298         |
Figure 10: Continued.
with the experimental expectations than the other two fiber materials in any index. It is also the closest to the finite element simulation data. For example, a transverse and longitudinal load is applied to a bridge. In each displacement interval, the load of CFRP material is always larger than that of other materials. The data analyzed by the finite element simulation of each material are proportional to some extent. When the displacement reaches more than 30 mm, the lateral load will reach more than 900 kN. When the displacement is still increasing, the load changes little and floats in the range of 800–900. Combining with Table 4, it can be seen that the error difference of the experimental data of CFRP materials accounts for 78% between 0 and 10, while the other two materials account for about 40%.

5. Discussion

In this paper, three kinds of fibers, namely carbon fiber (CFRP), glass fiber (GFRP), and aramid fiber (AFRP), are compared and tested. These three materials are applied to concrete. Then a bridge of 2100 mm × 150 mm × 300 mm is made. In addition, the finite element analysis of the bridge is carried out, and the relevant finite element model is established. The comparison data are obtained through experimental simulation, and then the experiment is carried out on the fabricated sample bridge in the laboratory. Bridges are detected by using two data mining techniques, decision tree and neural network, through different levels of loads. Then the experimental data are obtained, and the data analysis is carried out. However, there are still some shortcomings in this experiment. In this experiment, there is no experimental comparison of concrete with different proportions of carbon fiber materials. In this way, it is impossible to find the best ratio of carbon fiber-reinforced concrete bridges. But in general, it is proved that carbon fiber-reinforced concrete materials are better than other fiber materials.

Table 4: Number of times the simulated data differ from the experimental data.

|        | AFRP | GFRP | CFRP |
|--------|------|------|------|
| 0–10   | 41   | 43   | 78   |
| 10–20  | 43   | 42   | 12   |
| 20–30  | 11   | 9    | 8    |
| 30–40  | 3    | 5    | 1    |
| 40–50  | 2    | 1    | 0    |

Figure 10: Strain data of three fiber-reinforced concrete bridges. (a) Strain data for decision tree methods. (b) Strain data for neural network approaches. (c) Strain data for the finite element method.

6. Conclusions

In this paper, carbon fiber (CFRP), glass fiber (GFRP), and aramid fiber (AFRP) are used to make concrete bridges, and load experiments are carried out. The lateral and longitudinal loads of the bridge are carried out to different degrees respectively, and it is found that the displacement is proportional to the load to a certain extent. 78% of the experimental data of finite element simulation of CFRP materials have an error difference between 0 and 10. The other two are around 40%, and this experiment has largely studied the advantages of carbon fiber. With the development of society, the concrete of fiber material will be further studied, and better materials will be continuously found, thus promoting the development of bridges.
Data Availability
No data were used to support this study.

Conflicts of Interest
The authors declare no potential conflicts of interest in this study.

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