Research Article

Condition Detection and Maintenance of Steel-Fiber-Reinforced Concrete Based on Markov Random Matrix

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The condition detection and maintenance of steel-fiber-reinforced concrete (SFRC) involves a combination of qualitative and quantitative assessment methods, while the ineffectiveness of the Markov chain can analyze the fluctuation law of gray fitting accuracy indexes and use this to correct the detection results of the residual gray model, having outstanding advantages. On the basis of summarizing and analyzing previous works of literature, this study expounded the research status and significance of the condition detection and maintenance of SFRC, elaborated the development background, current status, and future challenges of the Markov random matrix, introduced the methods and principles of feature extraction network and loss function, proposed the detection process analysis of SFRC based on Markov random matrix, constructed a detection model of SFRC, analyzed the maintenance monitoring method of SFRC based on Markov random matrix, discussed the maintenance effect evaluation of SFRC, and finally carried out a simulation experiment and its result analysis. The results show that the most important feature of Markov random matrices is the absence of aftereffects, which means that the condition evolution of SFRC can be regarded as a multiple Markov chain. When carrying out the dynamic condition maintenance of SFRC, the maintenance object should be first determined, then the condition detection of the object should be carried out to obtain information characteristics and to assess its condition, and then the condition should be compared with the condition set to determine its position in the set to make fault prediction based on the Markov chain constructed from the set of conditions. Under other expected standards and maintenance conditions with the increase of steel fiber content, the flexural strength of concrete decreased first and then increased, but the difference of maintenance conditions had obvious influence on the flexural strength of concrete. The results of this paper provide a reference for further research on the condition detection and maintenance of SFRC based on the Markov random matrix.

1. Introduction

Steel-fiber-reinforced concrete (SFRC) is a new, high-performance, special composite material composed of short and discontinuous steel fibers uniformly distributed in concrete or reinforced concrete. As a composite material, SFRC is composed of two parts: concrete and fiber admixture, in which concrete is used as matrix and steel fibers are used as admixture [1]. It has high tensile, flexural, and shear strength, as well as significant fatigue resistance, crack resistance, impact resistance, excellent toughness and ductility, good heat resistance, shrinkage resistance, and wear resistance. It is an excellent new type of cement concrete pavement material [2]. After SFRC specimens are formed, if their surfaces are covered and stood for 24 or 48 hours at an indoor environment with a temperature of 20±5°C and relative humidity of 95%, this indoor maintenance is called standard maintenance. While the common practice at the construction site is to put SFRC into water or bury it in wet sand for 28 days or put it in a house in winter to heat it up with an electric furnace or a coal furnace, this maintenance method is better than the same condition maintenance but worse than the standard maintenance, commonly known as natural conservation [3]. Although the structural performance of SFRC has been significantly improved, there are still many quality
accidents, so it is also very important to strengthen the detection of concrete conditions [4].

Markov chain evaluation method is a statistical method based on probability theory and stochastic process theory, through the establishment of stochastic mathematical model to analyze the condition of dynamic system and the statistical model of condition transition, its outstanding feature is from the perspective of system condition change to evaluate the system [5]. The model fitting curve of the residual is an exponential curve, which reflects the fluctuation degree of the original data around the fitting curve and also reflects the dynamic time-varying degree of the residual, and its variation trend is nonstationary and random [6]. Both the maintenance time and the concrete strength grade have a certain influence on the size effect strength of SFRC, that is, the size effect phenomenon is more obvious, in which the concrete strength grade has a greater influence on the size effect coefficient. The ineffectiveness of the Markov chain can analyze the fluctuation law of the gray fitting accuracy index and use this to correct the residual gray model detection results and improve the detection accuracy. There are two traditional Markov chain detection methods, namely, the Markov chain detection method based on absolute distribution and the superposition Markov chain detection method. Therefore, many evaluation methods combining qualitative and quantitative have been paid more and more attention [7]. The evaluation method based on the Markov chain evaluates from the analysis of the condition of the dynamic system and the condition transition, which has good versatility and strong practical value [8].

On the basis of summarizing and analyzing previous works of literature, this study expounded the research status and significance of the condition detection and maintenance of SFRC; elaborated the development background, current status, and future challenges of the Markov random matrix; introduced the methods and principles of feature extraction network and loss function; proposed the detection process analysis of SFRC based on Markov random matrix; constructed a detection model of SFRC; analyzed the maintenance monitoring model of SFRC based on Markov random matrix; discussed the maintenance effect evaluation of SFRC; and finally carried out a simulation experiment and its result analysis. The results of this paper are expected to provide a reference for further research on the condition detection and maintenance of SFRC based on the Markov random matrix. The detailed chapters are arranged as follows. Section 2 introduces the methods and principles of feature extraction network and loss function; Section 3 analyzes the condition detection of SFRC based on the Markov random matrix; Section 4 deals with the condition maintenance of SFRC based on Markov random matrix; Section 5 carries out a simulation experiment and its result analysis; Section 6 is the conclusion.

2. Methods and Principles

2.1. Feature Extraction Network. The mathematical definition of Markov stochastic process is a stochastic process whose conditional probability is only related to the previous condition and has nothing to do with earlier conditions:

$$A_i = \frac{a_i}{b_i} \sum \left( \frac{1}{a_i} - \frac{1}{b_i} \right),$$

where $A_i$ is an independent random variable; $a_i$ is the condition vector of the $i$th step; and $b_i$ is the condition transition probability of the $i$th step. The Markov random matrix is completely determined by the initial probability $a_i$ and the condition transition matrix $b_i$. It can be seen from this formula that the Markov random matrix can be used to express various first-order iterative processes with random characteristics.

Assuming that the initial condition of SFRC is $c_i$ and the time is $d$, the conditions that may be experienced from this condition to the fault condition are $c_i, c_i + 1, \ldots, c_n$. Because only the fault condition is an absorbing condition, to predict the moment when the fault condition occurs, it is only necessary to calculate the total residence time $B_i$ of other conditions experienced before the fault condition occurs:

$$B_i = \frac{1}{e} \sum_{j=1}^{n} \frac{d_j - c_i}{f - j} - \frac{1}{k} \sum_{j=1}^{n} \frac{d_j - c_i}{f - j},$$

where $e$ is the transition matrix; $f$ is the average number of visits to the condition; $j$ is the average shortest time required for the Markov chain to reach the fault condition; $k$ is the residence time of the Markov chain in the condition $c_i$ before reaching the fault condition; and $l$ is the shortest average number of steps from the initial condition to the fault condition.

In order to construct a random measurement matrix, the random numbers generated by the Markov chain are used as elements in the measurement matrix, so that the measurement matrix has randomness. Part of the random measurement matrix is both random and deterministic, and its reconstructed image effect is good, but because it needs to randomly extract rows from an orthogonal high-order square matrix to construct the matrix, it will cause waste of storage resources. If the sand content is low, the mortar cannot completely fill and wrap the aggregate voids and the surface of the coarse aggregate, reducing the workability of concrete. The compressive strength of SFRC is closely related to the propagation speed of ultrasonic waves in SFRC. The setting of two pumping positions increases the mobility, and speed effect of the construction and fiber-reinforced concrete has high impact resistance [9]. The slump of SFRC should generally be significantly lower than that of ordinary concrete. If the steel fibers are not properly added, it is easy to cause uneven distribution of the steel fiber in the concrete, and the fibers form a ball, which greatly reduces the strength of SFRC and seriously affects the quality. The positioning of the pumping equipment is arranged according to the construction site and the flow operation area, within the range of proximity, corresponding elevation, load span, etc. After the pump pipe is arranged and installed, it should be carefully checked and accepted, and a trial run should be carried out.
2.2. Loss Function. In order to fully consider the hardening and softening phenomena in the full stress-strain curve of concrete, the concrete constitutive model is established based on the theory of plastic mechanics in the strain space, in which the concrete stress increment $C_i$ is decomposed as follows:

$$C_i = \left( m - \frac{1}{o} - \frac{1}{p} \right) \left( m - \frac{1}{q} - \frac{1}{r} \right),$$

where $m$ is the total stress increment; $o$ is the elastic predicted stress increment; $p$ is the residual stress increment corresponding to the plastic strain increment under elastic conditions; $q$ is the concrete elastic strain; and $r$ is the elastic stiffness matrix of the concrete.

The gray fitting accuracy index $D$ sample times of transition from condition $s_i$ to condition $t_i$ after $n$ steps is recorded as $D_i$, and then the transition probability $E_i$ from condition $s_i$ to $t_i$ after $n$ steps is

$$E_i = \frac{\sum_{j=1}^{N} D_{ij}}{\sum_{j=1}^{N} (x_j - y_j)} = \sum_{j=1}^{N} \frac{u_j}{v_j} = \left[ \begin{array}{cccc} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mn} \end{array} \right],$$

where $u_i$ is the gray fitting accuracy index of the $i$th order; $v_j$ is the autocorrelation coefficient of the $i$th order; $w$ is the maximum order calculated of the $i$ condition according to the prediction; and $x_i$ and $y_j$ are the lower and upper bounds of the $i$ condition.

A Markov chain is a discrete-time random process with Markov properties in mathematics. In this process, given the current knowledge or information, only the current condition is used to predict the future, and the past is irrelevant for predicting the future. As shown in Figure 1, at each step of the Markov chain, the system can change from one condition to another according to the probability distribution, or it can keep the current condition. After the steel fibers are mixed into the concrete, the properties of the concrete and reinforced concrete are greatly improved, and the tensile, flexural, crack resistance, impact resistance, wear resistance, and fatigue resistance of the concrete or reinforced concrete are significantly improved [10]. The addition of steel fibers to concrete not only improves the mechanical properties but also increases the durability, reduces the maintenance times of the pavement, and has obvious technical and economic benefits. The requirements for the mix ratio of SFRC should firstly reduce the thickness of the pavement and secondly ensure that SFRC has a high flexural strength to meet the structural design requirements for strength grades, namely, compressive strength, flexural strength, and workability of construction. The stress is transmitted to the steel fibers through the binding force between the concrete and the steel fibers and the concrete is restrained by the steel fibers, which limits the occurrence of new cracks and delays the expansion of the cracks.

3. Condition Detection of SFRC Based on Markov Random Matrix

3.1. Detection Process Analysis of SFRC Based on Markov Random Matrix. For a list of dependent random variables,
the superposition of absolute distributions obtained by various step-size Markov chains is used for prediction analysis, which is called the superposition Markov chain prediction method, which is a more commonly used Markov chain prediction method. The basic steps of the prediction of the superimposed Markov chain model can be briefly summarized as follows: (1) calculate the mean value and mean square error of the series; (2) establish the grading standard of the series value; (3) calculate the condition transition matrix of Markov chains with different step lengths; (4) use the mean vector of each condition and the row vector of the condition transition matrix to superimpose and predict the condition of SFRC at this time point; and (5) compare the predicted value with the actual observed value and evaluate the prediction effect (Figure 2). During the compression process of steel fiber rubber high-strength concrete, the supersonic speed of sound decreases with the increase of load. The three stages of the sound speed and stress curve are stable, slow, and accelerated decline, which are related to the generation, development, and penetration of cracks. During the loading process of high-strength concrete, its supersonic velocity decreases with the increase of load. Therefore, in the structural inspection, the ultrasonic pulse method can be used to detect and analyze the development of cracks in the steel fiber rubber high-strength concrete structure.

In order to realize the training of the segmentation network model for cracks and corrosion instead of categories, the model marks the crack dataset pictures with segmentation masks and generates files such as target crack masks and category labels. It flips, rotates, increases brightness, pans, and adds noise to get the desired image. In order to obtain a continuous and complete crack image of the concrete block, the toughness and fatigue properties of SFRC have certain advantages. By introducing regularization, the model fine-tunes the network parameters with the validation set after training, tests on the test set, and puts the trained network model into the test set to test the results [11]. The original model intersection ratio is a standard for measuring the accuracy of detecting corresponding objects in a specific data set. However, the commonly used intersection ratio optimization is not completely equivalent, and the commonly used intersection ratio cannot be directly optimize the parts that do not overlap. During the maintenance period, the surface of the concrete test block will appear different colors, and the later shooting factors will also affect the crack area. The crack accuracy rate is lower than the other two categories, and the artificial addition of categories is simple and features are easy to extract.

Compared with the cement concrete without steel fiber, the slumps of the cement concrete with steel fibers are correspondingly reduced, and the difference between the two slumps is relatively small and not constant. Steel fiber can reduce the slump of concrete, but the reduction is relatively small, and the fluidity of concrete mixed with steel fibers is small, and it can be commercialized. During the deformation process, the surface of the concrete simply supported beam germinates, then large cracks are formed, and finally, the failure is unstable. Regardless of whether it is a reinforced concrete simply supported beam or a plain concrete simply supported beam, during the vertical loading process, cracks appear first in the tension zone at the lower part of the simply supported beam. Different from the failure of reinforced concrete simply supported beams, plain concrete simply supported beams often have a short failure process during the loading process because there are no stressed steel bars at the bottom, and they often fail immediately after cracks appear, and the failure section generally presents smooth characteristics, mainly as follows: brittle failure. After adding steel fibers into plain concrete simply supported beams, although the compressive bearing characteristics of the simply supported beams cannot be completely improved, the failure process of the concrete simply supported beams is delayed, and the failure surface presents irregular characteristics, which clearly expresses the steel fibers [12].

3.2. Detection Model Construction of SFRC Based on Markov Random Matrix. The optimal volume ratio of the steel fiber content in SFRC can be determined by the laboratory test method for tensile and compressive tests and according to the curve drawn by the test results. Flexural strength is the main mechanical index of SFRC, the basic parameter to characterize the mechanical properties of the material, and the main content of construction quality control and inspection. Therefore, whether SFRC is used for pavement or bridge deck pavement, the flexural strength is generally used as the control index during design and verification [13]. The SFRC and ordinary concrete specimens can be tested simultaneously to compare the relevant data. The early strength of SFRC is high, and early wet maintenance should be paid attention to, and at the same time, finished product protection should be done to prevent surface damage. The surface of the concrete entering the maintenance stage should have a certain hardness, which can be gently pressed with your fingers. Specifically, straw bags, sacks, or wet sand are used to cover the concrete thinly, and at the same time, regular watering is carried out to maintain the wetness of the road surface, and the road surface maintenance should be carried out continuously for at least seven days. Figure 3 shows the distribution of autocorrelation coefficients in the condition detection model of SFRC based on the Markov random matrix. The density and compression of concrete is expressed by the propagation speed of ultrasonic waves, and the strength of concrete is determined by the density of concrete. The less dense the concrete, the lower the strength and the slower the sound waves travel. When mixing concrete, it is required that the mortar can completely wrap the surface of the coarse aggregate and fill the pores between the coarse aggregates. If the sand content is too high, on the basis of using the same amount of cement, the amount of cement mortar on the surface of the aggregate will be reduced, resulting in a decrease in the force between the aggregates, and will affect the propagation speed of ultrasonic waves in the concrete [14]. Under the action of dynamic load, when SFRC develops
cracks, first of all, the steel fibers are pulled out against the cohesive force of the concrete, or the steel fiber reaches the yield strength and is pulled off, which requires a lot of energy, so the steel fibers are pulled out. After the concrete is solidified, the propagation speed of sound waves in the concrete will also decrease, so there must be an optimal sand content that can improve the compactness and workability of the concrete in different steel fiber dosages (Figure 4). The greater the density of concrete, the faster the propagation speed of ultrasonic waves, and the better the compressive strength of SFRC, so the use of ultrasonic testing technology can effectively detect the strength of SFRC.

Based on a series of mechanical tests of SFRC, it can be seen that steel fiber mainly plays a reinforcing role in the concrete after tensile cracking, and the tensile cracking failure is the main failure form of the concrete structure. By studying the constitutive model of SFRC under tension, the strengthening mechanism of steel fiber on the strength and toughness of cracked concrete can be obtained, and it also provides a theoretical basis for the finite element numerical simulation of concrete structure. After SFRC is cracked in tension, the steel fibers play a crucial role in preventing the crack from continuing to propagate. The most important feature of the Markov random matrix is that it has no after effect, that is, the condition of the next period is only affected by the condition of the current period and not affected by the conditions of the past periods. After cracking, the stress is transferred to the steel fibers through the bridging effect of the fibers on the cracked surface. In the finite element model of concrete, it is assumed that each element has only one crack, which passes through the center point of the element. The normal direction of the cracking surface is the direction of the maximum plastic strain on the initial yield surface. After the concrete cracks, the steel fibers pass through the bridging effect on the cracked surface and bear the tensile stress, and the bridging effect of the steel fibers on the cracked surface can make the concrete continue to be tensioned after the cracking.

4. Condition Maintenance of SFRC Based on the Markov Random Matrix

4.1. Maintenance Monitoring Method of SFRC Based on the Markov Random Matrix

After SFRC specimens are...
formed, if their surfaces are covered and are stood for 24 or 48 hours at an indoor environment with temperature of $20 \pm 5^\circ C$ and relative humidity of 95%, this indoor maintenance is called standard maintenance. Standard maintenance conditions can be achieved in the laboratory, but most engineering sites cannot. The common practice at the construction site is to put SFRC into water or bury it in wet sand for 28 days, or put it in a house in winter to heat it up with an electric furnace or a coal furnace. This maintenance method is better than the same condition maintenance but worse than the standard maintenance, commonly known as natural conservation. In many areas, the strength of steel fiber reinforced concrete maintained in this condition is often used as the basis for evaluating the quality of the acceptance of the concrete project [15]. This maintenance method has a great influence on the strength of the steel fiber reinforced concrete constructed in winter and summer, which makes the strength of the steel fiber reinforced concrete has great dispersion, so that the statistical method is often unqualified. This maintenance method is incorrect, so it is recommended that the construction unit pay attention to this problem; engineers can buy a standard maintenance box for steel fiber reinforced concrete and establish a standard maintenance room so that the steel fiber reinforced concrete is really in a standard maintenance state. The flowchart of maintenance monitoring method of SFRC based on Markov random matrix is shown in Figure 5.
Under other maintenance conditions except for the standard maintenance conditions, with the increase of steel fiber content, the flexural strength of concrete decreased first and then increased, but the difference of maintenance conditions had an obvious influence on the flexural strength of concrete. However, from the comprehensive comparison of the entire maintenance conditions and different dosages, the flexural strength of concrete gradually increases with the increase of steel fibers. Similarly, the flexural strength of concrete is also significantly affected by the maintenance conditions; in this way, there is a large temperature difference between day and night. In order to objectively reflect the possible impact of maintenance conditions on the flexural strength of concrete, the temperature change data during the maintenance time were also collected on the spot. As shown in Figure 6, under each maintenance condition, although the flexural strength of concrete varies with the increase of the steel fiber content, the comprehensive judgment shows that, under the condition of the large temperature difference and constant temperature, there is still a tendency to become stronger, which once again verifies the maintenance conditions. With the change of steel fiber content in concrete, the flexural strength of concrete under different maintenance conditions changes obviously. After the steel fiber content changes, the flexural strength of concrete under standard maintenance conditions is always better than that under natural maintenance. It reflects the adverse impact of poor maintenance environment on construction.

Under the condition that the volume ratio of steel fibers is different, the more the amount of expansion agent is added, the greater the increase rate of compressive strength with mold curing; this is because, during curing, the expansion agent is hydrated under the constraints of the steel mold. Formed or columnar crystals are more likely to block capillary pores in concrete and honeycomb pores in cementation. The crystals are intertwined with the cementation to form a three-dimensional spatial network structure, which makes the network structure inside the concrete more compact, but the compensation shrinkage concrete for
standard curing cannot achieve such a good effect [15]. After the concrete cracks, the normal stress on the cracked surface is shared by the steel fiber and the plain concrete. Based on the diffuse cracking constitutive model of concrete, plain concrete enters the softening section when cracks occur and can withstand a rapid decrease in stress. When the pressure exceeds the pressure that the concrete can bear, in order to facilitate transportation, pumping, and pouring of steel-intensive structures, it can generally be solved by adding admixtures. A slump loss of steel fiber reinforced concrete should also be considered. In addition to climate, there are also influences such as transportation process and pumping failures, which can be adjusted in the test according to experience.

4.2. Evaluation of the Maintenance Effect of SFRC Based on the Markov Random Matrix. Both the maintenance time and the concrete strength grade have a certain influence on the size effect coefficient of the flexural strength of SFRC, that is, the size effect phenomenon is more obvious, in which the concrete strength grade has a greater influence on the size effect coefficient. At the same time, the flexural strength of SFRC specimens of various sizes will increase with the increase of the volume ratio of steel fibers. The splitting tensile strength of concrete specimens with different strengths and sizes was improved to different degrees by the incorporation of steel fibers (Figure 7). The splitting tensile strength of the small-sized specimens is more obviously improved than that of the larger-sized specimens. The reason for the analysis may be that the splitting tensile strength of the small-sized specimens has been significantly enhanced due to the influence of the side wall effect. With the increase of the size of the concrete specimen, the measured splitting tensile strength at both ages decreased, indicating that the phenomenon of size effect also exists in the splitting tensile strength of SFRC. The flexural strength of concrete specimens in both sizes increases with the increase of the steel fiber volume ratio, and the flexural strength of small size specimens is significantly higher than that of larger size specimens, indicating the resistance of SFRC. There is a size effect phenomenon in flexural strength.

After the construction of SFRC pavement is completed, the slitting treatment should be carried out. The cutting time should be reasonably controlled: if the cutting time is too early, the cement hydration is incomplete, and the bonding strength between the aggregate and the fiber is not formed; if the joint time is too late, the fiber concrete has already developed strength, and it is prone to uneven cracking in the later stage. The spacing of the slits should be determined according to the size of the actual pavement project, and cement paste or other materials should be selected for grouting after slitting. Things are always in constant development and change, and when they are disturbed or stimulated, certain fluctuations will inevitably occur, and sometimes the fluctuations are very large. The various conditions of the finite Markov random matrix have both an intercommunication relationship and a one-way relationship. Therefore, when conducting evaluations, firstly, the outstanding ones must be selected; it is undeniable that evaluation is not the purpose. The purpose is to promote things to better perform their functions, which is not enough to simply sort according to the results. More importantly, it is necessary to observe the changes of things after a period of time; only in this way can the evaluation be more reasonable and more efficient [16].

SFRC is a concrete-based composite material mixed with steel fibers, which is a composite material mixed with granular materials and fiber materials. Therefore, the internal structure of SFRC presents a heterogeneous multiphase complex system, and its performance mainly depends on the properties of concrete matrix, steel fiber properties, and interfacial bonding. Such microcracks are mainly caused by chemical shrinkage caused by cement hydration and volume change during drying. Many studies have found and proved that concrete-like materials are the result of the
internal cracking microcracks that continue to expand and eventually penetrate after being loaded, and the damage is only the final stage of the crack development process [17]. The damage is the phenomenon that microdefects in materials under monotonic loading or repeated loading lead to the progressive weakening of its internal cohesion and lead to the destruction of volume units. The damage description models of materials can be roughly divided into three types: micromodel, macromodel, and characteristic model. That is to say, the damage is only the last stage of the crack development process, and to truly describe the various properties of concrete, it is necessary to study the evolution law of microcracks within it and carry out concrete damage mechanics analysis.

5. Simulation and Result Analysis

As a stochastic process, the evolution of SFRC condition seems to be relatively close to a Markov random matrix, which can be approximated by a Markov chain. The probability is only related to the condition of the current period and has nothing to do with the condition of the past periods. This view means that the evolution of the condition of SFRC is regarded as a multiple Markov chain, but as long as the current condition is regarded as being affected by the past condition, the influence of the current condition on the future condition already includes the past condition impact [18]. As shown in Figure 8, from the mathematical point of view, it is possible to reduce the multiple Markov chains into a single Markov chain by increasing the dimension of the indicators that characterize the current condition and including the influence of the past condition. Under the condition of different amount of expansion agent, the larger the volume ratio of steel fiber, the larger the ratio of compressive strength improvement. This is because the restraint effect of steel fibers on concrete is reflected in the interior, while the restraint effect of steel formwork on concrete is reflected in the exterior; the combination of internal and external restraint effects increases the compressive strength ratio of concrete. The basic feature of the martingale process is that the expected value of random variables in each period is equal to the actual value of previous period, and the difference between the actual values of two adjacent periods is a white noise process.

If the potential failure of SFRC is detected at any time, preventive maintenance is carried out, and this method can effectively prevent the occurrence of functional failure of SFRC. However, when the reliability of SFRC itself is good, too much testing will not only lose economy but also affect the performance of SFRC. Increasing the inspection interval may alleviate this situation, but this brings a more serious problem, which may lead to some SFRC with shorter intervals not being cured in time, resulting in greater losses [19, 20]. When carrying out the dynamic condition maintenance of SFRC, the object of condition maintenance should be determined first, and then the condition detection of the object should be carried out to obtain the information characteristic quantity (Figure 9). Then, the model compares...
the condition with the condition set, judges its position in the condition set, and predicts the fault according to the Markov chain constructed by the condition set. The quality of SFRC should not only control the raw materials, mixing ratio, and the main links of the construction process but also focus on the control of the mixing of SFRC, the input of steel fiber, and the vibration of concrete. The flexural strength and compressive strength of broken blocks have all met the design requirements so that the flatness, slump, and main technical indicators have been effectively controlled.

The expansion effect caused by the hydration of the high-energy expansion agent can compensate for the volume shrinkage of the concrete. Its continued expansion and deformation are limited, the hydration products are forced to grow into the internal voids, improving the concrete pore structure and the interface between the concrete and the pipe wall. On the one hand, the shrinkage-reducing composite superplasticizer has a high water-reducing rate, which can reduce water consumption, reduce porosity, and maintain concrete plasticity for a long time. In the middle and late
stages, the surface tension of the liquid in the capillary pores of the cement body is reduced, and the self-shrinkage is reduced. At the same time, the water required for the hydration of the material can be supplemented, and the hydration of the material can be promoted continuously. The steel fibers are distributed uniformly and disorderly in the concrete, with the aggregate as the core, and interspersed around it to form a network-like structure stiffening skeleton, which restricts the formation of microcracks and inhibits the extension of macrocracks, improving the flexural and tensile mechanical properties of concrete [21, 22]. In addition, the existence of steel fibers can also constrain the expansion and deformation of concrete, so that the self-stress level of microexpanded concrete is further improved, the self-restraining effect is enhanced, and the volume deformation is more stable. Therefore, the composite of steel fiber and expansion agent promotes and stimulates each other, which greatly improves the mechanical properties of concrete, and at the same time better maintains the volume stability of concrete.

6. Conclusion

This study introduced the methods and principles of the feature extraction network and loss function, proposed the detection process analysis of SFRC based on Markov random matrix, constructed a detection model of SFRC, analyzed the maintenance monitoring method of SFRC based on the Markov random matrix, discussed the maintenance effect evaluation of SFRC, and finally carried out a simulation experiment and its result analysis. If the potential failure of SFRC is detected at any time, preventive maintenance is carried out, and this method can effectively prevent the occurrence of functional failure of SFRC. However, when the reliability of SFRC itself is good, too much testing will not only lose economy but also affect the performance of SFRC. After cracking, the stress is transferred to the steel fibers through the bridging effect of the fibers on the cracked surface. In the finite element model of concrete, it is assumed that each element has only one crack, which passes through the center point of the element. The normal direction of the cracking surface is the direction of the maximum plastic strain on the initial yield surface. The results show that the most important feature of Markov random matrices is the absence of aftereffects, which means that the condition evolution of SFRC can be regarded as a multiple Markov chain. When carrying out the dynamic condition maintenance of SFRC, the maintenance object should be first determined, and then the condition detection of the object should be carried out to obtain information characteristics and to assess its condition, and then the condition should be compared with the condition set to determine its position in the set to make fault prediction based on the Markov chain constructed from the set of conditions. Under others, except the standard, maintenance conditions, with the increase of steel fiber content, the flexural strength of concrete decreased first and then increased, but the difference of maintenance conditions had obvious influence on the flexural strength of concrete. The results of this paper provide a reference for further research on the condition detection and maintenance of SFRC based on the Markov random matrix.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interests to influence the work reported in this paper.

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References

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