RESEARCH ON CRACK PROPAGATION LAW OF ASSEMBLY CONCRETE STRUCTURE IN HYDRAULIC ENGINEERING BASED ON LARGE DATA ANALYSIS

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Abstract: In order to grasp the law of crack propagation in concrete structure, the research on the law of crack propagation in assembly concrete structure of hydraulic engineering based on large data analysis is put forward. The mechanical parameters in the process of concrete structure fracture are obtained by digital image measurement method, and the loss difference is calculated. According to the calculation results, the fracture orientation change is judged, and the law of concrete fracture orientation change is concluded, thus the law of crack propagation in assembled concrete structure is deduced. At last, the experiment proves that the research on crack propagation law of assembly concrete structure in hydraulic engineering based on large data analysis has high accuracy and practicability, and fully meets the research requirements.

1. Introduction
The fracture of concrete shows a fracture process with aging process, rather than focusing on an instantaneous state. It is due to the cohesive effect of tooth bond between aggregate and sand after cracks occur in concrete materials. In the past, linear elastic fracture mechanics method is usually used to classify cracks in concrete structures, but in concrete materials. In the process of crack direct tension, the softening of concrete occurs in the strain process, which leads to the vulnerability of concrete structure. Therefore, linear elastic fracture mechanics is difficult to be directly applied to the study of crack law of concrete structure[1]. Inspired by the plastic fracture mechanics model and model, some experts and scholars first proposed a virtual crack model to describe the cohesion distribution in the softening zone of concrete materials and introduced a new concept of "fracture process zone"[2]. In recent years, there is a point of view that the expansion law and cohesion distribution should be studied in the fracture analysis of concrete structures, and its influence on the fracture properties of concrete materials should be investigated. However, the effect of this method on the fracture process at the front of cracks in the actual research process is not good enough, and the effect of this method on the fracture properties of concrete materials cannot be considered effectively in time, resulting in the change of its characteristics. It is difficult to judge the actual fracture variation parameters effectively when the fracture energy and the initial fracture degree are two fracture parameters[3]. It is of great significance for the development of concrete fracture mechanics to carry out research on the characteristics of fracture process zone. Therefore, based on the principle of large data analysis, the law of crack propagation in assembled concrete structure of water conservancy project is studied.
2. Analysis of Crack Propagation Law of Assembly Concrete Structure in Water Conservancy Project with Large Data

2.1 Calculation of Fracture Parameters of Concrete Structures

Firstly, the extension process of fracture process zone of concrete three-point bending beam specimens was measured by digital image correlation method. This method has the advantages of simple data acquisition, real-time measurement, high accuracy, simple test instrument, easy realization of measurement process, easy realization of automatic measurement, and can be completed in ordinary laboratories[4]. This method can be used to determine the size of specimens under arbitrary load levels and the opening width of crack zone. The results show that in the fracture process of specimens, the formation first increases with the increase of load, and then decreases with the decrease of load after increasing to the length of the complete fracture process zone[5]. The length corresponding to peak load and the length of complete fracture process zone increase with the increase of specimen height and decrease with the increase of initial fracture height ratio, which indicates that the length is related to the initial ligament length. The main reasons for cracks in concrete dams in hydraulic engineering construction technology are as follows:

(1) The unreasonable allocation of raw materials for concrete dams or the excessive thickness of coarse materials in the mixing process but insufficient and uneven vibration tamping work result in settlement cracks.

(2) During the hardening process of concrete dams, volume deformation of concrete occurs, and this force will counterbalance the self-restraint force of concrete, resulting in shrinkage cracks.

(3) In the process of concrete forming and hardening, the concrete will maintain the plastic shrinkage state. At this time, the smaller and lighter particles in concrete will gradually move upward, while the larger and heavier particles will gradually move downward. Plastic cracks occur when the moving process is restrained by the external steel bar or steel plate structure.

(4) It is difficult to reach an agreement between the temperature of concrete itself and the temperature of external environment, and there will be some errors, which will result in different degrees of thermal expansion and cold contraction between the inside and outside of concrete, and produce certain tensile stress, and cracks on the surface of dam body.

(5) Another is the cracks caused by the construction not in accordance with strict construction standards.

The first three are cracks caused by concrete itself, and the second two are cracks caused by external objective factors.

After the concrete is tampered with the flat warehouse, it is easy to be affected by temperature, deformation and other factors in the depth of 10 cm below the concrete surface before the concrete is covered. The formula for calculating the difference of concrete pouring cracks is as follows:

\[ A = B + (C + B) \cdot (D_1 + D_2 + \cdots + D_n) \]  \hspace{1cm} (1)

In the formula, B is the mass parameter of concrete mixing process, C is the thickness of coarse aggregate in concrete pouring, \((D_1 + D_2 + \cdots + D_n)\) is the peak load of concrete in the construction process; under the absolute closed condition, that is, when there is no heat dissipation around, the cement in the concrete is a variable produced in the process of chemical heat. The mathematical formulas are expressed as follows:

\[ E = F \left( 1 - G \right) \]

\[ = \frac{H \cdot I}{J \cdot \rho} \left( 1 - G \right) \]  \hspace{1cm} (2)

In the formula, E is the restraint value of concrete at a certain time; F is the maximum damage value; H is the loss parameter of water conversion per kilogram of cement, as shown in Table 1; I is the cement content in concrete per cubic meter; J is the specific heat of concrete; \(\rho\) is the density of concrete; G is
a constant, usually 2.5345, and the value of H is regulated as follows:

| Wastage parameter | 5   | 10  | 15  | 20  | 25  | 30  |
|-------------------|-----|-----|-----|-----|-----|-----|
| H                 | 0.264 | 0.364 | 0.367 | 0.378 | 0.381 | 0.427 |

After pouring concrete according to the designed building model, a pouring change will occur. Afterwards, influenced by hydration, the temperature and hardness of concrete will gradually increase. However, due to the constant exchange of environmental parameters with surrounding media, the internal temperature of concrete has a process from low to high and from high to low. Therefore, the probability of concrete cracks is estimated, and the estimation formula is as follows:

\[ K = L + \zeta M \]  (3)

In the formula, K is the internal hardness of concrete at a certain time, L is the pouring quality of concrete, M is the adiabatic temperature rise of concrete. \( \zeta \) For density damage coefficient, the numerical formula for coagulation crack generation is as follows:

\[ N = O + \frac{4}{P^2} R (P - R) \]  (4)

In the formula, N is the surface temperature of concrete at a certain time. O is the ambient temperature; P is the thickness of concrete after pouring and forming; R is the virtual thickness of concrete when one side of heat dissipation. The calculation formula is as follows:

\[ \Delta (\max, \min) = K - N \]  (5)

2.2 Change law of fracture orientation of concrete

In the process of studying the crack propagation law of concrete structure, the fracture orientation is one of the most important research parameters in the fracture mechanics of concrete. The research shows that the fracture excess parameters have a direct impact on the crack propagation of concrete. Fracture excess is a fatigue damage accumulation process, which is caused by the cyclic process of recycled concrete with compressive constraints. Recycled concrete is subjected to the combined action of cyclic frost heave pressure and osmotic pressure, and its internal microcracks are constantly generated and multiplied, which gradually deteriorates the performance of recycled concrete materials and expands the cracks of concrete. According to Aas-Jakobsen model, the fracture orientation of concrete material is calculated. Firstly, the fatigue life formula of concrete material is designed, which is as follows:

\[ W = \Delta (\max, \min) / [1 - \alpha (1 - k) \log(S)] \]  (6)

W is the stress level, Ft is the tensile strength, \( L_{\max}, L_{\min} \) are the maximum stress and the minimum stress respectively, \( \alpha \) is the orientation parameter of concrete material. \( K \) is the stress ratio, \( (L_{\max}/L_{\min}) \); S is fatigue life. Considering that the stress of recycled concrete is the smallest during thawing and the largest during frost heaving in cycling. Thus, the fatigue equation of recycled concrete cyclic assembly can be expressed as follows:

\[ W_0 = 1 - \alpha \log(S) \]  (7)

The internal damage of recycled concrete increases with the increase of recycled concrete cycles, which leads to the decrease of its ultimate bearing capacity and the increase of stress level. Assuming that the ratio of maximum stress to tensile strength before freezing is defined as initial stress level \( W_0 \); With the increase of cycle times, the actual tensile strength of recycled concrete gradually decreases and the actual stress level \( W \) gradually increases. When the actual stress level increases to 1, the concrete material will be destroyed. Therefore, the change of actual stress level can indicate the damage degree
of concrete regeneration cycle\[10\]. The damage variable \(P(n)\) is defined as the actual stress ratio. Under the action of the fatigue \(W_0\) of the initial concrete cyclic assembly, the regenerative cycle life is \(S\), and after \(n\) cycles, the residual life is \(S_n\). At this time, the actual stress ratio \(W'(n)\) borne by the material is the same as the stress ratio corresponding to \((S_n)\) in the fatigue life equation, namely:

\[
W' = 1 - \alpha \log (S - n) \quad (8)
\]

According to the definition of equation (8), it can be obtained that the algorithm of concrete fracture direction change equation is internal:

\[
P(n) = 1 - \frac{W_0}{1 - \alpha \log (S - n)} = 1 - \frac{1}{1 - \alpha \log \left( \frac{1 - \frac{n}{S}}{W_0} \right)} \quad (9)
\]

\[0 \leq n \leq S - 1\]

It can be seen from the formula that for the same stress level \(W\), the larger the material parameter \(\alpha\) is, the shorter the regenerative fatigue life \(S\) is. Therefore, the parameter \(\alpha\) is an index to measure the regenerative capacity of materials. Under the same recycling environment, the smaller \(\alpha\), the stronger the ability of recycled concrete to resist the damage of recycling, and the longer its fatigue life. With the increase of regeneration times, the damage inside the concrete also accumulates continuously, and the ability to resist freeze-thaw fatigue damage gradually decreases, resulting in the material cracks will inevitably increase gradually. Through the above calculation steps, the attenuation of tensile strength and the change rule of concrete fracture orientation during recycled concrete circulation can be effectively mastered, so as to further understand the crack propagation rule of fabricated concrete structures.

### 2.3 Crack Propagation Law of Concrete Structure

In water conservancy projects, due to the impact and corrosion of tide, the impact on concrete structures is relatively higher. Therefore, based on the hardened cement slurry of high-performance concrete commonly used in water conservancy projects as the basic material, combined with the previous research results, the influencing factors of concrete crack change in water environment in water conservancy projects are further studied as follows.

**Table 2** Influence Factors of Concrete Crack Change under Water Conservancy Environment

| Physical influence          | Chemical influence               |
|-----------------------------|----------------------------------|
|Aggregates and slurries are  | The slurry is eroded             |
| frozen and thawed           |                                  |
| Wet and dry slurry          | Salt cream appears in the slurry |
|The temperature changes of  | Aggregates have alkaline properties|
|aggregate and slurry are     |                                  |
|obvious.                    |                                  |
|Aggregates and slurries are  | Steel bar corroded               |
| worn                        |                                  |

As the concrete surface is the first line of defense for the erosion of harmful substances, in order to prolong the service life and greatly reduce the maintenance cost of concrete, the selected coating protection must have strong anticorrosion, waterproof, crack bridging and decorative properties. Therefore, the crystalline waterproof inorganic material with cement-based infiltration is selected, which has high concentration characteristics, and is convenient for external coating of concrete and internal infiltration. When the material is coated on the surface of the concrete, the material can freely penetrate into the interior and react with calcium ions of the concrete without hydration, thereby forming crystals, seriously blocking pores of the internal structure of the concrete, and effectively inhibiting erosion of destructive harmful substances on the concrete. The material is composed of silicate cement, quartz sand and other base materials, including active chemical substances. The principle of cement-based seepage waterproofing is as follows: (1) Precipitation-reaction mechanism

After hydration reaction of high-performance concrete, a lot of \(\text{Ca}^{2+}\) will appear, which will be
converted into new substances with high density through chemically active substances. In this way, not only the compactness of concrete can be improved, but also the internal permeability can be improved, and the invasion of erosion factors can be effectively inhibited. When the cement-based waterproof material is coated on the surface of the concrete, the active substance of the coating will reflect and promote the internal structure to become more compact, thus avoiding cracks in the material structure. The specific reflection process is shown in the figure.

Fig. 1 schematic diagram of concrete crack generation

If there are many gaps on the concrete surface, water is easy to penetrate, and the penetration depth of the chemically active substance in the coating will increase. If the concrete is very dense, then the coating is applied to the surface. Assuming that no water is used as a carrier to carry out infiltration activities, the chemical substance will not penetrate by itself, but only stay on the concrete surface. As time passes, the chemical substance will penetrate into the interior with the decrease of the compactness of the concrete, and then crystallization reaction will occur, thus achieving the aims of waterproof and anticorrosion again.

In case of cracks in the concrete structure, when the active substance needs to infiltrate into the concrete through the carrier, calcium ions will form cement crystals with the cement that has not been hydrated, thus generating water-insoluble crystals, thus blocking capillary pores. At this time, the active substance also becomes free radicals, which will continue to expand with the infiltration of water. The process is shown in the figure.

Fig. 2 crack propagation diagram of concrete structure

Through the analysis of figs. 1 and 2, it is found that in the process of crack propagation, there is a micro-crack area at the front end of the macro-crack, i.e. the crack propagation is guided by the micro-crack area formed at the front end of the crack. although the concrete distributed in this area, i.e. the concrete has tensile damage, the material structures still have the "bridging" function, i.e. the cohesive force blocking the crack propagation is distributed in the fracture process area. According to the above rules, we can further master the crack propagation rules of fabricated concrete structures in water conservancy projects under big data analysis, and carry out crack prevention and maintenance according to the above rules. To ensure the safety and standard of water conservancy construction.
3. Analysis of experimental results

In order to verify the validity of the research on crack propagation law of fabricated concrete structures in water conservancy projects under the new type of large data analysis, a comparative experiment was carried out with the traditional construction technology of water conservancy projects. Select a region in the south to build a concrete dam for water conservancy project. The dam is 320m high, the arc length of arch crown is 780.00m, the thickness of the bottom of arch crown is 90.0m, and the concrete of dam body is $660.6 \times 10^4 \text{m}^3$, as follows:

![Fig. 3 plane diagram of concrete structure of hydraulic engineering building](image)

The scale and quantity of the project are very large. In the following, the concrete of dam section 12 of the dam is taken as the research object, and the concrete crack control effect in the construction technology of water conservancy project is explored in detail.

| Equipment information | Detection result | Information parameter comparison | Calculation result | Detection result | Calculation result |
|-----------------------|------------------|----------------------------------|--------------------|------------------|------------------|
| Stress parameter      | 47.45            | 47.45                            | 40.45              | 07.41            |
| Fracture parameters   | 52.49            | 52.49                            | 41.12              | 09.57            |
| Earth pressure parameter | 46.48          | 46.46                            | 32.42              | 06.48            |
| Stress-free parameter | 60.12            | 60.12                            | 32.41              | 06.25            |
| Displacement parameter | 58.17            | 58.48                            | 23.41              | 06.84            |
| Grouting parameters   | 57.12            | 57.12                            | 31.89              | 09.15            |

The dam concrete parameters are shown in Table 3:

| Name          | Parameter (kg/m$^2$) |
|---------------|----------------------|
| Cement        | 3100                 |
| mineral power | 900                  |
| Sand          | 6650                 |
| Stone         | 1074                 |
| swelling agent| 2500                 |
| Admixture     | 68.50                |
| Water         | 2400                 |

In the above environment, the accuracy and effectiveness of the algorithm for concrete crack propagation law were compared and tested in combination with the previous algorithm. In the
experiment, a fixed area was found. A large, visible crack appeared on the surface of the concrete dam body in this area. The crack propagation was recorded and the actual situation was compared with the expected results of the two groups of methods. Due to the relatively complicated comparison steps, no explanation was given here, and the accuracy values of the two groups of methods were calculated after completing the statistics. The test results of this method are respectively recorded as the research group and the test results of the traditional method as the control group. The test results are shown in the following figure:

![Comparison Test Results](image)

**Fig. 4 Comparison Test Results**

It is not difficult to observe the above detection results. Compared with traditional methods, the crack propagation law of fabricated concrete structures in water conservancy projects under the big data analysis proposed in this paper has higher accuracy in the actual research process. It can effectively grasp and judge the occurrence and change of concrete cracks in water conservancy projects, so that relevant staff can timely repair and control according to the propagation law, and ensure the safety and effectiveness of water conservancy project development.

**4. Concluding remarks**

Concrete is a kind of building material widely used in engineering construction, which has the characteristics of low tensile strength and easy fracture. Because the basic composition, microstructure, and atomic bonding properties of concrete materials are different from metal materials, their fracture behavior is also different from metal materials. Therefore, the existing research results on fracture mechanics of metal materials cannot be simply applied to the fracture performance research of concrete materials. The crack propagation law of concrete materials should be studied according to the specific material properties and mechanical properties of concrete, and the crack propagation law should be judged by calculating the fracture parameters and the change law of fracture orientation of concrete structures. Finally, the experiment proves that the method has higher practicability and accuracy and fully meets the research requirements.

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