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Research on Spalling Mechanism and Bond Strength Evaluation of FRP

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Abstract: Fiber reinforced composite is a kind of material with high mechanical strength and high performance based on the mixture of fiber material and the base material, which can be widely used in bridge engineering, construction engineering and underground engineering. Because of its high tensile strength, the interface strength of FRP and concrete is insufficient, which is easy to cause interface spalling and affect the bond of the whole structural engineering. This paper mainly analyzes the spalling mechanism and bond strength of fiber reinforced composites, so as to give reference and basis for many engineering construction and application in China.

1. Introduction

With the widespread application and development of bridge engineering and road engineering nowadays, we need to focus on the comprehensive evaluation of its stability and safety in the process of road and bridge construction in China, that is, the comprehensive application based on certain concrete and material structure is used to improve the application life of road bridge. [1] Fiber Reinforced Polymer (FRP) has unique characteristics of tensile strength, corrosion resistance and fatigue resistance, which can be widely used in columns, walls, beams, plates and other structures in civil engineering. However, due to the influence of multiple external factors, FRP and other materials are easy to cause interface peeling failure of concrete structure due to insufficient interface strength. It is necessary to carry out bond strength evaluation on the basis of its spalling mechanism analysis, so as to ensure the safety and stability of its material application.

2. Analysis on Spalling Mechanism of FRP

FRP material is light and hard with high mechanical degree and corrosion resistance. This kind of composite material presents many advantages, which can make it fully combine with other base materials, so as to achieve complementary structural advantages in the combination of a variety of materials. It can help to form a construction project with strong compression resistance and high bearing capacity. In the process of FRP application, due to the slightly high tensile strength of the material, its tensile strength is significantly higher than that of steel bars, and there is no much difference with the tensile strength of high-strength steel wires. Generally speaking, its strength can reach 2 or even 10 times that of steel bars. [2] However, in the actual processing and application of FRP materials, before reaching the tensile strength, plastic deformation will not occur in the process of application. However, under the influence of tensile force, the stress will show an elastic upward trend, and elastic deformation and brittle fracture will occur under the influence of multiple tensile forces. It can be said that in the process of interaction between FRP composite and concrete structure, the material leads to the peeling failure of concrete structure interface, resulting in the structural spalling of FRP. It is often not because the FRP material is broken, but because the interface strength is insufficient in the process of bonding between FRP and concrete.

3. Factors Affecting the Bond Strength of FRP

In the process of practical application, when the bond strength of the composite reaches a certain critical value, the structure of FRP will have spalling, and the spalling position should be at the maximum bond strength, due to the influence of external strength. This can be used in the process of research, according to the location of FRP spalling to explore its bond strength; in the process of strength evaluation for the stress intensity factor to conduct a comprehensive study, a comprehensive analysis and evaluation of the safety of FRP structure should be conducted in the comprehensive analysis of various indicators.

3.1 Fiber Diameter Factor

In the current application of FRP materials, the fiber diameter mainly presents a trend of fine denier. This application mode can make the cross section of the fiber maintain a certain uniformity and stability, and can control the defects of the original material in the application of the fiber, so as to greatly improve the tensile strength of the fiber. But this form also reduces the bending resistance of the fiber and the compression stability in the application process, which will lead to the reduction of the longitudinal compression strength of the final composite in engineering application. And according to the actual investigation, fiber diameter as an influence factor, the main reasons are as follows. First, increasing the fiber diameter can effectively reduce the initial deflection angle of the fiber; second, increasing the fiber diameter can improve the bending stiffness of the fiber, so as to have higher bending resistance; third, in the case of the same fiber volume fraction, the larger the fiber diameter is, the smaller the interfacial bond is, and the smaller the effect of interfacial defects on the longitudinal compressive strength.

3.2 Fiber Modulus Factor

As an important supporting body in FRP structure, fiber can ensure the bearing capacity of its composite materials in the process of practical application through certain fiber structure, so as to better strengthen the stability of its structure. For example, in the application process of glass fiber, carbon fiber and other fibers, when the fiber volume fraction and resin modulus are basically the same, the increase of fiber elastic modulus will improve the longitudinal compressive strength of the composite. In addition, in the case of compression load, the higher modulus of carbon fiber will not appear obvious fiber knot structure, which also reflects that the fiber modulus will have a certain degree of influence on the compression effect.

3.3 Fiber Volume Fraction

The higher the volume fraction of fiber is, the higher the stiffness and mechanical properties of the composites are. It can be said that increasing the volume fraction of fiber will have a certain impact on the longitudinal compressive strength of the composites. Especially, with the increase of fiber volume fraction, the failure mode changes from interlaminar splitting to fiber instability, and then to kink band structure at higher fiber volume fraction. This means that different fiber volume fraction affects the compression failure mechanism of fiber. At the same time, the properties of resin matrix play a decisive role in the failure mode when the volume fraction of fiber is low. [3] It can be said that fiber volume fraction can be used as an important factor to evaluate the bond strength of FRP structures.

3.4 Initial Fiber Deflection Angle

The initial deflection angle is a kind of dislocation offset phenomenon caused by the difference of specific heat capacity between resin, equipment and mold during the processing of reinforced composite materials. The occurrence of this phenomenon will have an impact on the compressive strength of the fiber. For example, when the single fiber is arranged in order, the initial deflection angle of the fiber is in a non-existent state, which makes the predicted value of the longitudinal compressive strength at a high level. With the increasing of the initial deflection angle, the longitudinal compressive strength will also decrease significantly. It can be said that the fiber initial deflection angle has a significant effect on the longitudinal compression strength.

3.5 Influence of Base Modulus

The elastic modulus and shear modulus of the base modulus have a certain influence on the bonding degree of the whole composite. From the point of view of elastic modulus, increasing the elastic modulus of resin matrix can enhance the resistance of matrix to compression deformation, reduce the plastic deformation of matrix, and improve the longitudinal compressive strength of composites to a certain extent. On the other hand, from the perspective of shear modulus, the initial deflection angle of the fiber will produce huge transverse shear stress on the resin matrix, improve the shear deformation resistance of the matrix, thus helping to improve the transverse support ability of the fiber, and comprehensively improving the longitudinal compressive strength of the composite. [4]

3.6 Environmental and Other Factors

As an important factor, environmental conditions also affect the spalling mechanism and bond strength of FRP in the whole environment. The coefficient of thermal expansion of FRP composite is close to that of concrete, so when the ambient temperature changes, FRP and concrete work together, and there will be no large temperature stress between them, but the external environmental factors are easy to have a certain impact on their stability. For example, Galati and other related studies show that the bond strength between FRP and concrete decreases by 16% when FRP materials are exposed to air at 70 ℃ for 200 hours. It can be said that with the increase of temperature, the adhesion between the material and the structure will also decrease. When the temperature drops to room temperature, the adhesion can be basically restored. The influence of external factors can be used as an auxiliary force to affect the bond properties of the whole FRP structure, which will also affect the stability of the structure and function.

4. Conclusion

To sum up, FRP laminate structure is mainly affected by multiple tensile forces, resulting in elastic deformation and brittle fracture, and the location of the laminate structure will be formed based on a certain bond position. This requires a comprehensive analysis of the influencing factors of FRP bond strength, and a comprehensive consideration of other factors such as fiber diameter, fiber modulus, fiber volume fraction, fiber initial deflection angle, base modulus and environment. It aims to continuously challenge the structure and morphology of FRP on this basis, so as to build a fiber-reinforced composite meeting the needs of engineering construction.

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