

# Discussion on Bonding Performance between FRP Bars and Concrete

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**Abstract.** As the physical and mechanical properties and surface shape of FRP(Fiber Reinforced Polymer) bars are quite different from those of steel bars, the bonding properties of FRP bars and concrete are lower than that of steel bars. How to effectively improve the bonding performance between FRP bars and concrete is a hot issue for scholars at home and abroad. The precondition of combining FRP bars with concrete is to ensure the cooperation between FRP bars and concrete under the action of external load. The bonding performance between FRP bars and concrete is one of the key technologies for designing, applying and popularizing this kind of structure. In this paper, based on a large amount of researches at home and abroad, the center pull test is carried out, and the adhesion mechanism, failure mechanism, influence factors of bond strength and slippage behavior between fiber reinforced polymer and concrete are studied through experiments .

## 1.Introduction

In the process of the use of reinforced concrete structures, the corrosion of the reinforced bar has a serious effect on the durability of the structure due to the carbonization of concrete, the corrosion of chloride ion and the environmental factors. It is estimated that nearly 100 thousand of the nearly 600 thousand bridges in the United States are seriously corroded[1]. The reinforced concrete structures built in the UK in the marine environment, one third of the steel bars that need to be rebuilt or replaced due to corrosion of steel bars [2]. Therefore, how to improve the durability of reinforced concrete structure is an urgent problem to be solved in the civil engineering field.

## 2. Bond Slip Experiment

### 2.1.Characteristics of FRP Bars

Fiber Reinforced Polymer Rebar is abbreviated as FRP Rebar. FRP bars have the advantages of light, high strength, corrosion resistance and good electromagnetic resistance. It can replace the steel bars in the concrete structure, which can greatly improve the use and durability of the concrete structure, extend the service life of the reinforced concrete structure, and reduce the cost and maintenance cost of the building structure[3].

### 2.2.Research Status of Bonding Properties of FRP Reinforced Concrete

Many foreign scholars, such as Adimietal, Castro, P.F., BrahimBenmokrane, SakaiT., Tao, S., Kanakubo, T.,etc, have carried out a lot of experimental research on the bond anchorage performance of the FRP tendons (mainly GFRP tendons), and given the average bond stress and anchorage through



the test. The formula of the length of the calculation or the suggestion of design[4]. In 1970, Chaallal O and Benmokrane B passed the pull out test of the GFRP tendon implanted in the concrete, and suggested that the anchorage length of the GFRP tendons in the concrete could be approximately 20 times that of the diameter[5]; Ehsani, Saadatmanesh and Tao tested 48 beam specimens and 18 pulling specimens in 1996, and deduced and corrected the calculation formula of the anchorage length of the GFRP tendons. However, the tensile strength and the influence coefficient of FRP bars have not been unified[6]. Zenon Aehillid and Kyprosilakoutas pull out the specimens through 130 cubes, and discuss various factors that affect the bond stress[7].

In terms of bond strength, bonding mechanism, and influencing factors, Kabakubo has studied the bonding mechanism between FRP tendons and concrete into two categories: one is a friction-based bonding mechanism, and the other is a mechanical bite force[8]. The main adhesion mechanism; Experimental study found that the bonding of FRP tendons and concrete is affected by many factors.

### 2.3. Experiment Material

The new thread-like surface-bonded FRP ribs used in this test were mainly made of continuous glass fiber and continuous carbon fiber. The pultrusion process and epoxy resin were glued together according to a certain proportion. The fiber bundle was recessed into the surface of the fiber ribs to form a thread, and on the surface of the sand, the fiber content is about 68%, as shown in Figure 1. For the purpose of comparison, surface-globular GFRP ribs were also processed. The surface was smooth and there was no surface-adhered sand and shaped treatment. The fiber content was about 45%. The mechanical properties of various types of FRP bars are shown in Table 1.

Table 1. Mechanical properties of FRP bars

FRP bars	d(mm)	Tensile strength (MPa)	Elongation (%)	Tensile modulus of elasticity (GPa)
Thread surface sand stick CFRP bars	9.5	1779	1.65	136
Threaded surface gritty GFRP reinforcement	9.5	993	2.31	72
Plain GFRP	9.5	40	2.15	40

### 2.4. Test Device

This test adopts the symmetrical pull-out test method. The pull-out test specimens are embedded with fiber polymer bars in the center of a 100mm x 100mm x 100mm concrete cube and divided into 5 groups of 7 threaded surface-sanded GFRP bars and 7 pieces respectively. Thread-like surface-bonded CFRP ribs, 2 rebars, 2 plain GFRP ribs, and 2 plain rebars, a total of 20 test pieces. The test specimen is shown in Figure 2 and the loading device is shown in Figure 3.



Figure 1. Thread shaped surface bonded sand CFRP bars, GFRP bars and plain GFRP bars



Figure 2. Test specimens



Figure 3. Loading device

### 3. Analysis of Results

#### 3.1. *The Composition and Function of Adhesive Force*

The adhesive composition of FRP tendons and concrete is also similar to that of reinforced concrete, and is mainly composed of chemical adsorption force, friction force, and mechanical bite force. Unlike steel bars, the surface hardness and shear strength of FRP bars are lower than that of concrete. Therefore, when slip damage occurs, the main feature is that the surface ribs are weakened, peeled or sheared.

#### 3.2. *Analysis of Bond Failure Mechanism*

The chemical bonding force between the FRP tendon and the concrete is very small, which causes the specimen to slip at the free end of the FRP tendon when the load level is not large. After the slip occurred, the adhesive force between the FRP tendons and the coagulation disappeared. At this point, the cohesive force is provided by the frictional force and the mechanical bite force.

Since all the components of this test are the thread of the fine fiber tow recessed on the surface of the fiber ribs, the adhesive force is still provided by the frictional force and the mechanical occlusal force. The failure mechanism is not due to the damage of the external tangs of the FRP ribs or the delamination of the FRP ribs, but the shearing and sliding of the FRP ribs on the surface of the FRP ribs and the FRP ribs at the core, and the surface viscous layer is ground into a powder, forming longitudinal shear damage.

### 4. Bond Strength Factors

According to the test and related references, the bond strength is affected by many factors and conditions, which are mainly divided into the following categories.

#### (1) Effect of FRP Bar Diameter

In the case of concrete strength, buried depth, rib surface form and type are the same, with the increase of the FRP tendons diameter, the bond strength between FRP tendons and concrete decreases. When the FRP tendons are drawn, the shear lag makes the deformation of the center of the cross section and the edge of the cross section different. The non-uniform distribution of the positive stress of the cross section is not conducive to the development of the bond strength, and the bond strength between the FRP reinforcement and the concrete is reduced[9].

#### (2) Effect of Surface Form of FRP Ribs

In this test, thread-like vitreous fiberglass ribs and carbon fiber ribs formed by recessing thin fiber tows on the surface of fiber ribs were used, and compared with the test results of GFRP ribs. The surface form of the FRP rib is an important factor affecting its bonding performance with concrete.

#### (3) Effect of Fiber Type

Since the tensile strength and elastic modulus of each type of FRP tendon are different, their bonding properties with concrete are also different. The fiber type has little effect on the bond strength of the thread-like surface-bonded FRP ribs used in this test.

#### (4) Effect of Concrete Strength

Tests have shown that this bond strength is proportional to the square root or tensile strength of concrete's compressive strength. However, the material properties of FRP bars are fundamentally different from those of steel bars. According to studies by scholars at home and abroad, for the pull-out test, the strength of the concrete has little effect on the bond strength of the pull-out failure.

### 5. Conclusions

The main conclusions of this paper are as follows:

(1) For the FRP tendons concrete drawn specimens, the bond with the concrete is controlled by the chemical gluing force before slipping at the free end, and the initial slip load of the light round FRP ribs and the sticky sand FRP ribs are close to each other.

(2) After the FRP ribs have been treated on the surface, they can obtain better bonding properties

with the concrete.

(3) Under the condition of ensuring the thickness of the concrete protective layer, the FRP reinforced concrete specimens are pulled out and destroyed, and the damage form is the flaking of the surface of the ribbed material.

(4) The adhesive properties of light-circular FRP ribs and concrete are not as good as those of ordinary round steel bars and cannot be used as ribs.

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