

Article

Experimental Study on the Bonding Performance between Fiber-Belt-Bar and Concrete

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Abstract: Fiber materials have advantages such as light weight and high strength, corrosion resistance, fatigue resistance, and easy processing and production, and they are widely applied in the repair and renovation of concrete structures. To promote the construction convenience of fiber materials, fiber raw yarn is continuously braided to form fiber-belt-bars. Based on the existing research, the performance of bonding between fiber-belt-bars and a concrete interface was investigated, and pull-out tests were performed to systematically investigate the effects of the fiber-belt-bar cross-sectional size, anchorage length, concrete strength, and fiber type on the bonding performance. The experimental results show that the bond strength reduces with an increase in the anchorage length, increase in cross-sectional size, and decrease in concrete strength, and the effect of fiber type on the bond strength is not obvious. On this basis, a formula for calculating the average bond strength of fiber-belt-bars is proposed. Experiments and calculations determined that the average bond strength between fiber-belt-bar and concrete with a cross-sectional size of 12 mm × 3 mm is 10–30% higher than that with a cross-sectional size of 20 mm × 3 mm for the same anchorage length. Finally, the minimum anchorage length of the fiber-belt-bar is proposed to provide a valuable reference for the use of fiber-belt-bar in concrete projects.

Keywords: fiber-belt-bar; pull-out test; bonding performance; bond slip; strength



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1. Introduction

Fibers are widely used in the field of civil engineering due to their strong mechanical properties, simple processing, and sturdy construction, especially during the repair and renovation of concrete [1–3]. Fibers have high tensile strength and corrosion resistance, and thus they are generally applied to concrete structures in the form of fiber-reinforced polymer (FRP) bars, plates, and fiber cloth to improve the load-bearing capacity of concrete structures and reduce the deformation of concrete components. Therefore, the application of fiber-reinforced polymers in concrete structures has become highly urgent [4–7]. The bonding performance between fiber-reinforced composites and concrete is the basis for combining the two types of materials, which directly affects the load-bearing capacity, deformation characteristics, and service performance of concrete structures; therefore, a clear understanding of the bonding performance of the interface between fiber reinforced composites and concrete is critical [8].

Despite the many advantages of fiber materials, they have not completely replaced conventional steel bars in widespread application, mainly due to the variability of their mechanical and physical properties. Conventional fiber-reinforced composites mainly apply a resin matrix to the continuous fibers to form bars or sheets to enhance the stiffness and strength of the polymer model. FRP materials consist of two or more materials. Their bond strength differs from that of the conventional steel reinforcement due to the differences in their material properties, resulting in a different load transfer mechanism

between the materials and the concrete [9]. Many researchers have conducted deep research on FRP materials and studied the bonding properties between FRP materials and concrete. The bonding performance of FRP bars was found to be influenced by more parameters than conventional steel bars, including the surface shape of the bars, concrete strength, a concrete protection layer, bar diameter, bar embedded length, and bar surface shape [9–14]. Experimental studies have been conducted to construct the bond–slip constitutive models between FRP bars and concrete, including the Malvar model [15], the BPE and modified BPE model [16,17], the CMR model [18], Tighiouart et al.’s model [19], etc. The bonding properties between FRP bars and concrete were analyzed using a bond–slip constitutive model. According to existing research [10,20], the bond between FRP bars and concrete is weaker than the bond between ribbed steel bars and concrete. Therefore, researchers have attempted to conduct a series of studies on the bonding performance of FRP bars in terms of fiber material type, surface characteristics, the material composition of the matrix, and the fiber concrete environment to improve the bonding performance between FRP bars and concrete [21]. Ren et al. [22] developed a gelation method using nano-silica deposition to improve the surface characteristics of plant fibers and enhance the bond performance between fibers and ultra-high-performance concrete. An experimental study showed that the bond strength increased by 28.0%. Lu et al. [23] investigated the bonding performance and durability of BFRP rods in corrosive environments and found that the mechanical properties and bonding performance of BFRP bars decreased with the increase in immersion time, while the addition of fly ash to concrete improved the interfacial bonding strength. Shi et al. [24] developed a wedge anchorage for BFRP bar composites and conducted an experimental study on bending beams of in vitro embedded BFRP bar prestressed concrete beams. The results showed that the anchorage performance could be improved using the new anchorage system, and the BFRP bars in the anchorage zone and the bars in the deviated zone maintained their integrity under the ultimate load of the beam. Solyom et al. [25] investigated the bond performance between FRP bars with different indicated characteristics and concrete. The investigated FRP bars indicated the use of a sand coating, helical wrapping, indentation, and ribbing affected bond strength, bond-slip relationship, and damage mode. The bond strength, as well as the bond stress slip behavior and damage mode, varied significantly depending on the surface characteristics. From previous research, it is evident that researchers have used approaches such as experimental studies and numerical analysis to investigate the bonding performance of fiber-reinforced concrete. They have attempted to enhance this bonding performance through modification of fiber material type, surface characteristics, and anchorage methods in order to improve the overall strength and durability of the concrete.

Existing studies have focused on the bonding between fiber-reinforced composites and concrete. This research group adopts the direct woven method of continuous fiber material to form the fiber-belt-bar, which is flexible, easy to process and produce, and easy to apply in the repair and renovation of concrete. Research examined the bonding properties of a fiber-belt-bar with concrete to promote the use of fiber-belt-bars in concrete projects and to provide a theoretical basis for further research on fiber-belt-bars. In this paper, the effect of influencing factors such as fiber-belt-bar cross-sectional size, embedment length, and concrete strength on bonding performance is investigated, utilizing pull-out tests to analyze the working mechanism and bond strength of the bond between fiber-belt-bars and concrete.

2. Experimental Program

In this study, a pull-out test was conducted to examine the bonding performance between fiber-belt-bars and concrete. This involved introducing variation in the anchorage length, cross-sectional area, concrete strength, and fiber type of the fiber-belt-bar.

2.1. Test Materials

(1) Fiber-belt-bar

Since aramid fiber and carbon fiber have higher strength, the fiber materials used in this test included aramid fiber (Kevlar49 series) and carbon fiber (T300 series) as raw materials, and the continuous fiber raw filaments were braided into fiber-belt-bars using plain weave, as shown in Figure 1a, b. The specific dimensions of fiber-belt-bars and raw materials are shown in Table 1. AF—aramid fiber; HACF—aramid fiber and carbon fiber hybrid weave; K49—aramid fiber (Kevlar49 series); 1—cross-sectional size of 12 mm × 3 mm; 2—cross-sectional size of 20 mm × 3 mm. Tensile tests were performed for the same batch of fiber-belt-bars employed in the pullout specimens. The tensile strength, elastic model, and elongation of the fiber-belt-bars can be obtained as shown in Table 2.

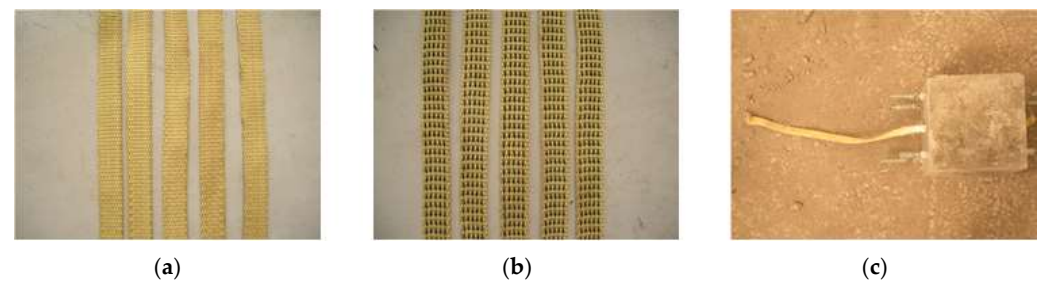


Figure 1. Fiber-belt-bar and pull-out specimen. (a) Fiber-belt-bar (Kevlar49). (b) Fiber-belt-bar (HACF). (c) Pull-out specimen.

Table 1. Specific parameters of fiber-belt-bars.

Number	Material	Cross-Sectional Characteristics		Cross-Sectional Area (mm ²)
		Width (mm)	Thickness (mm)	
AF-K49-1	AFRP(Kevlar49)	12	3	36
AF-K49-2	AFRP(Kevlar49)	20	3	60
HACF-2	80%K29 + 20%T300	20	3	60

Table 2. Specific parameter characteristics of the pull-out specimen.

Specimen Number	Material Properties					Embedding Length (mm)
	Fiber-Belt-Bar			Concrete		
	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation (%)	Compressive Strength (MPa)	Tensile Modulus (GPa)	
AF-1-10A	871	26	3.54	43	33	10
AF-2-10A	922	24	3.9	43	33	10
AF-1-20A	871	26	3.54	43	33	20
AF-2-20A	922	24	3.9	43	33	20
AF-1-30A	871	26	3.54	43	33	30
AF-2-10B	922	24	3.9	27	29	10
HA-2-30A	760	21	3.7	43	33	30

(2) Concrete

In this study, we researched the effect of different concrete strengths on the bonding performance. Two different proportions of concrete were used in the experiment. The concrete was poured using the on-site mixing method, the raw material was ordinary silicate cement P.042.5, the fine aggregate was natural river sand with an average particle size of 0.25–0.5 mm, and the coarse aggregate was crushed stone with particle size of 5–20 mm. To identify the mechanical properties of concrete, three standard

150 mm × 150 mm × 150 mm cubic specimens were created for each batch of concrete and cured at room temperature. The compressive strength and elasticity models of concrete were determined via pressure testing, and the specific values are shown in Table 2.

2.2. Specimen Fabrication

The test pull-out specimen is shown in Figure 1c, concerning GB/T50152-2012. The concrete specimen size is 150 mm × 150 mm × 150 mm. To determine the pull-out performance of the fiber-belt-bar embedded in concrete, the embedded length of the fiber-belt-bar was taken as 10 mm, 20 mm, and 30 mm. The fiber-belt-bar was embedded in the center of the specimen. The same cover thickness was applied around the fiber-belt-bar. The soft plastic PVC pipe was set for the fiber-belt-bar, and the embedded length of the fiber-belt-bar was controlled by the pipe. The pipe is poured into the concrete together with the fiber-belt-bar, and the fiber-belt-bar inside the pipe was regarded as being in an unbonded state, meaning it was able to slide freely. Since the fiber-belt-bar tendons are flexible, the fiber-belt-bar tendons were kept in a straightened state during the concrete pouring process. To facilitate a better connection of the pull-out specimen to the loading device, four bolted reinforcement bars were pre-buried in the concrete test block of the pull-out specimen to facilitate the pull-out test.

As shown by the specimen number column in Table 2, AF indicates aramid fiber; HA indicates aramid fiber and carbon fiber mixed braid fiber; 1 indicates a cross-sectional size of 12 mm × 3 mm; and 2 indicates a cross-sectional size of 20 mm × 3 mm.

2.3. Test Equipment and Test Methods

The loading device used in this test was a WE-300 tensile testing machine with specially designed anchorage. In this test, 7 groups of specimens were designed and fabricated with 4 main test parameters: tendon material type, tendon material size, bond length, and concrete strength. There were 3 specimens in each group and 21 pull-out specimens in total.

During the test, the pull-out specimen was placed on the tensile testing machine through the special anchorage to ensure that the force direction of the fiber-belt-bar was always in the direction of the axis, and then the tensile load was applied to the fiber-belt-bar. The free side and loading side of the specimen were equipped with displacement gauges to mark the position at the free side and loading side and monitor the relative displacement of the marked points. This test used the displacement-controlled loading method. The rate did not exceed 1.3 mm/min; when the load decreased, so did the loading rate. Figure 2 shows the loading device for the pullout specimen. The connection between the loading side and the fixed side of the pullout specimen is indicated, and the dimensions of the pullout specimen are also marked.

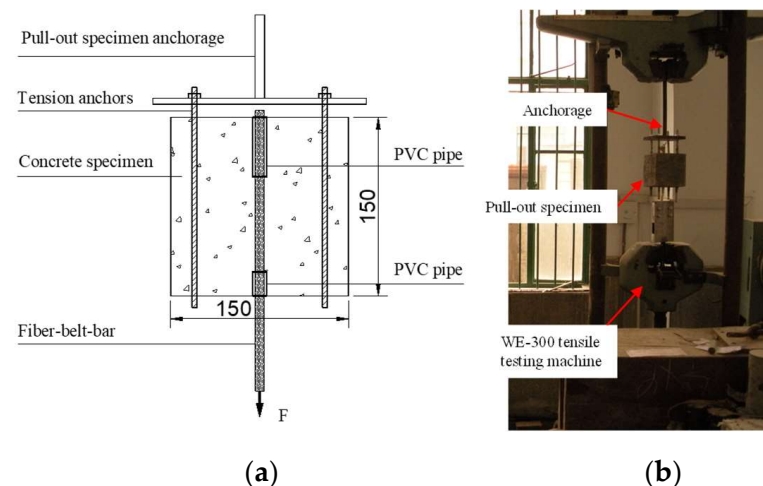


Figure 2. Pull-out test loading device. (a) Detail of pull-out specimen. (b) Configuration of pull-out test.

3. Test Results and Discussion

3.1. Experimental Phenomena

The damage to the specimens was researched using seven different groups of drawing tests, and all the specimens demonstrated a pull-out damage phenomenon. At the beginning of the loading, the fiber-belt-bar showed a state of “tension” under the action of tension and produced a certain sound, and then the relative slip between the fiber-belt-bar and concrete occurred. Finally, the fiber-belt-bar was pulled out. The damage mode of the specimen in this test mainly consisted of fiber-belt-bar pull-out damage (Figure 3a). It can be seen from the load–displacement relationship curve of the pullout test (Figure 3b) that the pull-out test process is generally divided into four stages: the micro-slip stage, the slip acceleration stage, the descending stage, and the residual stage.

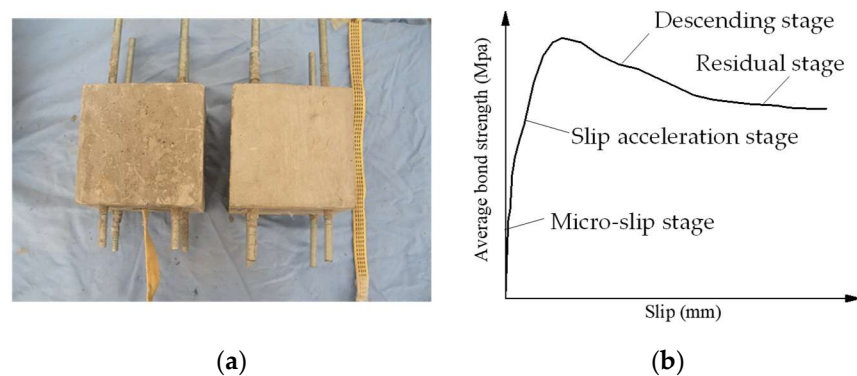


Figure 3. Pull out specimen. (a) Indicates the fiber-belt-bar is pulled out. (b) Indicates the typical bond–slip relationship curve of the fiber-belt-bar.

Description: 1. Micro-slip stage: in the initial stage of loading, the bond strength between the fiber-belt-bar and the concrete is on the rise, the loading side slips first, the free side does not slip, the fiber-belt-bar is in tension, and the deformation is mainly for the fiber-belt-bar elongation itself. 2. Slip acceleration stage: when the free side starts to slip, the slip gradually increases, and the tension force gradually reaches the maximum. 3. Descending stage: when the load reaches its peak, the bond strength degrades rapidly, the slip increases rapidly, and the curve begins a rapid downward trend. 4. Residual stage: With the increase in slip, the decline in bond stress gradually slows down, and ultimately remains constant. The bond–slip curve is also close to a horizontal line.

According to the above pull-out test damage phenomenon, the operational mechanism of bonding performance between the fiber-belt-bar and concrete can be analyzed. The bonding strength between the fiber-belt-bar and concrete is mainly composed of three parts: chemical bonding strength, mechanical adhesive strength, and frictional strength, which demonstrates different ways of bonding in the constant stage of loading. At the early stage of application, the bonding performance is comparable, and the bonding force consists of three aspects: chemical adhesive force, mechanical bite force, and friction force, in which the chemical adhesive force plays a major role. With the increasing applied load, the chemical adhesive force is gradually destroyed, and the bonding force mainly depends on the mechanical bite force and friction force between the two materials. With the increasing slip of the fiber-belt-bar, the surface of the fiber-belt-bar will be damaged by wear, and the mechanical bite force between the fiber-belt-bar and the concrete will be continuously reduced, the bonding force is mainly expressed as friction force, and the friction force is gradually extended from the loading side to the free side until uniform friction is generated along the contact surface. When the fiber-belt-bar is pulled out, the bonding force exhibits maximum friction. This is demonstrated by the pulled-out fiber-belt-bars: after the fiber-belt-bars were pulled out, the surface of the fiber-belt-bars was damaged partially due to the friction between the fiber-belt-bars and the concrete, and obvious scratches were generated on the surface.

3.2. Average Bond Strength and Bond–Slip Relationship Curve

Although the bond stress distribution varies along the direction of the length of the fiber-belt-bars, it is usually assumed that the bond stress is uniformly distributed to calculate the bond stress. The bond–slip displacement s and the average bond stress τ are calculated according to the following equations.

$$s = s_2 - s_1 \quad (1)$$

$$\tau = \frac{P}{2bL_a} \quad (2)$$

In the above equation, s is the bond–slip; s_1 is the slip of the fiber-belt-bar at the free side; s_2 is the slip of the reinforcement at the loading side; P is the pull-out force; b is the widths of the fiber-belt-bar; and L_a is the embedded length. The contact area in the direction of the thickness of the fiber-belt-bar is negligible.

After the above pull-out tests, the measured results of the maximum bond load between the fiber-belt-bars and the concrete are summarized in Table 3. The average bond strength τ_{ave} between the fiber-belt-bar and the concrete in each pull-out specimen can be derived from the maximum tensile load P_{max} applied to the fiber-belt-bar, and the specific values are shown in Table 3.

Table 3. Pull-out test results summary.

Specimen	Code	Failure Phenomenon	Ultimate Load P_{max} (kN)	Bond Strength τ_{max} (MPa)	Average Bond τ_{ave} (MPa)
AF-1-10A	1	Pull-out	2.80	11.67	11.80
	2	Pull-out	3.10	12.91	
	3	Pull-out	2.60	10.83	
AF-2-10A	1	Pull-out	3.50	8.75	8.75
	2	Pull-out	3.80	9.50	
	3	Pull-out	3.20	8.00	
AF-1-20A	1	Pull-out	3.80	7.92	8.27
	2	Pull-out	4.20	8.75	
	3	Pull-out	3.90	8.13	
AF-2-20A	1	Pull-out	6.60	8.25	7.67
	2	Pull-out	5.80	7.25	
	3	Pull-out	6.00	7.50	
AF-1-30A	1	Pull-out	8.50	7.08	6.39
	2	Pull-out	8.00	6.67	
	3	Pull-out	6.50	5.41	
AF-2-10B	1	Pull-out	3.20	8.00	8.75
	2	Pull-out	3.80	9.50	
	3	Pull-out	—	—	
HA-2-30A	1	Pull-out	1.80	4.50	4.67
	2	Pull-out	1.60	4.00	
	3	Pull-out	2.20	5.50	

AF-2-10B specimen group 3 in the process of pulling fiber-belt-bar tendons off. The measured data cannot be used as test results.

Figure 4 shows the bond–slip curves of seven groups of drawn specimens. To precisely reflect the bonding performance between the fiber-belt-bar and concrete, the deformation of the fiber-belt-bar itself from bending to straightening and the material stretching itself are not considered in the process of drawing the bond–slip relationship curve. Based on the bond–slip relationship curves, the bond–slip curves between the fiber-belt-bars and the concrete can be divided into two stages: the increasing stage and the decreasing stage. When the bond–slip reached about 0.6–1 mm, the bond strength reached its maximum

value, then the tensile load began to decline, and the slip rate increased. When the bonding force is mainly expressed as chemical adhesive force and mechanical bite force, the relative slip generated by the two materials is small; when the bonding force is mainly expressed as friction force, the relative slip generated is larger. The values in the figure show that the fiber-belt-bar cross-sectional size, anchorage length, and concrete strength all influence the bonding performance.

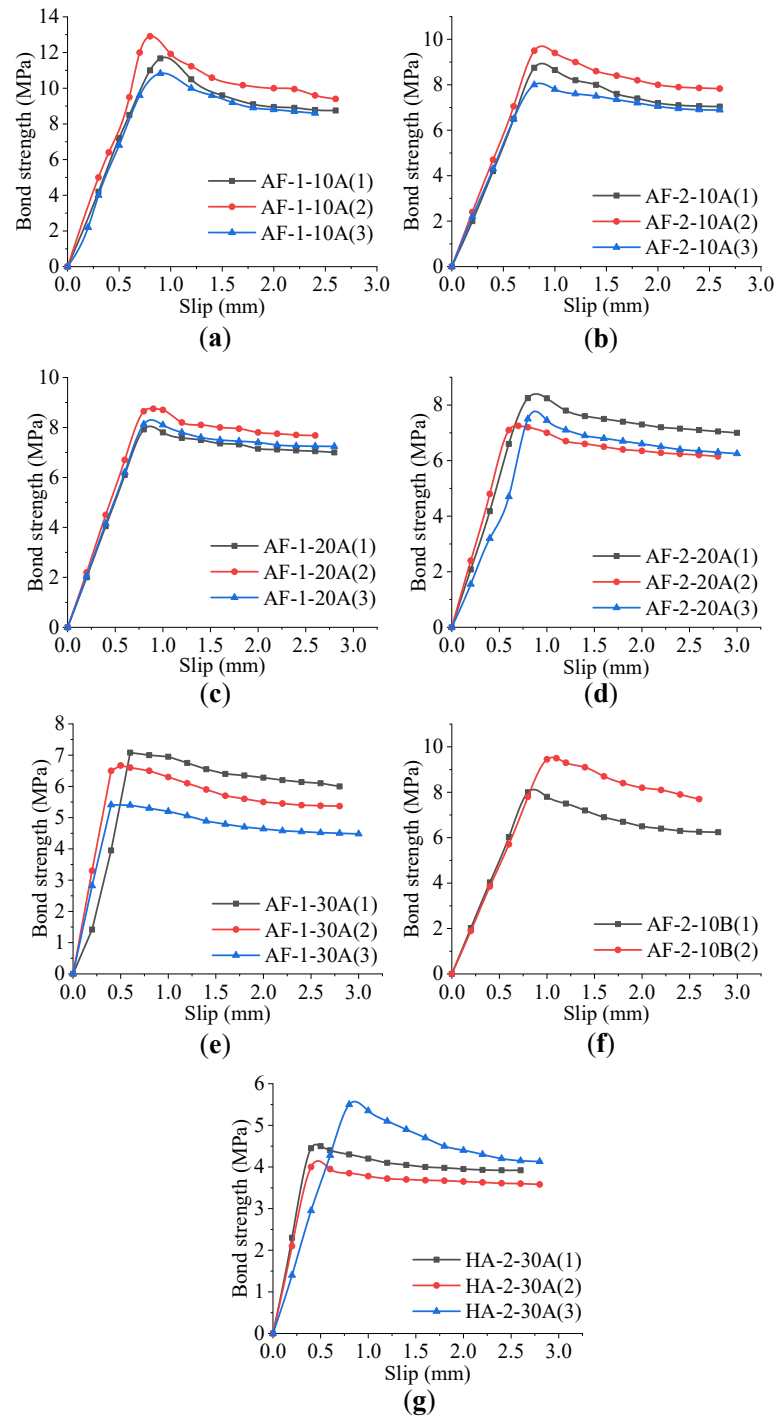


Figure 4. Bond–slip curves of pull-out specimens. (a) Bond–slip curve of specimen No. AF-1-10A. (b) Bond–slip curve of specimen No. AF-2-10A. (c) Bond–slip curve of specimen No. AF-1-20A. (d) Bond–slip curve of specimen No. AF-2-20A. (e) Bond–slip curve of specimen No. AF-1-30A. (f) Bond–slip curve of specimen No. AF-2-10B. (g) Bond–slip curve of specimen No. HA-2-30A.

3.3. Effect of Different Parameters

(1) Embed length

Figure 4 shows the average bond stress-slip curves for fiber-belt-bars with different embedment lengths. For specimens with shorter bond lengths, the closer the average bond stress is obtained from the specimen to the actual stress distribution in the bonded area, the larger the average bond strength. For a bond length of 10 mm, 20 mm, and 30 mm pullout specimens, when the relative slip of the fiber-belt-bar reaches about 0.6–1 mm, the bond strength is close to the maximum value, which indicates that the maximum bond stress between the fiber-belt-bar and the concrete is not closely related to the bond length.

Table 3 shows the relationship between the embedding length and the average bond strength for different cross-sectional dimensions of the fiber-belt-bars. For specimens with increasing bond length, the average bond strength decreased regardless of the cross-sectional dimensions of the fiber-belt-bars. For instance, for a bonding length of 10 mm, 20 mm, and 30 mm of different cross-sectional fiber-belt-bars, the bonding length of 10 mm specimens' bonding strength was generally higher than that of specimens with a bonding length of 20 mm, and the bonding strength increased by 5–30%. The shorter the bond length of the fiber-belt-bar, the smaller the amount of tensile force on the specimen; however, the average bond strength decreased as the bond length increased. The decrease in the average bond strength was attributed to the non-uniform distribution of bond stress along the fiber-belt-bar arrangement. For specimens with short bond lengths, it is possible to simplify the uniform distribution of the bond stress over the entire length of the fiber-belt-bar during tensioning of the fiber-belt-bar. On the contrary, for specimens with a long bond length, in the initial loading stage, on the loading side area, the bond stress is more difficult to redistribute along the fiber-belt-bar arrangement direction, the bond stress distribution is not uniform, and even the middle region appears not to bear the bond stress state. This situation may also affect the local area of bond damage phenomenon. Therefore, when setting anchorage length requirements for fiber-belt-bars, the maximum anchorage length needs to be set, unless it is necessary to ensure that the fiber-belt-bars bear the load function all along their length.

(2) Cross-sectional dimensions and types of fiber-belt-bars

As displayed in Figure 4 and Table 3, the slip curves and maximum bond strength of fiber-belt-bars are different for different section sizes. The trend of the bond-slip curve is the same for different fiber-belt-bars under tension load, but they are subjected to different maximum loads and different average bond strengths. The cross-sectional size of the 12 mm × 3 mm fiber-belt-bar has a significantly stronger bond than the cross-sectional size of the 20 mm × 3 mm fiber-belt-bar, with an average improvement in the bond strength of 10–30%. This also shows that for the same bond length of fiber-belt-bars, the fiber-belt-bars with smaller cross-sectional dimensions tend to have a more uniform surface bond stress distribution under load and fully utilize the bonding properties between the contact surfaces.

Figure 4 shows the different types of fiber-belt-bars subjected to pull-out experiments. Based on the results, the bond strength of the mixed fiber-belt-bars is lower than that of the pullout specimens with single fiber-belt-bars. The group also researched this phenomenon and investigated the mechanical properties of fiber-belt-bar containing a mixture of two fiber materials. In the mixed braiding process of aramid fiber and carbon fiber, the carbon fiber is often fractured during the process of machine braiding. The damage to the carbon fiber filaments in the fiber-belt-bars was obvious, causing the mechanical properties of the mixed braided fiber-belt-bars to be lower than those of the single aramid fiber braided fiber-belt-bars. This also shows that the carbon fiber raw filaments are less resistant to abrasion, which can easily cause fracture damage to certain fiber materials during the braiding process, reducing the strength of the fiber-belt-bars. Therefore, when braiding with carbon fiber material, it is necessary to protect the carbon fiber filament in advance.

(3) Concrete strength

As shown in Figure 4, AF-2-10A and AF-2-10B examined the bonding performance between the same fiber-belt-bars and concrete specimens of different strengths. As shown by the results of the experiments, the difference in bond strength between the concrete of different strength levels and fiber-belt-bars is relatively small, which also shows that the concrete strength is not the main factor affecting the bonding performance. According to previous research on the bonding performance between fiber materials and concrete of different strength levels, it is obvious that when the strength of concrete increases, the binding strength of concrete to fiber materials increases. This indicates an increase in chemical adhesion, enhancing the bonding strength between the two materials [26,27].

(4) Other influential factors

The study of bonding properties is an important part of the research on fiber-belt-bar-reinforced concrete structures. In the above-mentioned experiments, a pull-out test was used to consider the influence of bond length, cross-sectional size, fiber material type, and concrete strength of the fiber-belt-bars on the bonding performance. However, the pull-out test does not fully represent the stress state of the fiber-belt-bars, which is mainly represented by the typical bond stress between the fiber-belt-bars and the concrete material. Therefore, the different force states of the fiber-belt-bar tendons also have different effects on the bonding performance. In concrete structures, different cover thicknesses which affect the constraints of the concrete that constrain the fiber-belt-bars, will produce different bonding properties. Meanwhile, the different methods of fiber braiding will make the raw fiber volume ratio of fiber-belt-bars different, and the surface characteristics of fiber-belt-bars will also be different, with differing effects on the bonding performance.

Therefore, in future research, more experimental methods for constructing the bond-slip model between fiber-belt-bars and concrete are needed. On the basis of the study of bond performance between reinforcement and concrete for fiber-belt-bar-reinforced concrete structures, the size of coarse aggregate in the concrete, the cover thickness, the damage level of the fiber-belt-bar, the braiding method of the fiber-belt-bar, the anchoring form, and the external environment may affect the bond performance, so the test parameters need to be calibrated based on more data.

3.4. Proposed Minimum Anchor Length

To ensure that the strength of the fiber-belt-bar is fully utilized, the ultimate load of the fiber-belt-bar (F_f , Equation (3)) must not be stronger than the bond force between the fiber-belt-bar and the concrete (F_m , Equation (4)). Therefore, the load-bearing capacity requirements of Equation (5) must be met to provide sufficient anchorage length for bonding performance.

$$F_f = f_y A_f = b t f_y \quad (3)$$

$$F_m = 2 b l_a^{cr} \tau_{ave} \quad (4)$$

$$F_f \leq F_m \quad (5)$$

Therefore, the critical anchorage length l_a^{cr} can be calculated according to Equation (6).

$$l_a^{cr} \geq \frac{t f_y}{2 \tau_{ave}} \quad (6)$$

where l_a^{cr} is the critical anchorage length of the fiber-belt-bar; f_y is the yielding strength; A_f is the cross-sectional area of the fiber-belt-bar; and t is the thickness of the fiber-belt-bar.

The minimum anchorage length requirement of the fiber-belt-bar can be calculated as shown in Equation (6). As a result of different production processes and construction factors, the average bond strength between the fiber-belt-bar and concrete is different. Therefore, it is necessary to estimate the average bond strength between a certain fiber-belt-bar and concrete and propose the minimum bond length for a specific fiber-belt-bar.

Compared with steel reinforcement, the fiber-belt-bar is a flexible material that is easy to bend during the construction process. According to the existing experimental research, when the anchorage length of the fiber-belt-bar does not satisfy the requirements, the fiber-belt-bar can be wrapped around fixed members such as steel reinforcement bars, or devices such as clamps can be used to enhance the anchorage performance.

4. Conclusions

The performance of bonding between fiber-belt-bars and concrete was researched using pull-out tests, and the effects of the bond length, cross-sectional area, fiber material type, and concrete strength on the bonding behavior were evaluated. In addition, the average bond strength of the fiber-belt-bars was obtained from the experiment. Based on satisfying the load-bearing capacity, the minimum anchorage length of fiber-belt-bars is proposed, and appropriate treatment measures are proposed for the cases in which the anchorage length is not satisfied. The major findings of this research are as follows:

1. In this experiment, a pull-out test was used to research the performance of bonding between fiber-belt-bars and concrete. These damage phenomena were shown as pull-out damage. Some of the original fiber filaments on the surface of the fiber-belt-bars were broken, highlighting the slip abrasion state between the fiber-belt-bars and the concrete.
2. The bond–slip curve consists of two stages. At the beginning of the applied load, the bond stress rapidly reaches a peak, and with a further increase in slip, the bond stress begins to decrease and then tends toward a smooth stage. The bond strength in the smooth stage is 60–80% of the maximum bond strength, and the bond strength in the smooth stage can be used as the average bond strength for calculating the anchorage length of the fiber-belt-bar.
3. With an increase in the bond length of a fiber-belt-bar, the contact surface between the fiber-belt-bar and concrete increases, and the bond force between them increases. However, the increase in bond length and the non-uniformity of bond stress distribution on the contact surface reduce the average bond strength. To meet the requirements of the anchorage length of the fiber-belt-bar, it is necessary to satisfy the bearing capacity requirements and meet the minimum anchorage length requirements. It is also necessary to consider the stress distribution of the fiber-belt-bar and set the maximum anchorage length requirements, in addition to ensuring the fiber-belt-bar follows the full length of the shear load effect.
4. With an increase in the cross-sectional size of the fiber-belt-bar, the bonding strength increases and the average bonding strength decreases. For the same bond length of the fiber-belt-bar, a fiber-belt-bar with a cross-sectional size of 12 mm × 3 mm is about 10–30% higher than the average bond strength of a fiber-belt-bar with a cross-sectional size of 20 mm × 3 mm. In addition, protective measures must be implemented during the fiber-belt-bar concrete construction process; otherwise, the bonding performance will be affected.

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