Experimental Research on the Factors Influencing the Mechanical Property of CFRP bars

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Abstract: According to GB/T 26743-2011,Different diameters of CFRP bars are made on the mechanical properties test. The experiment process, experimental method and failure state are introduced in detail. The results show:1) Affect the production of pultruded rate and fiber volume fraction on the mechanical properties decreased after the first rise, there are optimum range. 2) Thread squeeze molding molding process is better than winding secondary molding process. 3) Epoxy film sticky sand, epoxy sticky sand, grinding treatment on anchorage performance is descending.

1 Introduction

Corrosion of steel has become one of the major factor in reducing the use and durability of structures.Whether at home or abroad, the direct losses and indirect losses caused by steel corrosion damagehas far exceeded expectations.CFRP bars have high-strength, light weight, corrosion resistance, fatigue and non-magnetic, etc., which applied as an alternative to steel are more and more attention in corrosion environment[1-4].5mm and 8mm CFRP bars are made on the mechanical properties test by GB/T 26743-2011[5]. Factors affecting the test results were analyzed. The reasonable suggestions to the testing method and production process are put forward.

2 Experiment on mechanical properties of CFRP bars

2.1 Parameters of CFRP bars. In the experiment, In 5 mm round steel experiment, fiber volume content and the anchoring handling are considered. 8 mm thread reinforcement considering pultrusion production rate and molding process, the influence of the fiber material properties. The basic parametersof5 mm round bars and 8mm threaded bars are shown in table 1, the surface state as shown in figure 1.

Table 1 parameters of CFRP bars

Group	Diameter （mm）	Fiber types	Fiber volume ratio （%）	Pultrusion rate （mm/min）	Thread Molding
A	5	T400+ High-strength glass fiber	68.5	400	Light round
B	5	T400	70.5	400	
C	5	T400	70	400	
D	5	T400	70.1	400	
E	8	T300	63	400	Squeeze
F	8	T400	65	350	Filament
G	8	T400	65	400	Squeeze
H	8	T400	65	500	Squeeze
I	8	T400	65	600	Squeeze

Fig.1 The differentsurface state of CFRP bars

2.2 Specimen making and anchorage. Because of high tensile strength, low compressive strength and low shear strength, CFRP tendon will be crushed before not reaching ultimate tensile strength if CFRP bar is directly install to the machine fixture[6].The test choose to use the anchorage of resin sleeve according to the standard. The inside diameter of sleeve is slightly bigger than CFRP tendon's diameter. Anchorage is depend on injecting binder into sleeve (see Fig.2).The test uses seamless steel pipe of inside 16mm, thickness 3mm and Anchorage length 250mm. Anchor design are shown in Table 2.

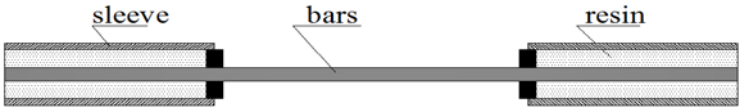

Fig.2 the schematic diagram of anchorage of CFRP bars

Table 2 The design of sample

Group	A	B	C	D		E	F	G	H	I
Number	2	5	14	10	10	3	5	2	10	5
Anchor end processing	Polish	Polish	Polish	Epoxy sticky sand	Epoxy film adhesive sand	Epoxy sticky sand				

2.3 Test methods. The test is the standard pull-out test. According to GB/T 26743-2011, the test measure the tensile strength of CFRP tendons and the stress-strain curve.

3 Test results

3.1 Damage state. The test damage state of specimens is mainly divided into four types：the explosive and brittle fracture, slip (anchorage failure) and outer fiber rib fracture failure (see Fig. 3).

1 ） the explosive and brittle fracture: The reasons is that surface wire of CFRP bars locally snapped ， produce sound and stress redistribution with increasing of tensile.Before of CFRP wire is broken, the energy that the fracture portion of the fiber strands released will enable a certain number of the CFRP wire separated from the specimen length direction in highly stressed state. As the load increases, the CFRP rib in the length direction is failure in the weakest point and release a lot of energy causing the CFRP bar rupture or brittle fracture appearance.

2）Slip (Anchorage failure):Mainly divided into: interface failure occurred in the surface of bars and resin ,the binder is shear failure(the reinforcement and the adhesive together, failure to occur at the interface adhesive)and binder pipe from steel.

3）Outer fiber rib fracture failure:When the tensile stress is very small，the fracture of outer fiber rib cause mechanical bite force of the binder and bar material greatlyreduced.Then the inner layer and outer layer fiber ribseparate from core material in the anchor end.

a)Explosive fracture failure b)Brittle fracture failure c)Anchorage failure d)Outer fiber rib fracture

Fig.3 Damage state of specimens

3.2 The stress-strain curve of CFRP bars. According to loading process of the specimens,The stress strain curve of CFRP bars from begin to remove the extensometer is approximately a straight line. The failure of specimen without symptom ,the sudden fracture, no yield stage, brittle failure.

3.3 The tensile strength, elastic modulus and elongation.According to the provisions processingtest results of A.6of GB/T 26743-2011 ,the test data are processed.

Table 3The experimental results of basic mechanical properties of CFRP bars

Group	The processing method of anchor end	The number	Tensile strength （MPa）	Modulus of elasticity （GPa）	Elongation （%）	Damage state
A	Grinding process	2	1765.0	134.0	1.60	The explosive destruction
B	Grinding process	5	2438.2	159.6	1.53	The explosive destruction
C	Grinding process	5	2338.6	163.3	1.44	The explosive destruction
	Grinding process	8	2059.0	159.8	1.29	Anchorage failure
	Grinding process	1	2321.0	157.5	1.47	Brittle fracture
D	Epoxy film adhesive sand	9	2604.2	159.1	1.64	The explosive destruction
		1	2321.0	163.8	1.42	Anchorage failure
	Epoxy resin bonded sand	3	2670.3	160.2	1.67	The explosive destruction
		5	2435.0	161.9	1.51	Brittle fracture
		2	2127.5	157.7	1.35	Anchorage failure
E	Epoxy resin bonded sand	3	1919.2	207.9	0.80	Brittle fracture
F		5	1349.6	157.8	0.86	Fiber rib fracture
G		2	2348.0	159.1	1.48	The explosive destruction
H		10	2380.3	165.0	1.44	The explosive destruction
I		5	2217.4	160.2	1.38	The explosive destruction

Note: The tensile strength, elastic modulus and elongation are average values in the table.

4 Analysis of test results

4.1 The influence of fiber type. This experiment adopts three kinds of fiber combination of CFRP bars.we can see that the elastic modulus of the combination of T400 andhigh strength glassfiber is smaller obviously, and the elongation larger. This is because the modulusofhigh strength glass fiber is small and the elongation is large. The strength of CFRP bars of T300 is smaller to CFRP bars of T400. which can be draw from the mixed law of composite materials.

4.2 The effect of fiber volume content. By the basic theory of composite material strength, the fiber tensile volume content and the tensile strength is greater than the matrix resin content and strength, the tensile strength of the composite material is mainly determined by the fiber tensile strength. We can see that the volume content of fiber bar of 5mm range from 68.5 percent to 70.5 percent, experiencing a rising stage and a dropping stage, the mainly reason is that the ability of wetting and penetrating of the resin matrix is not enough, causing shortage of glue in the fiber and gaps in the composites, eventually leading to the decrease of the tensile properties of composites.

4.3 The effects of pultrusion rate. For the screw thread steel of 8mm,eachpultrusion rate of G, H and I is 400 mm/min, 500 mm/min and 600 mm/min (see figure 6). What we can see from the diagram is that, as the product of pultrusion rate increased, tensile strength decline after growth first, variation coefficient of products increase rapidly, the reason is that the probability of the corresponding defects in the product increases companioning with the increase of the pultrusion rate. Once the pultrusion rate is too fast, product cure bad or can't cure, it will directly affect the product quality, leaving the thick resin layer on the surface of the product. On the contrary, if the rate is too slow, the CFRP bars remain in the mold for a long time, products will over solidified, and the production efficiencyreduced.

4.4 Threadmolding process. We carry a contrast experiment between group F and group H,the group F are around by the carbon fiber rid through step 2 molding process method and the group H are made by the method of extruding. Through date and phenomenon of the experiment, when the tensile strength of the samples of group F is 65-70KN, sample of outer fiber rib fracture from the inner core rod, even cause invalidation. On the contrast, the strength of the concave screw thread steel of 8mm reach nearly 110MPa, screw thread steel specimens occur explosive damage, the influence on the tensile strength of the specimens is shown in figure 7. The damage condition of thread bars is shown in figure 3.

4.5 The treatment of anchor end. The experiment conducted a contrast among three conditions. They are grinding process in the anchor end, epoxy resin bondedquartz and epoxy adhesive glue quartz sand (the shear strength of epoxy adhesive film is greater than the shear strength of epoxy

resin). From the point of damage state, in thesample of group D, epoxy film adhering sand damage state is explosive damage and there is little slip, epoxy adhering sand specimen is brittle fracture damage and have a certain slip. From the perspective of the value of tensile strength, the tensile strength of the explosive destruction is 2670.3MPa,and the brittle fracture failure is 2435.0MPa, so the effect of epoxy film adhering sand is much better than that of epoxy adhering sand. Secondly,we can know from the figure 8 and table 3, towards anchorage efficiency or the average tensile strength of the specimens, the adhering sand effect of epoxy adhesive film is the best, the effect of epoxy resin adhering sand in the middle and the effect of grinding process is the worst.So when need to test carbon fiber reinforcement, and to reduce the impact to the results of the experiment, we suggest to use high shear strength of carbon fiber reinforced resin for adhering sand process.

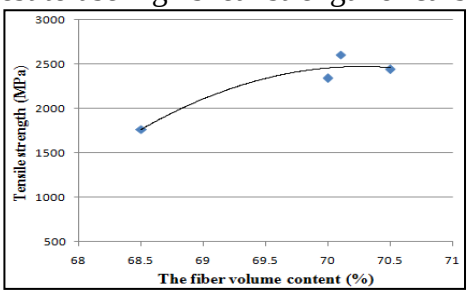

Fig.5 The effect of fiber volume content

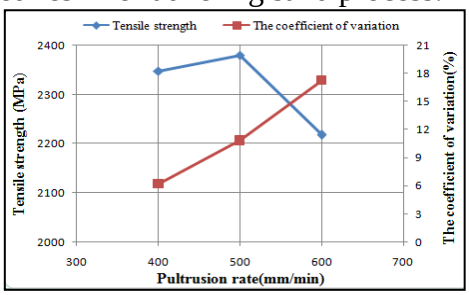

Fig.6 Product pultrusion speed impact on discrete degree

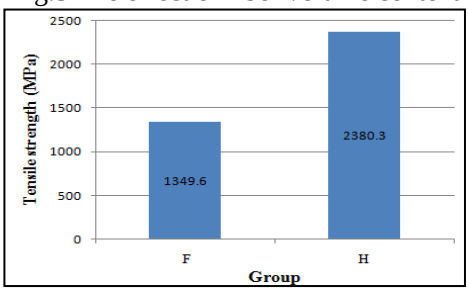

Fig.7 Influence diagram of process of rid

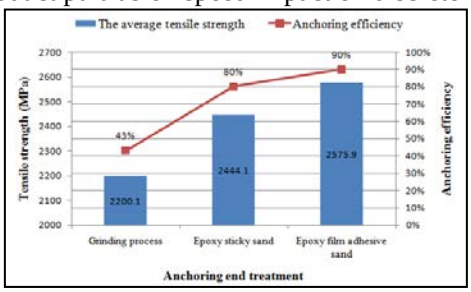

Fig.8 Influence diagram of processing mode of anchor end

5 Summary

1)The stress-strain curves are straight lines and the failure mechanism has brittle fracture characteristics.

2) Impact of fiber volume fraction of the tensile strength is increased and then decreased after the first. During production, it is recommended fiber volume content not exceed 70%.

3) Product pultrusion rate directly affects the cost and performance of the product. For the 8mm threaded bars, the fiber volume content of 65% and the rate of pultruded products 500mm / min is appropriate.

4) When CFRP tendons testing, we suggest using a large shear strength of colloid sticky sandIn the anchor end.

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