STUDY OF COAXIAL FRP SLEEVE / EXPANSION CEMENT CONNECTION OF FRP REBARS

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1 Introduction

Fiber-reinforced polymer (FRP) materials have emerged as a practical material for producing reinforcing bars for concrete structures. FRP reinforcing bars offer advantages over steel reinforcement in that FRP is noncorrosive, light-weight, strong and non-magnetic. FRP reinforcing bars and tendons are being more and more used for nonprestressed and prestressed concrete structures in the aggressive environments encountered in the construction industry[1]. Owing to limit in transportation and production, the connection of FRP rebars is also an unavoidable problem as steel rebars[2,3]. Due to differences in the physical and mechanical behavior of FRP materials compared to steel, unique connection methods for FRP bars are required.

The connection methods for steel rebars include banding lap connection, welding and mechanical connection etc. Thermoset FRP bars do not have the weldability. Although thermoplastic FRP bars can be welded, but the essence is matrix welding, not fibers welding. The strength and stiffness of FRP bars are anisotropic. The lateral bearing strength and shearing strength of FRP bars are weak. It is a brittle material. When it is destroyed there is no substantial yield deformation. Thus the ability of load re-distribution is poor. The splicings, which are suitable for steel rebars, such as welding, pressed sleeve splicing of ribbed steel bars, taper threaded splicing of rebars, parallel thread rebar splicing with cold upsetting end, parallel thread rebar splicing with rolled thread end, molten metal filling the sleeve splicing, etc., are not suitable for FRP rebars.

The study about the connection for FRP rebars is very limited. B. Tighiouart, B. BenmokraneU, P. Mukhopadhyaya[4] and C. Fu, Z. Zhou, B. Wang[5] have studied lap banding splice of FRP bars. Although it can be applied in the reinforced concrete structures, but it can’t be used under the following conditions according to the code for design of concrete structures [6]: 1) Longitudinal steel rebars of axial tension members and small eccentric tension members; 2) The diameter is bigger than 28mm for tension rebars or bigger than 32mm for compressive rebars; 3) The members need to assess fatigue. ACI [7] also have similar provisions. Thus lap banding splice of FRP rebars can not solve all connection problems. And it has the following drawbacks such as material waste, big in dimension, changing in the load transfer path.

The anchor of pressed sleeve with adhesive, which is proposed by J. Zhang etc.[10], is also expected to being a connector for FRP rebars. But it needs high pressing process level, and the steel sleeve is easy corrosion. In fact the test results show that the failure load of the specimens with dry pressed steel sleeve end reinforcement, which is provided to us by a company, is about 70% of the FRP rebars’ strength itself. Therefore there are a lot of problems with pressed sleeve splicing.

The thread rebars can be joined with a sleeve with female thread according to the literature [11]. But the thread connection strength is only 60-80% FRP reabrs’ strength. Thus the connecting efficiency can not meet the requirements about connection performance. J. Zhou, Q. Du, S. Chen [3], J. M. Lees, B. Gruffydd-Jones and C. J. Burgoyne[10] proposed a coaxial connection scheme with steel sleeve / adhesive or expansive cement. In various anchors of FRP rebars the anchorage of filling mortar can be applied in the connection. But the steel sleeve is not anticorrosion.

Therefore an effective method of coaxial connectors of FRP rebars for its reinforced concrete structure also must be studied to meet the needs of practical engineering. This paper presents a coaxial connecting method of FRP rebars with coaxial FRP sleeve filled with expansion cement.

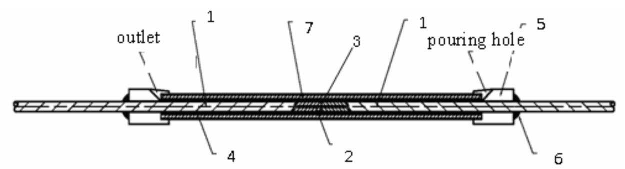
2 Coaxial FRP sleeve/expansion cement connection scheme of FRP rebars

2.1 Connector performance requirements

FRP rebars have high tensile strength and corrosion resistance advantages. The connector of FRP bars should have no less than the tensile capacity of FRP rebars. And it should also be resistant to corrosion.

2.2 A coaxial connection scheme of FRP rebars with FRP sleeve/ expansion cement

First, two being connected bars should be coaxial positioned with appropriate methods. And they will be covered with a FRP sleeve at the connecting position. Both ends of the sleeve can be set by coaxial locating ring. When horizontal pouring, a pouring hole/outlet is need to set in the locating ring. The expansion cement solution can be poured into the sleeve through the pouring hole. When perpendicular pouring, the locating ring needn't open pouring hole/outlet. The lower locating ring should be set firstly and sealing is necessary. After pouring the expansive cement solution into the sleeve from the upper openings, the upper locating ring can be set to make the bar and the sleeve coaxial. After the expansion cement hardens,the two FRP bars are connected together. Figure 1 is a conceptual diagram of the specimens with locating ring.



1 FRP rebar 2 Coaxial pin 3 Docking face 4 FRP sleeve 5 Locating ring 6 Sealing materials 7 expansion cement

Fig. 1 Connection diagram with locating ring

3 Experimental study

3.1 Experimental material

In this paper the GFRP bars, which are produced by Xiao Shi Da Composite Materials (Guangdong) Co., are made from non-alkali glass fiber (Owens Corning) and vinyl resin (Ashland) by pultrusion winding process. The surface is deformed and sand coated. The nominal diameter of the test GFRP bars is13mm. The measured tensile strength is 663.7MPa and elastic modulus is 39.2 GPa[12]. The expansion pressure of expansive cement can be up to 40MPa [10].

3.2 Specimen of coaxial connection of FRP rebars

Figure 2 is a photo of a specimen prepared by the above method. The length of FRP sleeve is 400mm. The preparation process is as follows:

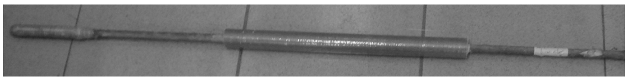


Fig.2 Specimen of coaxial FRP sleeve/expansion cement connection of FRP rebars

1) Prepare a FRP pipe. According to the connection design requirements, the FRP sleeve requires no less than the axial strength of the FRP bars. And because when the expansion cement hardens, expansive pressure can be higher up to 40MPa or more, so the FRP sleeve also need to have sufficient hoop strength to prevent splitting. It can be fabricated by the following method: Take a GFRP pultrusion pipe, which should behaves enough axial strength. According to the expansion pressure wind properly galss fiber impregnated epoxy on it. After curing it can be used as connection sleeve. For example, for the test GFRP rebars, the outer diameter of the GFRP pultrusion pipe we choosed is 30 mm, the wall thickness is 5 mm and the length is 3 meters. Two beams 500 TEX glass fiber impregnated epoxy are winded 3 layers on it by a winding machine. After curing the strength properties of the GFRP pipe can satisfy the connection requirements.

2) Drill a 3 mm diameter coaxial hole, about 35 mm depth, in the center of the end section of the two GFRP rebars respectively with hand drill.Clamp the terminal parts of the two GFRP rebars to be connected on a fixture.

3) Take a segment GFRP pultrusion bar or steel bar, which the diameter is 3 mm and the length is 60 mm.

4) According to the anchor characteristics of the selected expansive cement, cut a 400 mm long GFRP connecting sleeve from the prepared FRP pipe.

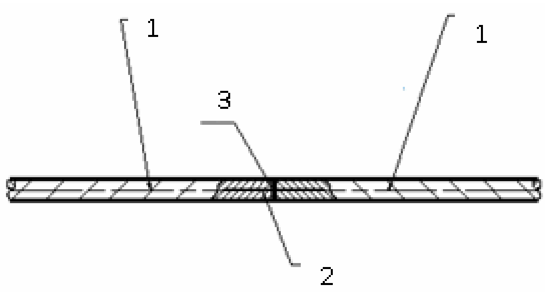
5) Put the connecting sleeve onto one rebar to be

connected, insert the FRP pultrusion bar or steel bar coated with 502 instant glue into the two hole , after a few seconds the two GFRP bars will have been coaxial positioned, as shown in Figure 3.

6) Move GFRP connecting sleeve to the connection part of the two connected bars. The half length section of the sleeve should overlap the dock of the two bars. Install a positioning ring at each end of the sleeve (The positioning ring is consist of two "Half" block composition. They can be assembled a whole ring by screws or adhesive tape, as shown in Figure 4.). When horizontal pouring, the pouring hole/ outlet of the two positioning ring should be facing up and the casting port should be slightly lower than the outlet 2 ~ 3 mm. When perpendicular pouring, the lower locating ring shold be set firstly and after pouring from the upper mouth of the sleeve the upper locating ring can be set then. The seams between the locating ring and the GFRP rebar should be sealed with rubber cement etc. sealing material.

7) Prepare expansive cement solution according to the provisions of the water-cement ratio. The water-cement ratio should be controlled generally in the 0.28-0.33 range. Pour the expansive cement solution slowly into the sleeve from the pouring hole (when horizontal pouring) or upper mouth of the sleeve(when perpendicular pouring) until it overflows from the outlet or upper mouth.

8) When the expansive cement have hardened under natural condition the connection is completed. In general the hardening time is usually 6 to 12 hours. It can carry whole load after 36 hours.

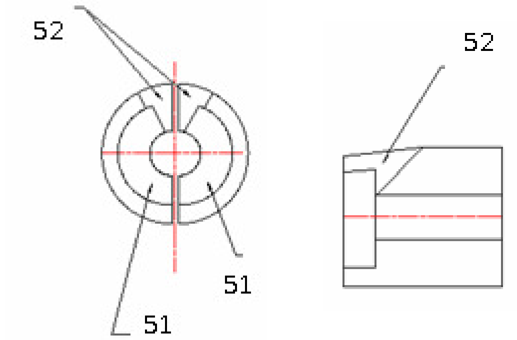


1 FRP rebar 2 coaxial pins 3 docking face

Fig.3 coaxial positioning of FRP rebars to be connected

3.3 Test equipment

The test machineWD-20A is produced by



51 "Half" locating ring 52 pouring hole/outlet

Fig.4 locating ring

Guangzhou Test Instrument Factory. The specimens were loaded at a rate of approximately 2mm/min. Fig.5 is a picture in the experiment.

Fig. 5 tensile test of coaxial connector

3.4 Test results

Table1 gives the test results. Fig.6 shows the sample destruction condition.

Table 1 Test Results

Specimen No.	1	2	3	4	5
Limit load(KN)	98.6	90.4	91.7	89.5	93.3
limit stress(MPa)	743	681	691	674	703

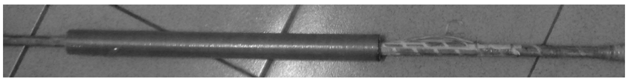


Fig.6 sample destruction condition

Failure locations of all specimens are not in the connection segment. Thus such connection scheme is successful.

4 Results

1) The coaxial connection scheme of FRP rebars with FRP sleeve /expansion cement can be achieved effectively. The splicing strength is stronger than FRP rebar itself.

2) The connection FRP sleeve can be prefabricated. The quality is easy to control. And the expansive cement is low cost. So this connection method has advantages such as simple in construction, light weight, high strength, and corrosion resistance. And it can be used for a degaussing requirements structure and so on.

Of course, to solve various issues about design, processing and testing that may be encountered in practical applications, the design theory of this coaxial connection system should be further studied. And its fatigue performance should also be done experimental and theoretical research.

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