Experimental study on the bonding performance of FRP and radiation shielded concrete

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Abstract. In order to ensure the safe service of reinforced concrete structures in the storage of spent fuel and the disposal of nuclear waste under the coast, this paper proposes the idea of replacing reinforced concrete structures with FRP-barite radiation shielding concrete structures. The cohesive properties of FRP and barite radiation-shielding concrete were characterized by the central pull-out test in terms of average ultimate bond strength and bond stress slip response. The results show that the bonding performance of BFRP bars is better than that of other types of FRP bars due to the large height of the ribs, and the bonding properties of spiral rib FRP bars are better than those of shallow ribbed bars and bonded sand bars.

Keywords: Architecture, Disaster prevention and control, Barite Radiation Shielding Concrete, Bonding performances, Centre pull-out test.

1 Introduction

Reinforced concrete materials are used as engineering barriers in the disposal units used as closed containers for storing spent fuel in nuclear power plants and permanent repositories for medium and low emission wastes With the develop-ment of radiation-resistant concrete in construction industry, it has been widely used in the construction of nuclear facilities because of its good shielding effect on neutrons and gamma rays [1-2] Barite anti-radiation concrete can improve its shielding ability to χ γ rays by increasing the apparent density of concrete and improving the compactness of concrete. Barite is rich in mineral resources and low in price, which is a research hotspot of anti-radiation materials [3-5] In addi-tion, most nuclear power plants are built along the coast, and chloride ions erode reinforced concrete structures along the coast. Service life of reinforced concrete structures [6] Many scholars have studied this subject for many years, and the results show that [7-9] using fiber reinforced polymer bars (FRP bars) instead of steel bars can solve the durability problem of reinforced concrete structures in corrosion to a great extent Whether the combination of GFRP bars and barite radiation-proof concrete is feasible in the closed containers of spent fuel storage and the disposal units of the permanent storage of medium and low level radioac-tive waste depends on the synergistic performance between them However, there are no scholars

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to study this problem In this paper, the bond performance be-tween FRP bars and barite radiation-proof concrete is studied by central pull-out test based on the research results of FRP and ordinary concrete.

2 Material

2.1 Material

The performance and quality of raw materials directly affect the performance of concrete, not only the quality must be qualified, but also to meet the radiation performance of concrete, construction performance, and durability and other requirements.

Cementitious materials: PO42.5 ordinary silicate cement was selected for the experiment, in order to improve the compatibility of fresh concrete and reduce the heat of hydration of concrete, 10% of the mass of cementitious materials was mixed with fly ash to replace part of the cement after several trial mixes and determined.

Aggregate: barite crushed stone and barite sand were processed from Shandong, China as shown in Fig. 1. where barium sulphate content was 93.1%, the diameter of barite fine sand ranged from 0-5mm, and the grain size of barite crushed stone ranged from 5-20mm.

Admixture: In order to improve the fluidity and plasticity of concrete mix and reduce the unit water consumption, polycarboxylic acid high-efficiency water reducing agent with a water reduction rate of 11% was used in this test.

2.2 Radiation shielding concrete proportion design

The design of barite radiation-resistant concrete mix is more complicated than that of ordinary concrete mix, and its quantitative indexes have increased the apparent density of concrete in addition to the concrete strength value. In this paper, with reference to JGJ55-2011 and GBT 34008-2017 and other related specifications, the concrete with strength of C30 was prepared according to the mix ratio shown in Table 1. The concrete was cured at room temperature for 28 days, and the 7-day and 28-day compressive strengths were measured as shown in Table 2.

Table 1. Radiation Shielding Concrete Proportions

Concrete Strength (MPa)	Water-cement ratio	sand rate(%)	Water (Kg/m^3)	Clinker (Kg/m^3)	Coal ash	Coarse aggregate	Fine aggregate	Water reducing agent
C30	0.48	35	200	374.99	41.67	1692.46	911.32	0.5

Table 2. Compressive strength test results

Design strength	7d Strength	7d Average strength	28d Strength	28d Average strength	Apparent density
C30	33.911	34.014	35.545	34.877	3258
	32.476		34.209		
	-		-		

3 Pull-out test

3.1 Specimen design

In this paper, with reference to the research results of domestic and foreign scholars on ordinary reinforced concrete, the bonding performance test of GFRP reinforcement and barite radiation-resistant concrete was designed. The bond specimens were designed according to the Canadian Standards Association (CSA) standards: 7 groups of 21 pull-out specimens were prepared and tested to investigate the effect of different surface treatments on the bond performance. The specimen size was 150mm x 150mm x 150mm.

During the test, a total of three LVDTs were used to monitor the bond slip between the GFRP bars and the BRSCs as shown in Fig. 1. The bond slip between the GFRP bars and the BRSCs can be determined according to Eq. 1, where d is the bond strength, is the maximum load during the pullout test, d is the nominal diameter of the bars, and L is the length of the bond.

$$\tau_u = \frac{F_u}{\pi d L} \tag{1}$$

Fig. 1. Drawing device diagram

3.2 Analysis of results

The test results of all pullout specimens in this paper are shown in Table 3. Where τavg is the average ultimate bond load, S1, S2 and S3 are the corresponding displacements, S stands for specimen splitting damage and P stands for pullout damage.

Table 3. Test results

Specimen	F_{max}/kN	τ_{max}/MPa	τ_{avg}/MPa	S1	S2	Failure mode
G18C305d-1	62.70	12.33	12.16	7.00	3.30	S
G18C305d-2	61.00	11.99		5.12	2.09	P
G18C305d-3	-	-		-	-	-
Gq18C305d-1	41.70	8.20	8.89	3.72	0.60	S
Gq18C305d-2	48.30	9.50		-	-	S
Gq18C305d-3	45.60	8.96		4.30	2.18	S
Gn18C305d-1	-	-	4.85	-	-	-
Gn18C305d-2	25.80	5.07		4.18	2.22	P
Gn18C305d-3	23.50	4.62		6.32	3.44	P
G14C305d-1	-	-	13.19	-	-	-
G14C305d-2	40.00	13.00		7.79	1.93	P
G14C305d-3	41.20	13.39		7.36	1.72	P
B14C305d-1	58.80	19.11	18.69	7.89	3.12	S
B14C305d-2	57.70	18.75		7.18	3.97	P
B14C305d-3	56.00	18.20		6.29	3.35	S
C14C305d-1	53.80	17.48	17.47	4.41	0.94	P
C14C305d-2	54.20	17.61		4.73	0.82	S
C14C305d-3	53.30	17.32		4.87	4.19	P
S14C305d-1	62.70	20.38	20.39	4.51	0.91	P
S14C305d-2	62.80	20.41		3.63	1.95	S
S14C305d-3	-	-		-	-	-

In this study, a deep-ribbed, smooth circular cohesive sand reinforcement material with a diameter of 18 mm was used as a comparison sample, and the effects of different surface treatments on the bond strength were studied. Figure 2 shows the ultimate bond strength of GFRP reinforcement and BRSC under three different surface treatments. It is not difficult to see that the spiral wound rib is the most suitable for this study, and the bond strength of the sand reinforcement and deep rib GFRP is only 45% and 68% of the spiral wound rib. Fig. 3 shows the bond-slip curves of three different types of GFRP bars measured experimentally.

Figure 4 shows the comparison of the viscosity strength of GFRP, BFRP, and CFRP bars with a diameter of 14 mm and thread bars with a diameter of 14 mm. As can be seen from the diagram. Different types of FRP bars have different ultimate bond strengths, among which BFRP bars are the highest, about 92% of the threaded bars, and the GFRP bonding performance is slightly insufficient, only 65% of the threaded bars. Different from previous studies on FRP and ordinary concrete, the bond strength between CFRP bars and BRSC is not the highest, which is due to the fact that the BFRP bars used in this study have a larger rib height than other types of.

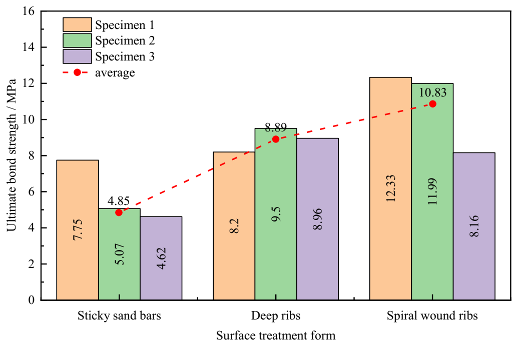

Fig. 2. Average bond strength in different surface treatment forms

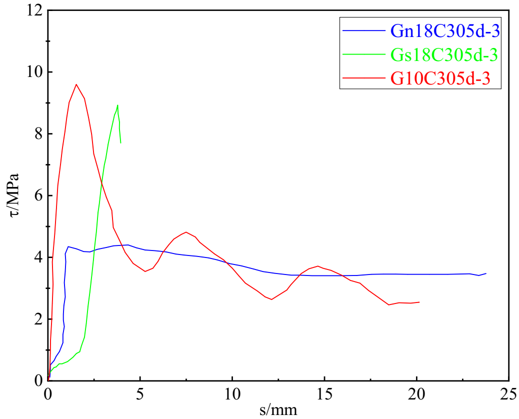

Fig. 3. Bond-slip curves

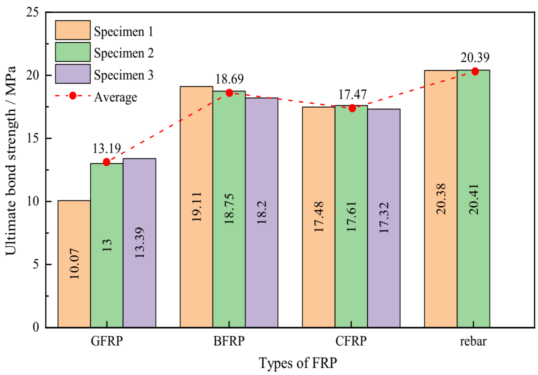

Fig. 4. Average bond strength of different FRP types

4 Conclusion

The workability, apparent density and compressive strength of the barite radiation resistant concrete designed in this paper can meet the engineering requirements.

GFRP reinforcement with helically wound bars has higher bond strength and should be given priority in engineering design, and BFRP with larger rib height has the bond strength closest to that of threaded bars.

The bond properties of GFRP and radiation shielding concrete have not been retrieved yet, and a lot of research work is needed.

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