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Experimental Study on Interface Strength Between Hardened Cement Paste-Aggregate

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Abstract: The interfacial transition zone (ITZ) is a weak part of concrete, which is the main reason that the mechanical properties of concrete are far lower than those of hardened cement paste and aggregate itself. In order to improve the mechanical properties of concrete ITZ, the effects of cement varieties, water-binder ratio, mineral admixtures and aggregate types on the strength of hardened cement paste-aggregate ITZ were studied by orthogonal test. A linear regression model between interfacial bonding splitting tensile strength and splitting tensile strength of hardened cement paste was proposed. The results show that the water-binder ratio has the greatest impact on the mechanical properties of ITZ, followed by aggregate. The interfacial bonding splitting tensile strength of five kinds of aggregate and cement paste is in the order of marble > coral > granite > basalt > quartzite. The optimal interface test combination is as follows: water-binder ratio 0.25, aggregate is marble, P·O52.5 cement, slag content 15%, fly ash content 20% and silica fume content 10%. The optimal cement slurry combination is: water-cement ratio 0.25, basic magnesium sulfate cement, slag content 15%, fly ash content 20% and silica fume content 10%. The linear regression model between interfacial bond splitting tensile strength and hardened cement paste splitting tensile strength is established by dividing aggregate, which is of great significance to study the law of interfacial strength.

Keywords: Interfacial Transition Zone, Interfacial Bonding Splitting Tensile Strength, Orthogonal Test, Range Analysis

1. Introduction

Concrete is a kind of building material with uneven, extremely complex and obvious differences in the composition of various internal components. Micromechanical model divides hard concrete structure into three parts: hardened cement paste phase, aggregate and interface transition zone (ITZ) formed between them [1]. ITZ is a weak link in concrete, and the damage and failure of concrete are largely attributed to the gradual destruction of ITZ structure [2].

At present, the strength test methods of ITZ include direct method and indirect method [3]. The direct method uses the depth sensing micro indentation method to directly measure the elastic modulus of ITZ, which is rarely used because of its difficulty in preparation and testing [4]. Indirect method is

generally through the "containing interface specimen" to determine ITZ interface bonding tensile strength, interface bonding splitting tensile strength [5-7]. Domestic and foreign scholars mostly adopt indirect method to study the mechanical properties of interface. Zhou et al. found that the interfacial bonding strength of concrete decreased with the increase of water-cement ratio [8]. Wang found that the addition of fly ash would reduce the thickness of ITZ, so the interfacial bonding splitting tensile strength was higher than that of concrete without fly ash [9]. Zhang found that the mechanical properties of concrete using different types of aggregates were different, and the concrete strength of each aggregate was granite≈basalt> marble [10].

At present, there have been a large number of literature on the micro-properties of ITZ [11-13]. However, due to the difficulty in testing the strength characteristics of ITZ, there are few macro-mechanical data of ITZ. In this paper, in order

to establish the ITZ interface mechanical properties database of common concrete, orthogonal design was used to systematically study the influence of cement varieties, water-binder ratio, types and contents of admixtures and aggregate types on ITZ strength, so as to determine the key factors of interface strength, and establish the relationship between interface strength and hardened cement paste strength.

2. Experiment

2.1. Mix Proportion Design of Orthogonal Test

In order to explore the influence of cementitious materials, water-binder ratio and aggregate types on the interfacial strength of hardened cement paste-aggregate, and to obtain the optimal mix proportion of the strength of the interface test specimen. Six factors including cement type, water-binder ratio, mineral admixture type and its dosage, and aggregate

type were studied, and five levels were selected for each factor. The $L_{25}(5^6)$ orthogonal table was used to arrange the experiment, and the factor-level table is shown in Table 1. In order to ensure the total quality of cementitious materials unchanged, the mineral admixture content is cement replacement rate. The mix proportion orthogonal design test plan sees Table 2, the mix proportion orthogonal design sees Table 3.

The orthogonal test index of the interface test specimen is the interfacial bonding splitting tensile strength. In order to establish the relationship between the interfacial bonding splitting tensile strength and the strength of cement paste, the cement paste mixture ratio with the same proportion of cementitious materials as the interface test specimen is designed, and a new orthogonal table is formed. The factor B of the orthogonal table is an empty column, and the specimen index is the splitting tensile strength.

Table 1. *Factor level table of hardened cement paste-aggregate interface test.*

Level	Factor					
	A (Cement)	B (Aggregate)	C (W/B)	D FA/%	E SG/%	F SF/%
1	P·I 52.5	Coral	0.25	0	0	0
2	P·O 52.5	Granite	0.33	10	15	5
3	P·II 52.5	Basalt	0.40	15	25	10
4	P·O 42.5	Marble	0.48	20	35	15
5	BMSC	Quartzite	0.55	25	45	5

Note: The "BMSC" in the table is basic magnesium sulfate cement.

Table 2. *Table of orthogonal test scheme for hardened cement paste-aggregate interface test piece.*

Number	A (Cement)	B (Aggregate)	C (W/B)	D FA/%	E SG/%	F SF/%
1#	1(P·I 52.5)	1(Coral)	2(0.33)	4(20)	3(25)	2(5)
2#	2(P·O 52.5)	1(Coral)	5(0.55)	5(25)	5(45)	4(15)
3#	3(P·II 52.5)	1(Coral)	4(0.48)	1(0)	4(35)	1(0)
4#	4(P·O 42.5)	1(Coral)	1(0.25)	3(15)	1(0)	3(10)
5#	5(BMSC)	1(Coral)	3(0.40)	2(10)	2(15)	5(5)
6#	1(P·I 52.5)	2(Granite)	3(0.40)	3(15)	4(35)	4(15)
7#	2(P·O 52.5)	2(Granite)	2(0.33)	2(10)	1(0)	1(0)
8#	3(P·II 52.5)	2(Granite)	5(0.55)	4(20)	2(15)	3(10)
9#	4(P·O 42.5)	2(Granite)	4(0.48)	5(25)	3(25)	5(5)
10#	5(BMSC)	2(Granite)	1(0.25)	1(0)	5(45)	2(5)
11#	1(P·I 52.5)	3(Basalt)	1(0.25)	5(25)	2(15)	1(0)
12#	2(P·O 52.5)	3(Basalt)	3(0.40)	1(0)	3(25)	3(10)
13#	3(P·II 52.5)	3(Basalt)	2(0.33)	3(15)	5(45)	5(5)
14#	4(P·O 42.5)	3(Basalt)	5(0.55)	2(10)	4(35)	2(5)
15#	5(BMSC)	3(Basalt)	4(0.48)	4(20)	1(0)	4(15)
16#	1(P·I 52.5)	4(Marble)	4(0.48)	2(10)	5(45)	3(10)
17#	2(P·O 52.5)	4(Marble)	1(0.25)	4(20)	4(35)	5(5)
18#	3(P·II 52.5)	4(Marble)	3(0.40)	5(25)	1(0)	2(5)
19#	4(P·O 42.5)	4(Marble)	2(0.33)	1(0)	2(15)	4(15)
20#	5(BMSC)	4(Marble)	5(0.55)	3(15)	3(25)	1(0)
21#	1(P·I 52.5)	5(Quartzite)	5(0.55)	1(0)	1(0)	5(5)
22#	2(P·O 52.5)	5(Quartzite)	4(0.48)	3(15)	2(15)	2(5)
23#	3(P·II 52.5)	5(Quartzite)	1(0.25)	2(10)	3(25)	4(15)
24#	4(P·O 42.5)	5(Quartzite)	3(0.40)	4(20)	4(35)	1(0)
25#	5(BMSC)	5(Quartzite)	2(0.33)	5(25)	5(45)	3(10)

Table 3. *Mix ratio of hardened cement paste-aggregate interface/g.*

Number	Cement Type	Content	Aggregate	Water	FA	SG	SF	water reducing admixture
1#	P·I 52.5	800	Coral	528	320	400	80	4
2#	P·O 52.5	240	Coral	880	400	720	240	0
3#	P·II 52.5	1040	Coral	768	0	560	0	0
4#	P·O 42.5	1200	Coral	400	240	0	160	7
5#	BMSC	1120	Coral	640	160	240	80	0
6#	P·I 52.5	560	Granite	640	240	560	240	0
7#	P·O 52.5	1440	Granite	528	160	0	0	4
8#	P·II 52.5	880	Granite	880	320	240	160	0
9#	P·O 42.5	720	Granite	768	400	400	80	0
10#	BMSC	800	Granite	400	0	720	80	7
11#	P·I 52.5	960	Basalt	400	400	240	0	7
12#	P·O 52.5	1040	Basalt	640	0	400	160	0
13#	P·II 52.5	560	Basalt	528	240	720	80	4
14#	P·O 42.5	800	Basalt	880	160	560	80	0
15#	BMSC	1040	Basalt	768	320	0	240	0
16#	P·I 52.5	560	Marble	768	160	720	160	0
17#	P·O 52.5	640	Marble	400	320	560	80	7
18#	P·II 52.5	1120	Marble	640	400	0	80	0
19#	P·O 42.5	1120	Marble	528	0	240	240	4
20#	BMSC	960	Marble	880	240	400	0	0
21#	P·I 52.5	1520	Quartzite	880	0	0	80	0
22#	P·O 52.5	1040	Quartzite	768	240	240	80	0
23#	P·II 52.5	800	Quartzite	400	160	400	240	7
24#	P·O 42.5	720	Quartzite	640	320	560	0	0
25#	BMSC	320	Quartzite	528	400	720	160	4

Note: Ordinary cement uses polycarboxylate superplasticizer, BMSC uses naphthalene superplasticizer.

2.2. Material

(1) Cementitious materials

Cement: P·I 52.5 cement produced by Shandong Cement Factory Co., Ltd.; P·O 42.5 cement produced by Nanjing Hailuo Cement Co., Ltd.; P·O 52.5 cement produced by Zhucheng Yangchun Cement Co., Ltd.; P·II 52.5 cement produced by Jiangnan Xiaoyetian Cement Plant in Qixia District, Nanjing City; BMSC is prepared by mixing magnesite calcined light-burned magnesium oxide powder (MgO) of Liaoning Huafeng Magnesium Industry Co., Ltd. and magnesium sulfate heptahydrate (industrial grade, $MgSO_4 \cdot 7H_2O$) of Shandong Yongxin Chemical Co., Ltd. with chemical admixtures in a certain proportion. The chemical composition of the main materials of BMSC is shown in Table 4. The chemical composition of other cements is shown in Table 5. Physical properties of five cements are shown in Table 6.

Table 4. *Chemical composition of basic magnesium sulfate cement raw materials /%.*

Material	Mg^{2+}	SO_4^{2-}	Ca^{2+}	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	Loss of ignition
$MgSO_4 \cdot 7H_2O$	9.73	40.06	0.03	-	-	-	-	-	-	-	50.18
MgO	-	-	-	0.34	0.23	0.55	1.98	0.51	0.37	0.74	15.16

Table 5. *Chemical composition of cement/%.*

Cement	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O
P·I 52.5	21.96	6.51	3.56	63.57	0.14	3.67	0.59
P·O 52.5	26.77	7.97	3.05	57.14	1.72	2.6	0.75
P·II 52.5	22.23	4.78	3.06	66.33	0.83	2.16	0.61
P·O 42.5	24.12	6.89	3.36	59.04	2.78	3.16	0.65

Table 6. *Tables of cement physical properties.*

Cement	Setting time /min		Flexural strength /MPa		compressive strength /MPa	
	Initial	Final	3d	28d	3d	28d
P·I 52.5	160	230	6.1	8.4	32.7	57.8
P·O 52.5	142	251	6.2	5.7	33.5	56.4
P·II 52.5	120	173	6.5	9.1	36.8	59.1
P·O 42.5	215	265	5.5	8.6	26.3	49.8
BMSC	115	282	7.8	14.5	29.6	54.3

Mineral admixtures: Grade I fly ash (FA) produced by Nanjing Electric Power Plant; S95 grade grinding slag (SG)

with specific surface area of 415 m²/kg was used in the production and processing of Jiangnan Grinding Company. Silica Fume (SF) is produced by Erken Silicone (Shanghai)

Co., Ltd., its SiO_2 content is more than 90% and its specific surface area is 20m²/kg. The chemical compositions of mineral admixtures are shown in Table 7.

Table 7. *Chemical constituents of mineral admixtures/%.*

Mineral admixtures	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	IL
FA	56.71	25.08	7.35	5.42	1.63	1.07	0.67	2.07
SG	33.31	14.34	1.61	38.87	9.97	0.87	0.64	0.39
SF	92.88	0.97	1.48	1.64	1.37		0.49	1.17

(2) Water: Use of tap water in Nanjing in line with national standards

(3) Aggregate

The coral is transported back from Nansha Islands in South China Sea. The measured uniaxial compressive cube strength is 82 MPa and the roughness is 2.024 μm, as shown in Figure 1(a). The granite is produced in Fuzhou, Fujian Province. The measured uniaxial compressive cube strength is 251 MPa and the roughness is 1.69 μm, as shown in Figure 1(b). The origin

of basalt is Fuding, Fujian Province. The measured uniaxial compressive cube strength is 147 MPa and the roughness is 2.115 μm, as shown in Figure 1(c). Marble is produced in Liuzhou, Guangxi. The measured uniaxial compressive cube strength is 111 MPa and the roughness is 2.512 μm, as shown in Figure 1(d). The origin of quartzite is Wuxue, Hubei. The measured uniaxial compressive cube strength is 223 MPa, and the roughness is 1.407 μm. As shown in Figure 1(e).

(a) Coral   (b) Granite   (c) Basalt   (d) Marble   (e) Quartzite
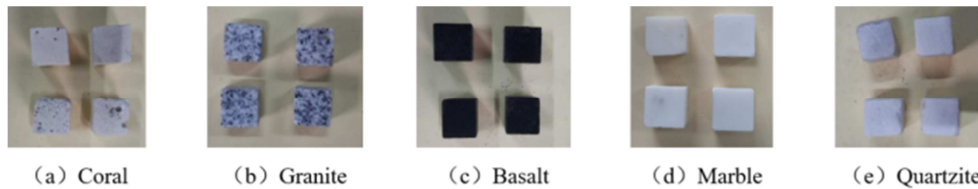
Figure 1. *Standard specimen of aggregate.*

(4) Water reducing agent

Polycarboxylate high performance water reducer: Jiangsu Subote New Materials Co., Ltd., model: SW-A, dosage 1.0%, density 1.044 g/mL, PH 5.5, chloride content 0%, total alkali content 1.02%, water reduction rate 26.3%, gas content 2.0%, suitable for ordinary Portland cement and Portland cement;

Naphthalene series superplasticizer: Jiangsu Subote New Materials Co., Ltd. Production, performance in line with GB8076, water reduction rate up to 25%, used for BMSC.

2.3. Sample Preparation and Test Method

Figure 2. *Standard interface.*

According to Table 3, 16 standard interface specimens with 20mm×20mm×80mm cement paste and aggregate alternately arranged were poured in each mix proportion (as shown in Figure 2) to measure the bonding splitting tensile strength of 3d, 7d, 14d and 28d interface specimens. According to the mix

proportion design of cement paste orthogonal test, 16 cube cement paste specimens of 20 mm × 20 mm × 20 mm were poured in each mix proportion for measuring the splitting tensile strength of 3 d, 7 d, 14 d and 28 d.

The strength test adopts HG-YH100D press machine of Jiangsu Zhuoheng Measurement and Control Technology Co., Ltd (as shown in Figure 3). The test force range is 100 kN/5 kN, and the test sensitivity is 0.01 kN.

Figure 3. *Press machine.*

3. Range Analysis of Orthogonal Test Results

When the age is 28 d, the orthogonal test results of the splitting tensile strength of cement paste and the bonding splitting tensile strength of interface test pieces are shown in Table 8.

Table 8. *Mechanical properties of 28 d orthogonal test.*

Number	Splitting tensile strength of cement paste /MPa	Bond splitting tensile strength of interface test pieces /MPa
1#	7.99	5.84
2#	4.12	3.42
3#	6.09	3.91
4#	10.06	6.18
5#	8.67	5.18
6#	7.62	4.17
7#	9.15	5.58
8#	6.86	4.70
9#	6.11	3.94
10#	9.98	5.87
11#	9.46	6.36
12#	7.85	5.27
13#	8.60	4.32
14#	5.98	2.85
15#	9.14	4.86
16#	5.96	4.39
17#	9.33	7.22
18#	6.98	4.76
19#	8.73	6.27
20#	5.96	4.39
21#	5.27	2.08
22#	7.04	4.93
23#	8.40	5.48
24#	7.22	3.96
25#	7.41	4.87

3.1. Range Analysis of Orthogonal Test Results of Cement Paste Specimens

The range method is used to determine the influence of various factors on the 28 d splitting tensile strength test results of hardened cement paste [14]. The range analysis results are shown in Table 9. The relationship between the level of various factors and the 28 d splitting tensile strength of hardened cement paste is shown in Figure 4.

The k_1, k_2, k_3, k_4, k and range of 28 d splitting tensile strength of hardened cement paste at different levels given in Table 9 show that the splitting tensile strength of 4 # is the highest, which is 10.06 MPa. The cement variety is P·O 42.5 cement, the water-binder ratio is 0.25, the fly ash content is 15%, the slag content is 0%, and the silica fume content is 10%. Among them, the range R_C (3.82MPa) of water-cement ratio and R_D (1.29MPa) of fly ash content are greater than the range R_B (1.14MPa) of empty column, indicating that the water-binder ratio and fly ash content of hardened cement paste have a significant effect on the splitting tensile strength of hardened cement paste, while the range R_A (0.98MPa), R_E (0.92MPa) and R_F (0.05MPa) of cement varieties, slag content

and silica fume content are less than those of R_B (1.14MPa), indicating that the cement varieties, slag content and silica fume content of hardened cement paste have little effect on the splitting tensile strength of hardened cement paste.
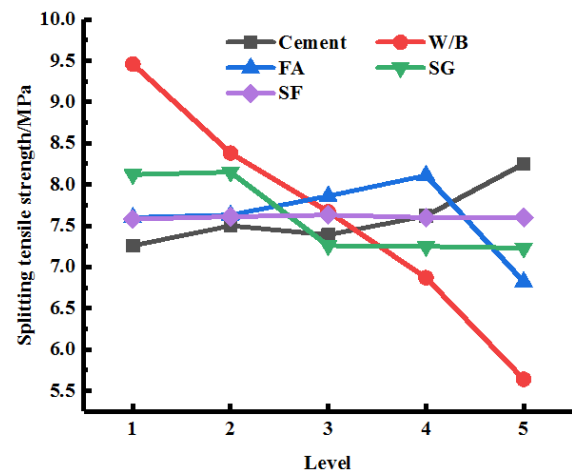

Figure 4. *Relationship between factors and splitting tensile strength of hardened cement paste at 28 d.*

Table 9. *Range analysis of splitting tensile strength of hardened cement paste at 28 d.*

Level	f_{ts}/MPa					
	A (Cement)	B (Aggregate)	C (W/B)	D FA/%	E SG/%	F SF/%
K_1	36.30	36.94	47.30	37.98	40.60	37.88
K_2	37.50	39.79	41.88	38.16	40.76	38.03
K_3	36.93	41.03	38.34	39.28	36.31	38.14
K_4	38.10	36.96	34.34	40.54	36.24	38.02
K_5	41.23	35.34	28.19	34.08	36.14	37.99
k_1	7.26	7.39	9.46	7.60	8.12	7.58
k_2	7.50	7.96	8.38	7.63	8.15	7.61
k_3	7.39	8.21	7.67	7.86	7.26	7.63

Level	f_{ts}/MPa					
	A (Cement)	B (Aggregate)	C (W/B)	D FA/%	E SG/%	F SF/%
k4	7.62	7.39	6.87	8.11	7.25	7.60
k5	8.25	7.07	5.64	6.82	7.23	7.60
R	0.98	1.14	3.82	1.29	0.92	0.05

Note: K_1, K_2, K_3, K_4 and K_5 represent the corresponding test results when the levels of each factor are 1, 2, 3, 4 and 5, respectively. k_1, k_2, k_3, k_4 and k_5 represent their average values, respectively. R represents the range between each factor.

It can be seen from Figure 4 that the five factors affecting the 28 d splitting tensile strength of hardened cement paste are in the order of water-binder ratio > fly ash content > cement varieties > slag content > silica fume content. The optimal combination obtained by orthogonal test method is: water-binder ratio 0.25, basic magnesium sulfate cement, slag content 15%, fly ash content 20% and silica fume content 10%.

3.2. Range Analysis of Orthogonal Test Results of Interface Test Pieces

The extreme results of bonding splitting tensile strength of interface test specimens at 28 d are shown in Table 10, and the relationship between each factor level and bond splitting tensile strength of interface test specimens at 28 d is shown in Figure 5.

Table 10. *Range analysis of interface bonding splitting tensile strength at 28 d.*

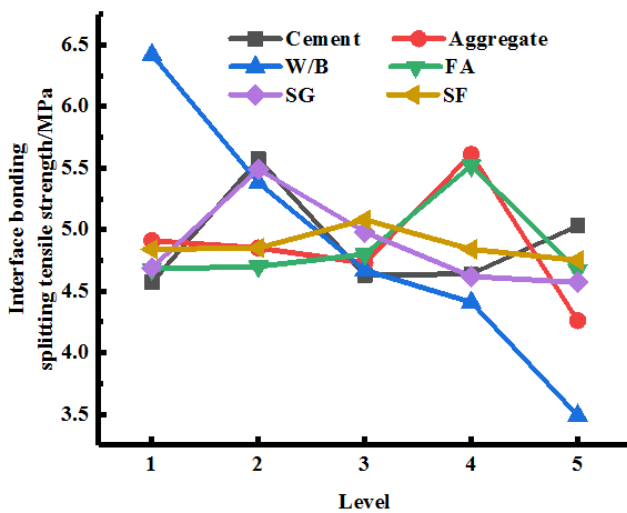| Level	Interface Bonding splitting tensile strength /MPa					
	A (Cement)	B (Aggregate)	C (w/b)	D FA/%	E SG/%	F SF/%
K_1	22.84	24.53	32.11	23.40	23.46	24.19
K_2	27.85	24.27	26.88	23.48	27.44	24.25
K_3	23.17	23.66	23.34	23.99	24.91	25.41
K_4	23.19	28.03	22.03	27.58	23.11	24.21
K_5	25.17	21.31	17.44	23.35	22.87	23.74
k_1	4.57	4.91	6.42	4.68	4.69	4.84
k_2	5.57	4.85	5.38	4.70	5.49	4.85
k_3	4.63	4.73	4.67	4.80	4.98	5.08
k_4	4.64	5.61	4.41	5.52	4.62	4.84
k_5	5.03	4.26	3.49	4.67	4.57	4.75
R	0.99	1.34	2.93	0.85	0.91	0.33

Figure 5. *Relationship between factors and interfacial bonding splitting tensile strength at 28 d.*

Table 10 shows that the interface bonding splitting tensile strength of 17 # is the highest, 8.22 MPa. The cement variety is P·O 525 cement, the aggregate is marble, the water-cement ratio is 0.25, the fly ash content is 20%, the slag content is 35%, and the silica fume content is 5%. Combined with Figure 5, it can be seen that the influence degree of the six factors affecting the 28 d bonding splitting tensile strength of the interface specimen is in the order of water-binder ratio >

aggregate type > cement type > slag content > fly ash content > silica fume content. The optimal combination obtained by orthogonal test method is: water-cement ratio 0.25, aggregate is marble, P·O525 cement, slag content 15%, fly ash content 20% and silica fume content 10%.

4. Relationship Between Interface Strength and Splitting Tensile Strength of Cement Paste

In order to explore the relationship between the interface strength and the splitting tensile strength of cement paste, Figure 6 is drawn with the splitting tensile strength of hardened cement paste as the abscissa and the interfacial bonding splitting tensile strength as the ordinate. It can be seen that all the test points are below the diagonal line, indicating that the interfacial bonding splitting tensile strength is less than the splitting tensile strength of hardened cement paste, which verifies the conclusion that ITZ is the weakest position in concrete structure. It also can be found that the test points of the same aggregate at different ages are linearly distributed, and the interfacial bonding splitting tensile strength increases with the increase of the splitting tensile strength of hardened cement. By Origin 9.0 fitting, it can be seen that the interface bonding splitting tensile strength and hardening cement paste splitting tensile strength linear correlation is very high, linear
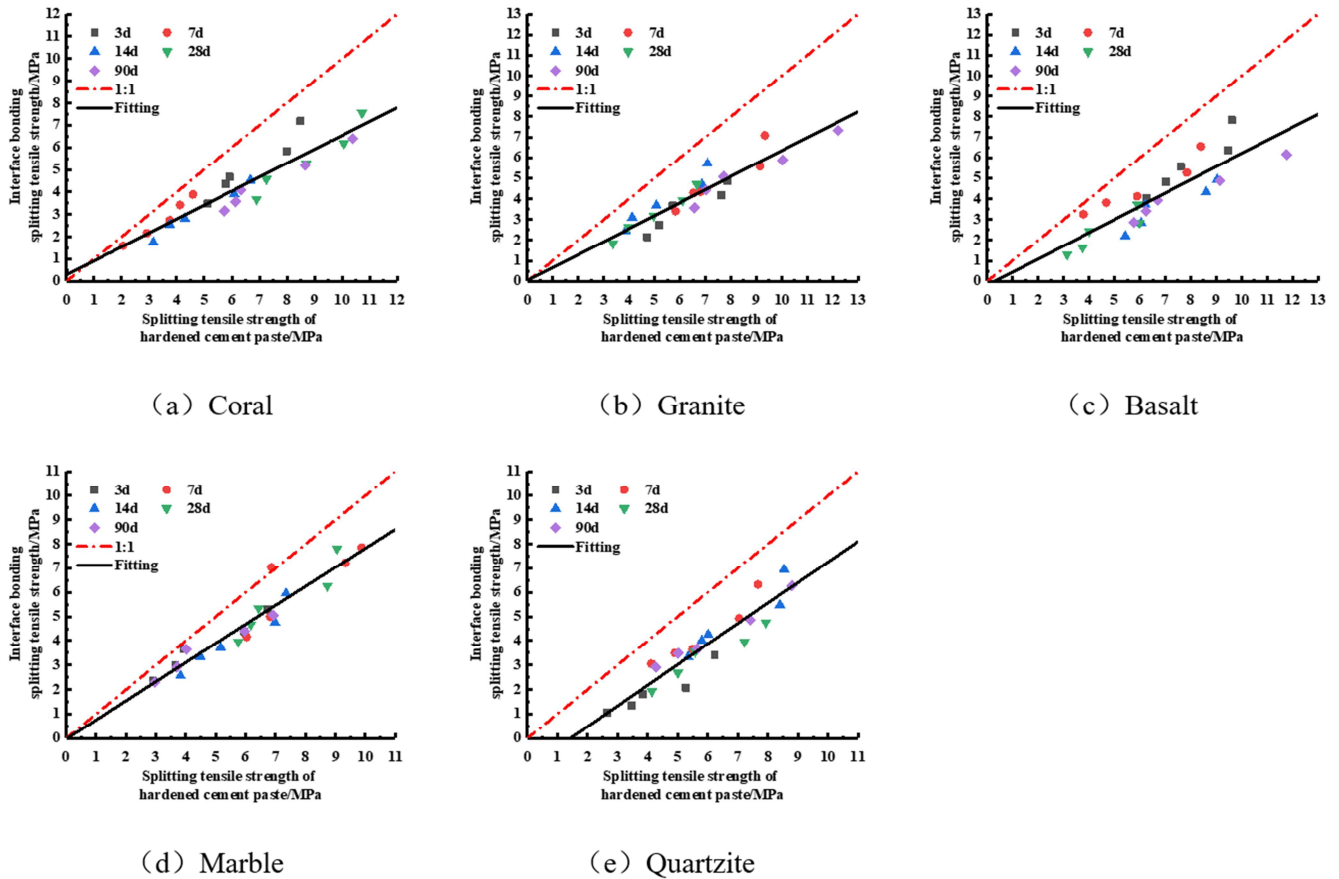
correlation parameters are shown in Table 11.

(a) Coral   (b) Granite   (c) Basalt

(d) Marble   (e) Quartzite

Figure 6. Relationship between interfacial bonding splitting tensile strength and hardened cement paste splitting tensile strength.

Table 11. Linear regression parameters of interfacial bonding strength and paste splitting strength.

Aggregate	k	b	n	R^2	R
Coral	0.624	0.297	25	0.871	0.933
Granite	0.631	0.034	25	0.867	0.931
Basalt	0.640	-0.195	25	0.719	0.848
Marble	0.785	-0.028	25	0.898	0.948
Quartzite	0.847	-1.208	25	0.859	0.927

The interfacial bonding splitting tensile strength and paste splitting tensile strength are calculated by formula (1) as follows:

$$f_{ts,ITZ} = k \cdot f_{ts} + b \tag{1}$$

Where $f_{ts,ITZ}$ is interfacial bonding splitting tensile strength (MPa), f_{ts} is split tensile strength of hardened cement paste (MPa).

Based on the correlation coefficient significance test table in reference, the R of the fitting formula between the splitting tensile strength of coral, granite, basalt, marble and quartz rock interface specimens and the splitting tensile strength of hardened cement paste are 0.933, 0.931, 0.848, 0.948 and 0.927, respectively, which are greater than the critical value of correlation coefficient $R_{0.001}(25) = 0.597$, so the α of the above regression formula is 0.001 (99.9% confidence) [15]. There is a significant linear regression relationship between the interfacial bonding splitting tensile strength and the splitting tensile strength of hardened cement paste.

5. Conclusion

(1) The influence degree of five factors on the splitting tensile strength of hardened cement paste is as follows: water-binder ratio > fly ash content > cement variety > slag content > silica fume content. The optimal combination is as follows: water-binder ratio 0.25, basic magnesium sulfate cement, slag content 15%, fly ash content 20% and silica fume content 10%.

(2) The order of influence of various factors on the interfacial bonding splitting tensile strength is as follows: water-binder ratio > aggregate type > mud type > slag content > fly ash content > silica fume content. The influence of silica fume content on the interfacial bonding splitting tensile strength is not significant. The optimal combination is: water-binder ratio 0.25, aggregate is marble, P·O525 cement, slag content 15%, fly ash content 20% and silica fume content 10%.

(3) The splitting tensile strength of interface bonding is less than that of corresponding hardened cement paste, which proves that the interface is the 'weak item' in concrete. At the same time, the regression model between the splitting tensile strength of interface bonding and the splitting tensile strength of hardened cement paste is established.

6. Prospect

In this paper, orthogonal test was used to explore the influence of various factors on the interfacial bond strength, and the linear regression relationship between the interfacial bond tensile strength and the strength of hardened cement paste was established, but the optimal combination was not verified. Follow-up can be obtained according to the optimal combination of orthogonal test interface ITZ optimal mix; Secondly, the relationship between interfacial bond splitting tensile strength and compressive strength and flexural strength of hardened cement paste is explored, and the database of mechanical parameters of ITZ is established.

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