Research Report on The Impermeability Test of RC-GUARDEX Waterproofing Materials

Department of Hydraulic Engineering
Tsinghua University
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1 The significance and purpose of the test

Waterproof engineering is one of the most important parts of civil engineering and it is a subentry engineering and special measure which is to prevent the external water from permeating inward or prevent the internal water from permeating outward. Traditional waterproof materials such as asphalt felt have the shortcomings of aging, short life, difficult construction, higher cost and so on. Recently, waterproof materials such as kind of ointment, coil, solvent viscous agent, water dosage form and powder dosage form have been developed and widely used, but due to the various reasons, it is still a common phenomenon of leaking or sweating in buildings and structures.

RC-GUARDEX is a liquid capillary crystalline waterproof material that is developed by NIHON KUTAI SYORI Co., Ltd. It can permeate into the concrete surface, react with it and then fill in the capillary voids inside the concrete. This kind of waterproof material has the advantages of good waterproof performance, easy construction, no environmental pollution and long service life, which has become the most favorable rigid waterproof material. Because of the differences of the testing methods and instruments between Japan and China, and in order to get the waterproof effect by using Chinese testing methods, Tsinghua University studies the impermeability effect of RC-GUARDEX commissioned by NIHON KUTAI SYORI Co., Ltd.

1.1 Significance of the test

There are differences between Japanese and Chinese testing methods and instruments which are used to test the impermeability of concrete. It is of great importance to verify if RC-GUARDEX can improve the impermeability of concrete effectively by using Chinese testing methods and instruments under the guidance of the relevant specifications, and it is helpful to improve RC-GUARDEX's performance and market application in China.

The composition of RC-GUARDEX is shown in table 1.

Table 1. the composition of RC-GUARDEX

	SiO_2（wt%）	Na_2O（wt%）	K_2O（wt%）	pH
RC-GUARDEX	4.20	2.08	0.00	11.3

1.2 Purpose of the test

(1) Verify if RC-GUARDEX can improve the impermeability of concrete.
(2) Compare the RC-GUARDEX's improving effect to the concrete with different impermeability levels.
(3) Research the effect differences by different spraying dosages and times of RC-GUARDEX.
(4) Study the effect differences by spraying RC-GUARDEX on the test specimen's upstream face and dorsal surface.

(5) Detect if RC-GUARDEX can improve the compactness and strength of concrete's surface.

2 Test scheme

Referring to the related content in the article 4.21 of specification SL 352-2006 Test Code For Hydraulic Concrete and Japanese related testing methods, we adopt two kinds of test schemes, i.e. graduated compression method and surface drawing method. The main instruments used in these two schemes are shown in Fig.1 and Fig.2.

Fig.1 impermeability instrument

Fig.2 pulling instrument

2.1 Raw materials

RC-GUARDEX waterproof material and its using method and dosage are all provided by NIHON KUTAI SYORI Co., Ltd.

Cement: ordinary Portland cement (42.5)

Fine aggregates: medium sand (FM=2.8)

Coarse aggregates: granite (continuous grading of 5~20mm).

2.2 Mix proportion reference concrete

In order to get two kinds of reference concretes, i.e. high and low impermeability levels respectively, this test mainly adjusts water to cement ratio(w/c). GB18445-2001 Cementitious Capillary Crystalline Waterproofing Materials states that the mix proportion of reference concrete is determined as the 28d's impermeability pressure being 0.3MPa~0.4MPa, and the cement content shall not be less than 250kg/m^3. So the water to cement ratio(w/c) is set as 0.8. To ensure its good workability and formability, another w/c of the concrete whose impermeability level is higher is set as 0.58. The specific mix proportion of the two groups of the reference concretes is shown in Table2.

Table2. the mix proportion of the two kinds of reference concretes

water to cement ratio	cement （kg/m^3）	medium sand （kg/m3）	coarse aggregates （kg/m3）	water （kg/m^3）
0.8	303	827	1030	242
0.58	400	810	960	232

2.3 Test group number

According to the test purpose, 10 groups of circular truncated cone concrete specimens (6 specimens in each group) are to be formed for the impermeability test and 6 groups of cube concrete specimens (3 specimens in each group) are to be formed for surface drawing test. Specific group information is shown in Table.3 and Table.4.

Table3. group number of impermeability test

group	number	instruction	remarks
1	HE	water to cement ratio 0.8, with no RC-GUARDEX	reference specimen
2	HB2	water to cement ratio 0.8, spraying RC-GUARDEX two times on the dorsal surface	spraying dosages are 150ml/m^2 and 100 ml/m^2
3	HB1	water to cement ratio 0.8, spraying RC-GUARDEX one time on the dorsal surface	spraying dosage is 150ml/m^2
4	HF2	water to cement ratio 0.8, spraying RC-GUARDEX two times on the upstream face	spraying dosages are 150ml/m^2 and 100 ml/m^2
5	HF1	water to cement ratio 0.8, spraying RC-GUARDEX one time on the upstream face	spraying dosage is 150ml/m^2
6	LE	water to cement ratio 0.58, with no RC-GUARDEX	reference specimen
7	LB2	water to cement ratio 0.58, spraying RC-GUARDEX two times on the dorsal surface	spraying dosages are 150ml/m^2 and 100 ml/m^2
8	LB1	water to cement ratio 0.58, spraying RC-GUARDEX one time on the dorsal surface	spraying dosage is 150ml/m^2
9	LF2	water to cement ratio 0.58, spraying RC-GUARDEX two times on the upstream face	spraying dosages are 150ml/m^2 and 100 ml/m^2
10	LF1	water to cement ratio 0.58, spraying RC-GUARDEX one time on the upstream face	spraying dosage is 150ml/m^2

Table.4 group number of surface drawing test.

group	number	instruction	remarks
1	H0	water to cement ratio 0.8, with no RC-GUARDEX	reference specimen
2	H1	water to cement ratio 0.8,spraying RC-GUARDEX one time on the surface	spraying dosage is 150ml/m^2
3	H2	water to cement ratio 0.8，spraying RC-GUARDEX two times on the surface	spraying dosages are 150ml/m^2 and 100 ml/m^2
4	L0	water to cement ratio 0.58, With no RC-GUARDEX	reference specimen
5	L1	water to cement ratio 0.58, spraying RC-GUARDEX one time on the surface	spraying dosage is 150ml/m^2
6	L2	water to cement ratio 0.58, spraying RC-GUARDEX two times on the surface	spraying dosages are 150ml/m^2 and 100 ml/m^2

2.4 Steps of the test

Impermeability test: At present the domestic impermeability test mainly evaluates the impermeability performance by exerting high pressure water to the concrete specimen step by step, to let the pressure water penetrate into the concrete's capillary channels. This method has been studied for a long time and accumulated rich test experience and been applied widely in building industry and water conservancy industry.

According to NIHON KUTAI SYORI Co., Ltd, the samples are cured for 14 days at T=20±3℃ and 90±5 RH. Exert water pressure until all the six specimens are completely permeable and keep record of the seepage pressure, take the third specimen's seepage pressure as the maximum impermeability pressure, compare with the reference specimen under the same condition to observe the effect of RC-GUARDEX to the concrete's impermeability. Since the maximum pressure of the impermeability instrument is 4.0MPa, the test should been stopped when the seepage pressure exceeds 4.0MPa and it states that the impermeability pressure of the concrete has exceeded 4.0MPa.The process of the test is shown concisely in Fig.3.

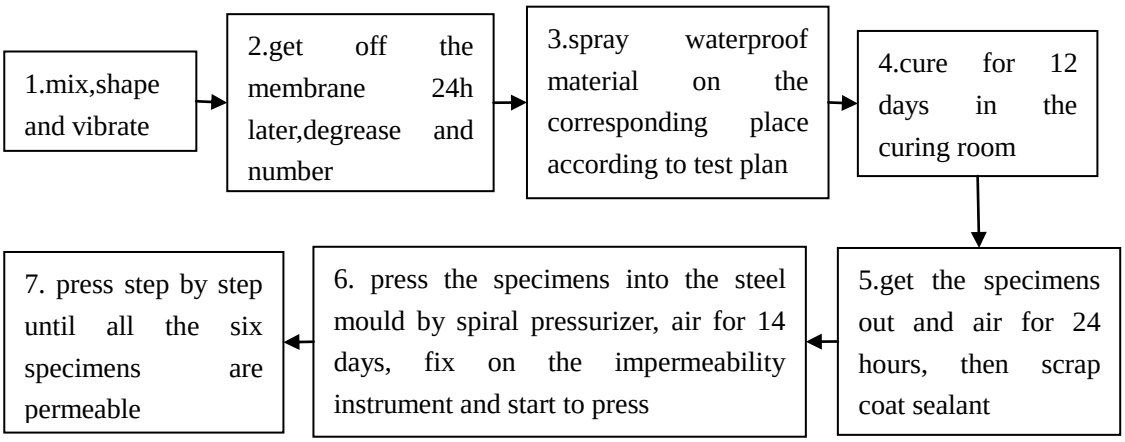


Fig.3 the concise process of the impermeability test

Some instructions for the test process:

1. Spraying is used in order to make sure that the dosage of the solution is all the same. The sprayer is shown in Fig.4.
2. Mixture of cement and butter is used in the previous tests to seal the side, but the effect is not very ideal. It leaks more from the side of specimens, especially when the pressure exceeds 1.0MPa. At last we get a good effect by using ketone sealant. Sealant and the specimens after sealed are shown in Fig.5.
3. Press the specimen into the steel mould by spiral pressurizer after sealing the side, shown in Fig6.
4. Pay attention to the sealing effect of its side around the bottom, preventing water from pouring into the specimen through the area between the specimen and the steel mould, especially the upstream face test, shown in Fig.7.

Fig.4 sprayer Fig.5 sealant on the side Fig6. Spiral pressurizer Fig7.bottom sealant

Surface drawing test: Referring to Japanese testing method and the pulling instrument to detect the bond strength of thermal insulation materials in China, we can judge if this kind of waterproof material can improve surface compactness and strength of the concrete by detecting the drawing force between the standard iron and the concrete. According to NIHON KUTAI SYORI Co., Ltd, specimens of each group

should be cured for 14 days in the curing room and aired for 7 days in the room condition(T=20±3℃ and 60±5 RH). The process of the test is shown concisely in Fig.8.

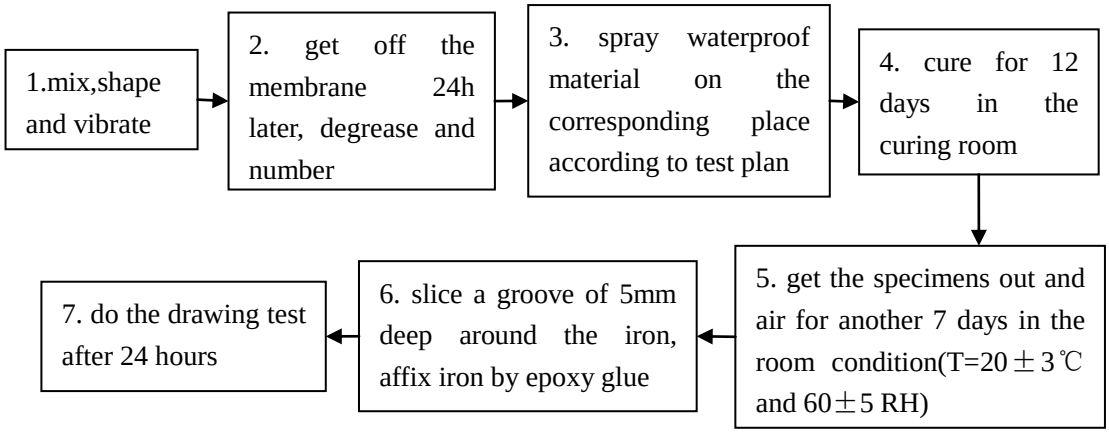


Fig.8 the concise process of the surface drawing test

Some instructions for the test process:

1. The size of the standard iron is 40mmx40mm. Slice a square groove around its border by dicing saw before affixing, shown in Fig.9.
2. Brush the dust on the surface after slicing, polishing the surface by sand paper, coating the epoxy glue uniformly and installing the standard iron, shown in Fig.10.
3. Install the pulling instrument when the glue has reached its strength, starting to test and the speed of shaking handles should be well-distributed when the pressure is rising. Fig11 shows the mounted drawing instrument.

Fig9. Square groove Fig.10 standard iron after affixing Fig11. Fixed drawing instrument

2.5 Using method of RC-GUARDEX

Dilute with the volume ratio 1 to 5 according to NIHON KUTAI SYORI Co., Ltd. The construction method with spraying two times and one time are shown in Fig.12 and Fig.13.

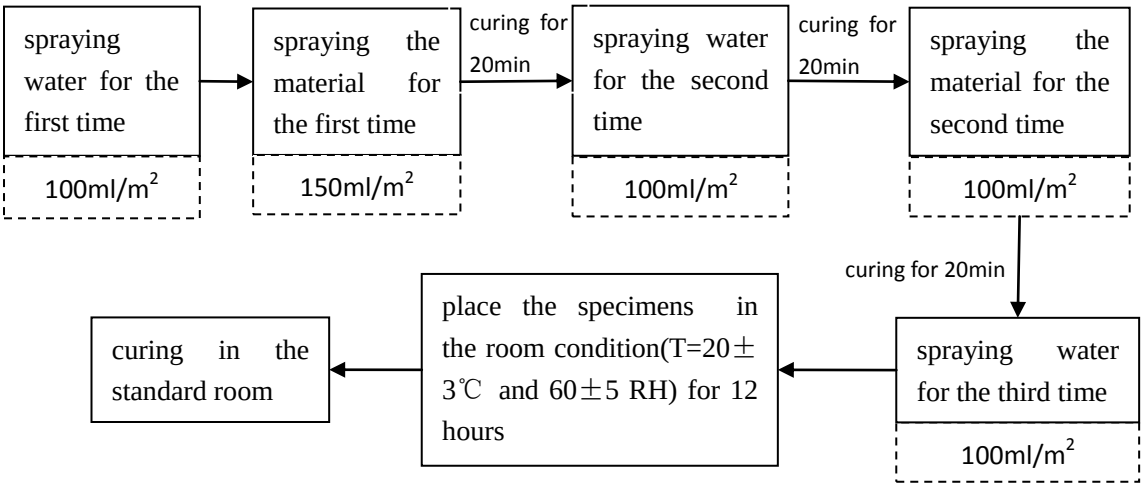


Fig.12 the construction method with spraying two times

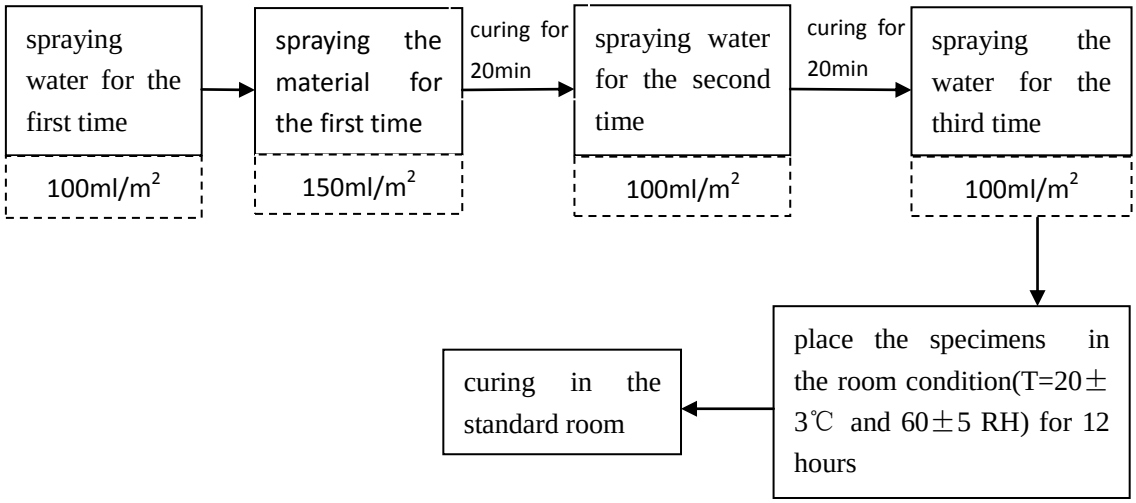


Fig.13 the construction method with spraying one time

3 Test results

3.1 Impermeability test

The results of the impermeability test for the 10 groups of specimens are shown in Table5.

Table5. the summary of the seepage pressure of the 10 groups（MPa）

number	1#	2#	3#	4#	5#	6#	The maximum impermeability pressure (MPa)	ramarks
HE	0.4	0.2	0.4	0.3	/	0.4	0.4	specimen 5# is not well sealed
HB2	0.6	1.0	0.7	>1.4	1.0	1.4	1.0	
HB1	0.4	0.4	0.3	0.2	0.2	/	0.3	Specimen 6# is crushed when it is pressed into the steel mould.
HF2	0.5	0.6	0.6	0.6	0.4	0.7	0.6	
HF1	0.7	0.3	0.2	0.3	0.2	0.3	0.3	
LE	0.7	/	0.6	0.6	1.5	1.5	0.7	The volume of the specimen 2# is a little small and pushed out from the steel mould.
LB2	>4.0	>4.0	>4.0	>4.0	2.7	>4.0	>4.0	
LB1	1.5	1.7	1.5	2.2	1.7	2.2	1.7	
LF2	>4.0	3.8	>4.0	>4.0	>4.0	>4.0	>4.0	
LF1	1.6	2.7	3.3	2.8	>4.0	3.3	2.8	

3.2 Surface drawing test

The test figures of the 6 groups are shown in Fig.14 and Fig.16 and the figures of the standard irons pulled out are shown in Fig.15 and Fig.17. The results of the test are shown in Table.6.

Table6. results summary of the surface drawing test

number	water to cement ratio	Specimen 1	Specimen 2	specimen 3	average	remarks
1	0.58	3.201	3.285	3.808	3.431	No spraying
2		3.981	3.244	3.602	3.609	Spraying one time
3		5.003	3.488	3.539	4.01	Spraying two times
4	0.8	1.774	1.239	1.643	1.552	No spraying
5		2.449	2.143	2.928	2.507	Spraying one time
6		2.470	3.014	2.684	2.723	Spraying two times

Fig.14 the result of the specimens of water to cement ratio 0.8

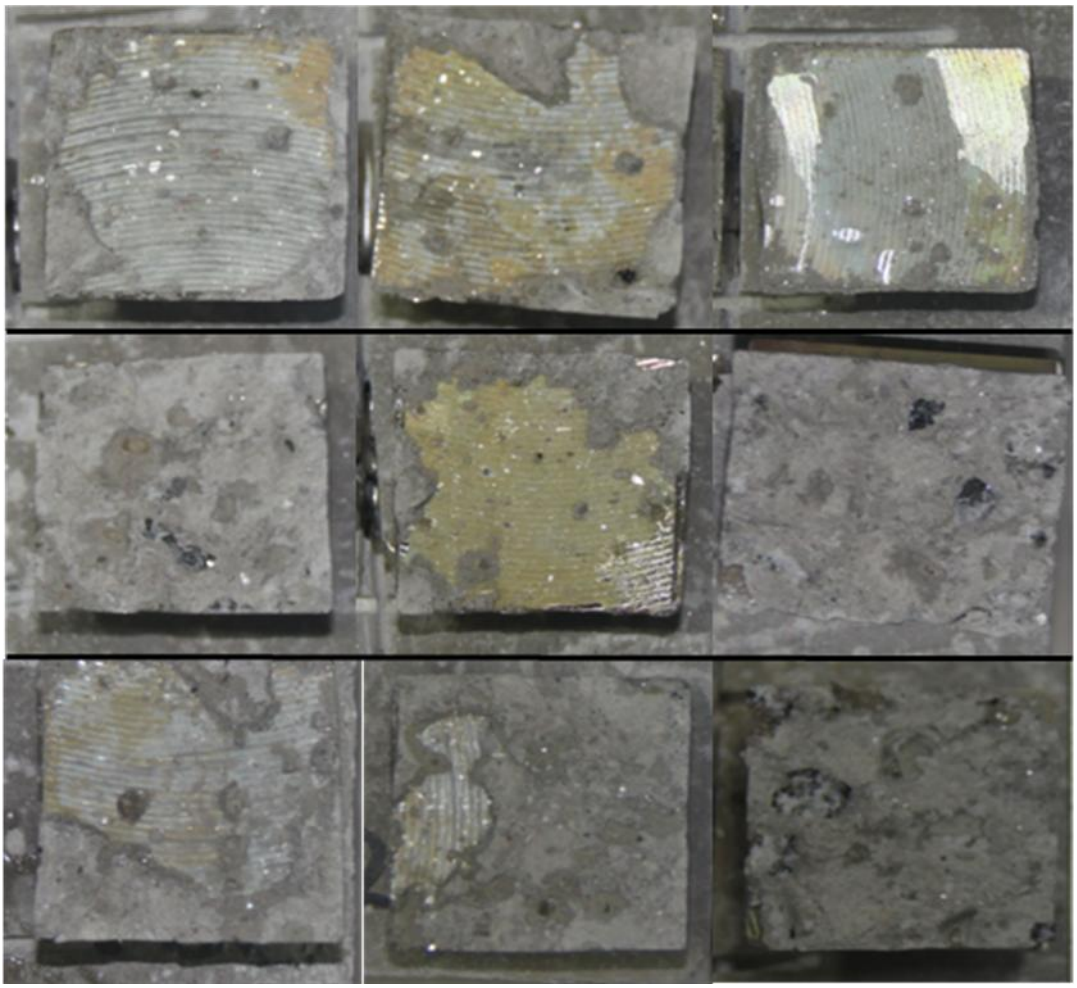


Fig.15 the standard irons of the specimens with water to cement ratio 0.8

Fig.16 the result of the specimens of water to cement ratio 0.58

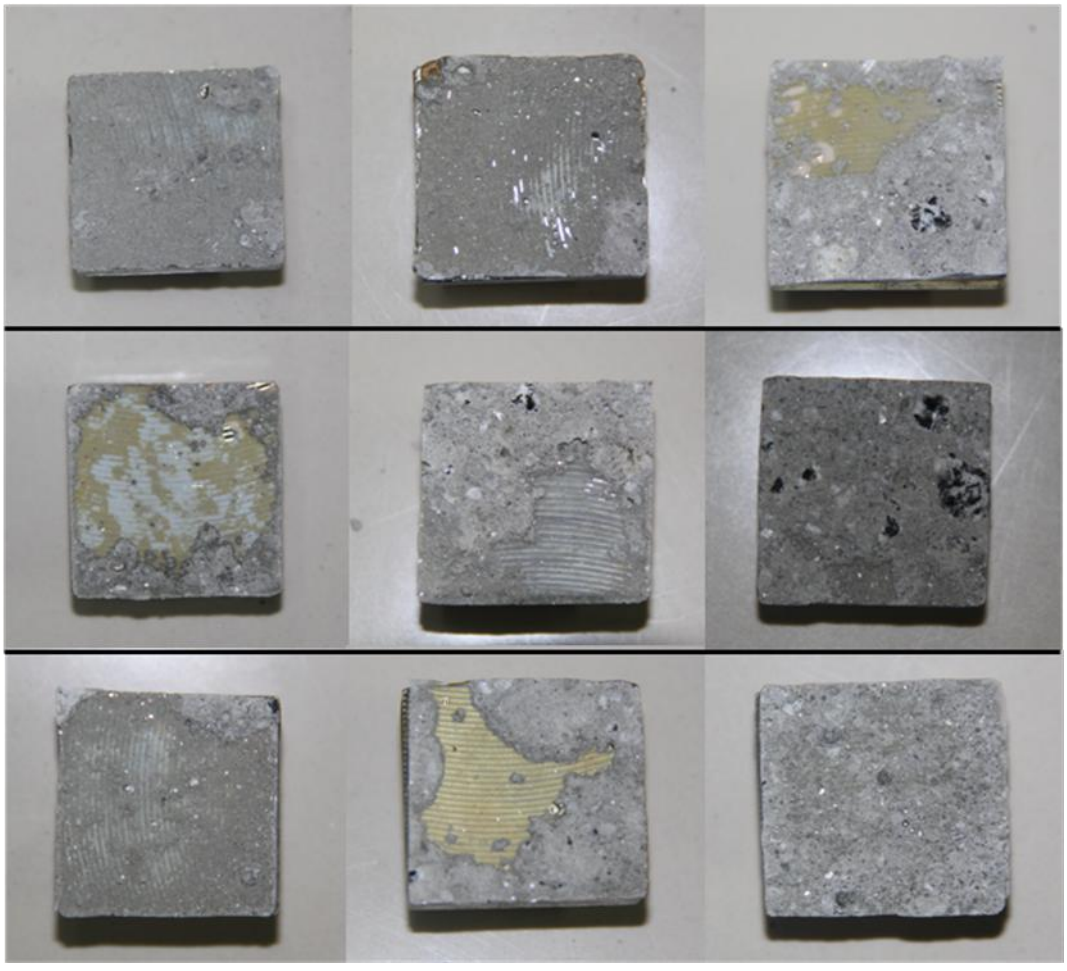


Fig.17 the standard irons of the specimens with water to cement ratio 0.58

4 Results analysis

4.1 Impermeability test

The results of the impermeability test are summarized according to the maximum seepage pressure and shown in Table 7.

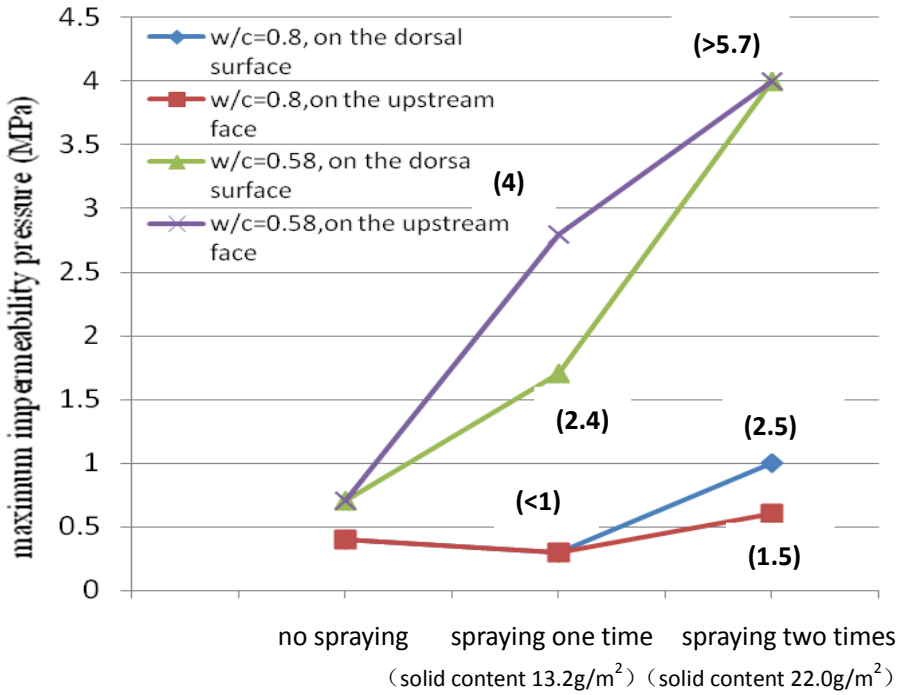
Table7. the summary results of the maximum seepage pressure

group	number	instructions	maximum seepage pressure of 14d	seepage pressure ratio
1	HE	water to cement ratio 0.8, with no RC-GUARDEX	0.4MPa	/
2	HB2	water to cement ratio 0.8, spraying RC-GUARDEX two times on the dorsal surface	1.0 MPa	2.5
3	HB1	water to cement ratio 0.8, spraying RC-GUARDEX one time on the dorsal surface	0.3 MPa	<1
4	HF2	water to cement ratio 0.8, spraying RC-GUARDEX two times on the upstream face	0.6 MPa	1.5
5	HF1	water to cement ratio 0.8, spraying RC-GUARDEX one time on the upstream face	0.3 MPa	<1
6	LE	water to cement ratio 0.58, with no RC-GUARDEX	0.7 MPa	/
7	LB2	water to cement ratio 0.58, spraying RC-GUARDEX two times on the dorsal surface	>4.0 MPa	>5.7
8	LB1	water to cement ratio 0.58, spraying RC-GUARDEX one time on the dorsal surface	1.7 MPa	2.4
9	LF2	water to cement ratio 0.58, spraying RC-GUARDEX two times on the upstream face	>4.0 MPa	>5.7
10	LF1	water to cement ratio 0.58, spraying RC-GUARDEX one time on the upstream face	2.8 MPa	4

(Notes: Seepage pressure ratio refers to the ratio of maximum impermeability pressure of sprayed concrete to the reference concrete.)

Draw the line chart of the maximum seepage pressure according to the volume

dosage of the material(translate into solid content), shown in Fig.18.



(The figures in brackets mean seepage pressure ratio)

Fig.18 maximum impermeability pressure

Results:

1. The maximum impermeability pressure of the reference specimen (w/c=0.8) is 0.4MPa and the average compression strength of 14 days is 19.65MPa. It is unreasonable that the maximum impermeability pressure of the specimen with spraying waterproof material one time turns to be 0.3MPa. Since we take the third specimen's seepage pressure as the maximum impermeability pressure, and there are different kinds of errors in the process of forming and curing, we regard the difference of 0.1MPa as regular and ignore it and consider that there's no effect on the specimens when spraying one time. In addition, the impermeability of the specimen sprayed waterproof materials two times shows various degree of improvement. The maximum seepage pressure of the specimens sprayed on the dorsal surface increases to 2.5 times and that on the upstream face increases to 1.5 times.

We can see from it that the effect is not obvious if it is not sprayed more than two times. The reason is that there are more micro voids because of the high water to cement ratio. Spraying one time is not able to fill in the voids fully and the maximum impermeability pressure will be further improved if it is sprayed more than three times.

2. The maximum impermeability pressure of the reference specimen (w/c=0.58) is 0.7MPa, and the average compression strength of 14 days is 29.5MPa. The maximum impermeability pressure of the specimens sprayed waterproof material one time has been improved largely and that sprayed on the dorsal surface increases to 2.4 times and that on the upstream face increases to more than 4 times. The effects of the

specimens sprayed two times are very obvious no matter sprayed on the dorsal surface or on the upstream face. The maximum impermeability pressures have all exceeded 4.0MPa and the seepage pressure ratio have all exceed 5.7. On the whole, the effect of this kind of waterproof material is remarkably obvious for the specimens (w/c=0.58).

3. The concrete (the compression strength is C30) is widely used in practical engineering, so the specimens of water to cement ratio 0.58 can basically represent the concrete most used in the practical engineering, and the waterproof performance will be improved significantly if sprayed RC-GUARDEX. It means that the waterproof material has been the main factor of all that influence the concrete's impermeability. On the contrary, the waterproof performance of the specimens of water to cement ratio 0.8 can't be improved obviously even if sprayed RC-GUARDEX one time. It means that waterproof material has not been the main factor of all that influence the concrete's impermeability so that we should use the test results of the specimens of water to cement ratio 0.58 to analysis. It is seen that the waterproof performance of the specimens sprayed on the upstream face is better than that on the dorsal surface on the condition of the same spraying dosage.

4.2 Surface drawing test

Draw the line chart of the average drawing force according to the volume dosage of the material, shown in Fig.19.

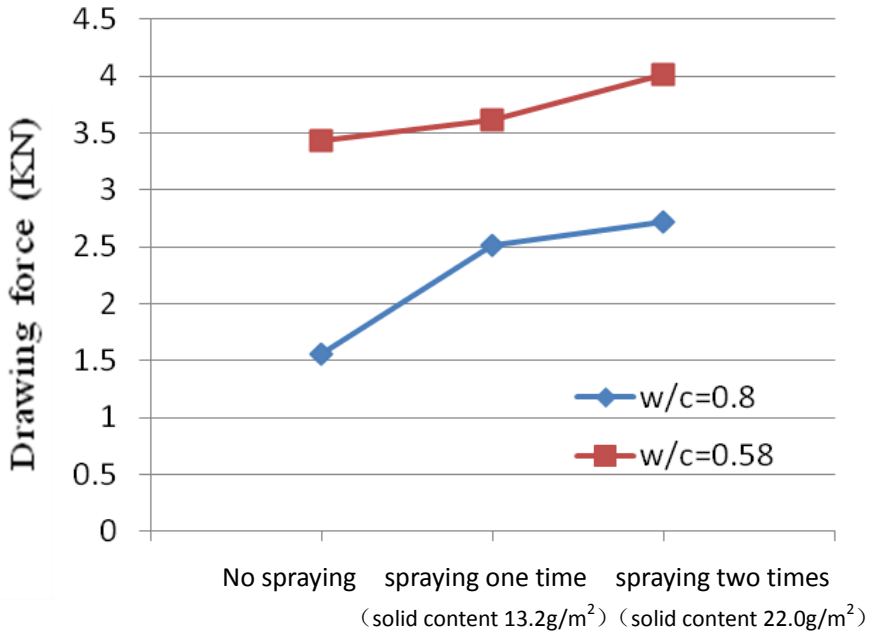


Fig.19 average drawing force of 14 days

From Fig.19 we can see that the surface drawing force (water to cement ratio 0.58) is evidently larger than that (water to cement ratio 0.8). It means that the surface density and strength of the former are larger than the latter and this phenomenon accords with the regular of engineering. In addition, the surface drawing force becomes larger while the dosage of the waterproof materials increase which means

that the surface density and strength of the concrete increase. So we can judge that RC-GUARDEX is useful for the concrete's impermeability by enhancing the surface density and strength of the concrete.

5 Summary

As to impermeability test, we choose two water to cement ratios (0.8 and 0.58) in our tests due to the time and workload. So this dosage can not guarantee that the effects are all obvious for all concrete used in practice. The concrete of C30 is widely used in practical engineering, so the specimens (water to cement ratio 0.58) can basically represent the concrete most used in the practice, in other words, the waterproof performance of concrete can be improved to at least 5.7 times, far more than the standard value($\geqslant$2).

As for the reference concrete of low impermeability level, the impermeability performance improves little with spraying just two times and for the reference concrete of medium impermeability level, it is quite obvious. The effect for reference concrete of high impermeability level remains to be further verified.

In general, the more dosages and the more spraying times, the better effect.

Spraying the RC-GUARDEX on the upstream face is better than that on the dorsal surface for the concrete with general strength.

As for the surface drawing test, from Fig.15 and Fig.17, we can see that discreteness of test data is large because of the uneven bonding between the standard iron and the surface of concrete or non-uniform stress or other reasons. Several individual test data may not reflect the real drawing force correctly but will not influence the trend that the drawing force becomes larger with the increase of the spraying amount, i.e. RC-GUARDEX can contribute to enhance the surface density and strength of the concrete.

If we connect the two tests, we can draw the conclusion that RC-GUARDEX can improve the impermeability of concrete by contributing to enhance the surface density and strength.

Reference

SL 352-2006 Test Code For Hydraulic Concrete

GB 18445-2001 Cementitious Capillary Crystalline Waterproofing Materials

CECS 195：2006 Technical Specification For Polymer Modified Cementitious Waterproofing Materials And Penetrating And Crystalling Waterproofing Materials

JGJ 110-2008 Testing Standard For Adhesive Strength Of Tapestry Brick Of Construction Engineering