Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(4):532-535

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Research on the protection of organo-silicone coating for hydraulic concrete in cold region

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ABSTRACT

In cold regions the hydraulic concrete is undergoing the damage from the freezing-thawing cycles so in this paper the protection of organo-silicone coating for hydraulic concrete structures is researched. The rusults show that the organo-silicone can penetrate to 4-11mm inside concrete for the different concrete. The hydrophobic layer is formed between polar group of organo-silicone and the hydroxyl group inside the concrete. The wetting angle is larger than 90° between the harmful medium and concrete, which effectively prevents the invasion of harmful substances. By single salt freezing method the organo-silicone coating can decrease the scaled mass and the dynamic modulus of elasticity loss rate. It increases the freezing- thawing cycles resistance of the concrete in cold regions.

Key words: Organo-silicone coating; Hydraulic concrete; Frost scaling resistance; Wetting angle

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In the cold region the damage of concrete structure is serious. Single-face scaling is main damage style of hydraulic concrete enginerring. It can affect the use of enginerring and enhance further deterioration of enginerring so the freezing-thawing scaling must be resolved. Scaling-resistance of concrete can be improved by adjusting the internal factors such as increasing the water-binder rratio, adding mineral and chemical admixture[1~3]. More importantly, the external technical measures will also be taken to protect concrete. Organo-silicone coating is used broadly for the bridge structure, tunnel engineering and marine engineering[4]. In this paper, the protection of organo-silicone for hydraulic concrete was researched in cold region.

EXPERIMENTAL SECTION

1.1 Raw materials

Grade 42.5 Portland cement(C) from Jidong Co., Ltd according to Chinese Standards was used. The mineral admixtures were fly ash(FA) and silica fume(SF). The chemical composition were shown in Table 1. The maximum size of crushed diabases used as coarse aggregate(G) was 25 mm. River sand(S) with a fineness modulus of 2.80 was used as fine aggregate. A naphthalene-based superplasticizer Mighty-100 (M) from Shanghai Huawang Chemical Corporations was used. Air entraining agent(M-A) was MICRO-AIR202 from shanghai. The main component of organo-silicone was methyl siloxane.Tap water was used for mixing the concrete.

Table. 1 Chemcial proportion （%）

Sample	SiO_2	Al_2O	Fe_2O	CaO	MgO	SO_3	R_2O
Fly ash	21.08	5.47	3.96	62.28	1.73	2.63	0.50
Silica fume	93.7	0.3	0.8	0.2	0.2	0.5	0.30

1.2 Test program

The test method in this experiment was acorrding to GBT50082-2009. 10 specimens with size of 150×150×55mm and 4 specimens with size of 100×100×100mm were tested for each mix. After demoulded, specimens were cured in the standard curing room (20 °C, 98% RH) until 28 days. Then the specimens were removed and desiccated for 24 hours in drying cabinet at 80 °C then cooled to room temperature. The specimens of 150×150×55mm were sealed on their lateral surfaces by aluminous foil with butyl rubber. 5 specimens were brushed with organo-silicone of 0.4Kg/m^2 on the surface of 150×150mm. After 1 day all specimens were placed in the test containers and there was 5 mm high space between test surface and container bottom. Subsequently, test liquid (97% by weight of distilled water and 3% by weight of NaCl) was filled into the container to a height of 10 mm without wetting the specimen's top. The test container must be closed with a cover. After 6 days the specimens were removed from containers. The transit time of ultrasonic wave throught the specimens must be determined before starting the freeze-thaw cycles. In addition, the above measurements should be carried out after 28 freeze-thaw cycles along two perpendicular transit axes. The scaling of concrete was also collected and filtered. Then scaling was dried to constant weight and quantified. The change in the relative dynamic modulus of elasticity and surface scaling mass were used as a determined index of the freeze-salt damage. Both are calculated as described in (1) and (2). The process of the freeze-thaw cycles was showed in Fig.1. For the specimens of 100×100×100mm, 2 speciments of every mix serise were brushed with organo-silicone. After 1 day the weight of all concrete were quantified then soaked in the solution of 3%NaCl for 2 d. Then the surface of specimens were dried and the the invasion depth of silicone were mesured according to reference 5.

$$m_n = \frac{\sum \mu_s}{A} \qquad (1)$$

$$\Delta E_{dynn} = \left[1 - \left(\frac{t_{tcs} - t_c}{t_{tnftc} - t_c}\right)^2\right] \bullet 100\% \qquad (2)$$

where m_n is the cumulative amount of scaled material per unit area after the n cycles (Kg/m^2) , μ_s is the mass of scaled material after n cycles(Kg), A is the area of the test surface(m^2), $\Delta E_{dyn\ n}$ is change in relative dynamic modulus of elasticity(%), n is the number of freeze-thaw cycles, t_{tcs} is the total transit time before starting the freeze-thaw cycles(μs) , $t_{t\ nftc}$ is the total transit time after n freeze-thaw cycles(μs), t_c is the transit time in coupling medium(μ_s).

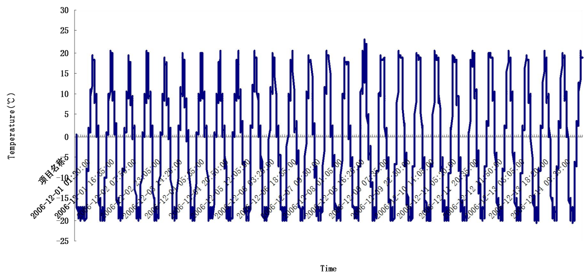


Fig.1 The system of freezing and thawwing cycles

1.3 **Mix proportion of concrete**

According to DL/T5330-2005，the mix proportion of concrete was designed showed in table.2. P1, P2 and P3 are common concrete and X1 is high performance concrete.

Table.2 Mix Proportion of Concrete

Sample	*C*	*S*	*G*	*FA*	*SF*	*W/B*	*M/B*	*M-A/B*
P1	414	642	1195	—	—	0.4	0.65	—
P2	414	642	1195	—	—	0.36	0.72	—
P3	414	642	1195	—	—	0.32	0.75	—
X1	311	642	1195	69	34	0.4	0.70	0.012

Note:B—Binder.

RESULTS AND DISCUSSION

2.1 Protecting performance

It can be seen from Table.3 that the scaled mass of common concrete is from 2.8Kg/m^2 to 3.0 Kg/m^2 and the loss rate of dynamic elasticity modulus ranges from 8.4% to 14.8% after 28 freeze-thaw cycles. The scaled mass of high performance concrete is 2.3 kg/m^2 and the loss rate of dynamic elasticity modulus is 6.9%. After brushed with organo-silicone, the scaled mass of common concrete is from 0.012 kg/m^2 to 0.03kg/m^2 and the loss rate of dynamic elasticity modulus ranges from 3.2% to 3.9% The scaled mass of high performance concrete is 0.028kg/m and the loss rate of dynamic elasticity modulus is 7.0%. So organo-silicone coating can improve the freeze-salt scaling resistance of hydraulic concrete obviously.

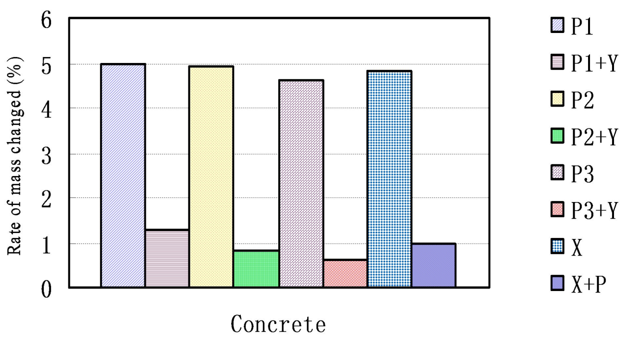
Table.3 Damage of concrete

Sample	Scaling	Loss rate of relative dynamic modulus of elasticity（%）
P1	3.6	14.8
P1+Y	0.03	3.9
P2	3.0	11.2
P2+Y	0.019	3.5
P3	2.8	8.4
P3+Y	0.012	3.2
X1	2.3	6.9
X1+Y	0.028	7.0

Note:+Y— brushing with silicone

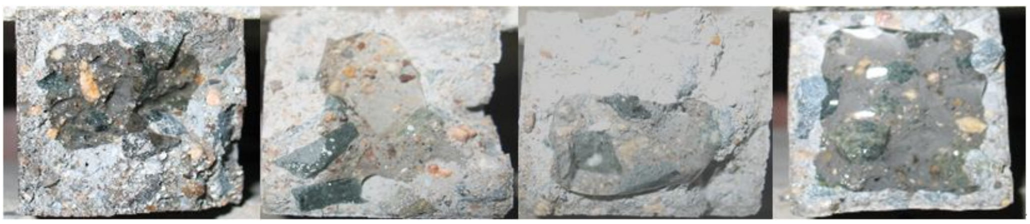
2.2 Mechanism analysis

Fig.2 shows that mass change is decreased obviously as result of organo-silicone brushed on the surface of concrete. It can be seen from Fig.3 that the invasion dept of silicone ranges from 4mm to 11mm。



Note:+Y— brushing with silicone

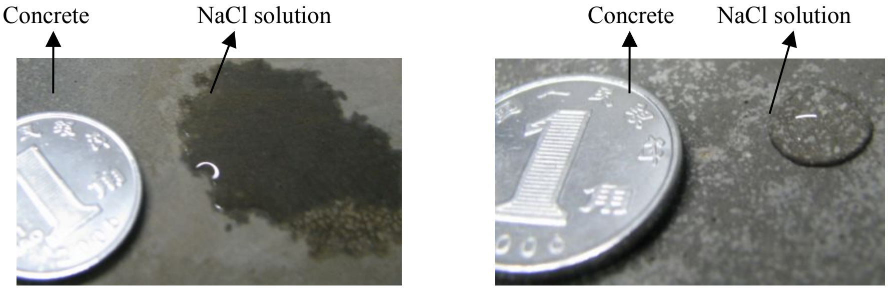
Fig. 2 Mass change of concrete soaked in the solution of NaCl



a) P1+Y **b) P2+Y** **c) P3+Y** **d) X1+Y**

Fig. 3 Invasion depth of silicone

It can be seen from fig.4a) that the wetting angle between concrete and NaCl solution is less than 90° because the —OH inside concrete can obsorb water. The main chemical component of organo-silicone is carboxy methyl siloxane. It can react with OH- inside concrete and form hydrophobic layer. So the wetting angle is larger than 90° showed as fig.4 b). All these increases the scaling-resistance of concrete.



a) X1 **b)X1+Y**

Fig.4 Wetting of NaCl solution on surfcace on the concrete

CONCLUSION

(1)Organo-silicone coating decreases the scaling mass and the loss rate of dynamic elasticity modulus. It can improve the scaling-resisitance of hydraulic concrete.
(2)The invasion dept of silicone ranges from 4mm to 11mm. Polar group of silicone can react with OH- inside concrete and form hydrophobic layer. The wetting angle between concrete and NaCl solution is larger than 90°. These can protect concrete from diffusing of Cl^- and improved the scaling resistance of concrete.

Acknowledgements
This work was financially supported by the Project (No. 201201040-03).

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