Journal of Highway and Transportation Research and Development
2024,18(1):63-72
ISSN 2095-6215
DOI: 10.26599/HTRD.2024.9480008

Study on Deicing Salt Corrosion Mechanism and Protective Materials of Highway Roadside Concrete Structures

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Abstract: This study focuses on understanding the deicing salt corrosion mechanism affecting highway roadside concrete structures and identifying appropriate protective measures. Initially, the mechanism of salt corrosion on roadside concrete is elucidated through thorough research and investigation. Subsequently, the effectiveness of protective materials such as acrylic, polyurethane, and epoxy coatings in mitigating salt corrosion in concrete is assessed by simulating salt corrosion conditions on the concrete surface. Optimizing the material formula based on the tests more effectively mitigates the corrosion effect. Results indicate that salt corrosion primarily results from the permeation of salts into concrete, triggering physiochemical corrosion. It is observed that all three types of protective materials significantly decelerate concrete corrosion caused by salt, demonstrating effective anti-corrosion properties. Among these, the optimized formulation of polyurethane coating 'C' demonstrates superior permeability and resistance to chemical corrosion. It effectively prevents the ingress of salt into the concrete, thereby reducing the occurrence of salt corrosion in concrete. The low cost of these measures indicates their suitability for widespread implementation.

Key words: road engineering; cement concrete; surface protective materials; salt corrosion; mechanization

0 Introduction

Freezing and thawing will occur in most parts of China in winter, especially in the north. After snow, in order to improve the road traffic capacity and operation efficiency, snow melting agents cause severe corrosion damage to concrete structures, and over time, corrosion problems accumulate and erupt after snow melting. In addition, due to the unstable quality control during the construction period, the concrete structure is often damaged and exposed with many honeycomb and pitted surfaces. As shown in Figure 1, some bridge members have different degrees of cracks and salt precipitation diseases, which has brought great hidden dangers to the durability and safety of the structure[1]. LI Lei[2] made an in-depth study on the corrosion resistance mechanism of concrete from the perspective of microstructure, and found that the corrosion severity and mechanism of concrete are different due to different corrosion solutions. In order to reduce the impact of salt erosion on concrete, people have developed various surface protection materials. Researchers studied the resistance of concrete to ice salt corrosion by applying silicone, epoxy resin and polymer cement-based waterproof Coatings on the surface of concrete[3-5]. The results showed that the three materials can significantly improve the resistance of concrete to ice salt corrosion. However, the weather resistance of other Coating materials in protecting concrete from salt corrosion remains to be studied. In this study, the performance of acrylic Coating, polyurethane Coating and epoxy Coating in preventing salt penetration into concrete and reducing corrosion rate were compared. The results of this study will help to better understand the mechanism of salt corrosion on concrete surface, and provide guidance for the selection and application of appropriate surface protection materials to prevent salt corrosion of coastal and marine structures.

1 Study on salt corrosion resistance mechanism

1.1 Overview of salt corrosion

Salt corrosion refers to the phenomenon of damage to concrete structural materials caused by chemical or physical reactions, and it is one of the most common diseases in concrete structures[6-8]. In cold climate areas, salt

Received 10 August 2023; Revised 3 November 2023; Accepted 15 November 2023
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Fig. 1 Curb corrosion

corrosion is often caused by the salt melting agent scattered on the road and groundwater with high salt content. When salt substances penetrate into the concrete surface, they will react with the water and calcium elements inside the concrete to produce a chemical reaction and form water-soluble hydrochloric acid, which will lead to the change of the chemical properties of the concrete and the loss of the original durability.

1.2 Salt corrosion mechanism of pavement

The mechanism of pavement salt corrosion mainly involves the chemical reaction between the salt melter on the pavement and the concrete surface. In winter, thawing agent containing salt substances will be spread on the road. As the melted snow flows into the tiny cracks and holes on the pavement surface, the salt substances in the thawing agent will enter the concrete, react with water and calcium elements, and finally form water-soluble hydrochloric acid[9-11]. Sometimes, high concentrations of chloride can directly decompose $Ca(OH)_2$ into soluble calcium chloride. It can also form hydrated calcium oxychloride and hydrated calcium chloroaluminate, resulting in cracking and damage of cement concrete. The chemical change formula is shown in formula (1), (2) and (3).

$$Ca(OH)_2 + Cl^- = CaCl_2 \quad (1)$$

$$Ca(OH)_2 + Cl^- + H_2O = CaO \cdot CaCl_2 \cdot nH_2O \quad (2)$$

$$3CaO \cdot Al_2O_3 \cdot 6H_2O + Cl^- + H_2O = 3CaO \cdot Al_2O_3 \cdot 3CaCl_2 \cdot 31H_2O \quad (3)$$

The process of salt substances penetrating into concrete is also one of the important factors leading to salt corrosion of pavement. Driven by water, salts can easily penetrate into tiny cracks and holes in concrete, and then destroy the structure of concrete through ion exchange reaction and dissolution reaction, making it more fragile and prone to erosion.

1.3 Freeze thaw corrosion mechanism

When water freezes, its volume will increase by about 9%, and the water permeating into the concrete pores will freeze, which will cause the pore wall to bear a great expansion stress. If it exceeds the tensile strength of the cement colloid, it will cause irreversible structural changes such as microcracks, so that it cannot be completely restored after the ice melts, and some of the expansion still remains, so that the porosity is larger and more water will permeating into it[12-14]. When it freezes and thaws again, the original cracks will expand due to icing. After repeated freeze-thaw damage, cracks become larger and larger, leading to spallation. Relevant studies have shown that water and free water in concrete will freeze at low temperatures under general natural conditions. Because the water in the pores is affected by surface forces, the finer the pores, the lower the freezing point. For example, water with a pore size of 100 Angstroms will freeze at -5 ℃, while water with a pore size of 35 angstroms will freeze at -20 ℃. Therefore, when the temperature drops below the freezing point, the free water from the surface to the inside and water with coarse pores will freeze first, and then, there are two main theories that the water in the finer and even finer pores freezes only with the decrease of temperature[15].

(1) Hydrostatic pressure theory: during the freezing process, part of the pore solution in the concrete pores will freeze and expand, forcing the unfrozen pore solution to migrate outward from the frozen area. When the permeability of concrete is large, the water pressure gradient will be formed, which will produce pressure on the hole wall. With the acceleration of cooling rate, the increase of water saturation, the increase of pore spacing, and the decrease of permeability and pore size, the water pressure will increase; When the water pressure exceeds the

ultimate tensile strength of concrete, the hole wall will crack and the concrete will be damaged. And this repeated freeze-thaw alternation has a cumulative effect, which makes the cracks of concrete expand, and the surface peels off until it is completely disintegrated.

Osmotic pressure theory: when the concrete is frozen, the freezing point of water in the pores is related to the pore size. The smaller the pore size, the lower the freezing point. When the large pores are frozen, the ion concentration in the pore water will increase, and the vapor pressure will decrease. At this time, the unfrozen water in the small pores may penetrate into the large pores to form pressure. When this osmotic pressure is greater than the tensile strength of the concrete, the concrete will be damaged.

2 Research on protective materials for structures

In order to improve the anti-deicing salt corrosion effect of highway concrete structure, brushing protective materials on its surface is one of the effective measures. The protective Coating can form a protective film to prevent oxygen, moisture and salt from entering the concrete, so as to improve the salt corrosion resistance of concrete and slow down the aging and damage of concrete. However, after deicing salt erosion, freeze-thaw cycle, and ultraviolet aging in summer, some existing Coating technologies quickly cracked, peeled and peeled, and the protective effect was very limited. This paper studies the effect of a variety of surface Coating materials in protecting concrete from salt corrosion, and optimizes the material formula to achieve better protection effect.

2.1 Raw materials

2.1.1 Cement concrete

In order to make the test results consistent with the actual project, the fly ash, mineral powder, cement, sand, stone (4.75-9.5 mm, 9.5-19 mm, 19-31.5 mm) and other materials required for concrete are all consigned from a project, and the mix proportion used is determined by the laboratory, as shown in Table 1 below.

Table 1 Concrete mix proportion

Composition	Water reducing agent	Water	Fly ash	Mineral powder	Cement	Sand	4.75-9.5 mm	9.5-19 mm	19-31.5 mm
Added mass (kg)	2.52	176	30	90	300	779	107.5	537.5	430

2.1.2 Mechanism analysis of different types of Coatings

(1) Influence mechanism and effect of acrylic resin on concrete surface

Acrylic resin is synthesized with acrylate or methacrylate as the main monomer, which has strong optical, thermal and chemical stability. Therefore, the Coating prepared from acrylic resin has excellent cost performance, weather resistance, pollution resistance and acid and alkali resistance. According to the curing mechanism, acrylic resin Coatings can be divided into thermoplastic acrylate Coatings and thermosetting acrylate Coatings. The thermoplastic acrylate Coatings will not be further crosslinked in the film-forming process. Thermosetting acrylate Coatings usually have cross linkable functional groups, which are crosslinked with curing agents to form bulk polymers in the film-forming process. The commonly used curing agents are polyurethane, amino resin and epoxy resin. Thermosetting acrylate Coatings have better corrosion resistance, weather resistance and high temperature resistance due to the formation of body structure during film formation. There are mainly two types of waterborne acrylate Coatings, emulsion type and dispersion type. Emulsion type waterborne acrylate Coatings are directly prepared by emulsion polymerization of acrylic monomers. Because it does not need to add organic solvents, it has very low VOC emissions and little environmental pollution. However, due to the limitations of the characteristics of emulsion polymerization, the prepared acrylate emulsion copolymer has high molecular weight, few crosslinking groups, and contains free emulsifiers, which makes the subsequent acrylate Coatings have poor film-forming performance, low adhesion, poor water resistance and corrosion resistance. This kind of emulsion can only be used in industrial Coatings with low requirements for corrosion resistance. Therefore, in recent years, due to the increasing pressure of environmental protection, acrylic resin aqueous dispersion is used as film-forming material in the field with high requirements for anti-corrosion performance. The preparation of hydroxy acrylic resin dispersion is first solution polymerization in water-soluble organic solvent, and then neutralization, emulsification and dispersion. Due to the use of organic solvents in solution polymerization, the VOC emission of dispersed acrylate Coatings is high. However, according to a series of characteristics of solution polymerization, the molecular weight of the prepared acrylic resin is controllable, and a large number of water-soluble crosslinking monomers can be introduced, which is conducive to the film formation and curing of subsequent Coatings. Compared with emulsion acrylic Coating, its water resistance and anti-corrosion performance are better, so at present, the dispersed acrylic resin is often used as the basic adhesive or film-forming material of waterborne acrylic anti-corrosion Coating, and the VOC emission of the final Coating is reduced by increasing the solid content of the solution polymerization in the early stage.

(2) Influence mechanism and effect of polyurethane on concrete surface

Polyurethane Coating is a common film-forming Coating. Scraping or spraying it on the concrete surface can close the defects or voids on the surface and form a layer of hydrophobic layer, so as to protect the concrete surface. Polyurethane waterproof Coating can not only firmly bond with the concrete interface to prevent the Coating from falling off, but also effectively block the invasion of water molecules and corrosive media, inhibit the aging of concrete and protect the substrate. The adhesion of the Coating represents the performance of mutual adhesion between the Coating and the substrate due to physical adsorption, chemical bond formation, mechanical bonding and other effects. The stronger the adhesion of the two, the greater the adhesion of the Coating. In practical application, polyurethane waterproof Coating is often used in railway bridge engineering and highway bridge engineering. The adhesion, shielding and corrosion inhibition of the Coating will decrease due to the influence and effect of various factors in the environment.

(3) Influence mechanism and effect of epoxy polymer Coating on concrete surface

Epoxy Coatings are the most widely used anti-corrosion Coatings at present. There are many kinds in the domestic market, and the main film-forming material is epoxy resin or modified epoxy resin. In the market, most of the epoxy resin Coatings for concrete form a smooth and flat Coatingfilm after crosslinking and curing through the interaction between its components. Like fluorocarbon Coatings, due to the shielding property of the Coatingfilm, it can prevent external invasive substances from entering the interior of the concrete, thus improving the durability of the concrete. The concrete coated with epoxy resin has good anti-corrosion performance.

2.1.3 Development and optimization of Coating materials

In this test, several types of Coatings widely used in construction and marine concrete are used, including epoxy, polyurethane and acrylic. On this basis, some of the Coatings are secondary developed and optimized. The Coatingcolor can be adjusted according to the actual needs of the project, and the change of color is required to have no impact on its performance.

Table 2 Different types of Coatings

classification	Coating type	Remarks
Acrylic acid	Coating A-acrylic resin, Coating J-PMMA	Coating A, Coating B, Coating C and Coating H are the secondary development and optimization products
Polyurethane	Coating B-primer, topcoat polyaspartic resin, Coating D-EXT primer, SJKR590F, CoatingC-primer PU205, topcoat PU203 - 1, Coating E-primer PU205, topcoat PU203-2	
Epoxy Coatings	Coating F-waterborne epoxy, Coating G-waterborne epoxy (reflective), Coating F-oily epoxy (with primer), Coatingi-oily epoxy (without primer)	

2.2 Test method

2.2.1 Formed test piece

The PVC plastic pipe with a diameter of 25 cm and a height of 8 cm was used as the mold for forming the test pieces, and three batches of test pieces were formed successively.

A total of 12 test pieces were made in the first batch, of which 3 were used as blank control and the other 9 were used as test pieces, coated with Coating A, Coating B and Coating C respectively.

A total of 15 test pieces were made in the second batch, one of which was damaged, and the other 14 test pieces were coated with Coating B, Coating C, Coating D, Coating E, Coating F and Coating G respectively.

A total of 15 test pieces were made for the third batch of test pieces, only 6 of which were Coatinged with Coating H, Coating I, and Coating J.

Fig. 2 Formed test piece

2.2.2 Specimen curing and Coating

The specimen is first cured for 24 days in a curing room with a temperature of (20±1 ℃) and a humidity of ≥95%, and then soaked in water for 4 days under the same environmental conditions. Finally, it is taken out and placed at room temperature of 20 ℃ to dry.

After the test piece is cured for 28 days (removing the laitance on the surface), the surface of the test piece is dry, the anti-corrosion Coating is applied, and the coated test piece is placed at 25 ℃ for 7 days.

2.2.3 Salt freezing test

In order to study the improvement effect of brush Coating anti-corrosion Coating on the salt frost resistance of kerbs, the test method adopted in this project is single-sided salt frost test, and the freeze-thaw time is 25 days. The evaluation index is whether the Coating has cracks or peeling.

After the test piece is coated with Coating and cured for 7 days at room temperature of about 20 ℃, it is put into the salt freezer for test. The test method is single-sided freeze-thaw method. The Coating surface of the test piece is immersed in 3% salt solution (100 g salt solution contains 3G NaCl) in the freeze-thaw box, and the Coating surface is about 2cm below the solution surface. At the same time, the test temperature is −20-20 ℃, and the cycle is 12 hours. See Figure 3 for details.

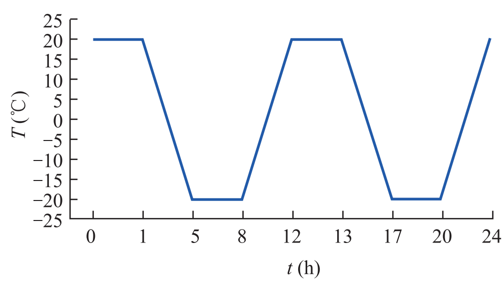

Fig. 3 Cycle time of salt freezing test

2.3 Analysis of test results

2.3.1 The first batch test results

There are four groups of test pieces in this test, one of which is the blank control test piece, and the other three groups are respectively coated with three kinds of Coatings: Coating A, Coating B and Coating C. After 25 freeze-thaw cycle tests, the test performance analysis is as follows Table 3 and Figure 4.

Table 3 Results of the first batch of tests

Coatingtype	Blank test piece	Coating A	Coating B	Coating C
Effect	The test piece appeared serious spalling after 25 cycles, and the spalling amount was 1.036 kg/m^2, which could not meet its service performance.	After 25 cycles of Coating A, serious peeling occurred on the surface of three test pieces, which could not meet its performance.	The Coating B did not show any adverse phenomenon in 15 cycles, but by 25 cycles, there were cracks and peeling around the surface of two test pieces. In order to eliminate the reaction result of brine not penetrated between the test piece and the test mold, its performance needs further verification.	The Coating C did not show any adverse phenomenon in 15 cycles. At 25 cycles, one of the test pieces had a stone protruding from the surface and peeling off. Its overall performance was relatively good, but the surface of the test piece was not polished enough (this group of test pieces was the first to be Coatinged, only slightly polished, and the other groups of test pieces were polished thoroughly), resulting in a thick Coating thickness and high cost, Therefore, it is necessary to further verify its performance when the Coating thickness is thin.

Fig. 4 Coating A after 25 freeze-thaw cycles

2.3.2 The second batch test results

The second batch of tests concluded that a total of 6 Coatings were selected for this test. After 25 cycles of freezing and thawing, the surface of the test piece had been seriously damaged, while the performance of the other four Coatings was better than that of the Coatings F and G, without serious cracking and peeling. In order to further explore the salt frost resistance of the Coatings, the test time of the other four Coatings was extended, On the basis of the previous 25 cycles, 21 more cycles have been carried out. The test performance analysis of the Coating is as follows Table 4 and Figure 5.

Table 4 Results of the second batch of tests

Coatingtype	Coating B	Coating C	Coating D	Coating G	Coating F
Effect	When Coating B was subjected to 25 cycles of freezing and thawing, cracks were generated on the weak surface of one specimen, while no new cracks were generated on the surface of the specimen at 46 cycles, only the original cracks were expanded, while there was little change on the surface of the other specimen before and after the test	When Coating C and Coating e are frozen and thawed for 25 and 46 cycles, the surface of the test piece has little change before and after the test	After 15 cycles of Coating D, the surfaces of the two test pieces have no obvious changes, and there are no adverse phenomena such as cracks and peeling, but the hardness is low; During 25 cycles of salt freezing, bubbles appeared on the surfaces of both specimens, and pits were formed at the same time; At 46 cycles, no cracks were found on the surfaces of the two specimens, but the bubbling phenomenon was more serious than that of 25 cycles, resulting in more pits	After 25 cycles of freezing and thawing, the surface of the specimen has been seriously damaged	After 25 cycles of freezing and thawing, the surface of the specimen has been seriously damaged

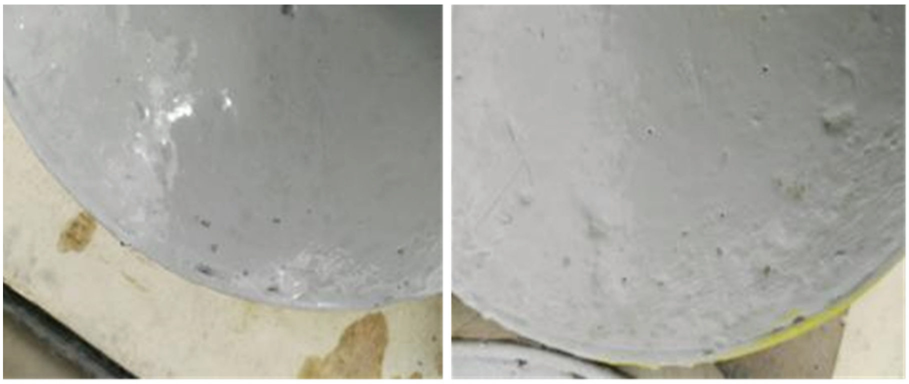

Fig. 5 Coating D after 25 and 46 freeze-thaw cycles

2.3.3 The third batch of test results

There are three kinds of Coatings in this test, of which Coating *h* and Coating I use the same finish, except that Coating *h* is coated with primer, while Coating I only has one finish. After 25 freeze-thaw cycles of the three Coatings, the test performance analysis is as follows Table 5 and Figure 6.

Table 5 Results of the third batch of tests

Coatingtype	Coating H	Coating I	Coating J
Effect	1) When the Coating H is cycled for 15 times, the surface of each test piece has begun to appear the phenomenon of fine cracks and peeling. When the Coating H is cycled for 25 times, the cracks further expand and new fine cracks appear at the same time	2) At 15 cycles of Coating I, cracks have begun to appear on the surface of each test piece, and at 25 cycles, the cracks have further expanded, and some parts of the Coating have also begun to fall off	3) When the Coating J is cycled for 15 times, the surface of each test piece has begun to appear the phenomenon of fine cracks and peeling. When the Coating h is cycled for 25 times, the cracks further expand and new fine cracks appear at the same time

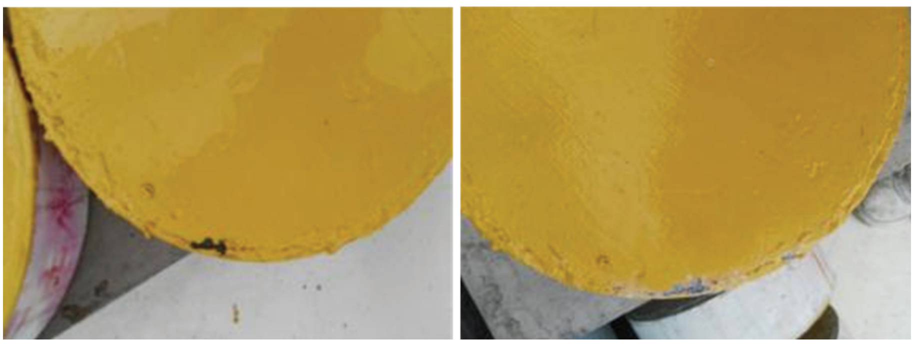

Fig. 6 Coating H after 15 and 25 freeze-thaw cycles

Through the single-sided salt freezing test of three batches of Coatings (a total of 10 kinds of Coatings), the salt freezing resistance decreased from Coating C, Coating E, Coating B, Coating D, Coating H, Coating I, Coating J, Coating A, Coating F to Coating G, in which only Coating C and Coating E, and Coating B could meet the requirements.

The performance of Coating C is equivalent to that of Coating E, and its construction process is the same, of which Coating C is more affordable. Therefore, in Coating C and Coating E, Coating C is preferred. The performance of Coating B is slightly worse than that of Coating C. during the whole test, there was no change on the surface of one test piece before and after the test, and there was also a crack on the surface of one test piece during the test. The analysis shows that the crack is the cement concrete itself. Therefore, the Coating C with the optimized formula is finally determined as the optimal material.

Its various performances are tested according to the specifications, and its performance indexes are shown in Tables 6,7, and 8.

Table 6 Test results of anticorrosive primer

Serial number	Test items		Unit	Detection result	Inspection method
1	Nonvolatile content		%	32.3	GB/T 1725—2007
2	Adhesion		MPa	4.21	GB/T 5210—2006
3	Impact resistance		cm	50	GB/T 1732—2020
4	Drying time	Epigastric stem	h	0.4	GB/T 1728—2020
		Practical work	h	4	
5	Appearance status		—	Uniform after mixing	Visual inspection
6	Alkali resistance		h	No blistering, cracking and obvious discoloration of 240 h Coating film	GB/T 9274—1988
7	Flexibility		mm	2	GB/T 1731—2020

Table 7 Test results of anticorrosive finish coating

Serial number	Test items		Unit	Detection result	Inspection method
1	Nonvolatile content		%	72.4	GB/T 1725—2007
2	Flexibility		mm	2	GB/T 1731—2020
3	Impact resistance		cm	50	GB/T 1732—2020
4	Drying time	Epigastric stem	h	0.4	GB/T 1728—2020
		Practical work	h	5	
5	Appearance status		—	Uniform after mixing	Visual inspection
6	Water resistance		h	The coating film shall be free of discoloration, blistering and cracking within 24 h	GB/T 1733—1993
7	Acid resistance		h	240 h coating film without discoloration, blistering and cracking	GB/T 9274—1988
8	Alkali resistance		h	240 h coating film without discoloration, blistering and cracking	GB/T 9274—1988
9	Salt resistance		h	240 h coating film without discoloration, blistering and cracking	GB/T 9274—1988

Table 8 Overall test results of Coating C supporting coating system

Test items	Test value	Test method
Adhesion (MPa, puller)	4.17	GB/T 5210—2006
Salt spray resistance (1 000 h)	The coating film shall be free of blistering, cracking and falling off	GB/T 1771—2007
Resistance to artificial climate aging (1 000 h)	The coating film shall be free of blistering, cracking, falling off and chalking	GB/T 1865—2009
Salt water freezing thawing cycle resistance (20 times)	No shedding	JG/T 25—2017

2.4 Construction process and engineering verification

In order to verify the engineering application effect of the protective materials studied, the concrete structures were treated with the developed Coating C on the Jiulong Malaba Expressway in 2020 and the Erqin Expressway in 2016. The jiuma Expressway starts from Barkam, ABA, Sichuan, and climbs from 3 100 meters to 3 800 meters above sea level. It is located in the plateau and cold area all the year round. The air is thin, the ultraviolet radiation is strong, the climate is changeable, and the snow cover period in winter is long. Zhangjiakou Erqin expressway has a long freezing period and a lot of ice and snow. The surrounding roads are often sprinkled with deicing salt in winter to quickly open the traffic. Under the coupling effect of saline alkali environment, dry wet cycle and freeze-thaw cycle, the cement concrete structures, especially the curbs in contact with the soil, are seriously corroded and damaged.

2.4.1 Construction process

(1) Preparatory work

Open the end of component B barrel of Coating C and mix it with special mixing equipment at low speed for 5-10 min to make the color uniform.

(2) Base level requirements

The roughness shall meet the design requirements, be dry and clean, free of rust, oil stain, water stain, floating ash and other loose substances, and the base surface temperature and ambient temperature shall meet the requirements.

The laitance on the surface of the concrete test plate can be removed with a manual angle grinder or sandpaper, and the laitance on the surface can be wiped off with a dry cloth.

(3) Coatinging process

① No pre protection of coatinged parts.

② Prepare butyl acetate and rags for cleaning.

③ Weigh the material according to the coating area and the coating rate.

④ The AB component of Coating C is evenly mixed and Coatinged on the surface of the treated concrete test plate. The coating is required to be uniform and can effectively cover the base course.

⑤ Recoating needs to wait for 4 h.

⑥ After drying, ultrasonic thickness gauge shall be used for testing, and corresponding pull-out test shall be carried out.

⑦ The unused materials can still be used in a cool and ventilated environment after being sealed.

⑧ Clean the brush or roller.

2.4.2 Engineering application effect

The two projects of jiulong-ma'an Expressway and Erqin expressway have been in service for 3 and 7 years respectively, and the effect is good, without corrosion cracking, peeling, decolorization, etc. As shown in Figures 7 and 8.

Fig. 7 Implementation effect diagram of Jiuzhi-Ma'erkang Expressway

Fig. 8 Implementation effect of Erlianhaote-Qinhuangdao Expressway

3 Conclusions

In this paper, the types and causes of salt corrosion of roadside concrete are analyzed. By simulating the salt corrosion of concrete surface, the effects of various surface coating materials in protecting concrete from salt corrosion are compared and analyzed, and the material formula is optimized to achieve better protection effect.

(1) Salt corrosion chemical reaction is that when salt substances penetrate into the concrete surface, they will react with the water and calcium elements inside the concrete to produce chemical reaction and form water-soluble hydrochloric acid, which will lead to changes in the chemical properties of the concrete and loss of the original durability.

(2) The commonly used concrete anti-corrosion coatings mainly include acrylic coating, polyurethane coating and epoxy coating. The acrylic coating has strong light, heat and chemical stability. The polyurethane coating can close the defects or voids on the surface and form a layer of hydrophobic layer; Epoxy coatings form a smooth and flat coatingfilm to prevent concrete from salt corrosion.

(3) The polyurethane Coatings C-primer pu205 and topcoat pu203-1 developed and optimized have good permeability and chemical corrosion resistance, and can effectively prevent salt from penetrating into the concrete, thus slowing down the occurrence of salt corrosion of concrete. The engineering verification confirmed the effectiveness and high property-to-price ratio of the project.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

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