Design of Corrosion-Resistant Coating System for Civil Air Defense Engineering Protective Equipment

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Abstract—Aiming at the durability quality problem of anti-corrosion coating for protective equipment in civil air defense engineering in China, the shortcomings of anti-corrosion coating technology in design and testing standards were combed. Referring to the existing domestic standards related to the service life of anti-corrosion protective coating, it was proposed that the reasonable service life of protective equipment coating system should not be less than 20. The performance requirements and testing methods of the coating system were studied, and the life of the coating system that can meet the requirements was predicted, and the results reached the expected protection life requirements. A set of matching systems for the external surface of steel components of protective equipment is designed, which can be used as specific measures to solve the quality problem of anti-corrosion coating of protective equipment in civil air defense engineering, and has reference value for the research and design of protective equipment coating protection system.

Keywords— Civil air defense engineering; Protective equipment; Corrosion resistance; Coating system

1 Introduction

Protective equipment is a device installed at the entrances and exits of personnel and equipment in protective engineering, as well as at the entrances and exits of weapon perforations and air intakes, and smoke exhaust pipes, used to intercept shock waves, biochemical agents, or weaken shock waves. Generally, it can be divided into protective doors, protective closed doors, explosion-proof wave valves, closed valves, and closed observation windows according to its function [1]. Protective equipment is a key facility that can achieve the functions of protective engineering [2], The most commonly used protective equipment for protective doors is new materials, new structures, intelligent control [3], and intelligent IoT, which are the main research topics in the field of civil air defense engineering protective doors. However, from the perspective of the quality of engineering entities, the issue of insufficient durability of civil air defense engineering protective equipment is very prominent. After 2-5 years of completion of many projects, the surface of many protective closed doors, closed valves, and other protective equipment is severely rusted, and many moving parts have already rusted and cannot operate. Especially in harsh environmental conditions such as coastal areas, multiple environmental harmful factors such as freeze-thaw and salt mist are intertwined, The surface coating problem of protective equipment and facilities is more prominent, and even raises doubts among some people about the durability and reliability of the entire project. The

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importance of research on corrosion resistance of protective equipment is constantly increasing. In response to this issue, this article proposes the reasonable service life of the protective equipment coating system, studies the performance requirements and testing methods that the coating system should have, proposes a protective equipment coating system, and predicts the service life of the coating system that can meet the requirements.

2 Insufficient anti-corrosion coating technology for protective equipment

Protective closed doors and closed doors are the most commonly used protective equipment. The standardized design drawings or industry standards for these types of protective equipment only provide general requirements for anti-corrosion performance, and the technical requirements are not deep enough. For example, the design requirement for the protective closed door coating is: "The exposed surface should be coated with two layers of anti rust paint and two layers of light yellow topcoat"; The maintenance regulations are: "Pay attention to maintenance and upkeep, at least comprehensively maintain every year", which includes the maintenance of paint film; The inspection items required by RFJ01-2002 "Quality Inspection and Construction Acceptance Standards for Protective Equipment Products in Civil Air Defense Engineering" and RFJ003-2021 "Quality Inspection Standards for Protective Equipment Products and Installation in Civil Air Defense Engineering" are only three: paint film adhesion, paint film weather resistance, and paint film thickness, with insufficient performance indicators affecting service life. There are basically no relevant requirements for wartime ventilation system protection equipment, except for filter absorbers.

Due to issues such as pre-treatment, process control, and material quality during coating construction, the quality of anti-corrosion coatings for protective equipment can still barely meet the standard during the factory stage. However, after completion acceptance, the quality problems of equipment coatings continue to be exposed, with widespread phenomena such as bubbles, peeling, and cracking. It is not uncommon for locking and hinge mechanisms to rust and lose their movement function, and even for ventilation system equipment interfaces to embroider through pipelines during wartime, Causing the sealing function of the ventilation system to fail.

3 Design of a protective equipment coating system

In response to the issues reflected in the current status of anti-corrosion coating technology for protective equipment, this article proposes a protective equipment coating protection system, with the technical roadmap shown in Fig.1.

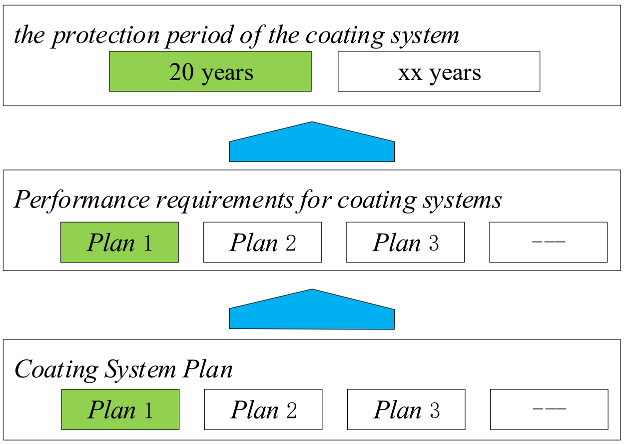

Figure.1 Coating System Design Roadmap

3.1 Determination of the protection period of the coating system

The design service life of civil air defense engineering protective equipment is generally 50 years, and the service life of anti-corrosion design is not clearly specified. Refer to the service life of long-term coating systems in standards such as SL105-2007 "Specification for Anticorrosion of Hydraulic Metal Structures", JT/T 722-2008 "Technical Conditions for Anticorrosion Coating of Highway Bridge Steel Structures", and JT/T 733-2008 "Technical Conditions for Anticorrosion Coating of Port Machinery Steel Structures", The protection period of the protective equipment coating system should be no less than 20 years.

3.2 Performance requirements for coating systems

To ensure that the protective equipment meets the environmental action levels B, C, D, and E specified in GB/T 50476-2008, the design protection period of the coating system for the main components shall not be less than 20 years, and the corrosion level of more than 95% of the coating area within the protection period shall not exceed the Ri2 level specified in ISO 4628 "Rating Methods for Performance Testing of Paints and Varnishes", without bubbles, peeling, and cracking. This article studies the performance requirements of the coating system on the outer surface of protective equipment steel components. Through multiple coating system test data processing, it is found that the system performance requirements should not be lower than the requirements in Table 1. The relevant performance test methods are: water resistance according to GB/T 1733, alkali resistance test according to GB/T 9274, salt water resistance and chemical resistance test according to GB/T 9265; Adhesion performance testing shall be carried out in accordance with GB/T 5210; The salt spray resistance test shall be conducted in accordance with GB/T 1771; The artificial accelerated aging performance test shall be conducted in accordance with GB/T 1865; The resistance to chloride ion permeability shall be tested according to Appendix B of JT/T 695.

Table 1 Performance Requirements for Coating System of Protective Equipment Steel Components

Environmental level	Anticorrosion life year	Water resistance H	Salt water resistance H	Chemical resistance H	adhesion MPa	Salt spray resistance H	Artificial accelerated aging H
B	⩾ 20	240	—	—	⩾ 5	520	680
C	⩾ 20	240	240	72		680	880
D	⩾ 20	240	240	240		880	1140
E	⩾ 20	240	240	240		1140	1480

3.2.1 Consideration of the level of action in corrosive environments

At present, there are two main standards for determining the level of corrosive environmental effects in China. One is the "Code for Durability Design of Concrete Structures" GB/T 50476-2008, which classifies environmental effects based on the degradation mechanism of concrete materials: general environment, freeze-thaw environment, marine chloride environment, deicing salt and other chloride environment, and chemical corrosion environment, respectively represented by the capital Roman letters I-V, as detailed in the standards; The second is ISO12944-2 "Paints and Varnishes - Corrosion Protection of Steel Structures by Protective Coating Systems" Part 2: Environmental classification divides the atmospheric environment into six categories of atmospheric corrosiveness, namely C1 very low, C2 low, C3 medium, C4 high, C5-1 very high (industrial), and C5-M very high (marine).

Due to the fact that the determination of environmental action levels mainly relies on qualitative descriptions of different environmental conditions, it may be difficult to determine when the actual environmental conditions are near the boundary of two adjacent action levels. Therefore, designers need to conduct investigations based on local environmental conditions and existing engineering degradation conditions, and comprehensively consider factors such as engineering importance before determining. The environment in which the protective equipment for civil air defense engineering is located is entirely within the engineering structure and has certain environmental control conditions. Therefore, its corrosive environmental action level can be designed according to GB/T 50476-2008 regulations B, C, D, E, and the commonly used level should be C, corresponding to C2 low or C3 medium according to ISO12944-2.

3.2.2 Coating area considerations

The coating protection system of protective equipment is classified based on whether the surface is a transmission surface and the degree of exposure to the air environment during use. The outer surface refers to the non transmission contact surface of the surface, which is completely exposed to the air environment during use, such as the outer surface of the civil air defense door leaf; The internal surface of a closed environment refers to the surface that is not in contact with the transmission and is not exposed to the air environment during use, such as the surface inside the interior of a civil air defense door leaf; The inner surface of a non enclosed environment refers to a surface that is not in contact with the transmission and is not completely exposed to the air environment during use, such as the inner surface of a civil air defense ventilation duct; Auxiliary steel components refer to the contact surface of the transmission surface, such as the contact surface between the lock head and lock sleeve of the locking mechanism of the civil air defense door. This article takes the maximum coating area and the corrosion measures mainly rely on the outer surface of the coating as the research object to consider the coating area.

3.2.3 Classification of painting stages

To address the issue of mismatch between the protection period of the coating system and the design life of the equipment, the coating protection system of protective equipment is classified according to whether it is applied for the first time or repaired after it is put into operation. During the service life of the equipment, the coating should be repaired and coated as appropriate.

3.3 Coating System Plan

The protective equipment coating supporting system can be adjusted based on the update of the coating and the construction conditions and process equipment of the coating during use. When designing, the corrosion environment and anti-corrosion life factors should be emphasized, but its performance should meet the requirements as listed inTable 1. A set of optional supporting systems for the outer surface of protective equipment components for steel components is designed, as shown in Table 2.

Table 2 Supporting System for Outer Surface Coating of Protective Equipment

Supporting system number	Environmental level	coating	Coating variety	Number of passes/minimum dry film thickness μm
G01	B	Undercoat	Epoxy zinc rich primer	1/60
		Intermediate coating	Epoxy mica iron intermediate paint	(1-2)/120
		Topcoat	Acrylic polyurethane topcoat	2/80
		Total dry film thickness		260
G02	C	Undercoat	Epoxy zinc rich primer	1/80
		Intermediate coating	Epoxy mica iron intermediate paint	1/100
		Topcoat	Hardtop PSO	2/120
		Total dry film thickness		300
G03	D	Undercoat	Epoxy zinc rich primer	1/80
		Intermediate coating	Epoxy mica iron intermediate paint	2/190
		Topcoat	Fluorocarbon topcoat	2/70
		Total dry film thickness		340
G04	E	Undercoat	Inorganic zinc rich primer	1/75
		Sealing coating	Epoxy sealing paint	1/25
		Intermediate coating	Epoxy mica iron intermediate paint	2/200
		Topcoat	Fluorocarbon topcoat	2/80
		Total dry film thickness		380

4 Prediction of Coating System Life

Previous studies have been conducted abroad. Miller et al. [1] constructed a coating life prediction model based on interface oxidation failure. DEMASI et al. [2] used TGO thickness to illustrate the relationship between interface oxidation and cyclic strain. Cmaitland et al. [3] proposed the "Coating Polarization Resistance Control Theory" by conducting electrochemical studies on coated steel plates. The relevant research in China was relatively late, and the research on anti-corrosion technology began to develop and progress on a large scale during the 11th Five Year Plan period, especially in the fields of aerospace, bridges, and steel structures. Huang [4] introduced the methods for predicting coating life and the current problems. Li Shiping [5] used the equivalent method to evaluate the aging of aircraft structural protective coatings, while Han Enhou [6] studied the role of corrosion and corrosion fatigue performance of typical connectors of aircraft structures with coatings in a 3.5% NaCl solution. Liu Guohua [7] applied grey theory to the life prediction research of anti-corrosion coatings for steel truss bridges. Lin Jie [8] combined the detection data of anti-corrosion coatings and applied grey theory to establish a life prediction method for anti-corrosion coatings on bridge steel structures based on corrosion area. Wang Yongcai[9]. conducted research on the evaluation and monitoring measures for the coating life of offshore drilling platforms. Ni Jingyi[10] systematically analyzed the impact of coatings on the durability of concrete structures in seawater environments through investigations and experimental studies on physical engineering, indoor accelerated aging tests, and marine exposure tests using coatings for corrosion protection. Ruan Xin [11] studied the failure modes of organic coating protection systems in marine environments and obtained the law of coating resistance values changing over time.

From the current research status in China, it can be seen that the degradation process of coatings has a long cycle. The commonly used aging test methods for predicting their service life include natural exposure test and accelerated aging test. Among them, accelerated aging test includes salt spray test, ultraviolet aging test, damp heat test, and combination method, and other methods. Direct application of these methods to protective equipment coatings is not applicable, This article uses the national standard method to predict the service life of protective equipment coating systems. GB/T 28416-2012 "Corrosion Testing in Artificial Atmospheres - Accelerated Corrosion Testing for Alternating Exposure to Corrosive Gases, Neutral Salt Mist, and Dry Environments" specifies that the coating life under industrial environmental conditions is 3, 8, 13, and 27 years, corresponding to salt spray times of 1, 2, 3, and 5 weeks, respectively. Based on this, the relationship between the fitting life (year) and the test time (h) is year=0.0359h -3.8286, R ² = 0.9914, the relationship diagram is shown in Fig.2.

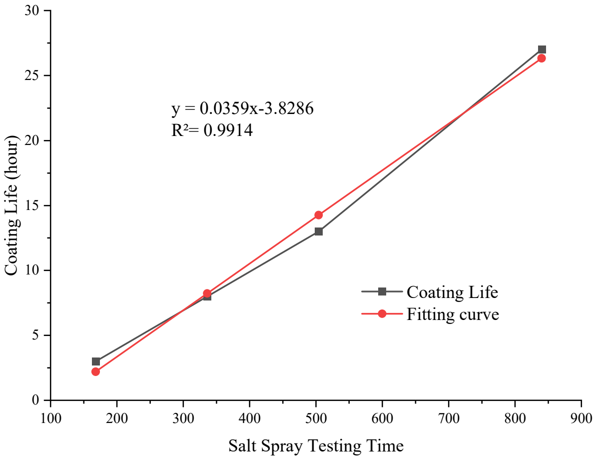

Fig.2 Relationship between coating life and neutral salt spray time under industrial environmental conditions

By incorporating the salt spray resistance time of 680 hours obtained from the corrosion environment action level C in the performance requirements of the external surface coating system of protective equipment steel components in Table 2 into the fitting relationship formula, it can be concluded that the service life of the coating is 20.5 years, which meets the design protection period requirements.

5 Conclusion

(1) Refers to the existing domestic standards for the service life of corrosion-resistant coatings, proposes that the protection period of the protective equipment coating system should be no less than 20 years. The performance requirements and testing methods of the coating system were studied, and the service life of the coating system that could meet the requirements was predicted, and the results reached the expected protection life requirements.

(2) In order to verify the rationality of coating system performance requirements under different levels of corrosive environmental effects, a supporting system for the external surface of steel component of protective equipment is designed, which can be used as a specific measure to solve the quality problem of anti-corrosion coatings for current civil air defense engineering protective equipment. It has important reference value for the research and design of coating protection systems for engineering equipment and facilities.

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