The Protective Effect of Silane Composite Emulsion on Steel Bars in Cement-based Materials

Li Li
Department of Architectural Engineering, Dalian Vocational & Technical College, Dalian 116035, Liaoning Province, China
2013511215@dlvtc.edu.cn

Abstract—This article analyzes the relevant factors affecting the durability of reinforcing steel materials. The research content of this paper includes chloride ion attack, sulfate attack, external load influence, water-cement ratio, etc. The author combines the preparation process of silane composite emulsion with raw material preparation, preparation process analysis, protection mechanism analysis, and surface contact angle measurement, and establishes correlation experiments to analyze the protective effect of silane composite emulsion on steel bars. The author's purpose is to enhance the awareness of the protective effect of silane composite emulsions, and to provide data support for the subsequent better promotion of materials.

1. INTRODUCTION
In the process of construction work, concrete is a frequently used application material. Its durability will also directly affect the service life of construction projects. As an important load-bearing structure of concrete materials, the durability of steel bar will directly affect the bearing capacity of the entire structure, and it will interfere with the service life of the building itself. As a kind of composite material, silane composite emulsion has a great effect on the corrosion protection of steel structure. It can not only reduce the risk of potential problems, but also has a positive effect on extending the service life of the structure.

1.1 Related Factors Affecting the Durability of Reinforced Materials
Summarizing the previous construction experience, it can be understood that the cement base material used in construction projects exhibits strong alkaline characteristics. The average pH value is maintained within the application range of 12-13. In this environment, the surface of the steel bar material will form a relatively dense oxide film due to alkaline oxidation, which will make the steel bar material in a passivated state. When chloride ions penetrate into the cement material from the outside, it will form an acidic environment locally when it is close to the steel material. Under the action of the chemical reaction, the oxide film on the surface of the steel bar will be destroyed, and a micro battery environment will be formed locally. This will cause the iron element in the steel bar to continuously lose electrons, leading to corrosion problems. Summarizing the specific reaction process, its content includes the following parts. (1) Anode reaction: Fe→Fe²⁺+e; (2) Cathodic reaction: O₂+2H₂O+4e→4OH⁻.
1.2 Sulfate Attack
The cement base materials used in construction projects are very susceptible to the influence of sulfate during the application process, which leads to greater corrosion of the structure. As shown in Figure 1, in the specific corrosion process of sulfate, its corrosive effect can be divided into physical corrosion and chemical corrosion. During the application of the former, because the internal sulfate solution is in a saturated application state, it is easy to cause some crystalline salts to appear at this time. At this time, the volume of the precipitated crystals will continue to increase. At this time, strong crystal stress will be generated inside the structure. Just after breaking through the critical value of the material, the problem of concrete cracking will appear. This will expose the steel bar to the air and accelerate its corrosion rate. The latter is that sulfate will react chemically with different elements in the cement base. There is also a big difference in the erosion effect of the material itself. But under the combined effect, it will continuously reduce the application strength of the material and shorten the service life of the material.

Figure 1. Schematic Diagram of Sulfate Attack Process

1.3 External Load Influence
As mentioned above, steel is an important load-bearing structure in concrete materials, and its durability will directly affect the bearing capacity of the entire structure and interfere with the service life of the building itself. The reinforcement material will be subjected to more loads during the application process. This will also have a greater impact on the permeability of the concrete itself and increase the number of cracks in the concrete structure. These cracks bring convenience conditions for the intrusion of external elements, thereby accelerating the deterioration rate of the structure itself. According to the corresponding data, the ion diffusion rate of concrete materials after cracking problems has increased by more than 10 times compared with the previous year. This is also an important factor leading to corrosion of steel reinforcement materials.

1.4 Water Cement Ratio
Except to the above-mentioned influencing factors, the water-cement ratio is also an important factor affecting the application of reinforced materials. In the actual application process, if the water-cement of the material is relatively low, it will not only reduce the workability of concrete, but also interfere with the density of concrete. This will make it prone to cracks when subjected to external loads, which will affect the application quality of the material. At the same time, the water-cement ratio will also have a greater negative impact on the distribution of concrete structures. Corresponding research content shows that with the continuous increase of the water-cement ratio, the void ratio between materials is also in a state of continuous increase. Moreover, the relationship between the pore spacing coefficient and the surface area will be in a state of decreasing. This can provide convenient conditions for the progress of material corrosion, which in turn affects the application of materials.
2. PREPARATION PROCESS OF SILANE COMPOSITE EMULSION

2.1 Raw Material Preparation
In the preparation process of silane composite emulsion, the raw materials that need to be prepared mainly include the following parts. (1) Silane monomer. Among them, the most widely used monomer is isobutyltriethoxysilane, which has the characteristics of stable properties and unsuitable chemical bonds to break. (2) Emulsifier. It can be used as a raw material for the production of composite emulsions. Currently, most emulsifiers used are Span80, PPGO, etc. (3) Dispersant. It can be used for further processing of mixed materials, and the commonly used reagent is PEG2000. (4) Distilled water. It is an important solvent when materials are mixed.

2.2 Preparation Process Analysis
In the material preparation process, the staff should pay attention to the following parts of the application content. First, the staff needs to prepare the oil phase, mixing 5% PPGO and 35% silane monomer. Subsequently, the staff need to fully stir it, the rotation speed during the stirring is controlled at 15000-23000r/min, and the stirring time is controlled at 5-15min. In this way, an oil phase with higher uniformity can be obtained. Second, the staff needs to prepare the water phase, take 5% PEG2000 and 15% Span80, and mix distilled water as a medium. Subsequently. The staff needs to fully stir it, the rotation speed during the stirring period is controlled at 15000-23000r/min, and the stirring time is controlled at 5-15min, so as to obtain a water phase with higher uniformity of distribution. Third, the staff needs to add the obtained emulsion and the prepared water phase to the flask. Subsequently, the staff should stir it, slowly add the oil phase to it during the stirring process, and place it at a constant temperature to keep stirring at a constant speed for 6 hours. In this way, the required silane composite emulsion can be obtained, and the obtained emulsion can be sealed and stored, so that the subsequent retrieval work can proceed smoothly.

2.3 Protection Mechanism Analysis
In the process of material application, the corresponding protection mechanism is as follows. During the application of the composite emulsion, a protective film will be formed on the surface of the material. Moreover, the surface material of the structure is denser, which can effectively resist the intrusion caused by the external environment. At the same time, the protective film also has a certain defense capability. It can not only effectively isolate the intrusion of external influence factors on the steel structure, but also ensure the stability and rationality of the structure application process.

2.4 Surface Contact Angle Measurement
When evaluating the performance of concrete materials, the water contact angle is an important measure. If the contact angle of the material is within 90°, the surface of the material is now hydrophilic. If the contact angle of the material exceeds 90°, the surface of the material appears to be hydrophobic, and the hydrophobicity of the material is directly proportional to the contact angle. In the specific experimental analysis process, the staff will use the contact angle analyzer to assist the detection work. In order to improve the intuitiveness of the analysis results, in the specific application analysis, the staff will use the titration method to determine the contact angle of the surface of the processed and unprocessed materials. In this way, the reliability of the material application after applying the processing method is judged.
3. ANALYSIS OF THE PROTECTIVE EFFECT OF SILANE COMPOSITE EMULSION ON STEEL BARS

3.1 Establish Correlation Experiment

3.1.1 Preparation of Experimental Materials

When analyzing the experimental conditions of the silane composite emulsion, we chose ordinary Portland cement as the experimental material. Its fineness is controlled at 340-3422 m²/kg, while standard sand is used as aggregate, and its fineness modulus is controlled at about 3.0. In the specific experiment process, the size of the mortar we chose was 40 mm×40 mm×160 mm. At the same time, when preparing the test block, we placed a steel bar with a length of 200 mm and a diameter of 10 mm in it as the primary material for this experiment. In the specific experiment, a constant potential needs to be passed inside the test block. In order to meet the basic requirements of the experiment, we need to arrange the wires connected to the steel bar in advance when installing the steel bar. At the same time, we need to derust the steel bar material in the application. Afterwards, we should screw on the protected experimental wires on both sides, the wires are preferably copper core wires, and the interface should be treated with epoxy resin. This can ensure the stability of the connectivity status. Moreover, in the process of application treatment, we also need to use heat shrink tubing to cover both ends of the steel bar to reduce the influence of the external environment on the steel bar material.

3.1.2 Silane Composite Emulsion Use

In the process of using silane composite emulsion, the following aspects should be paid attention to. Firstly, after waiting for the test block to reach the curing age, the staff needs to take out the formed material for drying. The temperature during drying is controlled at 50°C to ensure one-dimensional penetration of chloride ions. In practical applications, workers need to select one surface from several surfaces of the formed concrete to apply the silane composite emulsion. The other sides are sealed with epoxy resin to ensure the unity of data parameter changes. Secondly, the staff needs to perform the next stage of processing on the test blocks that have been processed. Workers need to place it in a ventilated and dry place, and need to wait seven days in this environment to perform follow-up electrochemical tests and other related work [1].

3.1.3 Experimental Method Analysis

In the specific experiment process, it is mainly divided into the following two parts. Firstly, conduct electrochemical experiments. In the specific experiment process, the staff can use the Princeton Versa STAT 3 electrochemical workstation to complete the experiment, complete the data collection and then perform the next stage of data analysis. Secondly, the scanning electron microscope processes the shape of the molded module. The staff need to do a good job of comparative testing and energy spectrum analysis to improve the reliability of the experimental analysis results [2].

3.2 Comparative Analysis of Protection Effects

3.2.1 Electrochemical Impedance Spectroscopy

Establish related experiments to analyze, and the corresponding experimental contents are the AC impedance spectra (Nyquist diagram) of blank test block, coated composite emulsion, and TEOS. Combined with the experimental data, the following can be learned.

3.2.1.1 AC Impedance Spectrum of Blank Test Block

It can be seen from the AC impedance spectrum of the blank test block that at the beginning of the test, the passive film impedance and capacitance of the steel bar are at a maximum value because the steel bar is not corroded in the passivation period. The figure shows a straight upward line. As the corrosion time continues to extend, the steel bar enters the corrosion development period (6-9 h), and the capacitive arc gradually changes from an upward straight line to an arc with a gradually smaller radius.
This shows that the impedance and capacitance of the passive film on the surface of the steel bar gradually decrease, and the passive film on the steel bar falls off. At this time, the steel bar begins to corrode. When the corrosion time is extended to 15 hours, the decrease in capacitive reactance arc radius becomes larger. At this time, micro-cracks began to appear on the surface of the test piece, and a small part of oxidized iron rust was discharged from the inside, and the degree of corrosion increased. After 21 hours, the capacitive reactance arc radius reached the minimum state. This means that the passivation film on the surface of the steel bar is basically destroyed, and the volume of the rust produced by the corrosion of the steel bar increases, which produces expansion pressure on the concrete. This caused obvious cracks on the surface of the test block, resulting in a large amount of rust discharge [3].

3.2.1.2 AC Impedance Spectrum of Coated Composite Emulsion
It can be seen from the AC impedance spectroscopy of the coated composite emulsion that after the composite emulsion is coated on the surface of the test block, the topological structure of the AC impedance spectroscopy of the test block remains stable during the 0~30 h stage of electrical acceleration, and no quality occurs. The capacitive reactance arc has not changed significantly. This means that under the protection of the composite emulsion, the corrosion rate of steel bars is slow. This is mainly because the composite emulsion can form a dense hydrophobic network on the surface of the substrate and the surface of the inner capillary wall to inhibit the intrusion of moisture. At the same time, it hinders the diffusion of Cl- and inhibits the corrosion of steel bars. Compared with the blank specimen, the initial corrosion time of the steel bar is extended by 4 times. Until 48 hours later, the topological structure of the low-frequency part gradually changed from an upward straight line to a flattened capacitive arc, and the radius of the capacitive arc was significantly reduced. This means that the impedance and capacitance of the passive film on the surface of the steel bar are reduced, the passive film on the surface of the steel bar is damaged, and the corrosion development period is entered. For 48 to 72 hours, the capacitive reactance arc is slowly decreasing, which is more stable than the blank specimen [4]. When the corrosion time reaches 72 hours, the capacitive arc radius tends to the smallest state. Due to the expansion pressure of the corroded steel bars, the capacitive arc began to appear micro-cracks and continued to develop, eventually rusting and cracking.

3.2.1.3 TEOS AC Impedance Spectroscopy
It can be seen from the TEOS AC impedance spectrogram that after covering the test module with TEOS protective material, the corrosion time of the steel bar material in the initial state is 1.2 times longer than that of the blank test block. The complete corrosion of steel materials has increased by 40% year-on-year. It can be seen that the application effect of using TEOS as an anti-corrosion material is relatively low. Summarizing the specific reasons, we can find that TEOS is a monomer solution during use, and it is easy to volatilize in early summer. Moreover, the material itself has strong permeability, and it is difficult to form an effective hydrophobic layer on the surface of the base material to prevent the intrusion of chloride ions and sulfates. This resulted in the emergence of the above-mentioned application situation [5].
3.2.2 SEM and EDS Analysis

### TABLE I. DISPLAY OF THE SCANNING RESULTS OF THE SURFACE ENERGY SPECTRUM OF THE TEST BLOCK

| Experimental Materials | EDS Silicon Content Ratio | EDS Calcium Content Ratio |
|------------------------|--------------------------|---------------------------|
|                        | Point Scan | Face Scan | Point Scan | Face Scan |
| Blank Material         | 3.75%      | 4.21%     | 7.55%      | 11.23%    |
| Composite Emulsion     | 13.25%     | 11.03%    | 1.55%      | 1.76%     |
| TEOS                   | 5.55%      | 7.23%     | 4.22%      | 6.33%     |

In the SEM and EDS analysis process, researchers will use different types of silane waterproof materials to smear the test block structure. Subsequently, the researchers will place it in a 5% NaCl solution to analyze its corrosion. During the application of the blank material, because the material has not been protected, a large amount of NaCl crystals will adhere to the surface of the material. Observed from a microscopic point of view, it can be found that these crystals present a needle-tip network-like application structure, and the corrosion situation is in a relatively serious state. In the application process of the composite emulsion, because the material has undergone a protective treatment, the number of NaCl crystals adhered to the surface of the material is very small. From a microscopic point of view, it can be found that chloride ions are not suitable for adhering to the composite emulsion material. This also reduces the corrosion caused by chloride ions. Moreover, the surface material of the structure is denser, which can effectively resist the intrusion caused by the external environment. In the application of TEOS, although the material has undergone protective treatment, a certain amount of NaCl crystals still adhere to the surface of the material. From a microscopic point of view, it can be found that chloride ions can still adhere to the material coated with TEOS. This also reduces the resistance of chloride ion erosion. Moreover, the surface material of the structure has a low density and cannot effectively resist the intrusion caused by the external environment, and the protection effect is relatively poor [6].

As shown in Table 1, this table is the statistical data of EDS testing after applying different waterproof materials. According to statistical data, it can be understood that after applying waterproof material, the silicon content in the material has increased significantly. This also shows that the material can well penetrate into the interior of the mortar test block to form a relatively stable silicon-oxygen protective layer, which in turn plays a good protective role [7].
4. CONCLUSION
In summary, in the process of concrete construction, steel bars are very important applied materials, and
their durability will directly affect the application effect of concrete. By applying the composite
emulsion to the protection of steel bar materials, it has a positive meaning for extending the service life
of the material and ensuring the forming effect of the material.

Acknowledgments
This work was supported by Scientific Research Innovation Fund Project of Dalian
Vocational&Technical College (NO.DZ2018CXJ01), Annual Scientific Research Innovation Platform
of Dalian Vocational&Technical College in 2019 (NO.2019XJPTYF1-1), Research Backbone Project
of Dalian Vocational&Technical College in 2019, Scientific Research Funding Project of Liaoning
Education Department in 2020 (NO. JYT202005), Education Science Planning Project of Liaoning
Province in 2020.

REFERENCES
[1] Gao Jing, Li Shaochun, Zhang Weifeng, Geng Yongjuan, Xiao Qilong, Hou Dongshuai. The
effect of isobutyltriethoxysilane composite emulsion on the waterproof performance of foam
concrete[J]. Coatings Industry, 2020, 50(05): 2-6+13.
[2] Liu Huanhuan. Synthesis of Poly (MPS-MAA) Nanocomposite Emulsion with Shell and Core
Structure and Its Modification of Composite Membrane Materials[J]. Guangdong Chemical
Industry, 2019, 46(23): 109-110.
[3] Li Shaochun, Geng Yongjuan, Chen Xu, Jin Zuquan, Gao Song. Protection of
TEOS/isobutyltriethoxysilane composite emulsion on damaged cement-based materials[J].
Bulletin of the Chinese Ceramic Society, 2019, 38(07):2004-2009.
[4] Li Min, Fan Ping, Han Yuheng, Huang Quju, Fan Xin, Wu Yuehuan. Properties of polyacrylic
acid/silica composite emulsions obtained from different silicon sources[J]. Plating and
Finishing, 2019, 38(08):375-379.
[5] Ma Guanhao, Zheng Hangbing, Hu Guangjie, Zhou Yang, Zheng Shaona, Zhao Lili, Liao Wenbo.
Preparation and hydrophobicity of silica modified fluorine-containing
silicone-styrene-acrylic composite emulsion[J]. Electroplating and Finishing, 2019,
38(06):246-251.
[6] Peng Guang, Xu Jinyu, Ren Weibo. Mechanical properties and pore structure of styrene-acrylic
emulsion cement composites modified by silane coupling agent[J]. Bulletin of the Chinese
Ceramic Society, 2018, 37(10):3076-3081.
[7] Zhang Youlai, Li Shaochun, Hou Dongshuai, Xiao Qilong. The influence of graphene oxide/silane
composite emulsion on the impermeability of concrete[J]. Coating Industry, 2018, 48(07):
13-18+52.