Development and application of an anticorrosion type water release agent

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Abstract. Water based release agents have attracted widely attention in recent years due to their advantages, such as environmental and convenience. However, during the application process, the resistance to the steel mould is not obvious, and the concrete surface is easy to rust, which affects the appearance of the concrete surface. The application of aluminium mould can’t solve the problem of bubble and surface ash. The ZJTM anticorrosion type water release agent developed in this paper can effectively solve the corrosion of the concrete surface, bubble and surface ash, and the effect is remarkable in all kinds of engineering.

1. Introduction
Concrete release agent, also known as concrete isolator or release lubricant. It is a kind of material that can be coated or sprayed on the inner surface of formwork to produce a layer of isolation film, which can effectively reduce the adhesion between concrete and formwork, and promote the smooth removal of concrete from formwork and keep the shape of concrete.

As a supporting material for concrete construction, Concrete release agent has almost the same history with concrete. In the nineteen-twenties, soap water solution, waste diesel oil, waste oil, lime, talc powder were used as releasing agent in concrete engineering in various countries, but the effect was general, and soap water solution was alkaline solution, which affected the surface quality of concrete. With the application of new concrete pouring technology, the emergence of new formwork such as steel formwork, FRP formwork, wood formwork, aluminium alloy formwork, reinforced concrete formwork and plastic formwork, and the improvement of concrete surface quality and decoration grade, new and higher requirements for Concrete release agent are put forward [1]. Since the early 1960s, after the advent of foreign commercial concrete release agents, great progress has been made in the research of concrete release agent for concrete moulding. The development of concrete release agent is very rapid, and a series of products have been formed, which are gradually matched with modern construction and template technology.

In recent years, water-borne release agent has attracted wide attention because of its environmental protection, easy to pollute the environment, easy to use and other advantages [2]. However, the embroidery resistance of steel formwork is not obvious in the application process, and the concrete surface is easy to rust, which affects the beauty of the concrete surface; the application of aluminum oxide template can’t solve the problem of air bubbles and surface ash.

According to the application problem of water-borne release agent, we developed a new kind of emulsifying release agent product: ZJTM water-borne release agent for corrosion inhibition of concrete. The test shows that the product with inositol hexaphosphate is stable, environmentally friendly, harmless to the body, film-forming effect is good, easy to demoulding, and can effectively
solve the corrosion and bubble on the surface of concrete after demoulding of various metal formwork. As well as the problem of ashing, the application effect is remarkable in all kinds of projects.

2. Experimentation

2.1. Major raw materials and instruments
Film forming agent, sorbitol trioleate, diethylene glycol monostearate, polyoxyethylene sorbitol monolaurate, 1,3-propylene glycol, triethanolamine, sorbitol monooleate, thiophosphate, inositol hexaphosphate, imidazoline oleate, water-borne concrete release agent 1, water-borne concrete release agent 2.
Fasks (1L), electric agitator (PTFE agitator), centrifuge, electronic balance, vacuum dryer, beaker.

2.2. Preparation of Rust-inhibiting Demoulding Agent
The rust-inhibiting water-borne release agent is composed of film-forming agent, emulsifier, dispersant, water and corrosion inhibitor. In this method, the selection and proportion of corrosion inhibitor is the key. The specific experimental steps are: (1) adding film-forming agent to four flasks at once, stirring and heating to 60 degrees; (2) adding compound emulsifier with HLB value of 9-10 at one time, stirring for 10 minutes at 60℃; (3) adding 65 degrees hot water to phase transition continuously and slowly, stirring for 30 minutes after adding; (4) adding compound emulsifier at last. Different corrosion inhibitors were stirred for 10 minutes to obtain water-borne rust-inhibiting release agent (effective ingredient content 12%[3].

2.3. Performance testing

2.3.1. Material and Ratio for Performance Testing
a. Cement
According to the use of cement in concrete production enterprises, Huaxin P.O 42.5 cement and Yadong P.O 42.5 cement are selected. The basic properties are shown in Table 1.

| Sample      | Water consumption for standard consistency /g | Initial setting/min | Final setting/min | Density /g/cm³ | Specific surface area /cm²/g | 3d mortar strength /MPa | 28d mortar strength /MPa |
|-------------|-----------------------------------------------|---------------------|-------------------|----------------|-------------------------------|------------------------|--------------------------|
| Huaxin Cement | 124                                           | 155                 | 220               | 3.08           | 4055                          | 30.0                   | 50.1                     |
| Ya Dong cement | 132                                           | 185                 | 236               | 3.02           | 3380                          | 26.5                   | 51.9                     |

b. Mineral powder
S95 mineral powder (KF) from a new building material plant has a specific surface area of 4250 cm²/g, a density of 2.86 g/cm³, an activity of 86% on 7d and 97% on 28d.
c. Fly ash
The grade II fly ash is used with fineness of 2.5%, loss of combustion of 8.0% and water requirement ratio of 105%.
d. Sand
Sand: its fineness modulus is 2.6, the mud content is 0.8%, and the mud content is 0.3%.
e. Gravel
C30 concrete adopts 5-31.5 mm continuous Graded Macadam with apparent density of 2730 kg/m³, mud content of 0.4%, mud content of 0.1%, needle-like content of 4.0%, crushing index of 6.5%. 
C70 concrete adopts 5-25 mm continuous Graded Macadam with apparent density of 2730 kg/m³, mud content of 0.4%, mud content of 0.1%, needle-like content of 4.0%, crushing index of 6.5%.

f. Water
   Tap water or groundwater meet the requirements of JGJ 2006 Water Standard for Concrete Mixing.

h. Admixture
   The admixture is the finished product with 10% solid content produced by the company, which meets the requirements of GB 8076-2008.

Table 2: The concrete mix

| Strength grade | Cement | Fly ash | Mineral powder | Sand | Gravel | Water |
|----------------|--------|---------|----------------|------|--------|-------|
| C30            | 190    | 100     | 85             | 860  | 1020   | 135   |
| C70            | 450    | 50      | 115            | 700  | 960    | 120   |

2.3.2. Performance testing methods

- Emulsion stability test: according to JC/T 949-2005 "release agent for concrete products" for testing. The product was diluted to 25 mL of the diluent of the concentration used and injected into the colorimetric tube. The product was stationary for 24 hours at 5-40℃. The homogeneity and stratification of the product under natural light were observed.

- Storage stability test: put the emulsion into the 10 mL centrifuge tube and put it into the high-speed centrifuge, set the speed of 4000r/min, centrifuge the 10min, and evaluate according to the 6 grades of emulsion stability.

- Demoulding performance test: refer to Appendix A of JC/T 949-2005 "Demoulding Agents for Concrete Products".

3. Results and Discussions

3.1. Rust Inhibiting Performance Test of Different Corrosion Inhibitors

The application of water-borne release agent in steel moulds for construction generally has some problems, such as easy corrosion on the surface of steel moulds and easy contamination of concrete surface by rust. According to the mechanism of electrochemical corrosion of steel moulds and the effect of film formation on the surface of steel templates, triethanolamine, sorbitol monooleate, thiophosphate, inositol hexaphosphate, oleic acid imidazoline and other substances were selected to carry out orthogonal experiments from Table 3. It can be seen that inositol hexaphosphate and imidazoline olate have good antirust effect. The inositol hexaphosphate molecule has 24 oxygen atoms, 12 hydroxyl groups and 6 phosphate groups which can cooperate with metal. It is a rare metal polydentate mixture. Only one of the six phosphate groups in the molecular structure is in a position, and the other five are in E position. Four phosphoric groups are on the same plane. Therefore, when inositol hexaphosphate complexes with metals on the metal surface, it is easy to form a dense single molecule protective film on the metal surface, which can effectively prevent O₂ from entering the metal surface, thus slowing down the corrosion of metals⁴.

Imidazoline corrosion inhibitors are widely used in various anti-corrosion fields because of their advantages of green, environmental protection and low toxicity. Compared with other types of organic inhibitors, imidazoline inhibitors can complex some oxidants in solution to reduce the electrode potential of metals to achieve the purpose of corrosion inhibition⁵.
Table 3. Test results of different rust inhibitors

| Sample                        | Emulsion stability | Storage period /d | Film forming time /min | Erosion resistance | Corrosion resistance (Rust spots appear) |
|-------------------------------|-------------------|-------------------|------------------------|--------------------|-----------------------------------------|
| -                             | UN stratified     | 200               | 10                     | no                 | 2d                                      |
| triethanolamine               | UN stratified     | 150               | 16                     | no                 | 2d                                      |
| sorbitan monooleate           | UN stratified     | 200               | 15                     | no                 | 5d                                      |
| Thiophosphate                 | UN stratified     | 120               | 14                     | no                 | 2d                                      |
| Inositol hexaphosphate        | UN stratified     | 210               | 18                     | yes                | 30d                                     |
| Oleic imidazoline             | UN stratified     | 180               | 12min                  | yes                | 30d                                     |
| Water-borne release agent 1   | UN stratified     | 90                | 20min                  | no                 | 1d                                      |
| Water-borne release agent 2   | Slight bleaching oil | 30               | 18min                  | no                 | 1d                                      |

3.2. Effect of Different Corrosion Inhibitors on the Appearance of Concrete after Demoulding

In the construction of concrete engineering, honeycomb pitting surface, lack of angle, bars and other quality defects often appear on the surface of concrete components, which not only affects the apparent effect of concrete, but also affects the internal quality and durability of concrete seriously. With the development of new technology and technology of concrete, the requirement for decorative effect of concrete surface is higher and higher. The use of demoulding agent can reduce or even avoid the above problems on the surface of concrete components, and improve the quality of the surface of components.

Combining with the basic performance test of demoulding agent, three groups of better performance anti-rust demoulding agent were selected to compare with oil demoulding agent. Fig. 1 is the application of different demoulding agent in experimental pier column. From the figure, it can be seen that the concrete using water-based demoulding agent is obviously superior to oil demoulding agent. At the same time, inositol hexaphosphate rust-inhibiting demoulding agent is coagulated compared with other anti-rust demoulding agents. There is no rust on the surface of the soil, no harmful stomata and uniform color.
3.3. Adaptability of Different Inhibitors to Template

At present, formwork in construction industry mainly includes wood formwork, steel formwork, plastic formwork, aluminum alloy formwork, etc. Among them, aluminum alloy formwork is more and more widely used because of its lightweight, convenient installation and disassembly, high turnover times, wide application environment, good durability, less garbage in construction site and high recycling value. However, the aluminum alloy formwork is assembled as a whole, and the formwork is easy to react with concrete, the wall surface is easy to peel off after demoulding, bubbles and other issues. Figure 2 compares the appearance of concrete after different rust-inhibiting demoulding agents are applied to the aluminum alloy formwork. It can be seen that inositol hexaphosphate rust-inhibiting demoulding agent has significantly improved the ash and bubbles on the concrete surface, which benefits from this. The corrosion inhibitor can form a dense protective film on the surface of the formwork to prevent the reaction between the aluminium alloy formwork and fresh concrete.
a. Oily release agent  

b. Oleic acid imidazoline rust-inhibiting release agent  

c. Sorbitol monooleate rust-inhibiting release agent  

d. Inositol hexaphosphate rust-inhibiting release agent  

Figure 2 Appearance of concrete after application of different demoulding agents to aluminium alloy formwork

4. Summary

- ZJTM embroidery-resistant release agent was prepared by using film-forming agent, compound emulsifier (HLB=9), corrosion inhibitor, co-emulsifier and stabilizer.
- The results show that the inositol hexaphosphate rust-inhibiting demoulding agent has short film-forming time and good stability, and forms a dense monomolecular protective film on the metal surface, thus slowing down the corrosion of the metal. After demoulding, the concrete has no harmful bubbles and no rust adherence.
- Inositol hexaphosphate rust-proof demoulding agent can prevent the reaction between aluminium sheet and concrete, and improve the ash and bubbles on the surface of concrete after using aluminium alloy formwork. Its application effect is better than other products in the market.

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