A quick method for repairing damaged coating of cladding reinforcements

Qiushi Li¹,²,³,⁴*, Wenfeng Zhang¹,³,⁴, Tao Chen¹,³,⁴, Liu Kai¹,⁴

¹ Tianjin Port Engineering Institute Ltd., CCCC First Harbor Engineering Company Ltd., Tianjin, 300222, P R China
² Tianjin Key Laboratory of Composite and Functional Materials, School of Materials Science and Engineering, Tianjin University, Tianjin 300072, P R China
³ Tianjin Key Laboratory of Underwater Tunnel Construction and Operation & Maintenance, Tianjin, 300222, P R China
⁴ CCCC First Harbor Engineering Company Ltd., Tianjin, 300461, P R China

*Corresponding author’s e-mail: qsli@tju.edu.cn

Abstract. A quick method for repairing the damaged coating of cladding reinforcements was proposed in this work. Four quick repair systems were applied and conducted salt spray test, including only heat shrinkable material, anti-corrosion tape+heat shrinkable material, anti-corrosion tape+glass fiber reinforced plastic, and viscoelastic anti-corrosion tape+glass fiber reinforced plastic. The results indicated that after 720h of salt spray test, no corrosion was observed on the steel substrates inside the protective layer of all the four quick repair systems. All these quick repair systems performed excellent property of corrosion resistance. The proposed method is easy to operate and can effectively improve the repair efficiency of the epoxy coating reinforced coating damage.

1. Introduction
The cladding reinforcement is a new type of reinforcements coated with a protective layer on the reinforcement surface. The protective layer can be composed of materials such as metals (eg. zinc or stainless steel) and polymer materials (eg. epoxy resin). Epoxy-coated reinforcements is one of the most widely used cladding reinforcements in recent years. Epoxy-coated reinforcement is a kind of reinforcement with tough, impermeable and continuous insulation coating. The production process is a powder made of additives such as thermosetting epoxy resin, filler and cross-linking agent. On the factory assembly line, electrostatic spraying is used to spray the surface-treated preheated reinforcements. The epoxy coating has advantages of extremely high chemical stability and excellent adhesion to metal surfaces. These advantages can effectively block the contact between reinforcements and corrosive media, resulting in good corrosion resistance.

Although the epoxy-coated reinforcement has a good anti-corrosion effect, once the surface coating is damaged and cannot be repaired, the coating damage will cause local corrosion during the service of the concrete structure, which will reduce the structural durability. The construction of epoxy-coated steel reinforcement involves multiple processes such as storage, handling, lifting, processing, positioning and connection, lashing, and pouring. Therefore, coating damages during the construction are almost unavoidable. For coating damages, the usual treatment is to manually repair the coating. This method
can solve the problem of coating damages to a certain extent, but the repair quality is often inferior to the original coating quality. In addition, the coating repair has certain requirements for the surface treatment. If the surface is not treated properly, it will often lead to a poor coating adhesion and a poor repair effect. However, due to the complexity and uneven quality of the construction personnel, it is difficult to ensure the quality of coating damage repair. Therefore, the repair of damaged coatings for epoxy-coated steel reinforcement construction requires a high level of responsibility and skill on the part of the construction staff, and requires a large amount of work due to the need for surface treatment, such as repeated brushing, waiting for the coating to solidify, and special protection. These requirements lead to a low efficiency, which seriously affects the progress of the project.

To resolve the above problems, a quick repair method is proposed. The method is used to quickly repair the coating damage generated during the construction process of epoxy-coated reinforcements and protect the connecting sleeve of epoxy-coated reinforcements. The proposed quick repair method can improve the repair efficiency and effect of epoxy-coated steel reinforcement construction damage.

2. Quick repair system for coating damage of epoxy-coated steel reinforcement

2.1. Structure of the quick repair system

The quick repair system consists of an anti-corrosion tape (or paste) wrapped around the coating damage, and a protective cover covering the outer side of the anti-corrosion tape (or paste). The anti-corrosive tape is a flexible tape-shaped material composed of a viscoelastic polyolefin polymer material and a tensile polymer anticorrosive film. The anti-corrosive paste is a kind of viscoelastic polyolefin polymer material. The protective cover consists of two layers, the outer layer is a polymer material such as PVC, ABS, EVA or PET with heat shrinkable characteristics, and the inner layer is a hot-melt solid polymer material. The cross-sectional schematic diagram of the quick repair system is shown in Figure 1.

![Figure 1](image_url)

Figure 1. Cross-sectional schematic diagram of the quick repair system (1-steel reinforcement, 2-epoxy coating, 3-protective cover, 4- anti-corrosion tape (or paste), and 5-damaged coating)

2.2. Implementation of the quick repair system

The implementation of the quick repair system includes the following steps:

1) The damaged part of the coating is cleaned and then the surface treatment is performed to remove pollutants.

2) An anti-corrosion tape or an anti-corrosion paste is wrapped or applied around the damaged part of the coating. The coverage of the anti-corrosion tape will extend 1 to 2 cm beyond the ends of the damaged part of the coating along the length of the reinforcement. The anti-corrosion tape is wound with 2 layers at the beginning, and then overlapped by 55% ~ 60% in turn, and then wound with 2 layers at the end. The anti-corrosion paste needs to be evenly coated on the damaged part of the coating, the coating thickness is about 5 ~ 8mm, and the coverage area should be about 1 ~ 2cm around the damaged part of the coating.

3) A suitable protective cover is selected according to the diameter and the installation state of the epoxy-coated reinforcement. For unbundled fixed reinforcements, a closed protective cover should be selected. The inner diameter of the closed protective cover must be larger than the diameter of the reinforcement covered with anti-corrosion paste or wrapped anti-corrosion tape 1 ~ 3cm, the length of the protective sleeve along the length of the reinforcement exceeds the ends of the coating by 5 ~ 6cm.
(4) A hot air gun is used to cure the protective sleeve on the outside of the anti-corrosion tape or anti-corrosion paste. For unbundled fixed reinforcements, a closed protective sleeve is inserted from the end of the reinforcement and moved to the outside of the anti-corrosion tape or anti-corrosion paste. The hot air gun is used to heat the protective sleeve uniformly along the circumference from the middle to make it shrink completely and then extend the heating to both sides. The uneven surface needs to be reheated, so that the protective cover is evenly covered by the anti-corrosion tape or anti-corrosion paste. After the overall heating is completed, the temperature is lowered. A reheating treatment is applied to ensure that the hot-melt solid polymer material inside the protective cover is fully overflowed. The heating temperature of the protective sleeve should be between 80 °C and 110 °C, and should not exceed 250 °C. The heating temperature should be increased gradually and the air should be removed by tools such as pressure rollers.

3. Experimental

3.1. Materials
The reinforcement used in this experiment are epoxy-coated reinforcements. The coatings of the reinforcements are intact and no damage can be observed on the surface. Artificial damages are made on the surface of the coating by using a mechanical grinding wheel. The reinforcing steel matrix inside the epoxy steel should be completely exposed. Then the artificial damaged epoxy-coated reinforcements are cleaned by ethanol and dried for the quick repair.

3.2. Quick repair
Four anticorrosive materials are applied for the quick repair systems of the artificially damaged epoxy-coated reinforcements. The quick repair systems used in this experiment are shown in Table 1. The application of the quick repair system strictly performed in accordance with the above implementation steps. After the quick repair, the damaged reinforcements are prepared for the salt spray test in order to compare the protective effects of these four quick repair systems.

Table 1. Quick repair systems in the experiment

| No. | 1 | 2 | 3 | 4 | 5 |
|-----|---|---|---|---|---|
| Quick repair system Unrepaired | Only heat shrinkable material (HSM) | Anti-corrosion tape (ACT)+HSM | ACT+Glass fiber reinforced plastic (GFRP) | Viscelastic anti-corrosion tape (VACT)+GFRP |

3.3. Salt spray test
The test solution is 5 wt.% NaCl aqueous solution. The salt spray tests perform at 35 °C with a duration of 720 hours. The samples to be tested is neatly placed on the salt spray test shelf. After the salt spray test, the repaired layer on the surface of the reinforcements are removed to observe the corrosion of the steel substrates.

4. Results and discussion
Figure 2 illustrates the macromorphologies of the unrepaired and repaired epoxy-coated reinforcements after 720h of salt spray test. As shown in Figure 2, the unrepaired reinforcement is severely corroded. The damaged part of coating is covered with corrosion products. No corrosion product can be observed on the surface of the repaired reinforcements.
Figure 2. Macromorphologies of the unrepaired and repaired epoxy-coated reinforcements after 720h of salt spray test (1-unrepaired, 2-HSM, 3-ACT+HSM, 4-ACT+GFRP, 5-VACT+GFRP)

Figure 3 illustrates the corrosion morphologies of the reinforcements after removing the protective layer. As shown in Figure 3, after 720h of salt spray test, no corrosion can be observed on the surface of the steel substrates. The protective layers of the quick repair systems prevent the corrosive medium from reaching the steel substrates. These four quick repair systems perform an excellent property of corrosion resistance.

Figure 3. Corrosion morphologies of the reinforcements after removing the protective layer (1-unrepaired, 2-HSM, 3-ACT+HSM, 4-ACT+GFRP, 5-VACT+GFRP)

5. Conclusions
(1) The quick repair method proposed in this paper can be applied to repair the coating damage on the surface of epoxy-coated reinforcements. This method is easy to operate and can effectively improve the repair efficiency of the epoxy coating reinforced coating damage.

(2) No corrosion is observed on the steel substrates inside the protective layer of all the four quick repair systems of HSM, ACT+HSM, ACT+GFRP, and VACT+GFRP. All these quick repair systems perform excellent property of corrosion resistance.

Acknowledgments
This work was supported by National Key Research and Development Program of China (2017YFB0309902) and National Natural Science Foundation of China (51771133).

References
[1] Jinyue Wu, Songgui Wu, Xufeng Xu, and Naixin Xu (2004) Epoxy-coated Rebar and Its Application. Corrosion and Protection. 25(3):105-108
[2] CN201610896236, CN Patent.
[3] Hehe Zhou, Jinbin Zhao, Jiayu Cai, Ming Liu, and Xuequn Cheng. (2017) Recent Status of Research on Corrosion Resistant Steel Bars and Analysis on Existing Corrosion Evaluation Methods. Corrosion and Protection. 38(9):665-670.

[4] Lei Hou, Weihua Li, Haibing Zheng, Tao Ji, and Huiwen Tian. (2017) Recent Advances and Development of Corrosion Prevention Technologies for Marine Reinforced Concrete Structures. Materials Protection. 50(3):62-67.

[5] Yiyong Peng, Lu Shen. (2017) Comparative Study on Treatment Methods of Corrosion Resistant Steel for Bridge Engineering. Northern Communications. (8):1-3.

[6] Yuwen Zhang. (2017) Corrosion of Steel Rods in Reinforced Concrete and Protection Research Progress. 31(6):44-49.

[7] Yanbing Yang, Yunpu Xu, Yingfei Wang, Jianbo Xiong, and Zhihong Fan. (2015) EIS study on coating damage of epoxy-coatings rebars. Port & Waterway Engineering. (5):40-43.