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A Review on The Research and Application Development of Adhesive Properties of Epoxy Resin Coated Steel Bar and Concrete

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Abstract

Based on the understanding of the bond mechanism of epoxy resin coated steel bar and concrete working together, combined with the performance parameters of epoxy resin coated steel bar, the research work on bond anchoring between epoxy resin coated steel bar and concrete at home and abroad is summarized. It provides some help and reference for the application of epoxy resin coated steel bar in building structure under certain environment, and has certain practical significance.

Keywords

Epoxy resin coated steel bar; bond strength; bond property; engineering application.

1. INTRODUCTION

In the structure of reinforced concrete working together, it is common to see structural damage caused by steel corrosion, and structural damage caused by steel corrosion is also one of the most common forms of damage in concrete structure. The corrosion of steel bars can cause a series of engineering problems, such as the decrease of tensile properties of steel bars, the decrease of bonding properties between steel bars and concrete, and the loss of protective layer of concrete due to corrosion and expansion of steel bars. Thus the structure is damaged or even completely failed.

In order to solve a series of engineering problems caused by corrosion of steel bars, epoxy resin coated steel bars have been widely used in eastern coastal areas and western salt lake areas. Because of a series of advantages of epoxy resin coated steel bars, it has become the optimal solution to the problem of steel bar corrosion in current engineering. In the practical application of epoxy resin coated steel bar, the bond between steel bar and concrete is the basis of their joint work, and it is also the focus of domestic and foreign scholars. Based on the bonding mechanism between reinforcement and concrete, this paper summarizes the research results and some engineering cases on the bonding properties between reinforcement and concrete coated with epoxy resin at home and abroad. It is hoped that it can provide help for the practical engineering application of epoxy resin coated steel bar.

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2. BOND MECHANISM OF REINFORCED CONCRETE

2.1. Bond mechanism of reinforced concrete

2.1.1 Research significance of bonding anchoring problem

In reinforced concrete structures, the interaction between concrete and steel occurs when there is relative slip or tendency or relative deformation between steel and concrete. Under the interaction, the longitudinal shear stress along the steel bar is the bonding force between the concrete and the steel bar. The bond property between concrete and steel bar is the basis to ensure the joint action of both, so the bond anchoring problem is the most basic problem in the research of reinforced concrete members.

2.1.2 Composition of bonding force

When the epoxy resin coated steel bar in the concrete is deformed and slipped by the axial external force (F), the bonding force between the concrete and the steel bar, as shown in Figure 1, is composed of three parts: adhesive force, friction resistance and mechanical bite force.

(1) The contact surface of cement gel and coated steel bar will produce chemical adhesive force, and the adhesive force only exists in the area without relative slip in the reinforced concrete member and is very small. When the coated steel bar and concrete have relative slip, there is no adhesive force between them.

(2) Oblique frictional resistance (f) is caused by the coated steel bar being held by concrete, and the frictional resistance is determined by the extrusion pressure between the coated steel bar and concrete and the roughness of the contact surface between the two, and the two are often positively correlated.

(3) The mechanical bite force (p) is due to the mechanical bite between the surface of the ribbed steel bar and the concrete. The mechanical bite force can be divided into horizontal component (τ) and vertical component (σ), which are shear bonding force between the coated steel bar and the concrete and vertical pressure on the concrete, respectively. Mechanical bite force is the most important component of the bonding force between coated steel bar and concrete.

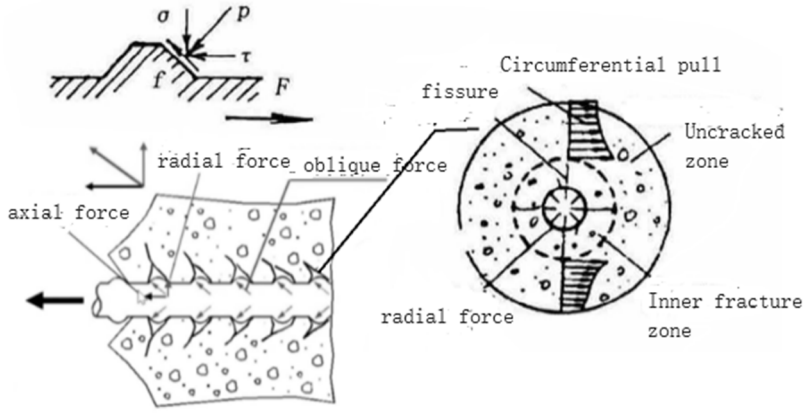

Figure 1. Schematic diagram of bond failure of deformed steel bars

3. MAIN CHARACTERISTICS AND MECHANICAL PROPERTIES OF EPOXY RESIN COATED STEEL BAR

Epoxy resin coated steel bar is the ordinary steel bar surface grinding, polishing and other operations, after meeting the specification JG/ T502-2016 steel bar surface purification quality technical indicators, the steel bar is heated to make its surface temperature reach 260 degrees

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Celsius. The epoxy resin powder is sprayed on the steel bar by electrostatic spraying process to form a continuous and uniform epoxy resin protective layer on the surface of the steel bar to prevent electrochemical corrosion on the surface of the steel bar, so as to meet the needs of the corrosion protection of the steel bar.

Generally, the coating thickness of epoxy resin coated steel bar should be controlled between 0.18 and 0.3mm, and the maximum coating thickness of steel bar with a diameter greater than or equal to 20mm is 0.4mm. Compared with other coated steel bars, epoxy resin coated steel bars have good performance in coating continuity, coating flexability, impact resistance and coating adhesion. For example, in the bending experiment, the epoxy resin coating can bend the steel bar 180° without cracking, which is difficult to achieve with other kinds of coatings. At the same time, the specification has clear provisions on the packaging, transportation, storage and on-site protection of epoxy resin coated steel bars, which is more convenient for the production line of this type of steel bars. Therefore, epoxy resin coated steel bars are very suitable for anti-corrosion operations in building structures.

The epoxy resin coated steel bar also has excellent performance in other mechanical indexes. Taking the HRB400E epoxy-coated steel bar with a diameter of 16mm produced by Shanghai Fu Steel Company as an example, the yield strength and tensile strength of this type of steel bar are $0.4550\,\mathrm{kN/mm^2}$ and $0.605\,\mathrm{kN/mm^2}$, and the strength and yield ratio are 1.33% and 1.14%, respectively. At the same time, this type of epoxy resin coated steel bar also meets the requirements of bending test and reverse bending test. It can be seen that the mechanical properties of epoxy resin coated steel bars are very excellent, and can be used as building materials instead of ordinary steel bars in many cases.

4. THEORETICAL RESEARCH STATUS OF EPOXY-COATED STEEL BARS AT HOME AND ABROAD

Since the eighties of last century, foreign scholars have studied the bonding properties between epoxy resin coated steel bars and concrete. The research in this direction is mainly divided into three aspects: determination of bond strength between epoxy resin coated steel bar and concrete, various influencing factors of bond strength between the two, and establishment of load-slip curve. After decades of exploration at home and abroad, a series of research results have been obtained.

American scholars have carried out an experiment on the bond strength of epoxy coated steel bar and concrete, and compared it with ordinary steel bar. In 1990, Choi et al.[1] studied the bond strength of epoxy-coated steel bars with different diametries. Compared with common ribbed steel bars, they concluded that the bond strength ratio of 16mm, 19mm, 25mm and 35 steel bars with ribbed steel bars of the same diameter was 0.88, 0.89, 0.82 and 0.83. Similarly, in 1998, Grundhoffer[2] obtained through experiments that the ratio of adhesion between epoxy resin coated steel bars and ordinary ribbed steel bars with three diametric diametric values of 19mm, 25mm and 35mm was 0.96, 0.91 and 0.79. The team of Chen Xingguo[3] in China measured the bond strength between epoxy-coated steel bars and ordinary steel bars with a diameter of 16mm and concrete. The average bond strength of coated steel bars is 0.00825, and that of ordinary steel bars is 0.00869. The ratio is about 0.95. It can be seen from the above experiments that the bond strength between epoxy resin coated steel bars and concrete can reach 85% to 95% of ordinary steel bars.

While studying the bond strength between concrete and epoxy-coated steel bar, scholars are also exploring the influence of various factors on the bond performance between the two. Meng Yang's team studied the effects of surface shape, coating thickness, inner protective layer thickness of concrete, hoop ratio and concrete strength on the bonding properties of epoxy resin coated steel bars.[4-5] The experimental results show that the bonding properties of steel bars

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and concrete can be improved by changing the surface shape of steel bars or increasing the coating thickness to a certain extent to increase the surface shape parameters of steel bars. For concrete, stirrup configuration, strengthening of concrete and thickness of protective layer can significantly improve the bond between coated steel bars and concrete. Yang Liu[6] studied the effects of reinforcement bond length, concrete protective layer thickness, reinforcement diameter, concrete strength and hoop ratio on the bonding properties between epoxy-coated steel bar and seawater sand concrete through central pull-out experiments. The study shows that the change of the above five variables will affect the bonding property between the epoxy resin coated steel bar and concrete, but the influence of different variables is different. The thickness of the protective layer and the anchorage length of the reinforcement both lead to the change of the failure form of the component. The diameter of the reinforcement has more influence on the slip amount of the reinforcement in the concrete, and the configuration of stirrup significantly increases the ultimate bond strength between the two, while the concrete strength has little influence on the bond performance of the two.

The ultimate goal of research on the bond performance of epoxy resin-coated steel bars and concrete is to establish the bond slip constitutive relationship between them. Xu Youlin of the Chinese Academy of Construction Science and Technology used the method of internal strain gauge of steel bars to calculate the five-stage bond slip constitutive relationship formula through statistical regression[7]. The detailed calculation formula of the bond anchorage constitutive relationship is shown in Figure 2. This model has also become the main calculation model of the constitutive relationship between epoxy resin coated steel bar and concrete.

Microslip stage: $\tau = \tau_s \sqrt[4]{\frac{S}{S_S}}$ $0 < S \le S_S$

Slip stage: $\tau = K_1 + K_2 \sqrt[4]{S}$ $S_S < S \le S_{cr}$

Splitting stage: $K_3 + K_4 S + K_5 S^2$ $S_{cr} < S \le S_u$

declining stage: $\tau = \tau_u - \frac{\tau_u - \tau_r}{S_r - S_u}(S - S_u)$ $S_u < S \le S_r$

Residual stage: $\tau = \tau_r$ $S > S_r$

$K_1 = \tau_{cr} - K_2 \sqrt[4]{S_{cr}}$, $K_2 = \frac{\tau_{cr} - \tau_s}{\sqrt[4]{S_{cr}} - \sqrt[4]{S_s}}$, $K_3 = \tau_u - K_4 S_u - K_5 S_u^2$

$K_4 = \frac{2S(\tau_u + \tau_{cr})}{(S_u - S_{cr})^2}$, $K_5 = -\frac{\tau_u - \tau_{cr}}{(S_u - S_{cr})^2}$

Figure 2. Detailed calculation formula of Xu You lin model

5. APPLICATION CASE OF EPOXY RESIN COATED STEEL BAR AND FEASIBILITY DISCUSSION

In 1977, the state of Virginia in the United States took the lead in applying epoxy-coated rebar to its 18 bridge decks, and evaluated the epoxy-coated rebar in these Bridges 18 years later[8]. In the 1990s, the Bank of China Building in Hong Kong used epoxy resin coated steel bars for the first time, and then epoxy resin coated steel bars began to be widely used in China's construction industry. For example, the Beijing West Railway Station used epoxy resin coated steel bars to solve the engineering problem of ice salt corrosion of steel bars in winter. The pier projects represented by Shantou LPG Pier and Majishan Port ore Pier and the bridge projects represented by Xiamen Huandao Road Sea Bridge, Ningbo Bridge and Yuehai Trestle Bridge all use epoxy-coated steel bars[9].

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At the same time, the feasibility of epoxy-coated steel bars in a wider range of projects is also worth discussing. According to the above introduction, epoxy-coated steel bars have many advantages in performance. From an economic point of view, although the cost of epoxy resin coated steel bars is lower than that of other types of anti-corrosion steel bars such as glass fiber bars, the production is simpler, but in actual engineering, compared with ordinary steel bars, coated steel bars require more complex production technology, larger anchoring length, and higher transportation costs, resulting in rising construction costs. Zhang Yanji et al. 's research shows that: The additional labor cost and construction cost generated by the adoption of epoxy resin coated steel bars have reached 25% of the total project cost[10]. For more common civil buildings, there are still many economic problems waiting to be solved in the application of epoxy resin coated steel bars.

6. CONCLUSION

The bond performance between epoxy resin coated steel bar and concrete can reach more than 85% of ordinary steel bar. Under the joint action of coated steel bar and concrete, the bond performance of the two is affected by the coating thickness of steel bar, surface shape, anchoring length, concrete protective layer thickness, concrete strength and hoop ratio, etc. The above factors will not only change the bonding force between the steel bar and the concrete, but also change the failure mode of the member and the relative slip amount between the steel bar and the concrete. In addition, the constitutive relationship between epoxy resin coated steel bars and various concrete is still scarce.

Epoxy-coated steel bar After decades of development, steel bar production process and national standard requirements have been very mature. In practical engineering, the service life of steel bars can be significantly increased, and satisfactory results have been obtained in practical engineering. There are enough reasons to believe that the development and application prospects of epoxy resin coated steel bars are very bright.

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REFERENCES

[1] Grundhoffer T, Mendis P A, French C W, et al: Bond of Epoxy-Coated Reinforcement in Normal and High-Strength Concrete,Special Publication, Vol. 180 (1998), p.261-298.

[2] Choi O C, Hadje-Ghaffari H, Darwin D, et al: Bond of Epoxy-Coated Reinforcement to Concrete: Bar Parameters,Bond of Epoxy-Coated Reinforcement to Concrete: Bar Parameters, Vol. 180 (1990), p.261-298.

[3] X.G. Chen. Test and application of epoxy resin coated steel bar, Fujian Construction Technology, vol. 02 (2019), 16-18.

[4] Y. Meng. Analysis of the influence of coating surface shape on the bonding and anchoring performance of epoxy resin coated steel bar and concrete, project quality, vol. 33 (2015), 79-82.

[5] Y. Meng. The influence of the internal structure of concrete on the bonding and anchoring performance of epoxy resin coated steel bar and concrete, project quality, vol. 33 (2015), 37-42.

[6] L. Yang: Experimental study on bonding properties of epoxy coated reinforced seawater sand concrete (MS., Dalian University of Technology, China 2020), p.28.

[7] Y. L. Xu: Experimental study on bond anchoring mechanism of steel bar,The second Symposium on Basic Theory and Application of Concrete Structures (Beijing, China, August , 1990). Vol. 1, p.154.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202406_10(6).0002

[8] Wioletta A. Pyc, Richard E. Weyers, Michael M. Sprinkel, Ryan M. Weyers: Field Performance of Epoxy Coated Reinforcing Steel in Concrete Bridge Decks in Virginia,Concrete International, Vol. 22 (2000) No.2, p.305-307.

[9] J. Z. Cao: Application of epoxy resin coated steel bar in reinforced concrete structure,The 12th China Coastal Engineering Symposium (Beijing, China,, 2005). p.791-793.

[10] Y.J. Zhang. Cost-benefit analysis of epoxy resin coated steel bar, Modernization of shopping malls, vol. 26 (2008), 158.