

# Research on Anchorage Performance of Grouting Anchor Connection of Precast Concrete Structure

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**Abstract.** The bonding of grouted anchor bars is one of the vertical connection forms of steel bars in fabricated concrete structures. The performance of grouted connection is mainly affected by the anchorage length and lap length of steel bars. The mechanisms of bond and anchorage between steel bar and concrete are analyzed, and the factors that influence the anchorage performance of steel bar are systematically summarized. Results show that the bond and anchorage performance of steel and concrete have been studied widely, but there are still shortcomings, and the connection forms need to be further improved.

## 1. Introduction

In China, the majority forms of residence are reinforced concrete structure, precast concrete structure is the only way to industrialize the production of reinforced concrete structure, the first to complete the component manufacturing in the production base, and then shipped to the construction site for assembly and forming [1]. A large number of engineering practice at home and abroad show that the system of precast concrete structure is one of the effective ways to realize the industrialization of residence, not only can meet the requirement of scale, standardization, quality and safety, energy saving and environmental protection, and can significantly shorten the construction period. Currently, the study about the use of precast concrete structure is of great significance, which is an important issue to promote the industrial construction of China's housing [2].

In developed countries, precast concrete structure has been developed more mature, but in China is still in the stage of research and application. The key of precast concrete structure is to solve the connection between steel bar and concrete interface, and the structure can be in good integrity based on the connection between precast components.

## 2. Anchoring performance analysis

### 2.1. Anchoring mechanism of reinforcement

The bond anchorage between reinforcement and concrete consists of three parts:

- 1) The chemical adsorption of cement colloid and steel surface in concrete is also called cementing force;
- 2) The friction between concrete and steel produced by shrinkage of reinforced concrete;



3) The surface of steel bar is uneven, and the steel and concrete interacts each other to produce mechanical interaction force.

Among them, mechanical interaction force is the main component of bond anchorage. Reliable anchorage reinforcement in concrete is to ensure the full use of the steel in concrete strength, which reinforcement with sufficient anchorage length [3].

The bonding strength of deformed reinforcement depends on the surface deformation of reinforced rib and mechanical interaction force of concrete, so the bonding between reinforcement and concrete are greatly improved by the deformed reinforcement. In the early stage of loading, the steel bar began to slip with the increased load, and the extrusion effect of ribs on concrete and the friction effect between reinforcement and surrounding concrete are the main part of sliding resistance. The radial component of the extrusion force, which produced by the oblique extrusion force of the rib, makes the circumferential concrete hoop pull. The occurrence of splitting cracks at the loading end does not indicate the depletion of the bond strength, but indicates the local failure of the loading end [4].

## 2.2. Basic anchorage length

The basic anchorage length is the minimum anchorage length, which to ensure the stressed steel bar do not occur bonding failure until yielded. Based on the pull-out test and the reliability calculation and the verification test, the basic anchorage length of the tensile steel bar is given in specification for concrete structures:

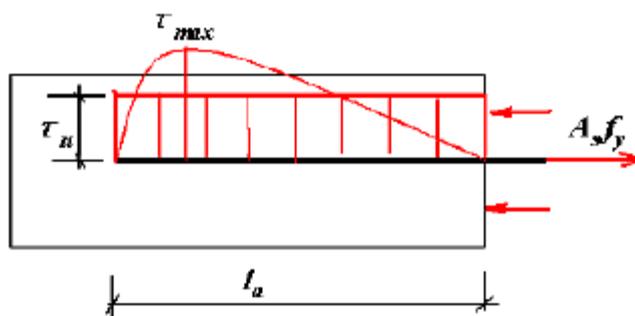
$$l_a = \alpha (f_y / f_t) d$$

Type:  $f_y$  —Tensile strength design value of tension reinforcing bar, MPa;

$f_t$ —Design value of axial tensile strength of concrete in Anchorage Zone, MPa;

$d$ —Diameter of anchor bar, mm;

$\alpha$  —Shape coefficient of anchored steel bars, in Table 1



**Figure1.** Bonding Stress Distribution

The bonding force acting on the unit area of the reinforcement surface is the bonding stress  $\tau$ , which is a shear stress, at the interface between the reinforcing bar and the peripheral concrete. The distribution diagram of the bonding stress is given in figure 1.

**Table 1.** Reinforced Shape Factor  $\alpha$

Reinforcement type	Round steel	Ribbed steel bar	Scoring bars	Spiral rib wire	Three stranded strand	Seven stranded strand
$\alpha$	0.16	0.14	0.19	0.13	0.16	0.17

## 3. Factors affecting the bond anchorage performance

### 3.1. Concrete strength

Teng Zhiming and other scholars, discussed the the influences of the thickness of the covers, rebar diameter and bond stress distribution and other factors on the performance of reinforced anchorage through the axial tensile test of 12 concrete specimens and pullout test of 92 reinforced concrete specimens[5]. The results show that the relative thickness of protective layer  $c/d$  is the main factor

affecting the bond stress and bond strength of cracking. As the thickness of the protective layer increases, the splitting resistance of the peripheral concrete can be improved, so that the cracking bond stress is increased accordingly.

In 2016, Zhao Yuxi et al. carried out the pull-out test of 16 reinforced concrete beam end specimens with different thickness and spacing of stirrups [6]. The results show that the ultimate bond strength can be significantly improved by increasing the thickness of the protective layer, and the ultimate bond strength increases linearly with the increase of the thickness of the protective layer. And the formula of ultimate bond strength considering the thickness and strength of concrete, the number of stirrups and the length of anchorage bond is put forward.

### *3.2. Anchoring length and lap length*

In 2008, Zhang Haishun carried out the anchorage test and lap joint test of bonded grout anchor. First of all, with steel diameter and anchorage length as parameters and 81 anchor bolt anchorage specimens are designed with concrete strength. The tests show that the anchorage length can be reduced, and the safety and reliability of anchor bar can be guaranteed by using restraint grouting anchoring, anchoring test for restraint grouting anchoring overlap joint of steel bar test provides a good foundation. In test on lap joint of restrained grouted steel bar, 108 specimens were completed as the parameters of concrete strength, longitudinal reinforcement diameter and lap length. In the experiment, the bond length has been reduced, the shortest is 0.3 times the design of lap length, longitudinal reinforcement lap length reasonable is derived through damage phenomenon and analysis of test data. Considering the reliability requirements of the structure and the actual construction deviation, reasonable lap length is 1 times the basic anchorage length, namely 1.0la. Then the reasonable lap length is applied to the actual precast shear wall specimens, through the pseudo static test of precast shear wall, Bonding connection mode of binding slurry anchor steel bar is verified to be reliable and meets the current specifications and actual construction requirements [7,8].

In 2010, Zhao Pei studied the relationship between stirrup ratio and lap length of spiral stirrups, and carried out a large number of experimental research. With lap length and stirrup ratio as parameters and 123 specimens were completed by using bonded lap joint. The law between stirrup ratio and lap length of spiral stirrup is obtained by combining the test phenomenon, stirrup strain and applied load. In addition, the core area of the spiral stirrups is analyzed, and the simplified model of the core force is obtained. The formula for the relationship between stirrup ratio and lap length of spiral stirrups is established. By comparing with the experimental data, the lap length of steel bars is determined to be 1 times of the basic anchorage length [9].

In 2014, based on the previous research results, Ni Yinghua studied the ultimate lap length of bonded lap joints [10]. With the parameters of steel bar diameter, spiral stirrup ratio and lap length as the parameters, a total of 54 lap joint specimens were completed. By changing the lap length and stirrup ratio, the ultimate lap length of three kinds of diameter steel bars is determined by means of specimen failure and test data. Finally, the ultimate lap length of three kinds of diameter steel bars is given.

### *3.3. The influence of other factors*

The shape characteristic of reinforcing steel has obvious influence on bond strength. The bond strength of ribbed bars is much higher than that of smooth steel bars. The bond strength of ribbed steel bars in China is about (2.5 -6.0) MPa, and that of smooth steel bars is (1.5-3.5) MPa. Xu Youlin et al. carried out 334 different kinds of steel bars and different types of pull-out test specimens in China Academy of Building Research [11]. The bonding and anchoring mechanism of Deformed Reinforcement and smooth steel bar are discussed, the influence of various factors on the bond strength between steel bar and concrete is analyzed, and the formula of bond strength is obtained.

M.Reza Esfahani and B. Vijaya Rangan studied the effect of transverse reinforcement on lap bond strength [12]. The influence of transverse reinforcement on the lap strength is determined by the lap test of 138 standard strength reinforced concrete bars. The test show that If the stirrups are arranged in the beam, the development of the splitting cracks or the width of the cracks can be delayed, and the bond strength can be improved. The contrast test of the specimens without stirrups and stirrups shows

that the bond strength will be increased with hoop reinforcement, and the increment of the bond strength is basically proportional to the stirrup ratio in the protective layer.

#### 4. Conclusion

In this paper, the bond and anchorage performance between concrete and steel bars in precast concrete members is summarized. With the development of the research and the increasing demand for housing, prefabricated concrete structure is an effective way to promote the construction industry. Grouting anchor connection technology has achieved rapid application and development in China, because of its safety, reliability and low cost. But for this technology, there are still shortcomings of longer lap length and lower bearing capacity. Therefore, further research and development of more reasonable form of connection is very meaningful.

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