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# Review on Shear Performance of Anchor Bolt in Post-anchoring Technology

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**Abstract:** Post-anchoring technology is the key means of building structure reinforcement and reconstruction, and the shear performance of anchor bolt directly affects the structural safety. This paper systematically reviews the research results on the shear performance of anchor bolts at home and abroad, and focuses on the shear mechanism and test findings of planting bars, chemical anchor bolts, embedded parts and direct shear anchor bolts. The domestic research reveals the influence of connection mode and thread shape on the cooperative force of group anchors through comparative tests. It shows that the shear performance of the anchorage nut fixation method is better, and the stiffness of the direct shear anchor bolt is more than 3 times that of the ordinary anchor bolt. The foreign research established the standard system earlier, and put forward the concrete cone failure model and the multi-stage stress theory. At the same time, the key influencing factors such as anchor bolt diameter, embedded depth and edge distance are summarized, and the differences between Chinese and foreign standard calculation methods are compared. The shortcomings of current research in complex environmental adaptability and group anchor coordination mechanism are pointed out, and the future research direction is prospected. This paper provides a reference for the engineering application and academic research of post-anchoring technology.

**Keywords:** Post-anchoring Technology, Anchor Bolt, Shear Performance, Group Anchor Coordination, Experimental Study, Norm Comparison.

## 1. Introduction

In the field of reinforcement and reconstruction of building structures, post-installed anchorage technology has become the core technical means to connect existing structures and new components with the advantages of convenient construction, controllable cost and strong adaptability. Among them, the anchor bolt is the key stress component of the post-anchoring system, and its shear performance directly affects the overall safety and reliability of the structure. With the improvement of the requirements for reinforcement accuracy and bearing capacity of modern buildings, the mechanical behavior, failure mechanism and design method of anchor bolts under shear force have become a research hotspot.

In recent years, scholars at home and abroad have carried out a large number of experimental and theoretical studies on the shear performance of different types of anchors such as chemical anchors, embedded bars, and embedded parts. The influence of anchor type, thread shape, group anchor synergy, embedded depth, edge distance and other factors on the shear capacity is discussed, and the corresponding design calculation method is proposed. This paper systematically reviews the research results of the shear performance of anchor bolts in post-anchoring technology, summarizes the key influencing factors and failure laws, compares the mechanical properties of different types of anchor bolts, and finally points out the existing problems and future development directions of the current research, so as to provide reference for engineering practice and academic research.

## 2. Research Status at Home and Abroad

### 2.1. Domestic Research Progress

Through one-way shear test, Liu Yulun and Xu Fuquan compared the shear performance of embedded parts, chemical anchor bolts and planting bars in the case of group anchors, and designed 8 groups of specimens ( 2 groups of embedded parts, 2 groups of chemical anchor bolts and 4 groups of planting bars )[1].Considering the influence of anchor bar diameter ( 12mm, 20mm ) and connection mode ( perforated plug welding, nut fixing ), the edge distance factor is not involved. The test results show that all specimens are damaged by steel, and the load-displacement curve can be divided into elastic stage and plastic growth stage. The anchor bar is in a bending-tensile-shear composite stress state under the action of shear force ; the force mechanism of the embedded bar welding is similar to that of the embedded part ( showing a double bending curve ), while the embedded bar nut fixation is similar to the chemical anchor bolt ( one-way bending curve ). It is found that the shear performance is better when the planting bar is fixed by nuts, and the internal force distribution of the anchor bar is more uniform. A calculation method for the shear capacity of the group anchors suitable for this connection method is proposed.

The test further reveals the stress difference between the embedded bar, the embedded part and the chemical anchor bolt : the embedded part is due to the root welding foot effect, the section of the anchor bar is below the surface of the concrete, and the damage is accompanied by the local crushing of the concrete ; when the anchorage nut is fixed, the section of the anchorage bar is flush with the concrete surface, the surrounding concrete appears fan-shaped cracks, and the shear displacement is large. The shear displacement of the chemical anchor bolt is small, but the initial uneven force is significant.

In order to solve the problem of non-coordination of ordinary anchor bolts, Xu Yili 's team developed a double-anchor shear test method and carried out a series of comparative tests[2] : 6 groups of half-threaded single anchors were compared with 6 groups of full-threaded single anchors, and 5 groups of ordinary anchors ( double anchors, three anchors, four anchors ) were compared with 5 groups of direct shear group anchors. The results show that the shear performance of the semi-threaded anchor bolt is better than that of the full thread, the ultimate load is about 1.2 times that of the latter, and the initial stiffness is increased by 20 %. The load-displacement curve of the direct shear group anchor has small discreteness, no obvious platform section, and the overall stiffness is more than 3 times that of the ordinary group anchor. The failure modes of each anchor bolt are consistent, and the synergistic force performance is significant.

Zhang Xinxiang andLiu Jiadifurther studied the shear performance of direct shear anchor bolt group, and designed 12 groups of single anchor ( half thread, full thread ) and 10 groups of group anchors ( ordinary three anchors, direct shear three anchors )[3][4]. The diameter of the anchor bolt is 16mm, the buried depth is 8d, and the concrete strength is C40. It is found that the initial stiffness of the semi-threaded single anchor is 1.8 times that of the full thread and 2 times that of the group anchor. The ultimate bearing capacity of direct shear three anchors is 40 % higher than that of ordinary three anchors. The load-displacement curve is stable and there is no local mutation, which proves that it can effectively solve the problem of uneven force of group anchors.

Through the chemical anchor bolt group anchor test, it is found that the front anchor bolt in the four-anchor form first undergoes edge damage, and the rear anchor bolt is finally cut off. The overall bearing capacity is lower than the single anchor superposition value[5]. It is recommended to introduce a reduction factor of 0.7 to 0.8 to correct the design value. The test of string on 195 single anchors with different sizes shows that when the diameter of anchor bolt is less than or equal to 16 mm, the concrete strength has little effect on the shear performance. When the diameter is greater than or equal to 20 mm, the concrete below C40 has a significant effect on the initial stiffness. When the buried depth is 6d ~ 8d, the bearing capacity increases significantly with the increase of buried depth, and the increase slows down after more than 8d[7].

In terms of the application of the specification, Zhang Chunlin compared the domestic and foreign specifications and found that China 's " Technical Specification for Post-Anchorage of Concrete Structures " ( JGJ 145-2013 ) refers to the European ETAG standard, adopts the concrete cone failure model, and considers the reduction of edge distance and spacing[6]. The American ACI specification assumes that the group anchors are uniformly stressed, and the ductility reduction factor is introduced. The European specification is stricter, and only the maximum anchor bolt is checked. The method in China is conservative but safer.

### 2.2. Foreign Research Progress

The research on post-installed anchorage technology in foreign countries started earlier and formed a relatively complete theoretical system and normative standards. Through a series of tests, Eligehausen et al.proposed that the shear process of anchor bolts can be divided into five stages : friction force transmission, anchor plate slip, direct force transmission, local crushing of concrete and steel failure. It is clear that the bearing capacity and ductility of steel failure mode are better than that of concrete edge failure. Based on the limit state design method, the American code ACI 318-14 stipulates that the shear bearing capacity of anchor bolts should consider three modes of steel failure, concrete wedge failure and shear prying failure, and the reduction coefficient is introduced to adapt to different stress scenarios.

The European ETAG 001 Guide proposes a concrete bearing capacity design method ( CCD method ) through a large number of tests. It is considered that the concrete failure cone and the edge are at an angle of 35 ° when the anchor bolt is sheared, and the bearing capacity is proportional to the 1.5th power of the edge distance. There is no mutual influence when the group anchor spacing is ≥ 3 times the edge distance[8].

ACI 318-14 of the United States stipulates that the calculation of the shear capacity of the anchor bolt needs to distinguish between steel failure and concrete failure. The group anchor needs to consider the non-uniformity coefficient, the ductility material reduction coefficient is 0.75, and the brittle material is 0.65.

German Eligehausen divided the shear process of anchor bolt into five stages : friction force transmission, slip, direct force transmission, concrete crushing and steel failure[9]. It is pointed out that the ultimate displacement of steel failure is composed of shear deformation, bending deformation and concrete crushing deformation, which makes full use of material properties more than concrete failure[9].

The shear test of embedded parts by Tantrung Bui shows that the edge distance and spacing are the key factors affecting the failure of double anchors. When the spacing is more than 3 times the edge distance, the bearing capacity of group anchors is the sum of single anchors. Otherwise, the influence of concrete wedge overlap should be considered.

## 3. Key Influencing Factors of Shear Performance of Anchor Bolt

### 3.1. Anchor Bolt Type and Connection Mode

The shear performance of different types of anchor bolts is significantly different. The embedded part is connected with the anchor plate by piercing plug welding. When the anchor bar is sheared, the welding foot of the root of the anchor bar will cause the section to be below the concrete surface, and the failure mode is synchronous shear of steel. The chemical anchor bolt is fixed by nut. In the early stage of loading, the force is uneven due to the gap between the anchor bar and the anchor plate. In the later stage, it gradually cooperates with the increase of load, but the overall stiffness is low.

The connection mode of the embedded bar has a significant effect on the performance : when welding, the high temperature is easy to cause local failure of the embedded bar adhesive, and the stress mechanism is similar to that of the embedded part, and the double bending curve appears. When the nut is fixed, the force is closer to the chemical anchor bolt, which is one-way bending, and the internal force distribution is more uniform, and the shear performance is better. The direct shear anchor bolt is in close contact with the anchor hole through the hoop, and the synergy of the group anchor is significantly improved. There is no obvious platform section in the load-displacement curve, and the stiffness stability is better than that of the ordinary anchor bolt.

## 3.2. Thread Shape

The thread shape of anchor bolt directly affects the effective cross-sectional area and force transmission. The test shows that the shear performance of the semi-threaded anchor bolt is better than that of the full thread. Under the single anchor state, the initial stiffness of the semi-threaded anchor bolt is 1.8 times that of the full thread, and the ultimate load is increased by about 20 %. In the group anchor state, the cooperative force capacity of the semi-threaded anchor bolt is better and the stiffness fluctuation is smaller.

Due to the weakened section of the thread, the full thread anchor bolt is easy to cause stress concentration at the root of the thread during shearing, resulting in premature failure ; the semi-threaded anchor bolt only has a thread in the anchorage section, and the shear section is a smooth circular section, with a larger effective area and stronger plastic deformation ability.

## 3.3. Buried Depth and Edge Distance

The embedded depth is the core parameter affecting the shear bearing capacity of the anchor bolt. When the buried depth is 6d ~ 8d ( d is the diameter of the anchor bolt ), the bearing capacity increases significantly with the increase of the buried depth ; after more than 8 days, the increase tended to be gentle. The test of Liu Yulun et al.shows that when the anchorage depth of planting bar and embedded parts is 15 days, the failure mode of steel can be guaranteed and the brittle failure of concrete can be avoided.

The edge distance plays a decisive role in the damage of concrete edge. When the edge distance is greater than or equal to 3 times the diameter of the anchor bolt, the risk of concrete wedge failure is reduced ; when the edge distance is insufficient, the reduction coefficient should be introduced to correct the bearing capacity. Tamon Ueda 's research found that for every 10 mm increase in edge distance, the shear capacity of group anchors can be increased by 5 % ~ 8 %.

## 3.4. Group Anchor Synergy

The force synergy of group anchors is the key to restricting the overall performance. Due to the construction error, the contact between the anchor bolt and the anchor plate is not synchronized. At the initial stage of loading, only part of the anchor bolt is stressed. With the increase of displacement, other anchor bolts gradually participate in the work. The load-displacement curve shows a platform section, and the overall bearing capacity is lower than the single anchor superposition value.

The direct shear anchor bolt realizes no gap contact between the anchor bolt and the anchor plate through the hoop preload, and the group anchor is subjected to synchronous force. The load-displacement curve is smooth and the discreteness is small, and the ultimate bearing capacity is close to the sum of the bearing capacity of the single anchor. The test shows that the overall stiffness of the direct shear three anchors is more than three times that of the ordinary three anchors, and the failure modes of each anchor bolt are consistent.

# 4. Shear Failure Mode and Characteristics of Anchor Bolt

## 4.1. Steel Damage

Steel failure is the most ideal failure mode, which shows that the anchor bolt is cut off, accompanied by obvious plastic deformation and good ductility. Its characteristics are as follows : the load-displacement curve first increases linearly ( elastic stage ), then enters the plastic growth stage, and finally suddenly cuts off ; the failure section is flat, and the anchor bolt material gives full play to its performance. This mode is more common in the case of sufficient buried depth ( ≥ 8d ) and large edge distance ( ≥ 3d ), and semi-threaded anchor bolts are more prone to such damage.

## 4.2. Concrete Edge Damage

The edge failure of concrete is brittle failure, which is characterized by the spalling of the fan-shaped wedge formed by the concrete around the anchor bolt, and the bearing capacity is low. Its characteristics are as follows : the load drops suddenly after reaching the peak value, and the displacement is small ; the angle between the failure surface and the edge is 35 ° ~ 45 °, which is significantly affected by the edge distance and concrete strength. The specification avoids such damage by introducing a margin reduction factor ( 0.7 ~ 1.0 ).

## 4.3. Skid Damage

The shear failure is more common in the anchor bolt with a shallow buried depth ( < 6d ), which is manifested as the bending of the anchor bolt along the concrete surface, accompanied by local crushing of the concrete. It is characterized by low bearing capacity and poor ductility, which often occurs in cantilever structures or scenes with too small edge distance. In the design, such damage should be avoided by increasing the buried depth or setting stirrup constraints.

# 5. Specific Engineering Application Cases

## 5.1. Reinforcement of Existing Building Beams

Engineering background : The concrete beam of an office building needs to be strengthened due to the increase of load. The anchor bolt steel plate reinforcement method is adopted. The beam span is 6 m. The original design bearing capacity is insufficient, and the shear bearing capacity needs to be increased by 30 %.

Scheme selection : direct shear anchor bolt ( diameter 16mm, half thread, buried depth 8d ), three anchor group anchors are arranged along both sides of the beam, with a spacing of 200 mm and an edge distance of 150 mm.

Application effect : After reinforcement, the shear capacity of the beam is increased from 180 kN to 250 kN, which meets the design requirements.

The load test shows that the maximum deflection of the beam is reduced from 15 mm to 9 mm, and the stiffness is increased by 40 %.

The anchor bolts were all damaged by steel and no concrete spalling occurred, which proved the synergistic force advantage of direct shear group anchors.

## 5.2. Connection between Steel Structure and Concrete Column

Engineering background : A new steel structure platform is added to a factory building. The steel column needs to be connected with the existing concrete column, and the horizontal shear force is about 120 kN.

Scheme selection : planting bar ( diameter 20mm, nut fixed, buried depth 15d ), group anchor arrangement 4, spacing 250mm, edge distance 200mm.

Application effect :

The shear bearing capacity of the joint is 140 kN, which exceeds the design value. The load-displacement curve is smooth and the ductility is good.

On-site monitoring shows that the displacement is stable in long-term use, and there is no loosening or crack propagation.

### 5.3. Bridge Bearing Reinforcement

Engineering background : The concrete at the bearing of a simply supported beam bridge is damaged, and it is necessary to repair and improve the shear capacity. The design shear force is 150 kN.

Scheme selection : chemical anchor bolt ( diameter 16mm, full thread, buried depth 10d ) and steel plate combination reinforcement, group anchor arrangement four anchors, spacing 180mm.

Application effect : the shear capacity of the bearing is increased from 100 kN to 160 kN after reinforcement, which meets the requirements.

After the fatigue test ( 2 million cyclic loads ), the anchor bolt did not loosen, and the steel plate and concrete worked well.

## 6. Existing Problems and Research Prospects

### 6.1. Insufficient Existing Research

The synergy mechanism of group anchors is not yet clear : the micro-mechanism of uneven force of ordinary group anchors lacks quantitative analysis, and the influence of the gap between anchor bolts and anchor plates on synergy needs to be further explored.

The research on the adaptability of complex environment is insufficient : there are few studies on the influence of environmental factors such as high temperature and corrosion on the shear performance of anchor bolts, and the existing results are mostly based on static load at room temperature.

The design method is conservative : the value of the reduction coefficient of the bearing capacity of the anchor group is conservative, which fails to give full play to the material performance, and the economy needs to be improved.

### 6.2. Future Research Directions

Multi-scale test and simulation: Combined with microscopic observation and numerical simulation, the evolution law of uneven force of group anchors is revealed, and a refined model considering gap effect is established.

Environmental adaptability research: The shear test of anchor bolt under high temperature, humidity and corrosion environment was carried out, and the durability design method was put forward.

Research and development of new anchor bolts: optimize the structure of direct shear anchor bolt ferrule, explore the application of composite anchor bolts, and improve mechanical properties and economy.

The specification system is perfect: based on a large number of test data, the reduction coefficient of the bearing capacity of the group anchor is modified to form a design method that is more in line with the actual project.

## 7. Conclusion

Significant progress has been made in the study of the shear performance of anchor bolts in post-anchoring technology. The influence of anchor bolt type, thread shape, buried depth, edge distance and other factors has been clarified, and a variety of bearing capacity calculation methods have been proposed. The direct shear anchor bolt has significant advantages in synergistic force and stiffness improvement, and the half-thread shape is more suitable for shear scenarios. In the future, it is necessary to further explore the group-anchor coordination mechanism and complex environmental adaptability, promote the optimization of the specification system, and provide more reliable technical support for engineering practice.

The sustainable development of post-anchoring technology will inject new vitality into the field of building structure reinforcement, and help the functional upgrading and safety guarantee of existing buildings, which has important academic value and engineering significance.

## References

[1] Y.L. Liu, F.Q. Xu, J. Xie, etc. Experimental study on shear behavior of anchorage group [ J / OL ]. Journal of Building Structures, Vol. (2025) (In Chinese).

[2] Y.L. Xu. Study on shear performance of direct shear anchor bolt [ D ]. (MS., Chongqing University, China 2019) (In Chinese).

[3] X.X. Zhang. Experimental study on shear performance of direct shear anchor bolt group [ D ]. (MS., Chongqing University, China 2016) (In Chinese).

[4] J.D. Liu. Experimental study on shear capacity of reinforced concrete beams strengthened with direct shear anchor plate [ D ]. (MS., Chongqing University, China 2021) (In Chinese).

[5] T.Z. Jiang. Experimental study on the mechanical performance of group anchors [ D ].(MS., Hebei United University, China 2013) (In Chinese).

[6] C.L. Zhang. Review on shear capacity of building anchor bolt [ J ].Industrial Construction, Vol. 37 (2007) (In Chinese).

[7] X. Zhang.Strings. Experimental study and numerical analysis of shear performance of single anchor bolt [ D ].(MS., Chongqing University, China 2016) (In Chinese).

[8] European Organisation for Technical Approvals (EOTA). ETAG 001: Metal Anchors for Use in Concrete [S]. Brussels, Belgium: EOTA,2006.

[9] Mahrenholtz, Philipp, Eligehausen, Rolf. Behavior of Anchor Groups Installed in Cracked Concrete Under Simulated Seismic Actions[C]. Proceedings of the Conference on Fracture Mechanics of Concrete Structures , Jeju, S. Korea, 2010.