

Research on the anchorage measures of reinforced concrete beam and wall plane external connection joint

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Abstract. In the external connection of the beam and wall, the anchorage of the end of the longitudinal reinforcement plays an important role in the bearing capacity of the whole node. Relevant information at home and abroad were reviewed in this paper. In this connection the existing anchor improvement measures research progress and application were summarized, which includes the improving and characteristics of visible beam or beam head, double anchor plate and so on. Put forward the problems to be further studied in the future.

Introduction

Reinforced concrete beam and wall plane connection joints are not uncommon in frame shear wall structure system. In the last few years, a lot of work has been done at home and abroad and has achieved a lot of research and engineering application results for this node. Existing standard in our country on basis of research results also made improvements, such as for the setting of the concealed column width, buttress, along the beam axis direction of the shear wall are given specific recommendations.

But in this connection using 90° standard bend hook or other mechanical anchoring measures if frame beam longitudinal reinforcement's diameter is large, or wall thick is small, usually encountered anchorage section of the horizontal projection length does not meet the requirements of the rules and standard of $0.4l_{aE}$ and this usually lead to brittle failure at the node. The so-called meet the anchorage requirements is that until the end of the steel yield, anchorage section of the strength is enough, sliding displacement of drawing end is small, beam crack is not malignant widening. The tensile stress of the steel bar is decreasing from the end of the drawing to the end of the steel bar, which requires that the anchorage reinforcement has enough horizontal section length, so that the reinforcement can yield before the large slip and crack. At the same time, under the same tension reinforcement effect, enough straight anchorage length will make critical reinforced section of shear force is small, effectively avoid reinforced pull off critical section concrete shear failure. Therefore, it is very important to study how to optimize the condition of reinforcement and reduce the length of the reinforcement. For this kind of situation, the present research has the following several aspects of the results.

1 Setting the transverse anchorage bars at the hook of the longitudinal reinforcement

This method is improved on the basis of the 90 degree bend hook anchoring at the end of the longitudinal reinforcement, by setting the transverse anchorage bars at the hook of the longitudinal reinforcement, the anchorage of beam longitudinal reinforcement in the wall is strengthened.

Zhihao Wang of Tsinghua University^[1] has adopted this method to strengthen the anchoring, and the anchoring schematic diagram is shown in figure 1, The method has the advantages of simple connection operation and good economic performance. The final test results show that this method has a certain degree of improvement of the deformation capacity of the test piece, and it shows that the anchorage of the longitudinal reinforcement in the wall is effective. But it is lack of essential and quantitative analysis on the effect of welding transverse reinforcement in the bending hook of longitudinal bars.

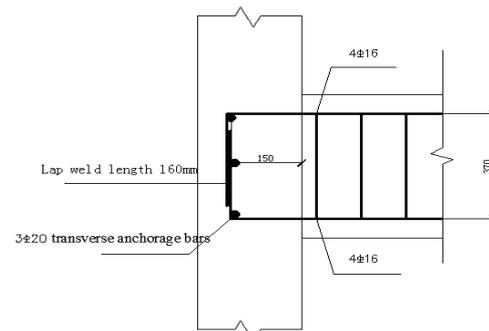


Figure 1. Anchorage details of beam longitudinal steel bars

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2 double anchor plate

With anchor plates or nut at the end of longitudinal reinforcement of beam provide greater bearing surface to help share the pulling force of the anchor bar. As is shown in the figure2 and 3, the tension is provided by the steel bar and the anchor plate. The United States, Canada, South Korea, Japan and China has carried out to set up research and development of the anchor plate at the end part of the longitudinal reinforcement, summed up the anchoring plate reinforced than traditional bending reinforced with obvious mechanics and engineering application advantages. In our country, the existing standard has specific requirements on the bearing area and thickness of the anchor plate, but the difficulty still lies in the problem of the horizontal projection length of the anchorage segment.

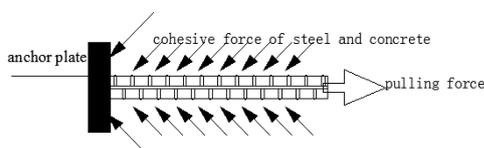


Figure 2. Reinforcement with double anchor plate



Figure 3. Reinforcement with anchor bolts

It is proposed by Qiaoling Gao of Chongqing University^[2] that the double anchor plate of the tensile steel plate and the anti sliding plate at the end of the beam longitudinal reinforcement as shown in figure 4 and 5. And the comparison of the test pieces with the tensile anchor plate measure only at the end of the longitudinal reinforcement. And in the case of thin walls, it was compared with the specimen only with tensile anchor plate measures at the end of the longitudinal reinforcement. Test results show that only welding tensile anchor plate although can improve the node bearing capacity but the plate in reverse loading will easily be pushed from the wall, and the use of double anchor plate increases the critical section area of pull-off failure and reduces the critical section of the uneven shear, it also effective the control of the "pull" and "shirk" damage and effectively improve the bearing capacity and ductility planar of the beam-wall connections. And through further theoretical analysis, the failure mechanism of the force model of the beam-wall plane external connection node is proposed. But it needs to be pointed out that although the double anchor plate measures can effectively improve the performance of the node, but the double anchor plate

measures exist a lot of inconvenience in the actual construction, especially when the wall is thin.



Figure 4. Reinforcement with double anchor plate

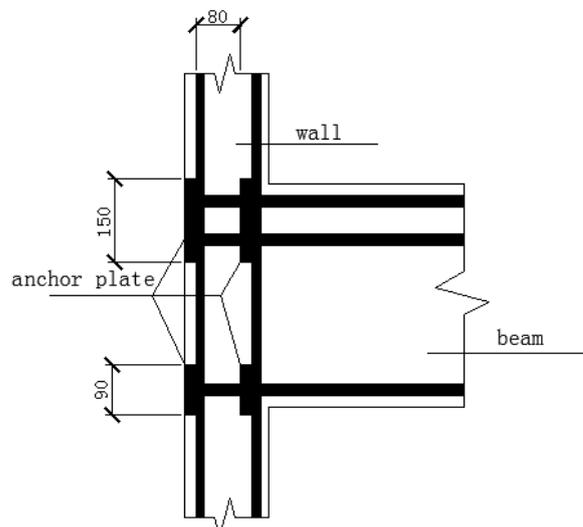


Figure 5. Schematic diagram of anchor plate

3 Visible beam and beam head

According to the specification that when the horizontal projection length of anchoring section does not meet the requirements, the floor beam can be put out of the wall to form a head beam, and the beam longitudinal reinforcement bent anchorage after extends into the beam head. And Zhiliang Li, Zujing Zhu of Chongqing University^{[3][4]}, completed 6 low cycle repeated load test of beam wall plane external connection node with the visible beam anchor measures and a preliminary approach to the design of the visible beam is presented. The two structures are shown in the figure below:

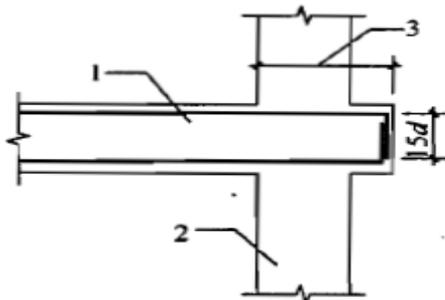


Figure 6. Schematic diagram of beam head

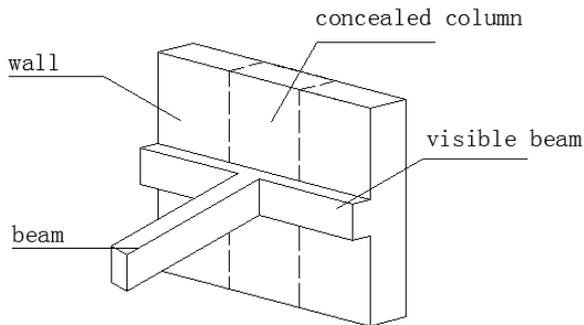


Figure 7. Schematic diagram of the visible beam structure



Figure 8. Schematic diagram of the visible beam

The two methods both can improve the anchorage performance, the bearing capacity and the ductility of the beam. But the common case is the frame core tube is connected with beam, the core tube is usually used as the elevator wells, and setting the beam head is not allowed. So there is a lot of limitations to set the beam head measures. And the setting of visible beam measures can effectively improve the bearing capacity and ductility of the node, And the deficiency is the process of construction is slightly complicated. the renovation will be needed in the late to avoid the lack of architectural aesthetics. But it is still a good choice to solve the problem of the lack of anchorage length by rational structure.

4 foreign related standards

4.1 ACI 318-02

The provisions of article 12.6 of the ACI318-02 code of the United States^[5] on the mechanical anchoring of steel bars are as follows:

- (1) Any mechanical device that can play the strength of a steel bar and does not damage the concrete can be used as anchorage;
- (2) External force of reinforcement composed by mechanical anchoring force and cohesion force of reinforced steel;
- (3) The full documentation of the mechanical anchoring device shall be provided in the contract issuing drawings, and shall be submitted to the relevant building authority.

4.2 ACI 352R-02

The relevant provisions of the United States ACI352R-02^[6] specification in section 4.5 on the use of steel bars with anchor plate in the joint shall be as follows:

- (1) reinforced with anchor plate should meet the A970 ASTM specification;
- (2) the anchor plate should be placed in the joint core concrete 50mm, the minimum anchorage length of ldt can not be less than 8db or 150mm;

4.3 CSA Standard CAN3-A23.3-94

The Canadian concrete structure design code 13.4.8 section CAN3-A23.3-94^[7] allows the use of a strip of anchorage plate shear reinforcement, as follows:

- (1)The reinforcement of the steel bar should be able to give full play to the yield strength of the whole reinforcement;
- (2)The head area of the reinforced head is at least 10 times the area of the reinforcing steel, unless the test proves that it can be used with a smaller size;
- (3)Total shear stress should not be more than $0.8 \lambda \phi_c \sqrt{f'_c}$ after multiplied by the coefficient, the total value is greater than 1.33 times the traditional shear stirrup component allowed.
- (4) The contribution of concrete should be not greater than $0.3 \lambda \phi_c \sqrt{f'_c}$ after multiplied by the coefficient, the value is greater than 1.50 times the total shear force of the traditional reinforced concrete members.
- (5)The increase of the shear capacity of concrete comes from the effect of the reinforcement provided by the reinforced bar.

5 Issues to be further studied

After the domestic vigorously advocate and a large number of scientific research institutions, enterprises and institutions continue to participate, the development of the exterior node of the beam-wall has made great progress and a lot of achievements. However, there are still many problems need to be further studied in the connection of the connection point with the hook or other mechanical anchoring measures: A lack of anchorage concrete bearing capacity calculation formula, so lack of detailed theoretical basis when using some other

measures to strengthen anchorage. Looking for engineering practice in the domestic application of anchorage strengthening measures to form with independent intellectual property rights that applicable to domestic engineering products and technologies, is the important issue in the future we still have to face.

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