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Research on the Application of Reinforced Concrete Building Structure Reinforcement Technology in Engineering

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Abstract

Old buildings because of long service life or natural damage, easy to appear durability, bearing capacity, stability decline, in order to ensure the safe use of building structure must take reinforcement measures. Increasing section method, carbon fiber cloth outsourcing, pasting steel plate method, planting reinforcement method and so on are commonly used reinforced concrete building structure reinforcement technology, but each technology is not the same application conditions and application effect. In this paper, the reinforcement and renovation project of a frame structure industrial plant in Tonglu, Zhejiang Province is taken as an example. Firstly, the basic ideas of reinforcement design and the basis of selection of reinforcement and renovation technology are outlined. Then, the application points of different reinforcement and renovation technologies are emphatically analyzed from four parts: basement frame column, first floor frame column, frame beam and sandwich structure. It provides some reference for the reinforcement and renovation of modern steel concrete building structure.

Keywords

Reinforced Concrete Building; Structural Reinforcement Techniques; Carbon Fiber Fabric; Reinforced with External Steel.

1. Project Overview

This industrial plant for four layers of reinforced concrete structure, including underground 1 layer, for the warehouse; There are 3 floors on the ground, the first floor is the production workshop, and the second and third floors are the offices. The seismic fortification intensity is 8 degrees. The building was completed and put into use in 2015. As a large number of production equipment and industrial raw materials were moved into the workshop, the existing structure could not meet the requirements of the current strength and standards, so it was necessary to strengthen and transform the beam, column and other parts of the building with relatively concentrated stress[1]. The transformation requirements are as follows: the open area in the middle part of the building is added to the floor, and the frame column of the atrium is increased from the original 0.7m to 4.2m; The top of the building was increased from 4.2m to 8.4m, and the height was increased to seal off the top. The new roof is light glazed with light steel structure. According to the design scheme of building structure reinforcement and transformation, the service life of the building shall reach 50 years after the completion of the reinforcement and transformation, and the safety grade shall be II.

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2. Application of Strengthening and Reforming Technology of Building Structure

2.1. The Basic Idea of Reinforcement Design

(1) Obtain engineering parameters of existing buildings through site investigation and collection of construction-related data, and use these parameters to establish building frame structure drawing in YJK software[2].

(2) Make use of the established calculation model of the building structure and combine with the reinforcement design requirements to carry out the force analysis and calculation of each layer structure, and judge which components need to take reinforcement measures according to the calculation results. Specifically, it can be divided into two cases: the first is for the calculation result M (deflection value) reinforcement area exceeds the limit, or the section of the original member is smaller than the calculation result, can increase the reinforcement effect of concrete member reinforcement and section. The second is that the section size of the existing member can reach the calculation standard after reinforcement, and the calculated value should also be compared with the actual reinforcement area of the member. According to the comparison results, if the reinforcement area of the building exceeds the actual reinforcement area of the beam and column[3], it indicates that the reinforcement design is feasible. Otherwise, it needs to be redesigned and calculated until it meets the requirements of the design specification.

(3) After the analysis determines the building components to be strengthened, the appropriate reinforcement and reconstruction methods should be comprehensively considered and selected in combination with the section design parameters of the existing components and the internal force diagram calculated after reinforcement. It should be noted that, for the selection of "increase the section method" reinforcement of all components, must be based on the section after the increase of the building model, recalculate the internal force and reinforcement, to ensure that the actual effect of the transformation and reinforcement can meet the requirements of the "Code for Design of concrete structure reinforcement" (GB50367-2013) and other related documents. If not, you need to readjust your design.

2.2. Design Reinforcement Scheme and Define Reinforcement Measures

2.2.1. Common Reinforcement and Reconstruction Method of Reinforced Concrete Structure

On the one hand, it is necessary to combine the design situation of the project, through obtaining the design parameters, understanding the reinforcement needs, etc., to scientifically select the applicable reinforcement technology; On the other hand, it is necessary to comprehensively consider the construction period, the degree of difficulty, construction cost and other factors, so as to select the best building structure transformation and reinforcement technology[4]. At present, there are several common reinforcement and reconstruction techniques as follows: The first is the method of increasing section, that is, increasing the reinforcement of members and repouring concrete, so as to increase the cross-sectional area of existing members on the basis of improving their bearing capacity. Its advantage lies in the low difficulty of construction technology, in the building beam, column and other components can be used. But its shortcomings are also more obvious, such as the new and old reinforced concrete joint site is easy to crack. The second is the external adhesive steel reinforcement method, that is, paste the section steel on the outside of the existing member, or connect the section steel with the member as a whole with stirrup, and use the outsourced steel to help the existing member share a part of the pressure, so as to achieve the purpose of strengthening and reinforcing. The advantage of this method is that it is flexible in operation and can be widely used to reinforce various components and different parts. At the same time, the amount of work

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is less, the construction period is short, the reinforcement effect is remarkable, it is a relatively ideal component reinforcement technology. The third method is pasting carbon fiber reinforced composite material. Carbon fiber is a kind of material with high tensile strength and light material, its thickness is only l ~ 3mm. Pasting it on the outside of the building member can achieve the reinforcement effect of pasting section steel[5]. But carbon fibre sheets take up almost no space and are cheaper to use.

2.2.2. Determination of Engineering Reinforcement and Renovation Method

After the stress analysis of the whole and local components of the existing building structure, it is shown that the building as a whole can bear the additional layer load, but there will be obvious stress concentration phenomenon in the individual parts of the beam and pillow. In order to avoid structural damage in these parts, it is necessary to take reinforcement measures. Based on the above analysis, it can be seen that there are several local strengthening technologies suitable for beam and column members, such as increasing section method, outsourcing section steel method and pasting carbon fiber cloth method. And the application of each kind of reinforcement technology, reinforcement effect is not the same. On the basis of site investigation, comprehensive consideration of construction cost, operation difficulty and other factors, finally decided to strengthen the basement frame, using the method of pasting carbon fiber cloth; For the first layer frame column, the reinforcement method of external section steel is adopted, and for the top frame beam, the composite reinforcement method of "pasting carbon fiber cloth at the bottom + pressure injection gluing steel at the top" is adopted. Compared with the conventional method of increasing section, these reinforcement and reconstruction methods have increased the construction cost and technical difficulty to a certain extent[6], but the construction period is shorter, and the comprehensive reinforcement effect is more ideal.

2.2.3. Selection of Additional Layer Structure

In this project, if the conventional reinforced concrete beam and plate are selected, although it can meet the basic functional requirements, it is easy to bend down because of the stress concentration on the one hand, and on the other hand, it will increase the pressure on the lower frame column, which puts forward a higher demand for reinforcement. Therefore, the glass curtain light steel is used as the added layer structure in this renovation design. In addition to the basic functions of the building, it can also increase the light transmittance[7], so that the building atrium can shine natural light as much as possible, taking into account practicability and energy saving.

2.3. Reinforcement Design of Frame Column

2.3.1. Reinforcement Design of Basement Frame Column

Combined with the requirements of strengthening and reconstruction of building structure and the analysis of bearing capacity of basement frame column[8], it is decided to adopt the method of pasting fiber composite material on the periphery of frame column for strengthening treatment. Among them, the basic parameters of frame column are as follows:

(1) Section size :$b_1\times h_1$ =600mm ×600 mm;

(2) Concrete strength grade C4 0 ;

(3) Compressive strength f_c= 15.2N/mm^2,bending strength f_f=1.32N/mm^2 ;

(4) The type of reinforcement used is HRB400,and the tensile strength of reinforcement is f_y=320N/mm^2;

(5) Structural importance coefficient γ=1.0.

In addition, referring to the "Code for Design of Concrete Structure Reinforcement" (GB50367-2013) in the relevant provisions, all the large eccentric compression concrete rectangular column reinforcement, in order to ensure the ideal reinforcement effect, all need to accurately calculate the normal section bearing capacity (N• e), the calculation formula is:

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$$N.e \leq \alpha_1 f_{co} bx\left[h_0-\frac{x}{2}\right]+f'_{yo}A'_{s0}(h_0-\alpha)+f_f A_f(h-h_0) \qquad (1)$$

In Formula(1),f_{co} and f'_{yo} Respectively represent the design values of the compressive strength of the existing member concrete and longitudinal reinforcement: ***b*** :Represents the section width of the frame column; A'_{s0} : Represents the section area of new longitudinal reinforcement;f_f: Represents the design value of tensile strength of fiber composite reinforced materials: h :Represents the section thickness of concrete on the compression side:h_0:Represents the shortest distance between the compression edge of the section after member reinforcement and the resultant point of tensile reinforcement;
A_f: Represents the sectional area of the carbon fiber material under tension [9]. Where, Ndenotes the design value of axial force of the member after reinforcement, and its calculation formula is:

$$N \leq \alpha f_{c0} bx+f'_{yo}A'_{v0}+f_{yo}A_{so}+f_f A_f \qquad (2)$$

e: Represents eccentricity,That is, the distance between the resultant force point of the longitudinal tensile reinforcement A_s and the application point of axial pressure. Its calculation formula is as follows:

$$e=(e_0-e_a)+\frac{h}{2}-a \qquad (3)$$

a : Represents the strength utilization coefficient between the newly added longitudinal reinforcement and concrete, and the value here is 0.8;e_a: Represents the additional eccentricity, and the maximum interface size h with the eccentricity direction is close, when h the value is greater than 600mm, the value is /30. When h the value is greater than or equal to 600mm, the value is a fixed 20mm. e_0 Represents the eccentricity of axial pressure to the center of section.The reinforcement design of the basement frame is shown in Figure 1

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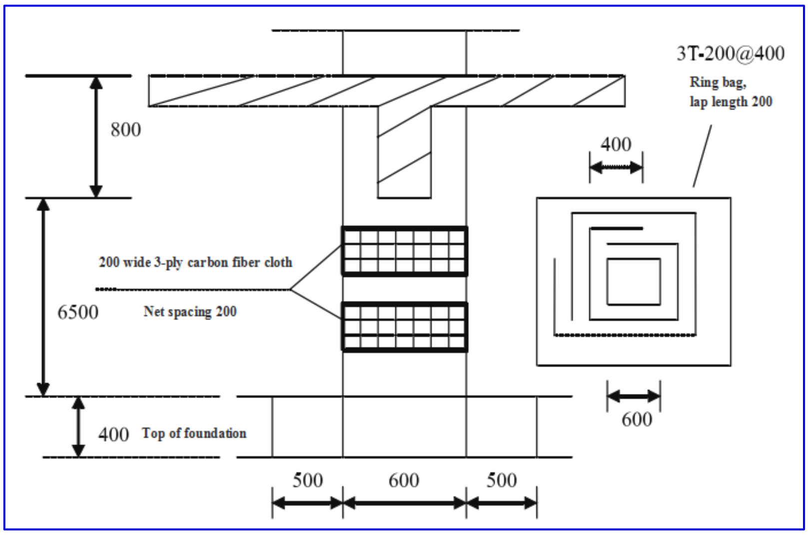

Fig 1. Schematic diagram of reinforcement of basement frame column

According to the calculation results, in the reinforcement of the basement frame column in this project, double-layer class carbon fiber cloth with a width of 200mm is used [10]. In order to achieve the expected reinforcement effect, its elastic modulus is more than 3.3×10^5MPa, tensile strength is more than 2990 MPa, elongation is more than 1.9%, and mass density is 268g/m^2.

2.3.2. Reinforcement Design of Frame Column on the First Floor

After comprehensive analysis of the frame column on the ground floor of the building, it was decided to use the external adhesive steel reinforcement method to transform it. The basic parameters of the frame column, such as cut length, concrete strength grade and structural

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importance coefficient, are the same as those of the basement frame column. Refer to "Code for Design of Concrete Structure Reinforcement" (GB50367-2013); It is stipulated that, in order to achieve the ideal reinforcement effect, the normal section bearing capacity () shall be accurately calculated when all RC eccentric compression members are reinforced with external viscous section steel(N. e). The calculation formula is:

$$N.e \le \alpha_1 f_{co} bx\left[h_0 - \frac{x}{2}\right] + f'_{yo} A'_{s0}(h_0 - \alpha) + \sigma_{s0} A_{s0}(\alpha_{s0} + \alpha_a) \tag{4}$$

In Formula,α, b, f_{co},are the same as above, without retelling.

σ_{s0}: Represents the stress of the longitudinal steel bar with less compression of the existing member;α_a:Represents the strength utilization factor of the outer section steel, which is 0.9 without considering the seismic action. Where,σ_{s0} it is related to the elastic modulus (E_{s0}) of the newly reinforced steel bar and the strain potential (ε_{cu}) of the existing concrete member. The calculation formula is as follows:

$$\sigma_{s0} = \left[\frac{0.8h_0}{x} - 1\right] E_{so}\varepsilon_{cu} \tag{5}$$

The formula for calculating the design value N of the axial force of the reinforced member is:

$$N \le \alpha_1 f_{co} bx + f'_{yo} A'_{s0} + \alpha_a f_a - \sigma_a A_a \tag{6}$$

In the above formula, the stress of the steel with less compression is represented. The reinforcement design of the first layer frame column is shown in Figure 2.

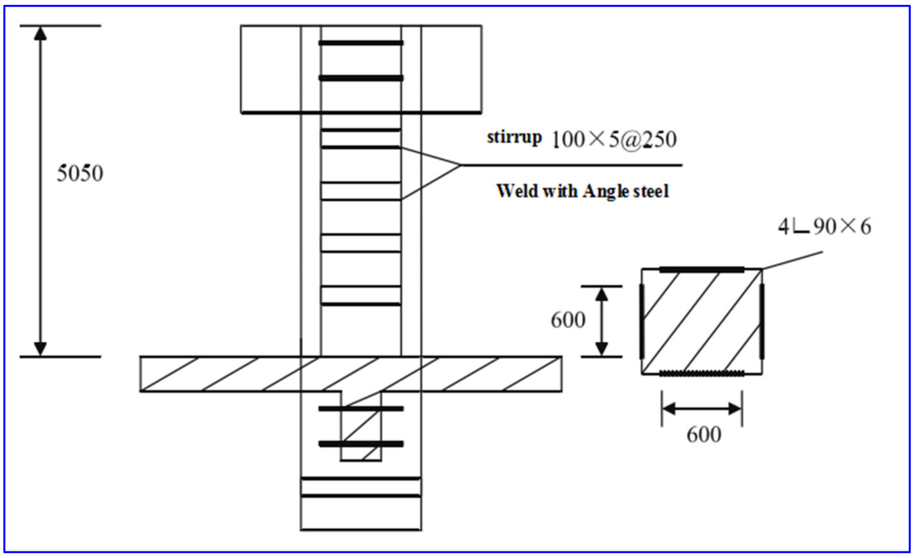

Fig 2. Schematic diagram of strengthening frame column on the first floor

According to the calculation results, Angle steel with a width of 4 L908mm is required to be used to reinforce the first-layer frame column in this project. The cross-sectional area of the reconstructed longitudinal steel bar is 5388.4mm^2, which exceeds the 3800mm^2 specified in the Standard and meets the requirements of the standard. In addition, the 100×6mm plywood is used to maintain 300mm distance between the Angle steel and the three side welding is used to connect, and the middle part of each plywood is reinforced with an M12 anchor bolt, which further improves the firmness of the external adhesive steel, and the reinforcement effect of the frame column is good.

2.3.3. Reinforcement Design of Frame Beam

Due to the large transverse span of the steel concrete building, the reinforcement of the frame beam should be paid more attention in the reinforcement design. Through the force analysis of

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the frame beam, two reinforcement designs are adopted: one is to paste carbon fiber cloth on the bottom of the existing frame beam, the other is to paste steel sheet on the top of the beam by pressure gluing. The upper and lower combination effectively prevents the middle of the frame beam from bending due to stress concentration. The basic parameters of the frame beam in this project are as follows:

(1) The section type is rectangular;

(2) **sectional dimension** b×h=250×600;

(3) Concrete: Strength class C4 0, Compressive strength f_c = 15.2N/mm^2, bending strength f_t=1.32N/mm^2;

(4) The type of steel bar used is HRB400 and the tensile strength of steel f_y=320N/mm^2 ;

(5) **minimum reinforcement ratio** ρ_{min}=max(0.2;45×f_t / f_y) =max(0.2;0.18)=0.2% ;

(6) Distance between longitudinal bar joint point and near side α_s=45mm.

In the reinforcement design of frame beams, several key points such as minimum reinforcement ratio and effective height of section need to be calculated. The calculation methods of key points are as follows:

1): The effective height of the section can be obtained by the difference between the height of the frame beam (h) and the distance between the resultant point of the longitudinal reinforcement and the near side (as), h-a$_s$=600-45=555mm

2): Relative to the height of the compression zone, the formula for calculating this value:

$$\xi = f_y \times \frac{A_s}{\alpha_1 \times f_c \times b \times h_0} \tag{7}$$

In the above equation, HRB400 steel bar,ξ=0.518 is greater than 0.2, so it meets the technical requirements of reinforcement.

3): The minimum reinforcement rate, combined with engineering data, we know that the minimum reinforcement rate of the frame beam in the building is 0.2%. Therefore, in the reinforcement design, the reinforcement ratio (ρ) after reinforcement must be greater than the value. Is calculated by:

$$\rho = A_s/(b \times h) \times 100\% \tag{8}$$

In this reinforcement scheme, it is 1347mm^2, b=250mm and h=600mm. After substituting the above values into equation (8), ρ it can be obtained that =0.898%>0.2%, thus meeting the requirement of minimum reinforcement ratio.

The carbon fiber sheet selected in this project is a high-strength Class I carbon cloth with an average thickness of 0.189mm, an average elastic modulus of 2.3×10^{5}MPa and an average strength of 2400N/mm^2. According to the formula, the number of carbon fiber layers (N) required for reinforcement of frame beams in this project is calculated:

$$N = M/(b \times h \times f_f) \tag{9}$$

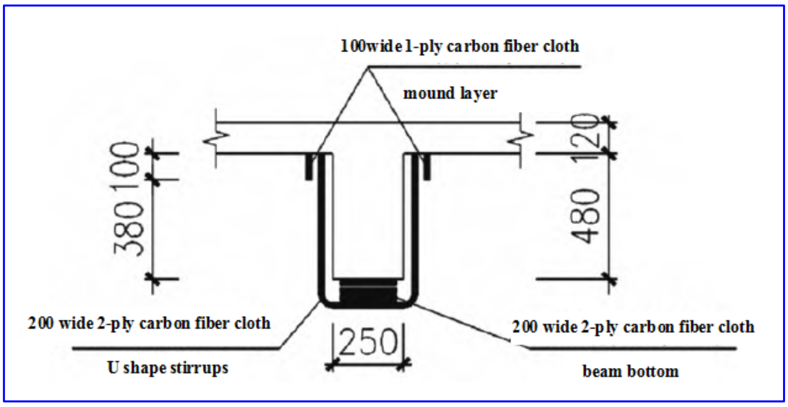

Fig 3. Frame beam reinforcement U-hoop structure

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In the above equation, M represents the design value of bending moment, which in this project is 199×106kN/m^{-1}. N=3.5 is obtained after all the data are brought in, that is, 4 layers of carbon fiber cloth are needed in the actual reinforcement and transformation of frame beams. In addition, since the carbon fiber cloth needs to be pasted at the bottom of the beam in the reinforcement of the frame beam, in order to improve the reinforcement effect and prevent the carbon fiber cloth from falling off and cracking due to concentration, U-shaped stirrups and platen are also used to further strengthen the carbon fiber cloth. The arrangement of U-shaped stirrups is shown in Figure 3.

2.3.4. Add Layer Structure Design

In this project, the reinforcement connection of the new frame column is fixed by column longitudinal reinforcement and planting reinforcement. The depth of planting reinforcement is 22 d (d which is the diameter of reinforcement).After the on-site reinforcement and reconstruction construction is completed, technical personnel need to be arranged to test the drawing force of planting reinforcement and judge whether the drawing force meets the design requirements. Non-destructive test was adopted in the field test, that is, ML-300 anchor bolt tension meter was selected to test the planting bars of 1-01, 1-02, 1-03, 1-04 and 1-05 respectively. The specific results are shown in Table 1.

Table 1. Test result of drawing force of implanted reinforcement in concrete structure

Component name	Reinforcement insertion depth (mm)	Schgarabal force (kN)	Description of post-stress condition
1-01/A-B axis first layer beam	550	46.2	There is no crack in the concrete, no slip in the bolt, and no reduction in the load within 120S
1-02/A-B axis first layer beam	550	45.2	There is no crack in the concrete, no slip in the bolt, and no reduction in the load within 120S
1-03/B-C axis first layer beam	550	46.8	There is no crack in the concrete, no slip in the bolt, and no reduction in the load within 120S
1-04/E-F axis first layer beam	550	47.5	There is no crack in the concrete, no slip in the bolt, and no reduction in the load within 120S
1-05/F-G axis first layer beam	550	44.9	There is no crack in the concrete, no slip in the bolt, and no reduction in the load within 120S

Combined with the data in Table 1, it can be seen that no cracking was found on the concrete of the implanted steel bars after the drawing forces of 46.2kN, 45.2kN, 46.8kN, 47.5kN and 44.9kN were provided for the 5 embeddedness bars tested in this test. The bolt did not slip, and there was no obvious reduction in the load within 120s, indicating that the reinforcement has achieved the ideal effect.

3. Conclusion

After the construction of reinforced concrete buildings for a period of time, due to the aging of materials, geological disasters and other reasons, the overall stability of the structure will be decreased in different degrees, so it is necessary to adopt reinforcement and reconstruction technology to ensure the stability of the building structure, reliable quality and safe use. Based on the field investigation and force analysis of the existing building structure, this paper puts forward a variety of reinforcement and transformation techniques around the requirements of

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reinforcement and transformation and the structural characteristics of different parts. For example, the basement frame column is reinforced by the external paste fiber composite material. For the bottom frame column of the building, the external adhesive section steel reinforcement method is used for transformation. For the frame beam, the composite transformation technology of "pasting carbon fiber cloth at the bottom + pressure injection adhesive steel sheet at the top" is used. Only by selecting the appropriate reinforcement method and reconstruction technology scientifically, can the ideal reinforcement effect be achieved at a lower cost. In addition, in the existing building structure reinforcement transformation, should also strictly follow the "concrete structure reinforcement design code" and other relevant provisions, and should pay attention to the site reinforcement transformation technology quality control measures, so as to effectively ensure the reinforcement along the building in bearing capacity, stability, safety and other aspects have been comprehensively promoted.

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