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Strengthening Design of a Business Architecture Built During the Period of the Republic of China in Nanjing

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Abstract Based on strengthening project of a business architecture built during the period of the Republic of China in Nanjing, some key problems in strengthening design of reinforced concrete frame structures built during the period of the Republic of China are roundly discussed, including methods of testing and appraisement, computing and analyzing, foundation reinforcement, brick wall reinforcement, concrete members reinforcement and seismic reinforcement, etc. Some effective methods are introduced to solve the problems, which can be referenced for similar design.

Keywords: Architecture built during the period of the Republic of China, reinforced concrete frame structure, strengthening

Introduction

The building of No. 1 of Zhongshan East Road in Nanjing was designed by Miao KaiBo Ltd in 1933. The building was finished in July 1935. Its predecessor was the Bank of Communication in Nanjing during the period of the Republic of China. During the period of anti-Japanese war, this building became Central Reserve Bank. Now, the building is Zhongshan Branch in Nanjing of Industrial and Commercial Bank of China. In 1991, it was appraised as an excellent modern architecture by Ministry of Construction and State Cultural Relics Bureau in China. In October 2002, the building was list as key cultural relics under the provincial-level protection by Jiangsu Province. The building is facing south. The length is about 35.4m. The width is about 31.5m. The area is about 3000m2. The main structure is reinforced concrete frame structure with three floors. The storey height of bottom and second floor is 4.30m, which of the third floor is 5.82m. In the center of the building, there is a large rectangular light well. The second floor is empty, the third floor has only two beams, and the fourth floor has skylight with slope roof. In the southwest corner and the northeast corner of the building, there are two reinforced concrete staircases. This building is an excellent representative of the constructions built during the period of the Republic of China. It has a very high architecture artistic value. The plane layout, the facade sculpt, the construction technology and the decoration detail all make this building appear forceful and delicate architectural aesthetic feeling. The building has important research value to the study of the architectures built during the period of the Republic of China. The facade and ground floor plan are shown in Fig. 1 and Fig. 2 respectively. In order to better preserve and use this building, he owner of building decide to change its function to become a new building called the Fortune Center of Industrial and Commercial Bank, and some space of the building will be used for the exhibition and public actions.

Figure 1: The facade of the building

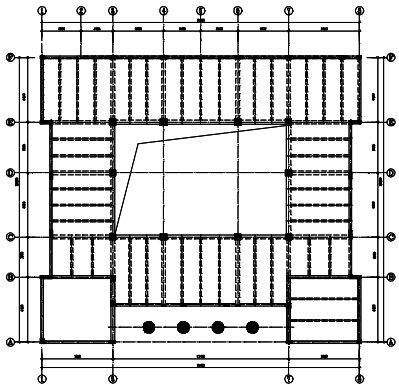

Figure 2: The ground floor plan of the building

Test and Appraisement

The building has been used for almost 80 years, which exceeded far beyond the reasonable using life prescribed by national design codes. Although it has been repaired many times during the using period, but the original design data and the repair information are incomplete. In order to understand the safety situation of this building and provide technical basis for the strengthening and reconstruction of the building, the test and safety appraisement for the structure are carried out. For this building, the earthquake intensity is set as 7 degree, the basic design acceleration of ground motion is set as 0.10g, and the anti-seismic grade is set as third-grade.

Test Contents Because the lack of original design information, the first step is on-site measurement, including the structural arrangement, structure type, member section size, supporting and connecting conformation, structural materials, etc. Then, the present situation of the building is surveyed, including the load of structure, the environment investigation of the building; the structure defects of various members (concrete beams, slabs, columns, brick walls) are detailedly carried out. The test results showed that the overall appearance of concrete members was relatively undamaged, but there were some honeycomb pitting surfaces on local columns. There was some phenomenon of reinforcement revealing on some columns.There was similar phenomenon on some concrete beams and slabs. The damages of structure are shown in Fig. 3.

Figure 3: the phenomenon of reinforcement revealing in concrete members

In order to calculate the main structure, the strength of materials and the reinforcement condition in the members should be understood. Using the method of drilling core, the concrete compressive strength is tested and the result is about 8.3MPa. With the method of sampling on the site, the yield strength of longitudinal reinforcement is tested as about 272MPa, the yield strength of hoop reinforcement is is tested as about 254MPa, the yield strength of slab reinforcement is is tested as about 228MPa.Using the rebound method, the compressive strength of the wall brick is about 10MPa. With the penetration method, the compressive strength of the wall mortar is about 0.7MPa. The thickness of concrete cover and the carbonation depth of the main members were test, the results showed that, the thickness of concrete cover is about 20 ~ 50mm,20~30mm and about 15mm for

columns, beams, slabs respectively, the carbonation depth is about 60mm for these kind of members, which has exceeded the thickness of concrete cover. This is the main reason that causes the corrosion of steel bars inside the concrete members. The corrosion damages of structure are shown in Fig. 4.

Figure 4: the corrosion of steel bars inside the concrete members

Appraisement Contents The building contains only one appraisement unit, which is divided into two sub-units: groundwork unit and upper load-bearing structure unit. The upper load-bearing structure mainly includes concrete columns, beams, slabs. Based on the result of field test and computational analysis, the appraisement results are derived: The structure layout of the building is reasonable, the load transfer path is clear, the foundation is comparatively stable, there is no obvious phenomenon of foundation settlement. But the bearing capacity of some column's foundation could not meet the design requirement. As the concrete carbonation depth of the columns and beams and slabs is too large, the damages of some concrete members is very serious, so the concrete cover has lost the protective effect for the internal reinforcement. Meanwhile, the concrete strength is relative low and there are some phenomenon such as the corrosion of steel-bars and desquamating of the local concrete. etc. The structure conformation is irrational in the early design,so its bearing capacity and seismic performance and durability can not meet the current specifications' requirement. Furthermore, there is no reliable connection between the outer wall and the main structure, the problem of water leakage on the outer wall appeared. So the outer wall can not meet the requirement of current specification and durability. The computational model of this structure is showed in Fig. 5.

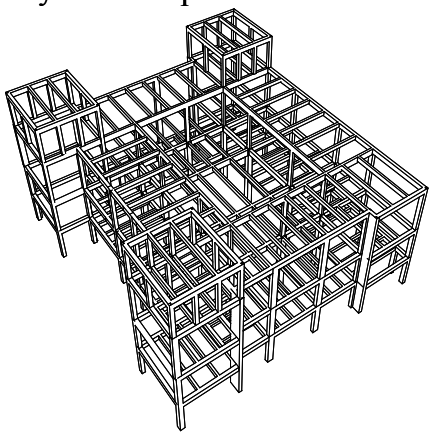

Figure 5: computational model

Strengthening Design

Strengthening Design Principles The building is list as key cultural relics under the provincial-level protection by Jiangsu Province,so the strengthening and repair design must strictly observe the relative regulations in《Law of the People's Republic of China on the protection of cultural relics》and 《Regulation for the implementation of law of the People's Republic of China on protection of cultural relics》 and 《Management methods of cultural relics conservation projects》. The

strengthening and repair could not change the original building's facade and the initial pattern. At the same time, the strengthening and repair must meet the new function requirements of the owner, and also must ensure the structural safety.

(1) Principle of complete and true

Before strengthening, the comprehensive and in-depth study for the building must be done, including the original drawings and documentations, photos, and other media coverage. The complete feature and history of this building should be roundly grasped. Thus, during the strengthening and repair process, the integrality and reality could be ensured.

(2) Principle of identifiablity

The historical forms of heritage buildings must be sufficiently respected. The historical lack and historical adding of heritage buildings should be carefully treat. During the strengthening and repair process, we must ensure the strengthening and repair is fairly identifiable.

(3) Principle of readable

The readability of heritage buildings should be reserved, this is an important work for the extension culture value of the heritage buildings. Excavating the history story of the heritage buildings, preserving original material and form and construction and installation method, these is an important work to ensure the readability of heritage buildings.

(4) Principle of minimum interference

If the strengthening and repair can meet the above requirements, we must decrease other unnecessary strengthening measures and decrease interference of the strengthening to the original situation.

Strengthening Contents According to the strengthening design principles and appraisement results, various strengthening methods are compared, the optimized strengthening method is chosen to meet the requirements of the building.

(1) Strengthening of foundation

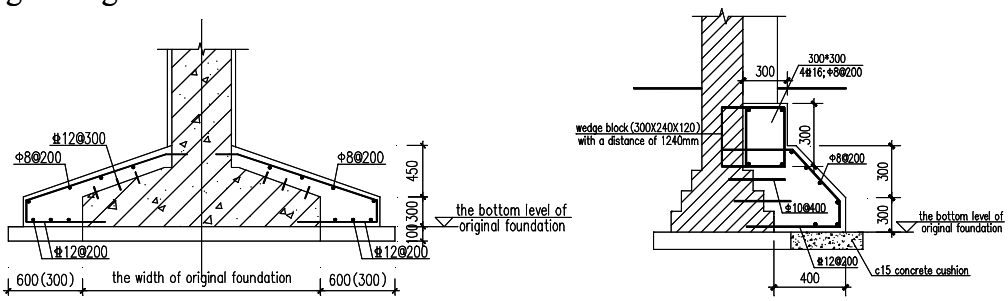

Figure 6: foundation strengthening

The columns' foundation is reinforced concrete isolated foundation. The brick walls' foundation is spread footing foundation. In the process of the strengthening and repair, because the floor hole in the third floor will be filled up, so for some columns, the vertical load are increased, these foundations are reinforced to increase the bearing capacity by increasing section with reinforced concrete. For some other columns, because the service load of floor and roof don't increased, and the strengthening will bring only a little weight to these foundations, and considering that the old foundation soil has been through more than 70 years, the bearing capacity of the foundation soil has been increased, therefore, the bearing capacity of these foundations could meet the requirements and the foundations don't need to be strengthened. Only the foundation of filler walls will be reinforced to enhance the integrity using the new increased strip footing with reinforced concrete. The strengthening method of the frame columns' foundation and the filler wall's foundation is showed in Fig. 6.

(2) Strengthening of concrete beams and columns

The concrete beams and columns are very urgent to be strengthened, because of these reasons: the compressive strength of the concrete is only 8 MPa, and the carbonation depth of concrete members are over the concrete cover thickness, the internal steel bars have started to be rusted in varying degrees, in the beam-column joint core area, the horizontal hoop reinforcement is not set, the seismic

performance of these joint core area is very weak. The beams and columns will be strengthened to improve the bearing capacity and durability by increasing their sections with reinforced concrete. The beam-column joint core area will be strengthened to improve the seismic capacity and durability by adding the horizontal hoop reinforcements. In order to preserve the main body of the heritage building to the maximum level, firstly, the concrete cover of the beams and columns are removed to expose the hoop reinforcements and the longitudinal reinforcements, then the rust treatment for the steel bars' surface is proceeded, finally the new reinforced concrete cover is casted. The strengthening concrete material have some obvious advantages, including the high early strength and final strength, flowing naturally and no vibrating, light expansion without contraction, good durability and weather-resistance, low-alkali and corrosion-resistance, meeting the requirement of the small casting size. etc. The strengthening method of beams and columns are respectively showed in Fig. 7 and Fig. 8.

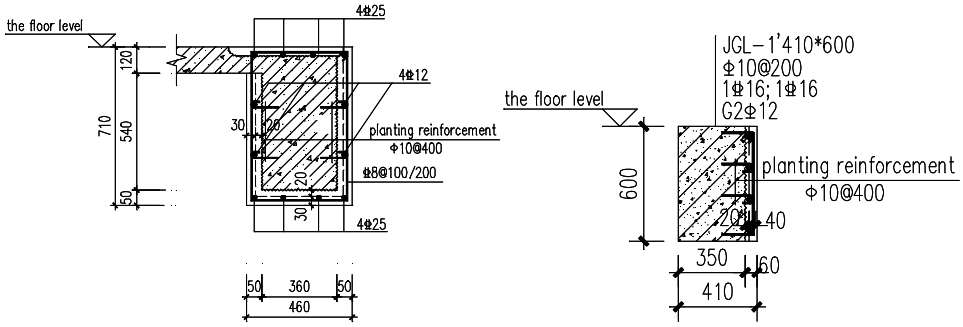

Figure 7: concrete beam strengthening

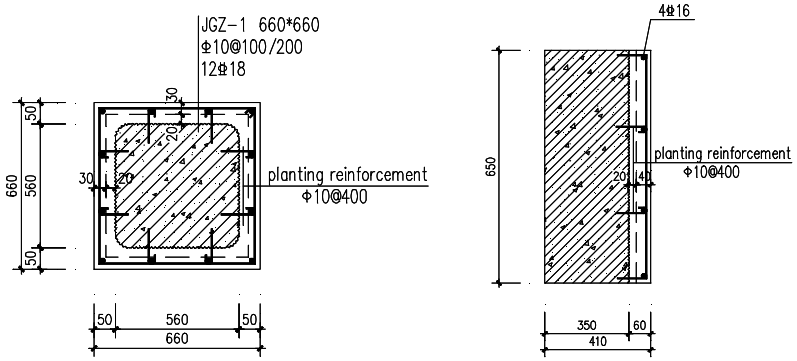

Figure 8: concrete column strengthening

(3) Strengthening of concrete slab

For the concrete slabs, on the one hand, the compressive strength of the concrete is only 8 MPa, the carbonation depth of the slabs is equal to the thickness of slabs, the slab reinforcements have started to be rusted in varying degrees; on the other hand, the conformation of slab is unreasonable, there is only single layer reinforcement in the slab. So, the slabs should be strengthened to improve the bearing capacity , durability and conformation rationality with the replacement method. The double layer and two-way reinforcements are be set in the new slabs. The original slabs will be removed with static and non-destructive cutting method to ensure not to produce any damage to adjacent structures. In the removing process, the original slab reinforcements with the length of 30 cm in the slabs and beams' junction should be kept to increase the connectivity of new and old structures. The new added slab reinforcements are connected with the surrounding concrete beams with planting reinforcement method. In order to ensure the reliability of the planting reinforcement connection, the anchor adhesive should meet the following requirements: being A-level standard glue of the strengthening specification, having the report about chemical composition and the chemical composition must meet the specification requirements, the complete solidification time of the anchor adhesive is as short as possible, meeting the appropriate fire resistance grade, passing the fatigue test with two million times,

passing the test of dynamic load and anti-aging, meeting the requirement of no less than 50 years of durability, passing the non-toxic test and getting non-toxic level.

(4) Strengthening of concrete stairs

The building's staircases are the reinforced concrete beam-type stairs. The ground is a marble floor and the balustrade is made of iron, all these retain the original style in the period of the Republic of China. Because the strength of concrete is relative low, the internal reinforcements have been rusted, the structural safety is seriously affect. So, it must be strengthened. In order not to affect the original appearance of the stairs, the strengthening is set in it's bottom by increasing section with reinforced concrete. The reinforcement materials is also the strengthen-type concrete. The strengthening method of concrete stairs is showed in Fig. 9.

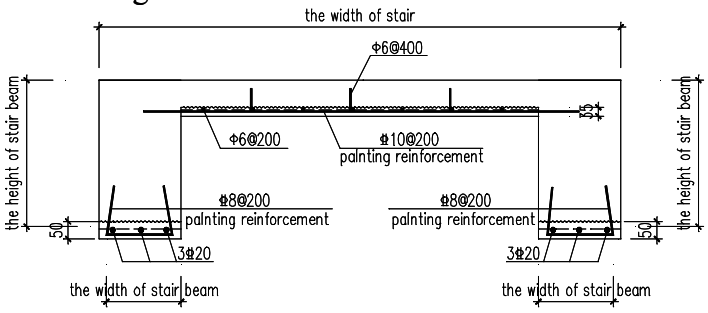

Figure 9: concrete stair strengthening

(5) Strengthening of wall

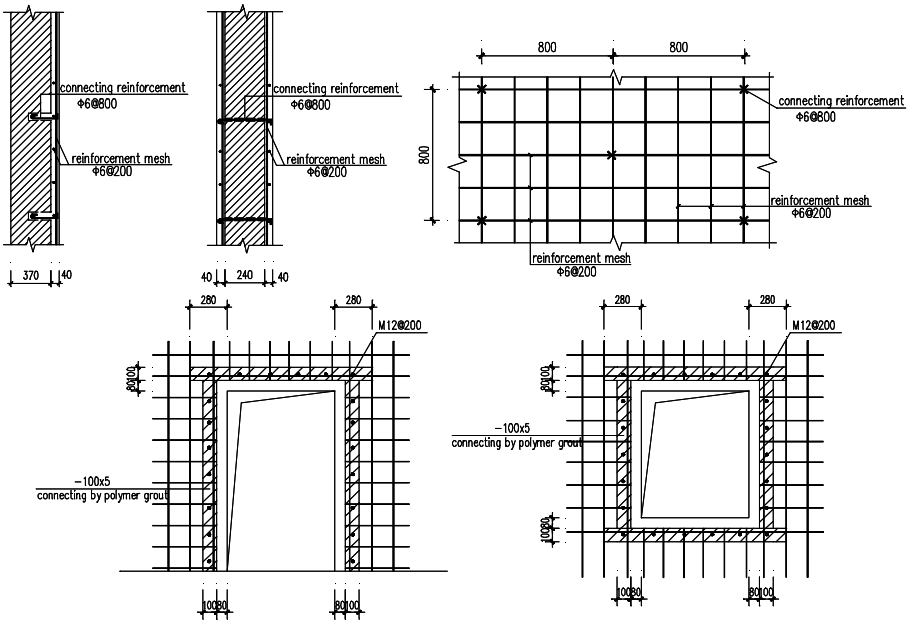

Figure 10: brick wall strengthening

The building's walls were built by sintered clay brick and lime mortar masonry. The strength of mortar is very low and the compressive strength is only 0.7 MPa.Some bricks have broken up. There is no any connection measure between the wall and the main structure, the problem of water leakage on the outer wall appeared. Therefore, in this strengthening and repair, the wall will be strengthened using the single reinforced mesh and the cement mortar rendering network reinforcement. On the one hand, the strengthening can improve the integrity of the walls and the reliable connection with the main structure. On the other hand, it can solve the problem of water leakage. In order to easily install the stone sets of doors and windows and improve the installation effect of doors and windows stone sets,in the process of wall strengthening, the strengthening is stopped at a distance of 8cm with the opening of the doors and windows, using the steel plates to strengthen the opening. The strengthening method of walls is showed in Fig. 10.

Conclusion

The building of No. 1 of Zhongshan East Road in Nanjing is a typical reinforced concrete structure built in the period of the Republic of China. For this kind of Buildings, there is not only the problem of the inadequate bearing capacity at present, but also the problem that the depth of concrete carbonation is too large and the internal reinforcements have been rusted. Therefore, these buildings are very urgent to be strengthened.. The author hopes that the introduction of the strengthening design for the building of No. 1 of Zhongshan East Road in Nanjing can provide some references for the similar strengthening design cases. The following requirements should be noticed:

(1) Before the strengthening design, the detailed test and appraisement should be carried out for the building, which can provide a reliable basis for strengthening design.

(2) In the strengthening design of heritage buildings, the cultural relics conservation principles should be roundly taken into account. The strengthening method should be feasible , convenient , economical and reasonable under the principles of cultural relics protection. At the same time, the structural safety and functional requirements should be met. We should also roundly preserve and use the original component and excavating their potential.

(3) The effective measures should be taken to ensure the reliable connection between the new and old structures in the strengthening design, which can also ensure them to work together.

(4) In the strengthening project, the inorganic materials should be used as much as possible, which can improve the durability of the structures after strengthening.

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