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Retrofitting and Strengthening Design for the Former Yihe Spinner Factory in Shanghai

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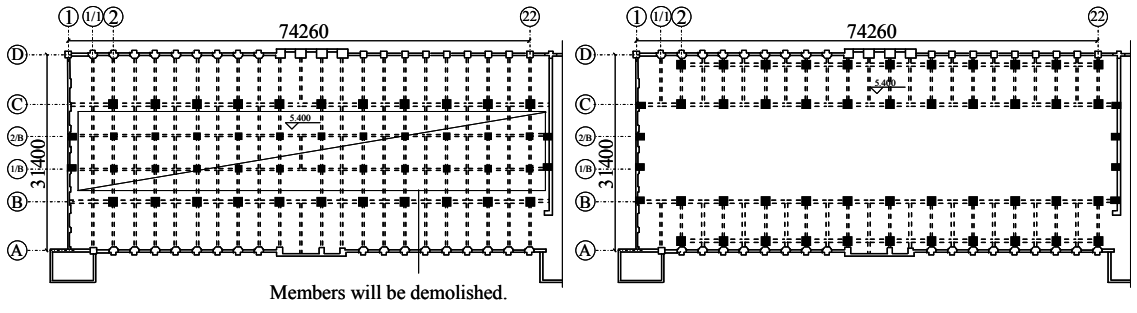
Abstract The building of the formerly Yihe Spinner Factory in Shanghai is a protected. To ensure its serviceability, appropriate retrofitting is necessary. Structural analysis based on the inspection result was performed. It is shown that the bearing capacity or the ductility of some members in the original structure as well as the retrofit proposal are inadequate. Strengthening design was then performed. The effect of the subsequent retrofitting process on the strengthened structure was analyzed. The historical building is then properly protected and the new manufacturing requirements are meet through the retrofitting and strengthening design. The proposed methods can serve as references for relative research or engineering practices.

Key words: Protective historical building, retrofiting, strengthening, structural analysis

Introduction

The building of the former Yihe factory in shanghai was constructed in 1896. The original building is a 2-story reinforced concrete frame structure. It is one of the oldest reinforced concrete factory buildings adopting saw-tooth roof in china (Cai and Zhong 2001). The structure was thoroughly retrofitted in 1970's. Retaining the façade and the load-bearing outer masonry walls, the other internal members were replaced by 22 5-span lateral reinforced concrete bents. The bents were connected longitudinally to form a spatial structure. The original saw-tooth roof was replaced by concrete truss roof. Having been used for more than 30 years, the structure is required to be retrofitted again. According to the development plan of Shanghai municipality, a modern waterworks will be established at the location of the structure. To be used as a pumping workroom, beam, column and floor slabs under the elevation of 5.400 m and between axis 1, axes 22, B and D need to be demolished, as shown in Fig.1. Ground soil within the structure needs to be excavated to form six 4.5 m-deep pitfalls for settling pumping machines after the demolishment. To connect to the underground pumping



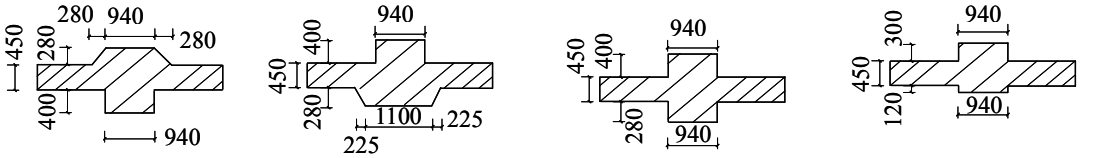
(a) Plan before retrofit (b) Plan after retrofit

Figure 1: Plan of the Retrofit for the Former Yihe Spinner Factory in Shanghai

machines, six water supplying pipes will then be pushed through the soil under the foundation of the original exterior masonry wall. To properly protect the profile of this historical building, detailed structure inspection should be conducted before retrofit, and response of the aged building in different phase of the retrofit procedure should be analyzed.

State of the Current Structure

The thickness of the load-bearing masonry walls along axes A and D is of 456 mm. The span of the pilasters in these walls is 3350 mm. Sections of the pilaster are shown in Fig. 2. No ring beam has been constructed. The strength grade of the brick is MU7.5 and the strength grade of the mortar is M10 according to the Chinese building code.



(a) Pilaster of Axis A of Story 1 (b) Pilaster of Axis D/1~9 of Story 1 (c) Pilaster of Axis D/14~21 of Story 1 (d) Pilaster of Axis A、D of Story 2

Figure 2: Pilaster Sections of the Longitudinal Wall

There are 5 spans in lateral direction in the first story. The two end spans are of 6700 mm, and the three middle spans are of 5250 mm. Rectangular section of 300mm×400mm is used for the reinforced concrete columns along axes B and C and 300 mm×300 mm is used for these along axes 1/B and 2/B. Concrete roof trusses are placed on top of the columns. The axial pressure strength of concrete is 20.8 N/mm^2. The diameters of the longitudinal steel bars and the stirrup are 22 mm and 6 mm, respectively. According to the Chinese building code, the strength grade of the longitudinal steel bar and the stirrup are HRB335 and HPB235, respectively. The column sections are shown in Fig. 3.

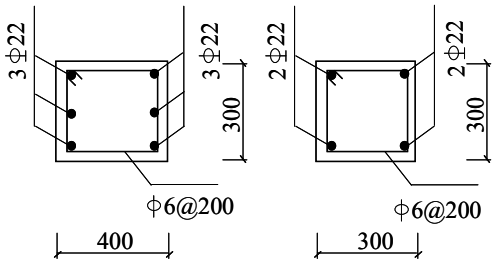


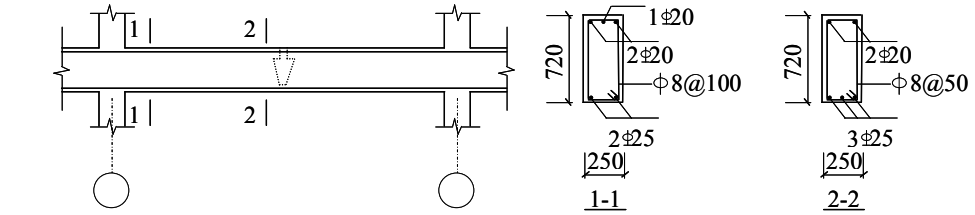
Figure 3: Sections of Concrete Column

The longitudinal girders are along with the axes B and C. Rectangular section of 720 mm×250 mm is used for these girders and 620 mm×250 mm is used for these along with axes 1/B and 1/C. All girders and beams are rigidly connected to the columns. The compression pressure strength of the concrete is 22.7 N/mm^2. The profile and the cross sections of the girders are shown in Fig. 4.

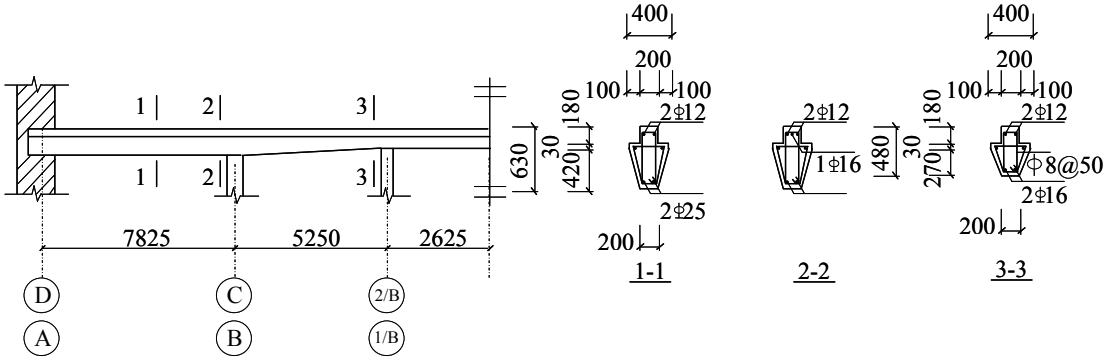
Retrofiting Proposal

Based on the inspected geometry and material properties, a calculation model can be established for the structure. The calculation results showed that the stability of the exterior masonry walls failed to meet the requirement. The resistance of some parts of the exterior masonry walls was less than the

load effects. The section size and the arrangement of the steel bars of some concrete columns were not qualified considering the earthquake effects (Wang 2008, Zhang et al. 2003). Some beams are unsafe after redistribution of inner force result from demolishment. Strengthening is necessary according to the calculation result.



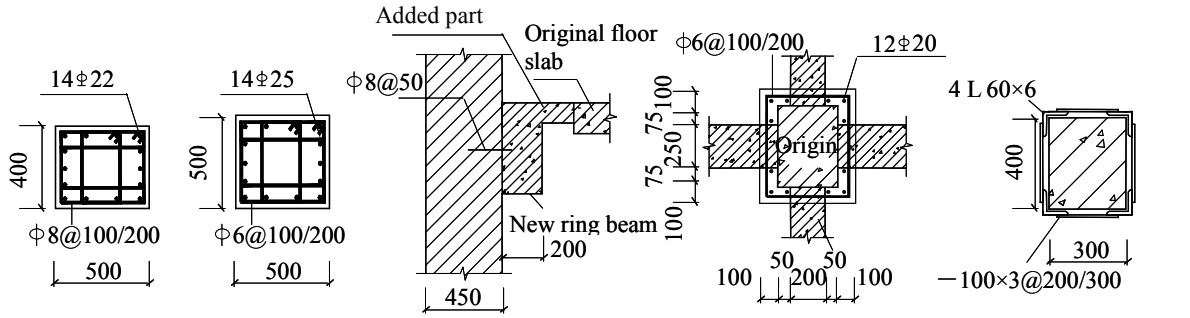
(a) Section of Longitudinal Concrete Beams of Story 2



(b) Section of Lateral Concrete Beams of Story 2

Figure 4: Sections of Concrete Beams

To strengthen the current structure, two wind resistant columns will be established inside each end walls. New reinforced concrete columns will be used to replace the masonry exterior walls as load-bearing members. The columns will be connected by longitudinal reinforced concrete beams to form a spatial frame structure. The inner columns will be strengthened by section enhancement method. The girders and beams will be strengthened by external steel gluing at mid-span and CFRP confining near the supports. To improve the integrity of the structure, concrete ring beams are added under the floor slab and on column tops (Lu 2000, Shi 2008). The strengthening details are shown in Fig. 5.



(a) Section of the New Wind Resisting Columns (b)Section of the New Frame Columns (b) Details of the New Ring Beam (c) Section Enhancement of Frame Columns (d) Externally Bonded Steel for Frame Columns

Figure 5: Strengthening of the Structure

Period of the strengthened structure, inter story lateral drift, and axial compressive ratio are shown in Table 1, Table 2 and Table 3. The values satisfy the requirement of Chinese building code.

Table 1: Periods of the Strengthened Structure (s)

T_1	T_2	T_3	T_4
0.3739	0.3056	0.2704	0.1792

Table 2: Story Drifts of the Strengthened Structure

Load case	*Earthquake input in **x** direction*	*Earthquake input in **y** direction*	*Wind load input in **x** direction*	*Wind load input in **y** direction*
Peak value	1/1387	1/4693	1/9999	1/9999

Table 3: Axial Compression Ratio of the Columns in the Strengthened Structure

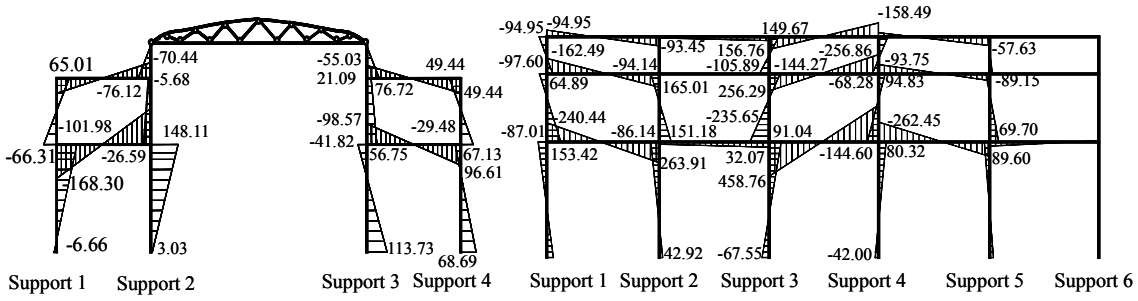
Location	*1st story*	*2nd stroy*
Ratio	0.44~0.50	0.33~0.80

Safety Analysis of the Strengthened Structure during Excavation and Pipe Push-Through

The excavation for the pumping machine foundation and the pipe push-through in the ground soil might result in uneven settlement. Inner force redistribution resulted from the uneven settlement might damage the members. It is necessary to predict the structural responses during these retrofitting steps.

The lateral and longitudinal frames in the strengthened structure were analyzed under possible uneven settlements. For the lateral frame, it is most unfavorable when support 1 move 20mm downward and support 2 move 10mm upward. Distribution of moments is shown in Fig. 6(a). For the longitudinal frame, it is most unfavorable when support 2 and support 3 move 20mm downward meanwhile support 4 move 10mm upward. Distribution of moments is shown in Fig. 6(b).

However, the uneven settlement is hard to properly predict in practice. Although the calculation results show the structure is safe under the uneven settlement mentioned above, monitoring during retrofit is necessary.



(a) Bending moment of the lateral bent under non-uniform settlement

(b) Bending moment of the longitudinal frame under non-uniform settlement

*Figure 6: Bending moment of the bent under non-uniform settlement (*kN.m*)*

Conclusions

To properly retrofit, protect and use the formerly Yihe spinnery factory. Detailed inspection on the structural system, member size, section size and material properties was necessary. Proper calculation model was established based on the inspection data. And the analysis of the structure under possible loading cases is helpful for refining or verifying the retrofit proposal.

References

[1] Cai, Y T, and Zhong, Y J (2001). *Excellent historic protective buildings in Shanghai. Shanhgai:* Press of people.s education. (in Chinese)
[2] Lu, X L (2000). *Strengthening design of building structures*. Beijing: Science Pres. (in Chinese)
[3] Shi, C X (2008). *Masonry Structure*. Beijing: Chinese building industrial press. (in Chinese)
[4] Wang, S L (2008) *Structural seismic design*. Wuhan: Press of Wuhan polytechnic university. (In Chinese)
[5] Zhang, Y, Jiang, L X, and Zhang, W P, et al (2003) *Introduction to the durability of concrete structure*. Shanhai: Shanghai Science and Technology Press. (in Chinese)