Upgrading and Renovating Practice of the Schoolhouse in the High-density Old Town

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Abstract: In view of the degradation of the existing structure of the school buildings in the old city and the need to update the education model in the new period, whether to upgrade the function of the school building has become a key issue for the education department to improve the quality of teaching. In the process of renovation, there are many challenges in the design and construction of how to upgrade and renovate the school buildings with excellent historical buildings with a long history in the old city with dense buildings and public facilities. This paper takes the renovation of excellent historical buildings at No. 95 Huqiu Road, Huangpu District, Shanghai as an example. Through the description of the buildings and implementation process, it highlights the important role played by technological innovation in the upgrading and renovation of school buildings.

1 Introduction
Huangpu District in Shanghai is the oldest urban area with the highest population density and the oldest history. It belongs to the high-density old urban area. The basic education facilities in this area are the most dense and outdated (excluding those that have been updated), 80% of which are included in historical buildings or excellent historical buildings or key cultural relics protection buildings. Figure 1 shows the distribution of basic education facilities in the area.

The current “Internet+” model has accelerated social development, and the cultivation of innovative and creative talents is a country’s core competitiveness.
In 2017, in order to deeply implement the national innovation-driven development strategy, efficiently promote the comprehensive reform of Shanghai education, and greatly complete the exploratory reform of emphasizing middle school teaching features, cultivating international innovative talents, and serving Shanghai as the key position for building a globally influential science and innovation center, the Huangpu District Education Bureau is in the process of transforming basic education facilities, innovation and pragmatism are guided by the school tenet of "different from the tradition, with a focus on the future". At the same time, the school buildings are functionally upgraded and transformed in compliance with the protection regulations of excellent historical buildings.

In the process of renovating school buildings, there are many problems need to be solved. For example, how to repair and improve the functions of the school buildings listed in the protection area in the high-density old city, how to deal with the relationship between the new and the old, how to highlight the cultural and special status of the original building, and how to create a innovative space that meet the requirements of safety and modern creativity training.

This article combines a new teaching model and takes the renovation of the old school building at No. 95 Huqiu Road, Huangpu District as an example. It focuses on the three aspects of architecture, structure and construction to explain how to upgrade the function of the school building and protect the cultural relics in the dense old city.

2 Function upgrade and renovate

2.1. Background
The school building at No. 95 Huqiu Road is the original 3-storey school building, located west of Huqiu Road and south of Hongkong Road in Huangpu District, Shanghai (as Figure 2 shows). The north side of the school building is Hongkong Road, the west side is adjacent to the current 6-storey building of Shanghai Industrial and Commercial College, and the south side is adjacent to the current Huqiu residential building, the east side is Huqiu Road, and the east side of Huqiu Road is the 2nd phase of the 174 block project under construction.

![Figure 2. Schematic diagram of plane position](image)

The school building was built in the 1920s, and the main structure of the house is a four-layer mixed structure. The seismic fortification intensity of the building is 7 degrees, and the earthquakes design are of the second group; the site belongs to the general earthquake-resistant level. The total length of the building is 35.18 m, the total width is 15.2 m, the total height is 22.5 m, and the total construction area is about 2502m².

The first and second floors mainly use the mixed load-bearing structure of brick wall, wood column and wood floor. The third floor mainly use the mixed load-bearing structure of brick wall, steel column, and concrete cast-in-place floor. The fourth mainly use brick wall bearing. The roof is mainly supporting purlin system of wooden triangular roof truss. The structure diagram is shown in figure 3.
The project is a model project for educational use after the renovation of the existing historical buildings in the central urban area. In order to meet the requirements of large space, multi-pattern and flexible architectural function layout of innovative education, the building adopts the construction technology of "retaining the exterior wall as a whole and replacing the internal structure" to transform the existing buildings as a whole, just like “replacing the tank of the hot water bottle”, this “replacing tank” method is suitable for upgrading the interior space of historical buildings [1,2], so as to achieve the purpose of activating and renewing historical buildings in the central urban area. It belongs to the renovation of old buildings under the conditions of "making track in snail shell" in typical central urban area.

2.2. Space optimization

The interior space of the building is designed according to the modern educational concept to highlight the use of public space and provide a reasonable space layout for stimulating students' innovation [3]. Based on the new teaching mode of innovation, openness, sharing and interaction, a green line with sustainable development is designed through the entire space of the building, and the diversified space with free, individual and flexible is designed around the green line.

2.2.1 Diversified Building Green Line. The building adopts a variety of sustainable technologies. For example, the roof with solar panels can provide part of the indoor electricity; collecting roof rainwater can be of secondary use, such as watering the indoor plants, configuring "urban agriculture ", and with the indoor and outdoor environment to form an ecological cycle system. All of these devices are of open innovation platform for innovative course teaching under the premise of ensuring their use function. Students can not only learn and understand its working principle intuitively, but also form teams in related fields to carry out special research and complete in-depth development. All these energy-saving technologies, ecological projects, sustainable courses form a green line that runs through buildings ( as shown in Figure 4). The diversity of space in the green line will create a innovative space full of inspiration for students. The specialization of equipment and solutions in the green line will provide support for "problem-oriented" teaching methods, and implant the frontier problems in the real world into the students' daily study life.
2.2.2 Functional spatial allocation. All kinds of teaching space are allocated around the Green Line, making it of freedom, individuality, flexibility and adaptability, and highly meet the requirements of versatility and diversity as PBL(Project-Based Learning) teaching methods need. All allocation design is "student-centered", fuzzy functional partition, fuzzy space separation, dramatic integration of functional needs, interesting experience and innovation interaction, while providing the participation opportunities for teachers, students and users of the innovation field. Many international innovation laboratory, such as FABLAB(Fabrication Laboratory), LIVINGLAB(Living Laboratory) and BIOLAB(Biology Laboratory), are also distributed inside the building( as shown in Figure 3). It not only serves innovative teaching, but also becomes the engine of continuous innovation in campus space.

2.2.3 Flexible spatial combinations. In order to comply with Tongji Huangpu Design Creative Middle School to emphasize the happy, relaxed and multi-functional teaching environment, nine kinds of classrooms were specially designed (as shown in figure 5), and the expansibility was studied. Increasing the combination forms and function arrangements will be beneficial to ensure the space use efficiency of building at No.95 Huqiu Road. In the future, in the operation of Tongji Huangpu Design Creative Middle School, the space of each classroom could be flexibly adjusted according to the teaching contents, so as to achieve the best effect of courses.

3 Structural repairs

3.1 Structural condition before repair

The selection and arrangement of components are unreasonable and there are weak points. There are many damages existed in the building, such as cracks in wall and brick columns, paint drop, seepage of roof and wall, mild mildew, split of beams, steel corrosion and so on. Especially, the cracks of walls and brick columns in second floor and the splitting damage of individual beams have become dangerous points. The comprehensive seismic capacity of the building does not meet the requirements. The seismic-bearing capacity of the wall from first to third floor does not meet the requirements, while the seismic-bearing capacity of the wall in fourth floor meets the requirements. The slope of the southeast corner of the building is large, and its maximum slope is 15.1‰ eastward, which exceeds the limit value [4,5].

3.2 Repair recommendations

In order to improve the seismic capacity of the building as a whole, it is suggested that the originally support parts, such as internal wooden columns, steel columns, wooden floors, wooden roof, should be removed, retain the exterior wall of the building, and re-install the load-bearing system inside. The new support foundation should be removed from the existing foundation. It is also suggested that a ring beam structure should be added to the building wall to improve the integrity of the building. Reinforcement and maintenance measures should be adopted immediately for the components that have forms the danger point. For the damaged walls and brick columns in the second floor, the pressure grouting should be carried out first, and then the reinforcement treatment should be carried out by using the method of reinforced mortar surface. For the structural cracks in brick wall, it is
suggested to use pressure grouting for sealing treatment. For the serious slope at the southeast corner of the building, it is suggested that the external reinforced mortar surface or other effective methods should be used to reinforce the walls. For other damages, it is suggested that repairs be carried out in accordance with the relevant provisions of the Technical Regulations for Building Repair Works (DG/TJ08-207-2008) [6].

3.3. Structural repair programme
Using the method of “remaining the entire external wall, replacing the entire internal structure” to upgrade and renovate the existing building just like “replacing the tank of the hot water bottle”, as shown in figure 6. The difficulties in this repair process is: relative relationship between old and new foundations, structure design of internal steel system, reinforcement measures of the external wall, connection forms of external walls to new structures.

![Figure 6. Schematic diagram of structural repair plan](image)

1) Relative relationship between old and new foundations. The support piles of the new foundation adopt the type of hollow pipe anchor, with size of 250×250 mm, and with length of 22 m. The number of support piles is 166, and the characteristic value (design value) of pressure-bearing capacity of each pile is 245 kN, all the piles is support on the gray silty clay. The new and existing foundation are separated, and their relative relationships are shown in Figure 7.

![Figure 7. Relative position between new and existing foundation](image)

(a) Relative position inside the building  (b) Relative position when passing through the wall

2) structure design of internal steel system. The internal steel system is supported on the new foundation and is reliably connected to the retaining exterior wall. The overall stability of the steel structure meets the requirements of the specification by setting inclined braces in the appropriate position.

3) reinforcement measures of the external wall. During the process of internal demolition, the external wall has lost horizontal restraint, and before any stabilization measures, the calculated length of the exterior wall is increased from the original height of the floor to the height of the whole building. The external wall changes from load-bearing to non-load-bearing wall.

Temporary horizontal support is added to the external wall in the process of demolition for better stability. At the same time, the outside of the existing external wall is added ring beam, and the inner side is added a layer of reinforced concrete slab to improve the stiffness and overall stability of the external wall; In addition, the outer ring beam is connected with the inner concrete slab through the pin key to form a overall structure, as shown in figure 7.

4) connection forms of external walls to new structures. When the internal steel structure is completed, the vertical load is mainly transmitted to this steel structure and nearly not transmitted to the existing external wall in principle, but the external wall is still used as the peripheral structure of
the school building, and the reliable connection between the external wall and the steel structure is needed. After the internal steel structure is completed, the concrete slab is firmly connected with the steel structure through the embedded anchor plate in the concrete slab, as shown in figure 8.

![Connection between external wall and steel structure](image)

Figure 8. Connection between external wall and steel structure

4 Organization and management

Difficulties: 1) Arrangements for demolition works; 2) Transporting and Stacking of materials and garbage; 3) Schedule arrangement for severe weather and major events; 4) Construction of the internal pile foundation; 5) Design and implementation of fireproof equipment

4.1 Demolition process

Improper demolition process will inevitably destroy the integrity of the school building, greatly reduce the stability, resulting in the serious crack problem. In this project, the reasonable demolition sequence is adopted in the demolition process. First, the old floor inside was removed; and the temporary internal supports was made. Then the wooden beam, column, part of the load-bearing brick wall, and the log truss roof were removed in sections. After this, the whole external wall was strengthened to maintain stability, and then the new internal steel structure was made and collected together.

4.2. Stacking and transporting of materials and garbage

East side of the project toward Huqiu Road, and the other three sides are adjacent to public and residential buildings, the construction site is very small. So it's a challenge to get rid of the garbage and move in the needed materials. All the garbage is stacked inside the building or at the north road which width is less than 5m, and then transported at night without affecting the normal living conditions of the surrounding public. At the same time, materials are also carried in at night, the roof position, which are removed at first, will be used to move in the materials by crane. Choosing the appropriate stacking position and transportation time solves the difficult problems of how to move numerous garbage and materials.

4.3. Schedule arrangement for severe weather and major events

The construction period encountered typhoon, heavy rain and other bad weather conditions for many times, as well as traffic control during the Expo, all of these will inevitably effect the construction schedule. Except having to stop work, most processes that are insensitive to external conditions are carried out as normal as possible to reduce the impact of weather on the duration of the project.

4.4. Construction of the internal pile foundation

In order to reduce the influence of vibration, soil-extrusion and excess pore water pressure on the surrounding environment during the construction of pile foundation, taking the following protective measures: 1) Layout of pressure release holes in adjacent roads and buildings; 2) The piling sequence deviates from the protective object and reasonably controls the piling rate. 3) Monitoring the surrounding environment during piling, Information construction ensures the safety of surrounding
buildings and pipelines, the maximum monitoring deformation not exceed 9 mm, less than the allowable value.

4.5. Renovation of fire facilities
In addition to implementing the mandatory provisions of fire protection requirements, new indoor fire hydrant system is adopted to enhance fire protection capability.

The system adopts the form of temporary high pressure water, connecting two diversions from the municipal water network, and the outdoor water pipeline uses the municipal pipeline to form the outdoor network together, and the valve is added to the municipal pipeline between the two channels of water intake.

In addition, two fire hydrants(one for use and another for backup) and fire hydrant pumps (one for use and another for backup) were set near the water pump room,. Air pressure tank was installed as required, and one pump connector was installed outside.

5 Conclusions
At present, it is imperative to upgrade the function of school buildings in high density area. Aiming at the dual task of protecting historical buildings and adapting to the teaching requirements of innovative education in the new era, reasonable measures have been taken in the design and construction, which lasted nearly a year and a half, and the school building renovation of 2500 m² at No.95 Huqiu Road has been completed.

In space allocation, the teach office area is reduced while the public space is expanded according to the training requirements of innovative talents. a green line that integrates teaching, practice and innovation go through the entire building. A free, personality and flexible space is set up around this green line to adapt to the project-oriented multi-function and diversity space.

In structural design, the “replacing tank” method is applied to realize the upgrading and renovating of school building function. The internal new foundation adopts reinforced concrete structure composed of anchor piles and its upper strip concrete. This new foundation is reasonably separated and traversed from the existing external wall foundation. The internal new steel frame is reliable connected to this new foundation and the existing exterior wall. In addition, a reinforced concrete layer is added to the inner surface of the existing wall to increase the strength and overall stability.

Technological innovation plays an important role in the construction and management of engineering projects. The implementation of the project has overcome many difficulties, such as narrow construction site, material transportation difficulty, hoisting difficulties, adjacent to the residential buildings, dust and noise, controlling the settlement of surrounding historical buildings and so on. The internal steel structure adopts the prefabricated installation, this kind of assembly construction have accelerated the construction progress. Reinforced concrete layer has be add to the inner side of the existing wall to reinforce the entire building. The original fire facilities have be overall upgraded, and the ground settlement was automatically monitored, all these construction works were in ordered operation and efficient process.

6 References
[1] Yan Lihui. A Brief Analysis of“Thermos Bottle Liner Change” Renovation Mode of Historical Building --A Case Study of the Renovation of No.179 Block East Nanjing Road[J]. Chinese & Overseas Architecture, 2018(8):138-140.
[2] Zhang Jianming. Quality Control of Old Walls during the "Hot Bottle Replacement" in Historical Buildings[J]. Development Guide to Building Materials, 2018(8):138-140.
[3] Liu Xin. Innovative Application of "Open" Teaching Mode in "Living Space Design" Course[J]. New Curriculum Research, 2018(12):68-69.
[4] Tongji University Building Quality Inspection Institution. Damage detection report of No. 95 Huqiu Road, Huangpu District, Shanghai[R]. 2017,1.
[5] Shanghai Municipal Housing Design Institution Co.,LTD. Earthquake Resistance Evaluation Report of No. 95 Huqiu Road, Huangpu District, Shanghai[R]. 2016.9.
[6] Shanghai Housing, Land and Resources Administration. Shanghai Construction Engineering Code "Technical Regulations of Housing Repair Engineering" (DG/TJ08-207-2008)[S]. Shanghai, 2008.