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Repairs and Construction Technique of Neoteric Buildings in China: A Case Study of the Building of College of Engineering in Wuhan University

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Abstract. Based on the principles of protection and repair of cultural relic buildings, this paper takes the repair project of the Building of College of Engineering in Wuhan University as an example, analyzes the architectural characteristics and construction difficulties, lays stress on scientific analysis methods, and determines the repair method combining modern technology with traditional technology. In the process of rehabilitation and construction, the principles of "not changing the original state of cultural relics" and "minimal intervention" are followed, and the requirements of facilities and functions are improved appropriately, so as to prolong the life span of the building and give full play to its use value.
Keywords: Neoteric building, Construction technique, Glazed roof tile, Roofing repair, Wall repair

1. Introduction

Neoteric buildings in China refers to the buildings built in China from the Opium War in 1840 to the founding of the People's Republic of China in 1949. These buildings, as the products of the specific historical period and the renovation period of construction technology, have unique value.

Since 1961, the China's State Council has announced the First Batch to the Seventh Batch of National Key Cultural Relic Protection Units, the proportion of which belongs to "neoteric" type is about 15%~20%, most of which are buildings. This proportion will be further enhanced with the expansion of heritage value recognition.

Compared with ancient buildings, the neoteric buildings have not experienced too much natural erosion and destruction, but with the continuous increase of service life, the natural impact is becoming increasingly apparent. In addition, some neoteric buildings have been transformed and overloaded, resulting in a lot of structural and decorative surface damage and aging.

The construction age of neoteric buildings was an important period when new materials and new construction systems had been widely adopted in the world. However, the relevant technical standards were both initial and experimental stages. Nowadays, the elimination and loss of technology and the extinction of materials have increased the difficulty of restoration. The earlier the protection technology is developed, the less the loss of the original and authenticity of materials and processes will be. Therefore, it is of great significance to protect scientifically the characteristics of neoteric historical buildings for the continuation of such special and precious cultural heritage [1-3].

Built following trend of the mountain, facing north with bilateral symmetry, the Building of College of Engineering in Wuhan University, which is a modern architecture combining Chinese and western style, is located between two flint mountains at the north foot of the Luojia Hill, opposite to the Building of College of Science to its front, lying on gentle and verdant Luojia Hill to its back for

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imitating traditional Chinese architecture blending with western architecture style.

The building completed in January 1936 consists of main building, four ancillary buildings and connecting corridor with 2 Roman-style watchtower observatories. The main building consists of 1 underground floor and 4 ground floors. The ancillary building consists of 2 ground floor and 2 regional underground floors. The building area covers 8140 square meters with 4981.16 m^2 for main building, 2757.92 m^2 for ancillary building, and 400.92 m^2 for connecting corridor (As shown in Fig.1 and Fig.2).

Figure1. Façade of the Building of College of Engineering in 1930s and 2013.

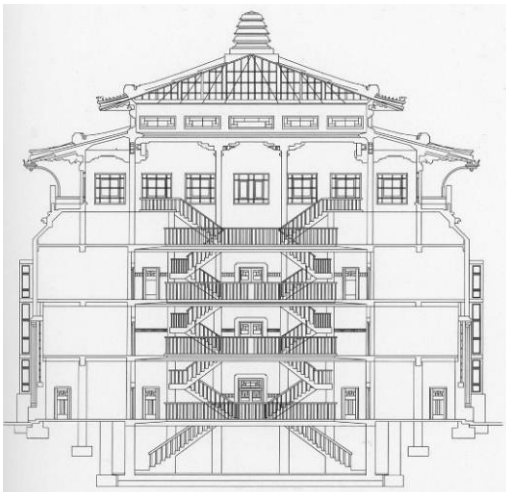

Figure 2. Section E-W thru light court of the Building of College of Engineering

The Building of College of Engineering in Wuhan University was listed into the Fifth Batch of National Key Cultural Relic Protection Units on June 25, 2001 by the China's State Council as a modern important history relic and representative building [4-6].

2. Historical Background and Architectural Characterization

The Building of College of Engineering is a representation of neoteric buildings in Wuhan University. It occupies a vital important position in Chinese modern education history, Chinese modern architecture history, and Chinese history of New Democratic Revolution. It was invaded by Japanese aggressors after completion for less than three years to be hospital of Japanese army. It has witnessed the atrocities committed by Japanese imperialists against China.

In 1952, the colleges and departments of all Chinese universities were restructured, and the College of Engineering of Wuhan University was integrated into other universities. The Building of College of Engineering in Wuhan University was converted it into the Administrative Building and always used to today.

The main building of the structure designed to a square building with four corner double eaves pavilion roof forms a mosaic painting on Luojia Hill that is a natural “screen” contributing elegance to the original gentle mountain.

The roof of the main building that embodies unique design shapes convergence of four corner double eaves pavilion roof with peacock blue glazed roof tile in lower eave and transparent glass as roof in the top and using four nacarat inverted buckled pottery jars folding a pagoda shape. The roof formation in combination of square and round, red, white, and blue is rare at home and abroad.

As for the main building, its high wall is beautified by wide floor-to-ceiling glass window and beveled-style walls, and the four corners are supported by Chinese style ancillary buildings with green glazed tile gablet roof are more elegant, graceful and splendid.

There are exquisite details in the main building mixing aesthetics and practicability. For example, it is full of originality above the wall with multiple rare leontiasis beasts of Chinese traditional architecture. However, under the four cornices of the roof, there are 4 disk-shape fountain bailers which are called “dew holding plates” shaping like hanging lamp but they are the outfalls of the roof to centralize and discharge the rain water in big double layer roof so as to not damage the wall feet and beautify the upturned roof-ridge of the cornice simultaneously.

Therefore, the Building of College of Engineering is a classical architecture with high architectural art value.

The neoteric architecture complex in the Wuhan University, from campus site selection to planning layout, from architectural decoration to architectural technology, fully reflects the broad mind and realistic and innovative spirit of the Chinese geologist Li Siguang and the American Architect F. H. Kales. The new material, new technique and new form, including steel frame structure with large span and concrete frame structure, three-hinge arch, shared space, and glass atrium that were under an exploring stage in the architecture at that time were applied to the buildings successfully.

3. The Repair Project

The Building of College of Engineering had been repaired from June 1, 2012. The main repairs included: the repair of steel structure glass roof and glazed tile roof in the main body of the building, lifting construction for ridge of annexes, reinforcement for roof truss of the connecting corridor, the repair for painted exterior wall of the building, the repair for steel windows of exterior façade, the repair for dados of indoor dry wall, wooden doors and wrought iron art railings. At the same time, the interior decoration construction was carried out according to the design drawings, so that it can regain its perfect use value [7-8].

3.1. Repair Technique for Steel Structure Glass Roof in Main Building

Fig. 3 shows the partially structural schematic diagram of the glass ceiling.

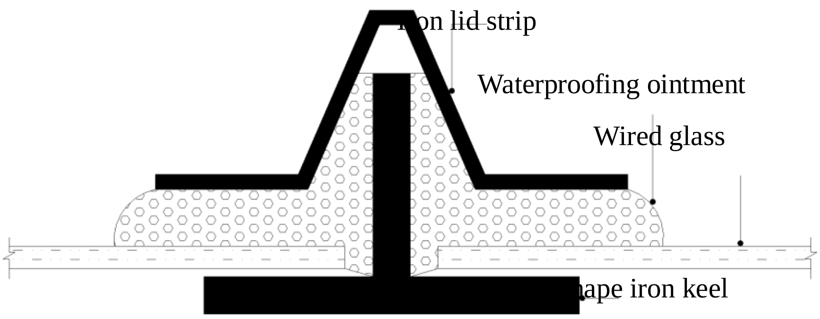

Figure 3. Partially Structure Schematic Diagram of the Glass Ceiling

Before the glass roof of the building was removed, the roof was photographed and imaged, and then the glass top surface was surveyed and mapped. According to the result of surveying and mapping, the components that couldn't continue to be safely used are processed according to the original condition. Glass iron lid strip, original wired glass and T-shape iron keel were protectively disassembled from top to bottom (As shown in Fig.4).

Figure 4. Disassemble glass iron lid strip

Steel components of the roof structure were repaired. All oil paint in original steel roof trusses were removed and rusts were removed by polishing. All steel roof trusses were brushed with antirust paint. Steel roof trusses were embedded twice with fluorocarbon putty and polished, and then coated with fluorocarbon paint. As for the steel structure wrapped in concrete outside, the coating material on the concrete was washed with high-pressure water gun, then the cleaned concrete was embedded with fluorocarbon putty and brushed with fluorocarbon paint.

The entire glass top surface was divided into north, south, east and west areas. The overall construction process was in accordance with dismantling area followed by restoring another area, and then the procedure of another area was conducted in the same way. Derusting and polishing of the dismantled iron T-shape keel were carried out, and two protective agents were brushed. Two protective agents were also applied to the reworked T-shape keel and the copper cover plate (As shown in Fig.5 and Fig.6).

Figure 5. Derusting and polishing of the dismantled iron T-shape keel

Figure 6. Protective agents were brushed

T-shape keels were installed according to original sample from top to bottom (As shown in Fig.7).

Figure 7. T-shape keels were installed according to original sample

Asbestos yarn and tung oil lime paste were installed in the T-shaped keel. Wired glass was installed according to original sample from top to bottom with its surrounding sealed by silicon sealant. The lap length of upper and lower glass block was 100mm. A copper bar hook was used at the lapping joint to avoid slipping of upper glass. At the same time, transparent silica gel was filled between lapping joint of glass and glass.

From the bottom up, the copper cover strips were covered, and tung oil lime paste was filled between the copper cover strip and the glass. Anti-fall stainless steel wire mesh was installed below the glass and in the inner side of the steel roof truss to prevent top surface glass from falling because of wind pressure and other factors.

3.2. *Repair Technique for Glazed Tile Roof*

Fig.8 shows the structure schematic diagram for concrete tile roof. The plane layout and paving method of the original roof were surveyed and recorded. The damage data of glazed cylindrical tile, clay tile, drip tile and eave tile were obtained.

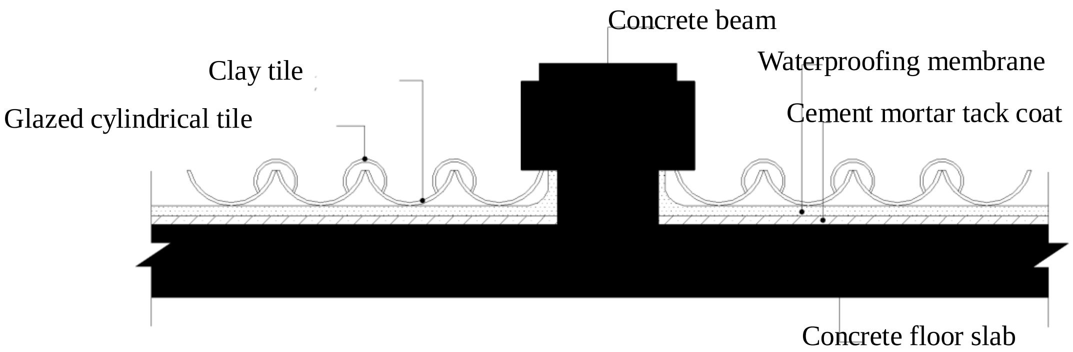

Figure 8. Structure schematic diagram for concrete tile roof

The supplementary tiles were custom processed according to the type, size and number of damage of the various tiles. These customized tiles were made of original size, original material and original color. The glazed cylindrical tiles and clay tiles were disassembled from top to bottom and classified and stacked (As shown in Fig. 9).

Figure 9. Glazed cylindrical tiles and clay tiles were disassembled

The surface of base was cleaned and the tiles were selected and prepared from the supplementary tiles. The ridges were positioned according to the original plane layout. Tiles were paved with cement mortar (As shown in Fig. 10). The way of tile paving was in accordance with original paving of mapping record before disassembly.

Figure 10. Tiles were paved with cement mortar

In ancient Chinese Palace architecture, beasts made of pottery or glazed tiles were indispensable parts of roof decoration. All beasts with badly damage were dismantled and they were copied with the same shape and installed by professional clay sculpture technicians on the site (As shown in Fig. 11).

Figure 11. Beasts were repaired

All drainage ditches of roof were dismantled during the repair, and new drainage ditches of roof were made of red copper and processed according to the original style. The repair process of the arc cornice downpipes and the drainage ditches of roof was the same.

3.3. Overall Uplifting for Main Ridge of Ancillary Building

Due to the long history of the buildings and the aging of the roofs, leakage occurred on the main ridge of ancillary building. Waterproof roll could not stick into main bridge at the time of roof paving so that waterproof requirements could not be improved. Therefore, main bridge was uplifted overall for waterproof roll to stick into it and copper sheet covered it for protection (As shown in Fig. 12).

Figure 12. Overall uplifting of main ridge

Specific construction method is as follows:

The steel pipe row frames were set up upwardly from building surface right below and on both side the main bridge and were beyond main bridge through roof.

Along the direction of the main bridge, lifting points were distributed, and then the bottom of lifting points in main bridge were dug through carefully so that the chain of the chain block could cross it, and the angle irons were pad and set on both side lifting point for protecting the lifting point of main bridge.

The main bridge was uplifted with chain block and the speed and height of each lifting point were controlled simultaneously. Then the waterproof roll and the copper sheet were stuck into the bottom of the main bridge after main bridge was uplifted to reserved height.

3.4. Repair Technique for Wooden Roof Truss of Corridor

After roof truss and purline were surveyed on site, it was found that stability of overall structure of

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wooden roof truss was reliable and partially wooden components were rotten. Thus, rotten sections were removed and replaced with new wooden components. New and old components in the replaced part were connected with steel plates and bolts.

Screws and nuts, missed in original reinforcing steel members, were added. Original antirust paints on all reinforcing steel members were removed. Protective agent was brushed for rust prevention so as to present original color of steel members and a retro style (as shown in Fig.13).

Figure 13. Repair of wooden roof truss of corridor

Original coatings of wooden roof truss were all polished and cleaned so as to remove surface paint. Then antique finishing was conducted for all wooden components. In the end, all wooden components were brushed with two coatings of protective agent so as to present original color of wood (as shown in Fig.14).

Figure 14. All wooden components were brushed

3.5. Repair Technique for Wall Rendering

Since external wall had been reconstructed for many times and brushed with multiple coatings, original style and features of the building were lost. In order to present original style and features of the building, the following construction methods were adopted:

1) Firstly, water pistol was used to clean original coatings on wall.

2) The hollow parts of wall base were chiseled, cleaned and broom-finished, rendered and repaired again.

3) Original tiny cracks in wall were repaired with cement mixed with glue (as shown in Fig.15).

Figure 15. Tiny cracks in wall were repaired

4) For cracks at four wall corners of the Building of College of Engineering, the base where cracks were located was cut and removed with steel wire mesh attached to the surface, and repaired and rendered again (as shown in Fig.16).

Figure 16. Repaires of cracks at four wall corners

5) For repair of fret above access to main building, similar cement was mixed with mortar. Subject to original diagram and in original location, steel wire gauzes were bound above inserted steel bars as framework, then mortar materials were added and brushed in batch. Thickness added each time was strictly controlled to be a maximum of 7 to 8mm, and the works were completed step by step, which was favorable to flaking control.

6) Due to color difference between repaired wall and original wall, the whole wall was colored. Namely, mixture, which consisted of yellow sand, cement and acid and alkali-resisting polymerizer, was used to brush external facade fully and uniformly from top to bottom with brush (as shown in Fig.17).

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Figure 17. Chromatic aberration processing of wall surface

7) In the end, colored external facade was sprayed with two coatings of protective agent in full.

3.6. Repair Technique for Steel Sash
Glass of old window is removed: Since steel sash was age-old and oily, dust become hardened. Iron hammer and clink were used to gently knock off oily dust, and glass was removed and placed in the fixed place.

Removed old hardware fittings were stocked respectively as per usable ones and scraped ones. The number of those fittings for filling a vacancy was recorded. Custom processing was conducted for those fittings in accordance with original sample and texture.

Steel sashes were firstly brushed with paint remover. 2 to 3 minutes after brushing, chemical action occurred in old paint film, which was softened, wrinkled, brittle and removed from base plate. Old paint film was cleaned with metal scraper and steel wool, washed with clear water and wiped to be clean with cleaning cloth.

For steel sashes with rusted surface, steel wool and electric grinding machine were used to polish and remove rust manually and mechanically. Steel sashes with partial deformation were rectified.

Paint was brushed subject to color and luster in original style and feature. Hollow toughened glass and hardware fittings were fitted.

3.7. Repair Technique for Wooden Doors
Paint remover with appropriate amount was uniformly brushed on surface of wooden materials with hairbrush. A little paint remover was brushed each time and repeated brushing was conducted for many times. After paint was peeling and flaking, sand paper was used to grind and remove paint. The said process was repeated for many times until original color of wood was recovered. Partially uneven paint, which was not removed, was scraped slowly and manually with blade. During paint scraping, the intensity was required to be well controlled so as to prevent wooden door cover from being damaged indirectly.

Partial damage, gaps and cracks on the surface of the wooden doors were repaired with putty. After partially repair were completed, surface of the whole wooden door cover was prepared with two coatings of putty and polished to be smooth with sand paper. Wooden door and wooden door cover were brushed with paint after surfaces were polished.

3.8. Repair Technique for Indoor Dry Wall Dado
Since dry wall dados have been brushed with coatings for many times in previous years of repair and coatings on the surface were thick. Coatings were removed with paint remover firstly. Effect of removing coatings with paint remover was bad. Thus, in the repairs, coatings were removed by polishing (as shown in Fig.18).

Figure 18. Coatings were removed by polishing

After coatings on all walls were removed, original brick wall seams were carved and slotted. Then brick powders were used to repair walls and pointing joints. In accordance with analysis for brick seams in wall with coatings removed, brick seams of original wall were ingot-shaped and thus renovated in accordance with the original approach. In the end, renovated brick wall surfaces were brushed with two coatings of protective agent in order to effectively stop weathering and corrosion and play a role in waterproofing (as shown in Fig.19).

Figure 19. Repaired brick wall surface

4. Conclusion

In order to retain the real historical information as far as possible, the most effective and reasonable technical measures were used in the restoration of this project, and good results were achieved. A large number of modern materials, technologies and methods were applied to removing paint from steel components, protecting wooden components and wall, and preparing elements of wall renovation materials [9-13].

Paints on steel components were removed with paint remover. By means of chemical action between paint remover and paint, old paint films were softened, wrinkled, brittle and removed from base plate. Thus, the problem that paints could not be removed thoroughly by conventional technology was settled.

With respect to protection for surface of wooden components and external wall, a kind of colorless and transparent protective agent was brushed on surface in a way that made surface of wooden components able to keep original color of wood and played a role in preventing corrosion. In addition, such protective agent was brushed on surface of external wall so as to play a role in reinforcing external and ensure change of color difference of renovated external wall.

In external wall repairs, in order to recover wall to the most original style, alkali-resisting polymerizer was added to yellow sand and cement and they were blended to be slurry and brushed on surface of external wall, making external wall present an antiquated style.

Modern waterproof materials and technologies were applied to waterproofing for roof of building and had thoroughly settled hazards caused by long-time water disaster to building. In waterproof layer laying on roof, waterproof PE-PP coiled material were used, which prolongs waterproof years of roof.

By all-round repairs for the main and ancillary buildings of College of Engineering, the original historical information of such buildings is preserved. The intervention measures for buildings in historical repairs were eliminated. The hazard factors affecting life of buildings were removed. The damages to natural and human factors of the buildings were repaired and prevented. The repairs ensured the safety of the buildings structure and made the facade of the buildings recreate the historical features of 1930s.

This repair was consistent with the repair principle of “no change in original state of cultural relics” and “the minimum intervention” for historic and cultural buildings [14-21], and it makes the life span of the building better.

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