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Construction Technologies and Conservation Strategies for the Bell Tower of Former Nanking University (Nanjing, China)—A Case Study of a Typical Architectural Heritage of the American Church School in the Late 19th Century

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Abstract: The bell tower of Nanking University, built in 1888, is a milestone of modern educational architecture in Nanjing. It fully introduced Western architectural concepts and is an important historical witness to the cultural exchange between China and the West. At present, there are few studies on the conservation and reuse of the building, so the authors conducted the project. In this paper, we conducted research by combining qualitative and quantitative methods. The qualitative analysis includes analyses of historical maps, photos, text, surveys, mapping of buildings, and a comparative analysis. The quantitative analysis includes statistics on the distribution of the urban school architectural heritage, the number of buildings at Nanking University, and China's school building design standards. Through the historical research and value analysis of the building, we explore its real information from the aspects of architectural style, space, structure, material, and construction technology, and propose a reasonable conservation method. According to the current urban planning policy and architectural heritage data, the functional upgrading and renovation of the building will be carried out. This paper explores authenticity and integrity-based restoration methods, as well as the adaptive-reuse strategy for China's architectural heritage, which can provide a paradigm for regional development and historic campus renewal.

Keywords: bell tower; church school; Chinese modern architectural heritage; construction technology; authenticity and integrity; conservation and adaptive-reuse strategies

Citation: Wang, H.; Hu, Z.; Huang, Y.; Chen, M.; Hu, L.; Zhou, Q. Construction Technologies and Conservation Strategies for the Bell Tower of Former Nanking University (Nanjing, China)—A Case Study of a Typical Architectural Heritage of the American Church School in the Late 19th Century. *Buildings* **2022**, *12*, 2251. https://doi.org/10.3390/buildings12122251

Academic Editors: Vaidas Petrulis, Raimondas Bliūdžius and Huriye Armagan Dogan

Received: 26 October 2022
Accepted: 13 December 2022
Published: 17 December 2022

1. Introduction

Nanking University was the first church university founded by the American Christian Church in Nanjing, China, in the 1880s. At present, there is only one piece of architectural heritage on the campus, the bell tower, which is a major historical and cultural site that is protected at the national level. The authors completed historical research on the bell tower through archival document research, on-site surveying, mapping, and an exploration of the building in terms of its architectural style, space, structure, material, and construction technology. We conserve and renovate based on the principles of authenticity and integrity so that the bell tower not only adapts to modern life but also retains its original historical flavor.

Church school buildings generally refer to school buildings built by Western churches on the Chinese territory after the first Opium War in the 1840s to the founding of the People's Republic of China in 1949. After the first Opium War in the 1840s, the Chinese government lifted the more than a 100-year-old policy of prohibiting foreign religions and allowed Western churches to build churches and schools in China [1]. Church school buildings are

the origins of public building types in China after it opened its doors to the West. They are tangible manifestations of the two-way flow of Chinese and Western cultures [2]. While introducing advanced Western educational concepts and culture, Western churches also directly adopted Western school architecture. Most of these school buildings are located in prosperous urban areas and have been used as educational buildings to this day, with unique historical, social, artistic, and scientific value.

Nanjing is one of the cities with the greatest quantity of modern church buildings. According to the third national census of immovable cultural relics, there are currently more than 1304 modern buildings that have been valued and registered in Nanjing [3], among which, there are more than 100 church schools. After decades of cultural heritage conservation work, China has established a systematic conservation system that reflects the characteristics of Chinese cultural heritage while maintaining the unique historical and cultural values of architectural heritage to meet current and future needs.

1.1. Literature Review

According to the "Principles for the Conservation of Heritage Sites in China" (2015), the conservation of cultural relics is carried out in accordance with the aspects of the investigation, assessment, formulation of conservation plans, and conservation practices. The value assessment of architectural heritage is the key to heritage conservation. Based on this, the conservation level, conservation content, the intensity of cultural relic buildings, and the possibility of reusing after repair, are determined, and finally, principles and measures are proposed for the next repair design. Historical, artistic, and scientific values are three aspects of architectural heritage assessment [4] ("Law of the People's Republic of China on the Protection of Cultural Relics" (revised in 2015)). The three-value evaluation method for cultural heritage is gradually being recognized. The historical value of architectural heritage is reflected in the history it has witnessed; its artistic value is reflected in its architectural art and style [5]; and its scientific value is reflected in its architectural structure, decoration, and construction technology.

Authenticity and integrity are two core principles of architectural heritage conservation. Authenticity focuses on the depth (or time axis) of heritage conservation, while integrity focuses on the breadth (or spatial axis) of heritage conservation. The two depend on each other. Both international and domestic heritage conservation documents impose requirements on the authenticity and integrity of cultural heritage. In 1931, "The Athens Charter for the Restoration of Historic Monuments" [6] clearly states: "it recommends that the historic and artistic work of the past should be respected, without excluding the style of any given period, especially in the neighbourhood of ancient monuments, where the surroundings should be given special consideration". Since then, authenticity and integrity have been the most important principles in the field of international heritage conservation. In 1964, "The Venice Charter" [7] clearly mentioned "protecting cultural heritage and passing them on in their true and complete form", and emphasized that the principle of restoration should respect the original materials and the overall conservation of the surrounding environment. The "Venice Charter" still serves as a general guide for the conservation of world cultural heritage and has played a guiding role in promoting the conservation of China's architectural heritage. In 1979, the World Heritage Committee determined that "authenticity" is the most important evaluation criterion for the nomination, selection, and conservation of world cultural heritage sites. Since then, "authenticity" has been widely promoted in the field of heritage conservation. However, the conservation standards and scope of use formulated by these international documents mainly focus on Western stone buildings and have not fully considered Eastern wooden buildings. Therefore, in 1994, the discussion on authenticity in the "Nara Document on Authenticity" [8] advocated for the expansion of the concept of "authenticity" from a variety of perspectives and proposed that attention should be paid to authenticity in different cultural environments, including oriental wooden architecture. The "authenticity" of cultural heritage provides important guidelines for the authentic conservation of oriental wooden buildings.

With the deepening of human heritage conservation work, the meaning of "integrity" has been expanded to include social, functional, structural, and visual aspects.

In 1982, the Chinese government promulgated the first law on the conservation of cultural relics after the founding of the People's Republic of China, the "Law of the People's Republic of China on the Protection of Cultural Relics" (revised in 2015), which clearly stipulates: "When cultural heritage is repaired, protected, or moved, the principle of not altering the original state of cultural relics must be observed (Article 21)". The "Beijing Document" [9] issued in 2007 represents the development and specific application of the "Nara Document on Authenticity". Its understanding of "authenticity" is based on Chinese wooden architecture, and it determined the guidelines for the conservation and restoration of oriental wooden architecture. It contributed to the standardization of the conservation of wooden architectural heritage in China and throughout Asia. In 2015, the "Principles for the Conservation of Heritage Sites in China" promulgated by the Chinese government, on the basis of emphasizing the value assessment of architectural heritage, emphasizes that the purpose of conservation is to preserve the historical information of architectural heritage with authenticity and integrity through technical and management measures. It emphasizes the complete conservation of cultural relics' environments and other elements that reflect the value of cultural relics and rebuilds a systematic and complete conservation principle system that reflects the characteristics of Chinese cultural heritage. It incorporates the oriental wooden building system into international architectural heritage conservation research and clearly proposes to protect the authenticity of the materials, craftsmanship, design, and environment of cultural heritage, as well as the historical, cultural, social, and other related information it reflects. During repairs, the original components should be retained as much as possible, traditional techniques should be used first, and the rationality of the traditional repair techniques of the oriental wooden building system should be emphasized because the nature of the building materials is different, and the repair methods are also different.

The authenticity of the architectural heritage continues to fade over time, and historical information disappears with each repair. Protecting the authenticity of architectural heritage can only be a purposeful choice, neither ignoring historical information, nor unrealistically retaining all historical information, and choosing to retain important historical information as much as possible. However, how to protect authenticity and to what extent to maintain authenticity has always been a hot topic and a focus of debate in academic circles. As early as the second half of the 19th century, there was a heated debate between the French "restore the original state" group headed by Viollet-le-Duc (1814~1879) and the British "keep the existing state" group headed by John Ruskin (1819–1900) [10]. Both groups seem to be striving for the authenticity of architectural heritage, with the former seeking authenticity at a point in time in history, and the latter emphasizing the authenticity of the entire historical process. At present, Chinese scholars are also divided into two groups.

Nonetheless, for a long time, Chinese scholars tend to "return to the original state" [11]. In China's heritage conservation practice, restoration is often made to the original state when it was created, and even some regulations advocate restoration to the original state. For example, the Qufu Declaration (2005) [12] mentioned: "The original state is the healthy state of the historical building, and the damage is the current state, which should be restored to its original state." In practice, more architectural heritage has been restored to its original state. For example, in 1974, the main hall of Nanchan Temple in Wutai Mountain, Shanxi Province, China, was repaired, in an attempt to restore it to its original state when it was first built during the Tang Dynasty (782 AD) [13]. However, there were some repair cases that retained traces of various periods. Take the maintenance of drum towers in Ningbo, China, for example. The Drum Tower was built in the Tang Dynasty (AD 821), and it was repeatedly built and destroyed. The existing building was built in 1855 and it is a typical traditional Chinese building. In 1935, a western-style bell tower was added to the middle of the roof of the building. When the building was repaired, this western-style component

was preserved [14], so that the historical information of each historical period could be truly presented. The author believes that the above-mentioned restoration of "return to the original state" can easily lead to the disappearance of historical information, and a large number of restorations have no authoritative basis for restoration, and many are conjectures. The author believes that adhering to the principle of authenticity is to truly protect the historical information of various historical periods. In regard to preserving the legitimate contributions of cultural relics in different historical periods, the purpose of restoration is not to pursue the unity of style (Venice Charter, 1964).

It is worth noting that the factors affecting the authenticity of the heritage include structures, materials, craftsmanship, functions, and the environment [15]. However, too much focus on architectural appearance in many current heritage conservation practices has led to the emergence of "facadeism" [16], forming a model of "external protection and internal reconstruction" [17], which is a response to authentically one-sided understanding.

As for integrity, the Chinese government delimits the "conservation scope" and "construction control area" to protect the surrounding environment of the cultural relics according to the cultural relics grade and status quo ("Law of the People's Republic of China on the Protection of Cultural Relics", Article 17). Therefore, although many scholars have conducted research on China's modern architectural heritage, summed up the conservation ideas and methods of different types of architectural heritage, and reached a consensus, in many respects, in architectural heritage conservation practice, the understanding of authenticity, integrity, and conservation methods are still controversial and often require a case-by-case strategy, which provides the opportunity for this study.

Adaptive reuse is an important conservation method, and its focus is on comprehensively considering the continuation of the original function or the upgrading and transformation of the function according to the value characteristics, conservation status, and environmental conditions of the heritage (Principles for the Conservation of Heritage Sites in China, Article 40). "The Barra Charter" promulgated in 1979 first proposed "compatible use"; that is, "use with little or no effect on cultural significance" [18]. Compatible utilization is an effective method of achieving a win–win situation for urban development and architectural heritage conservation that is related to the value assessment of heritage and social needs in reuse design. Academia has conducted extensive research on architectural heritage conservation and reuse, including adaptive reuse, sustainable reuse, and co-evolutionary approaches [19,20]. In recent years, the Chinese government has encouraged "compatible uses" of architectural heritage. In 2019, the National Cultural Heritage Administration issued Guidelines for the Opening of Architectural Heritage to ensure that heritage buildings are allowed to open to the public in the form of community services, cultural displays, tours, commercial services, and public welfare offices without compromising the safety of heritage buildings [21]. It provides guidelines for research on this topic.

To summarize, this article focuses on the core principle of "authenticity and integrity", analyzes the authenticity of heritage in various cultures, discusses the current status of "how to protect authenticity and to what extent to protect authenticity", and points out the deficiencies of current conservation practices (many heritages have removed historical traces, paid no attention to raw materials and original craftsmanship, paid attention to external protection but ignored internal functions, etc.). In view of this, the authors believe that under the current Chinese heritage protection system, the core issue of architectural heritage protection of modern Chinese church schools is to explore the strategy of heritage protection and adaptive reuse based on authenticity and integrity on the premise of value assessment, retain the traces of each period, protect the authenticity and integrity of the heritage itself and the surrounding environment, and upgrade functions according to current needs. This is the contribution of this paper. The following uses the protection of the bell tower in the former Nanking University campus in Nanjing City, Jiangsu Province, China, as an example (Figures 1–3). On the premise of retaining the traces of various periods, it focuses on the authentic and integral preservation of the architectural style,

structure, materials, and surrounding environment, and analyzes the current requirements for functional upgrading. A reasonable protection strategy based on authenticity and integrity is proposed.

Figure 1. Location of Nanjing in China (based on a map of the People's Republic of China by the State Bureau of Surveying and Mapping, map approval number: GS (2019)1683).

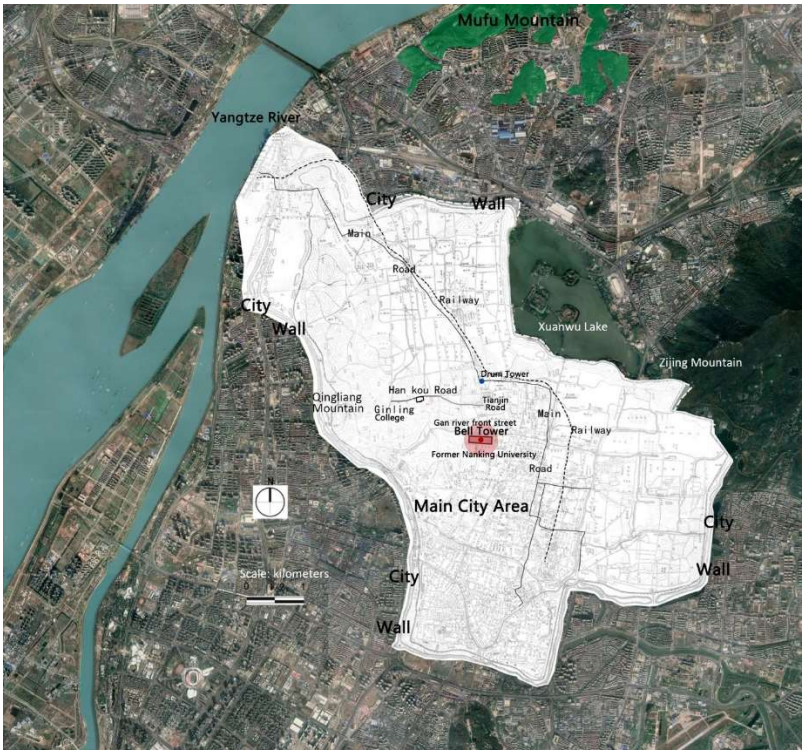


Figure 2. Location of the bell tower in Nanjing (based on Google Earth, 2022).

1.2. Aims and Methodology

The bell tower has a history that spans more than 120 years. The use of the building has changed many times. The current architectural form is somewhat damaged, and the building structure and materials need to be repaired urgently. According to the Nanjing Historical and Cultural City Conservation Plan (2010–2020) [22], Zhongshan Road is located

on the axis of modern historical buildings and has high regional value. The research goal of this paper is to explore the building from the aspects of architectural style, space, structure, material, and construction technology on the basis of value analysis and to propose repair and adaptive restoration methods based on authenticity and integrity so that these strategies can be taken advantage of (Figure 4).

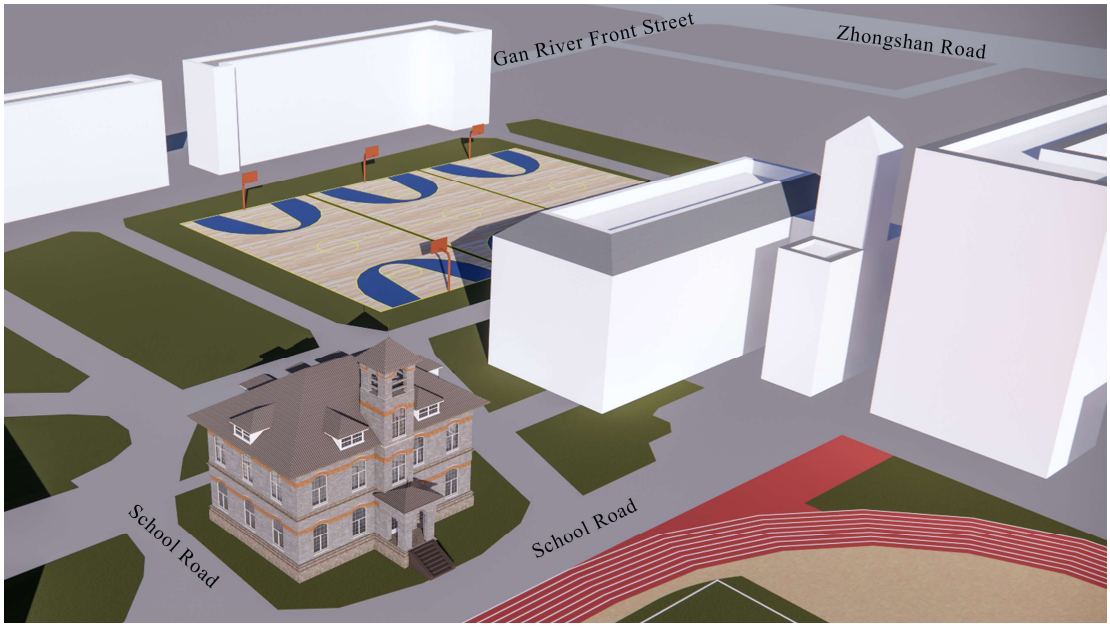


Figure 3. Location of the bell tower on the campus (source: author).

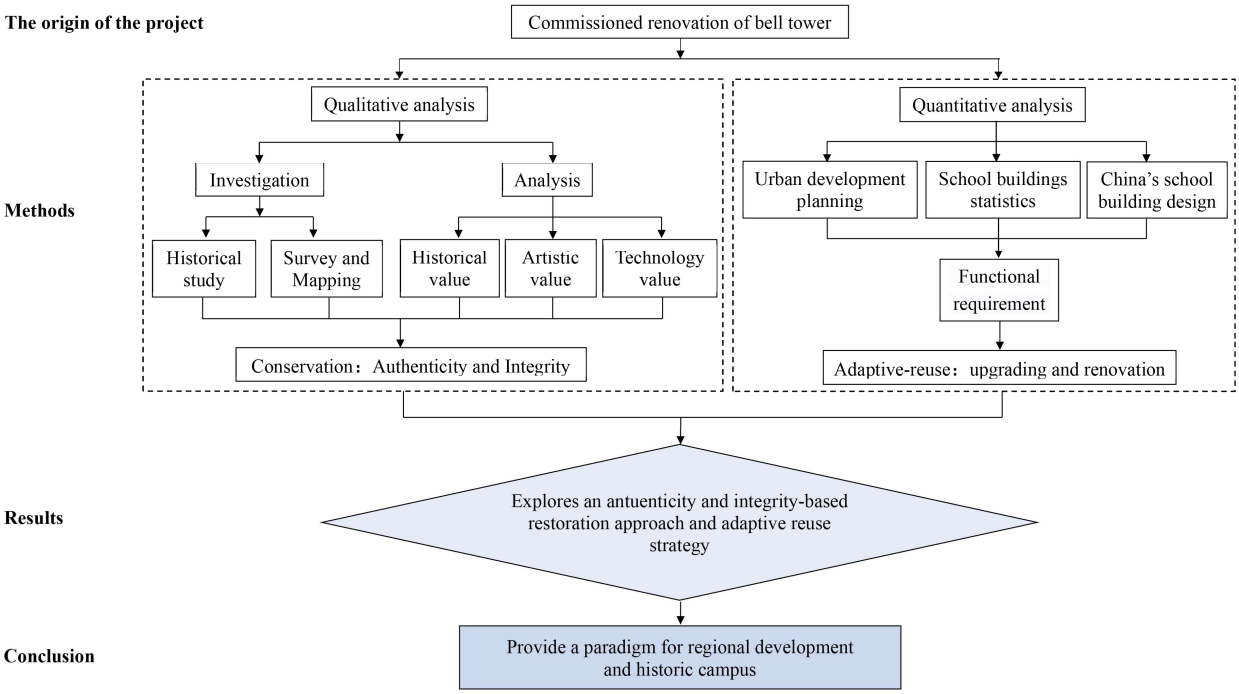


Figure 4. Research Framework (source: author).

This paper employs a range of qualitative research methods, including historical research, field surveys, and mapping. Its academic contributions are as follows:

(1) Through systematic and complete historical research, field surveys, and mapping, the historical background, cultural significance, and current situation of Nanking University and its bell tower are explored. According to the value types based on architectural heritage

in the "Principles for the Conservation of Heritage Sites in China" (2015), this paper qualitatively studies their practical significance and practical solutions. Based on the principles of authenticity and integrity, conservation principles and repair strategies are formulated.

(2) Quantitative analysis includes statistics on the distribution of urban school architectural heritage, the number of buildings in Nanking University, and China's school building design standards. Starting from the development needs of the campus, combined with the "Nanjing Historical and Cultural City Conservation Plan" and regional conservation needs, we discuss the feasibility and suitability of the bell tower's reuse. Based on the functional scheme of the current architectural spatial characteristics, the scheme has a minimal effect on the original structure. Additionally, we develop a restoration strategy compatible with conservation and reuse.

2. Case Presentation

2.1. History of the Building

2.1.1. The Historical Background of the Bell Tower

Nanjing, as the capital of the Republic of China, was the political, economic, and cultural center of China in the first half of the 20th century, and was, therefore, an important base for the missions of Western churches.

The establishment of schools is an important part of the missionary causes of Western churches in China [23]. The earliest kindergartens, primary schools, and middle schools in Nanjing all started as mission schools. Initially, churches were created inside rented private houses, then schools and churches were separated, and, eventually, land was purchased to build mission schools. The educational model and campus construction model provided a reference for Chinese schools in the same period.

The location of Nanking University along the Gan River (now no. 169 Zhongshan Road) in the middle of Nanjing City was influenced by missionary activities. At first, missionaries preached in the area of the Gan River and Drum Tower [24], where they built churches, hospitals, and schools, which was conducive to the formation of a religious cultural circle. The bell tower is a representative church building.

2.1.2. The History of the Bell Tower

In 1888, American Christian missionary C.H. Fowler founded Nanking University near the Gan River in Nanjing and hired Canadian missionary J.C. Ferguson (1866–1945) as its first president. In 1910, after Nanking University, Christ College and Yizhi College merged to form "The University of Nanking", the university department was set up in Huiwen College, the middle school was set up in Hongyu College, the primary school was set up in Yizhi College, and the middle school was changed. It was called Jinling High School [25]. In 1921, after the University of Nanking moved to a new campus near the Drum Tower, the former campus was handed over to Jinling High School for use, and it continues to be used by this school to this day.

Nanking University was the largest church school in Nanjing in the late 19th century, with its bell tower (built in 1888, rebuilt after a fire in 1917) (Figure 5), chapel (built in 1888), west teaching building (built in 1893), east teaching building (built in 1893), Collins dormitory (built in 1893), YMCA library (built in 1902), gymnasium (built in 1934), and seven other representative buildings, all of which were built in a Western style with the outer walls being built from gray brick masonry. The buildings were designed by an American architect and built by Chen Mingji Construction Factory (the first Chinese-founded construction factory in Nanjing. The owner of the factory, Chen Lieming, was a Christian, and he built many church buildings in Nanjing) [26]. Until the end of the 1980s, the school maintained the campus space form of the late nineteenth century. After the 1990s, due to a shortage of school land, all other historical buildings except the bell tower were removed. In 2006, the bell tower was rated as a major historical and cultural site

protected at the national level as the earliest existing school building built by Christians in Nanjing.

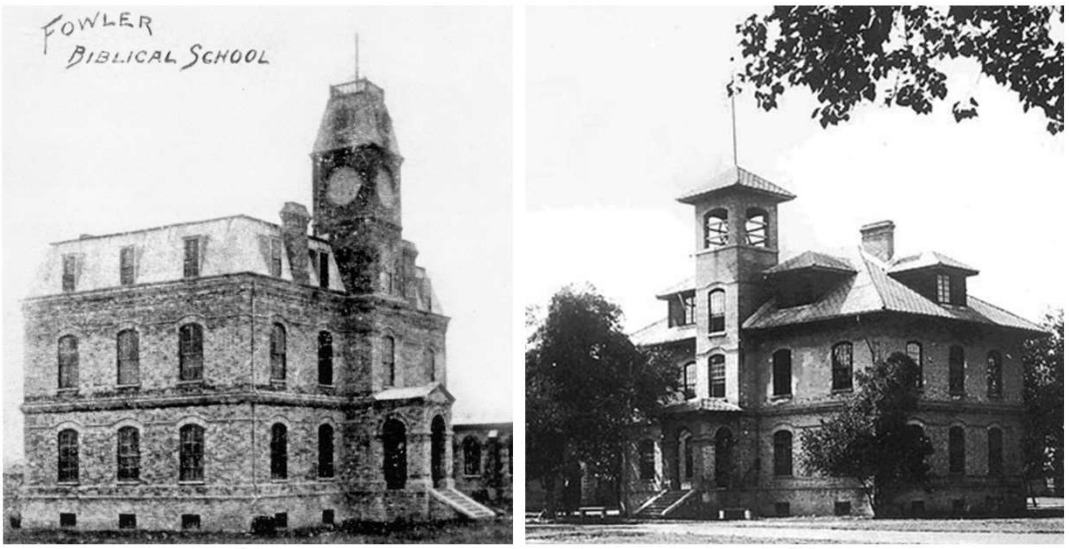


Figure 5. Historical photos of the bell tower. (**a**) It was first built in 1888. (**b**) It was rebuilt after fire in 1917 (source: [27]).

The bell tower was the first three-story western-style building built in Nanjing, and it is a symbol of education in Nanjing. The building survived the war and still stands tall. It not only records the historical development of Chinese society but is also an important reference for studying the history of modern Chinese education and architecture. It has important historical and cultural value.

2.2. Location and Current Function of the Building

The bell tower is now located on the campus of Jinling High School, no. 169, Zhongshan Road, Gulou District, Nanjing. It served as a classroom, dormitory, and office, and was an important meeting place for missionaries. It is currently an office building.

2.3. General Architectural Form

When the bell tower was first built, the main structure was three floors. After the fire in September 1917, it changed to two floors. The original third floor was changed to an attic with dormer windows. The original flat roof was changed to the sloping roof. The tower was originally five floors but was later changed to four floors. At present, The architectural form of the bell tower is slightly damaged, and its architectural style is the American colonial style (Figures 5 and 6).

Figure 6. Current photos of the bell tower (source: author). (**a**) Bird's-eye view of the bell tower from south to north.(**b**) Bird's-eye view of the bell tower from the northwest.

The building has three floors and a height of 16.76 m. It covers an area of about 239 m^2 and a building area of 645 m^2. The plane and elevation of the bell tower are symmetrical, and the building plane is rectangular. It is 18.2 m long and 12.4 m wide. There are four rooms on the first and second floors, with floor heights of 3.9 m and 3.3 m, respectively. The floor is an attic, the highest point is 3.2 m, and the dormer windows are opened using a sloping roof [28].

The building is a brick and wood structure. The exterior walls are built with clay bricks, the interior walls of the first and second floors are brick walls, and the interior walls of the third floor are wooden. Roof trusses, stairs, floors, and joists are all made of wood (Figure 7). At present, the building has some damage, for example, some walls are damaged or cracked, some roof tiles are falling off, many windows are missing, many window sills are damaged and a large number of drainage pipes are seriously damaged, which are in urgent need of repair (Figure 8). According to the "Safety Appraisal Report of the bell tower of the Nanking University" [29], the structural system needs to be strengthened.

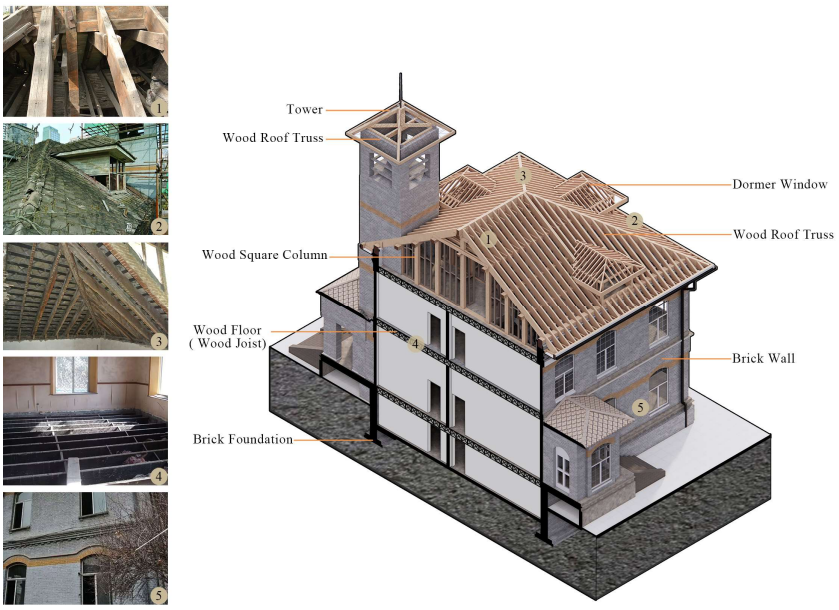


Figure 7. The structure of the bell tower (source: author).

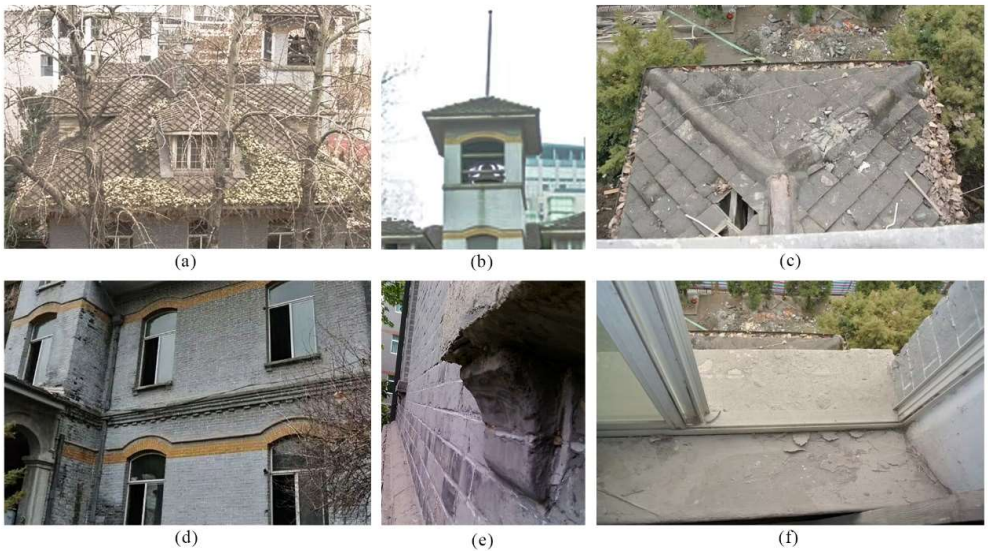


Figure 8. Damaged state of the bell tower(source: author). (**a**) Damaged roof (**b**) Damaged tower walls (**c**) Broken tile (**d**) Broken south wall (**e**) Broken wall detail (**f**) Broken window and window sill.

3. Present—Existing State of the Building

We excavate the real information from the architectural style, space, structure, material, and construction process, and propose reasonable protection methods. There are close logical relationships between these five points. We used raw materials and original craftsmanship for repairs to maximize the preservation of the original historical appearance and architectural style. Since authenticity is the core principle of architectural heritage conservation, the preservation of architectural style is the most important and difficult to implement in restoration practice. The use of historical buildings is a process in which authenticity is constantly disappearing. We used raw materials and original techniques to repair them as they are, and only preserved the authenticity of the architectural heritage to the greatest extent, including the true and complete preservation of the information of each historical period. In addition, safety is an important principle of conservation practice, and structural strengthening can eliminate potential safety hazards. At the same time, the building functions are updated according to the current regional development needs. Based on the above analysis, this paper focuses on the preservation of architectural style, structural strengthening, and functional renewal.

3.1. Artistic Characteristics

From 1840 to 1949, the dissemination of Western modern architectural culture in Nanjing mission schools went through two stages; according to the architectural form, it is roughly divided into the early "transplantation" and the later "combination of Chinese and Western". "Transplantation" is a direct adaptation of Western architectural styles.

The bell tower is a transplant of the colonial style of the United States, which originated from the rural and urban dwellings in Europe in the Middle Ages. After Europeans arrived in the Americas, this form became popular. The roof of the bell tower is steep, the outer wall is built with brick walls, not painted, and the round-arched windows are made of fine brick lines in the middle of the wall, the lower part of the cornice, the corners, and the entrance to form a more complex decoration [30].

The facade of the bell tower is symmetrical, the towering tower is located in the middle of the building facade, and the building is divided into three vertical sections; the platform base, the wall body, and the roof form the three horizontal sections. The facade is carefully composed according to geometric proportions involving equilateral triangles, golden sections, similar rectangles, etc. (Figure 9). The building as a whole creates a solemn and elegant architectural form through the symmetrical plan and elevation pattern of the central axis and the rigorous geometric proportions and scales. To summarize, as a representative of American architecture in early modern Nanjing, the bell tower shows the superb skills of American architects, reflects the rigorous geometric composition, and distinctive artistic features of Western architecture; it is of high historical and artistic value.

3.2. Constructional Characteristics

3.2.1. Structural System

The building is a brick and wood structural system. Wood roof trusses, wood purlins, wood-square columns, wood beams, wood joists, brick walls, and brick foundations constitute the load-bearing structural system of the building. In order to increase the stability of the structural system, wood beams are pre-embedded in the surrounding exterior walls to connect with the wood roof trusses. On the third floor, the pre-embedded wood beams are connected to the bottom of the wood-square columns (Figure 10).

The structural system bears the vertical load and horizontal load. The vertical load is transmitted as follows: the vertical load of the roof is transferred to the purlins, square columns, joists, and walls; the live load and dead load on the third floor are transferred to the wood joists, the wood beams are embedded in the wood joists and the wall on the second floor, and so on; the vertical load is transferred from the brick wall to the brick foundation and foundation soils.

Figure 9. Proportion analysis (source: author). (**a**) The three-fold division of the south facade (**b**) The tripartite division of the north facade (**c**) The golden section and similar triangles of the south facade (**d**) The golden section and similar triangles of the north facade (**e**) The similar rectangular of the south facade (**f**) The similar rectangular of the north facade.

The structural elements of the building are described as follows: the brick foundation is in the form of spread footing, the thickness of the exterior brick wall is 460 mm, and the thickness of the interior brick wall is 270 mm (Figure 10a,b). The walls are built with grey clay bricks and white lime mortar. The first to third floors are all wood floors with wood joists. The thickness of the wood floor is 50 mm. The height of the wood joists is 300 mm, the width is 50 mm, and the spacing is 500 mm. At present, a small number of wood joists are rotted and cracked, and we plan to add I-shaped beam strengthening at the bottom of the wood joists. After the mechanical calculation, the reasonable I-shaped beam size is

selected according to the space scale. For example, when the span is 6.8 m, the height of the I-shaped beam is 300 mm, the width is 200 mm, and the thickness is 8 mm; when the span is reduced, the size of the I-shaped beam is also reduced. The third floor is the attic. In order to reduce its own weight, wood roof trusses, wood purlins, and wooden pillars are used. The bottom of the pillars is connected with the pre-embedded wood beams in the wood joists, and the wood roof trusses are connected with the surrounding external walls, which together form a structural system (Figure 10c,d). The thickness of the interior walls of the attic is 150 mm; they are wooden walls and are used to separate rooms (Figure 10b), not a structural system [31].

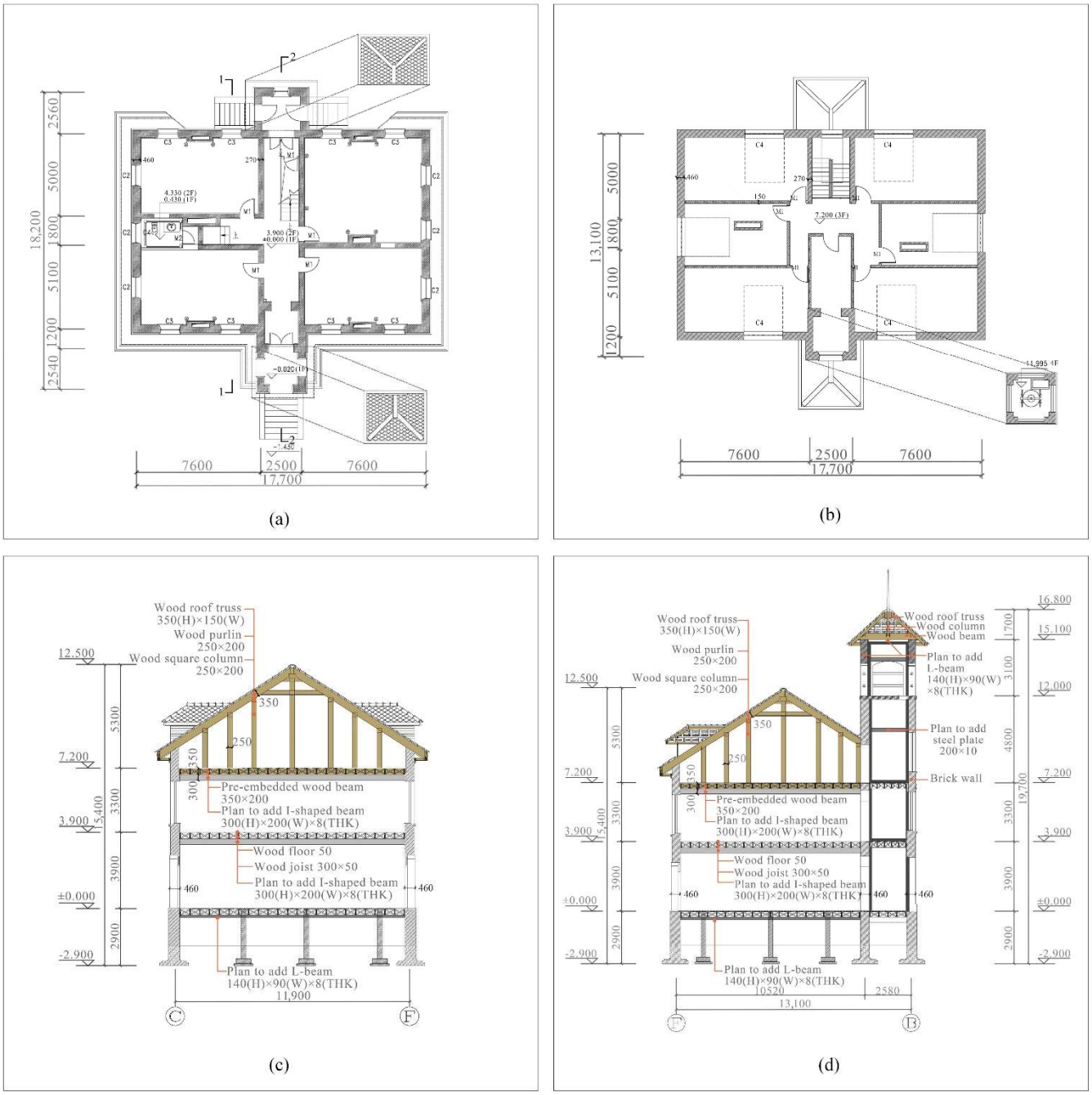


Figure 10. Structural elements of the bell tower (source: author). (**a**) The first and second floor plan (**b**) The third floor plan. (**c**) Building structure element (1−1 section diagram) (**d**) Building structure clement (2−2 section diagram).

3.2.2. Roof Truss System

The roof truss system is special. The authors learned through detailed historical research that after the bell tower caught fire in 1917, the American church funded the conversion of the third floor into an attic. Since it was only a partial renovation, there was no clear record of whether architects were involved. Therefore, the authors speculate that the attic was built by Chinese craftsmen based on experience and did not fully meet the requirements of the building structure. It was a common phenomenon at the time. In the early 20th century, Western construction technology had not been fully introduced into China [32]. Some missionaries would draw architectural sketches, and Chinese craftsmen would build according to the wishes of the missionaries and their own experiences. Ginling College, built at the same time in Nanjing, was built by Chinese craftsmen, who often discussed construction techniques with professional architects [33].

Because Chinese craftsmen participated in the construction, the roof truss is similar to the "cross type wood structure". It is a typical structural system of traditional Chinese architecture. Its characteristic is that the columns are erected along the depth direction of the house, and the spacing between the columns is relatively dense. Along the direction of the purlins, the columns in series with fangs (small beams) are connected. This forms an overall structural system [34] (Figure 11a).

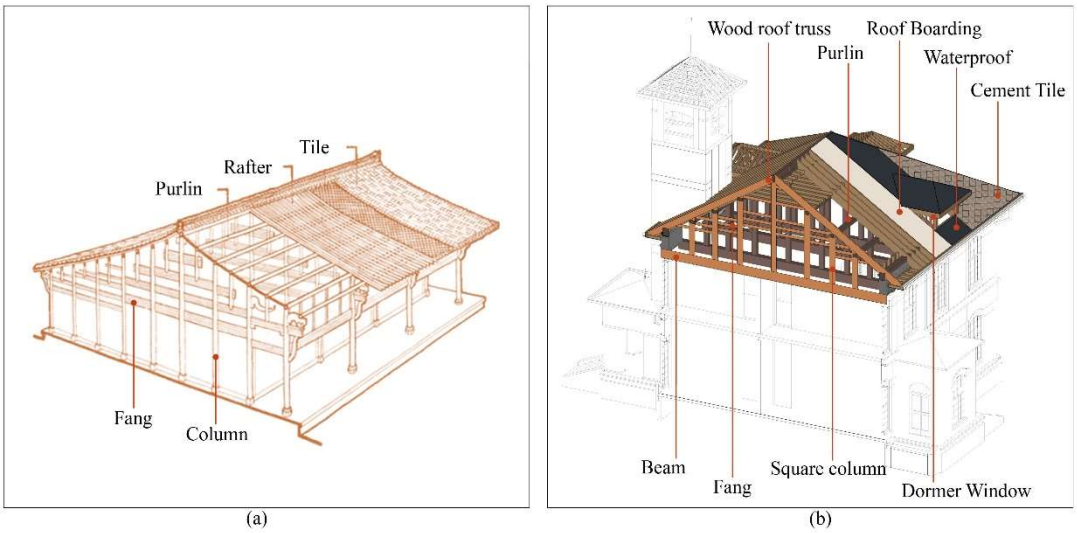


Figure 11. Comparison of the Chinese traditional roof-truss system and bell tower roof-truss system (source: author). (**a**) Chinese traditional roof-truss system "cross type wood structure" (**b**) Bell tower roof-truss system.

Similar to the bell tower, the columns are connected in series with fangs, and the roof trusses, purlins, and square columns are closely connected with the pre-embedded wood beams in the wood joists to form an integral structural system (Figure 11b). The connection of roof trusses, purlins, and square columns includes iron nails and "mortise and tenon" (a combination of concave and convex parts on two components). It is a connection method of traditional Chinese wooden components, which can make two wooden components tightly connected.

3.3. Materials and Technology Characteristics

The space layout of the bell tower is very good. The interior of the building is centered with corridors and stairs for the transportation system. The building plan is divided into four rooms with roughly equal areas, which not only reflects the Christian spirit of "equality of all living beings" but also makes the room-scale very suitable for modern teaching and office spaces. From the perspective of architectural design, the room is 5 m $\times$ 7.6 m, roughly rectangular, and suitable for desks and chairs; there are windows on both sides of the room,

the light is bright, and the window-to-floor ratio design can ensure the brightness of the room so as to meet the teaching needs of modern teaching (e.g., blackboard writing and drills). For China in the late 19th century, this was a brand-new space design concept, while traditional Chinese academies of the same period were dimly lit and accommodated few people.

In terms of building materials, the building's foundation and walls were built with local clay–ash bricks. It embodied the wisdom of construction according to local conditions. The masonry method of the brick wall was Flemish bond. They used white lime mortar for jointing. When the building was first built, the exterior walls were all made of clay–ash bricks. In daily use, the outer wall from the outdoor ground to the first window sill was often wetted by rainwater. Therefore, when repairing, we brushed a layer of cement mortar on the surface of the clay brick as a waterproof layer [35]. To accentuate the main entrance, the surface of the brick porch was covered with a hammered granolithic finish. It is a kind of artificial stone (Figure 12). During production, cement mortar mixed with stone chips and stone powder was applied to the surface of the building. After hardening, the mixture was made into a textured stone surface style by cutting and chiseling. They are widely used in modern China in important public buildings.

Figure 12. Materials and construction technology (source: author).

3.4. Equipment and Facilities

Nanjing is located in a climate zone with hot summers, cold winters, and abundant rainfall. Therefore, the comprehensive designs of drainage, ventilation, and equipment systems are particularly important.

The design of the drainage system is scientific and reasonable, and it is still in use after more than one hundred years. The main body of the building and the roof of the tower are steep four-pitched roofs. Rainwater is collected by the cornice gutter using the height difference and is opened into multiple catchment areas. Drainage pipes are installed at the four corners of the house and the porch. It flows into the outdoor ground open ditch and then flows into the school drainage pipe to the municipal drainage pipe (Figure 13).

The building focuses on natural ventilation. Since the dominant wind direction in Nanjing is the southeast wind in the summer and the northwest wind in the winter, the building is arranged facing south, with porches on the south and north sides, windows all around, dormer windows on all sides of the roof, and ventilation holes in the basement to form a natural ventilation system (Figure 14). Under well-ventilated conditions, the wood roof trusses, wooden pillars, and wooden stairs can be air-dried in time even if they are temporarily damp, and there is no major decay after more than one hundred years.

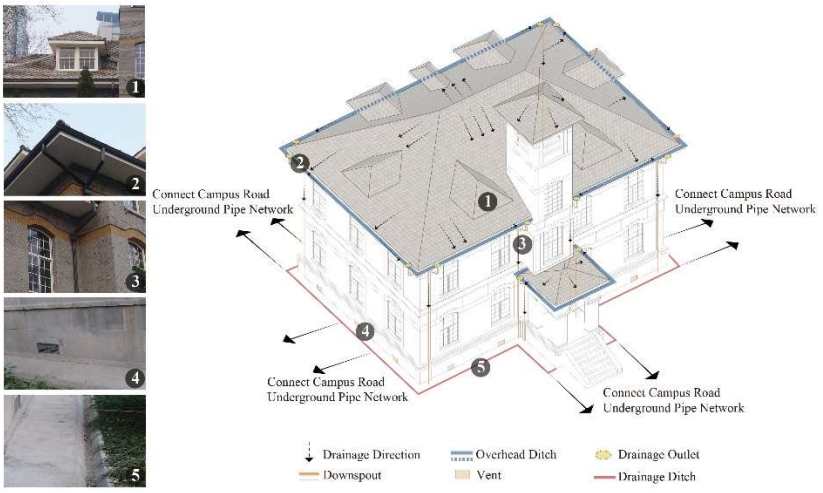


Figure 13. Water drainage system (source: author).

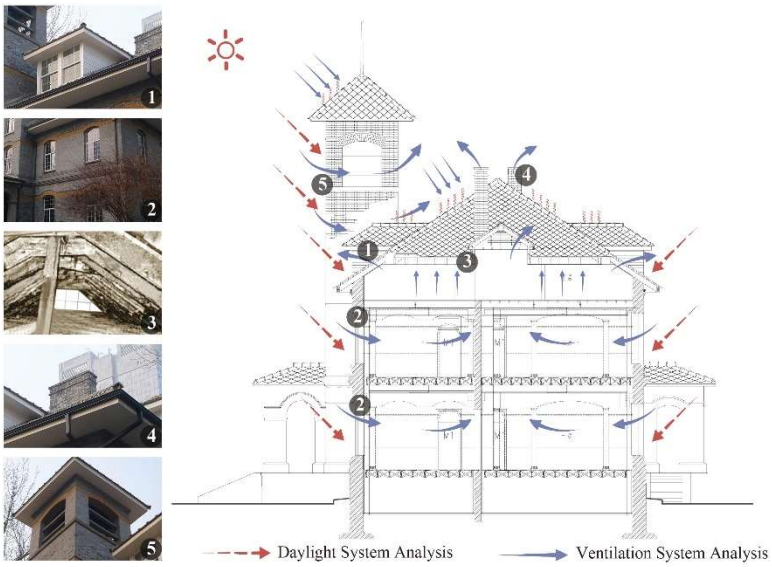


Figure 14. Ventilation system (source: author).

In the building's early days, a fireplace was installed indoors as a heating system, with a chimney protruding from the roof. At present, the fireplace is broken, and the building's cooling and heating systems need to be redesigned.

3.5. Damage to the Building and Assessment of the Technical Condition

In China, current building laws require historic buildings to be structurally identified before they can be repaired. For example, it is mentioned in the "Technical Standards for Building Structure Testing [36]" (GB/T50344-2019, Article 3.1.4) that we need to detect structural damage, structural component bearing capacity, structural deformation, and other items involving structural performance. It includes structural safety assessment, structural anti-seismic assessment, reliability assessment before building repairs, etc. In order to understand the safety condition of the bell tower and provide a basis for strengthening, we commissioned Nanjing Southeast Construction Engineering Safety Appraisal Co., Ltd. (Nanjing, China) to conduct a technical condition assessment.

The first is to examine the general condition of the structure. The building has no obvious uneven land subsidence, no cracks in the foundation, and no cracks in the superstructure caused by uneven land subsidence of the foundation. Wall materials are clay bricks and lime mortar. At present, the quality of the bricks is still good, but some exterior walls are damaged due to dampness and weathering (Figure 15a), and a small number

of windows have oblique cracks at the corners (Figure 15b). Therefore, the load-bearing capacity of the walls is basically acceptable based on a small number of structural cracks and material degradation assessments. Currently, small numbers of wood joists and trusses are rotted or cracked (Figure 15c,d).

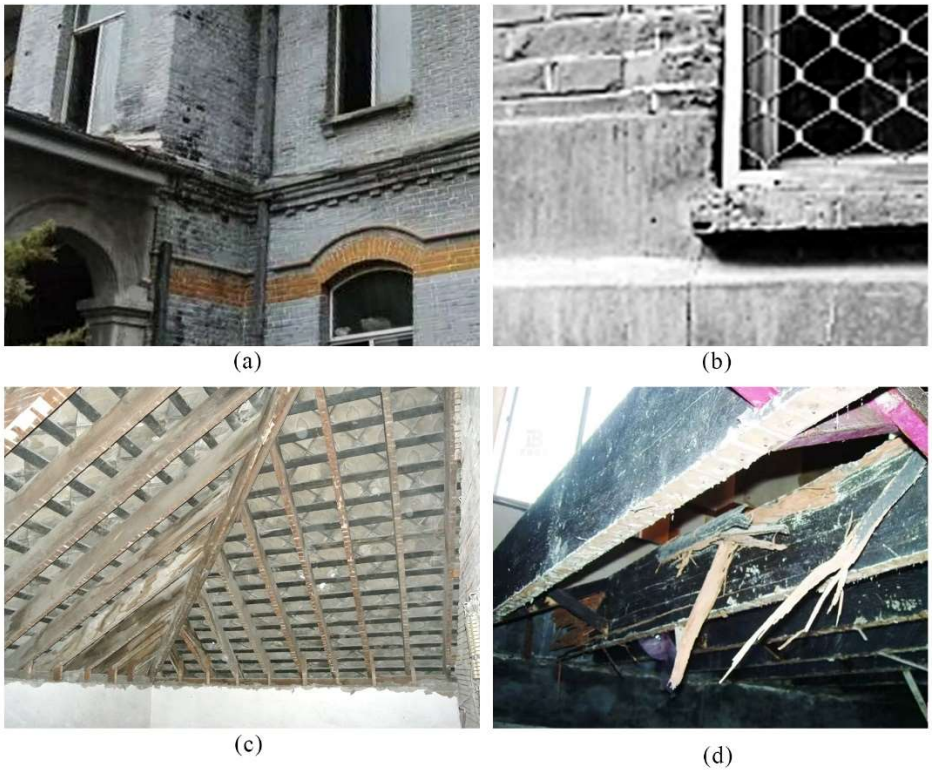


Figure 15. Damaged state (source: author). (**a**) Damaged exterior walls (**b**) Cracked window corner (**c**) Rotted wood roof trusses (**d**) Cracked wood joists.

The second is to analyze the bearing capacity of the main structure and evaluate the safety level of the house. We checked and calculated according to the structural layout and the geometric dimensions of the components based on the site investigation and mapping, combined with the Chinese structural standard. In Nanjing, this includes snow pressure ($q = 0.65\ kN/m^2$), floor live load ($qk = 3.5\ kN/m^2$), and wind load ($w = 0.40\ kN/m^2$). The seismic grade is 7. According to the current structural standard in China (Technical Standards for Maintenance and Strengthening of Wooden Structures of Ancient Buildings (GB/T50165—2020) [37]", "Building Structure Load Code (GB50009-2012)" [38], "Code for Seismic Design of Buildings (GB50011-2010)" [39], we concluded that the bearing capacity of the wood roof trusses can basically meet the national standards; the compressive capacity and seismic bearing capacity of some brick walls on the first and second floors do not meet the standards; the bearing capacities of wood joists do not meet the current national standards. In order to confirm the safety of the building and to make the analysis credible, we conducted a structural safety status assessment according to the appraisal procedures and methods of the "Dangerous House Appraisal Standard" (JGJ125-2016) [40], combined with on-site inspections. We evaluated the safety level of the building foundation and upper load-bearing structure (including dominant members, such as brick walls, wood joists, and wood roof trusses). According to the "Dangerous House Appraisal Standard" (JGJ125-2016) (Article 6.1.4), Class B basically meets the requirements for safe use, and Class C means that some load-bearing structures cannot meet the requirements for safe use, and the house is partially dangerous.

The details are as follows: According to on-site inspections, the building site is flat and has no slopes. The building does not have any obvious settlement cracks, deformations,

displacements, or other uneven settlement phenomena, indicating that the foundation is stable. The safety level assessment of the foundation is B_u level.

The safety appraisal grade of the upper load-bearing structure is comprehensively assessed according to the safety grade of the dominant member, the integrity grade of the structure, and the lateral displacement grade of the structure. The safety grade of the dominant member is assessed as the C_u level (an evaluation of the dominant members, such as brick walls, wood joists, and wood roof trusses. The overall seismic resistance of the walls is poor. According to on-site inspections, some load-bearing walls are damaged, and there are cracks at the corners of the windows. The two ends of the wood joists were placed in the wall for a long time, and some wood joists were rotted and broken due to humidity. Due to the deflection and deformation of some wood joists, the support length of the ends of the wood joists in the wall is less than 100 mm, and the ends are loose, which affects the overall stability of the floor. Some wood trusses are rotten or cracked, affecting the safety of the house). The integrity of the structure is evaluated as the C_u level (the building is not equipped with structural columns and ring beams, the roof truss is not equipped with vertical and horizontal supports, and the integrity and earthquake resistance of the house are poor). The lateral displacement of the structure is evaluated as the B_u level (according to the on-site inspection, the maximum inclination rate (to the east–west direction) of the building is 0.16%, which is less than the limit value (2%). In general, the safety level of the upper load-bearing structure is evaluated according to the lower level. Therefore, the safety level of the comprehensive assessment of the upper load-bearing structure is C_u level.

To summarize, according to the assessment results of the foundation and the upper load-bearing structure, the safety level of the building is assessed as the C_{su} level [41]. Some dominant members, such as walls, wood joists, and wood roof trusses must be strengthened due to material degradation. In addition, the building did not consider earthquake resistance in its previous design, and its structural integrity and earthquake resistance were poor. It should be combined with repairs and seismic strengthening to basically meet China's current codes.

4. Future—Campus Renewal and Utilization Analysis

4.1. Building Function Update

According to the "Nanjing Famous Historical and Cultural City Conservation Plan (2010–2020)", the former Nanking University area is defined as a cultural and educational area, forming a representative historical campus area with the nearby University of Nanking and Ginling College in the "Drum Tower—Qingliang mountain Historic District". The plan calls for maintaining the spatial pattern of the historic campus and the environmental features of high green coverage. At the same time, the former Nanking University is located on the historical axis of the Republic of China of "Zhongshan North Road-Zhongshan Road-Zhongshan East Road" [42], and the planning requires maintaining the public building functions along the line. According to the quantitative analysis of the quantity and distribution characteristics of the Nanjing school's architectural heritage, it can be concluded that the school's architectural heritage is concentrated in the Gulou District and distributed along the historical axis of the Republic of China (Figure 16).

To summarize, the bell tower is intended to continue to be used as a school building, which is a prerequisite for the renewal of the building, but its specific function requires further research and analysis. According to an analysis of the number of teachers and students, the types of buildings, and the number of buildings, the school has 3128 students [43]. The area of the teaching space and teaching auxiliary space is 25,283 m^2 (16,742 + 8541 = 25,283) [44] (Figure 17), and the average area of middle schools in China is 9.0 m^2 per student (dormitory not included) [45], so the total construction area is 28,152 m^2 (9.0 × 3128 = 28,152). Thus, it is necessary to provide a construction area of 2869 m^2 (28,152 – 25,283 = 2869).

At present, it has the most teaching space, followed by logistics and sports spaces. There is a lack of teaching auxiliary space, such as office and clubhouse spaces. Combined

with the current architectural functional requirements and in view of the important historical status of the bell tower, the National Cultural Heritage Administration, Jinling High School (the current user), and the Architectural Design Institute of Southeast University (the designer) have jointly decided that upgrading the bell tower and transforming it into an exhibition, clubhouse, and office space is more reasonable.

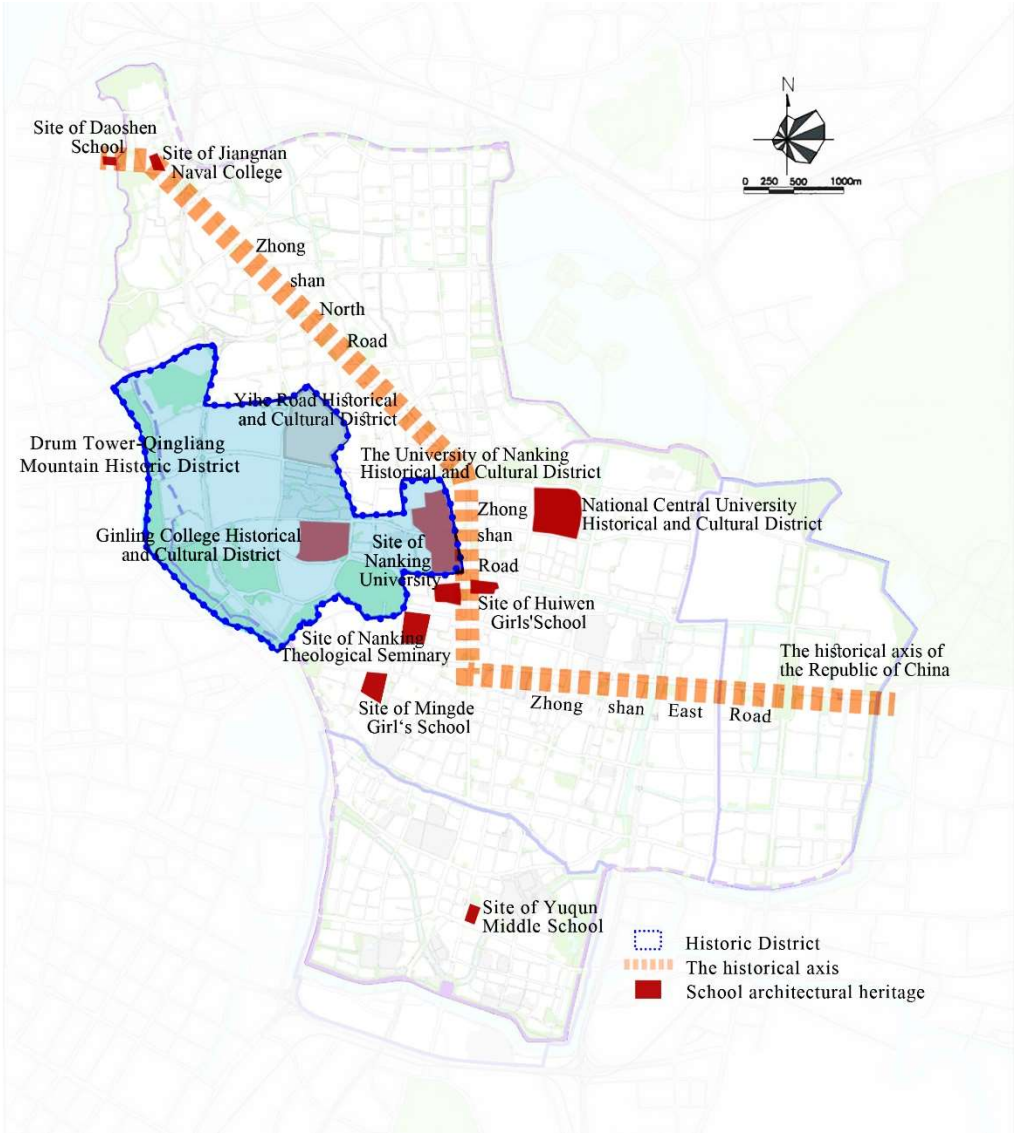


Figure 16. Conservation Plan of Historical City of Nanjing (2010–2020) (based on the Nanjing Famous Historical and Cultural City Conservation Plan (2010–2020) by Nanjing Bureau of Planning and Natural Resources).

The space and scale of the new functions should conform to the spatial characteristics of the historic building. According to the building's bearing capacity and functional requirements, there are plans for the exhibition space with a large load to be on the first floor. Combined with the outdoor exhibition hall and the environmental landscape, it will display the difficult process of the Western Church missionary's mission in China, the brilliant achievements of running a school, and the construction history of Nanking University. It is proposed that a historical building be set up on the second floor to create a small-scale exchange club for domestic and foreign architectural heritage protection enthusiasts and professionals in order to achieve the purpose of "meeting friends through architecture" and promoting the culture of historical buildings. The office space will be placed in the attic to reproduce the office scene of the principal (Table 1). To summarize,

the utilization of architectural heritage is a balance between historical value and use value after the rational analysis to achieve a win–win situation of protection and development.

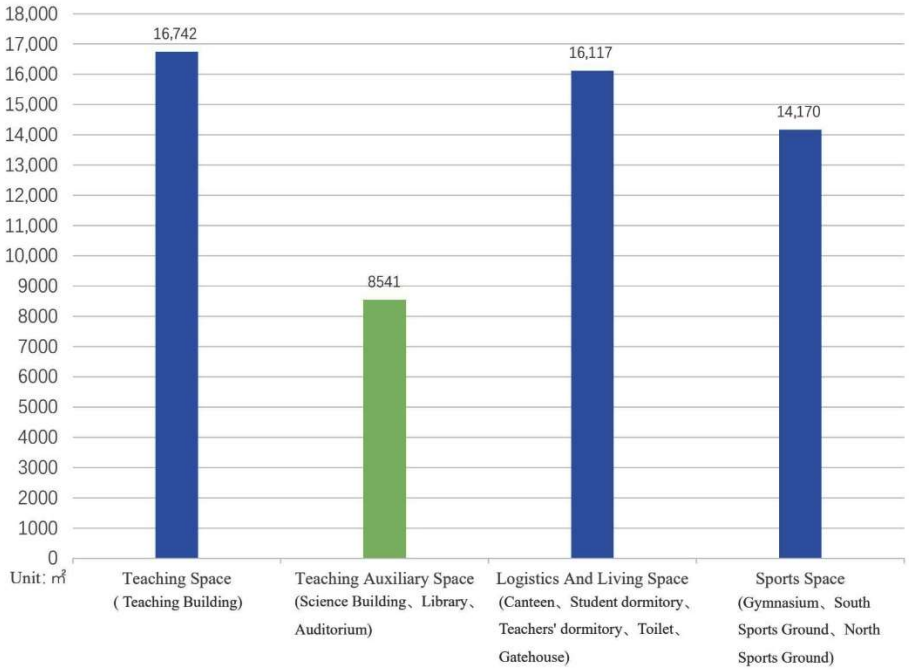


Figure 17. Statistics of the construction area ofJinling High School (source: author).

4.2. Repair Target and Principles

As a symbol of modern educational buildings in Nanjing, the bell tower is a national key cultural relic conservation unit. Based on the above analysis of heritage conservation and utilization, we plan to restore the building's external form, internal characteristics, and surrounding historical features and integrate new functions and supporting facilities. It has become an important "historical and cultural" landmark in Nanjing.

According to the "Renovation Design Plan for the Bell Tower" and "Structural Safety Appraisal Report of the Bell Tower", which were approved by the National Cultural Heritage Administration, the current architectural design specifications of the People's Republic of China, the "Venice Charter", "The Cultural Relics of the People's Republic of China" Conservation Law, other international and domestic cultural relic conservation rules, and the above analysis, the following principles of building repair are formed:

1. Authenticity principle

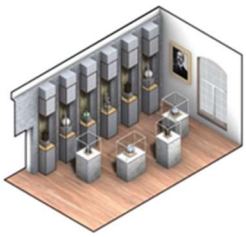
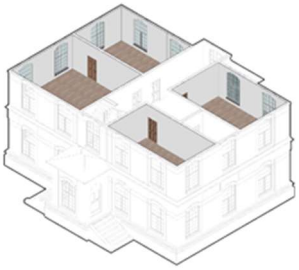
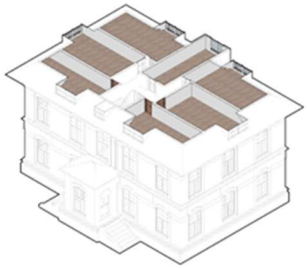
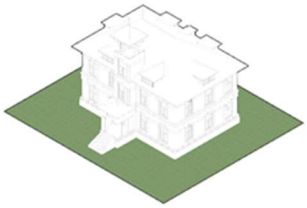
Use the original materials as much as possible, preserve the original components, use original craftsmanship, preserve as much historical information as possible, and maintain the characteristics of the bell tower (according to the Venice Charter, 1964, Article 9; the Principles for the Conservation of Heritage Sites in China, 2015, Article 10; the Law of the People's Republic of China on the Protection of Cultural Relics, 2015, Article 21; and the Guidelines for the Conservation of Cultural Relics in China, 2015, Article 10).

2. Integrity principle

It is necessary not only to conserve the individual historic buildings but also to maintain the overall spatial form and inseparable relationship with the surrounding environmental elements, especially the relationship between the historical buildings and the district and the overall landscape of the campus (according to the Venice Charter, 1964, Article 1 and the Principles for the Conservation of Heritage Sites in China, 2015, Article 14). Set up a cultural relic protection scope and construction control area around the cultural relic's body (according to the People's Republic of China Cultural Relics Protection Law, revised in 2015, Articles 15 and 18).

3. Set up a conservation scope and construction control zone (Figure 18) to completely protect the cultural relic building's body and demonstrate the authenticity and integrity of the cultural relic building [46].

Table 1. Adaptive reuse analysis of the bell tower (source: author).

Spatial Type	Analysis for Function Type	Spatial Diagram	Space Design
Main Space 1F Area: 167.2 m^2 Height: 3.9 m	Exhibition Hall The development history of Christianity in China. The construction course of Nanjing Missionary School.		
Main Space 2F Area: 167.2 m^2 Height: 3.3 m	Architectural Club Chinese and Western culture Exchange Club. Historic Building Heritage Preservation Club.		
Attic Space 3F Area: 169.9 m^2 Height: 1 m−3.8 m	Office President Office. Bright and open modern office space.		
Corridor Space 1F and 2F Area: 39.4 m^2 Height: 3.9 m (1F) 3.3 m (2F)	Gallery Dissemination and communication of the development process of Nanjing Missionary School.		
Outdoor Space Open ground	Temporary Exhibition Through landscape, plants, sculpture and light, the history and development of the mission school are presented.		

First of all, conduct a comprehensive and in-depth investigation into cultural relic buildings and strive to fully grasp the complete history and information of cultural relic buildings according to survey drawings, historical photos, and related text materials so that the repair process can be truly authentic and grasp the historical building's authenticity.

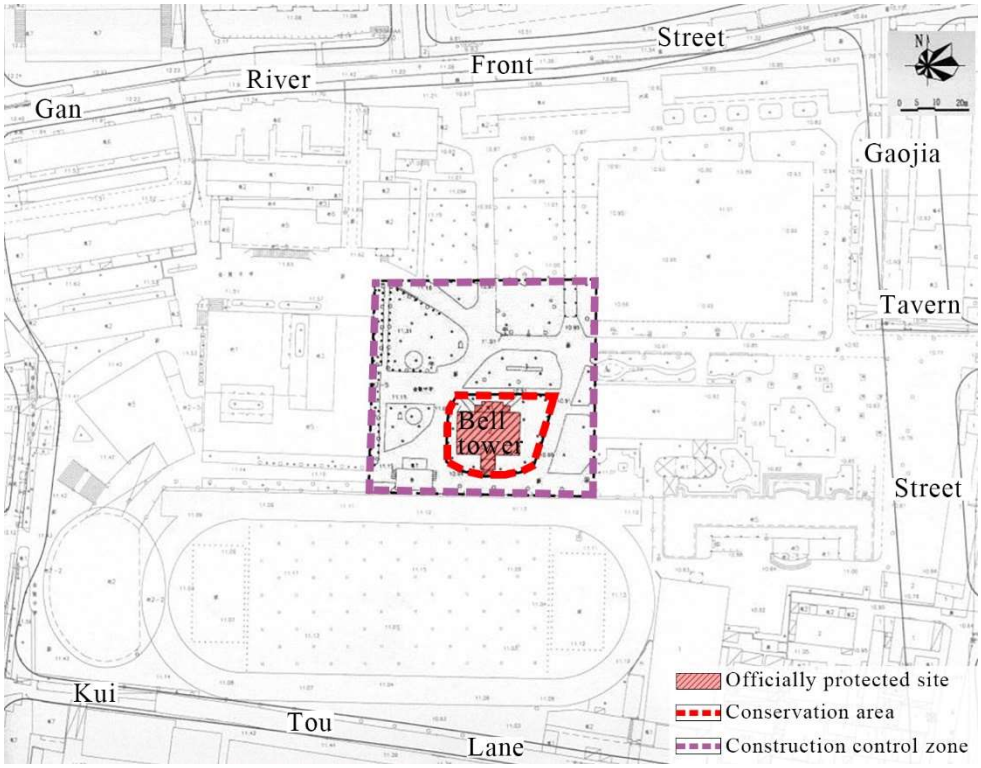


Figure 18. Set up a conservation scope and construction control zone (source: author).

4.3. Damage Cause Analysis and Repair Technology

4.3.1. Completely Preserve the Appearance of the Building

The original wooden doors and windows are rotten and damaged, and the wooden doors were replaced with similar copies. According to the style and color of the original wood window, it was replaced with a plastic–steel window, the surface of which imitates wood grain; double-layer insulating glass is used to improve the building's sound insulation and heat insulation performance. The diamond-shaped cement roof tiles are special features of this project. The two acute angles of the diamond-shaped tile are 65 degrees. They are laid obliquely and have the advantages of no dust accumulation, smooth drainages, and beautiful appearances. They were brought to China and were once used in church and mission school buildings. During this renovation, a batch of new tiles was ordered to replace the old tiles according to the style, size, and color of the original tiles.

We repaired the damaged brick wall by using brick powder with a similar color to the original wall, mixing it with water, and adding an appropriate amount of adhesive to repair the severely damaged part of the wall. We removed the decorations added to the interior.

We maintained the original appearance of the bell tower with original materials and original technology and strove to highlight the historical, cultural, and artistic values of the architectural heritage (Figure 19).

4.3.2. Structural System Strengthening

According to the safety assessment of the building (in Section 3.5 of this paper), the materials of the main structural components were degraded and needed to be strengthened in combination with repairs. Durability maintenance is required for the main structural components (to improve the durability of the structure) and the integral and seismic strengthening of the main structure.

1. Wall strengthening.

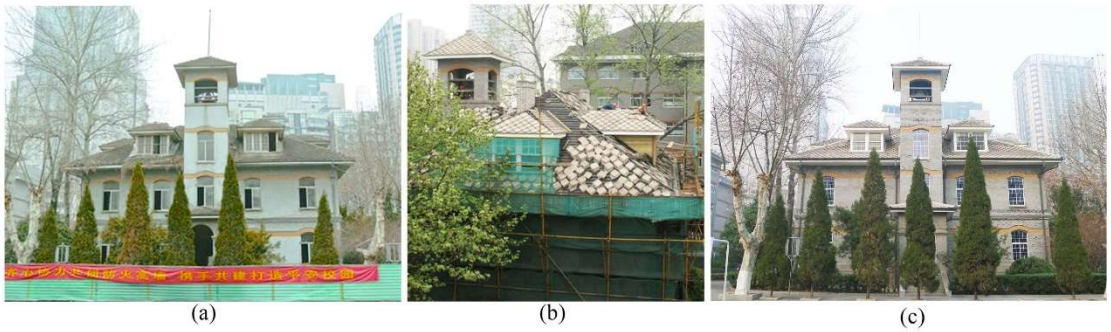


Figure 19. Photos of the bell tower before, during, and after repairs (source: author). (**a**) Before conservation. (**b**) Renovation in progress (**c**) After conservation.

The bell tower was built more than one hundred years ago, and some materials have degraded. According to on-site inspections, some exterior walls were damaged (Figure 20a), and oblique cracks appeared in some window corners. Since the earthquake resistance was not considered in the design at that time, the overall earthquake resistance of the structure was poor. Therefore, we attach great importance to the maintenance of the wall to ensure its integrity, and strengthen the bearing capacity and integrity of the wall to improve its load-bearing capacity and ductility to deal with earthquake risks (Figure 20b).

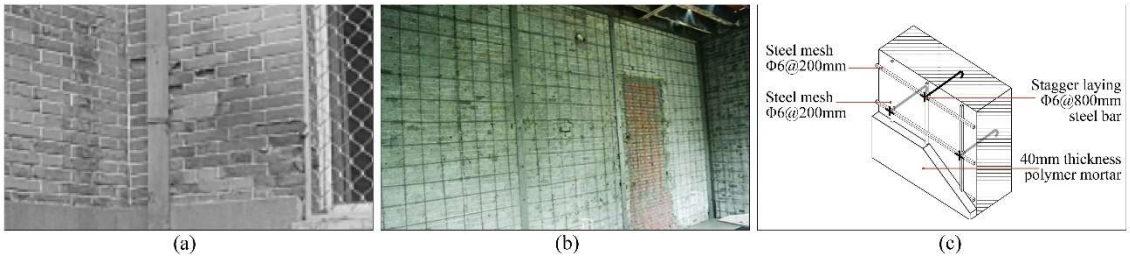


Figure 20. Wall strengthening (source: author). (**a**) Damaged exterior walls (**b**) Strengthening in progress (**c**) Wall strengthening methods.

A pressure pump was used to inject a cement slurry to seal the cracks in the wall. The broken brick walls were repaired to ensure wall integrity and improve the load-bearing capacity. Clay bricks adopt different repair methods according to the damage depth; when the damage depth of the brick is less than 10 mm, it will not be repaired, but only cleaned and protected. When the damage depth of the brick is 10–20 mm, it should be repaired with brick powder. The brick powder material has good compatibility with the original wall, and the color is similar to the original wall. After adding water and mixing well, an appropriate amount of adhesive was added, the damaged part of the wall was repaired, and then the mortar joints were filled. When the damage depth of the brick is greater than 20 mm, the damaged surface will be cleaned and repaired with brick bat.

The strengthened wall adopts the steel mesh and polymer mortar surface layer, which not only improves the bearing capacity and earthquake resistance but also minimizes the impact on the use of indoor space. A total of 40 mm of thick steel mesh and polymer mortar were added to the inside of the exterior wall for strengthening; 40 mm of thick steel mesh and polymer mortar were added to both sides of the interior wall for strengthening. The strengthening method is shown in Figure 20c.

2. Wood joists and wooden stair strengthening.

A small number of wood joists were cracked (Figure 21a) and needed strengthening. We first applied water-resistant glue to the two cracked surfaces, then used more than two steel hoops to hoop the cracked wood joists, and finally wrapped them with CFRP to secure them. Considering that the two ends of the wood joists were embedded in the wall for a

long time and are easy to rot or loosen after deformation, we strengthened the ends of the wood joists with L-section steel. The height of the L-section steel was 120 mm, the width was 90 mm, and the thickness was 8 mm. Not only does this increase the lengths of support at the ends of the wood grating, but it also forms a steel ring beam on the wall [47].

Figure 21. Wood joists and wood stair strengthening (source: author). (**a**) Broken wood joists (**b**) Wood joists strengthening (**c**) Stair strengthening.

After the renovation, the building will serve as a school history museum and club and will be visited by a large number of people. We set the standard value of the live load of the wood floor as 3.5 kN/m^2 (according to the Chinese standard "Building Structure Load Code (GB50009-2012)"), and according to the structural calculation, the wood joists need to be strengthened as a whole. We added steel beams along the vertical direction of the wood joists in the middle of the room span for strengthening. The I-shaped beam height was 300 mm, the width was 200 mm, and thickness was 8 mm (Figure 21b).

The deformation of the wooden staircase was large, and it needed to be strengthened according to the structural inspection. We used steel plates to make U-shaped steel beams to strengthen the stairs. The height of the steel beams was 200 mm, the width was 80 mm, and the thickness was 10 mm. Both sides of the beam were fastened with M20 bolts (Figure 21c)

3. Wood roof truss strengthening.

Before the strengthening of the wood roof truss, the president ofJinling High School (the current user) organized the design, supervision, and construction personnel to jointly inspect and determine the wood roof truss strengthening repair plan. Because the ends of some wood roof trusses have rotted, most of the roof truss components have cracked, and the connection nodes of most components have become loose and disengaged. Therefore, it is necessary to strengthen and repair the roof members and nodes to improve their integrity and durability.

(1) The rotten parts of the wood roof truss were replaced. Some wood roof trusses had rotted ends (Figure 22a). We sawed off the rotten parts and used the original wood to redo this place. First, we used water-resistant glue on the joint surface of the old and new materials. Then we used two pieces of anti-corrosion wood to clamp the old and new wooden components; we then used water-resistant glue to fasten and screw the bolts. Finally, we used CFRP to strengthen the wooden components and wrap the old and new materials tightly.

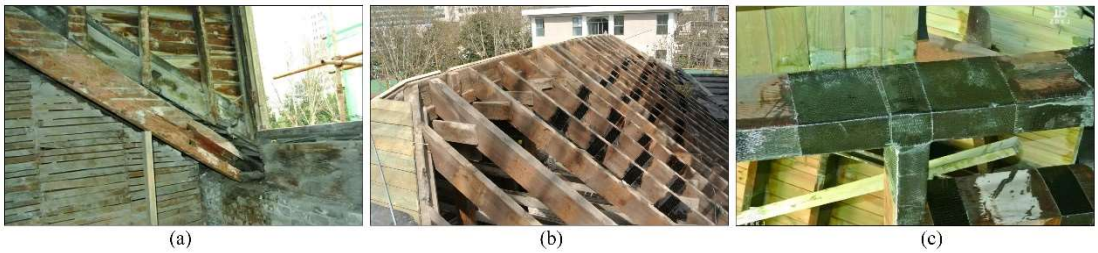


Figure 22. Wood roof truss strengthening (source: author). (**a**) Broken wood roof truss (**b**) Roof truss strengthening (**c**) Roof truss joints strengthening.

(2) For cracked roof trusses, CFRP was used to enhance durability in a circular direction. The thickness of CFRP was 0.167 mm, the paving width was 100 mm, and the interval was 400 mm (Figure 22b).
(3) CFRP paste strengthened the joints of the beams, purlins, and columns to enhance the integrity of the wood roof truss (Figure 22c).

When the cracks of the other wood components were less than 3 mm, we used putty to apply it tightly; cracks of 3–30 mm were filled with wooden strips and water-resistant glue, and finally strengthened with CFRP.

4. Tower strengthening.

The wood columns under the roof of the tower were strengthened with CFRP. The tower was much taller than the main building, which was prone to the whiplash effect during an earthquake and required seismic strengthening. We added L-shaped steel on the inner side of the tower wall to form structural columns and ring beams, which improved the integrity and earthquake resistance of the building and weakened the whiplash effect without affecting the appearance of the building [48] (Figure 23).

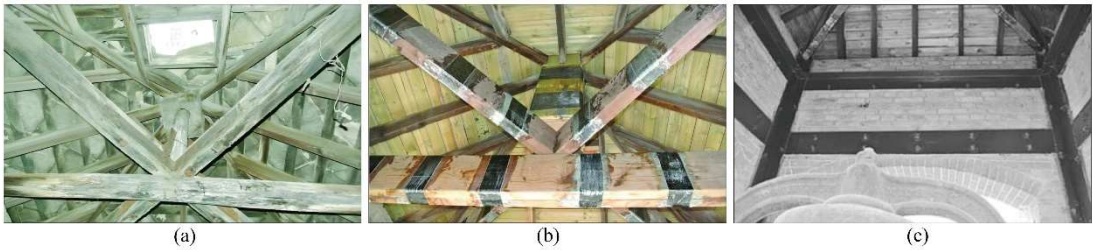


Figure 23. Tower strengthening (source: author). (**a**) Broken tower roof truss (**b**) Tower roof truss strengthening (**c**) Tower wall strengthening.

It is worth mentioning that all of the wood components of the building were brushed with preservatives and insect repellant before strengthening; after strengthening, the surface of the wood was painted with high-quality tung oil to prevent moisture, corrosion, and insects.

4.3.3. Update and add Construction Equipment

First, repair the existing drainage and power supply system, including the roof waterproofing and gutters, and replace drains, electrical wiring, and lighting.

Then, according to the needs of the new users, add fire hydrants, lightning conservation belts, and air conditioning systems. Install fire hydrants in corridors, roof lightning conservation belts at the eaves and ridges of the buildings, 20 m × 14 m lightning conservation nets on the roof, strengthen the steel columns as lightning conservation down conductors, and use the building foundation steel bars as grounding devices. Adopt a VRV small central air-conditioning system, and hide the air-conditioning unit in the green belt around the building (Figure 24).

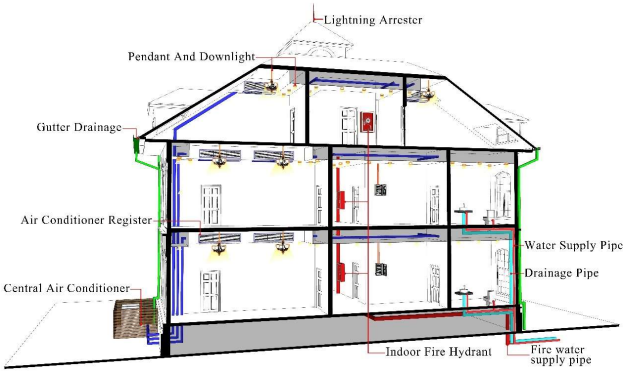


Figure 24. Renewal strategy of construction equipment (source: author).

5. Conclusions

Church school buildings are important historical achievements of cultural exchanges between China and the West and, globally, are common cultural heritages of mankind. At present, China is facing the difficult problem of rapid urban development and achieving win–win scenarios when it comes to heritage conservation. This paper uses the bell tower, the symbol of modern educational architecture in Nanjing, China, as the research object, and explores the path from an "investigation–value analysis–reconstruction strategy" to construct an architectural heritage conservation strategy that maintains the building's authenticity and integrity. This can serve as a reference for similar renewal and heritage conservation projects.

Authenticity and integrity are the core principles of architectural heritage conservation and are in line with the leading concept of "keeping cultural relics in their original state" advocated by China. The "Guidelines for the Conservation of Cultural Relics and Monuments in China" (2015) pointed out that "the original state of cultural relics" includes not only the state before restoration but also the state after historical restoration and reconstruction. However, in terms of the restoration of architectural heritage in China, sites have been restored to their original states on many occasions over a long period of time, which can easily lead to the disappearance of historical information.

The author believes that the "original state" is the superposition of real information in various historical periods. It requires a reasonable assessment of valuable information. The bell tower was originally a Western-style building with a flat roof (1888), but it was later converted into a building with a sloping roof due to a fire (1917). Its architectural form has been preserved to this day and has high artistic–historical value. Therefore, during this renovation, we do not advocate restoration to the original state, the emphasis is on sorting and restoring the existing information of the building. As the earliest Western-style building in Nanjing, the bell tower is an important historical witness of the cultural exchange between China and the West. The architectural style must be completely preserved, and the exterior walls, roofs, doors, and windows that affect the architectural style must be repaired as they are. The bell tower is an American colonial-style tower that combines ancient Chinese architectural techniques. It is an important architectural example in Nanjing and even in China. It reflects the architectural characteristics under the influences of Chinese and Western cultural exchanges, and its architectural technical characteristics have also been well preserved. Therefore, only through rigorous historical research and analysis of authenticity information can we avoid over-repairing and covering up of the historical information of the building, to preserve the authenticity of the information in different historical stages.

"External protection and internal reconstruction" is an inappropriate repair method, and this case avoids these defects. We keep the exterior of the building complete and minimize the internal changes. Therefore, while the functions are upgraded, the old and new functions are compatible and the original office functions are retained [49]. Adaptive reuse revitalizes architectural heritage, revitalizing it through functional enhancement and equipment renewal. Under the analysis of regional development and campus renewal needs, this paper proposes a reasonable heritage space renewal strategy from the aspects of culture and publicity. Based on the principle of minimal intervention, air conditioning, water supply, drainage, network, fire protection, lightning protection, and other facilities are implanted according to the needs of new functions, and structural strengthening is carried out according to structural inspection. After the renovation of the clock tower, it can better adapt to contemporary life while retaining its original historical appearance, achieving a win–win situation of protection and restoration. The strategy presented in this paper is not the only one. In the future, it will be possible to propose renewal strategies according to new needs to make the architectural heritage sustainable.

Author Contributions: Conceptualization, H.W.; methodology, H.W.; software, Z.H.; formal analysis, Q.Z. and Y.H.; investigation, H.W., Z.H., L.H. and M.C.; writing—original draft preparation, H.W.; writing—review and editing, H.W.; visualization, H.W.; supervision, H.W. and Q.Z.; funding acquisition, H.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China: "Research on the formation mechanism and development evolution of Nanjing modern educational architecture from the perspective of pedagogy (1840–1949)" (grant number 52008157), Doctoral Fund of Hubei University of Technology: "Research on the protection of modern educational architectural heritage from the perspective of sustainable development" (grant number BSQD2019044), The National Natural Science Foundation of China: "Research on Multidimensional Coupling Enhancement of the Resilience of the 'City-Rural' Space Complex Giant System in the Three Gorges Reservoir Area" (grant number 52078193), and the College Students' Innovative Entrepreneurial Training Plan Program: "Modular membrane structure medical architecture design based on ecological theory" (grant number S202110500063).

Data Availability Statement: The data presented in this study are available within this article.

Acknowledgments: The authors are thankful for the support from Southeast University to conduct this research. The authors thank Zhaoyi Yan, Jianwei Ge, Xinxin Chen, and Xinyi He for the surveying and drawing.

Conflicts of Interest: The authors declare no conflict of interest.

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