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# Ensuring the Authenticity of the Conservation and Reuse of Modern Industrial Heritage Architecture: A Case Study of the Large Machine Factory, China

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**Abstract:** The Large Machine Factory (LMF) was built in the complex historical context of the late Qing Dynasty (1840–1912). Its space and construction faithfully record the architectural and cultural fusion between Chinese and western traditions and mark the beginning of modern architectural techniques in China. Through historical data and empirical studies, the historical background and architectural characteristics of the LMF were analyzed, and interventions aimed at ensuring authenticity were established. The cultural significance and results of construction were considered two crucial elements in terms of outstanding characteristics. Comprehensive inspection and assessment strategies were discussed, with minimal intervention and interpretation principles. Preventive reinforcement of the foundation, complementary reinforcement of the main structures, restoration of the historic façade and environment, and adaptive spatial interventions were found to be effective ways to ensure authenticity. The principles of minimal intervention and interpretability, which include prevention, recognizability, invisibility, subsidiarity, and intertextuality, were proposed through a comparison with the literature and practical experience. This study provides an appropriate technical reference for ensuring authenticity in the conservation and reuse of modern historic buildings with complex contexts. We propose a new understanding of intervention principles and suggest a guiding intervention path that avoids the complexities arising from the generalized interpretations of authenticity.

**Keywords:** industrial heritage; historic building; authenticity; construction culture; targeted intervention; adaptive reuse

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## 1. Introduction

The transformation of traditional Chinese architecture began when western construction technology was introduced during the self-strengthening movement, which was a movement of the Qing government to learn advanced science and technology from the west in an attempt to save its rule between 1861 and 1895. The rise of the military industry at that time gave birth to a number of industrial buildings with obvious western characteristics. Industrial production has stricter requirements in terms of the spatial scale, efficiency, and structural carrying capacity of buildings, which could not be realized by China's traditional civil structure system [1]. Therefore, it was necessary to adopt the western modern architectural system at that time; thus, the transformation of China's modern architecture first started with industrial buildings [2].

At the end of the 19th century, with the emergence of European-style architecture, the new structures, materials, construction techniques, and equipment of western architecture, such as steel, cement, and glass, were introduced to China [3]. In terms of architectural structure, the introduction of the brick wall load-bearing system and steel–wood composite roof truss promoted the transformation of the traditional Chinese wood structure system, meeting the needs of modern society. The transformation mainly focused on the roof's stress method and structural form, which were different from traditional post-and-lintel construction and column-and-tie construction. This was reflected in using the Western spar roof, which was distinct from the Chinese purlin roof, and walls also became a part of the load-bearing system [4] (Figure 1). In addition, new technologies could not be fully applied in the construction of these buildings under the restrictions of China's social economy, engineering level, and lagging social consciousness at that time, but they were important components in the process of China's architectural modernization and represented the cultural exchanges between China and the west [5]. These buildings, formed under complex social transformation and cultural integration, urgently need to be restored and reused after more than a century.

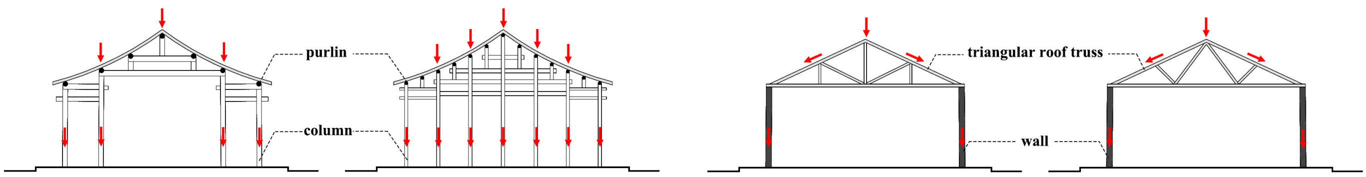



**Figure 1.** A comparison of typical Chinese traditional and wghhj43iestern roof structures. Pictures by X.X.

Regardless of the type of heritage, authenticity has long been considered as the basis for heritage conservation and value assessment. The Venice Charter of 1964, an international code of values, conservation, and restoration interventions on monuments, architectural artifacts, and historical sites, emphasizes the historical authenticity of monuments. With scientific means, the material elements of a heritage site that prove the historical values need to be preserved and restored with reliable original materials and documentation. The conservation of the historical superimpositions of the various periods and distinguished restoration and complementation were highlighted [6]. In consideration of heritage diversity in different cultural contexts, the Nara Authenticity Document, an international document that extends the spirit of the Venice Charter to respond to the diverse cultural significance of heritage, proposes that authenticity should be rooted in a specific cultural context. Authenticity is derived from a full recognition and understanding of the information sources and meanings of heritage values [7]. In American countries, the identity of the territorial culture, the evolution of historical places, the physical objects of heritage, and the spirit of the communities involved are treated as the basis of authentic values [8]. They need to be carefully identified, evaluated, protected, and presented [8]. With urbanization, threats to heritage preservation come not only from within but also from the surroundings, both the built and the natural [9]. Therefore, understanding and intervention in the specific setting also become important parts of heritage authenticity [10]. *Nara + 20*, the publication of the 20th anniversary of the Nara Document, continued the interpretation of authenticity in the Nara Authenticity Document and appealed for the examination of heritage values and authenticity within the dynamic perception of stakeholders in order to achieve sustainability [11]. The need to consider both integrity and authenticity was stated in the Operational Guidelines for the Implementation of the World Heritage Convention, which is an international code of conduct for the World Heritage Committee to periodically revise new concepts, knowledge, and experiences related to cultural heritage. In different cultural contexts, authenticity needs to be interpreted in terms of the ability to understand heritage values and the perception of information sources regarding the original and evolving characteristics. The convention defined eight characteristics for measuring authenticity, including form and design; materials and substance; use and function; traditions, techniques, and management systems; location and setting; language; other forms of intangible heritage, spirit, and feeling; and other internal and external factors [12]. The developing international consensus shows that the understanding of authenticity has extended from the initial focus on static materiality to a dynamic domain containing continuous changes in time, space, culture, and society.

For China, ICOMOS China first promulgated the Principles for the Conservation of Heritage Sites in China in 2002 based on international experience and Chinese reality, which has been revised twice, in 2004 and in 2015. The interpretations and regulations on authenticity have been gradually expanded from not changing the original state to the integrated conservation of tangible and intangible elements combining temporal and spatial dimensions. The public interest and sustainability of the continuation of original functions and the addition of new ones were also specifically emphasized [13]. In 2007, aimed at the characteristics of Chinese wooden architecture, the Beijing Document was promulgated by the National Cultural Heritage Administration in collaboration with ICOMOS, ICCROM, and UNESCO on the basis of the Nara Authenticity Document. Authenticity can be understood as the reliability and trueness of the source of heritage information. The Beijing Document highlights the respect for traditional techniques, which can be used to restore and repair paintings, decorations, and components of wooden buildings [14].

In early times, some scholars extensively discussed authenticity and originality, believing that authenticity means original, genuine, first-hand, noncopy, and nonimitation, particularly emphasizing the original state in the time dimension [15–17]. Chang Qing stated that relics not only reflect the original information of the historic buildings but also contain the traces that were superimposed during the historical process and that interventions should aim to "restore to its recent state, repair the defect with the new; renovate to its original state, re-create the new with the old" [18,19]. Authenticity also included the reality of conservation processes, relevant cultures, functions, and surroundings [20,21]. It is even regarded as an indicator to judge the truthfulness and reliability of heritage information to evaluate the faithfulness of the heritage ontology in the reflection of values [22].

In summary, considering authenticity is always an unavoidable issue in the conservation and reuse of architectural heritage. Interventions must avoid using inappropriate and unnecessary restoration measures to prevent negative impacts on historical information [23,24]. In this context, minimal interventions and interpretations through contemporary technical strategies are necessary to ensure authenticity [25,26].

The purpose of this study was to analyze the characteristics of Chinese architecture in the context of modern western colonial culture, focusing on a case study of the Large Machine Factory (LMF). Afterward, in the context of the cultural significance of construction characterized by steel–wood composite roof trusses and brick wall load-bearing systems, this study focused on the response to authenticity to discuss the appropriate relationship between conservation and the reuse of modern architectural heritage and contemporary interventions. At the same time, the repair and conservation reuse practices used for the LMF are used as evidence to reflect on the representation of authenticity during interventions into historic architecture. The specific aims were as follows: (1) based on authenticity, to propose an integrated intervention strategy including inspection from the whole to the local, unit assessment, assisted strengthening, in situ repair, and adaptive reuse, to provide a reference for the coexistence and intertranslation of values between traditional and modern construction techniques in historic building conservation projects; (2) in the case of a specific characteristic historical building, to reflect on how to guide practice through a clear path to ensure authenticity in accordance with the generalized interpretation of authenticity.

## 2. Methodology and Materials

### 2.1. Methodology

In general, architectural heritage conservation and reuse are responses to the history, current conditions, and redesign of architecture [27]. Based on a comprehensive empirical research framework, this study placed responsiveness to authenticity at the core of heritage conservation reuse. We discussed the scientific validity of an intervention from three aspects: descriptive analysis of historical materials, application of strategies, and discussion of empirical experiences (Figure 2). Through an examination of the literature, we reviewed the discourse on heritage authenticity and analyzed the changes in and focus of national and international understandings of authenticity. In the case study, the historical materials and archival drawings of the case were thoroughly researched. The plans, elevations, and partial structures were drawn according to the current state of the building, which was compared with the historical materials to clarify the parts of the building that were changed and preserved over more than 100 years of use. At the same time, three parts of its function, structure, and façade were selected to explain the original construction characteristics and cultural significance as the basis for the source of authenticity, thus establishing the core of preserving the mixed cultural significance of east and west as well specific construction results to ensure authenticity. Under the principles of minimal intervention and interpretability, the vulnerable parts of the building were identified through on-site inspection, nondestructive testing, and comprehensive assessment. Specific conservation and repair measures were proposed for the foundation, overall structure, historical style, spatial reuse, and environmental restoration. Finally, scientific strategies for responding to authenticity in the conservation and reuse of historic buildings in complex contexts were discussed through reflection on practical experience and a comparison with the literature.

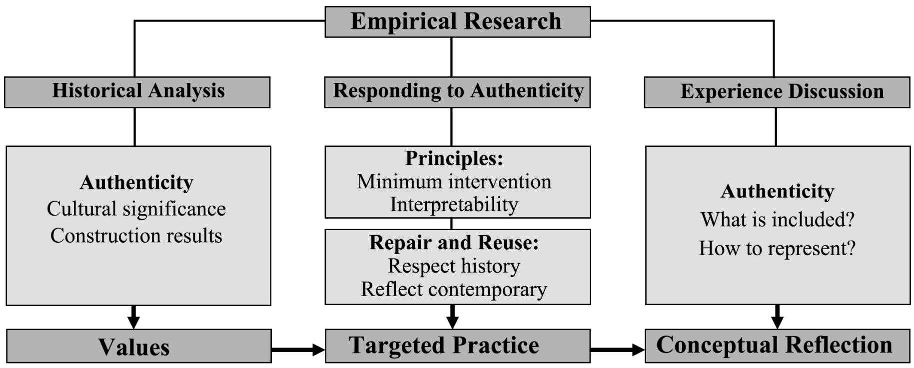



**Figure 2.** The methodological framework of this study. Picture by X.X.

The case in this study, the Large Machine Factory, is a typical military industrial production plant that was built in the nineteenth century. We were involved in the conservation, restoration, and reuse of the case study and conducted an in-depth study of its history, values, and appropriate interventions through surveys, data analyses, drawings, and engineering practices.

## *2.2. Materials*

### 2.2.1. Brief History

In the mid-19th century, with the expansion of western maritime territories in Asia, European industrial civilization was first introduced into China from the coastal cities of the southeast [28]. After the defeat in the Opium War, a war of aggression launched by Britain against China in 1840, the Qing government was forced to compromise with the colonization of western civilization in China and attempted to rely on the feudal system to learn techniques in the context of western capitalism to consolidate its rule and resist invasion, known as the self-strengthening movement [29]. Since then, Chinese architecture has also moved from a collision of Confucian essence and European forms to modernity [30]. Nanjing (Jinling) was an important capital city of Chinese rule for many generations because of its geographical advantage, as it was close to the Yangtze River and backed by the Purple Mountain and had better military defense and transportation conditions. In this context, Nanjing also became an ideal place for industrial development in modern China at an early stage (Figure 3) [31].


**Figure 3.** The location of Nanjing in the east–west cultural exchanges in 1889. Modified from [32].

The Jinling Machinery Bureau was built during the self-strengthening movement and was a specific product of the idea of Chinese essence and Western utility. The fusion of Chinese and western cultures was inevitable during planning and construction. In 1865, Li Hongzhang, then governor of Jiangsu and Jiangxi, considered the spatial needs of modern military–industrial production based on four standards [31]: (1) convenient water and land transportation to meet equipment and coal supply requirements; (2) a position close to residential areas to facilitate worker commutes; (3) the inconveniences of building in an urban area in order to prevent experiments and threats to security; and (4) the need for additional sites for later expansion. The final site was chosen outside the Zhonghua Gate in Nanjing, along the Qinhuai River (Figure 4) [33]. In 1886, Li reported to the Guangxu Emperor on the expansion project of the Jinling Machinery Bureau, writing that "the additional factory buildings were built with foreign solid wood, and all the construction technologies followed foreign modes" [34]. European engineers designed these buildings, and the construction and mechanical installation were completed by Chinese workers [30]. British engineer G. Bracegirdle designed and supervised the construction of the LMF, which was completed in 1887 [35,36]. Located on the west side of the Jinling Machinery Bureau, the LMF was the second plant built in the area and the largest one at the time (Figure 5).

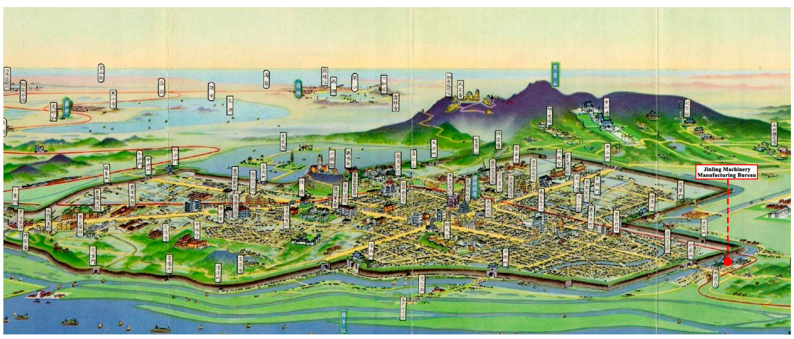



**Figure 4.** The location of Jinling Machinery Manufacturing Bureau in 1890s. Modified from [37].

**Figure 5.** The Jinling Machinery Bureau and the LMF in 1889. Modified from [38].

### 2.2.2. Functional Characteristics of the LMF

The LMF was initially used as a workshop for firearm parts, and its interior was spacious, with both upper and lower floors have unconventional dimensions for the time. The building is approximately 47.74 m long and 16.14 m wide, with a total construction area of approximately 1541 m$^2$. With a total height of approximately 8.88 m, the first floor is 4.82 m, and the second floor is 4.06 m. The longest span of the LMF reaches 14.5 m. These dimensions exceeded the scale of traditional Chinese single-span architectures [5]. As the Qinhuai River was a major transportation channel then, the main entrance of the LMF was oriented toward it for easy access (Figure 6). Due to the fact that the construction consultant of the Jinling Machinery Bureau, Macartney Halliday, and the architect of the LMF were both British, the design and function of LMF were inevitably influenced by the features of early nineteenth-century British industrial architectures, as demonstrated by a comparison of historical images (Figure 7), making it the first European-style two-story factory building in Nanjing [39]. During the Republic of China era (from 1912), the first floor of the LMF served as a workshop for military production tools, and half of the second floor served as an office. The other half was still used as a production workshop connected to the adjacent building through a corridor, and a steel staircase was added to the south outdoor area [40]. As a typical large-space industrial building, the LMF combines the Chinese and western characteristics of the late 19th century.

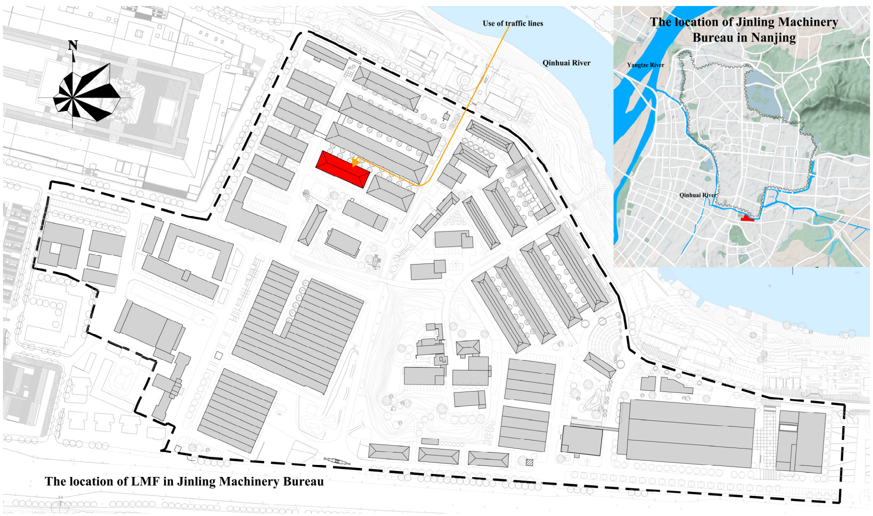



**Figure 6.** The location of the LMF. Picture by X.X.

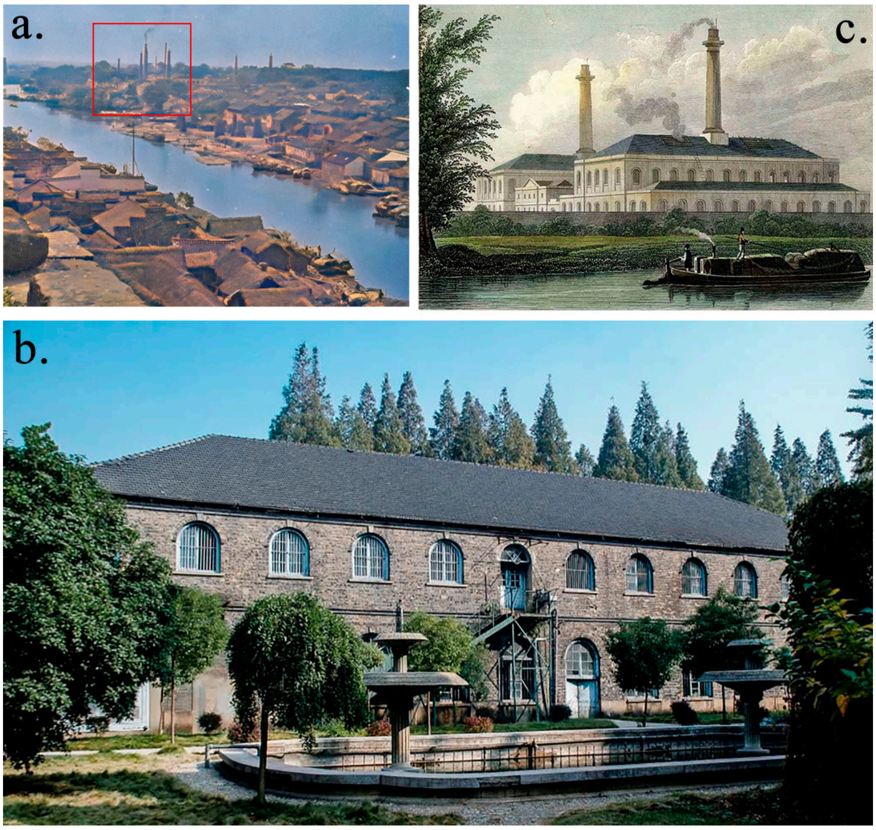
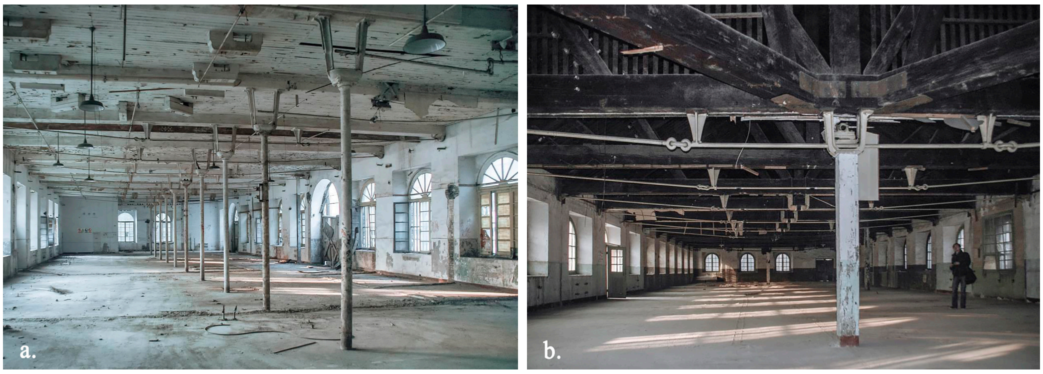



**Figure 7.** The Jinling Machinery Bureau in the early 20th century (**a**); the appearance of the LMF before restoration (**b**); the Imperial Gas Light Co. on Regent's Canal in London in the early 19th century (**c**). (**a**,**c**) from [40]; picture in (**b**) taken by Y.W.

#### 2.2.3. Structural Characteristics of the LMF

The LMF is a combined load-bearing system with wooden beam frames and brick walls. The load-bearing wall is an 800 mm thick continuous exterior wall made of gray bricks and lime mortar. A combined system of wooden beams and cast iron pull rods is applied on the first and second floors to solve the load-bearing problem of large-span wooden components (Figure 8). This structure is a typical string-beam structure, which did not appear in European industrial buildings until the mid-19th century. It is also the earliest and only case found in China [36]. This structure consists of a wooden beam and three pull rods, with the outer pull rod and wooden beam end connected by a metal anchor, the middle and outside pull rods hinged by a metal ring, and the middle pull rod and wooden beam connected through metal members to fix the force point. The string beam was an innovation of foreign engineers based on the construction conditions in China at that time. For the first-floor structure, the load-bearing method of combining string beams and cast iron columns was adopted. The wooden beams are made of American fir with 450 mm × 450 mm sections. Cast iron columns with a diameter of 140 mm were adopted for independent load bearing in the midspan. The stigma in the flower basket style allows the pull rod to pass through to ensure the transmission of lateral tension (Figure 9). For roof structure, a string beam combined with a triangle timber truss was adopted. Only two wooden columns are set at the node of the three-side slope roof at both ends of the building. Unlike the typical roof truss of the time, the roof truss of the LMF was designed with cast iron pull rods to reduce the midspan deflection of the lower chord timber beam through tension. In this way, the overall span of the roof truss was increased, and the number of diagonal tension members between the top and bottom chords was reduced (Figure 10). This unique structural design provided spacious and column-free space for industrial production on the second floor. This innovative harnessing of the properties of steel and wood hybrid structures was a milestone in the history of modern industrial construction technology in China.




(**a**) (**b**)

**Figure 8.** Structural system of string beams on the first (**a**) and second (**b**) floors. Pictures by X.X.

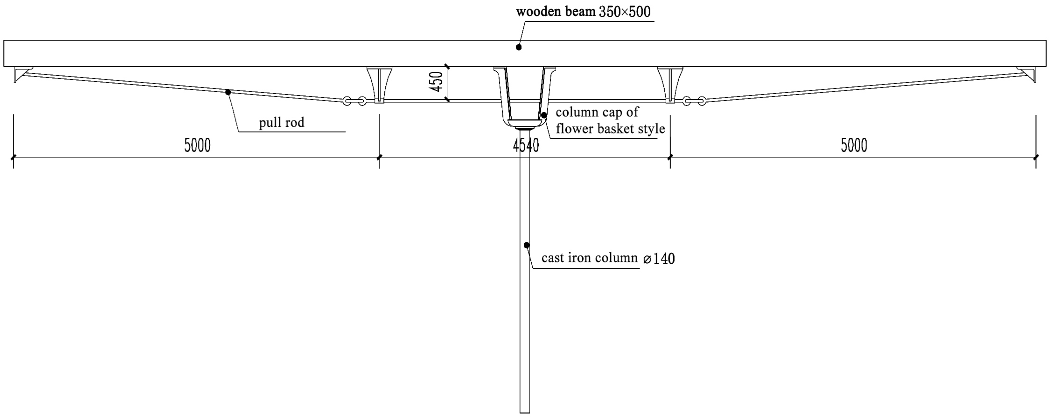



**Figure 9.** Composite structure system of the first floor. Picture by X.X.

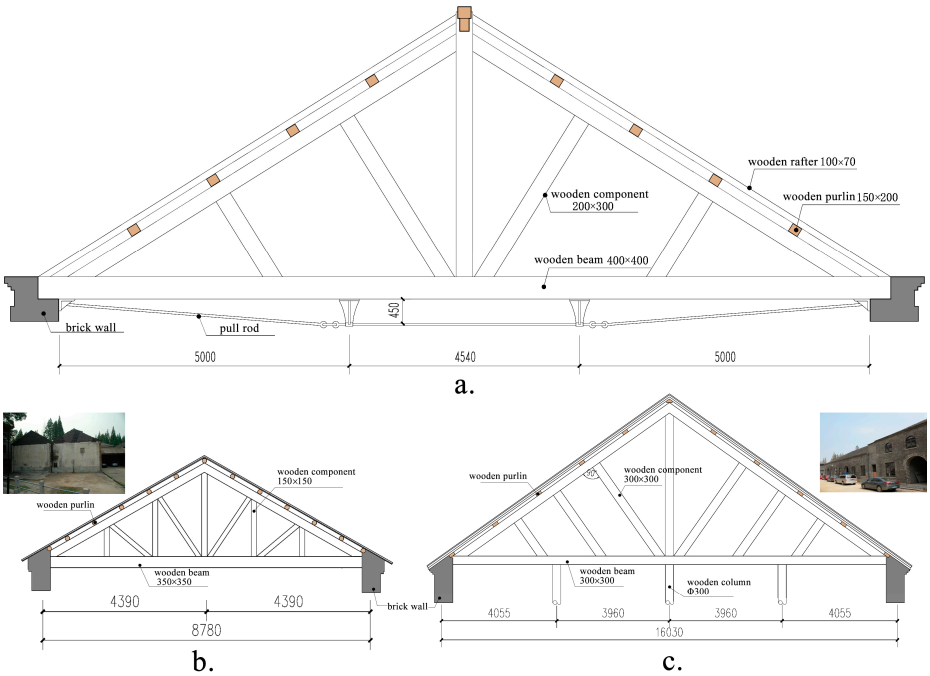



**Figure 10.** The roof truss of LMF ((**a**) 1887); the other two buildings in Jinling Machinery Bureau ((**b**) 1882; (**c**) 1886). Pictures by X.X.

2.2.4. Façade Characteristics of LMF

The façades of the LMF have plain decoration with main modeling elements, including gray brick and a tile roof, arched doors, and windows. The height of the roof is approximately one-half of that of the wall, which constitutes a harmonious proportion of the building. The walls were constructed with local gray bricks. The masonry method combined the traditional Chinese header–stretcher bond with the British bond of alternating header and stretcher courses. Laying one course of stretchers and two courses of headers brings into play the pulling performance of headers to increase the stability of the walls and leaves neatly arranged perpends that make the building façade elegant [41] (Figure 11).

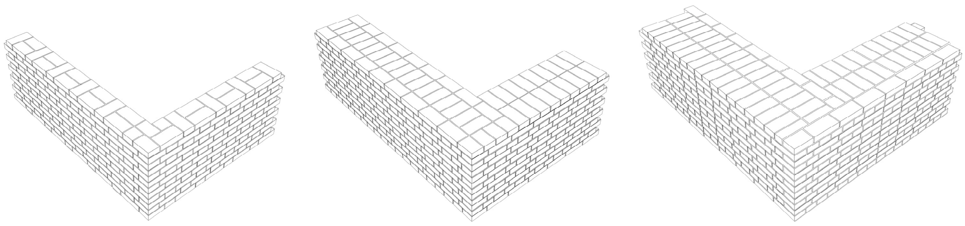



**Figure 11.** Typical traditional Chinese brick wall (**a**); English bond brick wall (**b**); the brick wall of the LMF (**c**). Pictures by X.X.

The roof and wall are organically combined by stacking eaves, and a complete stone is embedded into each wall corner, both of which approaches belong to the traditional construction methods of Chinese architecture [41]. According to the mechanical logic of brick wall load bearing, two rows of windows of the same size and form are evenly arranged on the wall. The top of the semicircular arch window is composed of a horizontal and a vertical brick arch and a set of arch core stones. The last brick at the arch bottom protrudes from the wall. Because the wall is relatively thick, the arch is only used on the outermost row of bricks, with rectangular interior window holes. The window arches are only decorative, without mechanical effect. This also shows that the Chinese craftspeople at that time only imitated the style of European arches and did not master the structural principles. The style of the door is also a semicircular arch, but because the door opening is larger than that of the window, the arch top consists of two horizontal, two vertical bricks, and a set of arch core stones (Figure 12). The whole façade is simple but solemn.

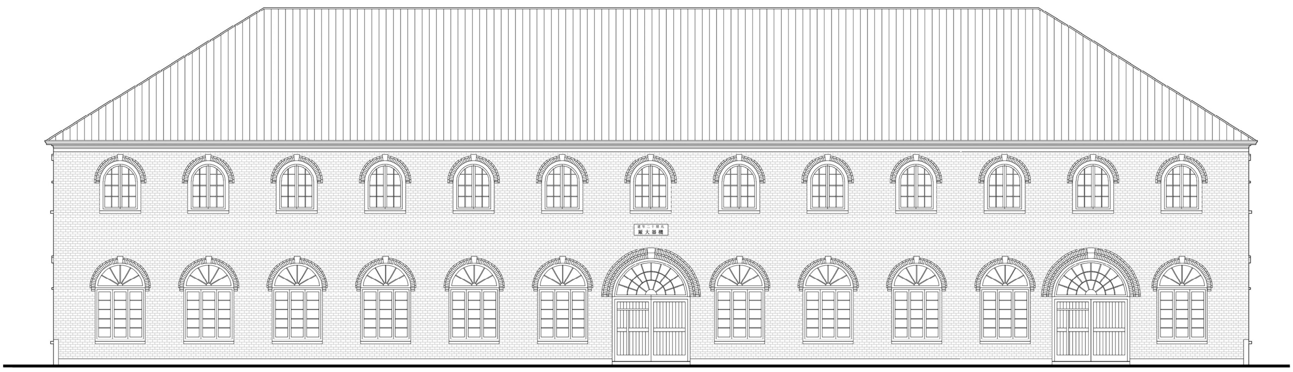


**Figure 12.** The main facade of the LMF. Picture by X.X.

2.2.5. Judgment of Authenticity

The purpose of emphasizing authenticity is to find justification for the continued existence of historic buildings and the cultural meanings they represent in the contemporary era [24]. However, what needs to be discussed before conservation and reuse is what represents the authenticity of a case under a different context. To preserve cultural diversity, the establishment of authenticity should not be confined to some specific criteria or regulations but needs to focus on the particular contribution of specific cases. As mentioned above, the authenticity of the LMF, as an isolated example built with special structures and mixed materials in the context of the cultural fusion between the east and west in modern times, stems from the historical and cultural significance behind the formation of the original construction techniques and the scientific values of the actual construction results.

Modern industrial heritage has a complex relationship with the historical and social context, with obvious tendencies in politics and national sentiment [42]. In particular, the government-run industries during the self-strengthening movement were built with the purpose of learning European techniques to develop themselves and thus resist the west. In the process of the expansion of modern civilization, this took the form of the colonization of western construction techniques in east Asia and the transformation of traditional Chinese practices. However, this mixed or ambiguous system of accidental construction was the result of a compromise between the interests of industrial civilization and feudal rule. Thus, the original construction techniques were a manifestation of the will of the nation in colonial culture and indispensable evidence of the complex historical processes of the modern era. Interventions that combine integrity, preservation, and interpretation facilitate the perpetuation of national memory and historical values.

In the mid-19th century, construction techniques such as large-span steel and wood roof frames, string beams, and brick arched windows and doors appeared for the first time in China, and these techniques were neither part of the traditional Chinese construction system nor were they original to China at the time [43]. The LMF presents the node of China's modern construction progress and is a specimen for the study of modern construction techniques. As seen in the comparison with other industrial constructions of the same period [44], the LMF is a fusion of Chinese tradition and the modern west, and its eventual technical outcomes are an important piece of history. It is of high value to the study of the history of architectural techniques to preserve the built form and mechanical logic of the original construction techniques.

## 3. Responding to the Authenticity of Protective Restoration and Reuse Strategies

### *3.1. Principles*

The original structure, materials, and appearance of historic buildings should be holistically protected to explain their past and their historical forms, and the traditional techniques used and the environments should be restored in reversible ways during the intervention process. Comprehensive inspection and assessment, protective restoration, and redesign are three necessary interventions [45]. Based on the current consensus [46,47], the principles of minimal intervention and interpretability are established, which include the following: (1) risk detection and assessment should consider the entire architecture and its elements and should not compromise the original function of the elements being inspected; (2) protective restoration should preserve the original architectural construction characteristics as much as possible with targeted technical strategies; (3) redesign must consider the recognizability and reversibility of the newly added elements and the adaptability to the new functions; and (4) new interventions are as essential as the original construction but should be favorable to the reading and interpretation of the original construction.

### *3.2. Comprehensive Inspection*

Comprehensive nondestructive methods should be used to examine the problem and damage mechanisms of components and materials without impacting the appearance, internal structure, or performance of the building [48]. The technical logic principle of detection is from the whole to the local, the external to the internal, and the macro to the micro. In particular, the seismic capacity and the reliability of each key part of a wood structure system are detected and analyzed [49,50]. In this case study, the composite beam–column structure system of the first floor, the composite roof truss system of the second floor, and the load-bearing brick wall system were separately inspected, and the whole building was comprehensively evaluated.

3.2.1. Preliminary Judgment of the Scene

The on-site observation and inspection of brick walls, beams, eaves, and door and window openings can visually reveal the overall deterioration of the building and the natural decay of each component (Table 1). The observation results of uneven settlement, cracks, the deformation or absence of components, and material damage are used as the basis for the identification of obvious problems in building parts.

**Table 1.** Security damage by observation.

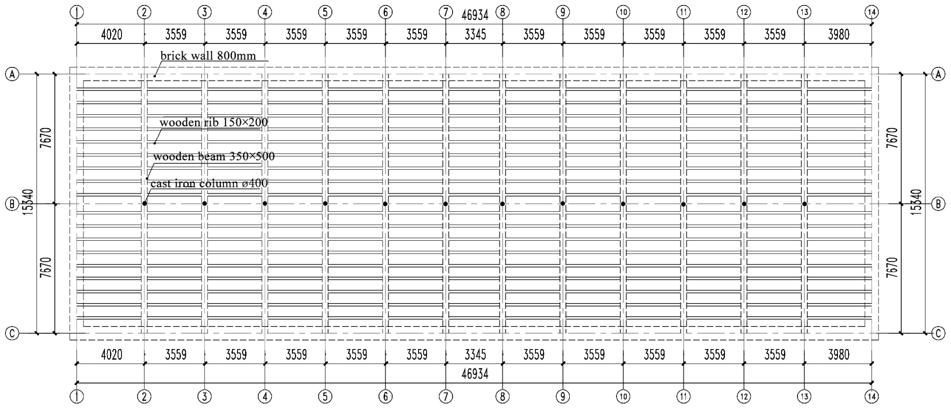
| Facade | Wall | String Beam | End of Beam | Timber | Joint of Roof Truss |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| • Some blocked windows<br>• Bricks missing and broken on some parts of the wall<br>• Ring of once-reinforced steel beam exposed on the wall | • Visible cracks on the load-bearing wall<br>• Mortar weathering | • Broken or deformed cast iron pull rods<br>• Rusted cast iron components | • Partially crushed supporting end of the composite beam | • Cracked timbers | • Detached mortise and tenon at the joints of the wooden components |

3.2.2. Nondestructive Testing of Materials

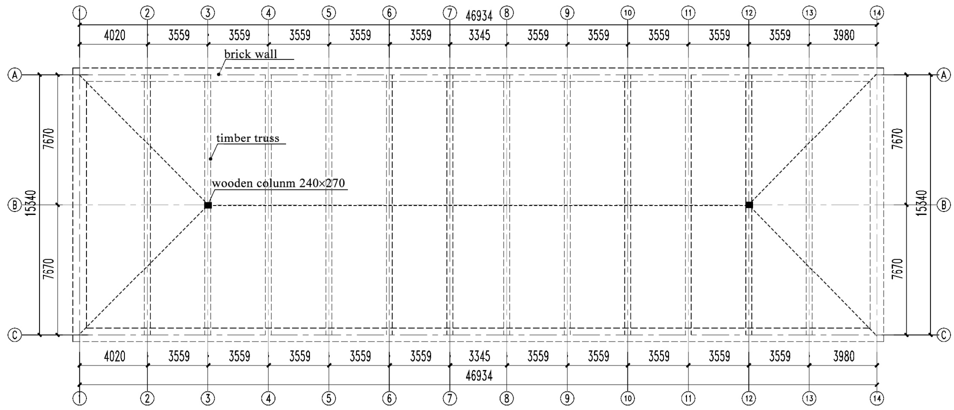
- Masonry: The main material of the load-bearing wall is gray clay bricks, with specifications of 315 mm × 150 mm × 65 mm. The compressive strength of the brick masonry was measured using the rebound method. Ten bricks of each longitudinal wall were taken, of which five bricks were from the first and second floors, and the average rebound value of the ten bricks was calculated.
- Mortar: Without the areas of vertical joints, door and window openings, for 10 bricks horizontal to the mortar layer, the depth of each shot hole was measured. The two deepest mortar joints with a thickness greater than 7 mm were measured on-site, and they were rubbed with sandpaper to remove superficial mortar. An SJY800 (Shaoxing Tianyun Instrument and Equipment Co., Shaoxing, China) penetrometer was used to drive the nails into the shallowest joints, and values were removed to calculate the average of the remaining six shot-hole depths.
- Cast iron: A 1 m long specimen was taken from a discarded cast iron pull rod.
- Wood moisture content: The main wood members were sampled for on-site tests, and the moisture content was 7% according to an electronic moisture meter (model XSD-18, Shanghai Longtop Instrument Co., Shanghai, China).

3.2.3. Review and Analysis of the Load-Bearing Capacity of the Main Structure

- Load-bearing wall analysis: The check calculation of the load-bearing wall was based on the structural layout and component geometry drawings surveyed and mapped on site (Figure 13). The compressive bearing capacity of walls in the seismic test was calculated with PKPM software [51] (Table 2).




(**a**)




(**b**)

**Figure 13.** (**a**) Structural diagram of the first floor. Picture by X.X. (**b**) Structural diagram of the second floor. Picture by X.X.

**Table 2.** (**a**) Structural check: calculation of load-bearing wall (seismic check). (**b**) Structural check: calculated value of load-bearing wall (compression bearing capacity check).

| **Ratio of Resistance to Effect (a)** | | |
|---|---|---|
| **Axis Number** | **1st Floor** | **2nd Floor** |
| | Parameter: G1 = 10,799.1 KN, F1 = 565.0 KN, V1 = 1161.1 KN, LD = 7.0, GD = 3.0, M = 1.2, MU = 10.0 | Parameter: G2 = 6276.6 KN, F2 = 596.0 KN, V2 = 596.0 KN, LD = 7.0, GD = 3.0, M = 1.2, MU = 10.0 |
| A (①)~A (⑭) | 3.94, 2.17, 2.60, 2.26, 2.26, 2.26, 2.60, 2.60, 2.26, 2.26, 2.26, 2.26, 1.93, 3.94 | 5.96, 2.98, 4.17, 4.17, 4.17, 4.17, 4.17, 4.17, 4.17, 4.17, 4.17, 4.17, 2.98, 5.96 |
| C (①)~C (⑭) | 3.91, 1.94, 2.30, 2.30, 2.30, 2.65, 2.60, 2.25, 2.30, 2.30, 2.30, 2.65, 2.18, 3.91 | 5.84, 3.58, 3.69, 3.69, 3.69, 3.69, 4.21, 4.21, 3.69, 3.69, 3.69, 3.69, 3.58, 5.84 |
| ① (A)~① (C) | 2.38, 1.08, 3.03, 1.08, 2.40 | 2.72, 1.34, 1.80, 1.34, 2.72 |
| ⑭ (A)~⑭ (C) | 1.83, 0.85, 0.93, 0.85, 1.83 | 2.72, 1.34, 1.80, 1.34, 2.72 |
| **Ratio of Resistance to Load Effect (b)** | | |
| **Axis Number** | **1st Floor** | **2nd Floor** |
| A (①)~A (⑭) | 1.6, 1.45, 1.35, 1.45, 1.45, 1.45, 1.35, 1.35, 1.45, 1.45, 1.45, 1.45, 1.53, 1.60 | 4.09, 3.96, 3.81, 3.81, 3.81, 3.81, 3.81, 3.81, 3.81, 3.81, 3.81, 3.81, 3.96, 4.09 |
| C (①)~C (⑭) | 1.70, 1.58, 1.45, 1.45, 1.45, 1.35, 1.42, 1.52, 1.45, 1.45, 1.45, 1.35, 1.49, 1.70 | 4.07, 3.94, 3.81, 3.81, 3.81, 3.81, 3.54, 3.54, 3.81, 3.81, 3.81, 3.81, 3.94, 4.07 |
| ① (A)~① (C) | 4.21, 1.44, 4.21, 1.42, 4.21 | 6.96, 6.80, 5.73, 5.85, 6.96 |
| ⑭ (A)~⑭ (C) | 2.37, 2.31, 2.24, 2.31, 2.37 | 6.96, 6.80, 5.73, 5.85, 6.96 |

- The standard values of the compressive and tensile strength of cast iron are 405 MPa and 325 MPa, respectively. Wood strength value was taken according to the Code for Design of Timber Structures [52]; the reduction coefficient value suggested in the Technical Standard for Maintenance and Strengthening of Historical Timber Building [53] was also considered. According to the ANSYS analysis [54], the load-bearing capacity of the combined beam and roof truss basically met the requirements of the current national standards [55].

### 3.3. Safety Grade Assessment

According to the Standard for Appraisal of Reliability of Civil Buildings [55], the LMF is regarded as an evaluation unit. The assessment considered the overall structure, foundation and upper load-bearing structure, and general components. The safety level of each subunit was evaluated based on the quantity of each component with the lowest safety level. The safety of the load-bearing wall was determined according to the proportion of masonry with the lowest safety level. The safety level of the evaluation unit was determined according to the lowest level of each subunit. According to the assessment of each subunit, the final safety level of LMF was rated as $C_{su}$ (Table 3). Therefore, corresponding measures for overall seismic reinforcements should be taken, and damaged components and architectural façades need to be repaired.

**Table 3.** Assessment and results of each unit.

| | | Conditions | Unit Level | Result |
|---|---|---|---|---|
| Overall structure | | • The seismic spacing of load-bearing walls does not meet the requirements, and the small size of the ring beam leads to a weak restraint effect, $c_u$<br>• The structural connection design is reasonable, $b_u$ | $C_u$ | $C_{su}$ |
| Foundation | | • The site is flat, without slope, obvious crack, deformation, or uneven settlement, $b_u$ | $B_u$ | |
| Upper load bearing structure | Brick wall | • The ratios of resistance to effect are smaller than 0.9 between axis ⑭ (A) and ⑭ (C) of the first floor, $d_u$<br>• The height-to-thickness ratio of the wall meets requirements, with correct connection and masonry methods, $b_u$<br>• The joints of vertical and horizontal walls are cracked, $c_u$<br>• The area rated as $d_u$ level is only 12% of all load-bearing walls | $C_u$ | |
| | Cast iron column | • The load-bearing capacity is very good according to calculation, $a_u$<br>• The construction methods are correct, $b_u$ | $B_u$ | |
| | String beams | • The load-bearing capacity is good by review calculation, $b_u$<br>• The construction is correct, $b_u$<br>• There are no obvious deflections, stress cracks, areas of rot, or moth-related damage, $b_u$ | $B_u$ | |
| | Roof truss | • The structural form of the roof truss is Howe truss with cast-iron pull rods, and the bending stress value and the maximum deflection value are larger than those of the general triangular roof truss, $a_u$<br>• Except for several tenon detachments, the other wooden components are well connected, $b_u$<br>• There are dry shrinkage cracks on wooden rods, $b_u$ | $B_u$ | |
| General components | | • The load-bearing capacity and construction of wooden keels, purlins, and rafters meet requirements; they are slightly rotten, and the damaged area is less than 5%, $b_u$ | $B_u$ | |

### *3.4. Repair and Reuse*

In the spirit of minimal intervention and the full presentation of the original construction, the concrete used for the new additions were hidden as much as possible. The concrete that could not be concealed was treated in a uniform and simple form, with priority given to maintaining the original style of the façade, wooden roof truss, and string-beam system. The new elements are light and transparent to reflect contemporary techniques in order to clearly contrast with the original.

#### 3.4.1. Preventive Reinforcement of the Foundation

The assessment results showed that the original foundation has a good load-bearing capacity without structural damage. However, corresponding preventive protection work was carried out to ensure the safety of the later use of the LMF. A new reinforced concrete strip foundation was added inside the original one to improve its overall performance, which was concealed in the ground to eliminate visual interference with the original structure and supported the load of the newly added polymer mortar reinforcement walls inside (Figure 14). According to the regulations [55], the overall bearing capacity of the reinforced foundation was raised by one grade to level $A_u$.

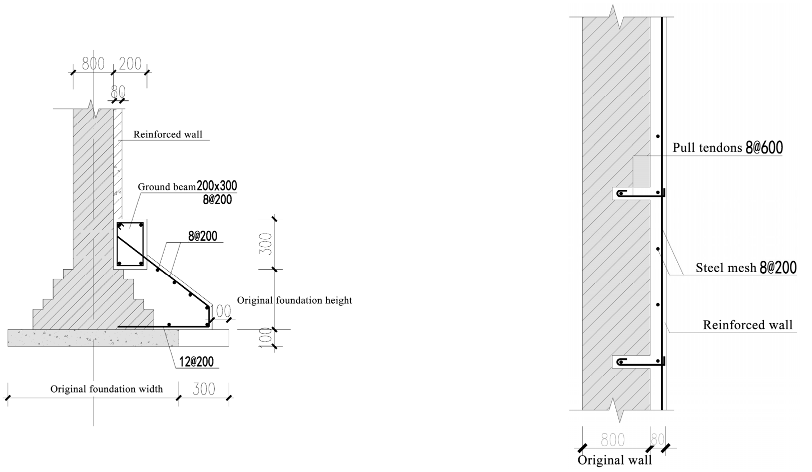



**Figure 14.** Diagram of reinforcement of foundation (**left**) and wall (**right**). Picture by X.X.

#### 3.4.2. Supplementary Reinforcement of the Main Structure

Structural reinforcement includes strengthening the load-bearing brick wall, composite beam of the first floor, and he composite roof truss of the second floor. The stress mode of the original structure should be kept, and the intervention should be minimized to avoid additional damage [56]. The load-bearing walls were reinforced overall, and 50 mm thick steel mesh polymer mortar layer was added inside (Figure 14). A reinforced layer can improve the vulnerability, carrying capacity, and deformation resistance of an original brick wall [57]. The grouting method was used to deal with the cracks in the external walls, and new mortar with strong adhesion and compatibility was injected [58].

To enhance the overall seismic performance of the structure and to realize the reversibility of the reinforcement technologies, 200 mm × 150 mm channel steels were taken inside of the wall as reinforcement ring beams and construction columns. The newly added structure is completely independent, so it has no impact on the original structure and reduces the rigid deformation of brick walls and wooden structures. The detached tenons and cracks of the timber truss and string beam were reinforced with steel plates and hoops. The broken cast iron pull rods were replaced based on the original proportion and style to preserve the unique structural system of the string beams (Figure 15).

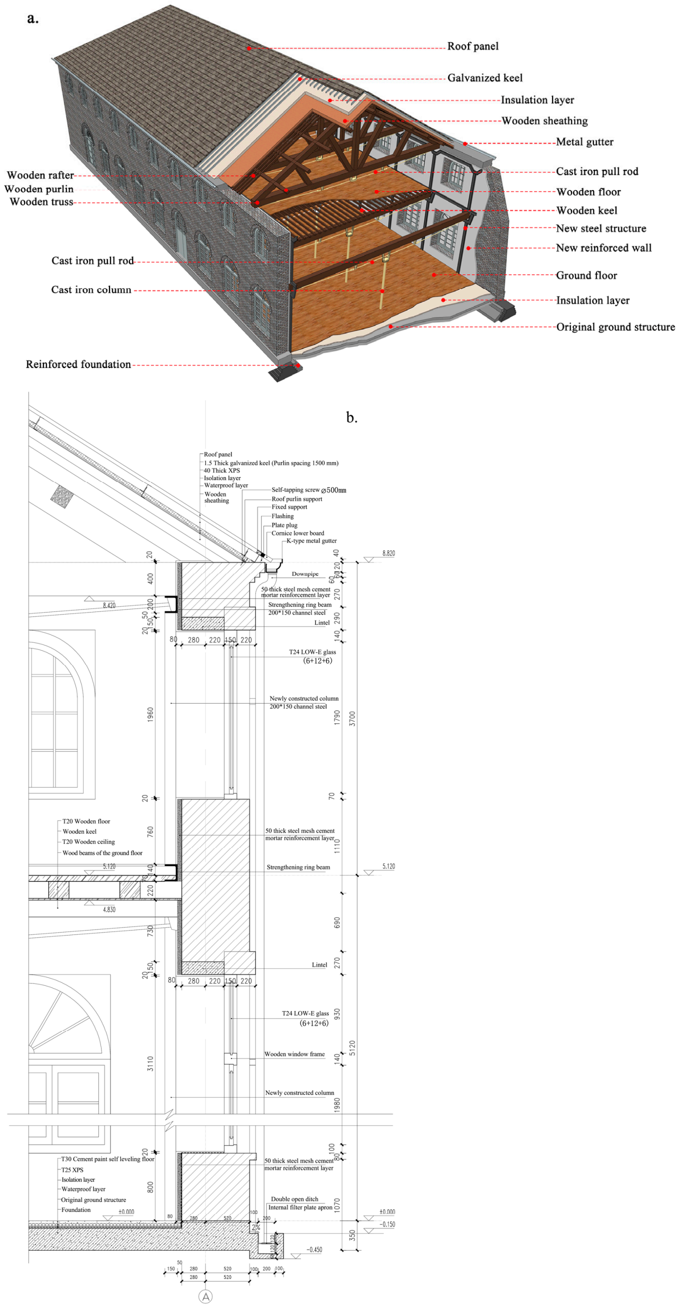



**Figure 15.** Spatial expression (**a**) and specific technique diagram (**b**) of restoration. Pictures by X.X.

The reinforcements of the preventive foundation and supplementary main structure form a complete and independent set of contemporary intervention techniques, which improve the safety and service life of the whole building on the basis of the maximum preservation of the original system. According to the relevant regulations [55], the safety level after reinforcement is grade $B_u$.

### 3.4.3. Restoration of the Historical Façade

As the restoration of historical appearance includes the preservation, repair, and renewal of the building to express its historical value, the objective identification of the historical elements on the building façade is a key step [59]. The historical elements of the façade from the first construction, such as architectural silhouettes and decorative details, should be preserved. Some damaged but necessary functional elements, such as windows, doors, drainage systems, and roof tiles, are repaired or renewed. During the restoration of the

LMF, its style elements were identified from the historical materials, and efforts were made to pursue the organic combination of new technologies and the original building. Bricks with over 1/4 broken cross-sections were replaced with new, customized ones according to the original size and material. Partially weathered wall bricks, with load-bearing capacity, were kept to maintain the historical sense. The doors and windows were repaired as they were. The messy security grilles were removed, and the glass and door panels were replaced with materials with better heat insulation properties. Specifically, the door panels and window frames were repaired with anticorrosive logs, and the windows were restored with double-layer low-e glass. Because the original gray terracotta roof tiles had extensively failed, custom-made replacements were accordingly prepared and installed to ensure a similar visual effect. In the meantime, insulation and waterproofing were added. The remaining gutter and downspouts were removed, and replacements of the original size were installed at the original location. All façade element renewals were performed to be as close as possible to their original state while eliminating safety hazards (Figure 16).

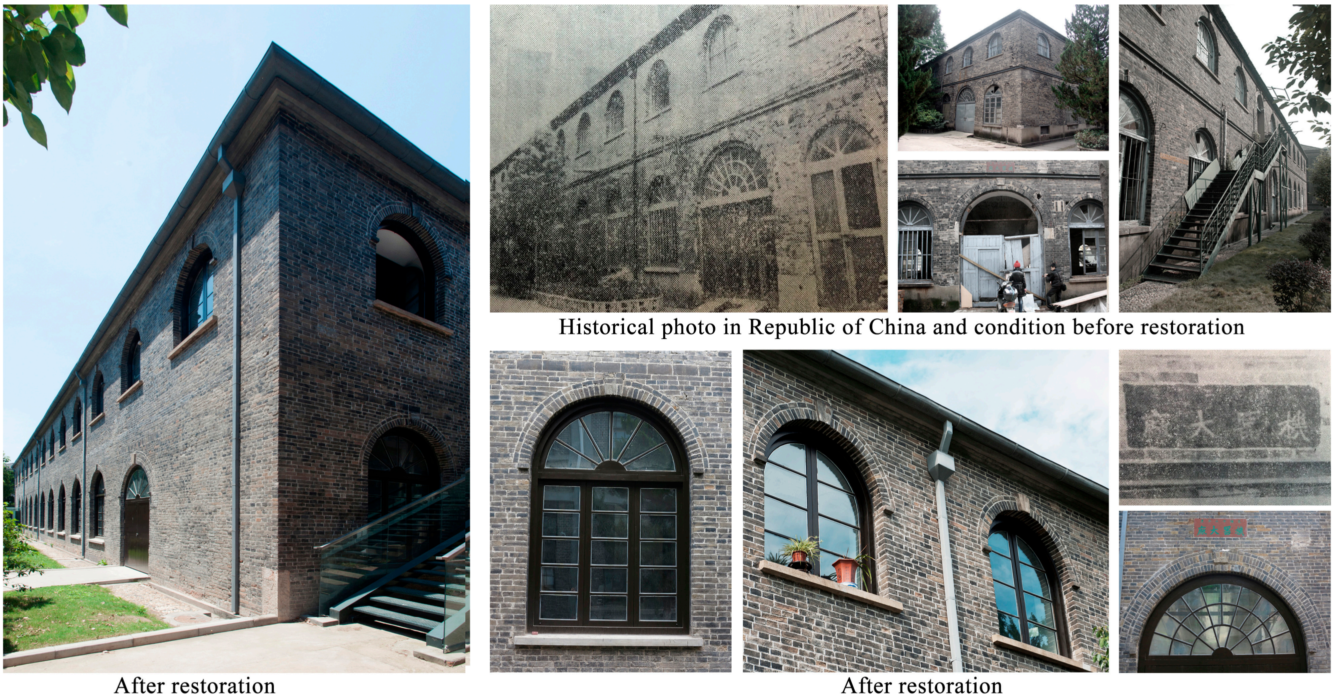



**Figure 16.** Facade comparison before and after restoration. Pictures by X.X.

### 3.4.4. Adaptive Reuse

The renewal and reuse of historic buildings should be adapted to contemporary needs and promote sustainability through appropriate utilization and maintenance [60]. Comprehensive conservation and a light intervention approach that facilitates the presentation and interpretation of original construction are prerequisites for the reuse of space [61].

To reuse the LMF, the openness of its functions must be strengthened and its historical characteristics must be retained so that the public can have an intuitive experience. Focusing on fully presenting the historic interior structure, the repurposing of the LMF was based on the strategy of preserving its large spaces to reflect the large scale of the original industrial production hall. The new functions were designed to make the most of the space and redefine it in the process. Therefore, the specific functional layout is as follows: The first floor was kept intact as an exhibition center of the Jinling Machinery Bureau to display the heritage materials, including architectural drawings, historical documents, images, and media, for the interpretation of the historical, cultural, social, economic, and technological value of this entity. The interior staircase was reconstructed in its original position. The steel staircase added to the south side in the 1970s is an unauthorized part of the building, which does not contribute to the esthetics of the building façade and obscures the historical features of this Qing Dynasty building. It was also not functionally necessary and was therefore removed. As the original evacuation exit, the connecting corridor on the east side of the second floor has been abandoned, but a new outdoor evacuation staircase is justified in its original position. In contrast with the openness of the first floor, the second floor is designed as a relatively quiet and private space for research and office management. The only two original wooden columns in the interior are used as anchor points for spatial separation, highlighting their contribution to the continuity of the roof structure and their monumental role in space repurposing. The three-stage layout of the public area, group office, and private office maximizes the structural characteristics of the roof truss with simple and lightweight glass partition walls (Figure 17). The entire reuse design achieved adaptability, recognizability, and reversibility of the new elements with a light intervention. Modern, lightweight, and transparent materials such as glass and metal, and simple geometric forms and bright colors were used to contrast with historical forms to emphasize the dialogue between the historical and the contemporary (Figure 18).


**Figure 17.** The comparison of plans before and after repurposing. Pictures by X.X.

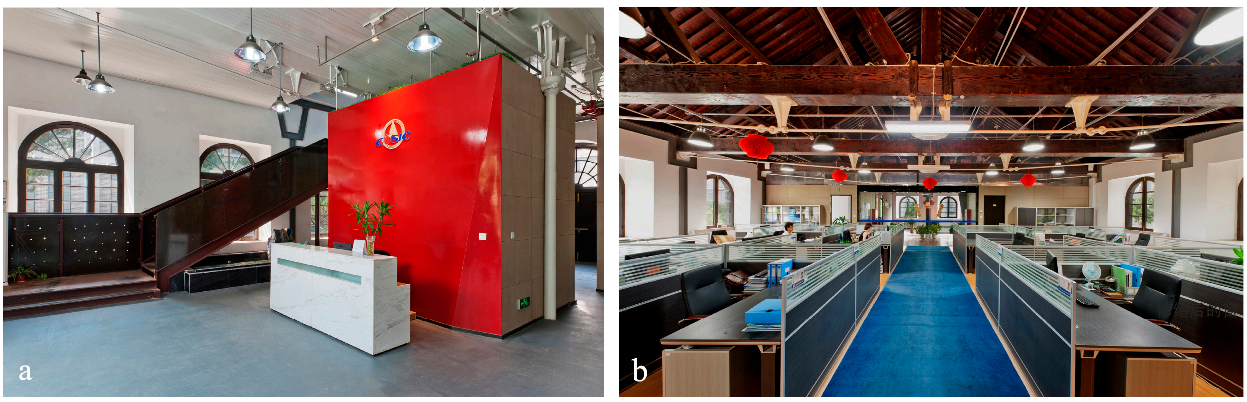



**Figure 18.** Interior space of the first floor (**a**) and second (**b**) floors after renovation. Pictures by Y.W.

### 3.4.5. Setting Conservation and Repair

Viewed from the perspective of the entire factory, all environmental elements within the Jinling Machinery Manufacturing Bureau are historical. Landscape elements such as spatial patterns, road networks, hills, and trees need to be preserved as a whole. Any other historic building, including the LMF, can only be given real historical and cultural significance within the overall historic environment. From the surroundings of the building, the pool built at the same time as the LMF has a traditional Chinese flower-style outline, while two European-style cylindrical fountains were built inside. They all reflect the characteristics of the mixture of Chinese and western cultures. These landscapes have been preserved intact and restored without changing their original shape and function (Figure 19).

**Figure 19.** The surroundings after restoration. Pictures by Y.W.

## 4. Discussion

### *4.1. New Understandings of the Intervention Principles of Authenticity in Specific Contexts*

The interpretation of the cultural significance of the original construction and the protective repair of the construction are the two dimensions that intervene in the authenticity in this case. The consideration of construction techniques, as the core of authenticity, is based on the essential characteristics of the case, unlike the large-scale conservation of monumental ruins and the authenticity of western masonry heritage [6,62] and the esthetic restoration of antique artworks [63]. Pevsner referred to the diverse coexisting and ephemeral architectural styles on the eve of modernism as a transitional period [64]. Modern historical buildings in complex cultural contexts are transitional in nature. Their conservation and restoration are firstly necessary to use the elements embodying transitional characteristics as the basis for preserving authenticity, including the technical, esthetic, and functional characteristics. The second is to give contemporary socioeconomic value to historic buildings through adaptive repurposing [5]. Brandi proposed that the restoration of cultural heritage should have dual aims of respecting both the first and second history [65], that is, focusing on the ephemeral characteristics of the object, including contemporary interventions. Especially in the case of modern historic buildings that must be repurposed by changing their functions, it is necessary to emphasize the equality between tradition and contemporaneity. In the case at hand, the intervention of the original construction techniques, as part of the transitional nature, should also be included in the historical superimposition. Preserving tradition and allowing new technologies both contribute to the context of authenticity while respecting history.

In this context, we need to emphasize that this unavoidable collage-like conservation must be based on a new understanding of minimal intervention and interpretability, especially for nonmasonry buildings. We think that in the face of the conservation and repurposing of buildings built of mixed materials in complex cultural contexts, it is important to learn from successful national and international experiences, such as prevention and identifiability [47]. It should also focus on the preservation of the local cultural identity and the construction characteristics of historic buildings, emphasizing the concealed, supplementary, and intertextual nature of the interventions. Minimal intervention and interpretability strategies should include the following:

- Preventive: Threats to the durability of the original construction from future use should be considered, and preventive reinforcement measures at key nodes should be appropriately carried out.
- Identifiability: The added or replaced parts should be easily distinguishable from the original construction, including style, color, material, and combination methods.
- Concealment: Unavoidable reinforcement and repair parts should be handled in a concealed manner to prioritize the presentation of the core characteristics of the building.
- Supplementary: New intervention techniques should follow the scientific logic of the original techniques and not change the original structural system or mechanical methods. The new one should be an independent, complete and reversible system.
- Intertextuality: Except for elements restored as is, new protective repair measures and functions should reflect contemporary features in a concise form that serves as a reference to traditional techniques, guiding the public to read and understand the past in clear contrast.

### *4.2. Authenticity Representation of Combining Original Construction and Contemporary Intervention*

From conceptual recognition to practice, we think that the appropriate intervention techniques selected for the preservation of the core features of the original construction give the historic building a new identity in the contemporary era. Both the past, represented by the original construction, and the present, represented by the new interventions, are objective periods represented by the historic building. The critical issue is how to favorably represent this authenticity. Facing a past that has already occurred, new interventions necessarily express authenticity by respecting the story of the past while reflecting contemporary features.

The tension chord beams, the combined roof truss, and the brick wall of the LMF represent the core elements of modern industrial building technology. The impact of the intervention method on the original structural and mechanical logic and performance should be minimized. Despite the various well-established structure reinforcement methods [66,67], for the LMF, in the case of the walls: (1) no reinforcing elements should be added to the façade to avoid any visual impacts; (2) the original 800 mm thick walls were unconventional and had relatively good load-bearing capacity. Thus, it was only necessary to strengthen their integrity and the bonding of the blocks. Therefore, laying the thinner reinforcing mesh on the interior walls is the best choice. In the case of the tension chord beams and the roof truss: (1) the new reinforcement should play a supporting role and has simpler forms to better complement the ornamental nature of the original structure; (2) the steel reinforcement structures are light, and their uniform form and position correspond well to the structural logic of the original, evenly arranged structural units, thus promoting the recognizability of the scientific nature of the original structural system; (3) the added steel structures are a completely independent system that can reduce the impact of future interventions on adjacent structural units.

Authenticity is strongly tied to the past, and historical symbols define the continuity and validity of mapping the past to the contemporary [68]. The stylistic restoration of historic buildings has been the subject of international debate since the nineteenth century [69]. The architectural style of the LMF is recognized as an example of the inception of industrial architecture in modern China. As an architectural specimen of a special historical context, it is necessary to restore the LMF as closely as possible to its original state to preserve its authenticity. Therefore, the historical nature of the architectural style and the practicality of the functional requirements were considered in the restoration process [70]. On the façade, the arched elements, window and door styles, brims, and roof tiles were replaced with custom-made replicas based on the original items. Some exterior walls were repaired with bricks from interior walls, and old bricks were retained to show the traces of time. Owing to these measures, the LMF has retained a sense of history from the original style of the windows and doors, the mottled brick walls, and the overall effect.

In terms of architectural heritage repurposing, it is necessary to justify the continued existence of the building in the present and even in the future through the interpretation of established historical information while meeting the specific utilization requirements [71]. In Europe, the adaptive reuse of industrial heritage buildings is considered as a sustainable way to link the past, present, and future [72]. New uses adapted to the times are not only catalysts for local development but are also able to increase the social, economic, and environmental value of heritage while enhancing cultural significance [73]. Unlike the long-term preservation of a building, there is no guarantee that the current floor plan will be suitable for the future. New interior decorations and functional arrangements can promote the mutual interpretation of historical and contemporary information to sustain heritage value [74]. For repurposing the LMF, a strategy of retaining the large spaces and differentiating between old and new was adopted. This strategy considered the original large industrial production space and facilitated possible repurposing in the future. Additionally, this strategy distinguished the new elements to highlight the values of the original items. Elements such as steel stairs, decorative colors, and glass partitions strictly defined the past and present of the space. The strong visual contrast enhances the tension of the dialogue between historical and contemporary times.

For the conservation and restoration of the surroundings, it is necessary to first focus on the spatial integrity of the historic area. The integrity of the setting is an essential condition for interpreting the heritage architectural context [75]. Next, landscape elements contemporaneously built with the historic building should be restored to their original form to facilitate the intimate relationship between the building and the site, including the connection of uses and the sense of place. The parts that must be changed due to contemporary use requirements should not disrupt the spatial, scale, visual, or material relationships between the building and the parts prioritized for conservation.

### *4.3. Crisis and Practice with Generalized Interpretations of Authenticity*

The understanding of authenticity within intercultural contexts has become increasingly generalized. The evolution of the concept of authenticity since the Venice Charter has indicated that appropriation, transformation, and even post3erejection reconstruction have become ways to designate authenticity [76]. This also means that the inclusive understanding of authenticity based on cultural diversity is causing a crisis regarding the generalization of authenticity. Cultural relativity makes authenticity a capricious concept, even involving contradictions of terms [77]. The various elements used to designate authenticity, such as material, form, originality, setting, function, and spirit, cannot be objectively and entirely defined within the same criteria. In terms of heritage architecture, objective authenticity derives from the original characteristics, while constructed authenticity is the projection resulting from contextualized human interpretation, negotiation, and identification [78]. In this context, we will have to re-examine the potential authenticity of specific architectural heritage cases and their protection, weighing them against the characteristics of each case.

Despite the abundance of interpretations of authenticity, it is actually more important in any heritage conservation practice to critically investigate the elements that represent authenticity than to be presupposed by those interpretations. As Ruskin asserted: “the greatest glory of a building is not in its stones, nor in its gold. Its glory is in its Age” [79]. Ensuring authenticity for the conservation and repurposing of heritage architecture largely lies in reflecting historical sources; therefore, it is crucial to emphasize the authenticity of the materials. This is because the original or historical materials of a building provide potential scientific resources [80].

As evidenced by the LMF, it is impossible to interpret authenticity through the conservation of all elements; interventions that are compatible with contemporary use are also important. In other words, in the conservation repurposing of heritage buildings that ensure authenticity, there needs to be a trade-off or a ranking of the steps taken in order of importance, so as to avoid the complexity caused by the generalized interpretations of authenticity through a practical guided strategy. With that in mind, we propose an intervention path that can be referenced (Table 4):

**Table 4.** An efficient intervention pathway.

| **Prerequisites** | Respect for historical facts and the original cultural context in which the building was constructed. Scientific contemporary interventions are as essential as the preservation of historical information. |
|---|---|
| Level 1 | Investigation: assess core building through prudent historical research and evaluate durability and safety. |
| Level 2 | Material preservation: Identify the material elements that express core characteristics, such as form, structure, materials, decoration, etc., which are prioritized to be preserved and shown. Select scientific intervention techniques, including nondestructive testing, safety assessment, targeted restoration or repair, and replacement. The application of traditional technologies needs to be considered, and new technologies and materials are considered for the part identified for reconstruction. |
| Level 3 | Conservation and repurposing of space: consider preserving original layout or adding new functions; adapt building performance to new use requirements without threatening the previous use. |
| Level 4 | Setting conservation: Preserve and repair exterior surroundings that contribute to the interpretation of the building's history, including trees, sculptures, pools, roads, plazas, etc. Consider abatement as a response to some of the site conditions that must be changed without threatening the integrity. |
| Level 5 | Adaptive changes: consider the requirements of the actual users and negotiate changes to the interior finishes without threatening the previous state. |
| Level 6 | Redesign of auxiliary elements: consider the redesign of necessary supplementary elements according to contemporary esthetics. |
| Level 7 | Conservation of related elements: consider the conservation and presentation of other related intangible elements. |
| Level 8 | Archive: record the entire process of intervention with texts and drawings. |

## 5. Conclusions

Industrial architecture in the late Qing Dynasty emerged during the self-strengthening movement, with strong political will and consciousness of national self-improvement. In terms of construction technologies, traditional Chinese wooden components were combined with western steel components, and the wooden beam–column load-bearing system changed to the combined load-bearing system of a roof trusses and brick wall, showing the characteristics of western industrial civilization. As a result, these buildings integrate Chinese and western features in structure and cover a large span of evolution in, representing a unique innovation. These historical buildings are representatives of the development of modern industrial architecture and important carriers of modern sociopolitical changes. Therefore, during their conservation and restoration, both historical–cultural factors and architectural techniques should be combined.

From the protective repair and repurposing of the LMF, it is evident that the accurate determination of historical value and reasonable intervention principles are the prerequisites for modern architectural heritage conservation, restoration, and repurposing. Minimal intervention and interpretability are the principles that are necessary for maintaining authenticity. It is important to understand and interpret authenticity based on the core characteristics of heritage architecture. A scientific intervention framework from the part to the whole that includes nondestructive inspection, comprehensive safety assessment, targeted techniques, and adaptive repurposing is needed to respond to authenticity. In generalized understandings, the conservation and repurposing of heritage architecture while ensuring authenticity cannot be all-encompassing but requires a clear intervention path of primary and secondary elements, starting with the preservation of material elements.

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