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Resourceedings
Proceedings of Science and Technology
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ISSN (Print: 2537-0731, online: 2537-074X)
International Journal on:
Proceedings of Science and Technology
DOI: 10.21625/ resourceedings.v2i2.614

Study on the Repairing Techniques of Near- Modern Historical Residences in Nanjing, China: The case study of the West Cabbage Garden Conservation project

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Abstract

Nanjing is a famous city in eastern China. The near-modern history of China was the history of the relocation of the Kuomintang regime to Taiwan and the founding of the People's Republic of China from the 1840 First Anglo-Chinese War to the 1949. There are many important near-modern architectural heritages left here. These historical residences have been used for nearly 90 years, and their structural safety performance has long been unable to meet modern standards. A large number of historical residences are in jeopardy and face a situation of extinction. In the past, some historical residences were demolished, and then people redone a new building with a highly similarly appearance. However, the historical information of the building was destroyed. In recent years, Nanjing's architects have been continually exploring better ways of architectural conservation, allowing these historical residences to meet current safety standards and performance while preserving the authenticity of the building's appearance. The repair method of this kind of building has not yet reached a conclusion. After participating in a series of conservation projects, we put forward our own theory for the conservation methods of Nanjing historic residences.

This article first gives a brief introduction to Nanjing's near-modern history and summarizes the characteristics and problems of residences during this period. Then, this article takes an architectural renovation and conservation project undertaken by the authors as an example to introduce the strategies and modern methods adopted in the conservation of the historical residences.

Keywords

Architectural heritage; Conservation; Residence; Nanjing

1. Introduction

The Republic of China（ROC）was founded on 1 January 1912, replacing the Qing Dynasty and ending over two thousand years of imperial rule in China. In 1927, experienced years of warlord separatism, most of China came under the control of the Kuomintang (KMT, Nationalist Party). The Kuomintang established Nanjing as the capital of the Republic of China. The following decade (1927-1937) is known as the “Golden Decade”. During this period of peace, the country's various constructions have made considerable progress, people introduced Western technology, and then combined with local construction techniques. This is the most rapid stage of architectural development during the period of the Republic of China in Nanjing, and it has formed a unique style. Today we call it "new nationalist style". The design of these buildings draw on traditional Chinese design elements and combines the advantages of western

architectural space design, breaking through the imitation of traditional architectural space form. During the Golden Decade, Nanjing became the capital of the time, and a large number of government agencies moved in. Nanjing's population grew rapidly, so a large number of residential buildings were built for use by government officials and civilians, creating a large number of new residences different from traditional Chinese style. These homes are mainly villas, and a few are large multi-storey residential buildings. The types of buildings studied in this paper focus on villa residences.

The decade ended with the outbreak of the Second Sino- Japanese War (1937-1945), then the Chinese Communist Revolution started from 1946, after the end of Second Sino-Japanese War. As the capital of the time, Nanjing became one of the main bases for war battle. In the war, Nanjing was severely damaged and a large number of buildings were destroyed. Due to aircraft bombings and fires, roads and buildings in Nanjing City were damaged by 1/3, and a large number of precious ancient buildings were destroyed. On October 1, 1949, The Communist Party of China proclaimed the establishment of the People's Republic of China(PRC)，established Beijing as the capital of the Republic of China. Kuomintang, 600,000 Nationalist troops, and about two million people retreated to the small island，Taiwan （Figure 1）. Today we refer to the period from the First Anglo-Chinese War (1840) to 1949 as China's near-modern times.

Figure 1 Nanjing in China map （Image source: drawn by the author）

After the founding of the People's Republic of China, because of the Soviet Union's aid to China at that time, the style of new residences began to learn from the Soviet Union, reflecting a strong collectivist style. The government began to promote the collective life of communism and tried to achieve equal wealth for the social population. Efforts have been made to transform China from an agro-agricultural country to an industrialized country, and many large-scale workers' communities have been built. The detached villa was considered a capitalist sentiment and was denounced. The residences built during the ROC period have become very unique in China's near-modern history, different from tradition and later. At that time, people were not aware of the importance of these architectural heritage. The villas and residential areas that survived the war were refurbished and distributed to the people.

From the perspective of historical research itself, Nanjing near-modern architecture is a carrier of historical witness, so it is necessary to protect its historical form. Due to frequent wars, dynasty changes and other factors, the most historical carrier left in Nanjing is the near-modern urban form and its near-modern architecture. They form the main historical features, historical clues and historical scenes of Nanjing. They construct the basic features of China's near-modern capital and are important physical evidence for people to understand Nanjing's history. China has a vast territory, a large number of ethnic groups, and a long history. Due to climate and culture, the architecture of each region is very different. Taking the climate as an example, China has a vast territory and complex terrain, with complex environments such as plateaus, plains, basins, deserts and rainforests. In order to adapt to the local climate,

local buildings have adopted different forms of construction to enhance the performance of the building. There are great differences in the structure and form of buildings in different regions. Therefore, there are also great differences in the repair methods of historical residences in different periods. This paper focuses on the study of residences' repair technology during the period of the Republic of China ear in Nanjing, enriching the content of Chinese architectural heritage conversation.

2. Literature review

Since the First Anglo-Chinese War in 1840, China has entered a semi-colonial and semi-feudal society and introduced a new set of building construction systems from the West. By the 1930s, the Western new building system had been used extensively in the reclamation cities. Due to the economic and technical conditions at the time, reinforced concrete buildings were generally only used in important public buildings. Other buildings were generally brick and wood. Structural system. Therefore, among the modern architectural heritages currently preserved in China, a large number of buildings adopt such structural systems, which are rich in types and numerous in number. This structural system is also used in the historical buildings of the West Cabbage Garden.

In recent years, some modern historical buildings have been repaired in different degrees and in different scales throughout the country. A certain number of achievements have been made and many lessons have been learned. Most of China's modern historical buildings have the characteristics of the integration of Chinese and Western concepts and technologies. Their structure and style are different from traditional Chinese architecture. They cannot simply be protected and repaired by the traditional Chinese ancient buildings. Due to the lack of understanding of the special characteristics of modern historical building protection and restoration technology, the current concept of protection and restoration of modern historical buildings is not uniform. At present, most of the researches on modern historical buildings in China focus on the study of historical documents. In the history of modern historical architecture, the history of modern history, the history of urban development, and the history of related social and human history have achieved remarkable results, while the research on architectural quantification and engineering technology is relatively rare, especially the lack of historical style architectural protection and repair technology strategy research. It presents the "incompleteness" and "unbalance" of the modern historical building research system.

In the developed countries of the West, the protection of historical buildings experienced long-term contradictions and controversies. Until the enactment of the Athens Charter in the 1930s, the international architectural community began to have a relatively consistent understanding of the protection of historical heritage. After years of exploration, the formation of contemporary Western historical architecture protection thoughts with "original truth" as the core idea has finally formed, and a series of international charters have continuously improved and enriched the connotation of architectural heritage protection. Under the principle of "originality", contemporary Western architectural heritage protection uses a large number of new technologies and materials to preserve the historical information of architectural heritage while enabling architectural properties to meet modern needs. (Wei Wei, 2011) At the same time, Western countries have emerged a large number of works on the restoration of architectural heritage, which is of great benefit to us to fully understand the advanced western restoration technology.

2.1. Related research in China

The theoretical research on the protection of architectural heritage in China started relatively late. The "Protection of Cultural Relics of the People's Republic of China" promulgated in 1982 defined the scope and content of the protection of historical buildings. The protection of near-modern architectural heritage has risen to the legal level in the 21st century. The "Guiding Opinions on Strengthening the Protection of Urban Outstanding Near-modern Architecture Planning" promulgated in the early 21st century officially marks the beginning of China's substantial protection of near-modern buildings. In recent years, a number of research results on the protection of near-modern architectural heritage have emerged in Chinese academic circles.

First of all, the Chinese academic community has published a number of monographs with high academic value, and has carried out research on the protection and utilization of Chinese indigenous architectural heritage.

Li Haiqing from Southeast University explores the modernization of Chinese architecture in the modern era from three perspectives: technology, system, and trend of thought. The book “The Modern Transformation of Chinese Architecture” was published in 2004 (Haiqing, 2004)， it describes the technical practices of brick and wood buildings in modern times in the technical section, which has helped the research work of this paper.

In 2016 the China Housing and Urban-Rural Development Department Disaster Prevention Research Center and the China Academy of Building Research Guest Development Research Institute jointly edited “Historical Building Protective Reinforcement Case - Masonry Structure Book”. This is an officially revised guide for historical buildings, marking the gradual standardization and proceduralization of China's historical building renovation (Historical Building Protective Reinforcement Case - Masonry Structure Book, 2016). The book lists some repair and reinforcement techniques for brick and wood residential buildings, which has played a very important guiding role in studying the reinforcement technology and specifications of near modern buildings.

In 2018, the corresponding author of this article, Professor Zhou Qi of Southeast University, based on his nearly 30 years of research results and more than 100 historical architectural conservation cases，finally formed a technical guide for architectural heritage conservation and renovation. It is called “Technical guide for conservation & renovation of near-modern architecture in Nanjing”. The main contents of this book include: Nanjing's modern city and architecture overview, protection principles and methods, structural system, internal structural system, external structural system and special structural system protection and repair, building performance improvement, protection and repair management procedures and protection and repair practice cases. The structural system, internal structural system, external structural system and special structural system protection and repair are the core of this book (Bin, Qi & Naidong, 2018). They explain the different repair methods of different parts in detail, and provide a set of simple and effective for protection and utilization repair technical guide.

As the latest architectural heritage conservation project of Professor Zhou Qi's team, West Cabbage Garden project is the concentrated presentation of the team's architectural heritage protection theory, protection technology and engineering experience for more than 20 years. The West Cabbage Project has accumulated some engineering and technical materials for the "Technical guide for conservation & renovation of near-modern architecture in Nanjing" published by the authors in 2018. Some of the technical practices adopted in West Cabbage Garden project have also been included in the book. After the publication of the book, West Cabbage Garden project has entered the construction stage, the smooth construction process confirms the feasibility of our architectural heritage protection technology.

Today China's architectural heritage protection has entered a multi-level protection from a single cultural relic protection. The “transplantation and application” of Western protection theory and experience has indeed promoted the practice of domestic building protection, but it has also produced a lot of unsuitable conditions. First, the special backgrounds of many foreign protection theories and their own adaptations are often overlooked. Chinese architects simply and bluntly copy foreign construction protection theories and methods. The values of architectural heritage are profoundly influenced by different cultures, and different social groups have different views and ideas on heritage protection. Different levels of protection technology also constrain the choice of protection strategies.

There is a lack of in-depth research on the systems, methods and cases of heritage protection in China, and there is still a lack of understanding of the background and reasons for the formation of cases or regulations in Western countries. Research on heritage protection strategies in China's specific regional characteristics and cultural background is still lacking, resulting in many conflicting methods in the current protection of architectural heritage. In 2016, Chen Hao of the School of Architecture of Suzhou University, through his monograph "The Evolution of Architecture Heritage Conversation Theory", clearly clarified the background and development logic of Western architectural protection theory, and at the same time carried out this logic in the Chinese environment. Compare and reflect, and draw the development direction and prospects of China's architectural heritage protection. (Xi, 2019)

2.2. Related research in Western countries

Western countries have begun to practice the conversation and utilization of modern architecture earlier. The theory is relatively mature and there are many academic achievements. The advanced experience gained in practice has a

good reference for Chinese scholars. The protection and utilization of historical buildings in Western countries began in the 1960s, and the system of protection and utilization has emerged so far, and is widely used in practical operations. Because Nanjing's modern historical buildings are based on the unique local climate, the technical and economic level of the time, the architectural style and construction process are local. Therefore, the protection methods of Western countries cannot be completely copied, but they should be combined with their theories for localization and improvement.

In 1931, the International Council of Monuments and Sites (ICOMS) developed a programmatic document, the Athens Charter, which is of great importance. In 1964, the formulation of the Venice Charter identified the value and role of historical relics, marking the beginning of a new era in the protection of cultural relics. Since then, the trend of protection and utilization of historical buildings has emerged internationally. In 1976, the United Nations Educational, Scientific and Cultural Organization at its nineteenth session adopted the Nairobi Proposal, which provided some views and recommendations on the protection of historical areas. The Nara Document, adopted by the International Council of Monuments and Sites (ICOMOS) in Nara, Japan in 1999, emphasizes the diversity of world cultural heritage. (Wei, 2011)

Kenneth Powell's “The Conversion and Reconstruction of old Architecture” was translated into Chinese in 2001. It produced a certain influence in China and opened up vision and ideas for the architects of the time. The book examines in detail the renewal and reuse of old buildings - a new area of architectural design. The book lists 44 international outstanding buildings, fully affirming the necessity and value of the reuse of old buildings, and predicts that this will definitely open up new areas for the construction industry. The architectural concept articulated in the book is neither to restore nor to protect old buildings, but to rebuild old buildings. Use science rather than traditional methods to give old buildings a new life. (Powell, 1999)

The book “Historic Preservation Technology” by Robert A. Young focuses on the protection of old buildings and related repair techniques, mainly from the late 16th century to the 20th century. The relevant engineering practice of the age, combined with a large number of practical repair engineering examples, specifically describes the problems encountered in the old building repairs and the corresponding solutions (Young, 2008). This book provides a lot of valuable content for our research.

3. History and Project Overview

The West Cabbage Garden historical area is located in the northern section of the commercial street of Taiping South Road, Baixia District, Nanjing (Figure 2，3). It is very close to the city's busiest city centre. Surrounded by modern urban buildings, this two- and three-story architectural heritage stands out (Figure 9). The West Cabbage Garden historical area is the epitome of Nanjing's near-modern residential construction and real estate development.

Figure 2 The West Cabbage Garden in Nanjing city map（ Image source：drawn by the author）

Figure 3 Site plan (Image source：drawn by the author)

3.1. History

Since the Ming Dynasty (1368-1644), the urban spatial pattern around the West Cabbage Garden has basically shaped, and it has been developed to this day. The main road network in this area has been used for hundreds of years. In the Qing Dynasty (1616–1912), the West Cabbage Garden belonged to the Jiangning Ministry of Textiles. The Jiangning Ministry of Textiles was the official department that provided silk and other textiles to the Qing Dynasty royal family.

On the map of 1910(Figure 4), it clearly reflected that there was no construction in the West Cabbage Garden, and there were small ponds in the area. At the time, this area was mainly used for growing vegetables, hence the name “Cabbage Garden”. The “Cabbage Garden” is divided into two parts by a north-south road, which is called “West Cabbage Garden” and “East Cabbage Garden”. In 1910, there was a continuous street building on the west side of the West Cabbage Garden. This street was called “Jiyang Street”, which was the main commercial street in the area at that time.

By 1927, some buildings had been built on the north side of the West Cabbage Garden, but there was still no construction in the area. There was a railway on the east side of the area. This railway is the earliest rail transit in Nanjing – “Jingshi Railway”. The railway was completed in 1909, however it was not shown in the city map of 1910. From the map of 1927, it can be found that there is still a lot of wasteland along the railway.

On the map of 1933, a small number of buildings began to appear on the south side of the West Cabbage Garden area. The map of 1941 shows that the construction of the West Cabbage Garden area has been basically completed. Compared to 1927, the area along the railway became very prosperous, and the railway promoted the development of Nanjing at that time. After 1949, Nanjing entered a long period of peace until today, the city began to develop rapidly, and Jingshi Railway gradually became an obstacle to urban development. It was demolished in July 1958.

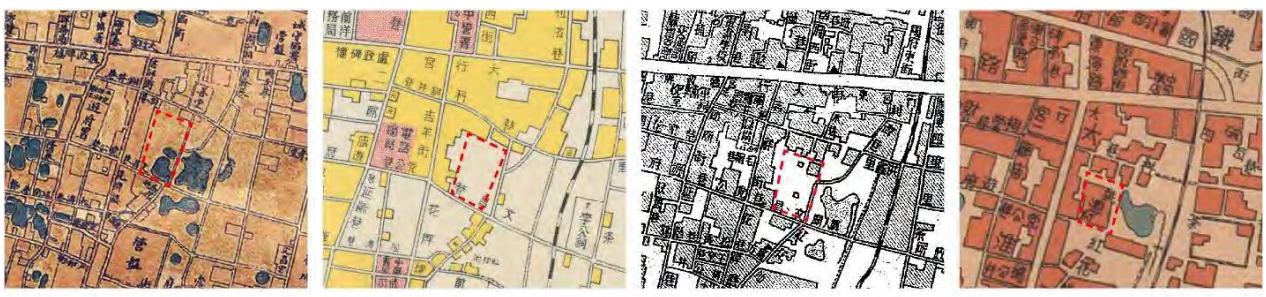

Figure 4 Historical map of different times around West Cabbage Garden （The red dotted frame is the scope of West Cabbage Garden）(Image source：drawn by the author)

3.2. Project Overview

In less than 1 hectare of the area, West Cabbage Garden includes 14 architectural heritages which were built during the 1930s (Figure 5). West Cabbage Garden has high historical value, artistic value and architectural technology value. It is the epitome of Nanjing's residential construction and real estate development boom in the 1930s, and they were also the residences of more than ten famous celebrities. West Cabbage Garden witnessed the changes in the way of living in Nanjing's near modern society, and also left many intangible cultural heritages such as celebrity anecdotes.

Project history study and conservation design was conducted in 2017-2018, and construction is currently underway. The entire project is divided into three phases, all of which are completed by the authors of this article.

The No. 1 to No. 3 building is the first phase of the project and is now close to the end of conversation. The No. 4-10 building is the second phase of the project. The second phase of the project has just begun. No. 11-13 is the third phase of the project, and the conversation design has been completed (Figure 6). Among them, Building No. 7 and Building No. 9-14 have the same form and they were built in 1937.

Figure 5 Aerial View of the West Cabbage Garden（Image source：xdkb.net）

Figure 6 Site plan (Aerial photo，image source： drawn by the author)

Table 1. List of representative residences

Representative residences	The Original Owners	Total Area
 No.1 Built in 1932	Li Feitang，President of the Central Supreme Court of the Republic of China	473 ㎡
 No.2 Built in 1937	Tan Daoyuan，Head of the 10th Army of the Kuomintang	332 ㎡
 No.3 Built in 1937	Tan Jitao，Major General of the Kuomintang Army	289 ㎡
 No.4 Built in 1930	Cao Xinbiao，Major General of the	191 ㎡

 No.5 Built in 1930	Republic of China	202 ㎡
 No.6 Built in 1931	Peng Xinmin，Lieutenant General of the Kuomintang Army	325 ㎡
 No.8 Built in 1937	Chen Heqin, Famous Chinese child educator and child psychologist	232 ㎡
 No.9 Built in 1937（No. 7, No. 10, No. 11, No. 12, No. 13, No. 14 are the same as this residence.）	Jin Xun，Former Deputy Governor of Jiangsu Province	232 ㎡

4. Problem statement

In recent years, the authors have participated in the conservation work of many historical buildings in Nanjing. The general structure of this type of residences has been summarized in detail. Therefore, we have summarized the various problems that have arisen after years of use of such residences. And we have developed corresponding repair measures using new repair techniques. It mainly includes new repair materials, new structural reinforcement technology, etc., to make the building reach the performance of modern architecture without changing the architectural style.

Below it will first show the general structure system of historical residences in West Cabbage Garden, and then point out the problems faced by this system after years of use. It is our aim to solve these problems through new technical means.

4.1. The structure system of West Cabbage Garden's residences

Under the influence of the West, Nanjing formed its own brick-and-wood structure residential building system. This system is widely used in residences. At the beginning of the 20th century, this brick-and-wood structure technology introduced into China from Europe and the United States has been rapidly developed and widely used. At present, there are nearly one thousand historical residences in Nanjing, most of which are buildings of brick and wood systems. The building uses brick walls as the vertical load-bearing structure, the roof structure is wooden truss, the horizontal structure is wooden beams and wooden slabs, and the buildings generally use strips basis (Figure 7).

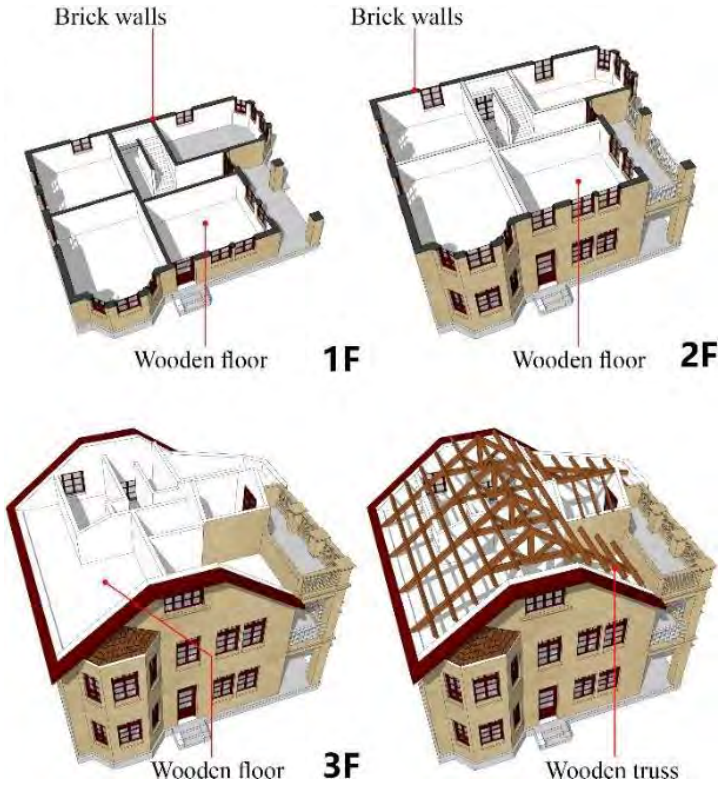

Figure 7 Brick-and-wood structure of building No.2（Image source：drawn by the author）

This type of system mainly uses bricks and wood as building materials. The bricks are clay bricks. The shape of the brick is generally imitation of the size and material of the Western system, and is made from Chinese clay. The bricks are divided into red bricks and blue bricks, mainly blue bricks and a small amount of red bricks. The size is 9*4.5*2.25 in inches. The timber in the building mainly uses Chinese native fir, and some buildings use Douglas fir. Wood is generally used in wood floor and roofing systems. The roof of the building is made of wood, with two slopes and four slopes, and is linked by steel and wood. (Bin, Qi & Naidong, 2018)

Nanjing's near-modern residences generally use natural foundations. Supporting the foundation of the building is the natural soil that has not been reinforced, and is generally only compacted. The building foundation is built with bricks to grow strips. The foundation of the building is brick-shaped, which has a high rigidity and a shallow depth. There

is a layer of gravel under the brickwork to protect the building foundation (Figure 8). This technical practice is used extensively in residences, it is generally simple and easy to construct. The first floor of the building has an overhead moisture barrier. The overhead moisture barrier is mainly to ensure the drying of the wooden structure of the floor to prevent the wood from decaying. The bottom layer of the aerial moisture barrier is made of bricks, on which wooden keels are laid and wooden floors are laid on the wooden keels.

The floor of Nanjing near-modern residences is generally made of wood flooring, which is made up of wooden keels and wooden panels (Figure 9). The wood floor layer can be divided into a surface layer, a structural layer and a ceiling layer from top to bottom. This technical practice is relatively simple in construction, light in weight and good in thermal insulation performance. Firstly, the wooden keel is built into the wall, and then the wooden slab is laid on the wooden keel. The thickness of the wooden board is generally 10 mm to 20 mm, the width of the wooden board is generally 85 mm, the length is different, and the wooden boards are interlocked with each other.

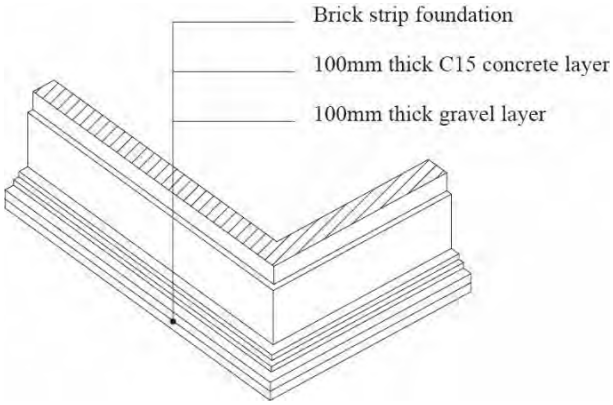

Figure 8 Brick strip foundation（Image source：Professor Zhou Qi's studio at the School of Architecture, Southeast University）

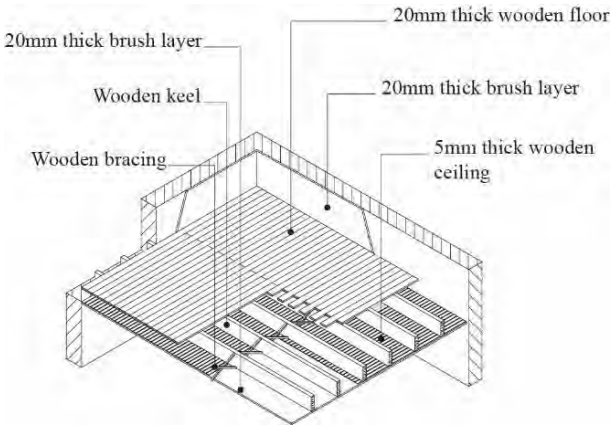

Figure 9 Floor structure（Image source：Professor Zhou Qi's studio at the School of Architecture, Southeast University）

In Nanjing's near-modern historical residences, brick partitions are commonly used on the first floor, and wooden gray slat partitions are commonly used on the second floor. The brick partition wall is approximately 120 mm thick (with the surface layer removed). The brick partition is used on the first floor to support the load of the second floor with brick walls.

4.2. Problems before conservation

There are three major problems in this type of building before conservation: poor structural safety performance, serious damage to wood components, building infrastructure needs improvement, and non-original parts change the style of historical residences.

First of all, the structural safety of the building is poor. Before conservation, there were some problem with the overall structure stability of the buildings' foundation subsidence and wall inclination. In the early 20th century, China's cement production was small, and a large amount of cement relied on imports from abroad, and cement was very expensive. Therefore, people at that time used a mixture containing a small amount of cement to bond bricks. The

bonding strength of brick wall was weak, and the bricks were bonded with a little cement, sand, clay and gypsum, etc. After over 90 years passed, most of the bonding material was

loose and fell off and the bonding strength was almost reduced to zero. The surface bricks are weathered due to weathering (Figure 10). Since the foundation was subsided, the entire foundation was 70cm-1m lower than the city road. The building drainage was impeded, and the entire building foundation was soaked in water and the building was eroded by groundwater. The brick foundation is gradually eroded and the strength of the bricks is greatly reduce (Figure 11). As a result, the seismic performance of the building has become very poor, posing a great risk to the residents living there. In this case, the structural seismic performance of the building must be strengthened.

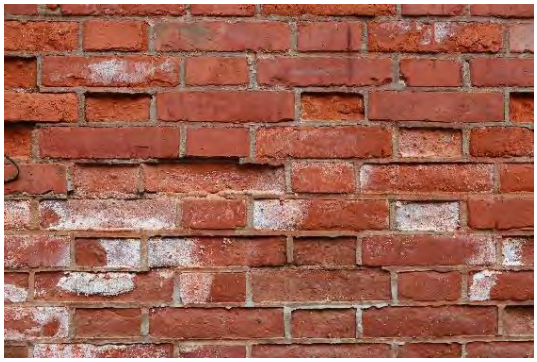

Figure 10 The surface bricks are weathered due to weathering. (Image source: photographed by the author)

Figure 11 The brick foundation is eroded. (Image source: photographed by the author)

Secondly, the wood components are extensively damaged. The wooden components of Nanjing's historic residences include wooden doors and windows, wooden stairs, wooden slabs, wooden trusses and some of the roofs on them. The climate in Nanjing is rainy and humid, suitable for the survival of termites. Therefore, the common problem faced by these wooden components is that they are easily destroyed by termites, which causes the decay of wood. The doors and windows are prone to cracking due to long-term rain and sun exposure. A large amount of windows and doors were damaged, fell off and leaked air. This has led to a significant reduction in the insulation and thermal insulation properties of the building, making it difficult to meet modern use needs. The roof of some buildings leaked, causing the wooden trusses and the boards above them to rot (Figure 12).

Figure 12 The roof of some buildings leaked r. (Image source: photographed by the author)

Thirdly, the buildings lack the infrastructure needed for modern living, such as air conditioning system, water supply and sewer pipes, sewage pipes, power systems. These residences were originally built without an air conditioning system, because at that time the air conditioner was just invented and China imported very little. Nowadays, air-conditioning is an indispensable equipment in the building. The air-conditioning installed by the residents not only destroys the historical features of the building, but also creates greater harm to the fragile wall. Some residences were originally designed for one family but later distributed to many families for use together. Therefore, a lot of toilets and kitchens have been added, and a lot of water pipes and wires have been added. The exposed pipes have negative impacts on the historical features of the buildings (Figure 13). Lastly, many residences also had illegal construction issues. In recent 60 years, because many families live together in one residence, users changed the interior of the building. The integral structure of the building was damaged and the internal functions were altered drastically.

Figure 13 The exposed pipes have influenced the historical features of the buildings. (Image source: photographed by the author）

5. Aims & Objectives

In this project, our aim is to evaluate the value of these historic residences, clarify strategies for future use. We are trying to challenge a complete set of building repair and function improvement strategies, so that these historical buildings can not only meet the current needs of use, but also become the regional highlights of the city in the future, driving the development of the surrounding areas and enhancing the overall image of the area. Moreover, we study the history of urban development around the West Cabbage Garden area and enrich the research results of Nanjing's near modern history.

In recent years, the first inhabitants of these historical residences have gradually moved out and lived in modern apartments. These historical residences are generally used for commercial purposes after conservation. The load and safety requirements of the buildings have been greatly improved compared to their previous residential uses, and the original historical construction techniques are difficult to meet the needs of modern commercial use. So using improved technology to repair historical residences is an effective way to resolve this contradiction. In order to achieve our aim，the authors set the objectives to the following:

First of all, restore their initial appearance at 90 years ago to the maximum extent. This requires a lot of historical investigations to find their original files and photos. In the absence of original files and old photographs, we often need to judge what is original and what is added later based on the materials and techniques used in the building.

Secondly, restore construction style to its original style and protect and conserve the ancient building material, which is the most significant feature of the conservation. Materials that have been placed for a long time will have a unique texture and oxide layer that is not present in the new material. Therefore, in the conservation, the damaged building components are usually repaired instead of replaced. When building components are seriously damaged, they should be replaced with old materials, such as old wood, old bricks, old tiles, and so on.

Thirdly, the specific work of the project cannot violate legislation/regulations. Especially the work cannot affect the appearance or damage the structure of the heritage. So we take the principle of least intervention and maintaining its original appearance, and everything including building structure system is maintained to its original status.

6. Methodology

The specific conservation methodology: modern bonding material, which is reversible cement-gypsum mixed material (easily peeled off), is used as bonding material for wall bricks. High-strength wire mesh is combined with cement mortal and attached to the inner side of the wall to strengthen wall integrity. Finally, steel structures are used to reinforce joints.

We use modern material to protect old structure and material of the architecture during conservation. For example, we use modern and reversible bonding material to strengthen the adhesiveness between bricks and to reinforce the integrity of the brick wall. Meantime, some light steel structures formed by hollow steel section are used to intensify the integrity of the wooden structure. Aluminum-wood composite windows with excellent performance in energy conservation and thermal insulation are used to replace the severely damaged and rotten wood windows, so as to improve the overall thermal performance of the architecture while maintaining the integrate appearance and to meet the needs of modern business use. All the illegal constructions over 90 years are demolished during the conservation and the historical appearance of the architecture is restored.

Traditional handicraft is used to restore the West Cabbage Garden. For example, some woods are painted for many times, and craftsmen have found a specific chemical material, which could clean the paints. The natural colour of the wood will be revealed after hundreds times of polishing and brushing. Handicraft method is used to restore the existing materials like woods, bricks, cement, steel structures, and decorative woods, etc. to reveal their historic appearance. We hire over-60-year-old and experienced Chinese workers, including carpenters, bricklayers and plasterers, etc., combine modern technology and manual work and restore the building with handicraft method for the purpose of restoring the West Cabbage Garden's historical appearance to the maximum extent.

We will explain our specific methodology through an ongoing historical residence protection conservation project in Nanjing.

6.1. Foundation reinforcement

Due to the lack of basic bearing capacity of the building, we have taken measures to expand the base width after calculation. The new base cushion is not lower than the original base cushion. At the joint of the new and old foundations, the two are connected as a whole by chiseling, cleaning, brushing the interface agent, and adding the steel bars.

We burrow the hole on the original strip foundation wall, then wear the reinforced concrete beam, make the foundation at both ends of the beam, and the beam concrete is cast into the whole with the original foundation wall. Before injecting the concrete, we will grind and clean the original foundation and apply a layer of concrete interface agent to increase the adhesion of the new and old concrete foundation. For the widened part, the foundation is laid with the same rammed layer of thickness and material as the original base layer (Figure 14,15).

Figure 14 The building foundation that has been reinforced. (Image source： photographed by the author)

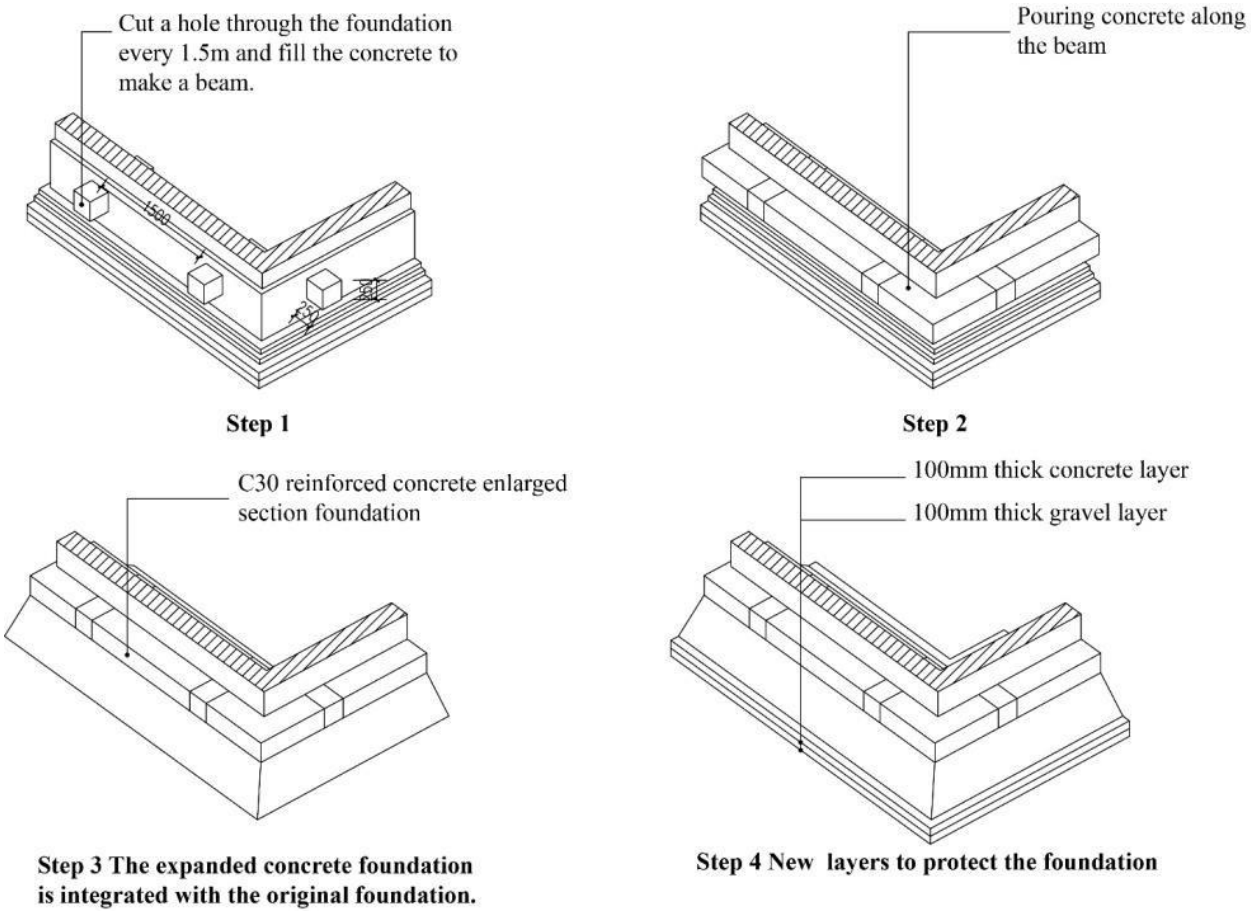

Figure 15 Building foundation reinforcement step (Image source: Professor Zhou Qi's studio at the School of Architecture, Southeast University)

In addition to the above method of foundation reinforcement, another method that has been used frequently in the Nanjing is to use a new reinforced concrete foundation if the building foundation bearing capacity and wall bearing capacity are both insufficient. This method is relatively simple, and the structural strength of the new foundation can fully meet the requirements. However, it should be noted that this method is not recommended unless the overall damage to the building is too serious. Although the foundation is invisible after the completion of the repair, the author believes that all building components carrying historical information should be repaired and reinforced as much as possible to preserve the original material and original form to the greatest extent. Instead of simply replacing it with new materials.

6.2. Wall reinforcement

After over 90 years of use, the walls of the building have been greatly reduced in strength and rigidity and have undergone a certain degree of deformation. After the structural engineer checked, the calculation capacity of the wall was insufficient. We used a single-sided or double-sided steel mesh to grind the cement mortar to improve the strength and rigidity of the wall. For the exterior of the building, we have a single-sided reinforcement on the inside of it to avoid affecting the overall appearance of the building. For the interior walls of the building, we use double-sided reinforcement for better load bearing performance. Specifically, the steel bars are embedded in the brick wall and then connected to the laid steel mesh. The original brick wall was coated with an interface agent and then painted with a 60 mm thick high-strength cement mortar (Figure 16).

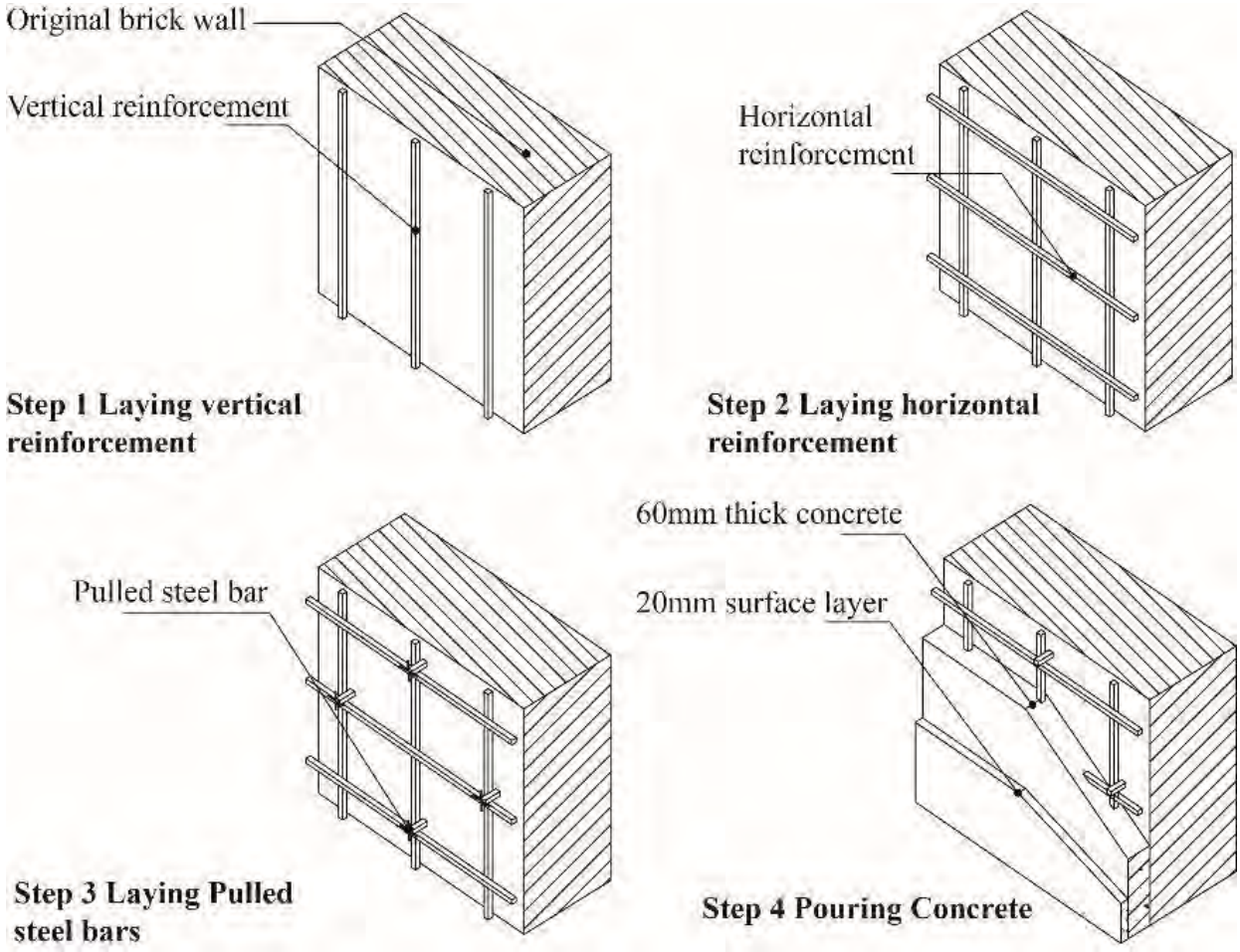

Figure 16 Wall reinforcement step (Image source: Professor Zhou Qi's studio at the School of Architecture, Southeast University)

The exterior wall of the building was originally a clear red brick wall. Later, when the residents were repairing the building, they were painted with cement mortar to cover the original wall. In the repair, we carefully peeled off the cement mortar and restored the historical appearance of the building (Figure 17). Some bricks on the surface of the wall have been powdered and damaged due to long-term weathering. Our severely damaged bricks are partially removed, replaced with old bricks of the same material, and integrated with the original wall.

If the level and importance of historic buildings are not very high, it is possible to dismantle the original walls and rebuild them with new and old brick combinations (Figure 18). After the original wall is removed, the wall must be rebuilt according to the current seismic design code. Under the premise of ensuring that the roof truss does not fall off, the truss remains unsupported for positioning, the original load-bearing wall system is removed, and the reinforced concrete strip foundation is re-made. At the same time, according to the brick-concrete structure, the structural column and the ring beam are re-made. The original clear water brick wall is built on the outside of the wall, and the new brick is used on the inner side. After being constructed according to this technical practice, the wall thickness is about 370 mm. The advantage of the new and old brick combination method is that one-time intervention of the structural system is in place, which can conform to the current structural design specifications and seismic design specifications. The disadvantage is that the authenticity of the historical building structure system has been greatly damaged. It is necessary to be cautious in dealing with such practices, and construction can only be carried out after a rigorous professional assessment. (Bin, Qi & Naidong, 2018)

Figure 17 Carefully peeled off the cement mortar and restored the historical appearance （Building No. 2, image source: photographed by the author）

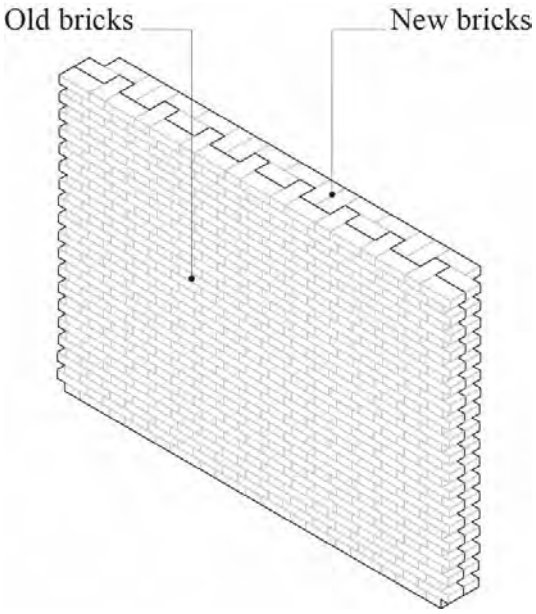

Figure 18 New and old brick combinations. （Image source: Professor Zhou Qi's studio at the School of Architecture, South`east University）

6.3. Floor reinforcement

Since the building will be used for commercial purposes after repair, the load on the floor is greatly increased compared to the original. We replaced the original wooden beams with I-beams (Figure 19,20), re-laid the original wooden keels between the steel beams, laid the original wooden floors on the log keels, and laid the original diagonal supporting wooden members between the wooden keels. The steel beam is placed inside the wall and bonded with cement mortar. In order to achieve the best effect of the added steel beam, special reinforcement must be applied to the joint between the steel beam and the wall. Otherwise, the brick wall may produce a large crack before the steel structure begins to function.

Although the original structural system has been greatly modified, the overall rigidity of the structure is strengthened, and the span of the building can be increased to meet the demand for the function to become a general public building. The new steel beam is reversible. If the use of the historic building changes in the future, the new steel beam can be removed and replaced with the original wooden floor.

If the building does not require a large floor load after repair, or if the building has a high level of cultural relics, the original wood floor system needs to be strictly followed. Judging and replacing damaged components, re-making according to the size, process and materials of the original components, and repairing and reinforcing the floor. The spacing of the wooden keels can be adjusted appropriately and become more dense. This method can improve the carrying capacity of the floor to a certain extent, but the carrying capacity after the completion of the reinforcement is far less than the first method of using steel beams. The repaired building cannot be used for public purposes with high traffic.

Figure 19 Replaced the original wooden beams with I-beams (Image source: photographed by the author)

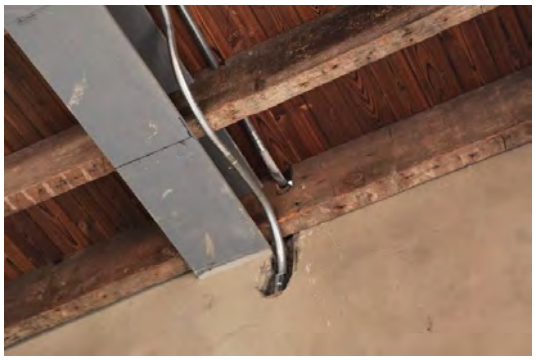

Figure 20 The steel beam is placed inside the wall and bonded with cement mortar （Image source: photographed by the author）

6.4. Wooden truss and roof repair

There are two main problems with the roof truss. First, the wood is partially decayed due to the foraging of termites and the leakage of rain. Secondly, the iron pieces connecting the nodes are loose and rusted (Figure 21). We try to preserve the original wooden roof truss system (Figure 22) and replace the damaged wooden components. First, identify and replace the damaged components, completely re-form according to the size, process and materials of the original components, and then strengthen the joints with steel bolts, etc., and finally carry out termite anti-crack treatment.

Figure 21 Roof truss of building No.2 before conservation (Image source: photographed by the author

Figure 22 Wooden roof truss system of building No.2 during conservation（Image source: photographed by the author)

The building slope roof is supported by a wooden truss, the wooden board is placed on the roof truss, and the tile is directly tiled on the board, generally using clay tiles. There are two main problems in this way: first, the thermal insulation performance does not meet the current requirements, and heat loss will quickly occur. Secondly, the rain and penetration resistance is weak, and the waterproof property of the building is achieved only by the physical properties of the tile itself.

We added a layer of insulation to the board, and the insulation used 4cm of high-density polystyrene insulation. The specific construction method is to lay a layer of high-performance modern coil waterproof material on the wooden board, and then makethe insulation layer. After the insulation layer is completed, a layer of waterproof material is laid on the insulation layer, and the wood strip is applied on the wood. Hang the tiles above the wood strip. Through this approach, problems such as moisture, water, leakage, and heat insulation can be better solved.

6.5. Equipment improvement

Nanjing's near-modern residences generally do not have an air conditioning system, because at that time air conditioning was very rare and expensive equipment, heating systems generally used fireplaces.

Since the fireplace has been unable to adapt to modern living requirements, the vast majority have been left unused by the residents. Residents installed a lot of air conditioners, and the placement of outdoor units had become a problem (Figure 23). Since the outer wall of the building is brick wall. After years of use and weathering, its strength is relatively weak. The residents fixed the air-conditioner outside the building directly on the outer wall of the building, which caused great damage to the building, which was not conducive to building safety or aesthetics.

Figure 23 Residents installed a lot of air conditioners before conservation (Building No. 2, image source: photographed by the author)

So we removed all the small air conditioners that were added, used a central air conditioning system, and repaired the damage of the wall. Place the outdoor unit of the central air conditioner on the outside of the building. When conditions permit, it can be placed under the adjacent window sill, or in the flower bed, to make appropriate enclosure shielding, without affecting the structural system of the building itself.

Nanjing's near-modern residences use a large number of wooden doors and windows, taking wooden doors and windows as an example, generally single- layer glass, usually glass thickness of 3mm-5mm, wooden window frame. The problem of this external window system is very obvious. Its heat insulation and heat insulation performance are very poor. After years of use, the window has many cracks, which leads to air leakage. We replaced the wooden window system with a modern Aluminum-wood composite door and window system, and the outer layer is made of wood-wrapped aluminum alloy, making it a historical style (Figure 24). This window uses double-layer insulating glass, a glass thickness of 6mm, a hollow layer of 8mm-10mm, plus another 6mm of glass. The thermal insulation performance of this kind of window is greatly improved compared with the wooden window, which can meet the requirements of China's current building codes, while maintaining the appearance of historic buildings.

Figure 24 Aluminum-wood composite window

7. Conclusion

By the end of May 2019, the historic residences of the West Cabbage Garden area had recently completed structural reinforcement and façade repairs, demolished scaffolding, and is currently undergoing internal repairs. Except the weathered bricks are replaced, more than 90% of the original bricks are reserved. The building's overall structure is reinforced. Through structure inspection, calculation and acceptance, the reinforced structure is capable to offer a service life for 100 years. It could also meet the use requirements of commercial use, including all kinds of loads, like water and electricity load, structural load, and infrastructure load, etc.

For the overall appearance and features of West Cabbage Garden area, restoration methods are taken to restore its original appearance, so that its value is preserved（Figure 25）. From a perspective of the city, the exhibition and restoration of West Cabbage Garden area, as a landmark, could promote the city status, and well preserve the historical value, scientific value and architectural value of the residences. Although West Cabbage Garden area is situated in a new city area and surrounded by many new buildings, the outstanding features of West Cabbage Garden could still bring profound historical memories to people.

Functioning as private residences at the beginning, after many years of use variation, West Cabbage Garden will be restored and open to the public as shops. For over 60 years, West Cabbage Garden is used as civilian residences and are not open to normal citizens. After this restoration, West Cabbage Garden comes back to public industry, where citizens could consume, stay and tour. A history museum will be established in one of the residences of the area, exhibiting many cultural relics, historical objects, and some excavated documentations and old photos, which tell stories of true historical events.

Figure 25 Building No.2 after conservation （Image source: photographed by the author）

Compared with other similar modern historical residential conservation projects in Nanjing, the cost of the West Cabbage Garden conservation project is relatively high, reaching 10,000 yuan RMB (1,448 US dollars) per square meter. There are several main reasons for this:

These houses are all clear water brick walls with no protective cover on the surface. Therefore, the weathering and damage of bricks are very serious. We employ experienced craftsmen, using hand-crafted techniques, using red brick powder materials to carefully clean, fill, polish, and age each brick on the outside of the wall. Finally, the bricks on the outer wall are re-joined, and water repellent is applied to protect the outer wall from rain. Therefore, labor costs are very high. Other low-cost repair projects in Nanjing usually use old bricks to rebuild the walls, which is less expensive. Because it is a completely rebuilt wall, there is no need to reinforce the wall structure, but the real historical information of the building is completely erased.

We hired experienced carpenters to make wood components on site using old wood that was purchased at a high price. The supply of old wood is hard to find, but compared to the new wood that is easy to buy, the old wood has been placed for many years, and the wood has undergone sufficient natural drying and natural deformation, and it is not easy to crack and deform after being made into building components. Their durability is greatly enhanced. The carpenter’s salary is 400 yuan RMB ($58) per day, and the production of wooden components is one of the main reasons for the high cost.

Modern architecture is an important part of architectural cultural heritage, and its practical significance and value cannot be ignored. These heritages not only have the value of continued use, but can be reused to obtain higher value. Therefore, it is very important and possible to selectively protect a group of excellent modern buildings in urban transformation. Today we organize and analyze the modern architectural art in order to learn from the heritage, find useful techniques and excellent rules, and evaluate them and give them the historical status they deserve.

Table 2. List of project participants

Majors	Participants	Affiliations
Architectural design	Zhou Qi	School of Architecture of Southeast University
Main participant in architectural design	Li Yinghan	School of Architecture of Southeast University
Structural design	Xia Shiyang	Architects & Engineers Co., Ltd. of Southeast University
Water supply and drainage design	Zhao Yuan	Architects & Engineers Co., Ltd. of Southeast University
Electrical Design	Liu Yonggang	Architects & Engineers Co., Ltd. of Southeast University

This work was supported by the National Natural Science Foundation of China (No. 51778123).

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