Research on the Renovation of Historical Buildings and Improvement of the Residential Environment of Hangzhou Zhuyangxin Plaster Store

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Abstract
This research focuses on the renovation of historical buildings of Zhuyangxin Plaster Store, Hangzhou, China. By following three architectural design strategies, namely protecting the surrounding environment, rejuvenating the commercial and cultural function and recovering the original appearance, the historical buildings are to be retrofitted to achieve a sustainable regeneration. Meanwhile, based on an on-site investigation into the present residential environment of the buildings, suitable architectural technologies to improve the residential environment are analyzed from the aspects of envelop, facilities, sun shading, passive technology and sunlight utilization. After some retrofit measures were adopted for the envelop of the historical buildings, the simulation results showed that not only the thermal and light environment will be improved, but also energy efficiency of 50.34% can be achieved according to the standard in China.

Keywords: historical buildings; residential environment; renovation; energy efficiency

1. Introduction
During the 1990s, cities across China have been engaged in a sensational national drive for the protection of urban historical heritage sites, with a great number of traditional buildings being retrofitted. However, a great many elements which can never be recovered were eternally lost, the fact of which is caused by the old understanding of historical building protection that only focuses on the extension of the life-span of a building's materials and structures, and the slowing of its natural ruin. It is often ignored that damage to a building's appearance is only the presentation of decay, while the total separation of historical buildings from the modern urban environment, leading to the long period of not being used, tends to be the fundamental reason.

The "Convention Concerning the Protection of Ancient Cities-Nairobi Declaration" has indicated that, in the process of protection and retrofit, the action of revitalization should also be carried out. The significance of protection lies not in the conservation of the buildings' "corpses", but in the regeneration of buildings, which has gradually received extensive recognition across the world. The concept of "Regeneration" refers to three different aspects as follows:
1. To Conserve an Urban Environment Necessary for the Regeneration of Historical Buildings;
2. To Endow Historical Buildings with Up-to-date Functions;
3. To Improve the Human Environment and Energy Consumption of Historical Buildings.

In the "Beijing Charter", passed in July 1999 at the 20th Congress of the UIA, a new concept of Human Environment was proposed, advocating that the planning and design of new urban areas and the retrofit, renewal and rebuilding of the old should be integrated into a dynamic recycling system, which is able to continuously improve environmental quality with the effect of time and space. The development of historical buildings is evolving from a unitary value of function towards a comprehensive value of ecology, with the guidance of the concept concerning sustainable growth.

The thermal indoor environment has a direct relationship with human comfort level. According to the ISO, this is described and judged based on two aspects: one is PMV (Predicted Measurement of Voting) and the other is PPD (Predicted Percent of Dissatisfaction). The recommended standard is...
PPD<10%, -0.5<PMV<+0.5, and the standard in China is PPD<20%, -0.75<PMV<+0.75.

Existing historical buildings are often badly damaged, with a relatively poor performance regarding heat insulation. Therefore, in order to meet the demand of comfort, the routine heat and cold energy supply often causes a huge waste of energy. However, the previous measures of protection focused more on how to restore the original state of the buildings, but less on the improvement of the residential environment. How to save energy is also one problem we have to consider during traditional building renovation.

The current state of China's building energy conservation is still at a low level, and importance was not paid to it until the 1980s. In 1986, the Energy Conservation Design Standard for Residential Buildings of Northern China was issued and in 1996 the Energy Conservation Design Standard for New Heating Residential Buildings (the section of heating buildings) was issued in which it was prescribed that the energy conservation rate should reach 50%. In 2001, the Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zones JGJ134-2001 was issued in which it was prescribed that the area of building energy saving should be extended to southern China. Nevertheless, there is no relevant standard concerning energy saving for traditional building renovation.

Wooden structures are mainly adopted for traditional Chinese buildings. Wood, as a kind of recyclable green building material, causes a relatively low consumption of raw materials. Nevertheless, existing wooden buildings are far below modern people's demands in terms of comfort and energy efficiency level.

This research focuses on the renovation of the historical buildings of Zhuyangxin Plaster Store, Hangzhou, China. The renovation is carried out by the Administration Committee of the Qinghe Block Historic District, Hangzhou City. Compared with the cost of ordinary renovation (about 1500-2000 RMB Yuan/m²), this comprehensive renovation costs about 25% more, about 2000-2500 RMB Yuan/m² (about 300-375 USD/m²). Since some of the residents have not moved out from the building yet, the renovation construction has not been completed and will last for around 1 year. The overall appearance of the Zhuyangxin Plaster Store after being retrofitted is shown in Fig.1.

Firstly the architectural design strategies to regenerate the historical buildings will be studied, and the in situ investigation results of the present residential environment of the buildings will be analyzed. Based on the investigation, suitable architectural technologies to improve the residential environment will be analyzed and some retrofit measures of the envelop will be applied to the historical buildings. Finally simulation will be carried out to demonstrate the effects of these measures.

2. Analysis of the situation of the former site of Hangzhou Zhuyangxin Plaster Store

2.1 The Existing Configuration of the Building

Hangzhou Zhuyangxin Plaster Store, established about 400 years ago during the reign of Emperor Wanli in the Ming Dynasty, has been settled in Dajing Alley, Hangzhou. The former site of Dajing Alley, regarded as an important historical site in Hangzhou, was rebuilt in the late Qing Dynasty (in the 1870s) (Fig.2.). Stores of different scale lined Dajing Alley, constituting the Golden Delta Business Zone in Hangzhou at the end of the late Qing Dynasty and the beginning of ROC. A lot of old houses from the Qing dynasty and ROC period are preserved here, including many famous old stores, such as Hu Qingyu Tang TCM Store, Fang Huichun Tang TCM Store, Baoda Shenhao TCM Store and Zhang Xiaoquan Scissors Store etc.

Zhuyangxin Plaster Store lies at the north entrance of Dajing Alley, featuring vast courts and magnificent buildings with large and tall Shanghai Stone Gates. Three courtyards stand in a line, with some auxiliary houses stretching to the Wushan Mountain, boasting the distinctive building style of our Anhui Province. The store has almost 40 rooms, with a total construction area of more than 1,000 square meters. (Fig.3.)

Fig.1. Overall Appearance of the Zhuyangxin Plaster Store after being Retrofitted

Fig.2. Main Configuration of the Dajing Alley Block
Historically, the main building in the east court of Zhuyangxin Plaster Store was an old Chinese style courtyard building, featuring a wooden and brick structure and three floors with several rooms. Regarding the moisture-proof property, the first floor of the building at the back of the court is built on short stilts. An ancient well in the court, with a history of more than 400 years, indicates to some degree that this old collection of buildings is the former site of the workshop of Zhuyangxin Plaster Store, where the configuration of "Stores downstairs, bedrooms upstairs" and "Stores in the front, workshop at the back" can still be made out. The central court enveloped a two-floor wood-structured building, with two small courtyards located in front of and behind the building, displaying a narrow and long configuration. The west court features its main building as a two-floor Chinese building with four rooms, which encompasses boulder strip staircases, wood carving banisters, doors and windows extending to the ground, and a stone panel paved courtyard, displaying the distinctive architectural style of the ROC with primitive simplicity and elegance.

2.2 The Existing Problems

Time has passed and the circumstances have changed. Currently, the commercial value of Dajing Alley Block has faded, with the replacement of prosperity in the past by an atmosphere of depression. As the buildings became older and older together with their residents, Zhuyangxin Plaster Store inevitably became dilapidated, with the emergence of numerous contradictions between these old buildings and the whole urban environment of Hangzhou, as well as the modern life style of the local residents.

(1) Fading of the Commercial Value

Zhuyangxin Plaster Store used to be a building encompassing the services of sales, diagnosis, pharmacy and residence, but finally lost its own characteristics and changed into a residence for several households.

(2) Breaking-up of the Original Configuration

Many immigrants from outside have made the original living space severely compressed. To compete for more space, residents here are reallocating the space of the buildings at will, or even building unauthorized cabanas in the courtyard, which has severely damaged the original appearance and layout of the historical building.

(3) Deterioration of the Architectural Quality

Although the whole structure of the building remains almost intact, several parts of the buildings were seriously damaged through the long-term absence of protection. The surface of the walls has flaked-off while the doors and windows have been eroded, with several parts being simply retrofitted. The building is considered as a C Grade dangerous building, with several leaks on the second floor.

(4) Low Living Standard of the Residents

The relatively high number of residents has led to a small living area per capita, which has further brought about the absence of privacy and a serious lack of living facilities including kitchens and washrooms. Damage to the guarding structure and the extremely poor tightness of the doors and windows have a negative effect on thermal comfort inside the building. It is no exaggeration to say that in some of the rooms the temperature indoors is no different from that of the outside. Moreover, because the building backs onto the mountains, and mainly relies on its courtyard for its daylighting, the sizes of its windows are relatively small, thus making the indoors light relatively bad. Most residents here wash and cook in the courtyard, where the environment is then severely polluted, with the rooms on the first floor becoming severely damp and drainage facilities often plugged up.

3. Investigation into the Physical Environment

In order to obtain clear information about the quality of the current human environment of the former site of Zhuyangxin Plaster Store and to obtain quantized standards as guidance for retrofitting work, a specific on-site test has been carried out on the quality and physical environment of the historical building. The first phase of the on-site test is to examine several physical indexes inside the houses when the heating equipment is absent. Test time refers to 22 hours (17:00PM-15:00PM the next day).

3.1 Relative Test on the Thermal Environment

(1) Temperature and Humidity

Three temperature and humidity meters have been allocated, 2 units indoors, and 1 unit outdoors. The average of the two results indoors should be applied.
As shown in Fig.5., there were obvious changes in the outdoor temperature which remained about 6-10°C. This was the average temperature in winter in Hangzhou on the whole. The outdoor average temperature was 7°C and the highest was 9.6°C while the lowest was 6.3°C. The indoor average temperature was 11.2°C, which was 4°C higher than the outdoor temperature. The highest indoor temperature was 13.25°C and the lowest was 9.6°C. There was obvious difference in the indoor temperature.

(2) Wind Speed

Thirteen groups of data on February 25th, and 4 groups on February 26th were applied in the wind speed test (Table 1.). The two curves of the data collected indoors have relatively small fluctuation, while that of the data collected outdoors appears to be rising and falling intensively.

The courtyard is enveloped in walls, while the balcony is exposed to the street. Therefore, it is reasonable that the average wind speed of the balcony is higher than that of the courtyard.

Table 1. Test Result of Wind Speed

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Indoor 1st</th>
<th>Indoor 2nd</th>
<th>Courtyard</th>
<th>Balcony Facing the Street</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Result</td>
<td>0.0452 m/s</td>
<td>0.0447 m/s</td>
<td>0.1423 m/s</td>
<td>0.2347 m/s</td>
</tr>
</tbody>
</table>

(3) Thermal Comfort

Whether human beings feel comfortable in a certain building depends on several factors, including the temperature, humidity, wind speed etc. In this test, such a method is adopted for the calculation of the value of PMV (Predicted Measurement of Voting) and PPD (Predicted Percent of Dissatisfaction) with the test results including indoor temperature, humidity and wind speed etc, while the temperature and humidity are tested once every 10 minutes with certain fixed and patrol instruments, and the wind speed is tested at two points indoors once every 15 minutes. The average value of each group of data is adopted.

From Fig.6. it can be seen that without any heating equipment, the average PMV was -1.07, and the best was -0.74 and the poorest -1.38. This is beyond the national standard by -0.75～0.75. People feel cold indoors.

Fig.7. shows that 45% of people feel uncomfortable while at least 14.4% are not satisfied with the thermal comfort.

(4) Heat Current Density

After the heat-collecting facilities were applied, tests of the heat current density were adopted on three parts of the buildings, namely, the wooden exterior walls, partition walls and the doors and windows. The thermal resistance and heat transfer coefficient were then calculated through the given formula. The results were compared with the requirements listed in the Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zones.

See Table 2., for details, items highlighted in italics refer to those which failed to meet the requirements.

From Fig.8. and Table 2. it can be seen that the heat current density of the enclosure structure is relatively high. Through calculation, it is concluded that both the
heat transfer coefficient of the exterior wall and the glass largely deviate from the requirements.

3.2 Test on the Optical Environment

The test was carried out during 5 periods between 12:00AM-16:00PM on February 25th and February 26th.

As shown in Fig.9., the lighting coefficient inside the building is relatively low, with its value decreasing exponentially according to an increase in the test points' distances from the windows.

3.3 Result Analysis

Through on-site investigation, it can be concluded that the thermal environment of this building is in a poor state. In winter, the heat comfort may fall to -1.39, far below the lowest requirement of the national standards, which is within the range of [-0.75 to 0.75]4). Residents here usually feel cold, because the building is not able to meet the requirement concerning heat comfort. The differentiation between the indoor and outdoor temperature is from 3 to 5°C, displaying no big fluctuations. The outdoor humidity is 90% while the indoor is 70% and the weather will have a strong effect on the change of humidity.

Besides, the lighting coefficient inside the building is relatively low and does not meet the requirement of people's daily lives.

Table 2. Comparison between the Actual Heat Transfer Coefficient and the Standard One

<table>
<thead>
<tr>
<th></th>
<th>Interior Wall</th>
<th>Exterior Wall</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Heat Resistance (m²·K/W)</td>
<td>0.469</td>
<td>0.146</td>
<td>0.028</td>
</tr>
<tr>
<td>Actual Heat Transfer Coefficient (W/m²·K)</td>
<td>1.451</td>
<td>3.378</td>
<td>5.618</td>
</tr>
<tr>
<td>Standard Heat Transfer Coefficient (W/m²·K)</td>
<td>2</td>
<td>1.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

4. Solutions for Protection and Regeneration

The inevitable contradiction between the lagging of the buildings' self-regeneration and the rapid development of social life, have led to the current situation of the former site of Zhuyangxin Plaster Store. Confronted with such a precious historical building, it is clear that the interior functions of the buildings can be appropriately eliminated or added, while some parts of the configuration can be reallocated. However, the general style, original dimensions, as well as some traditional configurations of the historical building should not be demolished.

Meanwhile, attention should be focused on the poor performance of the indoor human environment and envelope of the building regarding its heat insulation. Therefore, the rebuilding of energy-saving facilities should be taken into consideration when the buildings are protected and regenerated.

4.1 Protecting the Whole Environment

The protection and retrofit of Zhuyangxin Plaster Store should not be an independent project, but be regarded as a part of the rebuilding project of the historical block of Dajing Alley. Such a renovation project involves not only the retrofit of key buildings such as the former sites of Zhuyangxin Plaster Store and Huqingyu Tang TCM Store etc, but also the protection of ordinary residences along the streets, the maintenance of the streets' original dimensions, and the improvement of the infrastructure. Zhuyangxin Plaster Store is located in a collection of traditional buildings of different functions, along Hefang Street, Zhongshan Middle Road, Dajing Alley and among the Huancui Residential Quarter, forming a relatively integral and coordinated visual effect within a certain range (Fig.10.).

4.2 Rejuvenating the Commercial and Cultural Function

Zhuyangxin's Business is characterized by pharmacy production and sale. Following regeneration, the original commercial function of Zhuyangxin Plaster Store will be recovered, and the building will be transformed into a traditional drug store.
the services of pharmacy, sale, and diagnosis.

The central court can be designed to be the storefront, while the west court can function as a workshop open to the public. A small museum introducing the history of the plaster store will be located in the east court.

4.3 Recovering the Original Appearance, and Finely Reallocating Parts of the Configuration

The original configuration of the store, as three courts standing in a line, will be totally recovered, while the unauthorized cabanas in the east court will be removed, in order to maintain the integrity of the court space.

The concept of historical buildings here refers to the original ones, but not replicas or reconstructed buildings. Therefore, the retrofit of the historical buildings should be loyal to their original appearances. Methods of cosmetic retrofit, but not extensive rebuilding should be applied, and the original components should also be used to their best. Under the circumstances that some of the components may be severely damaged and cannot be used any longer, traditional construction materials and crafts should be used to replace the original ones. (Fig.11.)

4.4 Improving the Human Environmental Quality and Energy Efficiency Performance

(1) Improving the Thermal Environment

Analysis of the feasibility of the existing energy-saving methods is carried out (Table 3.), regarding the unique function and structure of the Zhuyangxin historical building, and the difficulties in their practices.

Suitable renovation methods were proposed concerning the historical urban residential buildings with consideration for their special wooden structure and historical value as follows: (Table 4.)

External walls: For the rammed soil walls, the external insulation of insulating mortar consisting of gelatinous power and expanded polystyrene pellets of 40mm thickness was applied. For the wooden wall, the internal insulation of rock wool of 20mm thickness was sandwiched inside two layers of wooden sheet.

Internal walls: Two layers of wooden sheet were used for the internal walls.

Windows: Double-glazed windows were installed.

Roof: 60mm XPS board was used in the roof for heat insulation.

The characteristics and protection of this historical building are fully considered in the renovation plan, and the renovation measures adopted here are designed to be implemented easily and effectively in order to minimize the influence on the building.

The response coefficient method was a proven dynamic whole-building simulation method and can accurately calculate the hourly building heating and cooling loads of one year. The only simulation program recommended in the Design Standard for Energy Efficiency of Public Buildings, Doe-2, was eligible and would be applied to calculate the energy consumption for heating and cooling loads of the subject buildings in the paper. The energy consumption of the design building for space heating and cooling after renovation is 133.2 (kWh/m²). Compared with the reference building (it has the same shape, size, orientation, space and function with the design building but different envelop thermal parameters, shape coefficient and area ratio of window to wall, which just meet the rigid requirements.), whose energy consumption for space heating and cooling is 155.9 (kWh/m²), the energy conservation efficiency of the renovation plan is 50.34%.

(2) Improve the Indoor Optical Environment

Opening bar-type clearstories above the corridors with poor lighting on the second floor will not only expand the lighting space of the surrounding rooms, but also reduce the demand for heating. Moreover, closing the clearstories in winter will make the corridors into sunlight rooms, which are able to pre-heat the air of the surrounding rooms, while opening them in summer will enhance the circulation of air in the corridors, thus eliminating heat.

Setting directional glass bricks over the side-windows will stretch the radiation of the natural sunlight. Applying light color decoration, and painting lime on the interior walls will increase the reflection ratio of the surfaces inside the building.

Integrating the lights with the intake of the air-conditioning system will enable it to take away the
extra heat on the surface of the lights and ensure the best luminous flux. A light transmitter should also be installed to control the man-made light intensity, while energy-saving illuminating devices should be adopted. (Fig.12.)

(3) Re-designing the landscape of the courtyards

The landscape of the two courtyards should be re-designed, with plants available for medicines planted. The vertical planting should be improved in order to coordinate the micro-climate of the building with its heat insulation property. (Fig.13.)

5. Conclusion

The "Regeneration" of historical buildings refers to a rational use based on the protection of buildings, through which they will be brought back to the recycling system of cities. Historical buildings remain not only the epitome of history, but also the homeland...
to which we belong. In practice, the protection and regeneration of historical buildings is a comprehensive problem, requiring the close cooperation of professionals from several disciplines, such as history, sociology, architectonics, and architectural technologies. In this renovation project concerning the former site of the Hangzhou Zhuyangxin Plaster Store, the historical significance and intimacy of the old buildings have been preserved perfectly, while the irreplaceable charm of this old site has been totally restored. Meanwhile, the ecological environment has attracted adequate attention, with the human environment evidently improved. This research should be considered as a favorable exploration into the new realm of the protection and regeneration of historical buildings.

### References

4. Moderate thermal environments-Determination of the PMV and PPD indices and specification of the conditions for the thermal comfort, GB/T18049-2000.

### Table 4. Parameters for Simulation of Thermal Environment

<table>
<thead>
<tr>
<th>Parts of the Enclosure Structure</th>
<th>Designed Building KW/(m²·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofing</td>
<td>0.57</td>
</tr>
<tr>
<td>Exterior Walls (Including non-transparent curtain walls)</td>
<td>1.00</td>
</tr>
<tr>
<td>Exterior Windows (Including transparent curtain walls)</td>
<td></td>
</tr>
<tr>
<td>Area Ratio of Window to Wall</td>
<td>Heat Transfer Coefficient KW/ (m²·K)</td>
</tr>
<tr>
<td>East</td>
<td>0.05</td>
</tr>
<tr>
<td>South</td>
<td>0.03</td>
</tr>
<tr>
<td>West</td>
<td>0.06</td>
</tr>
<tr>
<td>North</td>
<td>0.23</td>
</tr>
</tbody>
</table>

![Fig.12. Improvement of Indoor Optical Environment](image1)

![Fig.13. Landscape Re-design of the Courtyards](image2)